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Research Paper

LOW COST KNOWLEDGE BASE SYSTEM FOR DESIGN OF DEEP DRAWING DIE SET

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An expert system is a computer system used to distribute the expertise of a human or group of humans throughout a group of users. In this paper a low cost Knowledge Base System (KBS) is proposed for design of deep drawing die. 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 various logical operators especially IF Else loops and it is coded in ADOBE FLEX, FLASH CS5 language. The future module will be designed to be loaded into the prompt area of AutoCAD using AUTOLISP for automated design. The cost of implementation of proposed system makes it affordable for small and medium scale sheet metal industries.

Keywords: Knowledge Base System (KBS), Deep drawing die, Manufacturability, Sheet metal

INTRODUCTION

Conventionally 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. (Sing and Rao, 1997). Traditional process of design of deep drawing die is manual, tedious, time consuming, and error prone (Soman and Campbell, 2002). 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 (Kumar, 2006). In recent years, a number of commercial CAD/CAM packages are available to provide some aid to die designers and process planers to

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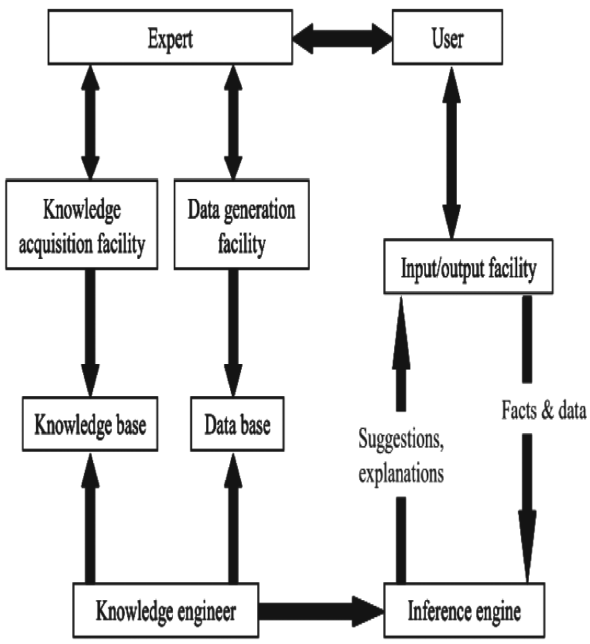
perform simple calculation, storage and retrieval of data, and visualization of part geometry. But these software packages have failed to integrate various die design activities and are unable to combine logically various functions of die design. Recently many researchers have worked on the development 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 (1995) developed metal forming expert system using principles of group technology for process planning of multi-stage forming processes. Pilani *et al.* (2000) developed a neural network based expert system for design of die face of forming die. Park and Yarlagadda (2004) developed a computer-aided process planning system for rotationally symmetric deep drawing products. Zhang *et al.* (2006) developed a computer-aided process planning for multi-stage, non-axi-symmetric sheet metal deep drawing using a Case-Based Reasoning (CBR) approach. Lin and Kuo (2008) proposed an integrated CAD/CAE/CAM system for designing stamping dies for trunk lid outer panels of automobile. Most recently a framework has been proposed by Vishal and Kumar (2010) which was just a way to achieve a successful KBS, but it was not any framework by itself.

Literature review reveals that most of systems developed for designing 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.

Expert system can be defined as an intelligent computer program, a repository of knowledge, a set of rules, like a human consultant, all aiming at delivering accurate solutions/suggestions to a problem at any level, say during planning, designing, manufacturing, and quality control. Some of the important definitions are quoted here.

