Springer Series in Materials Science 206

Rahulkumar Shivajirao Hingole

Advances in Metal Forming

Expert System for Metal Forming

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Springer Series in Materials Science

Volume 206

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ISSN 0933-033X ISSN 2196-2812 (electronic)
ISBN 978-3-662-44496-2 ISBN 978-3-662-44497-9 (eBook)
DOI 10.1007/978-3-662-44497-9

Library of Congress Control Number: 2014948736

Springer Heidelberg New York Dordrecht London

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

Dedicated to
My parents Mr. S.K. Hingole,
Ms. K.S. Hingole,
wife Ms. Shilpa
and
daughter Ms. Rashi

Preface

Today, technology is one of the bastions of our modern lifestyle and basic for our prosperity, in which metal forming technology plays a central role. Alongside for manufacture, a semi-finished product through rolling, wire drawing, and extension for production of discrete components using sheet metal and solid forming techniques is a major significance. The variety of parts produced in the press shop is large and enumerating the sheet metal parts going into diverse industrial products would make an endless list. Electric motors, transformer, switchgears, automobile components, and domestic products like mixers, kitchen ware and utensils are some of the common products.

This book highlights the area of sheet metal forming particularly in deep drawing, rolling, extrusion, bending, etc. Intelligent technologies have received much attention in a wide range of material forming applications in order to make a forming system with a large flexibility without the need of a skillful expert to achieve product accuracy and product quality. A number of attempts on its application have been made in the field of metal forming. Convergence of technologies on the Internet and the field of expert systems have offered new ways of sharing and distributing knowledge. However, there has been a general lack of research in the field of web-based expert systems for metal forming. This research work addresses issues associated with design, development, and use of web-based expert system for various types of sheet metal forming operations like deep drawing, rolling and extrusion, bending. Initially, the related literature is presented. This is followed by a presentation of client server methodology, test result, discussion, and summary.

Efforts have been made to present the subject in an easy, clear, lucid, and systematic manner.

The suggestions for further improvement in this book will be greatly accepted.

Wagholi, Pune Dr. Rahulkumar Shivajirao Hingole

Acknowledgments

In the first place I must express my deep sense of gratitude and sincere thanks to Prof. Dr. Vilas M. Nandedkar for his guidance in this book. He tirelessly enthused and motivated me.

I must express my gratitude to Dr. B.M. Dabade, Dr. T.R. Sontakke, Dr. S.P. Kallurkar, Dr. S.B. Sharma, Dr. V.B. Tungikar, Dr. M.M. Akarte, Mr. Rodge, Mr. Parvekar, Dr. L.N. Wankhade, Dr. J.V.L. Venkatesh, and Mr. Khandre for their helpful comments. Their hard-earned scholarship remains a constant source of inspiration to me.

I would like in particular to thank Mr. Takshak Chahande (Interminable Technologies), Mr. Shard S. Hingole and my colleague for their endless support.

I am indebted to Prof. K. Narasimhan of Indian Institute of Technology, Powai, Mumbai. I am thankful to the international referees whom I met at conferences.

I thank my parents Mr. Shivajirao K. Hingole and Mrs. Kalwatitai Shivajirao Hingole, my wife Mrs. Shilpa Rahulkumar Hingole, daughter Ms. Rashi Rahulkumar Hingole, brothers, in-laws, and friends for motivating me to complete my book.

Last but not the least, I thank all who have directly or indirectly helped me during the preparation of this book and also to my source of inspiration, Bharatratna Dr. B.R. Ambedkar.

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Dr. Rahulkumar Shivajirao Hingole is working as Professor in Department of Mechanical Engineering at Jayawant Shikshan Prasarak Mandal's, Bhivarabai Sawant Institute of Technology and Research (Women), Wagholi, Pune. He has completed his Bachelor's in Mechanical Engineering, Master's in Mechanical CAD/CAM, and Ph.D. in Mechanical Engineering. His area of specialization is metal forming, expert system, CAD/CAM, design. He has worked as Head and workshop superintendent in institutes. Currently he is the CEO of the institute. He has published more than 56 research papers in various national and international conferences and journals. He has reviewed several research papers in national and international conferences and journals. He is a member of ISTE, SMFRA, SAE, and ASME. He has organized several conferences, workshops, seminars and short term training programmes. He had given the several speeches in conferences and training programmes. He had been invited as chairperson in national and international conferences. He has guided graduate, master's and Ph.D. level students. He got the Best Teacher Award for outstanding teaching. He has visited Germany, USA, and Spain for technical assignments. He received Best Researcher Appreciation from University of Galati Romania. He received Best Chairperson appreciation in ICCE Spain which is organized by University of New Orleans USA.

Dr. Rahulkumar Shivajirao Hingole

Nomenclature

KBS	Knowledge-based system
ES	Expert System
WEBS	Web-based expert system
AI	Artificial intelligence
BHF (B)	Blank holder force
μ	Friction
K	Strength coefficient
H	Part Height
d	Part Diameter
D	Blank Diameter
Btotal	Draw ratio
Er	Radial Strain
n	Strain hardening exponent
R_0, R_{45}, R_{90}	Plastic strain ratios at 0°, 45°, 90° to rolling direction respectively
$\overline{R}$	Normal anisotropy
ΔR	Planar anisotropy
ho	Initial thickness
hf	Final thickness
k	Flow stress
R	Radius of curvature
b	Width of sheet
r	Radius
a	Moment of Arm
n	Roll Revolution
RL	Rolling Load
T	Torque
P	Power
Y	Yield Strength
σ	Stress
ε	Strain
n	Strain hardening exponent

R_m	Anisotropy factor
K	Strain coefficient
Qp	Thickness ratio
α	Die cone angle
C	% Concentration
F	Extrusion force
h_{CLA}	Surface roughness
d_i	Ram diameter
d_e	Final diameter
σ_y	Tensile yield strength
V_A	Axial velocity
L	Billet length
φ	Extrusion Angle
Lmax	Maximum Billet Length
PL	Friction power loss
Ft	Tensile strength of blank material
W	Width of v at top
t	Minimum flange thickness
CAD	Computer aided design
CAM	Computer aided manufacturing
CAE	Computer aided engineering
CAPP	Computer aided process planning
AGFPO	Automatic generation of forming process outline
WWW	World wide web
URL	Uniform resource locator
HTTP	Hypertext transfer protocol
IIS	Internet information server
FTP	File Transfer Protocol
SDK	Software development kit
ISAPI	Internet server application programming interface
DLL	Dynamic-link library
AP	Active platform
COM	Component object model
CGI	Common gateway interface
TMF	Manufacturing facility
TEAM	Technologies enabling agile manufacturing program
IKBSC	Intelligent knowledge-based supervisory control
G&TR	Generate and test, rectify
ANOVA	Analysis of variance
HTML	Hypertext markup language
LAN	Local area network
ICT	Internet-centered information and communication technologies
FEM	Finite element method
CNC	Computer numerically controlled
FLC	Forming Limit Curve

FLD	Forming Limit Diagram
RD	Rolling Direction
r	Percentage reduction, %
α	Die semi-cone angle
C	Concentration of lubrication

Chapter 1
Introduction

Abstract Metal forming is an important process since primitive days of human being. It is the process wherein the size and shapes are obtained through the plastic deformation of the material. The stresses induced during the process are greater than the yield strength but less than the fracture strength of the material. The intelligent press forming of sheet metal is a comprehensive subject that combines control science, computer science and sheet metal forming theory. The marked feature is to identify the material properties and friction coefficient in real-time according to the characteristics of the initial piece and utilizing physical quantities that are easy to be measured, so that the forming process can be completed automatically with the optimal processing parameters. The introduction chapter deals with recent development in metal forming operations like deep drawing, rolling, extrusion and bending. The classification of these operations has been covered with suitable information and neat sketches. The important forming parameters and their effect related to these operations are discussed in detail.

1.1 Advances in Metal Forming

Advanced intelligent technology is going to bring about the progress of sheet metal forming theory and the improvement of analysis precision at the same time. Thus, it has very important significance for degrading sheet metal level, eliminating technology difficulty between the die and the equipment adjustment, shortening the die setting time, improving productivity and the rate of finished products etc. The intelligent press system mainly consists of four basic elements: monitoring; identification; prediction; control. The globalization, the complexity and the dynamics of the business environments present real challenges to strategic manufacturing planning in the 21st century. The needs for appropriate techniques and technologies in support of strategic manufacturing planning have never been so great. Over the past years attempts have been made by researchers to develop computer-based systems to support the process of strategic manufacturing planning.

R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9_1

Traditionally, prototype and small batch production shops have been limited to competing locally for customers however the connectivity of the Internet and World Wide Web now allows manufacturers to offer their services globally for the first time. Some manufacturers have already utilized this strategy for various manufacturing processes, but no one has yet offered sheet metal forming operations over the internet. Another trend in industry has been the use of expert systems to aid designers in different aspects of the design phase. The task of matching product features with process capabilities and studying the tradeoffs inherent in using different processes to produce the same part are some of the most difficult a designer faces.

Expert systems are being used increasingly in manufacturing and it is estimated that by the year 2009 there will be five to six applications of expert systems in every manufacturing company, regardless of size. This research expands on these ideas by creating a Virtual Design System (VDS) on the World Wide Web that will guide designers through the process of matching the desired part features with the best or preferred manufacturing process to produce these features. Simulations will be incorporated into the VDS to aid in determining the final part characteristics and the VDS will be capable of transferring the part design to the production facilities for manufacturing. A number of works on its application have been made in the field of metal forming. Convergence of technologies in the internet and the field of expert system have offered new ways of sharing and distributing knowledge. However, there has been a general lack of research in field of web based expert system for metal forming. This research work addresses the issues associated with design, development and use of web based expert system for various types of sheet metal forming operations like deep drawing, rolling, extrusion, bending etc. Initially, the related literature has been presented. This is followed by the presentation of client server methodology and a typical sample session.

1.2 Deep Drawing Process

Deep drawing is a well-known industrial manufacturing process as shown in Fig. 1.1. It is the process of deforming sheet metal by the use of punch and die. In this process the sheet being drawn inwards and over the die profile by advancing punch. The flange is controlled by moderate "blank-holding" pressure supplied by a suitable shaped blank holder. The blank holding pressure is necessary to prevent the wrinkling and to control the material flow into the die cavity. Today, the art of deep drawing process has been advanced to a level where it can be offered for a wide variety of components. The components manufactured using deep drawing are—fire extinguisher cases, shock absorber tubing, outer panels and inner panels for automotive industry. It is also used to manufacture very thin walled containers for food and beverages industry and in any precision axi-symmetric shaped component.

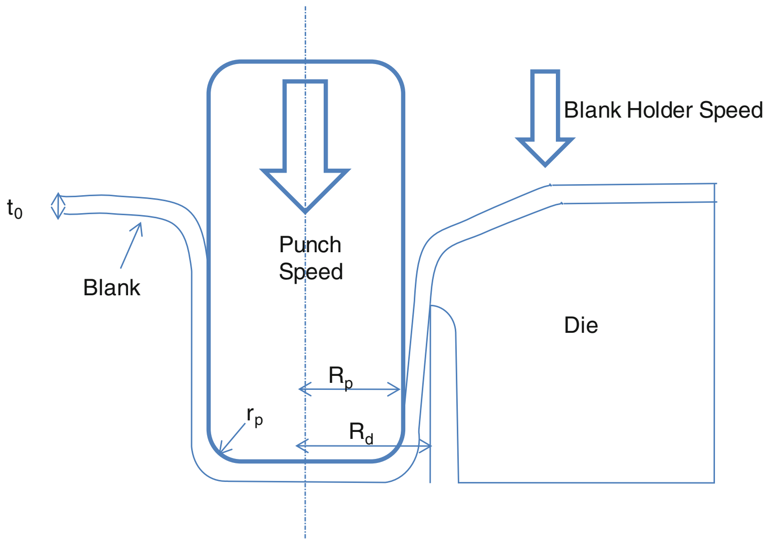

Fig. 1.1 Deep drawing processes

1.2.1 Influencing Factors

The influencing factors on the final shape of deep drawn product are as follows.

i. **Blank material properties**: The deformation patterns in the deep drawn component are influenced by material properties such as normal anisotropy or plastic strain ratio (r) and coefficient of strain hardening (n). Sheet material behaves anisotropically means the material shows a different deformation behavior in different directions. An example of anisotropy is the development of ears in cylindrical cup drawing. In materials with high n value, the flow stress increases rapidly with strain. This results in the distribution of strain uniformly throughout the sheet and even in low strain areas.

ii. **Tooling dimensions**: An incorrect design of tools such as punch and die can yield a product with a deviating shape or with failures. A deviating shape is caused by elastic springback after forming and retracting the tools.

iii. **Blank holder force (BHF)**: Even though the thickness of sheet metal and die radius offer some restraint to the flow of metal into the die, some additional constraint is usually required to control the flow of metal. This additional restraint is obtained by the use of blank holding plate. BHF is also one of the important parameters in the deep drawing process because an insufficient blank holder pressure causes wrinkles to develop on the flange, which may also extend to the wall of the cup. Further too much of a blank holder pressure and friction may cause a thinning of the walls and fracture at the flange, bottom and the corners. Normally blank holding pressure is assumed to be one third of maximum punch force.

iv. **Friction**: The deformation pattern in the deep drawn component is also influenced by friction conditions. The friction conditions during forming process depend on the lubricant, the presence of coatings on the blank, surface roughness of the tools, blank holder pressure and process velocity.

1.3 Development in Rolling

Rolling is the process in which the metals and alloys are plastically deformed into semi finished or finished condition by passing these between circular or contoured rotating cylinders (rolls) the metal is drawn into the opening between the rolls by frictional forces between the metal and roll surface as shown in Fig. 1.2. In deforming metal between rolls, the work piece is subjected to compressive force from the squeezing action of the rolls. Cast steel relatively weak mass of coarse, uneven metal crystals or grains. Rolling causes this coarse grain structure to re-crystallize into a much finer grain structure, giving greater toughness, shock resistance and tensile strength.

Sheet is between 0.2 and 6 mm in thickness and has a wide variety of uses in the construction industry including aluminum sliding and roofing. Sheet is also used extensively in transport applications such as automobile body panels, airframes and the hulls of boats. Plate is any rolled product over 6 mm in thickness. It also be found in a number of applications including airframes, military vehicles and structural components in bridges and buildings. The gap between the rolls is smaller than the steel being rolled, so that the steel is reduced in thickness and at the same time lengthened. One set of rollers is called a stand and in any one mill. There can be a number of stands.

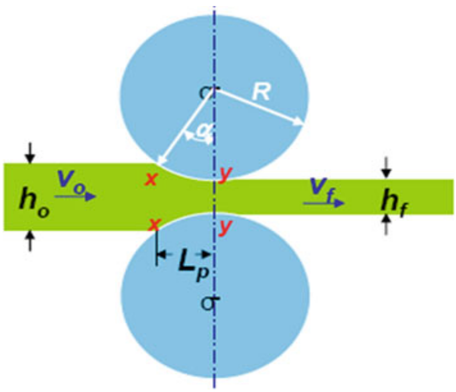

Fig. 1.2 Rolling process

1.3.1 Classification of Rolling Processes

1.3.1.1 Cold Rolling

Cold rolling is a process by which the sheet metal or strip stock is introduced between rollers and then compressed and squeezed. The amount of strain introduced determines the hardness and other material properties of the finished product. The advantages of cold rolling are good dimensional accuracy and surface finish. Cold rolled sheet can be produced in various conditions such as skin-rolled, quarter hard, half hard, full hard depending on how much cold work has been performed. This cold working (hardness) is often called temper, although this has nothing to do with heat treatment temper. Quarter Hard, Half Hard, Full Hard stock have higher amounts of reduction, up to 50 %. This increases the yield point; grain orientation and material properties assume different properties along the grain orientation. However while the yield point increases ductility decreases. Thus these materials can be used for in applications involving great amounts of bending and deformation without fracturing.

1.3.1.2 Hot Rolling

Hot rolling is a mechanical working process in which the metal is passed through a pair of rolls and the temperature of the metal is above its recrystallization temperature, as opposed to cold rolling, which takes place below it. This permits large deformations to be achieved with a low number of rolling cycles. Because the metal is worked before crystal structures have formed, this process does not itself affect its microstructural properties. Hot rolling is mainly used to produce sheet metal, or simple cross sections from billets. Hot rolling is primarily concerned with manipulating material shape and geometry rather than mechanical properties. This is achieved by heating a component or material to its upper critical temperature and then applying controlled load which forms the material to a desired specification or size.

1.4 Advancement in Extrusion Process

Metal forming by extrusion has predominant role in manufacturing sector. Many non-ferrous materials like aluminum, copper, lead, zinc etc. have major market share in end products due to the lower density and non-corrosive nature and are suitable for extrusion process. Extrusion process whereby the work piece placed in a chamber with an opening and is forced to escape through the opening, usually being pushed out by a mandrel. In the process of extrusion, a billet is placed into a chamber with a shaped opening called a die, on one end and a ram on other end.

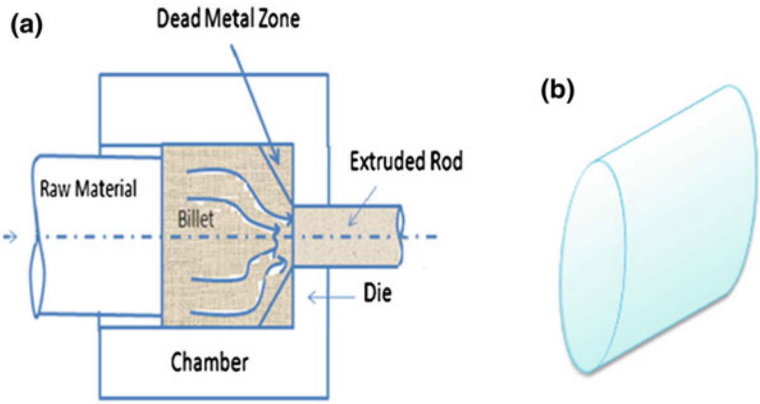

Fig. 1.3 **a** Extrusion. **b** An assortment of extradites

As the ram is forced into the chamber the work piece is forced out through the die. The extradite long product emerges through the die duplicating its cross sectional shape. Sliding occurs on the interface between the work piece and the tool, the friction is manifested, and lubrication is exercised. The tools are made from hard metals.

Lot of energy is required in extrusion process for plastic deformation of billet and the frictional drag between the billets and die land. There exist a sliding motion along the interfaces between the work piece and the tool. Whenever sliding occurs between the solids, a resistance to the sliding motion is observed which is called friction. The friction resistance is accompanied by damage to the surfaces, which is mostly manifested by the wearing of the surfaces. The friction and wear can be controlled by the introduction of the lubricants between interfacing surfaces. The lubricant severs not only to minimize friction and wear but also to cool the surfaces by removing the heat generated through sliding. Most effective lubrication method may provide a thin film of lubricant separating the two surfaces completely.

Metal forming process whereby the work piece is placed in a chamber with an opening and is forced to escape through the opening, usually being pushed out by a mandrel. In the process of extrusion ref Fig. 1.3a, a billet is placed into a chamber with a shaped opening (called a die) on one end and a ram on the other. As the ram is forced into the chamber, the work piece is forced out through the die. The extradite, ref Fig. 1.3b a long product (i.e., a rod), emerges through the die duplicating its cross sectional shape. The flow lines indicate that a dead metal zone forms in the corner on the exit side of the chamber where the separated ring of a triangular cross section remains stagnant.

1.5 An Overview of Bending Process

Bending is the plastic deformation of metals about a linear axis called the bending axis with little or no change in the surface area. Bending types of forming operations have been used widely in sheet metal forming industries to produce structural stamping parts such as braces, brackets, supports, hinges, angles, frames, channel and other nonsymmetrical sheet metal parts. One of the important characteristics noticed during the bending operation is that the tensile stress decreases toward the center of the sheet thickness and becomes zero at the neutral axis whereas the compressive stress increases from the neutral axis toward the inside of the bend as shown in Fig. 1.4. Even with large plastic deformation in bending, the center region (elastic metal band or zone) of the sheet remains elastic and so on unloading elastic recovery occurs.

Bending is the uniform straining of material, usually flat sheet or strip metal, around a straight axis, which lies in the neutral plane and normal to the lengthwise direction of the sheet or strip. Sheet metal bending is one of the most widely applied sheet metal forming operations. The fabrication of sheet metal bending is widely used in automobile and aircraft industrial processes with the trial-and-error method being employed to bend the plate to the required angle. The accuracy and success of the bending process depends upon the operating parameters as well as the material properties. In the bending processes, the elastic limit of material can be exceeded but yield stress limits cannot. For this reason the material keeps some of its original elasticity. At the end of the loading operation the part being formed conforms closely the tool shape. When the load is removed from the material, it tries to get back to its original shape and bent material springs-back partially.

