CHAPTER-3

KNOWLEDGE-BASED SYSTEM FRAMEWORK AND PROCEDURE OF DEVELOPMENT OF SYSTEM MODULES

3.1 INTRODUCTION

The process of progressive die design involves large number of activities. It requires many inter-related tasks and tooling skills based on theories and principles, design codes, heuristic procedures, personal expertise and experience. As the progressive die design activities are highly experienced based and hence, the same can be tackled through knowledge-based system (KBS) approach. The present chapter discusses the basic considerations for developing KBS of progressive die design and presents a KBS framework for intelligent design of progressive dies. The procedure being utilized for constructing KBS modules of the proposed framework is also described at length. Finally, the organization of the proposed system is presented.

3.2 BASIC CONSIDERATIONS FOR DEVELOPMENT OF KNOWLEDGE-BASED SYSTEM OF PROGRESSIVE DIE DESIGN

The critical analysis of literature survey reveals that the progressive die design is a complex process and should be structured into smaller inter-related manageable sub-tasks. The basic considerations [Vladimir 1986, Mackerle 1989] that should be taken into account for developing KBS of progressive die design involve the following-
1. Identifying the important progressive die design activities with clear-cut objectives and deciding whether such tasks are practicable to build the knowledge-base system,

2. Studying each activity critically for economic feasibility and manufacturability point of view,

3. Structuring traditional progressive die design process and identifying various modules using knowledge base system modular framework involving flow-charts, logic planning of functional components in form of knowledge-base system modules,

4. Developing of functional objectives for each module,

5. Selecting suitable hardware depending upon memory requirement, processing speed and needed configuration and selecting a suitable computer language to deal die design functional objectives for each module,

6. Analyze critically various factors responsible for decision-making in each module of knowledge-base system framework and accessing domain specific data, facts, and thumb of rules in form of recommendations of acquired knowledge for each module,

7. Framing of production rules for acquired recommendations for each module,

8. Verifying and testing the acquired domain knowledge for each module from the team of progressive die design experts,

9. Identifying suitable knowledge representation technique for programming of acquired knowledge for each module through a suitable identified language,

10. Validating and evaluating the knowledge-base system for implementation

Keeping in view the above considerations, a KBS framework for intelligent design of progressive die can be developed.
3.3 KNOWLEDGE-BASED SYSTEM FRAMEWORK FOR PROGRESSIVE DIE DESIGN

From the critical study of literature and discussion with experienced die designers, a KBS framework for intelligent design of progressive dies has been structured which is depicted in Fig. 3.1.

For the intelligent design of progressive die, initially a KBS module for checking of design features of sheet metal parts should be developed to check the design features from manufacturability point of view. Such checks are useful to reduce manufacturing defects and section weakness of the component. The knowledge base of this module must be capable of checking and imparting expert advices for necessary modifications if the design features such as holes, projections, internal contour, external contours, cut, notch, slots, bends etc. are not in accordance with the rules of good practice. For selection of type of die, another module should be constructed which is capable to identify a suitable type of die for manufacturing the undertaken product in the optimal manner. On requirement of mass production with moderate tolerance and multi operations involved in the part, this module should identify the progressive die for manufacturing the undertaken sheet metal component.

On checking of part design features from manufacturability point of view and identification of progressive die, the process planner models the blank and computes its orientation using AutoCAD and AutoLISP routines for maximum possible utilization of sheet.

For automating the strip-layout design, an intelligent system should be developed. The system should have different KBS modules for identification of operations, sequencing of operations, deciding about the proper piloting scheme and number of stations required, operations to be performed at each station of progressive die and selection of proper strip
Fig. 3.1 KBS Framework for Intelligent Design of Progressive Dies
width and feed distance. The system should also be capable of modeling the strip-layout for benefit of the user.

After the selection of type of die and design of strip-layout, the next important activity is the selection of press machine of required tonnage capacity. The KBS module developed for this purpose should initially computes and display the minimum force required for carrying needed sheet metal operations and then capable of identifying the optimal press using the concept of fixed and operating cost for each candidate press machine available on shop floor.

For selection of die components, a system comprising of KBS modules should be developed. The modules should be capable of selecting the type and proper size of progressive die components including die block, die gages, stripper, punches, stripper plate, punch plate, backup plate, die-set and locating and fastening elements.