The general structure of an expert system is shown in Figure 1 (Dym, 1985; and Tisza, 1995). The components of the expert system include—input/output facilities, which allow the user to communicate with the expert system and to use and create a database for a specific problem under investigation; an inference engine, which contains rules or reasoning methods, that acts upon the input query and knowledge base, data base, to provide solution and justification to the problem stated. This is like an executive that runs the expert system. It fires existing rules according to the problem stated that not only acts on the knowledge/data base to generate solution, but also updates the knowledge/data base by adding new knowledge/data to it; a knowledge base, containing the basic knowledge about the field including the facts, beliefs, procedures, expert opinion, etc.; a knowledge acquisition system, which does the job of acquiring knowledge automatically from varied

Figure 1: Basic Structure of an Expert System



Source: Dym (1985) and Tisza (1995)

resources like libraries, experts, other data bases and so on; a data base, which is similar to knowledge base, where in quantified data (e.g., material properties, tool conditions, forming machine parameters, etc.), pertaining to that field are located that will be used by the inference engine during solution generation; a data base generation system, which collects the input given by expert and from other resources so that data base can be developed and updated at any stage of expert system. Both the expert and user are linked to each other so that data, knowledge can be easily updated at the development stage of expert system itself. The inference engine and knowledge/data base are not considered always as entirely separate components and there is a lot of overlap between the concepts of both the components (Dym, 1985). A knowledge engineer, expert in artificial intelligent techniques, is the one who structures the expert's knowledge, which will be shared by the user. Sometimes the expert himself acts as a knowledge engineer. However in this case, there are two practical dangers worth noting. One is that the domain experts developing their own expert system must learn a lot about knowledge/data representation. This will become clearer in due course, and should not underestimate the immensity of the task. On the other hand, though knowledge engineers learn a lot about the field on which the expert system is built, they should remember that they are not field experts and hence should remain as talented amateur in that field and efficient knowledge base builders (Dym, 1985).

Expert system incorporates three types of knowledge:

1. Factual or data oriented knowledge,
2. Rule based knowledge, and
3. Procedural knowledge (Wang *et al.*, 1991) embodied within a model base.

The trend at present is to exploit the convergence of all the three kinds of knowledge representation in a single system. The knowledge base is contained in a set of rules or conditions and a secondary data base. Each production rule represents knowledge about a field, expressed in antecedent-consequent form and a knowledge base may contain hundreds of rules. For example, typical knowledge base can have some 700 rules on maximum load required for forming, press requirements and material properties. There are other ways of knowledge base representation like semantic networks, frame system, etc. (Dym, 1985). In semantic network, there are set of nodes that represent objects, concepts, events, etc. (say engines, hydraulic presses, die, burning) and links that connect the nodes and represent their interrelation (say function of, subset of, part of, in process). Frames are data structures where in, instead of symbols, declarative statements about the objects are included in pre-defined slots. The information can include material properties, engine names, manufacture name, applicable names, etc. One can exploit the advantage of each of the representation ideas to have an efficient expert system (Dym, 1985). For instance, production rules simplify the generation of explanation and prompt the user as it is easy to change antecedent-consequent "IF-THEN" form or rules into a questionnaire. In a rule that states "IF the effective strain rate in the notch to bulk is greater than or equal to 4 THEN the sheet material fails" can be seen as an explanation—"The effective strain rate in the notch to bulk greater than or equal to 4 indicates sheet material failure" or as a question—"Is the effective strain rate in the notch to bulk greater than 4". Thus an expert system might combine semantic network to relate objects to each other, a frame system that exposes the features of individual objects, and production rules to uncover the properties of individual objects.

Inference engine basically work on inference rules that tries to derive answers from a knowledge base. Backward chaining and forward chaining are the two main methods of reasoning when using inference rules. Forward chaining is data driven, and backward chaining is goal driven. An inference engine using forward chaining searches the inference rules until it finds one in which the 'IF' clause is 'true'. It then concludes the 'THEN' clause and adds this information to its data. It would continue to perform this operation until a goal is attained. An inference engine using backward chaining would search the inference rules until it finds one which has a 'THEN' clause that closely matches a prescribed goal. If the 'IF' clause of that inference rule is not true, then it is added to the list of goals. The selection of inference engine is important and is coupled to the nature of task the system is intended to perform. The selection of inference engine depends mainly on memory allocation for solving the problem, solution space required, tentative reasoning about the domain, and whether or not the data are noisy and varying with time. Initially LISP, the list processing language; Prolog, a logic oriented language are used, but an important trend in the expert system market is the evolution of systems towards more performance oriented programming languages like C, Pascal, Fortran, etc. The reason for such a shift is twofold. Not only the inference engines run faster (100 times faster than older LISP based), but also promote ease of integration with other software applications. Nowadays various methodologies are available to construct expert systems in any chosen field. Expert systems can be developed based on rules, knowledge systems, neural networks, fuzzy system, object oriented methodology, case based reasoning, system modeling, intelligent agents, database methodology, etc. (Liao, 2005).