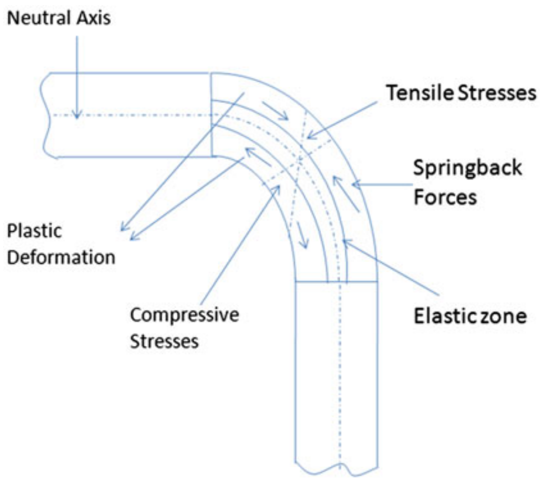

Fig. 1.4 Bending of sheet metal

Cold bending of metal tubes is a very important production method considering that metal tubes are widely used in a great variety of engineering products, such as automobile, aircraft, air conditioner, air compressor, exhaust systems, fluid lines. Although cold bending of metal tubes is an old metal forming process, it is becoming a precision metalworking process and requires high quality assurance. There are a variety of methods for cold bending including rotary drawing bending, compression bending, empty bending, ram bending, rolling bending, etc. Bending machines range from hand benders, hydraulic bending, to fully computerized CNC benders. The problem that is facing tubing production industry is that with the customer's demand on complex tubing parts and tight tolerances, there often exist defects and failures of tubing parts, such as undesired deformation, inaccuracy of bend angles and geometry, wall-thinning, flattening, wrinkling, cracks, etc.

All of these are in close relationship with the selection of bending methods, tool/die design, die set conditions, machine setup, material effects, a number of bending process parameters such as minimum bending radius, springback, wall factor, empty-bending factor, etc. Therefore, it is an urgent demand to develop a knowledge-based system (KBS) that can assist the engineers to optimize the process of cold bending of metal tubes. The KBS techniques have proven effective in solving a complex manufacturing problem where the optimal decision-making is based on the integration of facts, rules, equations, expertise, production data, and process knowledge. Previous work in the area of manufacturing includes engineering selection, optimization of machining parameters, process planning, jig and fixture design, steel material design, deep-drawing die design, metal forming process sequencing [1], etc. The objective of the work presented in this research work is to develop a web based expert system for design V and U bending process that integrates metal tubing theories, tube bending process knowledge, and human expert's experience.

1.6 Organisation of the Book

Chapter 2 **Enhancement in Expert System**: It is based on the expert system which are available in the various fields of sciences from last few decades. These web-based expert system applications of artificial intelligence have enhanced productivity in business, science, engineering, and the military. With advances in the last decade, today's expert systems clients can choose from dozens of commercial software packages with easy-to-use interfaces. In the literature survey number of expert system are available in the various areas. This research work is based on expert system in the area of sheet metal forming particularly in deep drawing, rolling, extrusion, bending etc.

Chapter 3 **Fundamentals of Expert system**: Expert systems (ES) emerged as a branch of artificial intelligence (AI), from the effort of AI researchers to develop computer programs that could reason as humans. Many organizations have leveraged this technology to increase productivity and profits through better business decisions. However, few web-based ES have been offered and analyzed to shed light on the methodology and challenges of developing them. This chapter appears to offer contradictory pictures on the status and use of web-based ES. Grove provided some examples of web-based expert systems in industry, medicine, science and government and claimed that "there are now a large number of expert systems available on the Internet".

Chapter 4 **Design of Web Based Expert System**: Apache Tomcat is the top-level entry point of the documentation bundle for the Apache Jakarta Tomcat Servlet/JSP container. Tomcat version 5.5 implements the Servlet 2.4 and JavaServer Pages 2.0 specifications from the Java Community Process and includes many additional features that make it a useful platform for developing and deploying web applications and web services for metal forming operations.

Chapter 5 **Implementation of Web Based Expert System**: The platform and design of expert system explained in Chap. 4 has been used for application work. Java and Apache tomcat is a platform provided for web based expert for metal forming to validate its functionality. In this way research work on web based expert system developed and demonstrated for metal forming processes like deep drawing, rolling, extrusion, bending on this platform.

Chapter 6 **Case studies and Discussion**: The working of client server sheet metal forming analysis application is shown in Fig. 1.2. Initially you can find and view information about sheet metal forming on web site address http://sggs.ac.in/production/Ph.D./Web based expert system for metal forming user can find out required information about sheet metal forming. Due space problem this link is not in working condition.

Chapter 7 **Summary and Future Scope**: In this book a web based expert system has been developed and implemented for metal forming processes in an innovative way. The web based expert system is successfully demonstrated for appropriate analysis of various metal forming operations like deep drawing, cold and hot rolling, extrusion and V and U bending along with the requisite forming parameters. But in the present book only the implementation of deep drawing process had been explained.

It has been proved that web-based expert system have become more sophisticated, complex, and capable and fulfill their great promise in area of metal forming. It is anticipated that web-based application could bring new life to the field of industrial sector and generate a new era for their applications. In this research work web based expert system is implemented and demonstrated for the sheet metal forming operations. In future this may enhance for the other applications in sheet metal forming as well as other areas in the engineering. Lastly the references are found useful to support this work and appendix and flow charts are attached for intensive information and clarification for this thesis work.

References found useful in carrying out this work are listed thereafter. Supporting tools and documents are attached as **Appendices**. The details of development programming of web based expert system for metal forming operations are provided in the appendices.

The literature survey, critical literature review and objective of these investigations are presented in Chap. 2.

Reference

1. A. Azushima, M. Kim, A PC-based expert system for forming sequence design. Ann. CIRP **39** (1) (1990)

Chapter 2
Enhancement in Expert System

Abstract The development of new sheet metal forming processes, tooling etc. has up till now to a large extent been based on experience, rules of thumb and trial-error experiments without or with only little use of scientifically based engineering methods. The experience is not enough, and trial-error experiments are very expensive with regard to both money and time. Intelligent technologies have received much attention in a wide range of metal-forming applications in order to make a forming system with a large flexibility without the need of skilful experts, to achieve higher product accuracy and product quality. Convergence of technologies in the internet and the field of expert systems for metal forming have offered new ways of sharing and distributing knowledge. However, there has been a general lack of research in the area of web-based expert systems. This literature addresses the issues associated with the design, development, and use of web-based ES from a standpoint of the benefits and challenges of developing and using them. The original theory and concepts in conventional ES were reviewed and a knowledge engineering framework for developing them was revisited. The study considered web-based ES for e-business strategy development, to promote intelligent interviews.

2.1 Expert Systems and Its Applications

In recent years, internet service has become an important issue that attracts the researchers from both computer science, manufacturing and communication fields. Artificial Intelligent has been applied to the development of intelligent systems for several decades. For example, Vasandani and Govindaraj [1] developed an intelligent tutoring system that assists in the organization of system knowledge and operational information in order to enhance operator performance. Antao [2] has presented their experiences in relation to the developing intelligent tutorial systems for teaching simulation in engineering education. While computer intelligence has inspired the development of intelligent systems, the advent of network technologies

R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9_2

in the mean time has helped the further realization of Intelligent Internet service systems. In recent years, researchers have attempted to develop more intelligent e-learning and e-commerce systems on the internet [3]. To develop an intelligent monitoring system for improving the stability and reliability of Internet service systems, it is important to know how intelligent behaviors of human experts can be simulated by a computer system. Most of the systems perform intelligent behaviors by eliciting knowledge from a group of domain experts [4].

An expert system is a computer program designed to imitate a human expert, mimicking the knowledge base and the decision making process of a human expert. An expert system is different from conventional programs because it can explain its behavior to the human expert and receive new information without new programming [5]. Puppe [6] has listed the necessary properties of expert systems as, Transparency, Flexibility, User friendliness, Competence. Most expert systems organize information into two bases, a knowledge base and an inference engine or rule interpreter [7]. Applying this to the process of designing for manufacturability, the knowledge base contains all of the various equations and rules the designer uses throughout the process, and the inference engine represents the method used to select which rules and equations to invoke. The World Wide Web has several capabilities that make it well suited for use, both as the container for the knowledge base and the inference engine.

A very large audience has access to the Web, estimated at between 20 and 40 million users in 1995 [7]. The cross-platform capability of the Web removes the problems of operating system compatibility, ensuring that users on any machine will have the same access to the information. Software for browsing the Web is generally simple to use and easy to install. Also, the ability for the site developer to keep large amounts of information updated regularly removes that burden from the end user: for example, there is no shipping out an updated CD every 6 months [8]. The great strength of the Web lies in the standardized language of all web documents; however, this can be the biggest obstacle to the implementation of an expert system. The programming language used for created web pages is hypertext markup language (HTML). This language can specify the formatting for the display of a document as well as create links between documents, within a document and to non-Web services. It can also insert graphics, sound and animation into a document [9]. However, it is not capable by itself of providing the real-time interaction a true expert system requires. To address these concerns, interactive tools like JAVA and VBASIC are becoming available for use on the Web, allowing a greater degree of real time processing for Web-based applications [10, 11].

There are knowledge based expert systems and web based expert systems are there in existence in different types of fields. The summary of that expert system has been given in following Table 2.1.

Table 2.1 A sample of recent expert system applications

Sr. No.	Application area	Expert system applications
1	Interpretation	Isaac Balaila developed a decision support system for machine selection with load balancing
		Predicts compound properties
		Determines the marginal value of building projects
		The novel EOS835 electronic nose and data analysis for evaluating coffee ripening [12, 13]
2	Diagnosis	Diagnosis in automobile assembly or textile manufacturing
		Assists in brain lesion diagnosis
		Neural network based framework for fault diagnosis in batch chemical plants [14]
		Diagnoses the state of a pilot-scale wastewater treatment plant
		Heuristic evaluation of paper-based Web pages: A simplified inspection usability methodology [15]
		Generating design activities through sketches in multi-agent systems, Turkey [16]
3	Prediction	Detects, and adapts to changes of customer behavior in internet shopping mall
		Used in CRM, interactive marketing and e-commerce
		Predicts customer purchasing behavior [17, 18]
4	Design	An expert system of progressive die design for electron gun grid [18]
		Design of ship systems automation
		Assists in preliminary design of liquid retaining structures
		Alternative design, cost estimating, and scheduling in engineering
		Web map-based knowledge management system in construction: lessons learned in Taiwan [20]
		JavaDON: an open-source expert system shell [19, 20]
5	Planning	A prototype solid-modeling-based automated process planning system [21]
		A cooperative agent modelling approach for process planning, computers in industry [51]
		Manage petroleum-contaminated sites
		Efficient enterprise resource planning (ERP) maintenance
		Productivity adjusted production schedule
		A web-based expert system for the planning and completion of multilateral wells, Kuwait [21, 22]
6	Monitoring	Evaluating agricultural loans
		Monitors an automatic stock control system
		Monitors instrument readings in a nuclear reactor
7	Debugging and repair	Repair and debugging of digital electric circuit cells
		Aids in configuring SAP implementations

(continued)

Table 2.1 (continued)

Sr. No.	Application area	Expert system applications
8	Instruction	Teaches the operation of a steam propulsion plant
		A rule-based expert system approach to process selection for cast components [23]
9	Control	Control of manufacturing cells
		Blood pressure control
		Pain control and symptom relief in advanced cancer
		Blank holding force control in panel stamping process using a database and FEM-assisted intelligent press control system [24]
10	Computer aided design	Some aspects of a knowledge-based approach for automating progressive metal stamping die design [25]
		Direct slicing of STEP based NURBS models for layered manufacturing,
		Decomposing the problem of constrained surface fitting in reverse engineering
		A parametric feature-based CAD system for reproducing traditional pierced jewellery
		Feature-based design and material blending for free-form heterogeneous object modeling
		A piecewise hole filling algorithm in reverse engineering [25, 26]
11	Manufacturing	The development of an online knowledge-based expert system for machinability data selection [27]
		A knowledge-based system to improve the quality and efficiency of titanium melting
		Intelligent approach for generating assembly drawing from 3D computer models of mechanical products [28]
		Integration of expert system for design of material handling equipment selection system [27, 28]
12	CAM	An artificial intelligence approach for generating assembly sequences in CAD/CAM
		A compact and practical CAD/CAM system for the blanking or piercing of irregular shaped-sheet metal products for progressive working [17]
		Application of an integrated CAD/CAE/CAM system for die casting dies [29]
		Computer-aided design and manufacturing of scroll compressors [29, 30]
13	Mining	Mining protein–protein interaction information on the internet [31]
14	Flood Forecasting	A web-based flood forecasting system for Shuangpai region, China [32]

2.2 Deep Drawing Process

In the area of sheet-metal forming, deep drawing is that most commonly used process. However, traditional deep-drawing process design is performed by human experts with their empirical knowledge. In recent years, some computer-aided process design systems based on the empirical knowledge of the field experts have been developed for axisymmetric deep drawing products [33]. In these often called conventional CAD systems, the time-consuming numerical calculations and the graphical capabilities are mostly emphasized and are strongly supported by the computer, but the process planning often requiring intuitive human expertise—is still realized by the interactive interference of the user. It is obvious, that the process planning can rather be fitted into the problem-solving mechanism of so-called knowledge based systems, since it can organise the domain-specific expert knowledge and the criteria on which the human expert's decision making resided. On the basis of the before-mentioned facts, it can be stated that knowledge based systems can be regarded as the best solution for solving process planning tasks of manufacturing processes. There were only a relatively few attempts made so far to apply expert systems in the metal forming field. This is particularly true if we compare the number of expert systems applied in the metal forming industry to the number of them elaborated for other fields of manufacturing technologies. Lengyel [34] describes an early interactive CAPP system for cold forging of steels elaborated at the Imperial College of Science and Technology in London. In this expert system, for a particular part a number of various sequences are coded into program. Then the program can select those ones which may be regarded as feasible by checking tool stresses and other constraints.

A rule based system called FORMEX was written in PROLOG for the process planning of multi-stage cold forging by Altan and his coworkers in the United States at the Ohio State University. It relies on a broad classification of the various shapes of cold forged parts. The knowledge base of FORMEX contains detailed production rules which can be added to or changed as required. FORMEX is basically a data-driven, forward chaining system. A knowledge based expert system for sheet metal forming was also elaborated [35, 36]. This system is capable of handling a certain group of axisymmetric deep-drawn components. It incorporates empirical formulations, press working practice and plasticity theory, as well. In this system an automated reasoning program manipulates the deep-drawing rules stored in the knowledge base to generate feasible process plans. A knowledge based die-design automation system has elaborated by Cheok [37] at the National University of Singapore. Some special techniques for work piece representation, punch shape recognition and die-composition were presented in this work. Several program packages were also elaborated for metal forming processes at the University of Miskolc at the Department of Mechanical Engineering. They can be regarded as part of a complete system for metal forming. Within this systematic development work program packages have been elaborated for the technological and tool design of deep-drawn components with complicated geometric configuration [38, 39], for technological and tool design of sheet forming processes performed in progressive dies [40] and for process planning of various bulk-forming processes including multi-stage wiredrawing, upsetting and various types of extrusion processes [41].

In many forming process, the blank material is subjected to deformations that are mixture of typical stretch forming and typical deep drawing, interlaced in an intricate manner with the progression of forming. Though varying complex forming parameters such as blank size, tool profile and blank holding force [42, 43]. This study explores complex relationship between the mixture and the overall formability of sheet metal. The deep drawing and stretch forming are extreme processes in sheet metal forming. In deep drawing, the entire blank is pushed though a die to produce a complete cup with an essentially unchanged thickness. The parameters such as blank size, blank holder force and tool profile enable one to perform optimization such as maximization. Complex formulas are required to calculate those parameters. For this we can't relay on human as the calculation may be error prone which ultimately result is bad quality. This software has been developed keeping in mind the above limitations [44, 45]. This software going to provide the accurate dimension of all parameters within short period of time.

Recently, researches of expert system for deep drawing process have been widely reported. Park et al. constructed an automated process planning system for axisymmetric deep drawing products. Eshel et al. [46] developed the Automatic Generation of Forming Process Outlines (AGFPO) system for axisymmetric deep drawing product. They suggested Generate and Test, Rectify (G&TR) strategy for the process planning of axisymmetric deep drawing products. The system relies on experience-based die-design guidelines for its process sequence design. Altan has developed a knowledge-based system in axisymmetric sheet metal [47, 48]. Tisza presented a group technology and modularity in an expert system [49]. Zhao, has worked on various aspects of deep drawing process such critical flange wrinkle condition. Further he has analyzed the common general features of an axis-symmetric part on the process of deep drawing and has concluded a completely mechanical model and finally realized the deep drawing intellectualized control of an axis-symmetric shell part [50–52]. The application of the expert system for sheet metal forming design creates the possibility to design the sheet metal forming processes without expensive and time consuming trail and error techniques, so that the necessity of investigation by using real tools may be reduced or eliminated [53, 54]. All the above study explores complex relationship between the mixture and the overall formability of deep drawing process by using different types of expert systems.

The expert system for sheet metal forming design is helpful to develop the modern sheet metal forming processes design technique and diagnostic system. Currently, there are many different methods of assisting the designer, ranging from simple design rule packages to very sophisticated expert systems. However, many of these systems are extremely application specific and lack interfaces with simulations and real-time manufacturing capabilities. The main objective of research work in this thesis is to provide web-based expert for formability analysis of sheet metal component by using 27 shapes classified geometries. This will facilitate the user to find out the formability analysis of deep drawing process. This formability analysis is going to provide blank diameter, number of draws, radial stain, freedom to access from any location at any time and the latest version with online helps.

2.3 Recent Trends in Rolling

One of the major concerns to the producers of aluminium sheet is the quality and consistency of the rolled product. The metallurgical and dimensional properties of rolled strip must be carefully controlled if the product is to be of prime quality. Mill control systems have been introduced to automate many tasks normally performed by the mill operator. This paper details the development of a prototype mill set-up and control system that runs under the supervision of an expert system. The system has been developed around an expert system shell and tested in simulation [55, 56]. Knowledge-elicitation is a common technique used to produce rules about the operation of a plant from the knowledge that is available from human expertise. Similarly, data-mining is becoming a popular technique to extract rules from the data available from the operation of a plant. In the work reported here knowledge was required to enable the supervisory control of an aluminium hot strip mill by the determination of mill set-points. A method was developed to fuse knowledge-elicitation and data-mining to incorporate the best aspects of each technique, whilst avoiding known problems. Utilization of the knowledge was through an expert system, which determined schedules of set-points and provided information to human operators. The results show that the method proposed in this paper was effective in producing rules for the on-line control of a complex industrial process [57, 58].

Reactive scheduling is essential in any scheduling system to incrementally reconcile the discrepancies between the generative schedule and current status of the factory. Typical events requiring the reactive scheduling process include the delayed delivery of materials, machine breakdown, and failure to meet quality control standards [59, 60]. A new integrated approach to build an expert system to generate and evaluate alternative steelmaking aim compositions that not only meet the customer requirements but also suit the established rolling schedules. Surface defects have been a long-standing troubling issue in hot rolling processes due to the ineffectiveness of existing detection methods. This paper presents an advanced statistical analysis method to identify the impacting factors in surface defects of hot rolling processes. The surface defects on the steel are measured by a new sensing system, the hot eye imaging system. The result obtained can provide guidelines for root cause identification and quality improvement of hot rolling processes [61, 62]. In order to solve various limitations, the hybrid of a knowledge-based expert system and a computer-aided design system (CAD) was successfully applied recently. Perotti et al. have designed the roll pass for manufacturing cylindrical bars by introducing CAD and Liu and Boer have applied computer aided design/computer-aided-manufacturing (CAD/CAM) for roll profile design. Kennedy and Akgerman have developed a computer program to design the process by combining FE analyses and a CAD system [63].

Applications of neural networks and optimization of irregular shape in the rolling of steel are very important. In most applications today, so-called back propagation networks are used. By using the model developed it is possible to study whether a new product with a given width, strength or thickness can be produced, and the optimised mill settings can then be determined. The temper rolling force could be predicted with good accuracy, which can be exploited in determining mill pre-settings [64, 65]. This approach is appropriate for generalized information searches since it is based on statistically generated user profiles. However, in some applications, such metal forming and rolling, an individualized search for a specific user at a given point in time is desired.