The modules for intelligent design of progressive die should be constructed in such a way that their outputs are stored in different files. The data stored in these output files can be utilized for automatic modeling of die components, die accessories, and die assembly using AutoCAD facilitates and AutoLISP routines.

The last major activity of progressive die design is the selection of suitable materials for progressive die components. It has become one of the important aspects of progressive die design because long die life has become a necessity for achieving higher productivity and reducing cost of sheet metal parts. An intelligent system possessing experienced knowledge of die designers and manufacturers should be developed for tackling the problem of material selection of progressive die components. The system should be capable of giving expert advice on selection of materials for active & inactive components of progressive die and selection of close hardness range of selected materials during the design stage of progressive
dies. The user should be provided an option to select easily available materials from the intelligent advice imparted by the system and then a bill of materials can be prepared suitably.

All the above knowledge-based system modules should be user interactive and designed to be loaded in the prompt area of AutoCAD. To construct the system modules, a proper procedure is developed through critical study of literature related with knowledge-based systems and die design.

3.4 DEVELOPMENT PROCEDURE OF KNOWLEDGE BASE SYSTEM MODULES

The procedure for constructing KBS modules of the proposed framework has been developed which is schematically shown in Fig 3.2. A brief description of each step of the procedure is given as under.

1. KNOWLEDGE ACQUISITION

Knowledge acquisition for each module of progressive die design is essentially a collection of bits and pieces of published or unpublished, analytical or empirical knowledge from a variety of sources including experienced progressive die designers, shop floor engineers, and handbooks, monographs, research journals, catalogues and industrial brochures. The major sources of knowledge acquisition used for the present investigation are listed in Table 3.1. A brief description of these sources is given as under.

Literature Reviews:

Review of the literature including die design handbooks and published research papers on die design and CAD provides detailed, academically fundamental information and latest research progress in these areas. Although the information obtained from the die design
Knowledge Acquisition in Form of Objects of Different Modules of Domain Data, Facts, Judgment, Empirical Rules, Expert Advices, Rules-of-thumb etc. for Each Identified Module of Progressive Die Design Process

Framing of Production Rules for Each Module

Verification of Production Rules for Each Module from Die Design Experts

Sequencing of Production Rules for Each Module

Identification of Suitable Hardware and Computer Language

Construction of Knowledge Base

Choice of Search Strategy

Preparation of User Interface

Fig. 3.2 Procedure for Development of KBS Modules of Progressive Die Design
# Table 3.1 Major Sources of Knowledge Acquisition Used for Development of the Proposed System

<table>
<thead>
<tr>
<th>DIE DESIGN HANDBOOKS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>11. Strasser, F. (1971), Functional design of metal stampings, SME.</td>
</tr>
</tbody>
</table>
DIE DESIGN EXPERTS:

1. S. L. Gupta, Head (Tool room), M/S Mindarika Private Ltd., Gurgaon, Haryana
2. Sh. Naveen Sharma, Design Engineer (Tool room), M/S Mindarika Private Ltd., Gurgaon, Haryana
3. Sh. C. S. Chaudhary, Manager (works), Tool Room Training Centre, Wazirpur, Delhi
4. Sh. A.K. Sehgal, Manager (Training), Tool Room Training Centre, Wazirpur, Delhi.
5. Sh. P. V. Mohan Rao, Manager (Tool Design), Tool Room Training Centre, Wazirpur, Delhi.
6. Sh. Manoj Taneja, Design Engineer (Tool room), Havell’s India Ltd., Delhi.
7. Sh. Jaibir Rathee, Design Engineer, Horizon industries, Industrial area, Badli, Delhi.
8. Sh. C.L. Sehgal, Manager (Design), Atlas cycle industries Ltd., Sonepat Haryana

INDUSTRIAL BROCHURES:

1. Tool Engineering Parameters, Indian Society of Tool Engineers, Balanagar, Hyderabad.
5. Tool catalogue of Sandeep enterprises, New Delhi.
REPORTS:


PUBLISHED RESEARCH PAPERS:

As listed in the Reference section.

handbooks is not always the same as what is currently being practiced, literature survey is an easy and inexpensive mode of knowledge acquisition.

