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A Low Cost Knowledge Base System Framework for Design of Deep Drawing Die

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Abstract**—**In this paper a low cost knowledge base system (KBS) framework is proposed for design of deep drawing die and procedure for developing system modules. The task of building the system is structured into different modules for major activities of design of deep drawing die. A manufacturability assessment module of the proposed framework is developed to check the manufacturability of deep drawn parts. The technological knowledge is represented by using IF- THEN rules and it is coded in AutoLISP language. The module is designed to be loaded into the prompt area of AutoCAD. The cost of implementation of proposed system makes it affordable for small and medium scale sheet metal industries.

Keywords**—**Knowledge base system, Deep drawing die, Manufacturability, Sheet metal.

I. Introduction

TRADITIONALY the task of design of deep drawing die is performed by highly experienced die designers. It involves numerous activities such as process planning, determining number of draws required, calculations for blank holding force and drawing speed, design/selection of various die components etc. [1]. Traditional process of design of deep drawing die is manual, tedious, time consuming, and error prone [2]. Also the knowledge acquired by die design experts after long years of service is often not available to others even within the same company. It creates a vacuum whenever expert retires or leaves the company [3]. In recent years, a number of commercial CAD/CAM packages are available to provide some aid to die designers and process planers to perform simple calculation, storage and retrieval of data, and visualization of part geometry. But these software packages are failed to integrate various die design activities and unable to combine logically various functions of die design. Recently many researchers have worked on the development of knowledge base system (KBS) for process planning and design of deep drawing die to ease the difficulty of die designers and process planners and to reduce manufacturing lead time of sheet metal parts. Tisza [4] developed metal forming expert system using principles of group technology for process planning of multi-stage forming processes. Pilani et al. [5] developed a neural network based expert system for design of die face of forming die. Park et al. [6] developed a computer-aided process planning system for rotationally symmetric deep drawing products. Zhang et al. [7] developed a computer-aided process planning for multi-stage, non-axisymmetric sheet metal deep drawing using a case-based reasoning (CBR) approach. Lin et al. [8] proposed an integrated CAD/CAE/CAM system for designing stamping dies for trunk lid outer panels of automobile.

Literature review reveals that most of systems developed for design automation of deep drawing die are prototypes in nature and restricted to specific application. Also these prototypes are unable to handle information from various sources effectively. Therefore a knowledge base system (KBS) is required for design of deep drawing die, which must have rich knowledge of experienced die designers, can logically integrate all design task of deep drawing die and having low cost of implementation. The present work describes a KBS framework for design of deep drawing die and a procedure for developing system modules. The proposed system will have low cost of implementation.

II. Proposed knowledge based System Framework

The proposed KBS framework for design of deep drawing die is presented in Fig. 1. First of all, a module for checking the manufacturability of deep drawn parts is required to be developed. Such checks are useful to identify and resolve potential problems on the part such as splitting and excessive thinning or wrinkling. The knowledge base of this module must be capable to check and give advice for modification if the design features are not in accordance with the rules of good practices. For process planning, various modules are required to be developed such as blank diameter calculation and shape determination, determining of no number of draws, punch and die radius, drawing and blank holder force, drawing speed, selection of lubricant and determination of other drawing parameters. These modules must be capable of handling simple as well as complex part geometry. Next, KBS modules for design / selection of die components are required to be developed. The major die components are punch, die, plate elements, die-set, stoppers, fastening and locating elements.

