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Knowledge based reverse engineering tool for near net shape axisymmetric forging die design

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1. Introduction

The increasing worldwide interest in the production of forging products leads the researchers to study on forging technology. Net shape forming processes have a special place in forging and it is one of the most important goals for metal forming technology to achieve due to its economical benefits.

The last thirty years have seen the development of a wide range of computer programs for computer aided design (CAD) and computer aided manufacture (CAM) in order to improve the effectiveness and economics of each function. The introduction of CAM techniques resulted in productivity depending on the type of CAM technique introduced. The most effective systems however are those that combine CAD and CAM to form the centres for computer integrated manufacture (CIM) and so take advantage of the natural links between design and manufacture.

At present, the forging process is designed by engineers with the knowledge and experience in this field. There is as yet no general analytical method available for the design of axisymmetric forging dies, which currently relies mainly on engineers' experience. This is however often inaccurate and brings about some problems, such as metal flow rate, excessive forging load, forgeable geometry and die wear and fracture in the product. But, several approaches have been attempted to overcome these problems.

There are several studies for the two important stages of forging die design which are the determination of forgeable geometry and forging load. Anza et-al. [1] described an application of axisymmetric forging pieces and dies based on design rules and variational geometry to design. Yilmaz et. al. [2] developed a coding system to generate the forgeable geometry which is necessary pre-work for geometry decomposition. They applied upper bound technique in the calculation of forging load for the analysis of axisymmetric forging. Choi et-al. [3] described some developments of an automatic forging die design system for two dimensional components and discussed several applications of the system. Nategh and Bakhshi [4] developed a CAD program for rotational forgings, which can design the forging, finishing dies and the punched and trimmed parts, together with the calculation of forging parameters.

One of the early study was carried out by Kudo [5, 6] for theoretical analysis of the experimental tests. It was chosen for its simplicity. He described a general method of analysis that could be used to analyse forging and extrusion type processes to produce predictions of forming loads. Kobayashi [7] suggested curved discontinuity surfaces for the unit regions, which resulted in better upper bounds for some axisymmetric problems. Lee et. al. [8] developed an upper bound elemental technique program to analyse the forging load, die cavity filling and effective strain distribution for forgings with and without flash. They made an experimental study to determine the forging load in axisymmetric and nonaxisymmetric parts. Another forging load calculation study was made by Yilmaz and Eyercioglu [9]. Geometry is recognised and simplified in order to make the calculations easy. The forging load estimation is then made for each region separately. The results can be put into together in building block manner to obtain the load required for the deformation of rather complex axisymmetric forging. A one of final study was carried out by Bramley [10] for upper bound elemental technique. The tetrahedral upper bound analysis was presented which enables a more realistic flow simulation to be achieved.

The main objective of this research is to put a holistic design approach for axisymmetric forging dies. This design process guides the engineers, who interact with the forging die design, from final component geometry to proposed die shape by reverse engineering methodology.

2. Knowledge-based framework

An Expert System (ES), also called *a knowledge-based system* is an intelligent computer program that uses knowledge and reasoning techniques to solve problems that are difficult enough requiring significant human expertise for their solution [11]. The key feature of the knowledge based engineering application is that it integrates the whole design process within one computer model. The relational database encapsulates the design rules as well as their complex interdependencies on material, production unit and manufacturer' capabilities [12]. The main components of this system are; user interface, knowledge base, inference engine and a knowledge acquisition mechanism.

2.1. User interface

The *user interface* is designed to provide a convenient means of two-way communication between the user and the inference engine. The developed knowledge based system, called EXFOR, provides an interface for development. The menu interface provides menu support for defining EXFOR objects and building applications. Rule base menu provides structured menu support for entering rules without programming syntax.

2.2. Knowledge acquisition mechanism

A *knowledge acquisition mechanism* is used to acquire human expertise and transform into the knowledge base. This module processes the data entered by the expert and transforms it into a data presentation understood by the system. The process of acquiring knowledge from a human expert is an iterative process that requires close interaction between the expert and the knowledge engineer. In another way, knowledge acquisition is getting information from human expert and codifying it within an expert system. But, unavailability of a standard methodology used by experts to solve a domain problem is an important issue. If there was an only one standard method for a problem there would be no need to develop an expert system to solve the problem.