Die design experts:

The major bottleneck in the development of knowledge-based system for progressive die design is the process by which the knowledge of die design expert(s) is extracted and work is done in close coordination with expert(s) and serves for the adequate modeling of expertise and human inference capabilities. The process of knowledge acquisition from experienced die designers involves presenting a few typical problems to the expert(s) and letting the expert(s) talk through the solution. During the verbal analysis, the expert(s) would be questioned/interrupted to explain why a particular decision was reached. Knowledge may be acquired from domain experts by holding discussions on typical problems pertaining to the major activities of progressive die design and letting the experts talk about the approach, formulae and thumb-rules relied upon by them. They may be asked as to how and why a particular decision can be reached. This is to identify the parameters influencing particular decision. However for
acquiring the maximum possible knowledge in die design domain they should be provided a list of situation based questions. Experts should be requested to reply the quarries in form of various possible situation of ‘IF-Then’ kind of that specific domain. They should also be observed while working. Domain experts may face difficulties to represent their knowledge in form of facts, rules etc. They prefer to represent their knowledge through examples.

**Industrial visits:**

This knowledge, not always quantifiable, is useful in getting a better ‘feel’ for the problem of progressive die design and in understanding the common terminology used on the shop floor of stamping industries, and thus facilitated constructing a practical knowledge-based system that would cater to needs of stamping industries and also be equipped with a friendly user interface. A knowledge base system with such a front-end is expected to have a relatively easy learning curve and therefore, is likely to be accepted more by the industrial users.

**Industrial Brochures:**

The information obtained through industrial brochures of stamping industries is a compromise between the academically fundamental knowledge obtained through literature reviews and the practical, experience-based knowledge obtainable from industrial experts.

2. **FRAMING OF PRODUCTION RULES**

Production rule-based systems constitute the best means available today for codifying the problem solving know-how of die design experts. The syntax of a production rule is -

\[
\begin{align*}
\text{IF} & \quad <\text{condition}> \\
\text{THEN} & \quad <\text{action}>
\end{align*}
\]
The condition of a production rule, sometimes-called LHS (Left-Hand side) contains one or more conditions, while the action portion, sometimes called RHS (Right-Hand side) contains one or more actions.

3. VERIFICATION OF PRODUCTION RULES

The production rules framed for each module must be verified from a team of die design experts and tool manufacturers by presenting them IF-condition of the production rules and then matching their recommendations with the THEN-action part of rules. The conflicting situation in production rule(s) was tackled through discussion with the team of die design experts consulted in the framing stage of production rules. Then the necessary modifications in production rules were further verified from some other team of die design experts.

4. SEQUENCING OF PRODUCTION RULES

Production rules in each module of the knowledge-based system of progressive die design may be arranged either in an unstructured (arbitrary) or a structured manner. In the latter case, the rules tend to be simpler and briefer because they are designed to "fire" in some hierarchical manner.

5. IDENTIFICATION OF SUITABLE HARDWARE AND A COMPUTER LANGUAGE

Suitable hardware elements depending upon memory requirement, processing speed and needed configuration should be selected. Today, most of the KBS modules are being developed on a PC/AT because it involves low cost. Early knowledge-based systems were written in language interfaces derived from FORTRAN. Later on, object-oriented languages such as KEE, OPS, PROLOG, TURBO PROLOG and LISP were developed specifically for the artificial intelligence systems [Barr 1981]. LISP and PROLOG have been won wide
acceptance for building knowledge-based systems [Gaines 1988]. However, the user of LISP and PROLOG languages encounters difficulties when handling design problems involving graphical information. For this reason, AutoCAD [Danial 1989, Gary 1990] and AutoLISP [George 1987, Robert 1988] have found greater acceptance for the development of knowledge-base system [Jain 1988] for progressive die design.

6. CONSTRUCTION OF KNOWLEDGE BASE

Knowledge base is a part of a knowledge-based system that contains domain knowledge, which may be expressed in the form of production rules of IF-THEN variety [Kinnucan 1984]. The inference mechanism allows manipulating the stored knowledge for solving problems. The rules and the knowledge base are linked together by an inference mechanism. The user input information provide guidance to the inference engine as to what "IF-Then" rules to fire and what process of information are needed from the knowledge base.

7. CHOICE OF SEARCH STRATEGY

When searching for a solution to progressive die design problems, two strategies called forward chaining and backward chaining are generally used. Forward chaining is a good technique when all on most paths from any one of much initial or intermediate state converges at once or a few goal states. Backward chaining is an efficient technique to use when any of many goal states converging on one or a few initial states.