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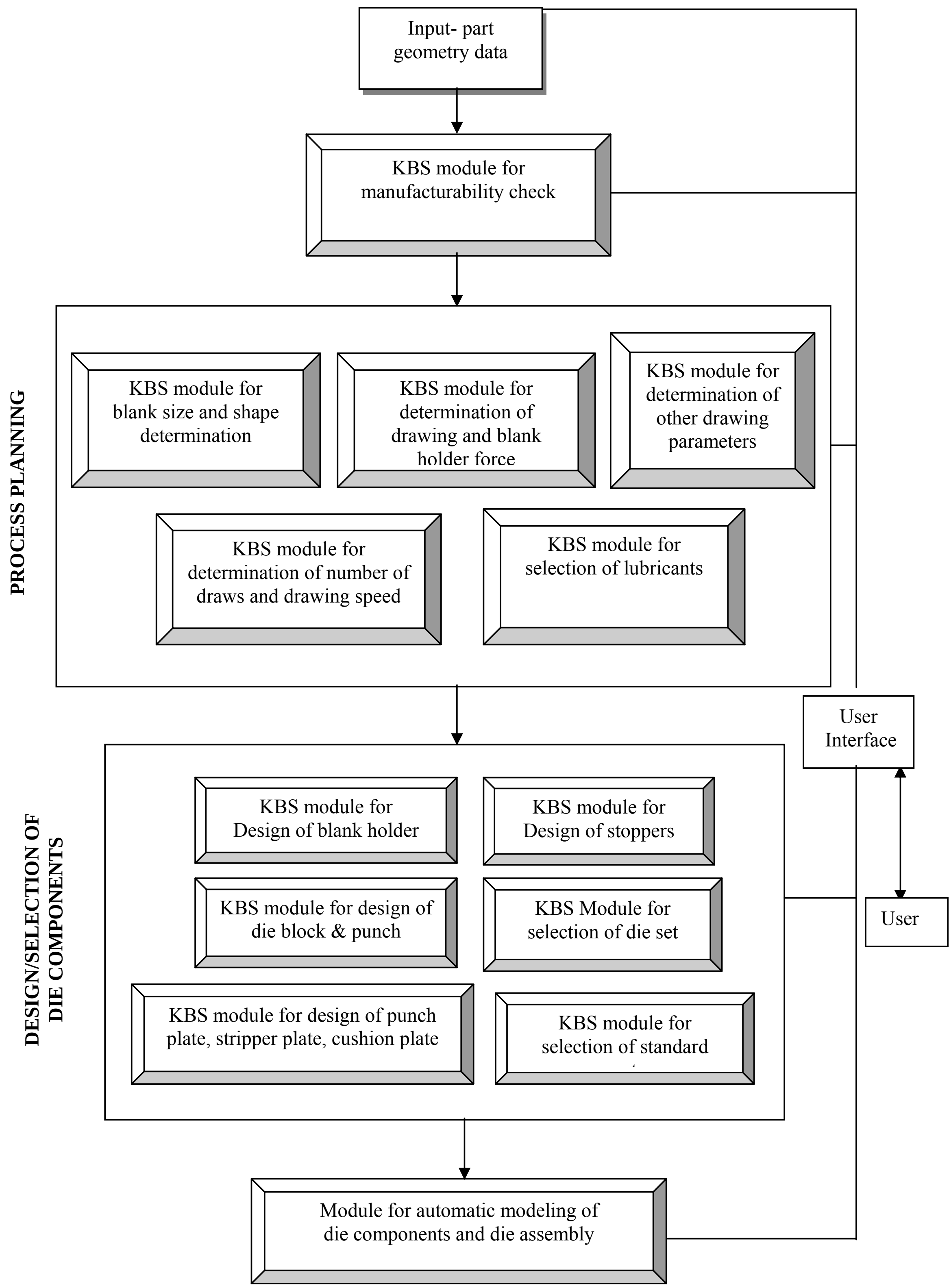

Fig. 1 Proposed KBS framework for design of deep drawing dies

The output of each module must be stored in different data files, which can be further used for modeling of die components, die accessories and die assembly using CAD facilitates and suitable AI language.

The procedure being utilized for development of each module of the proposed framework is described as under.

III. Procedure For Development Of Knowledge Base System MODULES

The procedure for development of proposed KBS modules for design of deep drawing die is identified and schematically shown in Fig. 2. A brief description of each step is given in following paragraphs.

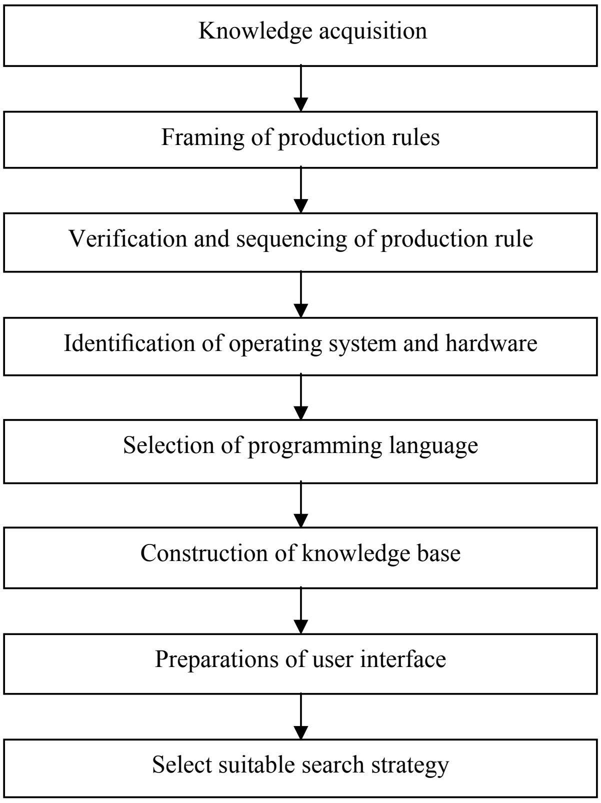

Fig. 2 Procedure for development of KBS modules for design of deep drawing dies

A. Knowledge Acquisition

Knowledge acquisition is first step in the development of expert system. The domain knowledge for design of deep drawing die is required to be collected from various sources of knowledge acquisition such as published literature, die design experts, catalogs and manuals of industries etc. The process of knowledge acquisition from die design experts 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 to explain why a particular decision was reached.