2.3. Inference engine

The *inference engine* is the knowledge processor that looks at the problem description and tries to find a solution with the help of factual and meta-knowledge. An inference engine is necessary to support intelligent agent behaviour. One of the major functions of the inference engine is the implementation of a procedure for reasoning with the rules and data found in the knowledge base.

In EXFOR, both forward and backward chaining methods are used. For forging die design process forward chaining method is used while backward chaining method is used for the verification.

In this process, the agent uses a knowledge acquisition mechanism to gather facts, then these facts and associated sets of rules are supplied as input to the inference engine. Then, the new facts that are produced by the engine are fed to actuators, mechanisms that implement agent reactions. Consequently, an agent framework should be flexible enough to allow integration of one or more inference engines.

2.4. Knowledge representation for EXFOR

Knowledge representation in EXFOR is structured in the network representation. Parent frames such as geometry, forging load, die geometry, die assembly and material, are connected to the top frame. Each parent frame has also child frames. Parent frames are used to describe the general class of objects. In database, the data definition of a record specifies how the data is stored so that the database can search and sort through the data. To actually enter the values into the system, child frame and instances are formed to represent the specific objects. The geometry frame is defined as a parent frame. All geometric processes, feature recognition and forgeable geometry determination are held in this parent frame. Child frame of geometry frame is shown in the following Fig. 1.

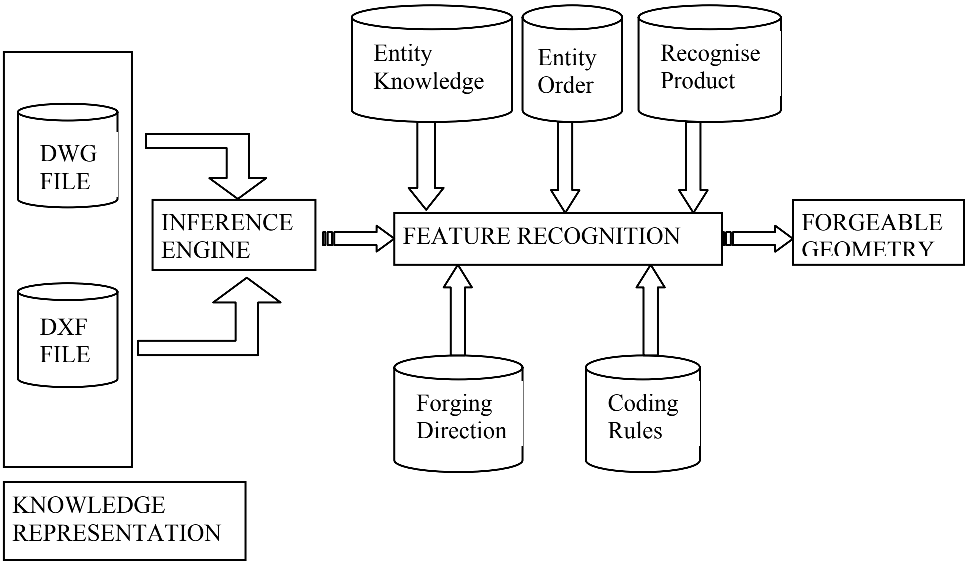


Fig. 1 Child frame of geometry frame

2.5. Knowledge base

The *knowledge base* is a file that contains the facts and heuristic that makes up an expert's knowledge. A knowledge base is different from a typical data file or database.

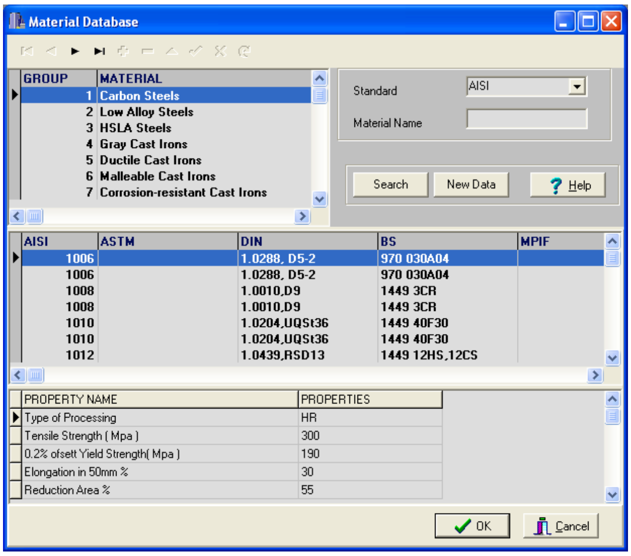
In EXFOR, especially, material database has a big amount of knowledge on material type and their properties. There are 29 different material groups and 27 different material properties for each material. Material database entry is shown in Fig. 2.