8. PREPARATION OF USER INTERFACE

The knowledge-base system modules should be interactive in nature. The purpose of user interface in the development of each module is two fold:
(i) To enables the user to input the essential sheet metal component data, and
(ii) To displays the optimal decision choices for the user's benefit.

The former is accomplished by flashing AutoCAD prompts to the user at appropriate stages
during a consultation to feed data items. Messages or items of advice are likewise flashed into
the computer screen whenever relevant production rules are fired.

3.5 ORGANIZATION OF THE PROPOSED KNOWLEDGE-BASED
SYSTEM FOR INTELLIGENT DESIGN OF PROGRESSIVE DIES

Organization of the proposed knowledge-based system for intelligent design of
progressive dies (INTPDIE) is shown in Figure 3.3. The whole system INTPDIE has been
organized into the following systems, modules and sub-modules:

1. Module CCKBS for checking of part design features,
2. Module SELDIE for selection of suitable type of die,
3. Module MAXUTL for determining the optimal angle of orientation of blank for maximum
   utilization of sheet.
4. Intelligent CAD system called as ISSLD for intelligent modeling of strip-layout
   comprising of following six modules -
   (i) Module OPRPLAN for identification of operations,
   (ii) Module OPRSEQ for operation sequencing,
   (iii) Module PLTSEL for selection of piloting method,
   (iv) Module OPRSTAGE for deciding number of stations required and staging of
        operations on progressive die. It consists of following two sub-modules -
        (a) Sub-module OPRSTAGE1, and
        (b) Sub-module OPRSTAGE2
Fig. 3.3 Organization of the Proposed Knowledge-Based System for Intelligent Design of Progressive Dies (INTPDIE)
(v) Module SWLSEL for selection of strip width and feed distance. It comprises of following two sub-modules -

(a) Sub-module SWLSEL1 for selection of strip width, and

(b) Sub-module SWLSEL2 for selection of feed distance

(vi) Module STRPLYT for automatic modeling of strip-layout in the drawing editor of AUTOCAD


6. System PROCOMP for selection of progressive die components. It comprises of following modules and sub-modules -

(i) Module DBLOCK for selection of dimensions of die block,

(ii) Module DIERGAGE for selection of dimensions of die gages,

(iii) Module DIALCL module for selection of die-angle, die-land and cutting clearances,

(iv) Module STRPR for selection of stripper details,

(v) Module PCHPL for selection of punch details, dimensions of punch plate and plate and back plate,

(vi) Module IDSS for selection of die-set. It consists of following two sub-modules -

(a) Sub-module DSSEL for selection of type of die-set, and

(b) Sub-module DSDIM for selection of dimensions of die-set

(vi) Module FSTNR for selection of number of Allen bolts & dowels and their sizes

7. Intelligent system AUTOPROMOD for automatic modeling of progressive die components and die assembly. It is structured in form of following modules -

(i) Module DBMOD for modeling of die block,

(ii) Module STRPRMOD for modeling of stripper plate,

(iii) Module BPMOD for modeling of back plate,
(iv) Module PPMOD for modeling of punch plate,
(v) Module BBDSMOD for modeling of bottom bolster of die-set,
(vi) Module TBDSMOD for modeling of top bolster of die-set,
(vi) Module BDAMOD for modeling of bottom die assembly of progressive die, and
(vii) Module TDAMOD for modeling of top die assembly of progressive die

8. System SMPDC for tackling the problem of selection of materials of progressive die components. The system comprises of two modules, namely -

(i) Module DIEMAT for selection of materials of active and inactive components of progressive die, and

(ii) Module HRDSEL for determination of hardness range of selected materials of active components of progressive die.

The proposed knowledge-based system overall comprises of more than 650 production rules of IF-THEN variety. The rules are coded in AutoLISP language. Each module is designed to be loaded in the prompt area of AutoCAD.

3.6 CONCLUSION

The basic elements for constructing KBS for progressive die design have been considered and analyzed critically in this chapter. The major activities of traditional progressive die design have been identified in form of modules and KBS framework for intelligent design of progressive dies has been constructed. The procedure for development of each KBS module of the framework has been formulated and described at length. For convenience, the whole system INTPDIE has been organized into various modules and sub-modules.