In recent years, attention has focused on the development of level II systems that work hand-in-hand with level I systems. Several advanced level II rolling mill set-up systems have been developed. In addition to using classical mill set-up models, some advanced model adaptation techniques have been adopted in level II control. Expert systems and knowledge-based applications have grown, impacting many areas of decision making (especially in manufacturing) such as dynamic scheduling, production planning, quality management, plant layout, advanced manufacturing processes, process optimization, purchasing and materials. Integrated reasoning systems have been implemented to improve the quality control in a rolling mill. Artificial Intelligence techniques have been used in mill set-up systems [66, 67].

The paper describes the design, implementation and testing of an intelligent knowledge-based supervisory control (IKBSC) system for a hot rolling mill process. The results from the trials demonstrate the advantages to be gained from the IKBSC system that integrates knowledge contained within data, plant and human resources with existing model-based systems. In the present study, the results obtained from the present study can be used to establish a database for looper control in hot rolling processes by determining the effect of the front and back tensions and selected process parameters on the maintenance of the uniformity of the strip thickness. Through this study, the capability and usefulness of fuzz application in thickness control in hot rolling was clearly demonstrated [68]. Current Web-based search engines presume a category search for a specific group of users. This approach is appropriate for generalized information searches since it is based on statistically generated user profiles. However, in some applications, such metal forming and rolling, an individualized search for a specific user at a given point in time is desired. The web based expert system developed in this research work gives the rolling load prediction, torque, power cold rolling process and rolling load prediction for the hot rolling process. The design and development of this system has explained in detail in this work. The demonstration and the result are discussed for validation of the web based expert system result.

2.4 Development in Extrusion Process

Sheet metal extrusion is a process in which the extrusion punch penetrates one surface of the sheet metal material to cause it to extrude and flow toward the outlet of the die. In fact, this process is a combined process in which both extrusion and penetration occur at the same time. The process can be seen in production processes, such as in the forming of a protruding part on a strip material, in the preforming of a staged hole in a forming step with a progressive die, and in the forming of the extruded part in a combined fine-blanking and extrusion process. According to recent development of computer technology, the application of computers in manufacturing has been growing rapidly in the area of Computer Aided Design/Computer Aided Manufacturing (CAD/CAM), Computer Aided Engineering (CAE), Computer Aided Process Planning (CAPP), and numerical simulations of manufacturing processes using numerical techniques. In the area of process planning of forming processes, a number of developments have been reported after pioneering work by Niebel and Barker in the late 1960s. In the 1970s, Akgerman and Altan have developed a CAD system for hot forging, Biswas and Knight extending their work in the same area [69–71].

The system developed is, in general, composed of several modules to assist the users in generating forging design rules that are incorporated into the programs and formulated on the basis of grouping relations and process limitations relevant to each operation. In addition, due to the development of knowledge treatment technique, knowledge based manufacturing systems have become popular, based on qualitative and ambiguous human experiences. In these systems, expert system, neural network or fuzzy theory, and artificial intelligence are used with the help of the operator's skill. It is widely known that the expert system has emerged as one of the most active and fruitful areas for research in the application of human knowledge for problems which do not lend themselves to solution by conventional methods because of a lack of quantitative data regarding the input output relations [72, 73]. Expert systems can therefore provide a user-friendly, flexible, intelligent solution to the kind of problem involving complex logic which occurs in engineering, automatic generation of sequence design for multi-stage cold forging being a good example.

In the Cold extrusion of steel is economically attractive due to savings in material, dimensional accuracy, good surface finish, and improved mechanical properties. Hence, cold extrusion is a promising area to explore the process sequence for reducing the manufacturing costs [74]. The shape of a part is usually the major factor that determines the process sequence used for extrusion. Other factors influencing sequence design are composition and condition of the steel, required dimensional accuracy, quantity and cost. Although most cold extrusion of steel is confined to relatively small parts (slugs weigh less than 10 kg), much larger parts have been successfully cold extruded. The practical limits of part size for press operations are governed by availability of machinery and tool materials, plasticity of the work material and economical production quantities. Bodies for large caliber ordinance shells have been produced successfully by both hot and cold extrusion processes. It is still desirable, however, to increase the productivity of shell manufacturing facilities through improvements in process sequence. The selection of optimum process sequence is an art, and so far it has been mainly achieved by using extensive experience and expensive trial-and-error [75, 76].

Several computer-aided approaches to process sequence design have been studied [77, 78]. The methodology for the forming sequence design of axisymmetric parts based on expert systems has been proposed and CAD systems which can assist the design in the production of a shell body have been developed [79, 80]. The finite element method, which is one of the most powerful tools for the analysis of metal forming processes, has been used for process sequence design and the fundamental methodology for systematic design based on the finite element method has been proposed. The process sequence design in cold extrusion to produce a large shell body is investigated by the rigid-plastic finite element method. The main objective is to reduce the number of operations from the currently established sequence (expert's method) for forming a satisfactory final product [81, 82].

In recent years, computer aided process planning (CAPP) and knowledge-based expert systems have been proposed for the forging industry mainly by academics. These systems focus on optimizing both component design and process selection to produce defect-free components. Required parametric information includes component specification, available machines, tooling design/manufacture and cost estimates [83, 84]. Empirical rules and experience-based methods used in conventional design are generally not easy to represent and implement in CAPP systems. This is especially true when components need to be designed with different geometric shapes, dimensions and material type for subsequent forming. Consequentially, most of the CAPP and expert systems in metal forming adopt a variant, also known as retrieval, approach. These systems have typically been designed for specific component families. For each component family there are stored standard process plans that can be retrieved when designing new components belonging to any of the families. The research described here is focused on the development of a process selection module for a generative CAPP system in metal forming [85]. The generative approach produces process plans for a new component based on an analysis of component geometry, material and other factors that may influence manufacturing decisions. This system requires an appropriate representation of component geometry as well as the support of database systems in which all geometric and technological parameters required for an optimal manufacturing process are included [86].

Based on the literature survey and the preliminary investigations, the following three parameters i.e. reduction ratio, die cone angle and % concentration in lubricants are chosen as input parameter which affect the extrusion load, F, and surface roughness, h_{CLA}. The process selection module provides extrusion process options that can produce the features of components required to be formed. The process selection module also provides an evaluation of the formability of the same features. Further work on developing modules for process sequence, design and process validation integrated with experimental analysis will enable this expert system to be a very useful and powerful tool having practical applications in the metal forming industry.

2.5 Review of Bending Process

Bending is the plastic deformation of metals about a linear axis called the bending axis with little or no change in the surface area. Bending types of forming operations have been used widely in sheet metal forming industries to produce structural stamping parts such as braces, brackets, supports, hinges, angles, frames, channel and other nonsymmetrical sheet metal parts. Various V-bending systems have been proposed by many researchers [87]. However, few solutions are applied in actual industrial operations, because it would often be difficult to achieve the efficient tact time and allowable precision at the same time [88]. On press brake, the final bending angle is determined by the addition of two angles: clamp angle and spring-back angle. The first one is the angle of the plate at the lowest position of the punch and the second one is the angle of elastic recovery of plate during the releasing phase. Therefore, an accurate control and prediction of both clamp angle and spring-back are necessary for precision in V-bending. There are two methods for prediction of spring-back. One method consists of calculating the spring back based on load-stroke chart [89].

Based on the predicted spring-back, the clamp angle is determined. It should be noted that the plate should not be over-bent when the final stage is carried out. If there is a possibility of over-bending, a couple of final stages should be conducted by increasing clamp angles gradually before the final target of the punch. However, increase of final stages would lead to increase of tact time. To decrease the number of final stages, an accurate prediction of clamp-stroke angle diagram would be necessary. In the sheet metal industry, it is said that about 70 % of plates are bent at 90° and the angle error margin should be within ±0.25° for so-called high precision bending [90, 91]. Therefore, in this research, the target of the angle error margin is set as ±0.25° for bending plate at 90°. The material of plate is cold-rolled carbon steel sheets, which is widely used in industry. The computing time was set within one second considering application in industrial use.

In the bending processes, the elastic limit of material can be exceeded but yield stress limits cannot. For this reason the material keeps some of its original elasticity. At the end of the loading operation the part being formed conforms closely the tool shape. When the load is removed from the material, it tries to get back to its original shape and bent material springs-back partially [92]. Usually two types of bending, U and V, are considered. The spring-back effect is the main defect of both U and V shaped parts, exhibiting significant modifications of the angles between bottom, sidewall and flange, especially for materials with higher strength-to-modulus ratios like aluminums and high strength steel. Spring-back parameters are mainly influenced by the following factors: punch and die radii, punch and die angles, initial clearance, friction conditions, blank-holder force, draw beads geometry, sheet thickness, elastic modulus, Poisson's coefficient, blank material and constitutive behavior of the material in plastic field [93, 94]. Nowadays, with the advent of computation technology, sheet metal bending processes can be analyzed using the finite element method prior to experiments, which depend on the designer's experience and involve trials and errors to obtain the desired result. From 1993, there have been several papers reporting research work on the numerical simulation of sheet metal bending processes [95, 96].

Commercial codes correctly simulating U and V bending processes have become available as long as sensitive factors, such as the damping value, number of integration points, the blank mesh size, and punch velocity are chosen correctly. Numerical techniques allow taking benefit from predictions of simulation methods in order to determine the optimal process parameters. The computation of process evolution and final results is called a direct problem. An inverse problem is a more complex one and its goal is to determine one or more of the direct problem input data leading to a given result. This inverse technique has been used to optimize different metal forming processes [97–102].

Nowadays, with the advent of computation technology, sheet metal bending processes can be analyzed using the finite element method prior to experiments, which depend on the designer's experience and involve trials and errors to obtain the desired result. From 1993, there have been several papers reporting research work on the numerical simulation of sheet metal bending processes. Prior [103], Finn [104], Huang and Leu [105] reported explicit-implicit solvers to simulate bending processes taking special attention to the spring-back effect. Since then many more articles have been presented with interesting contributions to the understanding and simulation of bending processes and their main defects. Commercial codes correctly simulating U and V bending processes have become available as long as sensitive factors, such as the damping value, number of integration points, the blank mesh size, and punch velocity are chosen correctly [106, 107]. The main objective of this work is to provide web-based expert system application for V and U bending of sheet metal component. This will facilitate the user to find out bending force, springback effect and developed length. It has freedom to access from any location at any time and the latest version with online helps. The main objective of this research work is to provide web-based expert system for analysis of sheet metal bending process. This will facilitate the user to find out the bending force and freedom to access from any location at any time and the latest version with online helps.

2.6 Need of the Expert System

The primary goal of web based expert systems research is to make expertise available to decision makers and technicians who need solution quickly in the area of sheet metal forming. There is never enough expertise to go around certainly it is not always available at the right place and the right time. Portable with computers loaded with in-depth knowledge of specific subjects can bring decade's worth of knowledge to a problem. The same systems can assist supervisors and managers with situation assessment and long-range planning. Many small systems now exist that bring a narrow slice of in-depth knowledge to a specific problem, and these provide evidence that the broader goal is achievable. These web-based expert system applications of artificial intelligence have enhanced productivity in business, science, engineering, and the military. With advances in the last decade, today's expert systems clients can choose from dozens of commercial software packages with easy-to-use interfaces. As stated in the literature survey number of expert system are available in the various areas. But there no web bases expert system in the area of sheet metal forming particularly in deep drawing, rolling, extrusion, bending etc. So there is need to develop web based expert system in the area of metal forming operations. In this research work the main objective is to provide a web based expert system for metal forming operations in the areas such as deep drawing, rolling, extrusion, bending etc. to give appropriate analysis of metal forming operation. The methodology of research work is shown in the following Fig. 2.1 which is based on web based architecture and metal forming expert system.

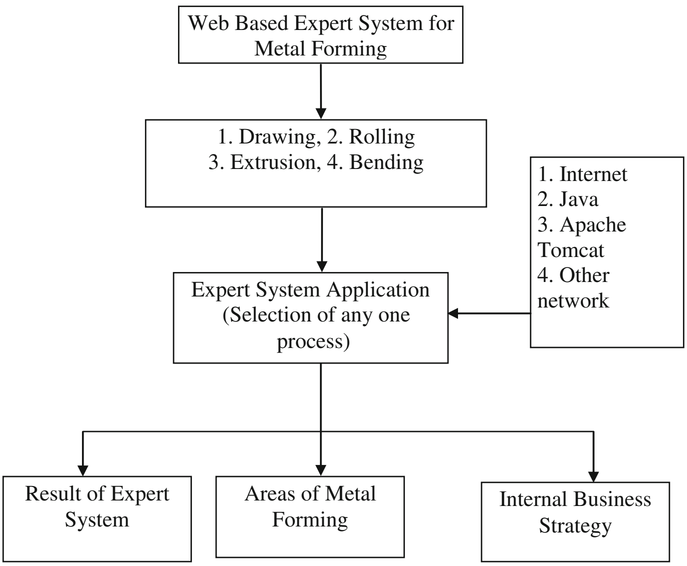

Fig. 2.1 Methodology

2.7 Objectives

Today's industries are facing number of challenges because of technology driven competition. Sheet metal forming plays vital role in this competitive world and it is key area to overcome those challenges. The field of application range from automotive engineering, production line and container constriction through to building constriction, household appliance and packing industries. In the present era of high-speed global networking, the increasingly small role played by spatial separation can be regarded as fully logical. Nowadays, all encompassing data networks at local and global levels are part of the infrastructure of every modern fully automated industrial society. The present trend is to develop web based expert system application for offering solutions to industrial problems. Already there are few web based applications available in quality control, inspection planning and casting area, design, CAD/CAM, Medical sciences etc. Web based expert systems are not available in sheet metal forming area particularly in deep drawing, rolling, extrusion, bending etc. The main objective of this research work is to provide web based expert system for deep drawing, rolling, extrusion, bending processes.

The main objective of this research work is to design and develop a web based expert system for metal forming operations with following features:

i. Provide forming analysis for deep drawing process.
ii. Rolling load prediction in cold rolling process and hot rolling process.
iii. Prediction of forming parameters in extrusion process.
iv. Prediction of force in V and U bending process.

The design and development of web based expert system is presented in the Chap. 3.

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Chapter 3
Fundamentals of Expert System

Abstract Expert systems (ES) emerged as a branch of artificial intelligence (AI), from the effort of AI researchers to develop computer programs that could reason as humans. Many organizations have leveraged this technology to increase productivity and profits through better business decisions. ES are one of most commercially successful branches of AI. Although there have been reports of ES failures, surveys show that many companies have remained enthusiastic proponents of the technology and continue to develop important and successful applications. The detailed fundamental concepts and application expert system has been discussed in this chapter.

3.1 Introduction

The early applications of expert systems were standalone, based on mainframe, AI workstations or PC platforms. Later came LAN-based distributed applications. Despite their commercial success, there are several problems and limitations are associated with traditional ES applications:

1. Knowledge bottleneck: It is difficult to acquire knowledge from different sources. Experts are often unable to express explicitly their reasoning process.
2. Performance brittleness: An ES is limited in its coded expertise, which relates to a narrow domain and the ES therefore performs poorly outside its boundary.
3. Availability: Having the expertise provided by an ES at the place and time where it is needed is a problem when limited to the use of a stand-alone system.
4. Software distribution: Updating the software and interface requires many separate installation and upgrades over time. This is often beyond the competence of the users.
5. Communication between distributed applications: A lack of common protocols for knowledge transfer tends to discourage designs involving co-operation or dynamic information sharing.

Internet-centered information and communication technologies (ICT) are changing IS applications. Power argued that rapid advances in Internet technologies

R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9_3

have opened new opportunities for enhancing traditional DSS and ES. Internet technology can change the way that an ES is developed and distributed. For the first time, knowledge on any subject can directly be delivered to users through a web based ES. Since its main function is to mimic expertise and distribute expert knowledge to non-experts, such benefits can be greatly enhanced by using the Internet. However, few web-based ES have been offered and analysed to shed light on the methodology and challenges of developing them. This is all the more surprising when commercial ES development tools such as EXSYS CORVIDTM and XpertRule Knowledge BuilderTM have been extended to offer web-based delivery.

3.1.1 Web-Based Expert System

The literature appears to offer contradictory pictures on the status and use of web-based expert system. There are some examples of web-based expert systems in industry, medicine, science and government and claimed that there are now a large number of expert systems available on the Internet. It has been proved that there are several factors that make the Internet, by contrast to standalone platforms, an ideal base for knowledge based system (KBS) delivery. These factors include:

1. The Internet is readily accessible.
2. Web-browsers provide a common multimedia interface.
3. Several Internet-compatible tools for KBS development are available.
4. Internet-based applications are inherently portable.
5. Emerging protocols support co-operation among KBS.

It is also identified several problems in the development of web-based KBS:

1. Keeping up with rapid technological change to servers, interface components, inference engines, and various protocols.
2. Reducing the potential delivery bottleneck caused by communication loads and a limited infrastructure.

There are numerous examples of expert systems on the web, but many of these systems are small, non-critical systems. The most successful example is probably the web-based legal expert system reported. It is remarked that manufacturing firms are collecting hundreds of thousands of dollars in subscription fees from clients who use web based expert system on the web.

It is stated that there are not many expert system on the web due to the fact that the Internet was not created with applications such as expert systems in mind. As a result, the manner in which the web and web browsers interface made it difficult to perform the actions required by ES. The research reported a dynamic web-based knowledge system for prototype development for extended enterprise. It is suggested that the use of emerging Internet technology made the development of multifunctional AI systems relatively easy and less expensive, but that many users in the business arena were unaware of these technologies and their potential benefits. Consequently, the business community was not aware of the value or educated to deploy the potential available from these technologies in making their business more efficient and competitive.

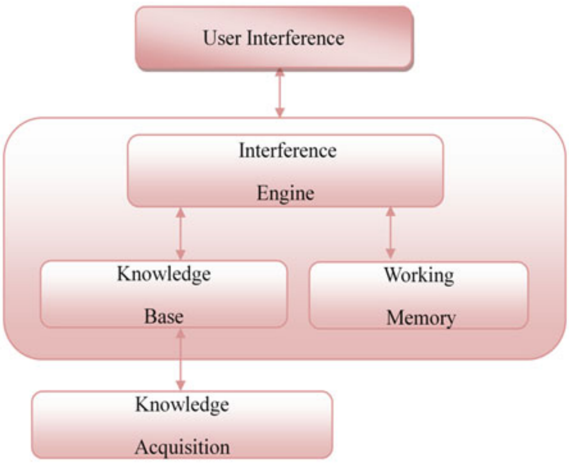
3.1.2 Knowledge Based Expert Systems

KBS are computer programs which capture and retain expertise that has been gained over many years of engineering experience and also employ knowledge gained from other (than human) knowledge sources. KBS can reason intelligently about necessary action to take in real time, thus freeing operational staff. An expert system consists of an inference engine, a knowledge base and a working memory as shown in Fig. 3.1. The inference engine makes predictable and consistent decisions using the rules stored within the knowledge base. The use of a knowledge base enables the distinct separation of the process knowledge from its control and manipulation. The working memory stores information derived from both the input data, and conclusions drawn by the inference engine. Interactions with the expert system are made in defining the rules (knowledge acquisition) and from the external user of the system.

The principle components of KBS include:

i. The knowledge base to represent the facts, rules and events.
ii. The database, which contains information about the current problem.
iii. The inference engine, which draws conclusions from the knowledge base.
iv. A system interface in order to pass conclusions to the system.
v. The explanation component, which informs the user on how conclusions are obtained.
vi. The workspace, which is an area or memory for storing the problem description.

Fig. 3.1 Architecture for knowledge based expert system



KBS are designed to be modular in that the knowledge base is separated from the inference engine and algorithms so that new situations can be accommodated. Rules can easily be added, deleted or changed without affecting other rules. Also separation of the knowledge base from the algorithms means that algorithms can be separated from heuristic knowledge thus allowing for higher-level reasoning, making the intelligent control system more robust and flexible. Moreover, separation of the knowledge base from the control elements allows the inference engine and algorithms to be generic so they can be applied to a variety of processes. This means that it is possible to begin operating a process with an empty knowledge base and create a new knowledge base for the particular process.

3.1.3 Limitations of Expert Systems

The classical expert system structure has two main weaknesses:

i. The control of the application of the knowledge is implicit in the structure of the knowledge base. For example, in the ordering of rules for a rule-based expert system.
ii. The representation of the knowledge is dependent on the nature of the inference engine.

The blackboard model covered in a later section, serves to eliminate the weaknesses of the classical expert system structure. By separating the problem-solving knowledge into separate knowledge sources, separate solution methodologies can be applied each using their own inference engine. Hence, the representation of knowledge would no longer be dependent on the nature of the inference engine. Another weakness of the classical expert system is that for increasingly large problems, as the size of the knowledge base increases, the inference engine must cope with the focus-of-attention-problem. In general, classical expert systems are application specific where each expert system must be developed for each individual expert system application. The main objective of this research work is to the develop web based expert system for metal forming operations which include deep drawing, rolling, extrusion and bending processes.