3. Part geometry and feature recognition

The system consists of a user interface, a system shell, and IF-THEN rules. The system shell has graphic input and output modules. According to the given input, the system gets drawing from CAD environment and obtains DXF file for geometry manipulations. The algorithmic techniques that are most effective in numerical computations are used to perform geometry manipulation.

In order to simplify geometry manipulations, two-dimensional cross sections are dealt with entities such as lines and arcs. Since forgeable geometry is the crucial stage for forging die design, the initially given input geometry of the final product is controlled whether it is forgeable in a closed die or not. As an output module, by removing undercuts, small steps and unforgeable fillets, forgeable geometry is presented.

General outlines of the developed program are shown in Fig. 3. It has four main parts. Once the final product geometry is provided as input, the system obtains



GROUP	MATERIAL
1	Carbon Steels
2	Low Alloy Steels
3	HSLA Steels
4	Gray Cast Irons
5	Ductile Cast Irons
6	Malleable Cast Irons
7	Corrosion-resistant Cast Irons

Standard: AISI

Material Name:

AISI	ASTM	DIN	BS	MPIF
1006		1.0288, D5-2	970 030A04	
1006		1.0288, D5-2	970 030A04	
1008		1.0010,D9	1449 3CR	
1008		1.0010,D9	1449 3CR	
1010		1.0204,UQSt36	1449 40F30	
1010		1.0204,UQSt36	1449 40F30	
1012		1.0439,RSD13	1449 12HS,12CS	

PROPERTY NAME	PROPERTIES
Type of Processing	HR
Tensile Strength (Mpa)	300
0.2% ofsett Yield Strength(Mpa)	190
Elongation in 50mm %	30
Reduction Area %	55

Fig. 2 Material database entry and material selection

the DXF file, extracts entities formed by arcs and lines and puts them into order from top to bottom of the shape.

The current program can handle rotational axisymmetric geometries. Moreover, since the program structure has individual rules for each entity and geometry, it is possible to regenerate the system by adding new rules and knowledge to get forgeable geometry for different geometric shapes without modifying the system shell.

In this system a new coding system is generated. Each entity is coded by a number from 1 to 9. The developed software eliminates undercuts and small steps which can not be forgeable by using IF-THEN rules. This section of study differs itself from the previous studies in that it is not only determining geometry feature, but also it determines which section is unforgeable and how it can be converted into forgeable one.

3.1. Feature recognition module (FRM)

The main deficiency with feature-based modelling is associated with the difficulty in representing composite features with complex curves and surfaces.

Lee et. al. [13] proposed a methodology for overcoming this deficiency by using complex features from basic geometrical features and entities. These geometric features for each entity are structured in a knowledge base. The knowledge base contains the required data to execute the program and it is available for new geometric shapes to generate the knowledge base without modifying the overall system shell. Knowledge within the system is not stored in memory locations. Knowledge is distributed throughout the system and it is dynamic response to the inputs. Since the knowledge is distributed, the system uses many connections to retrieve solutions to particular problems.