B. Framing of Production Rules

The collected knowledge represented using production rule-based systems. The syntax of a production rule is: IF <condition>, Then <action>

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.

C. Verifications of Production Rules

The knowledge for design of deep drawing die is generally collected from discussion with die design experts. These rules may differ from industry to industry. Therefore, production rules framed for each module must be crosschecked from die design experts by presenting them IF-condition of the production rule of IF-THEN variety.

D.Sequencing of Production Rules

The production rules can be presented in either in unstructured (arbitrary) or structured manner. But structured presentation of production rules is simple to refer and consume less time and if query is fired it take less time to get the result. Also ambiguity in understanding the knowledge will be less.

E.. Selection of Suitable Hardware and Programming 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. The efficiency, flexibility, development cost and maintenance of KBS largely depend on the programming language used. LISP and PROLOG have been won wide acceptance for building KBS. But the user of LISP and PROLOG languages encounters difficulties when handling design problems involving graphical information. For this reason, AutoCAD and AutoLISP have found greater acceptance for the development of KBS for die design.

F. Construction of Knowledge Base

Knowledge base is a part of the KBS that contains domain knowledge, which may be expressed in the form of production rules of IF-THEN variety. The inference mechanism allows manipulating the stored knowledge for solving problems. The rules and the knowledge base must be linked together by an inference mechanism. The user input information provides guidance to the inference engine as to what 'IF-THEN rules to fire and what process of information is needed from the knowledge base.

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G. Choice of Search Strategy

Inference mechanisms search through the knowledge base to arrive at decisions. Two popular methods of searching are backward chaining and forward chaining. 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 converge on one or a few initial states.

H. Preparation of User Interface

KBS modules should be interactive in nature. The purpose of user interface in the development of each module is twofold: (1) to enables the user to input the essential sheet metal component data; (2) 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 onto the computer screen whenever relevant production rules are fired.

The above procedure has been utilized for development of one KBS module namely MCKBS of the proposed framework. The description of the same is given as under.

IV. KBS Module MCKBS

Manufacturability assessment plays an important role in concurrent product and process development. It is generally estimated that decisions made at the stage of product design determine 70 to 80 percent of the manufacturing productivity [9]. A manufacturability check module labeled as MCKBS of the proposed KBS framework is developed to check the manufacturability of deep drawn parts at early design stage of part. Heuristic knowledge for the construction of proposed module is obtained from various sources as discussed earlier. A sample of production rule incorporated in present module is given in Table 1. These rules are encoded in AutoLISP. The system incorporates an interface through which it asks the user to input the needed data. The user initially loads the program by using the command (LOAD "A: MCKBS.LSP") in to the prompt area of AutoCAD. After entering the required input data, the program scans through the production rule on after another. Whenever IF condition in a production rule gets satisfied, the module displays the THEN advice to the user. The proposed module has been tested by considering the problem of checking manufacturability of the part for several different types of sheet metal parts. Execution of module for one real industrial component (Fig. 3) is given through Table 2. The recommendations obtained were found to be reasonable and very similar to those actually used in industry (M/s Bhagyashree Accessories Pvt. Ltd., Pune Maharashtra, India) for the example component.

TABLE I
A Sample of Production Rules Included in The Proposed Knowledge Based System

Sr. No	IF	Then
1	Sheet material thickness is => 0.50 mm	"Accept the sheet material thickness"
2	Sheet material thickness is < 0.50 mm	Set the sheet material thickness ≥ 0.50mm
3	Diameter of raw material sheet is ≥ diameter of required blank	"Accept the raw material"
4	Chemical composition of sheet material is within the range	Accept the sheet material
5	Chemical composition of sheet material is not within the range	Select another suitable material
6	Mechanical properties of sheet material is within the range	Accept the sheet material
7	Mechanical properties of sheet material is not within the range	Select another suitable material
8	Diameter of required blank < = diameter of raw material sheet	Set blank diameter > raw material diameter
9	Actual drawing ratio ≤ limiting draw ratio	"Accept the drawing ratio"
10	Actual drawing ratio > limiting draw ratio	Set actual drawing ratio ≤ limiting draw ratio
11	Actual height ratio ≤ limiting height ratio	"Accept height ratio"
12	Actual height ratio >limiting height ratio	Set actual height ratio ≤ limiting height ratio
13	Sheet thickness to blank diameter (T/D) > 0.25	"Accept sheet thickness ratio"

