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Knowledge-based Forging Die Design of Crankshaft

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Abstract - *Design of forging dies is tedious and complex process, which is a skill-based activity, and it needs more effort and time. The purpose of this work is to analyze the elements of design and knowledge experience for Designing the forging die of Crankshaft by Computer Aided design, establishing knowledge bases such as hammer load, hammer dimensions and flash dimensions by using Visualbasic to link knowledge bases and Solidworks. This system is experimental. The results indicate that the benefits of using this system to save time and effort and reduce errors caused by designers and improving the design quality.*

Key Words: Computer Aided Design, Forging Die, Crankshaft, CAD, Solid Work, Visual Basic

1. INTRODUCTION

Process of forging design is the crucial task in process planning of forging industry. It depends on the skills and accumulative expertise of the forging experts. Such knowledge of the experts is not easy to elicit directly. However, this knowledge should be managed and used to improve the efficiency, reduce time and cost of the process of forging design. Although, now forging process has new technology such modern machine with high capacity, high quality tool materials and engineering software like CAD/CAM/CAE, however, the process of forging design is still need to the experience and knowledge of the experts[1].

When designing of forging dies, design process Parameters such as metal flow, consideration of the type of metal die and product, product weight, friction, hammer condition temperature, inclination angles within the die, skill of forging workers, ---etc.

Computer-aided design (CAD) and manufacturing (CAM) are increasingly implemented at all phases of design and fabrication of forging dies. Techniques include analysis of elements used during design [2-4]. The design of forging dies depends on the following:

1. Design of dies depends on the expertise and knowledge of the specialists.
2. Design of dies is tedious and complex process.
3. The dies design is an innovative process, Taking into account the Parameters of the design process, such as the determination of the materials of die, the type of metal product , the steps of the forging and the forging machine --- etc. [5].

From 1970 until now, researchers have made a lot of efforts to develop computer-aided design templates to design different types of dies which used to produce forging dies parts. Very few researchers have attempted to develop a computer-aided design of forging dies scheme, and less research has covered the design of the die. Therefore, there is a need to develop a system for the rapid design of forging dies. Many researchers have done their efforts to develop CADD systems for drilling and cutting of forging [6-10].

2. THE FRAMEWORK AND MAIN FUNCTION MODULES OF CRANKSHAFT FORGING DESIGN SYSTEM

The disadvantages of traditional CAD systems for the design of forging dies are:

1. The process of designing forging dies is based on the expertise and skill of designers, which affects the result of the design of forging dies [11].
2. There is no mechanism for knowledge management. The system cannot give the designer the right knowledge in decision making. In order to getting benefit from accumulated engineering knowledge and increased design efficiency, a knowledge-based system has been developed for the design of Crankshaft diagram, this is illustrated in Fig.1.

2.1 System structure and main functional modules

The system is composed of four subsystems: product model design, product model analysis, forging process planning, and die structure design. These subsystems are interrelated based on the integrated product model. This is illustrated in Fig.2.

2.1.1 Product model design

The three-dimensional shape of Crankshaft is designed by using the Solid Works software.

2 .1.2 Product model analysis

Based on Crankshaft design that was created, analyze drawing elements from Solid Works, establishing knowledge bases such

As hammer load, hammer dimensions, and flash dimensions. These variables include: space, load used, weight, and all variables will be used in the design process.

