CHAPTER - 1

INTRODUCTION

1.1 SHEET METAL OPERATIONS

Metal stampings are important structural components of automobiles, computers, refrigerators, type writers, kitchen utensils, electrical, electronics and tele-communication equipments. According to a survey in the US, some 100 000 metal stampings could be found in the average American home in the 1980s [Nee 1989]. Sheet metal operations are economical and quick means of producing intricate, accurate, strong and durable metal stampings in huge quantities. Applications of these operations are increasing day by day due to their high productivity, low cost per part, improvement in material quality, minimum scrap material and energy consumption. One of the important tasks in the production of metal stampings is the design of dies to suit the product features.

Sheet metal operations can broadly be classified into shearing and forming operations. Shearing operations are further classified as cropping, piercing, blanking, notching, trimming, shaving, parting off, lancing, and slitting. Forming operations are sub-classified as bending, coining, forming, stamping, embossing etc. During sheet metal operations, the sheet metal is brought into the desired product shape by pressing the metal strip between the die block and the punch. Single or multiple operation dies are used to perform the sheet metal operations. The single operation dies perform only one operation with each stroke of the ram of the press.
machine, whereas two or more than two operations can be performed by using multi-operation
dies. Multi-operation dies may further be classified as progressive dies, compound dies and
combination dies. In a progressive die, the work pieces are advanced from one station to
another. At each station, one or more sheet metal operations are performed on the metal strip.
The result is a finished component at the last station of die with every stroke of the press. The
unwanted parts of the strip are cut out as it advances through the die, and one or more ribbons
or tabs are left connected to each partially completed part to carry it through the stations of the
die. One or more idle stations may be incorporated in the die to locate the strip, facilitate
interstation strip travel, provide maximum-size die sections, or simplify their construction.
Progressive dies are widely used for production of sheet metal stampings due to their high
productivity, high precision and relatively economic cost in terms of per piece of product.
However, progressive dies are costlier as compared to single-operation dies, but the saving in
total handling costs by progressive fabrication in mass production as compared with a series of
single operations may be great enough to justify the cost of the progressive dies.

1.2 DESIGN OF PROGRESSIVE DIES

The design of progressive dies is a complex and highly specialized procedure [Lee 1993,
Ismail 1995, Pilani 2000, Tor 2005] and typically progressive die design takes 20% of the lead
time from the concept design to the final stamping manufacture [Fallbohmer 1996]. The
diverse nature of products produced by progressive dies demands a high level of knowledge
on the part of the die designer [Wagener 1997, Choi 2000] that can only be achieved through
years of practical experience [Cakir 2005]. Checking the design features of sheet metal parts,
design of strip-layout, selection of die components, selection of materials for die components;
and modeling of die components and die assembly are major activities for designing a
progressive die [Cheok 1995]. The traditional methods of carrying out these tasks require expertise and are largely manual and therefore tedious, time consuming and error-prone [Soman 2002, Hambli 2003, Tor 2005]. Also the knowledge gained by die design experts after long years of experience is often not available to others even within the same company. It creates a vacuum whenever the expert retires or leaves the company. Modern CAD/CAM technology, new ideas in design and construction of press tools, coupled with increased speed and rigidity of the presses have contributed towards the continual use of metal stamping production processes to manufacture increasingly more sophisticated products. However, these developments demand greater skills of the designers. In rapidly developing countries, the problem is further compounded by two factors:

1. Young technical educated people do not have the patience to undergo long periods of apprentice training to acquire the skills to be a good die designer. Hence, there are fewer people joining the trade of die design. Stamping industries are facing acute shortage of skilled die designers. Further, the mobility of experienced die designers in stamping industries has caused much inconvenience to the sheet metal industries all over the world.

2. Owing to the rapid changes in consumer taste, the products have very short life cycles. In other words, there is a rapid demand for more sophisticated metal stampings. The die designers are under constant pressure to exploit the latest design and manufacturing technology in order to meet the market demand. Currently, some sheet metal industries are using traditional CAD/CAM systems to design and manufacture progressive dies. These CAD/CAM systems help to improve productivity of the designers by providing interactive graphical aids and a common geometrical database for them to model the components, produce the drawings and generate the NC codes for fabricating the components.
However, there is a limit to the amount of productivity gain that these CAD/CAM systems can offer to a company.

To overcome the above problems, there is an urgent need to develop an intelligent system for progressive die design to assist die designers and process planners working in sheet metal industries, especially small and medium sized stamping industries. The system should be capable of providing an intelligent aid to the die designers for carrying out major activities of progressive die design such as checking of design features of sheet metal parts, design of strip-layout, selection of components of progressive die, material selection for die components, and die modeling.