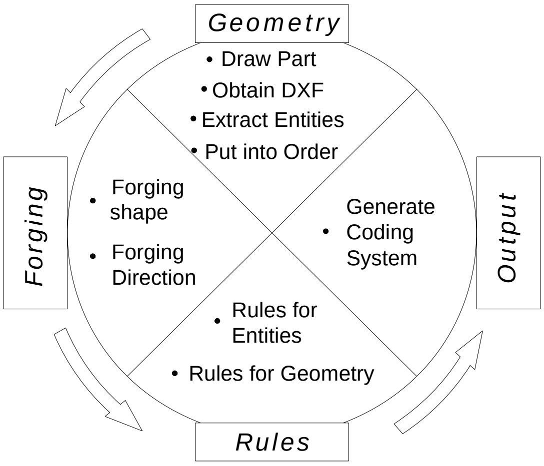


Fig. 3 General outlines of future recognition

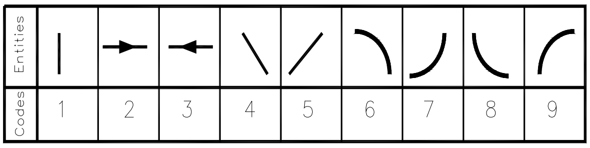


Fig. 4 Entity codes

Feature Recognition Module is designed to interpret the part geometry from DXF file of the drawing. Drawing entities of lines and arcs can be drawn in different ways. Each line and arc is named and a code number is given individually according to its property. These codes are used for the determination of part feature.

3.2. Forgeable geometry

From input geometry of the final product, each LINE and ARC entity is coded. These codes can be seen in Fig. 4. This coding system is used for eliminating undercuts and small steps which can not be forgeable in closed die. Undercut means; unforgeable area in near net shape forging. Since each code represents an entity, prepared program, which is formed by IF-THEN rules, evaluates these codes. Then, program tries to find the unforgeable section. Program provides not only the determination of unforgeable sections, but also elimination of unforgeable area. Finally, program recommends the forgeable geometry.

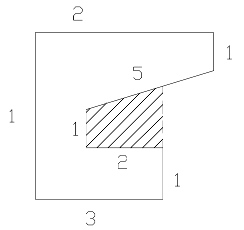
In Fig. 5, only one sample for undercut section is given. The generated rule “RULE-52-B” eliminates this section. There are lots of alternatives for undercut but, EXFOR overcomes the deficiencies from all of the different shapes. In coding system, the outer and inner sides of the shape are investigated individually since their forgeable rules are slightly different. For the outer side, the entities coded by 3-5-7 and 9 may cause some problems. Maximum diameter side of the shape must be at the top for unilateral shapes. Therefore, the shape geometry gets small from top to bottom. For bilateral shape the maximum diameter is neither the top nor the bottom portion of the shape.

4. Forging load estimation

Vazquez and Altan [14] stated that the goal in forging operation starts with the optimisation of part geometry to achieve the smallest load to fill the die cavity without causing defects. The estimation of forging load and necessary forging energy has vital importance. To determine the forging energy, the forging load at various stroke positions must be estimated.

Many methods have been used to predict the forging load for axisymmetric forging. As compared to other methods used in the calculation of the forging load for the analysis of axisymmetric forging, upper bound elemental technique is one of the most appropriate methods [15].

Rule-52-B



IF 5sx > 2ex

THEN

- Remove codes from 5 to 2 (except 5) **AND**
- Add 1 instead of removed codes **AND**
- Coordinate 1, by the following:

1sx=2ex 1ex=2ex 1ey=2ey **AND**

$$1\text{sy} = 5\text{sy} - \left[\frac{(5\text{sx} - 2\text{ex}) - (5\text{sy} - 5\text{ey})}{5\text{sx} - 5\text{ex}}\right]$$

- Change ex and ey value of code 5 by the following:

5ex=2ex 5ey=1sy

Fig. 5 A sample rule for undercut elimination

The seed corn study of Kudo's approach was restricted to subdividing the deforming regions into elements of rectangular cross-section thus limiting the range of forming geometries that could be analyzed. However, the metal forming industry was recognizing the requirement for a general and reliable method of predicting loads and the associated benefit of enabling press overload [2]. The upper bound technique is essentially applied to the analysis of axisymmetric forging and bases on the subdivision of geometry into eight basic simple regions as shown in Fig. 6.

In the previous studies, regions do not contact each other completely. In Fig. 7, for example, a part of region IV contacts with the die while the other part contacts with the material [15]. Since metal flow is directly related with the friction of the regions, geometry must be divided in such a manner that one of its side should contact with the die or material.