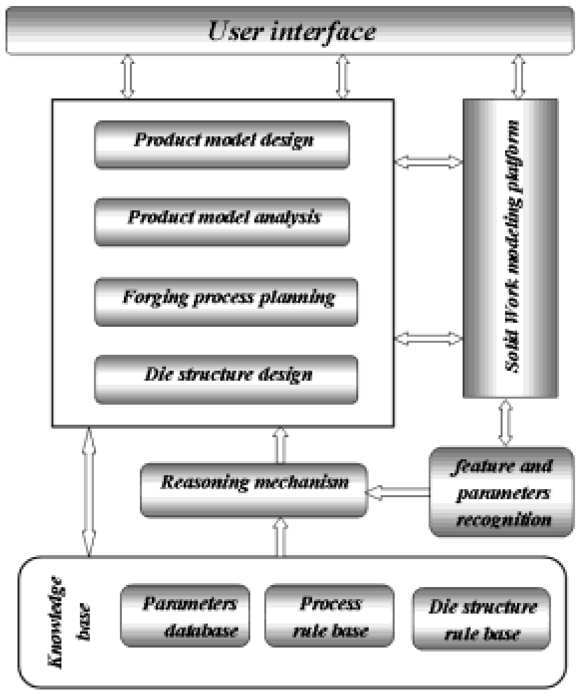

Fig -1: knowledge-based design system for Crankshaft forging

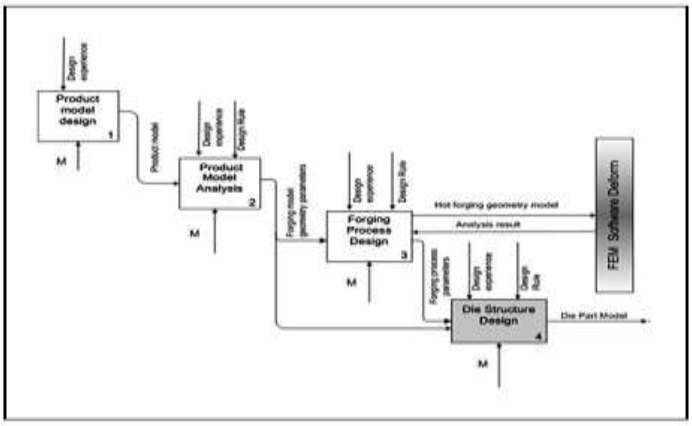

Fig -2: Functional model for knowledge-based design support system

2 .1.3 Forging process planning

In order to obtain the final design of Crankshaft, several steps must be taken. In this design module, the system will plan forging operations, such as: design of hot metal and metal size, the line between two parts die, modifying the shape of the forging part, determining the shape and dimensions of the bending process, determining the shape and dimensions of the crankshaft, and determining the hammer load and flash dimensions, Add a radius and drag angle. -- etc., and choose configuration steps based on forgery features and design rules.

2 .1.4 Die structure design

After planning the forging process, the system will design the forging dies of Crankshaft: Design of cavity of the die, selection of the appropriate hammer, Choose the forging equipment, design lock valves, design die variables, and exit, as well as design of keyway ---etc.

The program screen consists of six main screens, the first screen shows a 2d drawing of the product, the second screen in which the program design 3d for the crankshaft is in the case of hot forging, the third screen where the program is designed for the crankshaft in the case of hot forging and flash, the fourth screen in which the program designed lower die model of Crankshaft in the case of hot forging, the fifth screen in which the program designed the upper and lower die model of Crankshaft in the case of hot forging and The sixth screen where the program covers a comprehensive report of all the design elements as well as the file designed template.

2. 2. System components

Rule-based thinking is applied at each stage of the design process to help engineers for making the right decision. Compared to the traditional CAD system of design, this system has the following components.

2 .2.1 Design guide system

The design system of the forging dies allows design engineers to make the right decision as well as to know the design steps, thus reducing the time of design errors.

2 .2.2 Knowledge - Based Design Support System

The integration of knowledge, experience and intelligent thinking into the design system is the fundamental difference between the traditional systems of drawing software and the output of the new design system. The system checks the design result of each design step using the design rules stored in the knowledge database and provides the best solution.

3. APPLICATION OF KNOWLEDGE

Knowledge-based reasoning is a process of acquiring conclusion from known knowledge and it is the application of knowledge. Generally, human reasoning includes deduction, induction and analogism. However, the present reasoning technology that is applied in computer fields is containing a logical reasoning, uncertain reasoning and commonsense reasoning. Reasoning technology includes three methods: rule-based reasoning (RBR), model-based reasoning (MBR) and case-based reasoning (CBR).

In the process of forging die design, RBR is the primary reasoning technology to provide proper knowledge. In the forging die design, there are several design rules. These rules are saved in the rule database of the system by way of the production rule. While designing, rule-based reasoning is applied according to specific conditions. Producing rules are put forward by US mathematician Post, and developed by Newell and Simon. Producing representation is also called rules representation. Each rule is a producing expression. Every rule contains two parts, one is situation of recognition (premise/antecedent part), and the other is the activity part (conclusion/consequent part). Producing rules were looked at the situation-activity pairs or premise-conclusion pairs.

Base Production Production rule is similar to logic in form: P→ Q, CF. In this formula: P is antecedent, Q is consequent, and CF is the certainty factor of the rule. The following is the BNF description of producing rules using the logical knowledge representation method:

< Predication >::=< Name of predication>[< Parameter >,...]

< Action >::=< Name of action >[< Parameter >,...]

<Premise>::=empty| < Predication >1, < Predication >|

<Conclusion>::=< Predication >| < Action >{ Conclusion...}

< Production rule >::=< Premise >< Conclusion >,<CF>

<CF>::=<(0,1)real number>

< Production knowledge>::=< Production rule >1, < Production rule >2,...