14	Sheet thickness to blank diameter (T/D) ≤ 0.25	Set Sheet thickness to blank diameter (T/D) > 0.25
15	$4t \le$ bottom radius (r_{punch}) $> 10t$	"Accept punch radius "
16	$4t \le$ Die radius (r_{die}) $> 10t$	"Accept die radius "

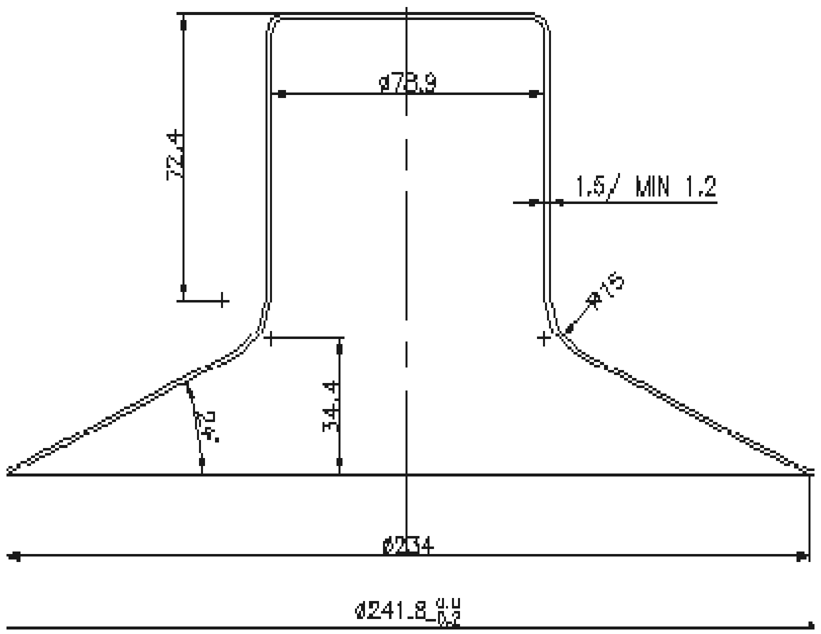

Fig. 3 Example component (dimensions in mm, sheet material M.S., sheet thickness: 1.5 mm)

TABLE II
TYPICAL PROMPTS, USER RESPONSES AND EXPERT ADVICE DURING EXECUTION OF THE PROPOSED MODULE

S. No	Prompt	Example data entry	Advice to user
1	Please enter sheet material	M.S.EDD	
2	Please enter sheet thickness	1.5	
3	Please enter diameter of blank	300	"Accept the blank Diameter"
4	Please enter diameter of shell	241.8	"Accept diameter of shell"
5	Please enter height of shell	106.8	"Accept height of shell"
6	Please enter punch radius	5	"Set punch radius on part in mm = 6"
7	Please enter die radius	15	" Set die radius on part in mm" = 12"
8	Please enter height of taper	44.1	"Accept taper height"
9	Please enter flange width	7.8	"Accept flange width"
10	Please enter taper angle	24	"set taper angle to 30 degree"
11	Enter height to diameter ratio	0.49	"Accept height to diameter ratio"
12	Enter draw ratio	1.24	"Accept draw ratio"
13	Enter flange width to blank diameter ratio	1.02	"Accept the flange width to blank diameter ratio"
14	Enter sheet thickness to blank diameter ratio	0.641	"Accept sheet thickness to blank diameter ratio"

V. Conclusion

In this paper a knowledge base system framework is proposed for design of deep drawing die. The procedure for the development of system modules is explained at some length. This methodology is being pursued for the development of different modules of the proposed framework of design of deep drawing die. The development procedure and execution of one module constructed for manufacturability check of deep drawn parts is presented. The rules are coded in the AutoLISP language and loaded into the prompt area of AutoCAD. This arrangement facilitates interfacing of design process with modeling and can be operated on a PC/AT. The system supports the modification in the knowledge base of each module depending upon the newly acquired knowledge and addition of new modules for updating the system capabilities. The knowledge base system developed using proposed framework can be implemented on a PC and hence has low cost of implementation and user-friendly.

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