3.1.4 Proposed Hierarchical Structure

Sardis functional hierarchy is the most common method used to describe integration of tasks and is based on management models. It is organized according to the Principle of Increasing Precision with Decreasing Intelligence (IPDI principle). Three levels were proposed:

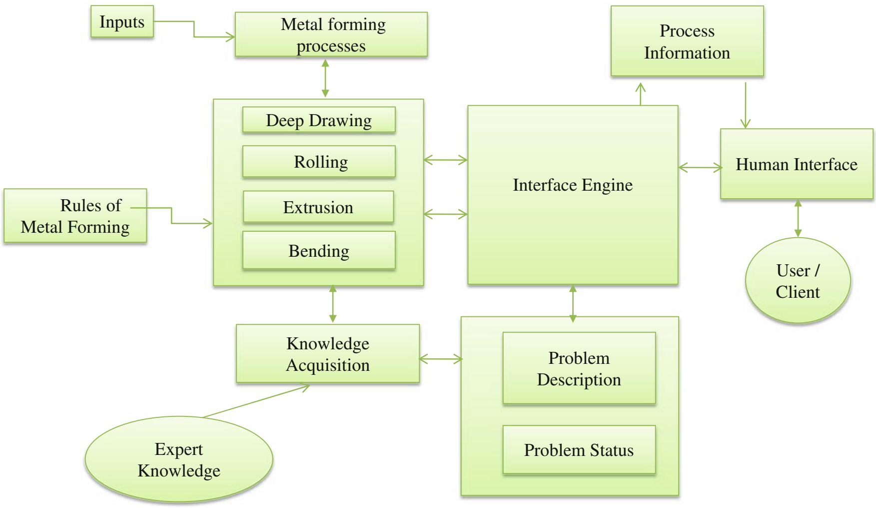


Fig. 3.2 Web based expert system architecture

i. The execution level (lower level),
ii. The coordination level (or intermediate level) and
iii. The organization level (higher level).

The motivation behind this structure is that tasks and operations are ordered from a more abstract, less time crucial levels to more specific, data intensive and time crucial levels as shown in Fig. 3.2 of Web based expert system architecture. In this hierarchical level expert system applications are available in it. The areas selected are deep drawing, cold and hot rolling process, extrusion and bending processes.

All theses metal forming processes are get interacted with the interface engine. In the interface engine there are problems and problem status information is placed. The interface engine has interaction with the process information and human interface. The execution of expert system takes place in the server side and the client will get the solution of the expert system. In this way web based expert system architecture plays a central role in the area of metal forming operation.

3.2 Background of Web Based Expert System

3.2.1 Expert Systems

An expert system is a computer program designed to imitate a human expert, mimicking the knowledge base and the decision making process of a human expert. An expert system is different from conventional programs because it can explain its behavior to the human expert and receive new information without new programming. The necessary properties of expert systems as:

i. Transparency: expert systems explaining their solution by quoting the knowledge used.
ii. Flexibility: single pieces of knowledge being easily added, changed or deleted.
iii. User friendliness: the use of expert systems requiring no previous knowledge of programming languages (neither for the end user nor for the expert).
iv. Competence: on account of the expert knowledge, expert systems having a high problem-solving capability in their domain.

3.2.2 Rationale for a Web-Based System

The web based expert systems organize information into two bases, a knowledge base and an inference engine or rule interpreter. Applying this to the process of designing for expert system for metal forming and the knowledge base contains all of the various mathematical equations, theories and rules the designer uses throughout the process and the inference engine represents the method used to select which rules and equations to invoke. The World Wide Web has several capabilities that make it well suited for use, both as the container for the knowledge base and the inference engine. The cross-platform capability of the Web removes the problems of operating system compatibility, ensuring that users on any machine will have the same access to the information. Software for browsing the Web is generally simple to use and easy to install. Also, the ability for the site developer to keep large amounts of information updated regularly removes that burden from the end user.

In the development of web based expert system the information of metal forming processes taken for analysis purpose. The detailed mathematical formulation, theories and hand book information has taken for various operations of metal forming processes.

The great strength of the web lies in the standardized language of all web documents and kept it on line. However, this can be the biggest obstacle to the implementation of an expert system. The programming language used for created web pages is hypertext markup language (HTML). This language can specify the formatting for the display of a document as well as create links between documents, within a document and to non-web services. It can also insert graphics and mathematical formulation into a document format. However, it is not capable by itself of providing the real-time interaction a true expert system requires. To address these concerns, interactive tools like JAVA and VBASIC are becoming available for use on the web, allowing a greater degree of real time processing for web-based expert system applications.

3.2.3 Web Manufacturing

The internet and World Wide Web are beginning to be used more and more as manufacturing tools. The web based expert system is useful for the metal forming operations. It is also possible to do online manufacturing. The internet system connects several computer numerical control (CNC) machining platforms, along with industrial robots to load and unload parts, to an Internet connection allowing remote control and operation. The model work is designed to support research in the planning, scheduling, control and analysis of intelligent manufacturing systems. This project is concerned with rapid prototyping over the Internet. In this program, designers at several sites around the country work together over the Internet on different part features and the finished part is prototyped at a remote location. Researchers have proposed connecting manufacturing systems to design and analysis systems over the Internet. Figure 3.3 shows a schematic of the typical web-based design and manufacturing system. Users access the World Wide Web or the Internet through their computer and the web then provides access to the system's server. The user then interacts with the server, designing the part, transferring data, obtaining quotes and delivery estimates. Finally, the newly created part design is transferred to the manufacturing facility, produced and then shipped back to the design.

3.2.4 System Architecture

The different types of technologies available in the market for interactive applications on the Web. CAD/CAM developers using Microsoft platforms and software tools have a wide range of options supporting creation on interactive application on the Web. This includes Internet software development kit (SDK), Internet server application programming interface (ISAPI), dynamic-link library (DLL) in Visual C or other programming languages, site development tools such as Microsoft Front Page and Internet Studio. Web based expert system applications can be created using visual tools as well. Other technologies such as client-side and server-side components, client-side and server-side scripting are also available and presented shortly below.

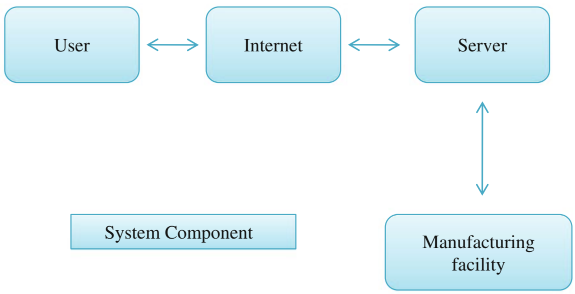


Fig. 3.3 Typical web based manufacturing system component

3.2.5 Active Platform Concept

Microsoft active platform (AP) has been designed to simplify creation of interactive application on the Web. Component architecture of the AP allows reuse of components, language transparency and adapting platform to specific applications related with metal forming. It is based on open standards and allows creation of multiplatform applications in the area metal forming and engineering sciences. Open standards assure interoperability of software products from different vendors running on different platforms. Because AP idea is based on simple rule, i.e. HTML, scripting components, there is no limitation in languages used in writing scripts or components and Web browser to be applied. The AP concept is presented in Fig. 3.4. It can be noticed that the AP idea is based on enrichment of both server and client sites in such elements as follows:

1. HTML which is a programming tool for designing of interactive application on the Web. The front page design of web based expert system is completed by using HTML.
2. Scripts performing additional tasks, written in script languages, i.e. Visual Basic Script (VBScript), Java Script, servicing objects in HTML documents such as Java applets, ActiveX controls. Java Script is used for formulation of deep drawing, rolling, extrusion and bending processes.
3. Components which are well defined programs performing specific tasks in the application on the web based expert system. These are helpful to perform specific task associated with metal forming operations.

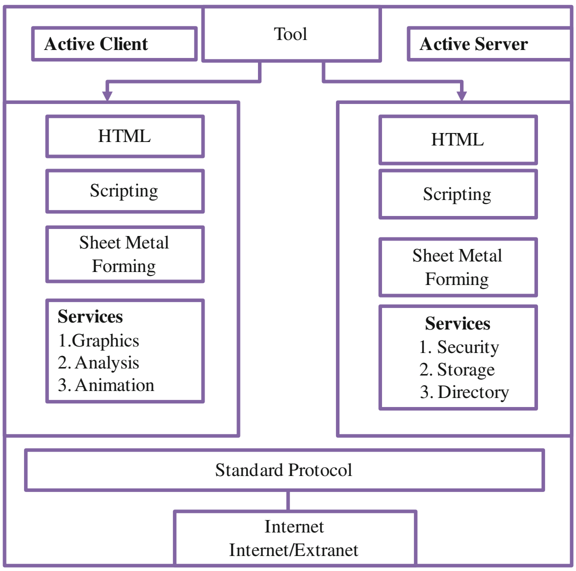


Fig. 3.4 Microsoft active platform concepts

The basis of object services is component object model (COM). This is a standard for defining creation of application components assuring reliability of their interoperation. The COM makes easy creation of distributed, scalable components to be reused. Distributed COM enables communication between user and expert system component running on different computers. Automation built in COM supports scripting tools for manipulation of objects inserted in web pages or other applications. System designer is not limited to only one language because AP accepts components written in Java and C. Using tools available in AP, HTML documents, ActiveX controls can be created both for server and a client. System designer is neither limited to one operating system for running the application of expert system because all objects used in Internet are accepted by Macintosh, Windows 95, NT and UNIX operating systems.

3.2.6 Active Server, Active Client and ActiveX Active Client

Active client supports web based expert system implementation of HTML, Microsoft's Java Virtual Machine (VM), language-independent scripting using VBScript or Microsoft's JavaScript compatible scripting (JScript). Access to local and networked objects via ActiveX is available as well. Functionality of active server can be formed by HTML, scripts, components of interactive applications and unnecessary services. Combining these technologies in server, active server can be obtained. Active server includes the services necessary to make component and web-based applications of expert system run over the Internet/Intranet.

Chapter 4
Design of Web Based Expert System

Abstract The design of expert is important to formulate the problem for specific application. In the web-expert system application server domain, Java servlets are fast replacing the CGI. By year 2008, most of the Java based application servers are expected to be based on Java servlets for connecting the middle-tier components with the HTML content (or templates for different web pages of metal forming operations).

4.1 Introduction

The presented work is an extract of an internal development effort, during which the author happened to examine some of the development issues associated with developing small-to-medium scale web expert system applications using Java Servlets in response to development of web based expert system for metal forming.

4.2 Java Servlets

Java servlets are small, platform independent server-side programs that programmatically extend the functionality of the web server to run different application web based expert system. The Java servlet API provides a simple framework for building metal forming applications on web servers. This API is described in the Java Servlet API Specification (currently version 2.1) by the Java Software Division of Sun Microsystems Inc. This platform is used for development of 27 shape classified geometries.

Java servlets are not user-invocable applications. Servlets interact with a servlet engine (an implementation of the Java Servlet API specification) through requests and responses to run application of expert system. The servlet engine in-turn interacts with the web server by delegating requests to servlets and transmitting responses to the web server.

R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9_4

When compared to the Common Gateway Interface (CGI) and proprietary server extensions such as Netscape Server API (NSAPI) or Microsoft's Internet Services API (ISAPI), servlets provide a better abstraction of the Hypertext Transfer Protocol (HTTP) request-response paradigm. In addition, servlets have all the advantages of the Java programming language, including platform independence which helpful to run different types of expert system applications. Java servlet based expert system applications can be deployed on any web server with built-in (in-process) or connector-based (out-of-process) servlet engines, irrespective of the operating system and the hardware platform. This is one of the reasons for servlets is used in design of web based expert system.

4.3 Java Servlet Framework

In the HTTP based request-response paradigm, a client user agent (a web browser or any such application that can make HTTP requests and receive HTTP responses) establishes a connection with a web server and sends a request to the server. If the web server has a mapping to a servlet for the specified URL in the request, the web server delegates the request to the specified servlet. The servlet in turn processes the request and generates a HTTP response. For a description of the HTTP protocol and the request-response paradigm, see RFC-2068. This protocol is developed for all metal forming operations used in this research work.

For web based expert system application development, the servlet API provides three primary abstractions: HTTP requests, request processing based on some application logic, and HTTP responses. These abstractions simplify the application development as far as the requests and responses are concerned. These are involved in execution of expert system. The client has to give the request. This request goes to server side. The execution of request takes place and client will get requires solution of expert system application. These are described as below.

4.3.1 HTTP Request

The interface Http Servlet Request is the first abstraction provided by the servlet API. This interface encapsulates HTTP request from a user agent. When the servlet engine receives a request, an object of this type is constructed and passed on to a servlet. This object provides methods for accessing parameter names and values of the request, other attributes of the request, and an input stream containing the body of the request. This type of request should come from client side that is going to utilize the expert system of metal forming.

4.3.2 HTTP Response

The Http Servlet Response interface of the servlet API provides an encapsulation of the HTTP response generated by a servlet. This interface defines an object created by the servlet engine that lets a servlet generate content in response to a user agent's request. This object provides methods to set type and length of the content, character encoding, cookies, response status including errors, and an output stream into which binary response data may be written. Alternatively, this object also provides a print writer object for writing formatted text responses. The response is the output of the expert system which is related with the specific operation of metal forming.

4.4 Application Logic and Content Generation

The Http Servlet interface specifies methods for implementing the application logic and generating content in response to a HTTP request. These methods handle the GET, POST, HEAD, DELETE, OPTIONS, PUT and TRACE requests of HTTP. These methods are invoked by the servlet engine and act as placeholders for implementing web based expert system application logic. The servlet engine also supplies Http Servlet Request and Http Servlet Response objects to these metal forming operations.

These interfaces are shown in Fig. 4.1 in the context of a request and a response. In this diagram, the service method of the HttpServlet is shown to implement the application logic and content generation, although one of the doGet, doPost, doHead, doDelete, doOptions, doPut or doTrace methods can handle HTTP requests. This frame work has implemented for interaction between expert system for metal forming and the client side.

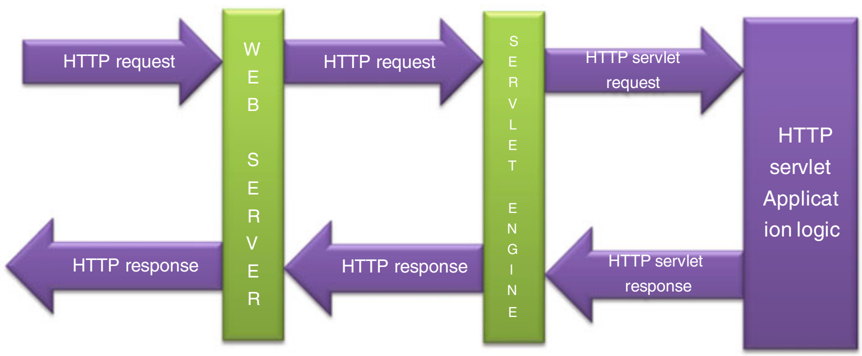


Fig. 4.1 HTTP servlet framework

4.5 Session Tracking and State Management

The HTTP, which is the underlying protocol for web applications, is stateless. This protocol covers only a single request (with the connection initiated by the user agent) and a response. In this protocol, irrespective of the status of the protocol, the connection may be closed by either of the transacting parties. This has the following ramifications:

- The protocol has no mechanism by which a series of unique requests from a user agent may be identified as being from the same user agent. Consequently, in a transaction spanning multiple requests and responses, the web server cannot uniquely determine that all the requests are from the same user agent. A user, therefore, cannot establish a dialogue with the web server to perform a application of the web based expert system.

The Java servlet API provides the HttpSession interface for session tracking and state management in a session. A servlet obtains an HttpSession object from the associated HttpServletRequest object. Servlets track sessions by URL rewriting or by cookies (See the tutorial on Servlet Essentials at http://www.novocode.com/doc/servlet-essentials for more details). Objects of type HttpSession can be set or obtained for new and existing sessions respectively from HttpServletRequest objects. Session specific data can be stored into these objects.

4.6 Web Based Expert System Development Issues

The Java servlet framework provides an object-oriented abstraction of the request-response routing model of CGI, and is well suited for gluing back-end applications to the web server. However, this framework is not adequate for object-oriented application development because of its inherent nature. This section examines the issues associated with servlet management and some of the possible application architectures for metal forming operations. These issues are taken into consideration while designing the web based expert system for metal forming.

4.6.1 Servlet Management

Java servlets are server-side programs and are completely managed by the host servlet engine as described below. A host servlet engine manages Servlets for running the different application developed for 27 shape classified geometries. The servlet specification guarantees that a servlet is available for service against a request pointing to that servlet. Based on application of expert system, the servlet engine might destroy and reinitialize a servlet between two consecutive and identical requests from the same or different user agents. Alternatively, the servlet engine may maintain a pool of servlet instances and execute one of the free instances in the request thread of metal forming operations.

The web server may have a load-balancing scheme under which identical requests to a servlet URI (Universal Resource Interface) may invoke service methods of different servlet instances in different servlet engines running on two different platforms so that we can run other application of expert system such as rolling, extrusion or bending. Thus, identical requests may be serviced by different servlet instances in different Java virtual machines.

4.7 Architecture of Expert System

The following architectures are possible within the Java servlet framework.

4.7.1 Single-Tier Architecture

One of simplest approaches for servlet-driven web application development is based on the single-tier architecture. In this architecture, the application consists of a number of servlets each generating one or more web pages. The simplicity of this approach arises from the fact that there is often a one-to-one correspondence between a business transaction and a web page generated dynamically by the application. This usually leads to a one-to-one correspondence of a web page to a servlet generating that web page. The resulting architecture is shown in Fig. 4.2. The arrows towards HTML pages indicate HTTP responses from servlets while the arrows in the reverse direction are HTTP requests. By using architecture client can view only HTML pages of web based expert system only.

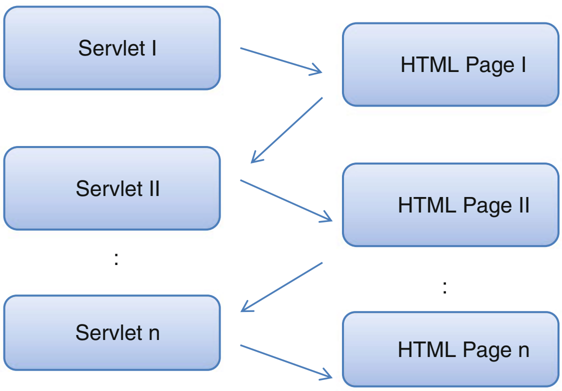


Fig. 4.2 Single-tier architecture

Note that, in the cases of client-side programs (for example Java Applets or ActiveX components) in the generated content, this architecture may be treated as a two-tier architecture. Web browsers rendering plain HTML pages should not otherwise be considered to form the additional client-layer, since this approach does not actually partition the application.

4.7.2 Two-Tier Architecture

The single-tier architecture is not adequate for applications requiring data or services from additional servers. In this case, some or all the servlets need to connect to such back-end systems. This results in two-tier architecture as shown in Fig. 4.3. In this architecture, servlets act as gateways for the backend systems. The programme of different application expert system can format with this architecture. But is also insufficient architecture to design and implement web based expert system application.

4.7.3 Three-Tier Architecture

This is the most common architecture for servlet-based applications. In this architecture as shown in Fig. 4.4, the application logic is implemented in a set of helper classes. Methods on objects of these classes are invoked by the service methods in the servlets.

If instances of helper classes contain session-specific state, such instances should be stored in session objects, as servlets cannot hold references to such objects across multiple requests. This leads to breaking encapsulation of the application.