For example, during system design the capacity of hammer (H) can be selected according to average diameter of workpiece (D) of the metal used and can be determined according to Table 1 .

$$H = 10\,(1-0.005*D)\,(1.1+2/D)^2\,(0.75+0.001D^2)*D*p \quad (1)$$

Table -1: The relationship between the capacity of hammer (H) and average diameter of workpiece (D) [12].

D (cm)	< 4.5	4.5 ≤ 8.5	8.5 ≤ 17	17 ≤ 20	20 ≤ 24	24 ≤ 31	31 ≤ 44
H(ton)	0.63	1	2	2.5	3.15	5	10

The design rules:

IF D <=4.5 THEN H= 0.63

IF D >4.5 AND D <=8.5 THEN H=1

IF D >8, 5 AND D <=17 THEN H=2

IF D >17 AND D <=20 THEN H=2.5

IF D >20 AND D <=24 THEN H=3.15

IF D >24 AND D <=31 THEN H=5

IF D>31 AND D<=44 THEN H=10

For example, during system design of Dimensions of the flash (F) can be selected according to the capacity of hammer (H) of the metal used and can be determined according to Table 2

The design rules:

IF F1 THEN H=0.63

IF F2 THEN H=1

IF F3 THEN H=2

IF F4 THEN H=2.5

IF F5 THEN H=3.15

IF F6 THEN H=5

IF F7THEN H=10

Table -2: The relationship between the capacity of hammer (H) and the flash (F) [12].

H (ton)	F (mm)	A	R2	h	R	R1	L	L1
0.63	F1	0.5	0.5	4	4	1	8	25
1	F2	0.8	0.8	4	4	1.5	8	30
2	F3	1.5	1.5	4	4	1.5	10	35
2.5	F4	1.5	1.5	5	5	1.5	10	35
3.15	F5	1.5	1.5	5	5	1.5	10	35
5	F6	2	2	6	6	3	12	40
10	F7	2.5	2.5	8	8	3	12	50

For example, during system design of Dimensions of the hammer (Dh) can be selected according to the capacity of hammer (H) of the metal used and can be determined according to Table 3.

Table -3: The relationship between the capacity of hammer (H) and Dimensions of the hammer(Dh) [12].

H (ton)	Dh(mm)	H min	H max	B	L
0.63	Dh1	280	380	400	380
1	Dh2	320	500	500	450
2	Dh3	360	550	600	700
2.5	Dh4	430	650	700	710
3.15	Dh5	480	650	700	800
5	Dh6	530	800	700	1000
10	Dh7	610	810	1000	1200

The design rules:

IF Dh1 THEN H=0.63

IF Dh2 THEN H=1

IF Dh3T HEN H=2

IF Dh4 THEN H=2.5

IF Dh5 THEN H=3.15

IF Dh6 THEN H=5

IF Dh7 THEN H=10

4. CASE STUDY OF CRANKSHAFT HOT FORGING DIE DESIGN

Crankshaft forging die is designed by the case study to clarify the characteristics of the knowledge-based system and explain the operation of the system. The product model is shown in Fig.3.

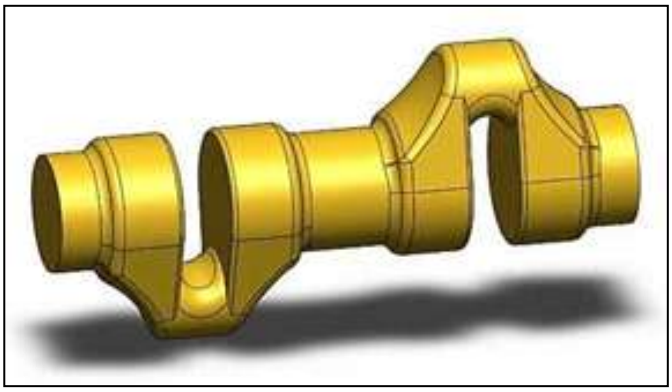

Fig -3: Solid model of Crankshaft part

According to the three-dimensional hot forging model, as shown in Fig. 4. The system gets maximum limiting dimensions of forging die parting line, the maximum height of the forging , the center of forging die , forging die cavity, and the flash shape and dimensions. Then, the system will calculate diameter, weight, hammer type selection, the lower die model is shown in Fig.5, and the upper and lower die model of Crankshaft in Fig. 6.