1.3 KNOWLEDGE-BASED SYSTEM APPROACH TO PROGRESSIVE DIE DESIGN

Knowledge-based systems (KBS) or expert systems are intelligent computer programs that use knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution. These are the most significant practical products to emerge from 30 years of Artificial Intelligence (AI) research. Knowledge-based systems, also known as intelligent systems, are poised to become the latest Artificial Intelligence (AI) technology and have wide spread impact on decision-making processes in most of the engineering fields which require expertise.

While there have been numerous applications of knowledge-based systems in manufacturing, few of them concern press tools, and even fewer are for progressive dies. Progressive die design is a very knowledge demanding process. Designers often base their decisions on past experience rather than theoretical knowledge and to some extent, it remains a process of trial and error. As one design company suggested "You would never know if the
press tool would work properly until it really produced the product you wanted". In today’s
highly competitive industrial scenario where there is a shortage of experienced die designers,
the requirement of high quality products with short lead times and low cost have emphasized
the importance and urgency of developing computer aided progressive die design systems with
embedded and easily modifiable knowledge. This is a task, which needs both existing
conventional CAD technology and knowledge-based system approach and that is the aim of
this research.

1.4 MOTIVATION OF THE PRESENT INVESTIGATION

Producing better quality, reducing the manufacturing cost and delivering the product
quickly, have now become three major targets for sheet metal industries. To achieve these,
companies have to adopt new technology-based strategies. Progressive dies are widely used
for mass production of stampings in sheet metal industries. Checking of design features of
sheet metal parts, design of strip-layout, selection of die components, selection of materials for
die components, and die modeling are the major activities for designing a progressive die. The
traditional methods of carrying out these tasks require expertise and are largely manual and
therefore tedious, time consuming and error-prone. The quality of die design depends to a
large extent on the designer’s skill, experience and knowledge. Commercially available
CAD/CAM systems are providing assistance in drafting and analysis in die design process, but
human expertise is still needed to arrive at the final design. Also, the high cost associated with
setting up such systems is quite often beyond the reach of small and medium sized sheet metal
industries, especially in developing countries.

Various researchers have used AI techniques to deal with the problems, which require
domain expertise for their solution. The main reason of there being only a few knowledge-
based systems developed for die design and even fewer for progressive dies, is the inherent difficulties to elicit the design know-how from experienced die designers and then to code the same into the knowledge base of an expert system [Ismail 1995, Tor 2003]. Also the use of these systems is very limited. They can either handle only blanking and piercing operations or parts with relatively simple geometry. Thus, there is a stern need to develop a low cost intelligent, progressive die design system using both CAD and KBS approach collectively, which can be easily affordable by small and medium scale sheet metal industries. The aim of present work is to contribute to the development of knowledge-based system for intelligent design of progressive dies.

1.5 OBJECTIVES OF THE PRESENT WORK

The specific objectives of the present research work are as follows-

1. Development of a knowledge-based system for checking of design features of sheet metal parts from manufacturability point of view.

2. Development of an intelligent CAD system for modeling of strip-layout for progressive dies. The system should be capable of identifying the sheet metal operations and their proper sequence, staging of operations on progressive die and finally modeling the strip-layout automatically.

3. Development of a knowledge-based system for selection of progressive die components

4. Developments of an intelligent system for modeling of die components and die assembly of progressive die.

5. Development of an intelligent system for selection of materials for progressive die components.
1.6 PRESENT WORK

The aim of the present work is to contribute to the development of knowledge-based system for intelligent design of progressive dies. Through the critical study of literature and discussion with experienced die designers, a knowledge-based system framework has been developed. To construct the system modules, a procedure has been formulated. This procedure recommends that the steps of development of system modules should include knowledge acquisition, framing production rules, verifying production rules, sequencing production rules, identifying suitable hardware and a computer language, constructing knowledge base, choosing search strategy and preparing user interface. The present investigation has mainly five facets, namely the development of a knowledge-based system module for checking of design features of sheet metal parts, intelligent CAD system for modeling of strip-layout, construction of system modules for selection of die components, automatic modeling of die components and die assembly, and selection of materials for progressive die components.

The first facet of present investigation comprises of two KBS modules namely CCKBS and SELDIE. The module CCKBS has been developed for checking the design features of sheet metal parts from manufacturability point of view. The module is capable of checking the part design features such as size of blank, size of holes, hole pitch, corner radius, distance of the internal features from the edge of the part, distance between two internal features, width of recesses or slots or projections, bend corner radius etc. It also recommends the minimum scrap web allowances for manufacturing the parts on a progressive die. The module SELDIE has been proposed for selection of suitable type of die for producing sheet metal parts.