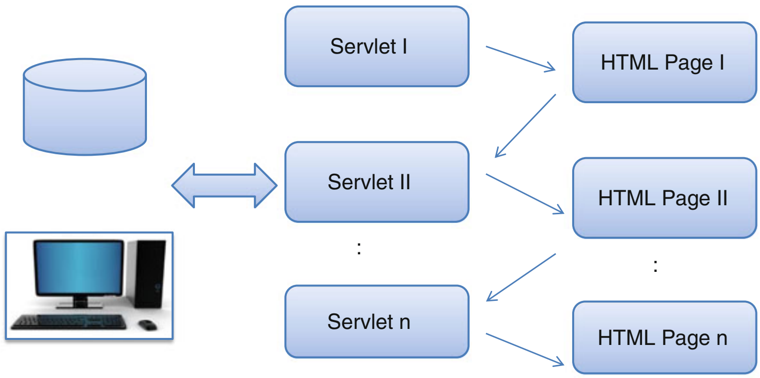


Fig. 4.3 Two-tier architecture

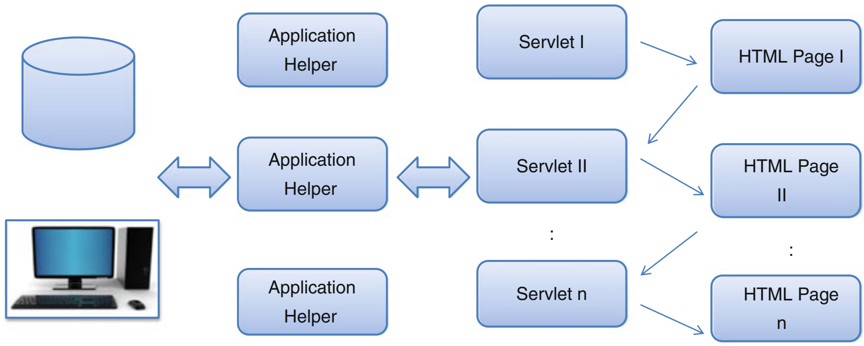


Fig. 4.4 Three-tier architecture

In all the above architectures, each servlet typically performs the following tasks:

1. Session tracking: The first servlet establishes the session and the rest of the servlets in the application track the session either by cookies or by URL rewriting.
2. State management, by storing pre-identified state of the application (including instances of helper objects, if necessary) in HttpSession objects associated with HTTP requests.
3. Application logic, as necessary.
4. In the case of a two-tier and three-tier architectures, connections to back-end systems for data or services.
5. In the case of a three-tier architecture, invocation of methods on helper objects.
6. Content generation.

Further, additional methods may be specified in servlet classes for performing application logic of different operation such as deep drawing, rolling process, extrusion and bending process. In such cases, it is possible (with some constraints as discussed above) for a servlet to invoke these methods on other servlets. This three tier architecture has been implemented for design and development of web based expert system.

4.8 Role of Servlets

While embarking web based application development based on Java servlets, it is necessary to recognize the fact that HTTP servlets provide an object-oriented abstraction of various HTTP requests. Servlets are not meant for enterprise-level application development. Note that a servlet engine manages servlet instances. A servlet engine provides the necessary framework for design of web based expert system for metal forming. As in the case of any framework, the developer must carefully examine the constraints associated with application of metal forming operation.

4.8.1 Databases

In an effort to web-enable databases, the most common practice is to obtain database connections and to operate on databases. However, such an approach is not scalable and manageable. Here are some of the issues.

4.8.1.1 Connection Management

Since servlets do not maintain their own state, database connections cannot be maintained across multiple executions of servlet methods. This necessitates an additional connection-pooling layer. In general, any distributed application can gain significant performance improvements by pooling connections to servers. This is implemented for client side to access the information related with recent development in metal forming area.

4.8.1.2 Manageability

As is the case with typical two-tier architecture, knowledge of database tables and SQL gets spread across all the servlets in the application. A good practice is to consider a separate layer to do most of the database-centric processing. However, not so surprisingly, most of the application servers (including the popular Netscape Application Server) encourage this style of programming in the name of RAD.

4.8.2 Application Logic

For scalability sake, servlets should not be used to process complex application logic. Accurate formulation of metal forming operation is to consider a distributed architecture and move complex application logic into a separate layer of Apcahe Tomcat servers.

4.8.2.1 Two-Tier Applications

You can view the client-server model as being a two-tier application structure. This is extended in the three-tier model by the addition of a middle layer that fits between the client and the data sources. The three physical tiers breaker down as follows.

4.8.2.2 The Client Tier

It is the font-end tool with which the end user interacts. It may take the form off any type of user interface, such as visual basic application or a web browser in JSP applications; the client tier usually takes the form of a web browser. The client tier is also referred to as the presentation tier. It contains all the presentation logic; the code responsible for displaying data to the end-user and also for retrieving information forms the end user. The information of metal forming operations like deep drawing, rolling, extrusion and bending is formatted in client format by using HTML language.

4.8.2.3 The Presentation Tier

The presentation tier of a 3-tier application may take the form of any type of user interface such as a VB application or a web browser. These applications, the client tier usually takes the form of a web browser, In any case applications and components in the presentation tier run on the client's machine and consume client resources.

The presentation tier has two key characteristics.

The presentation tier only contains presentation logic. It does not concern itself with the inner workings of the application. The presentation tier does not access data source directly. In order to access data, it moist passes requests to the business tier, which performs data access on the client's behalf. The level of separation and encapsulation obis important, because it shields the browser forms the complexity of our applications inner workings. As a consequence, we can make changes in the middle tier without having toy update client. For example, we could change the metal forming operations rules, we could add new servers to enhance performance, and could even add or change databases.

4.8.2.4 The Middle Tier

This tier represents most of the logic that makes the application functional in case of JSP this is where our JSP page resides, upon the web server. It is where the metal forming rules come in picture and where you will find a collection of metal forming operation rules. As you may realize those obeys make up the greater part of the applications functionally and also account for a big percentage of its size too.

The client tier collects information-required form the sure so that the middle tier can perform whatever processing is necessary to achieve thee tasks; the application is intended to perform. Sometimes this will require additional information to be written to some form of persistent storage. The third tier however handles the data transactions of metal forming operations.

4.9 Basics of Web Based Expert System

The internet provides an effective solution for broadcasting information across different platforms. For example, many metal forming industries use the Internet to distribute product information, directories, or company policy manuals to people both within and outside of the organization. By applying Internet technologies to their internal network, organizations can help third employee's share, analyze, and find information more easily. In this way web based expert system has to implement to access information and expert system for metal forming processes analysis to clients.

4.9.1 Basic Terms and Concepts

The internet is a collection of computer networks that connects millions of computers around the world. The World Wide Web is client/server technologies used to access a vast variety of digital information form the Internet. This technology is used in in development of web based expert system for metal forming processes. By using a software client called web browser, such as metal forming information and a modem of other connection to an Internet Service provider (ISP), you can easily access text, graphics and analysis of metal forming analysis form practically any computer in the world that is running the appropriate server software on the Internet such as Apache's Internet Information Server.

4.9.2 Web Browser

If you want fall access to www and its features, you need a browser. Web browser uses variety of standardized methods for addressing and communicating with Internet servers such as metal forming and other area in engineering. The most common protocol is Hypertext Transfer Protocol (HTTP), which was originally created to publish and view liked text documents of metal forming, but has been extended to display and run a growing variety of graphic, sound, video, and other multimedia content. Other common protocols include File Transfer protocol (FTP), Gopher, telnet, RealAudio, as well as protocols used to start other applications such as e-mail and Usenet newsreaders.

To run or display Internet content with a web browser, you have to type an address called a Uniform Resource Locator (URL) into its address box. For example, this is the URL for the development of web based expert system for metal forming operation on web site of SGSIE and Technology, Vishnupuri, Nanded MS India: http://sggs.ac.in/prod/p.hd/web based expert system for metal forming.

A URL specifies the location of a file on an Internet server. On it web browser uses a URL to download and open the file, which is most typical a page, formatted with Hypertext Markup Language (HTML) tags. This URL and HTML are implemented for design of web based expert system.

4.9.3 The Web Server

The heart of any web interaction is the web server. The web server is a program running on the server that listens for incoming requests and services those requests as they come into execute the application web based expert system for metal forming operations. Once the web server receives a request, it then springs into action. Depending on the type of request the web server might look for a web page or it might execute a program on the server. Either way, it will always return some kind of results to the web browser, even if it's simply an error message saying that it could not process the request.

Apache Tomcat is the top-level entry point of the documentation bundle for the Apache Jakarta Tomcat Servlet/JSP container which has been implemented for this research work. Apache Tomcat version 5.5 implements the Servlet 2.4 and Java Server Pages 2.0 specifications from the Java Community Process and includes many additional features that make it a useful platform for developing and deploying web applications and web services for metal forming operations. This is platform provided for web based expert for metal forming to validate its functionality. In this way research work on web based expert system developed and demonstrated for metal forming processes like deep drawing, rolling, extrusion, bending on this platform.

4.9.4 Internet Protocols

Web browsers use a variety of standardized methods for addressing and communication with Internet servers. These methods are called protocols. The most common protocol is Hypertext Transfer Protocol (HTTP). Which was originally created to publish and view linked text documents of initial information of deep drawing, rolling, extrusion and bending? It has been extended to display and run a growing variety of features of operations.

4.9.5 Uniform Resource Locators

To run or display Internet content with a Web browser, you type an address called a Uniform Resource Locator (URL) into its address box. You can enter a URL that points to any Internet file type or resource supported by the browser that will be used to display or run it. You enter most URLs in the following format:

Protocol://serveraddress/path

This protocol is implemented for this expert system in the following format. http://sggs.ac.in/prod/p.hd/web based expert system for metal forming.

Protocol specifies the Internet protocol used to establish the connection to the server and is generally followed by a colon and two slash markets. Server address specifies what is usually called the domain name of the Internet server. Path specifies the location and name of the page or file on the Internet server.

4.9.6 Hypertext Markup Language and Hyperlinks

Most files you download and open with a web browser are pages formatted with Hypertext Markup Language (HTML) tags. HTML tags are coded enclosed in angle brackets that are used bay a Web browser to determine the structure and appearance of an HTML tags in the following sentence:

Make <B> Metal Forming </B> look bold
Cause the text to display like this when viewed with a Web browser:
Make *Metal Forming* look bold.

4.9.7 Extension to Standard Web Browser Functionality

Standard web browser functionality is evolving through the addition of variety of new technologies such as helper applications, plug-ins, activeX controls, java applet, and java servlet languages. These are useful for development of expert system applications.

4.9.7.1 ActiveX Controls

By using an ActiveX controls, web based expert system author can extend the kinds of content that can be displayed on a web page. They can also enhance their web pages with sophisticated formatting features animation, and embedded programs that performer operations such as background downloading. ActiveX controls don't need to installed beforehand they can be downloading when a user fires it opens a web pages of metal forming operations.

4.9.7.2 Java Applets

By using the java programming language, design of web based expert system can produce application called applets, which can performer functions similar to plugging and ActiveX controls. To display or run a java applet from a web page a web browser must be able to compile and run code of metal forming operation.

4.9.7.3 Server Side Technology

The web based expert system are looking to internet technology to improve productivity, reduce cost and provide access to exiting information and knowledge in new, dynamic, and interactive ways. Businesses want to run web-based expert system applications on third servers in order to realize the advantages of providing users access to information at their fingertips.

For example you can

- One can put design handbook online, rather than printing copies that are obsolete soon after publication. This also reduces cost involved in putting new edition.
- One may use existing inventory database and order processing system of metal forming.

While much of this can be done today through creative programming tricks, the challenge until now has been to find a technology that is easy to use, open and saleable and takes advantage of existing skills and investments in the area of metal forming.

4.10 Building of Web Based Expert System

Web based expert system building or programming is the next step after designing the system. The empire of system design does not immediately give way to analysis of a metal forming operation. As one phase rises in importance, the previous one begins to fade and is sometime briefly resurrected when there are new discoveries.

The system building has been conducted through different stages namely tool selection for developing the application, programming the design into codes and finally the testing of the web based expert system application.

4.10.1 Tools Selection

One of the important tasks in the process of software development during the web based expert system building is the estimation and selection of tools required accomplishing the effort. Two types of tools should be considered i.e. software and hardware.

4.10.1.1 Hardware Resource

Within the resource context, hardware plays a very important role in the software development. Two hardware categories are considered for the work.

- Target machine (client machine): It is the machine on which the software will eventually run/be executed. As stated earlier the target machine i.e. the client machine would be any machine having any specification irrespective of the operating system.
- Development system: It is the system consisting of computing machines and related peripherals that will be used during the software development. Also called as host system. The project requirement stands out to be having with sufficient primary and secondary memory. The available facilities for running the expert system are given below in Table 4.1. There are other types of advanced facilities are also available to run the expert system (Table 4.2).

4.10.1.2 Software Resources

Some basic software has to aid in the development of new software. System software utilities, editors, compilers and debuggers are the legitimate part of the application development. Object oriented programming tools, fourth generation programming languages advanced database query systems and a wide array of pc tools (Active x controls, ADO, etc.) all fall in this category.

It's very difficult or merely impossible to remember the logic of a complicated program forever. Good documentation of metal forming is the key that opens the lock. Some of the ways planned for the documentation of the program are

Table 4.1 NT server machines specifications

NT server	
Operating system	Windows NT, Windows 98, Windows XP
Processor	Pentium III, IV, 500 MHz, 128 MB RAM, 20 GB HDD
Support	Multimedia kit with 52x CDROM Drive, 107 Keyboard 15″ color monitor

Table 4.2 Client machines specifications

Client machines	
Operating system	Windows NT, Windows 95, 98, Windows XP
Processor	Pentium II/III, 330 MHz, 128 BRAM, 10 GB HDD
Support	Multimedia kit with 48x CDROM Drive, 107 Keyboard 15″ color monitor

Table 4.3 Software tools specification

Languages	Java, HTML
Server	Apache Tomcat 5.5
Graphics	CatiaV5R7, AutoCAD

- Including the pseudo code/outline of the program module on multiple remark statements.
- Including the remark for major steps of program.
- Use of meaningful variable names.
- Setting the naming conventions for forms
  - *Software resources used* (Table 4.3).

In this way Chap. 4 gives the overall structure of the server side technology, web based expert system building, languages and software used for development of web based expert system for metal forming operations. The Chap. 5 is going to present the implementation of web based expert system for metal forming processes.

Chapter 5
Implementation of Web Based Expert System for Deep Drawing Process

Abstract Today's industries are facing number of challenges because of technology driven competition. Metal forming plays an important role in this competitive world and it is a key area to overcome those challenges. The previous chapter deals with design of expert system design. That design architecture has been used and implemented for deep drawing process. The detailed information about implementation has discussed in this chapter.

5.1 Introduction

The forming of complex sheet metal component involves interaction of various deformation modes such as deep drawing, stretching and bending. The sheet metal forming is undergoing a transition from an art to a science. The guesswork has been replaced by engineering analysis. The successful forming requires the right combination of material, lubrication, parameters and die design. The varieties of part produced in press shop are large and enumeration of the sheet metal parts going in diverse industries products would make an endless list.

5.2 Shape Classified Geometries

Benchmarking is the process of identifying, understanding and adopting outstanding practices from within the same organization or from other business to help improve performance. This involves the process of comparing practices and procedures to those of the test to identify ways in which an organization can make improvements. Thus new standards and goals can be set which in turn will help better satisfy the customer's requirement of quality, cost, product and service.

Majority of operations carried out in industry are the deep drawing operations. Battery calls to the big house gas cylinder are all formed by the deep drawing

R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9_5

operations. Capacitors used in every electrical component, compressors used in refrigerators having complex shapes are formed using the deep drawing operations.

Hence the various parameters such as blank size, punch die dimensions, number of draws required are to be very much accurate. Complex formulas are required to calculate those parameters. For this we cannot relay on humans as the calculations may be error prone which may result is bad designing which ultimately result is bad quality. This web based expert system is going to provide accurate analysis of deep drawing operations within short period of time.

5.2.1 Deep Drawing Process

Deep drawing is used to form containers by a process in which a flat blank is constrained while the central portion of the sheet is pressed into a die opening to draw the metal into the desired shape without folding of the corners. The process is capable of forming circular shapes, such as cooking pans, box shapes or shell like containers, automobile panels etc. Generally a clamping or hold-down pressure is required to press the blank against the die to prevent wrinkling. This is done by means of blank holder or hold down ring in a double action press.

In the deep drawing of a cup the metal is subjected to three different regions of deformations. Figure 5.1 represents the deformation and stresses developed in a pie-shaped section. The metal at the center of the blank under the head of the punch is wrapped around the profile of the punch. The metal in this region is subjected to biaxial stress due to the action of the punch. Metal in the outer portion of the blank is drawn radially inward towards the throat of the die. As it is drawn in, the outer circumference must continuously decrease from that of the original blank, $\pi D_{0,}$ to that of the finished cup, πD_p. This means that it is subjected to a compressive strain in the circumferential, or hoop, direction and a tensile strain in the radial direction.

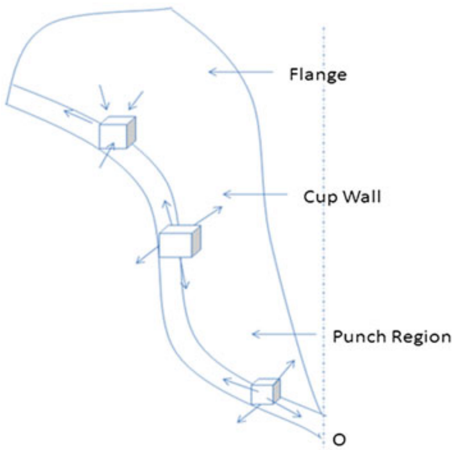


Fig. 5.1 Stresses and deformation in a section from a drawn cup

As a result of these two principal strains there is a continual increase in the thickness as the metal moves inward in the flange region.

However, as the metal passes over the die radius, it is first bent and then straightened while at the same time being subjected to the tensile stresses. This plastic bending under tension results in considerable thinning, this modifies the thickening due to the circumferential shrinking. Between the inner stretched zone and the outer shrunk zone there is a narrow ring of metal which has not been bent over either the punch or the die. The metal in this region is subjected only to simple tensile loading throughout the drawing operation. Typically, cracking takes place in this region when the drawability of the sheet metal is exceeded. Generally, drawing operation exhibits positive major strain and negative minor strain during deformation.

5.2.2 Blank Size

Before starting drawing operations the size and form of the blank must be determined for the desired final part geometry and die layout. This should be shown using the example of simple rotationally symmetrical body. In order to calculate the blank diameter, it is necessary to divide the entire axisymmetric part into various individual axisymmetric components and then calculate the surface areas of those components. The total surface area as a sum of the individual areas enables the calculation of the diameter of blank D.

This is shown in Fig. 5.2, for commonly used drawn shapes, starting from the desired inner diameter d. As the material will be somewhat stretched in the drawing process, there is more surplus material on the upper edge of the draw part, which cannot be precisely calculated. With high parts this can lead to distorted edges, because of the non-uniform deformation properties of the blank material like anisotropy factor (R_m), strain hardening exponent (n) and strength coefficient (K). Therefore, in general the drawn parts must be trimmed accordingly on the edge, when produced via deep drawing. The selection of the blank size for non-symmetric and irregular parts is often carried out on trial and error basis, as it is not possible to use simple formulas. Based on practical experience, the blank geometry is determined with experiments. Initially a sufficiently large blank size is selected for the drawing operation. After observing the actual material demand and flow, the blank size is reduced to satisfy the material requirements. More recently, computer programs are being increasingly used for the determination of the blank size. The 27 shape classified geometries and descriptions of shape are given in Fig. 5.2.