Sheet metal forming is one of the important manufacturing processes used predominantly in automotive, aerospace, electronics, electrical, house-hold appliances, and building sectors. This process involves plastic deformation of metallic sheet materials to make sheet metal components for any application. Typical applications can be seen in cars, washing machines, and air plane wings, house-hold appliances like gas cylinders, beverage cans, and building roofs. The sheet metal forming processes include deep drawing, stamping, bending, rolling, spinning, cutting, and blanking. Generally the sheet components are made by any one of the mentioned process or combination of processes. Most of the sheet forming processes requires a sheet material to be formed; tools like die, punch, sheet holder, draw bead, mandrel and machines to perform the operation. The material properties like chemical composition, microstructure, texture; mechanical properties, viz., yield strength, ultimate tensile strength, elongation; formability factors like strain hardening exponent, anisotropy index, strain path; process parameters like friction conditions between sheet and tools, working temperature, strain rate, blank holding force, draw bead restraining force; and finally tool (die, punch) geometry influence the sheet forming behavior in a compounding fashion.

In industrial practice, the sheet forming engineer should be aware of the process sequence, tool design aspect, process parameter design, sheet material behavior, blank design, and machine usage for successful fabrication of sheet parts. For example, the process sequence required for single stage and multi-stage components are different. Similarly the tool design requirements for making a sheet product made of un-welded blank and tailor welded blanks (two or more sheets of different thickness, grades, etc., welded before forming) are not same because of the presence of different thickness, grade sheets, and weld line movement. The properties and behavior of the sheet material play a vital role in deciding its applicability in making a sheet part. The material behavior requirement will differ from product to product and hence knowledge on materials used is essential. It is known that the parameters mentioned above determine the sheet formability in a synergistic manner. Designing sheet product for a typical application will be successful only by knowing the appropriate material behavior, process parameter design, process sequence, tool and machine design, and specific issues pertaining to advances in material and forming technology. Predicting these sheet stamping parameters in advance will be helpful in determining the formability of any sheet part. In order to fulfill this requirement, one has to perform lot of simulation trials and experiments separately for each of the cases which are time consuming and resource intensive. Automotive sheet forming designers will greatly benefit if ‘expert systems’ are available for sheet stamping that can deliver its forming behavior for varied material, process and tool conditions. Developing an expert system or knowledge based system, especially in fields like material forming and deformation behavior, die design, casting design, machining processes, metallurgy, etc., is of interest to manufacturing and design engineers. In this Paper, the expert system and its application to predict the sheet metal formability in terms of tool, process and material design is discussed through published literature. The expert system based analyses in sheet process design, process planning, strip layout design, tool design, material forming is focused. The various techniques used to develop expert systems is presented. The available expert systems and their applicability in sheet forming field is highlighted.

PROPOSED SYSTEM

The procedure for development of proposed KBS modules for design of deep drawing die is identified and schematically shown in Figure 2.

Figure 2: Procedure for Development of KBS Modules for Design of Deep Drawing Die Set

Knowledge acquisition
↓
Framing of production rules
↓
Verification and sequencing of production rule
↓
Identification of operating system and hardware
↓
Selection of programming language
↓
Construction of knowledge base
↓
Preparations of user interface
↓
Selection of suitable search strategy

RESULTS AND DISCUSSION

The image shown in Figure 3 is the page where the user specifies the input parameters and a calculate button is provided with to get the design parameters of deep drawing process. The image shown in Figure 4 indicates the results, i.e., the design parameters of deep drawing process. These values are output of the program. The program is written in Adobe Flex and Flash CS5.

