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.
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 tasks 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.
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 recrystallize 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.
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](image_url)
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 lever-
aged 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 pro-
vided 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 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.

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 sophisti-
cated, 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

Advances in Metal Forming
Expert System for Metal Forming
Hingole, R.S.
2015, XIX, 116 p. 26 illus., 23 illus. in color., Hardcover
ISBN: 978-3-662-44496-2