The second facet comprises of development of two modules namely MAXUTL and PRSSEL and an intelligent system called as ISSLD. The module MAXUTL has been designed
The system ISSLD has been developed for intelligent design of strip-layout for metal stamping work on progressive die. It comprises of six modules. The system modules impart intelligent advices for the type of operations required for manufacturing the parts, sequencing of operations, selection of piloting scheme, deciding number of stations, staging of operations on progressive die and selection of size of stock strip. The system finally models the strip-layout automatically in the drawing editor of AutoCAD. The module PRSSEL has been developed for assisting the user in the selection of suitable type of press machine of required tonnage capacity.

The third segment comprises of a knowledge-based system namely PROCOMP developed for tackling the problem of selection of types and proper dimensions of die components. The system PROCOMP has been structured into seven modules. The outputs of system modules include the type and proper dimensions of progressive die components namely die block, die gages (front spacer and back gage), stripper, punches, die-set, punch plate, back plate and fasteners. The system has been designed in such a way that the advices imparted by its modules are automatically stored in different output data files.

In the fourth segment of present investigation, an intelligent system called as AUTOPROMOD has been designed for automatic modeling of progressive die components and die assembly. The system comprises of eight modules. The data stored in various output data files generated automatically during the execution of developed modules for strip-layout design and selection of die components has been utilized for modeling of die components and die assembly. The interfacing of AutoLISP and AutoCAD has been used for development of modules of AUTOPROMOD. The system automatically models major progressive die
components namely die block, die gages, stripper plate, back plate, punch plate, bottom bolster and top bolster of die-set and die assembly.

The fifth facet comprises of an intelligent system namely SMPDC developed for tackling the problem of selection of materials for progressive die components. The system has been structured into two modules. The first module has been constructed for selection of materials of active and inactive components of progressive die. The second module has been developed for determination of hardness range of selected materials of active components of progressive die.

The proposed knowledge-based system for intelligent design of progressive die overall comprises of more than 650 production rules of IF-THEN variety coded in AutoLISP language. However, the system is flexible enough as its knowledge base can be modified and updated depending upon the capabilities of a specific shop floor and advances in new technology. System modules are user interactive and designed to be loaded in to the prompt area of AutoCAD. The system is capable of checking the design features of sheet metal parts, design of strip-layout, selection of progressive die components, modeling of die components and die assembly, and selection of materials for progressive die components. The system can be implemented on a PC having AutoCAD software and therefore its low implementation cost makes it affordable by small and medium size enterprises.

1.7 THESIS LAYOUT

The goal of the present work is to provide contribution in the growing area of knowledge-based system for intelligent design of progressive dies. The thesis is organized as under.
Chapter 1 describes the sheet metal operations, design of progressive dies, knowledge-based system approach to progressive die design, motivation of the present investigation, objectives of present work, research work carried out and the organization of the thesis.

Chapter 2 presents a review of the work done by different researchers in the area of checking of design features of sheet metal parts, strip-layout design, computer aided design of progressive dies, knowledge-based systems for progressive die design, and material selection for die components. It also discusses the various commercial packages available and their limitations. Based on the critical review of past works, the research problem is formulated.

Chapter 3 describes the development of a knowledge-based system framework for progressive die design. To construct the system modules, a procedure has been developed and described at some length. The last segment of this chapter presents the organization of the proposed knowledge-based system for intelligent design of progressive dies.

Chapter 4 presents KBS modules developed for checking of design features of sheet metal parts and selection of suitable type of die. Usefulness of the modules has been demonstrated through an example of an industrial component.

The first segment of Chapter 5 describes the modeling of blank and a module developed for determining the orientation of blank for maximum possible utilization of sheet. The second segment of this chapter presents an intelligent system developed for strip-layout design. A module constructed for the selection of press machine is also described in this chapter. The sample run and validation of modules has been presented through industrial example components.
Chapter 6 describes a knowledge-based system developed for selection of progressive die components namely die block, die gages, stripper, punches, stripper plate, punch plate, die-set and locating and fastening elements. The execution of system modules is demonstrated through examples of industrial components.

Chapter 7 presents an intelligent modeling system developed for automatic modeling of die components and die assembly of progressive die. The system is validated using two example components. The drawings of major progressive die components including die block, stripper plate, back plate, punch plate, bottom and top bolster of die-set and die assembly generated automatically in the drawing editor of AutoCAD by the system modules for example components demonstrate the usefulness of the system. The second segment of this chapter discusses the considerations for selections of materials for progressive die components. An intelligent system developed for selection of materials for progressive die components is presented. The sample run using an example component validates and demonstrates the usefulness of the system.

Chapter 8 discusses the contributions of the present research work and scope of work for further research in the area of die design.