Figure 3: Sample Page for the User to Specify Input Parameter

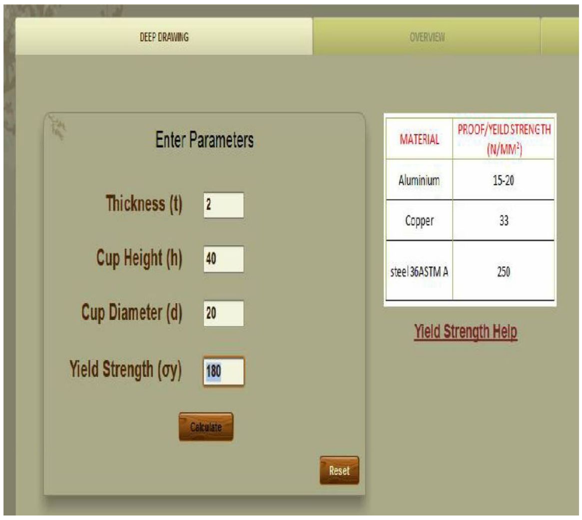
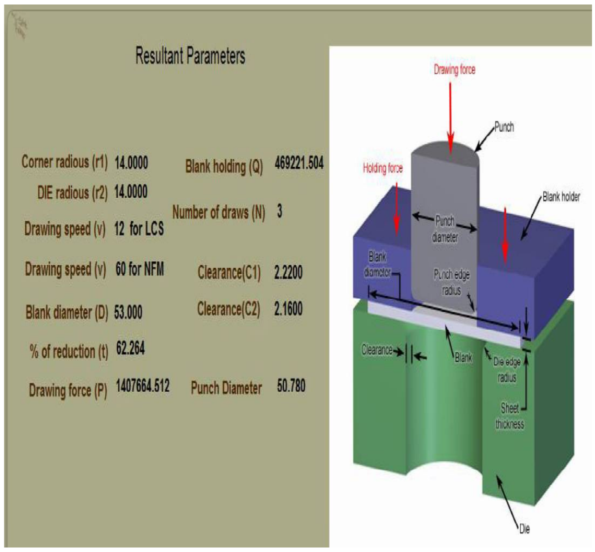


Figure 4: Sample Page of Output Parameters



After giving above inputs the below values are obtained and about 25 such problems were verified to have same answers with those of standard texts like Metal Forming by Nagapal, Manufacturing Process by P N Rao and Production Engineering by P C Sharma, Manufacturing Technology by Kalpak Jain, etc.

The other modules also have their answers were verified.

As the modules created are successful, but yet they are not capable of full fletched industrial (batch production) application, so some of the alterations which are considered in future are discussed in here. The following considerations were made in design module:

- It is known that KBS is for effect knowledge transfer, so it can also be used for automating the process including some of the available automation tools, hence instead of giving the design parameters in design section, the next version will aim @ directly designing the die using AUTOLISP that can be used to automate AUTOCAD drawings, and then a program can be written to use this DWG file as input for Rapid Prototyping which is emerging rapid manufacturing technology.
- Next to that the defects section now included in the software is more R&D oriented where a person has access to every part and time to examine individually, but for industrial application, we are proposing the new and already known image processing technology which is very useful to detect any defective components and pull them out before they are delivered.

CONCLUSION

In this paper a knowledge base system is proposed for design of deep drawing die. The procedure for the development of system modules is explained. This methodology is pursued for the development of different modules of the proposed framework of design of deep drawing die. The development procedure and execution of two modules is done for manufacturability check of deep drawn parts is presented. The rules are coded in the Flex and Flash, Auto LISP language (future) 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.

Though the presented modules work flawlessly, they are still hard to use in industries with batch production and hence a future scope in Results and Discussion are explained, for effective deployment of this KBS in industries.

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