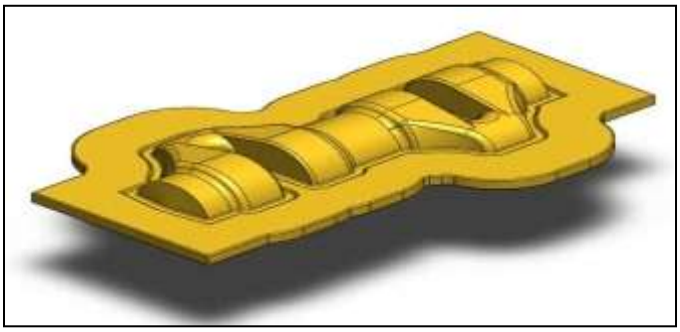

Fig -4: The hot forging part solid model of Crankshaft

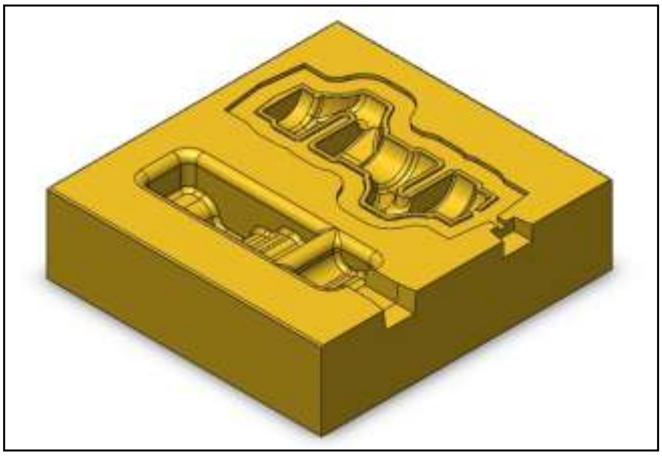

Fig -5: The lower die model of Crankshaft

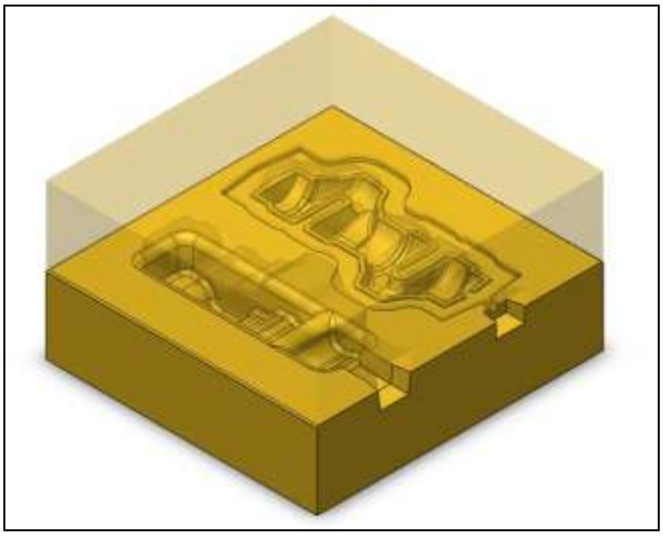

Fig -6: The upper and lower die model of Crankshaft

The process of Forging is a very complex and flexible formation process, The experts and know-how of technicians are essential and very valuable for the process of design of forging dies, the Crankshaft design support system was developed based on knowledge by integrating knowledge and experience into the design support system. Which provides the correct knowledge to support the designer's decision-making / selection and step-by-step design. In this method, knowledge and experience can be efficiently shared and reused, the process of forging can be automatically processed by the program. Therefore, the design time of the Crankshaft mold can be reduced using the knowledge-based system, compared to the traditional CAD method, resulting in increased design quality.

The application indicates that during the process of forging dies design, the system provides an access to the proper knowledge and information in a timely manner for supporting the designer in decision making / selection and design of the entire scheme and step-by-step detail.

5. CONCLUSIONS

During forging dies design process, the accumulated experience and knowledge of designers is very important. For the design of die. In order to optimize the accumulated engineering knowledge, it is necessary to integrate knowledge and experience in designing forging dies systems into a CAD system and developing a knowledge-based design support system. In this work, a knowledge-based Crankshaft design support system has been developed on the basis of methodology. Through the representation of engineering knowledge, knowledge acquisition and knowledge-based design support techniques. A case study shows in this work by adopting this system the following:

1. Using the automatic design instead of manual design
2. The product development cost reduced
3. To save time and effort greatly
4. To reduce errors caused by designers
5. Improvement the quality of the design

NOMENCLATURE

Symbol	Description	Unit
H	The capacity of hammer	ton
p	Density	Kg / cm^3
D	Diameter	cm
F	Dimensions of the flash	mm
Dh	Dimensions of the hammer	mm
H min	Maximum Height	mm
H max	Minimum Height	mm
B	Die Width	mm
L	Dei Length	mm

SUBSCRIPTS

CAD	Computer Aided Design
CAM	Computer-Aided Manufacturing
CAE	Computer-Aided Engineering
CADD	Computer Aided Design And Drafting
RBR	Rule-Based Reasoning
MBR	Model-Based Reasoning
CBR	Case-Based Reasoning

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