Description of shapes

1. Cylinder
2. Cylinder (flanged)
3. Two cylinder combined
4. Two cylinder combined (flanged)

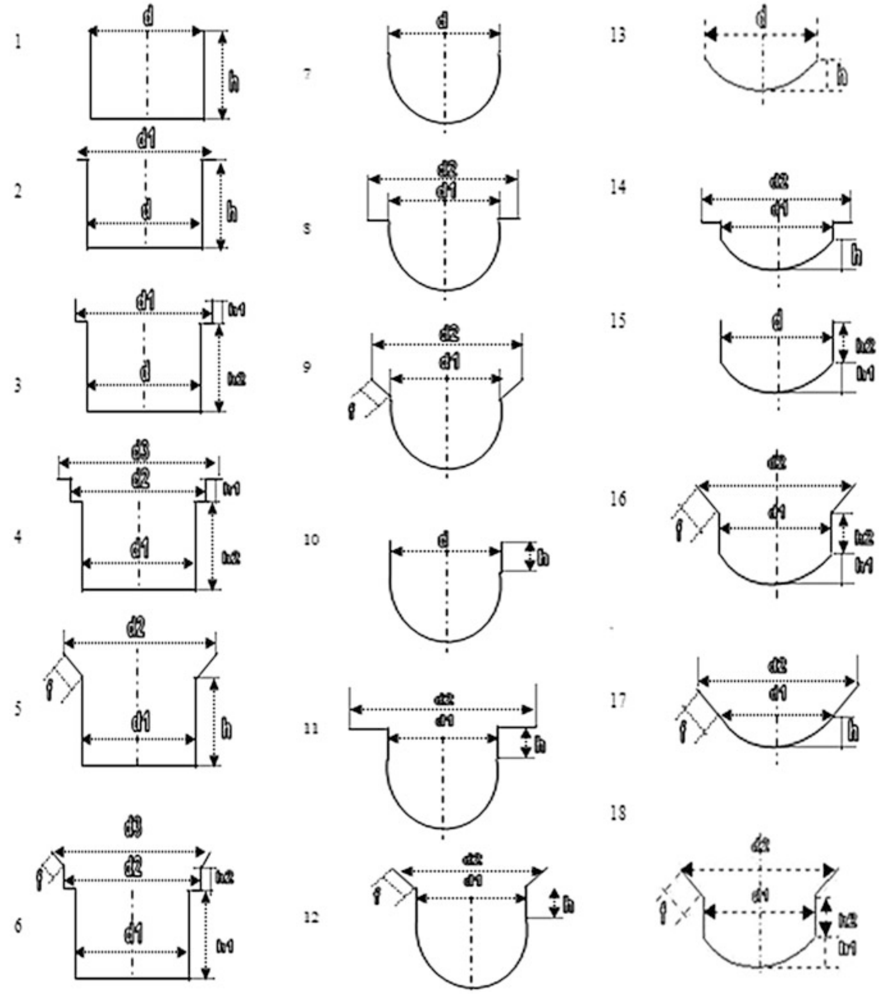


Fig. 5.2 Shape classified geometries

5. Cone and cylinder combined
6. Two cylinder and one cone combined
7. Hemisphere
8. Hemisphere (flanged)
9. Hemisphere and cylinder
10. Hemisphere and cylinder combined
11. Hemisphere and cylinder combined (flanged)
12. Hemisphere, cylinder and cone combined
13. Elliptical hemisphere
14. Elliptical hemisphere (flanged)

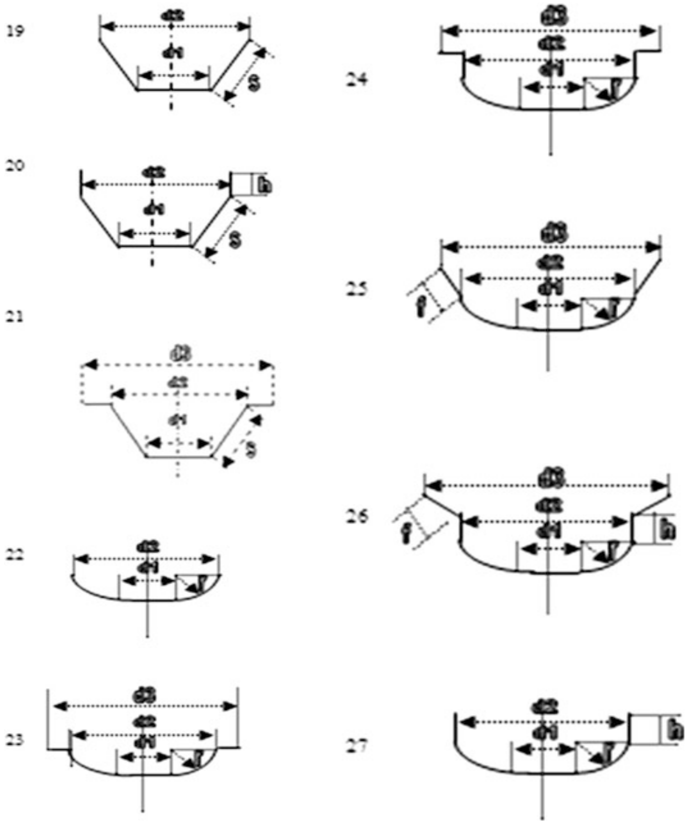


Fig. 5.2 continued

15. Hemisphere and cylinder combined (flanged)
16. Hemisphere and cylinder combined
17. Hemisphere and cone combined
18. Hemisphere, cone and cylinder combined
19. Cone
20. Cone (flanged)
21. Cone and cylinder combined
22. Flat bottomed hemisphere
23. Flat bottomed hemisphere (flanged)
24. Flat bottomed hemisphere and cylinder combined
25. Flat bottomed hemisphere and cone combined
26. Flat bottomed hemisphere, cone and cylinder combined
27. Flat bottomed hemisphere and cylinder combined

5.2.3 Draw Ratio

The draw ratio Beta is an important numerical value for cylindrical draw parts in determining the required number of drawing steps. The draw ratio is the ratio of the diameter of the initial blank form to the diameter of the drawn part. For the first drawing process, that is to say for only one drawing operation, the draw ratio Beta results in the following equation

$$\text{Beta} = \frac{\text{Blank Diameter}}{\text{Punch Diameter}}$$

$$\text{Beta} = \frac{\text{D}}{\text{d}} \text{ with one drawing}$$

$$\text{Beta 1} = \frac{\text{D}}{\text{d1}} \text{ for first drawing}$$

$$\text{Beta 2} = \frac{\text{D}}{\text{d2}} \text{ for second drawing}$$

or

$$\text{Beta 3} = \frac{\text{d2}}{\text{d3}}$$

and so on. In subsequent drawing steps, d1 represents the diameter of the draw punch in the first drawing operation and d2 the diameter of the second, etc. The total draw ratio Btot is calculated as the ratio of the diameter of the blank to the final diameter of the drawn part:

$$\text{Btot} = \frac{\text{Initial Diameter}}{\text{Final Diameter}}$$

The maximum draw ratio depends on the properties if the blank material used. As a rough estimate, the first drawing can be calculated as having a maximum ratio of $B = 2$. It achieves $B > 2$ several drawings are required and it must be noted that Beta because of work hardening, can only achieve a level of 1.3 in the next drawing step. If the part is annealed before the next drawing operation, a Beta of 1.7 can be assumed.

With several drawing steps, the total draw ratio becomes product of the individual draw ratios

$$\text{Btot} = \text{B1.B2...Bn}$$

In order to have a robust and reproducible production sequence, the maximum permitted draw ratios should not be fully utilized.

After selecting the Beta values, calls for punch diameter of

$$d1 = \frac{D}{B1}$$

$$d2 = \frac{d1}{B2}$$

and so on where d1 is before mentioned diameter.

5.2.4 Radius of Draw Dies

The edge radius of the first draw die, over which the blank is drawn, is very important. If the radius is too small the resistance to the flow of metal increases resulting in cutting or tearing of the metal. On the other hand, too large a die radius may induce the formation of wrinkles in the metal as it is drawn into the die cavity from beneath the blank holder. This radius rd, usually ranges from 4 to 10 times the blank thickness.

5.2.5 Punch Radius

Like the radius of draw die, the punch radius is also critical. The edges of the punch must be rounded to avoid cutting or tearing the metal. An excessive pitch radius increases tendency of material to buckle. When more than one draw is need to give the final shape to the part, the maximum punch radius rp, should be 4 times the stock thickness.

5.2.6 Draw Clearance

The side clearance between the punch and the die should be more than the stock thickness is taken into account the thickening of metal over the die radius when the flat blank is drawn into the die cavity, otherwise the blank may get jammed in the die cavity. The side clearance between the punch and the die is usually taken as 1.25 times the stock thickness.

5.3 Formulation of Rules for Deep Drawing Process

The sheet metal deep drawn technology is one of the most challenging process in manufacturing. The sizes, shapes, thickness and deep drawn metal used to produces sheet metal deep drawn parts cover a diverse range of variables. Individual variables should be evaluated carefully to determine the optimum manufacturing method.

Regardless of the many factors involved affecting the draw quality, the most important element to a successful sheet metal deep drawing operation is the smoothness of sheet metal flow. The following are key elements affecting metal flow during deep drawing process and each of them should be considered when designing or troubleshooting sheet metal deep drawing stamping tools:

1. **Type of material used and its thickness**. In deep drawing process, thicker materials are stiffer, they can be gripped better during deep drawing. Thicker materials also have more volume, so they can stretch longer distances during deep drawing process (deeper draw).
2. **Tool surface finish and type of Lubricant used**. Die surface finishes and lubricants are important to reduces the friction between tool surfaces and metal been drawn, it allowing materials to flow through tools more easily. Die temperatures can affect the viscosity of lubricants. Slower deep drawing speed gives better metal flow.
3. **Blank size and shape**. Blank sizes and shapes that are too large can restrict metal flow, and the geometry of parts affects the ability of metal to flow during deep drawing process.
4. **Punching speed**. Sufficient punching speed allows time for materials to flow through the tool. Corner cracking will always occur if press speed is too fast in deep drawing process.
5. **Draw radii**. Radius on the draw die where the material flow through, too big the radii will result wrinkling where too small will creates cracking at bottom radius of drawn part.
6. **Draw ratio**. Refers to the ability of a material to flow or draw. Affecting the draw depth and size per any single draw.
7. **Draw bead height and shape**. To control metal flow and gripping pressure in deep drawing process, draw bead height and shape can cause materials to bend and unbend to creates restrictive forces going into a tool. Increasing pressure will exerts more force on a material, creating more restraint on material going into the tool.

5.3.1 Failures in the Deep Drawing

1. **Metal fracture during deep drawing process**

   (a) Deep drawing radii too small, creating resistance to metal flow to cause undue thinning or fracture. Correct by increasing die radius or by changing die entrance to conical or elliptical shape.
   (b) Clearance between punch and die too little, too great or uneven.
   (c) Blank holder pressure too great.

(d) Lubricant inadequate or unsuitable.
(e) Punch nose radius too small.

2. **Wrinkles on top edge or flange**

(a) Blank holder pressure too tight.
(b) Draw radius too large.
(c) Punch nose radius too large.
(d) Wrinkles on the side of cup or flange caused by burr on blank or by an unbalanced blank holder pressure.

3. **Uneven top rim or flange**

(a) Nicks or burr along the periphery of the blank.
(b) Punch die or blank locator not concentric. Too much material pulled into the die by off center forming punch preventing forming of an even cup depth or flange.
(c) Blank holder exerting an unbalanced force on the blank, permitting the material flow unevenly into the die.

4. **Flange wrinkled, Puckered**

(a) Blank thickness wrong or out of tolerance.
(b) Draw radius too large.
(c) Clearance between punch & Die too large for the stock thickness.
(d) Depth of previous drawn too short or redraw operation too deep. Or side wall of drawn cup being tinned down.

5. **Fracture at bottom of redrawn cup**

(a) Draw radius and blank holding surface scratched, nicked or galled. Restricting metal flow into the die.
(b) Punch nose and draw radius too small.
(c) Diameter Reduction too great.

6. **Fracture in or at Flange of drawn cup**

(a) Punch and die clearance too small.

7. **Excess material at top of deep drawn shell**

(a) Material thickness too great or punch die clearance too small or uneven.
(b) Punch nose radius larger than cup bottom radius, causes excess sheet metal to flow up side wall.
(c) Draw radius too large, permitting wrinkles to start that enlarge during redraw of cup.

Chapter 6
Case Studies and Discussion

Abstract The development of web based expert system for metal forming involves a series of production activities where opportunities for injection of human fallibilities are enormous. The errors may begin to occur at very inception of the process where the objective may be erroneously or imperfectly specified as well as error that occurs in later design and development stages. Because of human inability to perform and communicate the expert system has been developed to give high equality and better performance. The rapid development of internet technology has changed the way that metal forming solution can be developed and distributed. The word web based expert system flashes images upon the canvas of the mind.

6.1 Introduction

With the help of web based expert system connection and browser, you can find and view the information about web based expert system for metal forming on the web. The working of client server web based expert system for various operations like deep drawing; rolling, extrusion and bending are available on site as shown in Fig. 6.1.

Initially you can find and view information about sheet metal forming on web site address http://sggs.ac.in/prod/p.hd/webbasedexpertsystemformetalforming/ user can find out required expert system solution about metal forming.

6.2 Prediction of Forming Parameters in Deep Drawing Process

The user can view the formability analysis of deep drawing process on home page of web based expert system, which is related to 27 shape classified geometries. Now user has to choose the one matching geometry according to his requirement and he

R.S. Hingole, *Advances in Metal Forming*, Springer Series in Materials Science 206, DOI 10.1007/978-3-662-44497-9_6

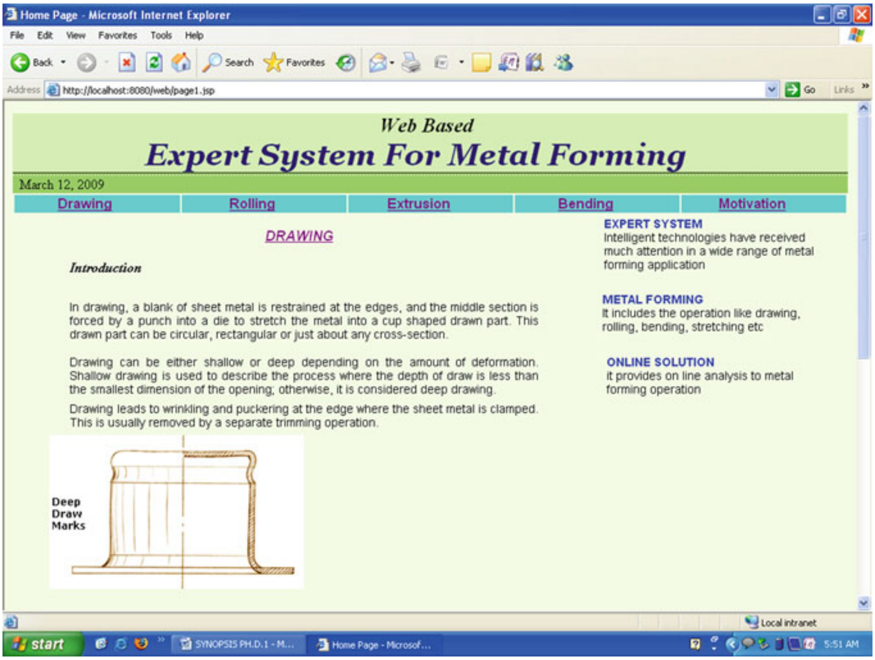


Fig. 6.1 Web page of information of web based expert system for metal forming

has to give specification (depend upon type of geometry being selected). On receiving the request from the client, the request goes to server side. The apache tomcat server is used for analysis of metal forming processes. It takes the request and gives response to client side that is it provides the required forming parameters of deep drawing process. There are 27 shape classified geometries are taken for offering the solution of expert system. The sample session of shape classified geometries is shown in Fig. 6.2.

The first geometry is taken for validation of this web based expert system. The experiments are carried out for first shape out of 27 shape classified geometry. The work of deep drawing process is carried out for the water heater tank. The initial parameters and the material for component are DDQS, DDQS of grade 1 and DDQS of grade 2. The diameter and height are input dimension of the blank design.

This input data has to provide for web based expert system for deep drawing process of material DDQS that is part height 31.5 mm and part diameter 200 mm as shown in Fig. 6.3. After receiving the request from the client side, this information goes to server side. The Apache tomcat server is used for data analysis. It performs the specific task associated with the shape classified geometry and sends the response to client side. In this case it provides the required formability analysis of

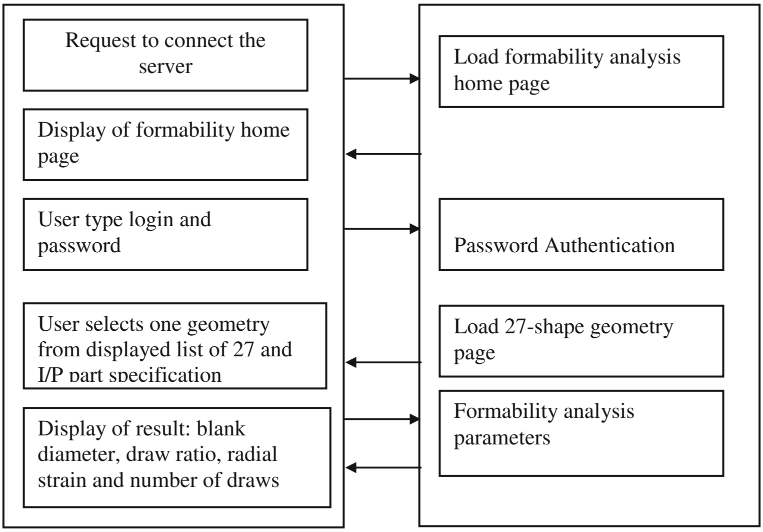


Fig. 6.2 Sample session

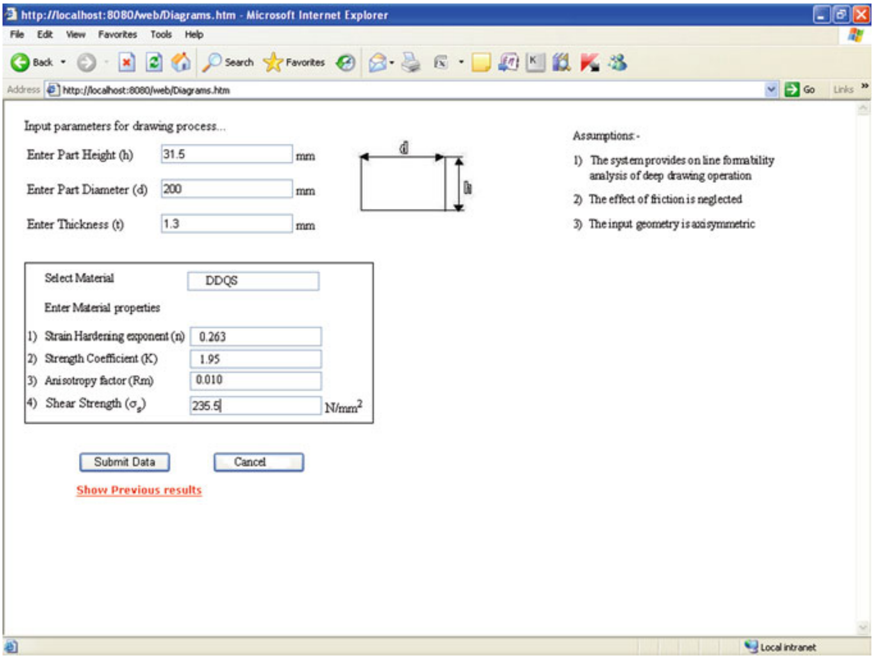


Fig. 6.3 Web page for input parameters for material DDQS in deep drawing process

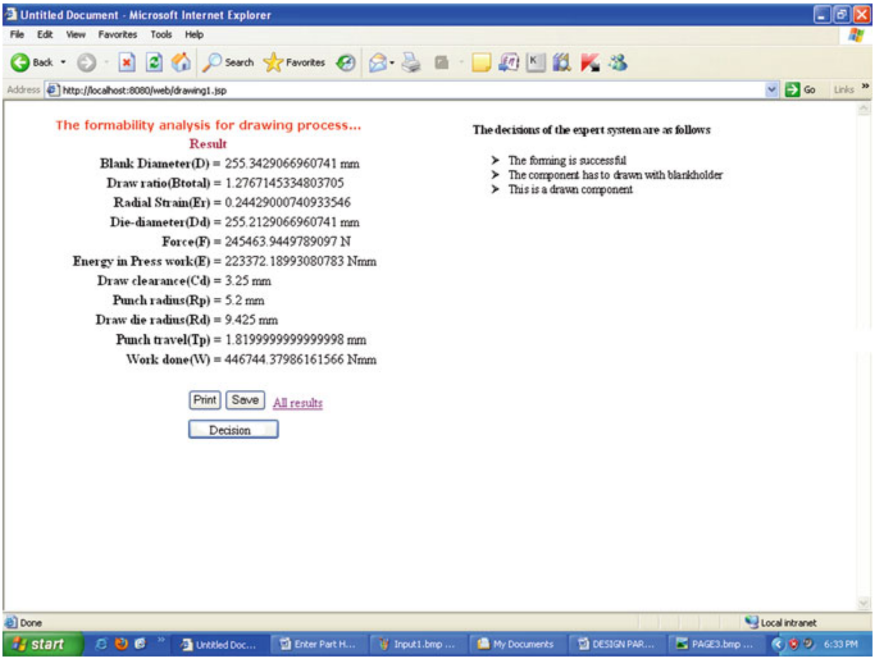


Fig. 6.4 Web page for output of formability analysis of material DDQS in deep drawing process

deep drawing process that blank diameter as 255.34 mm draw ratio 1.28 and radial strain 0.24 to the client side along with punch and die dimensions. The system provides the expert decision about the forming is successful or unsuccessful, the component drawn with blank holder or not and component is drawn or not as shown in Fig. 6.4. The same procedure is adopted for the material DDQS of grade 1. The result of input dimension and output analysis for this material are shown in Figs. 6.5 and 6.6. For the third material DDQS of grade 2 input parameters and its output results are shown in Figs. 6.7 and 6.8.