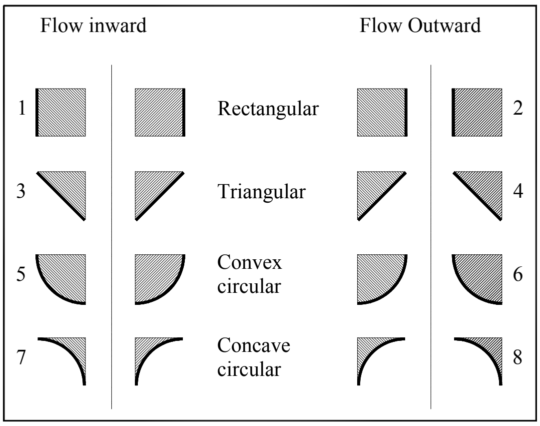


Fig. 6 Basic elemental regions

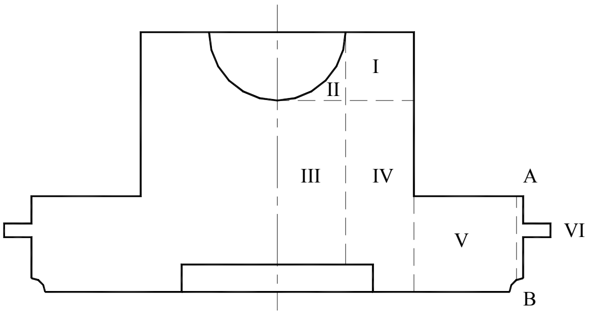


Fig. 7 Divided geometry [15]

The present approach overcomes this problem. Firstly, outer cross-section of the forging is examined. Triangular and circular regions are removed from the forging whether it is inward or outward flow. And then, all their coordinates are transferred into related table. By this way, forging remains with only rectangular regions.

A one of comparative divided geometry between the latest approach [10] and the present work is illustrated in Fig. 8, respectively. It is obviously seen that the number of divided regions are less than previous work. As it is seen from Fig. 8, there are 88 different regions. But in the new approach, arcs and triangular regions are removed and therefore, remaining same shape has only 36 regions. It is almost one third of the previous study. This ratio changes with complexity of the shape. This means that the less number of regions require shorter computation time and provides more correct estimation for forging load.

Equivalent load is: $P = \pi R^2 \sigma \left(1 + \frac{2}{3\sqrt{3}} m \frac{R}{A}\right)$ where, m is the coefficient of friction and the term; $\left(\frac{2}{3\sqrt{3}} m \frac{R}{A}\right) \pi R^2 \sigma$ resembles the effect of friction.

Based on upper bound the remaining part; $\pi R^2 \sigma$ is the calculated load. These equations are derived from velocity fields of regions [16].

5. Die stress

The stresses in dies arise mainly from the high level of internal pressure during forging. However, the pressure is not constant over the whole length of the die. Since it is concentrated in the portion of the die, the pressure will vary during forging. The dimension of forging is different from the die because of the following factors [17-19]:

a) Elastic Die Expansion (U_e). Under a forging load the die will expand elastically and the final forging radius R_1, will be greater than original die radius R_0, by an amount U_e.

$$R_1 = R_0 + U_e$$

$$U_e = \frac{a\left(a^2(1-\upsilon_{d1}) + b^2(1+\upsilon_{d1} - 2n)\right)2S_y - 2ab^2 P_p}{E_{d1}\left(b^2 - a^2\right)} +$$