The results of web based expert system for deep drawing process are matching with the experimental results which are shown in Table 6.1. The result of web based expert system gives blank diameter along with draw ratio, punch diameter of each draws and the radial strain. But in this case the expert system provides the output analysis as blank diameter, draw ratio and radial strain. It has been proved that the result of web based expert system for deep drawing processes are validating with

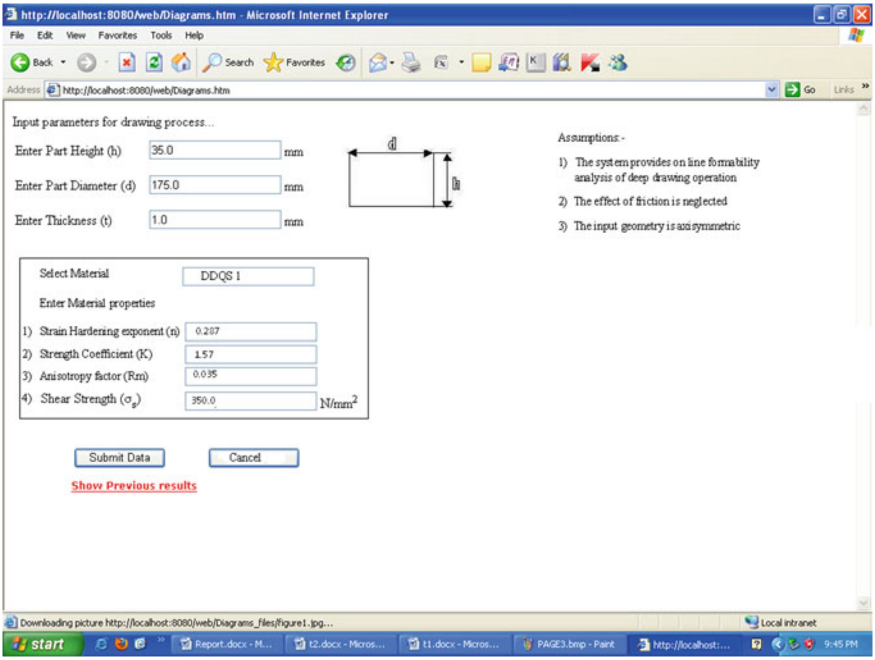


Fig. 6.5 Web page for input parameters for material DDQS-1 in deep drawing process

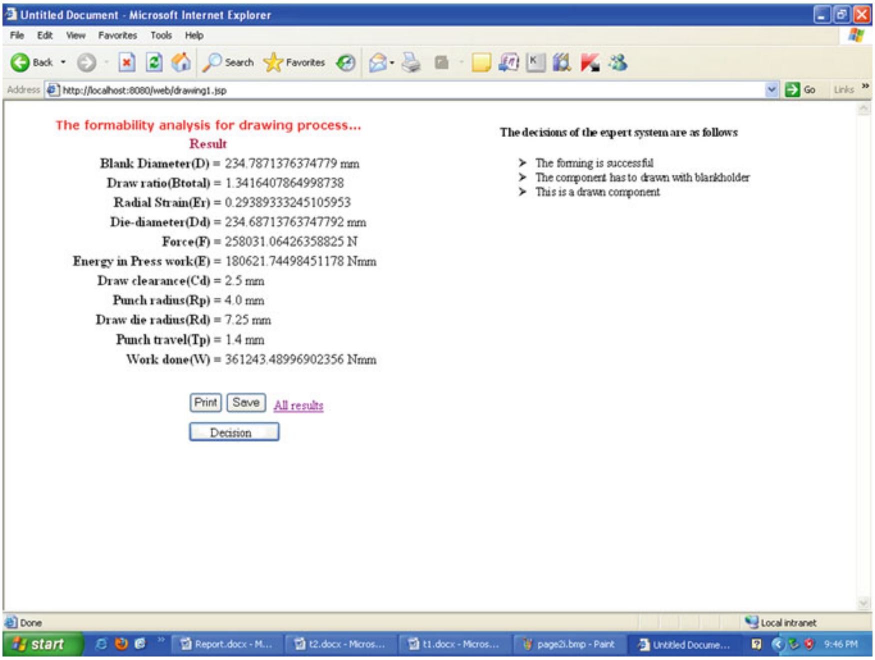


Fig. 6.6 Web page for output analysis for material DDQS-1 in deep drawing process

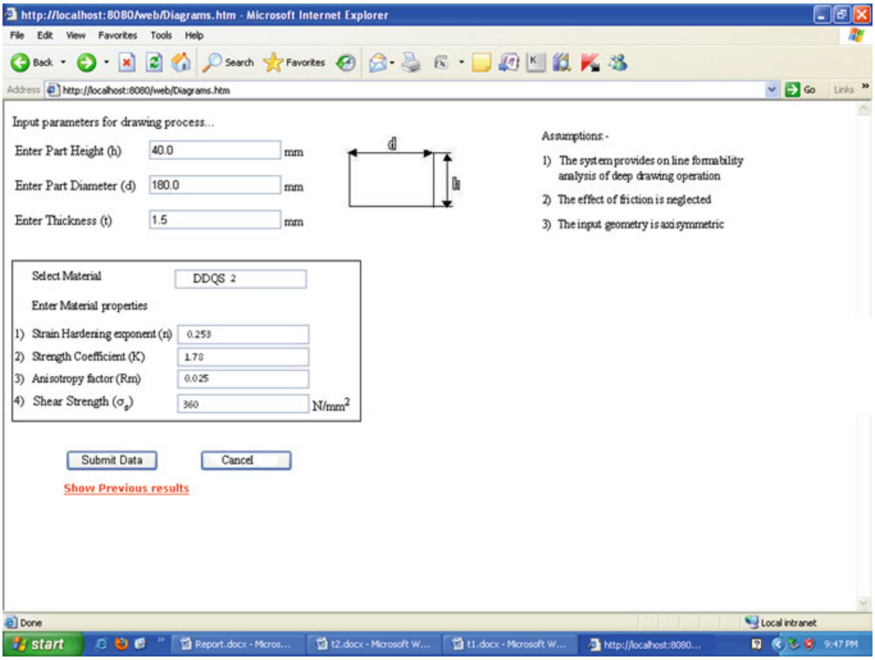


Fig. 6.7 Web page for input parameters for material DDQS-2 in deep drawing process

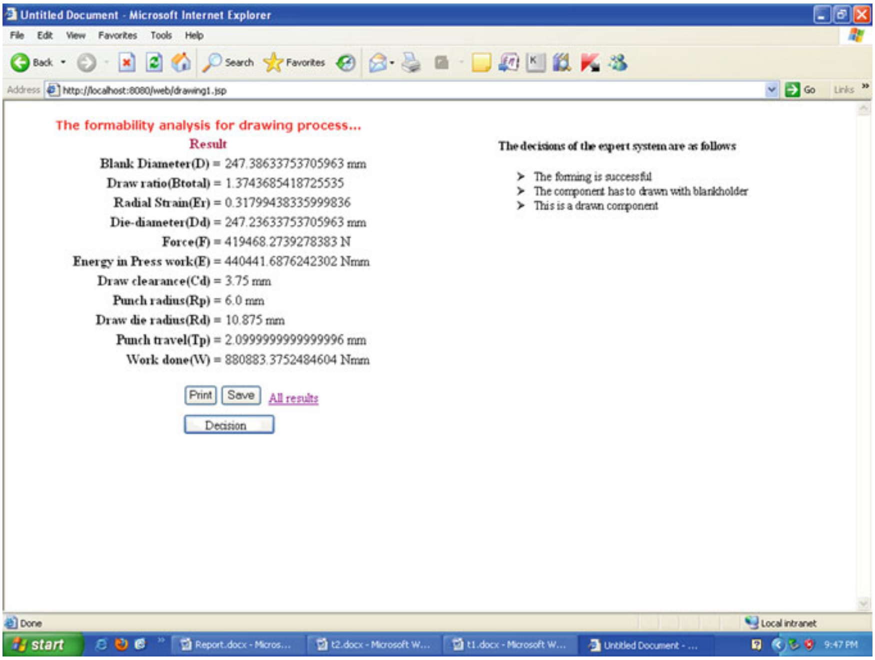


Fig. 6.8 Web page for output parameters for material DDQS-2 in deep drawing process

Table 6.1 Experimental result versus result of web based expert system for deep drawing process

Material	Input parameters		Experimental result	Result of web based expert system		
	Height (h) mm	Diameter (d) mm	Blank dia. (D) mm	Blank dia. (D) mm	Draw ratio (Btot)	Radial strain (Er)
DDQS	31.5	200	255.34	255.34	1.28	0.24
DDQS 1	35.0	175	234.79	234.79	1.34	0.29
DDQS 2	40.0	180	247.39	247.39	1.37	0.32

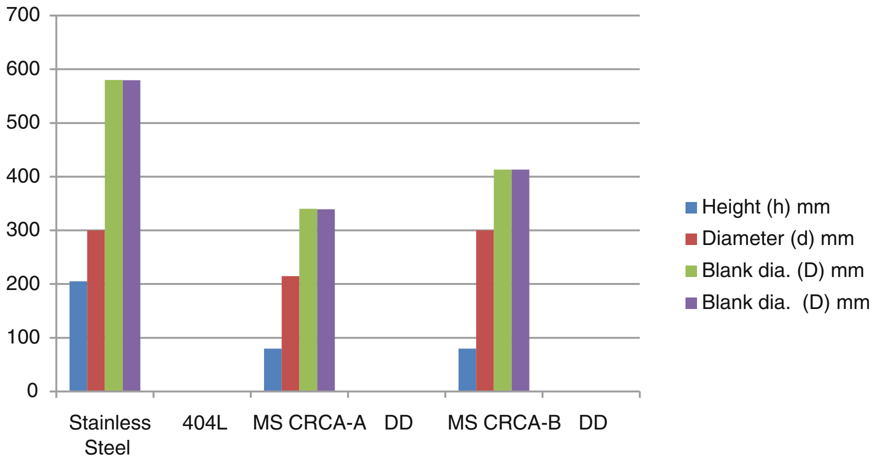


Fig. 6.9 Graph of experimental result vs web based expert system result of deep drawing process

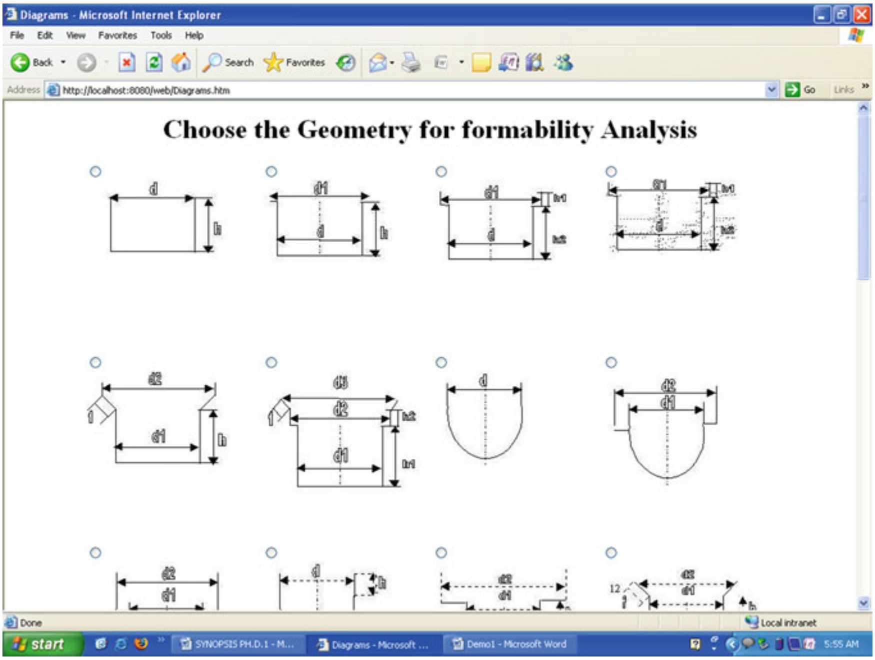


Fig. 6.10 Web page for formability analysis of 27 shape classified geometries

experimental result. The graph of experimental result versus web based expert system result of deep drawing process shows that results of experimental data are very much closer to result of the web based expert system of deep drawing process (Figs. 6.9 and 6.10).

Chapter 7
Summary and Future Scope

Abstract To survive in the highly competitive metal forming environment, successful companies need powerful and accurate tool for design and analysis of metal forming operations. The FEA based systems are currently the most accurate tool available to users for design. However the current set of CAD/FEA tools are not designed for multiple users classes, such as product designers, die design experts and shop floor engineers. FEA based systems are not suited for those users who have limited experience using FEA. Problems of diversity in input and output formats, the need for prior working experience and the different methods of representing and handling information restricts the usability of current CAD/FEA software. In addition many design decisions are based on past experience. These experience based knowledge is crucial in determining the success or failure of any design. The knowledge acquisition bottleneck has limited the development of generic design for metal forming operations. Hence there is an increasing necessity for integration of these CAD/FEA tools and knowledge based system in an single integrated environment. So far integration had been difficult to the diversity in knowledge representation technique and the lack of control knowledge for managing these diverse tools. The goal of present research work is to design and development of alternative model for metal forming operation basically for deep drawing, rolling, extrusion and bending using expert system. Web based expert system provides fast, accurate information to various class of users involved in metal forming operations. The objective for the integrated expert system is derived from critical literature review and interaction with various product designers, die design expert and shop floor engineers from wide range of metal forming industry in India. The broad objective for the integrated system is develop a intelligent expert system for design and analysis in sheet metal forming in a knowledge based system framework with the combination of features.

R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9_7

7.1 Summary

In this research work a web based expert system has been developed and implemented for metal forming processes in an innovative way. The web based expert system is successfully demonstrated for appropriate analysis of various metal forming operations like deep drawing, cold and hot rolling, extrusion and V and U bending along with the requisite forming parameters. In the procedure of developing web based expert system, the following conclusions are obtained.

- It provides web based expert system for forming parameters in deep drawing process.
- Author has implemented the expert system for another application like rolling, extrusion and bending process. That system offers the solution which are as follows.
- It offers solution for rolling load prediction in cold rolling process and hot rolling process.
- The expert system investigates the forming parameters in extrusion process.
- The web based expert system predicts forces in V and U bending process.

The web based expert system has following feature

1. Business moves with the speed of internet.
2. Implement new applications and upgrades more quickly.
3. Affordable access to technology.
4. Improved total IT cost/performance.
5. This system clears views on IT staff recruitments and retention.
6. It provides freedom to the end user to access it form any device such as desktop computers, terminal.
7. Developed the application that is flexible and expandable to accommodate necessary additions with minimum changes.
8. Provided online help.
9. Reduction in manpower attached to support functions.
10. Standardization of work practices.
11. Low cost connectivity.
12. Ease of rapid deployment of the technology.
13. User-friendly standards.

7.2 Knowledge Based Expert System

A Knowledge Based Expert System or Expert System (ES) is system of software or combined software and hardware capable of competently executing a specific task usually performed by a human expert. Expert system are highly specialized computer software capable of simulating that element of a human specialist's knowledge and reasoning that can be formulated into knowledge chunk characterized by a set of facts and heuristic rules. Heuristic rules are rules of thumb accumulated by a human expert through intensive problem solving in the domain of a particular task, usually over a period of years. The essential qualities of good expert system are:

1. Transparency: It provides explanation to the line of reasoning and answers to queries about the knowledge.
2. Flexibility: It integrate new knowledge into existing store of knowledge.

ES is the most promising engineering outgrowth of artificial intelligence research. In the rule based representation rules are typically written in a simple "IF/THEN" or "IF/THEN/ELSE" syntax. If a rule premises i.e. the set of conditions specified in the "IF" part is true, which implies that the conditions are consistent with the current set of facts in the knowledge base, then the conclusion i.e. the group of conditions associated with the "THEN" part, is executed often adding new facts in the knowledge base, then the conclusion i.e. the group of condition associated with the "THEN" part, is executed often adding new facts to the knowledge base. Inference or deduction in the rule based system.

7.3 Limitation of Expert Systems

The following points identify some of the limitation of ES

1. Cognitive versus other human task: ES function in the domain of extracted, cognitive, logical thinking process. They are generally not adept at managing highly sophisticated sensory input or mechanical motor output.
2. Narrow versus general intelligence simulation: ES exhibits a narrow band of simulated intelligence based on narrow range of codified domain, heuristic knowledge (i.e. a single task). Current ES technology can not tackle broad multiple direction problem spaces. In addition, only knowledge that can be derived from the expert and implemented into the system can be used.
3. Error exception and recovery: ES typically do not respond well to suggestion outside their range of expertise. Performance degradation is almost immediate and total in such situations.
4. Common sense knowledge: Common sense knowledge and judgment, the final stage in human decision making, is based on arrange of contextual information including social surrounding random memories, feelings, emotions and other non rational information. Common sense knowledge and broad ranging contextual information are not available in the typical ES.
5. Qualitative simulation: Human reason extremely well with in exact context sensitive concept such as large small, mere, far and almost. This type of qualitative simulation in difference to quantitative seasoning is intimately related to

our ability to make decision based on common sense knowledge which can not be handled by current ES.

6. Intuitions: Decision makers often go more by bunches than by proven facts or logical arguments and thus operates in a cognitive domain that is beyond the reach of current ES technology.
7. Learning: Automated learning processes are hard to come by in ES, especially when compared with the great ease with which learn from experience.
8. Self-knowledge: Some of the human higher level cognitive capabilities stem from the ability to step back and see our system running as whole.

7.4 Knowledge Acquisition

Knowledge acquisition is essentially collecting knowledge, experience, thumb or empirical rules, and other important relevant information from domain experts or other reliable sources. Domain expert refer to people who have considerable expertise in the chosen problem domain. For the present expert system for metal forming operations, well experienced and reputed metal forming rules can be thought of as domain expert. Available literature on building expert system has outlined various sources that the research team can employ to obtain knowledge for constructing the knowledge based system.

1. Knowledge through literature reviews: Reviews of literature on metal forming can provide detailed, academically fundamental information on metal forming techniques. Although, the information obtained from the literature is not always the same as what is currently being practiced in industry, literature survey is an easy and inexpensive mode of knowledge acquisition. Information found in the open literature can be reviewed and the knowledge should be formalized to be able to be added to the knowledge base.
2. Knowledge through industrial visit: This knowledge not always quantifiable is useful in getting a letter feel for the problem domain and in understanding the common terminology used on the shop floor, also be equipped with a friendly user interface. An expert system with such a front end is expected to have a relatively easy learning curve and therefore, is likely to be accepted more readily by the industrial users.
3. Knowledge from industrial experts: The process of knowledge acquisition from industrial experts would involve presenting a few typical problem to the experts and letting the expert talk through the solution. During the verbal analysis, the expert would be questioned/ interrupted to explain why a particular decision was reached. This would enable him to identify what parameters influenced what decisions.

7.5 Future Research Direction

It has been proved that web-based expert systems have become more sophisticated, complex, and capable and fulfill their great promise in area of metal forming. It is anticipated that web-based application could bring new life to the field of industrial sector and generate a new era for their applications. In this book web based expert system is implemented and demonstrated for the sheet metal forming operations. In future this may extend for the other applications in metal forming areas as well as other areas in the engineering.

Appendix A

Programme of Web Based Expert System for Metal Forming Operations

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"http://www.w3.org/TR/xhtml1/DTD/xhtml1-transitional.dtd">
<html xmlns="http://www.w3.org/1999/xhtml">
<!-- DW6 -->
<head><!-- Copyright 2005 Macromedia, Inc. All rights reserved. -->
<title>Home Page</title>
<meta http-equiv="Content-Type" content="text/html; charset=iso-8859-1" />
<link rel="stylesheet" href="Ingle/mm_health_nutr.css" type="text/css" />
<script language="JavaScript" type="text/javascript">
//--------------- LOCALIZEABLE GLOBALS ---------------
var d=new Date();
var monthname=new
Array("January","February","March","April","May","June","July","August","September",
"October","November","December");
//Ensure correct for language. English is "January 1, 2004"
var TODAY = monthname[d.getMonth()] + " " + d.getDate() + ", " + d.getFullYear();
//---------------   END LOCALIZEABLE   ---------------
</script>
<style type="text/css">
<!--
.style2 {
	font-family: Georgia, "Times New Roman", Times, serif;
	font-size: 36px;
	font-weight: bold;
```


R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9

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.style3 {font-size: 14px}
.style5 {font-size: 14px; font-family: Geneva, Arial, Helvetica, sans-serif; }
.style6 {
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        font-size: 24px;
        font-weight: bold;
        font-style: italic;
}
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        font-weight: bold;
}
.style8 {font-family: Geneva, Arial, Helvetica, sans-serif}
.style9 {
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US;mso-bidi-language:TA">Intelligent technologies have received much attention in a wide
range
           of metal forming application</span></p>
    <p class="style5"><span class="subHeader"></span></p></td>
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metal is restrained at the edges, and the middle section is
      forced by a punch into a die to stretch the metal into a cup shaped drawn part. This drawn
    part can be circular, rectangular or just about any cross-section. </span></div></td>
    <td width="67"> </td>
    <td width="259"><p class="style5"><span class="subHeader style12"><strong>METAL
FORMING</strong></span><br />
      It includes the operation
      like drawing, rolling, bending, stretching etc</p>
    <p class="style8"><span class="style3"></span></p></td>
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or deep depending on the amount of deformation. Shallow
      drawing is used to describe the process where the depth of draw is less than the smallest
    dimension of the opening; otherwise, it is considered deep drawing.
</span></div></td>
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```
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class="style12"><strong>ONLINE SOLUTION</strong></span><br />
it provides on line analysis to metal forming operation </span></span></td>
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puckering at the edge where the sheet metal is clamped.
    This is usually removed by a separate trimming operation. </span></div></td>
    <td width="72"> </td>
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  </tr>
</table>
<table width="100%" border="0" >
            <tr><td width="65%" class="pageName style6"><ul>
          <p><img src="draw.gif" alt="draw.gif (8680 bytes)" width="300" height="181"
class="style3"></p>
          <div align="justify"><p><em><strong>Design Considerations
 </strong></em></p>
          </div>
          <li class="style10">
            <div align="justify" class="style11">Round shapes (cylinders) are easiest to draw.
Square shapes can
              also be drawn if the inside and outside radiuses are at least 6 X stock thickness. Other
              shapes can be produced at the cost of complexity of tooling and part costs.</div>
          </li>
      <p><img src="draw_radius.gif" width="449" height="277" alt="draw_radius.gif (8982
bytes)"></p>

      <li>
        <div align="justify"><span class="style5">The corner radiuses can be reduced further by
successive drawing</span><span class="style5"> operations, provided there is sufficient height
for the draw.</span></div>
      </li>
```

```
      <li>
        <div align="justify"><span class="style5">The corner radiuses can be reduced further by
successive drawing</span><span class="style5"> operations, provided there is sufficient height
for the draw.</span></div>
      </li>
      <li>
        <div align="justify"><span class="style5"> Perpendicularity can be held to ±1º, flatness
can be held to
          0.3%. This can be improved by performing extra operations.   
<br>
          <br>
        </span> </div>
      </li>
    </ul></td>
        <td width="35%" class="smallText"><p class="style5"> </p>
       </td>
            </tr>
</table>

 <table width="165" border="0" >
      <tr>
<td width="165" align="center" bgcolor="#66CCCC" ><a
href="http://localhost:8080/web/home.jsp" class="style7" >Home</a></td>
      </tr>
</table>
</body>
</html>
```

Appendix B

Programme of Expert System for Deep Drawing Operation

```
<META content="MSHTML 6.00.2600.0" name=GENERATOR></HEAD>

<BODY>
<FORM>
<CENTER>
<H1>Choose the Geometry for formability Analysis </H1>
<TABLE border=0>
 <TBODY>
 <TR>
  <TD><INPUT onclick=figure1() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure1.jpg"> </TD>
  <TD><INPUT onclick=figure2() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure2.jpg"> </TD>
  <TD><INPUT onclick=figure3() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure3.jpg"> </TD>
  <TD><INPUT onclick=figure4() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure4.jpg"> </TD>
 <TR></TD>
  <TD><INPUT onclick=figure5() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure5.jpg"> </TD>
  <TD><INPUT onclick=figure6() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure6.jpg"> </TD>
  <TD><INPUT onclick=figure7() type=radio name=fig><BR><IMG
   src="Diagrams_files/figure7.jpg"> </TD>
```


R.S. Hingole, *Advances in Metal Forming*, Springer Series
in Materials Science 206, DOI 10.1007/978-3-662-44497-9

```
<TD><INPUT onclick=figure8() type=radio name=fig><BR><IMG
 src="Diagrams_files/figure8.jpg"> </TD>
<TR></TD>
 <TD><INPUT onclick=figure9() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure9.jpg"> </TD>
 <TD><INPUT onclick=figure10() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure10.jpg"> </TD>
 <TD><INPUT onclick=figure11() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure11.jpg"> </TD>
 <TD><INPUT onclick=figure12() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure12.jpg"> </TD>
<TR></TD>
 <TD><INPUT onclick=figure13() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure13.jpg"> </TD>
 <TD><INPUT onclick=figure14() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure14.jpg"> </TD>
 <TD><INPUT onclick=figure15() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure15.jpg"> </TD>
 <TD><INPUT onclick=figure16() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure16.jpg"> </TD>
<TR></TD>
 <TD><INPUT onclick=figure17() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure17.jpg"> </TD>
 <TD><INPUT onclick=figure18() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure18.jpg"> </TD>
 <TD><INPUT onclick=figure19() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure19.jpg"> </TD>
 <TD><INPUT onclick=figure20() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure20.jpg"> </TD>
<TR></TD>
 <TD><INPUT onclick=figure21() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure21.jpg"> </TD>
 <TD><INPUT onclick=figure22() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure22.jpg"> </TD>
 <TD><INPUT onclick=figure23() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure23.jpg"> </TD>
 <TD><INPUT onclick=figure24() type=radio name=fig><BR><IMG
  src="Diagrams_files/figure24.jpg"> </TD>
<TR></TD>
```

```
    <TD><INPUT onclick=figure25() type=radio name=fig><BR><IMG
    src="Diagrams_files/figure25.jpg"> </TD>
   <TD><INPUT onclick=figure26() type=radio name=fig><BR><IMG
    src="Diagrams_files/figure26.jpg"> </TD>
   <TD><INPUT onclick=figure27() type=radio name=fig><BR><IMG
    src="Diagrams_files/figure27.jpg"> </TD>
   <TD></TD>
  <TR></TR></TBODY></TABLE></CENTER></FORM>
<SCRIPT language=javascript>
        {

                function figure1()
                {
                        //alert("figure no 1 function");
                        document.writeln(" <form name='figure1' action='rsh.jsp'
METHOD='POST'> ");
                        document.write(" <Table border='0'> ");
                        document.write(" <tr><td colspan='2'>");
                        document.write("</td></tr>");
                        document.write("Input parameters for drawing process...");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Height (h) ");
                        document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                        document.write("  mm");
                        document.write(" </td> ");
                        document.write(" <td rowspan='2'><image
src='Diagrams_files/figure1.jpg'></td> ");
                        document.write(" </tr> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Diameter (d) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write(" </table> ");
```

```
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
        document.write(" </form> ");

        }

        function figure2()
        {
                //alert("figure no 21 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Height (h) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" <td rowspan='3'><image
src='Diagrams_files/figure2.jpg'></td> ");
                document.write(" </tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Bottom Diameter (d) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Cup Diameter (d1) ");
                document.write(" <input type='text' name='cup_diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");

        }
```

```
function figure3()
{
    //alert("figure no 3 function");
    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
    document.write(" <Table border='0'> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Height of bottom(h1) ");
    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
    document.write("  mm");
    document.write(" </td> ");
    document.write(" <td rowspan='4'><image
src='Diagrams_files/figure3.jpg'></td> ");
    document.write(" </tr> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Height of cup(h2) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write("Enter Part Bottom Diameter (d) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Cup Diameter (d1) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" </table> ");
    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
    document.write(" </form> ");

}
```

```
function figure4()
{
    //alert("figure no 4 function");

    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
    document.write(" <Table border='0'> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Height of bottom(h1) ");
    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
    document.write("  mm");
    document.write(" </td> ");
    document.write(" <td rowspan='4'><image
src='Diagrams_files/figure4.jpg'></td> ");
    document.write(" </tr> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Height of cup(h2) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write("Enter Part Bottom Diameter (d) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Cup Diameter (d1) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" </table> ");
    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
    document.write(" </form> ");
}
```

```
function figure5()
{
    //alert("figure no 5 function");
    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
    document.write(" <Table border='0'> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Height of bottom(h) ");
    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
    document.write("  mm");
    document.write(" </td> ");
    document.write(" <td rowspan='4'><image
src='Diagrams_files/figure5.jpg'></td> ");
    document.write(" </tr> ");
    document.write(" <tr><td> ");
    document.write("Enter part flange height(f) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write("Enter Part Bottom Diameter (d1) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Cup Diameter (d2) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" </table> ");
    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
    document.write(" </form> ");

}
```

```
function figure6()
{
    //alert("figure no 6 function");
    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
    document.write(" <Table border='0'> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Height of bottom(h1) ");
    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
    document.write("  mm");
    document.write(" </td> ");
    document.write(" <td rowspan='6'><image
src='Diagrams_files/figure6.jpg'></td> ");
    document.write(" </tr> ");
    document.write(" <tr><td> ");
    document.write("Enter part Cup height(h2) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" <tr><td> ");
    document.write("Enter part flange height(f) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write("Enter Part Bottom Diameter (d1) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
    document.write(" <tr><td> ");
    document.write("Enter Part Cup Diameter (d2) ");
    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
    document.write("  mm");
    document.write(" </td></tr> ");
```

```
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Diameter (d3) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");

            }
                function figure7()
            {
                //alert("figure no 7 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part diameter(d) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" <td rowspan='1'><image
src='Diagrams_files/figure7.jpg'></td> ");
                document.write(" </tr> ");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");
            }
            function figure8()
        {
            //alert("figure no 8 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
```

```
                    document.write(" <tr><td> ");
                    document.write("Enter Part cup Diameter (d1) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" <td rowspan='2'><image
src='Diagrams_files/figure8.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Diameter (d2) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" </td></tr> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");
                        }
                function figure9()
        {
                //alert("figure no 8 function");
                    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                    document.write(" <Table border='0'> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part cup Diameter (d1) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" <td rowspan='2'><image
src='Diagrams_files/figure9.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Diameter (d2) ");
                    document.write(" <input type='text' name='diameter' size='20'
```

```
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Dimension (f)");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </td></tr> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
              document.write(" </form> ");
                           }
              function figure10()
       {
              //alert("figure no 8 function");
                    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                    document.write(" <Table border='0'> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part cup Diameter (d) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" <td rowspan='2'><image
src='Diagrams_files/figure10.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part cup Height (h) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </td></tr> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
```

```
                    value='Submit Data'> ");
                    document.write(" </form> ");


                    }


                    function figure11()
          {
                    //alert("figure no 8 function");
                              document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                              document.write(" <Table border='0'> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part cup Diameter (d1) ");
                              document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                              document.write("  mm");
                              document.write(" </td> ");
                              document.write(" <td rowspan='2'><image
src='Diagrams_files/figure11.jpg'></td> ");
                              document.write(" </tr> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part Flange Diameter (d2) ");
                              document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                              document.write("  mm");
                              document.write(" <tr><td> ");
                              document.write("Enter Part Flange Height (h)");
                              document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                              document.write("  mm");
                              document.write(" </td> ");
                              document.write(" </td></tr> ");
                              document.write(" </table> ");
                              document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                    document.write(" </form> ");
                    }
```

```
                function figure12()
        {
                        //alert("figure no 5 function");
                        document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                        document.write(" <Table border='0'> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Flange Height (h) ");
                        document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                        document.write("  mm");
                        document.write(" </td> ");
                        document.write(" <td rowspan='4'><image
src='Diagrams_files/figure12.jpg'></td> ");
                        document.write(" </tr> ");
                        document.write(" <tr><td> ");
                        document.write("Enter part flange Dimension(f) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write("Enter Part Cup Diameter (d1) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Flange Diameter (d2) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write(" </table> ");
                        document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                        document.write(" </form> ");
                        }
```

```
                    function figure13()
          {
                              //alert("figure no 1 function");
                              document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                              document.write(" <Table border='0'> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part Height (h) ");
                              document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                              document.write("  mm");
                              document.write(" </td> ");
                              document.write(" <td rowspan='2'><image
src='Diagrams_files/figure13.jpg'></td> ");
                              document.write(" </tr> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part Diameter (d) ");
                              document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                              document.write("  mm");
                              document.write(" </td></tr> ");
                              document.write(" </table> ");
                              document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                    document.write(" </form> ");

                    }

                    function figure14()
          {
                    //alert("figure no 8 function");
                              document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                              document.write(" <Table border='0'> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part cup Diameter (d1) ");
                              document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
```

```
                document.write("  mm");
                document.write(" </td> ");
                document.write(" <td rowspan='2'><image
src='Diagrams_files/figure14.jpg'></td> ");
                document.write(" </tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Diameter (d2) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Height (h)");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
            document.write(" </form> ");
            }

            function figure15()
        {
            //alert("figure no 8 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Height of bottom(h1) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" <td rowspan='4'><image
src='Diagrams_files/figure15.jpg'></td> ");
```

```
                document.write(" </tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Height of cup(h2) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write("Enter Part Bottom Diameter (d1) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Diameter (d1) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");
        }

        function figure16()
        {
                //alert("figure no 3 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Height of bottom(h1) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" <td rowspan='4'><image
src='Diagrams_files/figure16.jpg'></td> ");
```

```
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Height of cup(h2) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Cup Diameter (d) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" </td></tr> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                    document.write(" </form> ");

        }
          function figure17()
        {
                    //alert("figure no 5 function");
                    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                    document.write(" <Table border='0'> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Height (h) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" <td rowspan='4'><image
src='Diagrams_files/figure17.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter part flange Dimension(f) ");
```

```
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write("Enter Part Cup Diameter (d1) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Diameter (d2) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("mm");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");
                }
        function figure18()
        {
                //alert("figure no 6 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Height of bottom(h1) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("mm");
                document.write(" </td> ");
                document.write(" <td rowspan='6'><image
src='Diagrams_files/figure18.jpg'></td> ");
                document.write(" </tr> ");
                document.write(" <tr><td> ");
                document.write("Enter part Flange height(h2) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
```

```
				document.write("  mm");
				document.write(" </td></tr> ");
				document.write(" <tr><td> ");
				document.write("Enter part flange Dimension (f) ");
				document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
				document.write("  mm");
				document.write(" </td></tr> ");
				document.write("Enter Part Bottom Diameter (d1) ");
				document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
				document.write("  mm");
				document.write(" </td></tr> ");
				document.write(" <tr><td> ");
				document.write("Enter Part Flange Diameter (d2) ");
				document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
				document.write("  mm");
				document.write(" </td></tr> ");
				document.write(" </td></tr> ");
				document.write(" </table> ");
				document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
				document.write(" </form> ");
			}
			function figure19()
		{
			//alert("figure no 8 function");
				document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
				document.write(" <Table border='0'> ");
				document.write(" <tr><td> ");
				document.write("Enter Part Bottom Diameter (d1) ");
				document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
				document.write("  mm");
				document.write(" </td> ");
```

```
                    document.write(" <td rowspan='2'><image
src='Diagrams_files/figure19.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Slient Diameter (d2) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Slient Height (s)");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </td></tr> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
            document.write(" </form> ");
            }
            function figure20()
            {
                    //alert("figure no 3 function");
                    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                    document.write(" <Table border='0'> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part slient dimension (s) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" <td rowspan='4'><image
src='Diagrams_files/figure20.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Bootom Diameter(d1) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
```

```
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write("Enter Part Cup Diameter (d2) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Slient Diameter (d3) ");
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" </td></tr> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");

        }
        function figure21()
        {
                //alert("figure no 4 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Slient Height (s) ");
                document.write(" <input type='text' name='height' size='21'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" <td rowspan='4'><image
src='Diagrams_files/figure21.jpg'></td> ");
                document.write(" </tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Bottom Diameter (d1) ");
```

```
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Cup Diameter (d2) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Slient Diameter (d2) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" </td></tr> ");
                        document.write(" </table> ");
                        document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                        document.write(" </form> ");
                }

                function figure22()
                {
                //alert("figure no 8 function");
                        document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                        document.write(" <Table border='0'> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Bottom Diameter (d1) ");
                        document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                        document.write("  mm");
                        document.write(" </td> ");
                        document.write(" <td rowspan='2'><image
src='Diagrams_files/figure22.jpg'></td> ");
                        document.write(" </tr> ");
                        document.write(" <tr><td> ");
```

```
                              document.write("Enter Part Upper Diameter (d2) ");
                              document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                              document.write("  mm");
                              document.write(" <tr><td> ");
                              document.write("Enter Part radius(r)");
                              document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                              document.write("  mm");
                              document.write(" </td> ");
                              document.write(" </td></tr> ");
                              document.write(" </table> ");
                              document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                        document.write(" </form> ");

                        }
                        function figure23()
                        {
                        //alert("figure no 8 function");
                              document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                              document.write(" <Table border='0'> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part Bottom Diameter (d1) ");
                              document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                              document.write("  mm");
                              document.write(" </td> ");
                              document.write(" <td rowspan='2'><image
src='Diagrams_files/figure23.jpg'></td> ");
                              document.write(" </tr> ");
                              document.write(" <tr><td> ");
                              document.write("Enter Part Upper Diameter (d2) ");
                              document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                              document.write("  mm");
                              document.write(" <tr><td> ");
```

```
                        document.write("Enter Part Flange Diameter (d3) ");
                        document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                        document.write("  mm");
                        document.write(" </td> ");
                        document.write("Enter Part radius(r)");
                        document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                        document.write("  mm");
                        document.write(" </td> ");
                        document.write(" </td></tr> ");
                        document.write(" </table> ");
                        document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
                document.write(" </form> ");
                }
                function figure24()
                {
                //alert("figure no 8 function");
                        document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                        document.write(" <Table border='0'> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Bottom Diameter (d1) ");
                        document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                        document.write("  mm");
                        document.write(" </td> ");
                        document.write(" <td rowspan='2'><image
src='Diagrams_files/figure24.jpg'></td> ");
                        document.write(" </tr> ");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Upper Diameter (d2) ");
                        document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                        document.write("  mm");
                        document.write(" <tr><td> ");
                        document.write("Enter Part Flange Diameter (d3) ");
```

```
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write("Enter Part radius(r)");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </td></tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Height (h) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
             document.write(" </form> ");
             }
             function figure25()
             {
             //alert("figure no 8 function");
                    document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                    document.write(" <Table border='0'> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Bottom Diameter (d1) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" <td rowspan='2'><image
src='Diagrams_files/figure25.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Upper Diameter (d2) ");
```

```
                document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                document.write("  mm");
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Diameter (d3) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write("Enter Part radius(r)");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" </td></tr> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Flange Dimension (f) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
                document.write(" </table> ");
                document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
        document.write(" </form> ");
        }
        function figure26()
        {
        //alert("figure no 8 function");
                document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
                document.write(" <Table border='0'> ");
                document.write(" <tr><td> ");
                document.write("Enter Part Bottom Diameter (d1) ");
                document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                document.write("  mm");
                document.write(" </td> ");
```

```
                    document.write(" <td rowspan='2'><image
src='Diagrams_files/figure26.jpg'></td> ");
                    document.write(" </tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Upper Diameter (d2) ");
                    document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
                    document.write("  mm");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Diameter (d3) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write("Enter Part radius(r)");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </td></tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Height (h) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </td></tr> ");
                    document.write(" <tr><td> ");
                    document.write("Enter Part Flange Dimension (f) ");
                    document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
                    document.write("  mm");
                    document.write(" </td> ");
                    document.write(" </table> ");
                    document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
            document.write(" </form> ");
            }
```

```
			function figure27()
			{
			//alert("figure no 8 function");
				document.writeln(" <form action='rsh.asp' METHOD='POST'> ");
				document.write(" <Table border='0'> ");
				document.write(" <tr><td> ");
				document.write("Enter Part Bottom Diameter (d1) ");
				document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
				document.write("  mm");
				document.write(" </td> ");
				document.write(" <td rowspan='2'><image
src='Diagrams_files/figure27.jpg'></td> ");
				document.write(" </tr> ");
				document.write(" <tr><td> ");
				document.write("Enter Part Upper Diameter (d2) ");
				document.write(" <input type='text' name='diameter' size='20'
maxlength='25'> ");
				document.write("  mm");
				document.write(" <tr><td> ");
				document.write("Enter Part Flange Height (h) ");
				document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
				document.write("  mm");
				document.write(" </td> ");
				document.write("Enter Part radius(r)");
				document.write(" <input type='text' name='height' size='20'
maxlength='25' > ");
				document.write("  mm");
				document.write(" </td> ");
				document.write(" </td></tr> ");
				document.write(" </table> ");
				document.write(" <input type='submit' name='figure1'
value='Submit Data'> ");
			document.write(" </form> ");
			}
		}

		</SCRIPT>
</BODY></HTML>
```

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R.S. Hingole, *Advances in Metal Forming*, Springer Series in Materials Science 206, DOI 10.1007/978-3-662-44497-9