$$+ \frac{1-\upsilon_w}{E_w} 2S_y a + r\alpha_w \left(T_f - T_r\right)$$

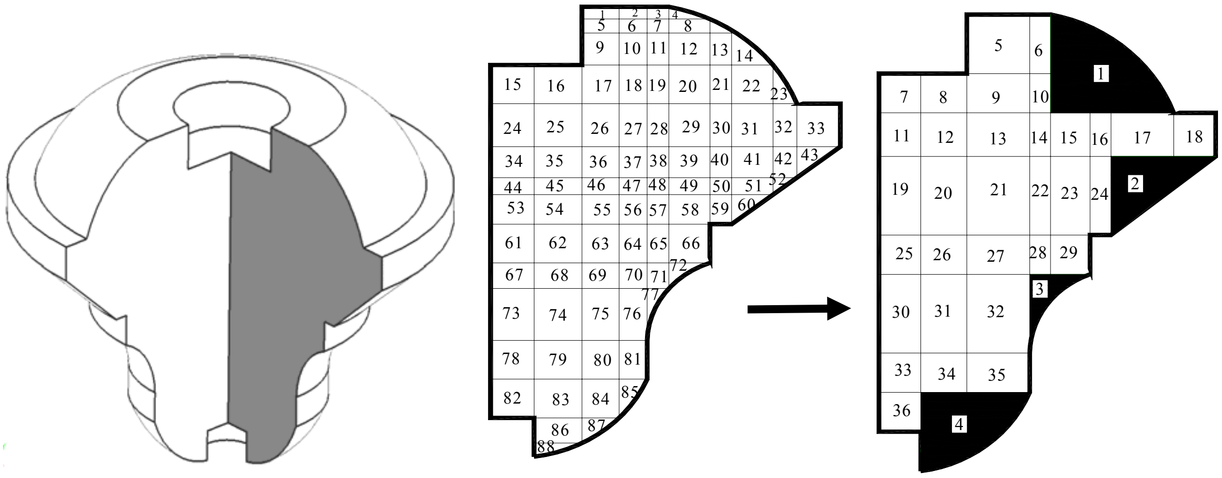


Fig. 8 Generation of elemental regions

b) Thermal Die Expansion (U_t). For forging at elevated temperatures, dies are preheated. Therefore, the die will expand by an amount U_t, compared to its original size and the workpiece radius R_2, is given by

$$R_2 = R_0 + U_e + U_t$$

$$U_t = r\alpha_d\left(T_p - T_r\right) + \frac{-\alpha_d\delta T}{3(b-a)} \times$$

$$\times\left[\frac{-(1+\upsilon_d)a^2b^2}{a+b}\frac{1}{r} + (2\upsilon_d - 1)r^2 + \frac{(1-\upsilon_d)(b^3-a^3)}{b^2-a^2}\right]$$

c) Thermal Product Contraction (U_c). In warm and hot forging the product will shrink during cooling and its final radius will be decreased by an amount U_e. Final product radius R_3, is given by

$$R_3 = R_0 + U_e + U_t - U_c$$

$$U_c = r\alpha_w\left(T_f - T_r\right)$$

d) Spark Gap. Die cavities for precision forging are normally produced by electrodischarge machining and electrode dimensions are different from that of the die cavity due to the spark gap. Therefore, electrode radius R_4, should be smaller than the die cavity by an amount of G

$$R_4 = R_0 + U_e + U_t - U_c - G$$

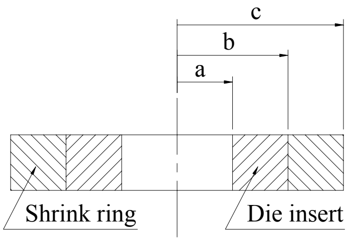


Fig. 9 Die insert and shrink ring notations

Hence, to obtain the desired accuracy in forged product, each of the geometrical variations listed above has to be estimated and the die geometry has to be corrected accordingly

$$R_1 = R_0 + \frac{a\left(a^2(1-\upsilon_{d1}) + b^2(1+\upsilon_{d1}-2n)\right)2S_y - 2ab^2P_p}{E_{d1}\left(b^2-a^2\right)} + \frac{-\alpha_d\delta T}{3(b-a)}\left[\frac{-(1+\upsilon_d)a^2b^2}{a+b}\frac{1}{r} + (2\upsilon_d-1)r^2 + \frac{(1-\upsilon_d)(b^3-a^3)}{b^2-a^2}\right] +$$

$$+ \frac{1-\upsilon_w}{E_w}2S_y a + r\alpha_d\left(T_p - T_r\right) + r\alpha_w\left(T_f - T_r\right)$$

It is assumed that dimensional changes of the forging takes place in radial direction. Also, from the foregoing theory, for a given forging condition the extent of this movement is proportional to the magnitude of that radius [18].

Using the above analysis, the parameters affecting forging dimensions were calculated and for a given condition the profile of the die was determined. A program has been written to make these calculations and to create the corrected die dimensions. Die insert and shrink ring notations are stated in the following Fig. 9.

The determinations of die insert and shrink ring dimensions have vital importance in die design. The following equations give the formulae for these dimensions [16, 19]

$$b = \frac{a}{\sqrt{\frac{1}{2}\left(1 + \frac{S_{yring}}{Sydie}\right) - \frac{P_i}{S_{ydie}}}}$$

$$c = \frac{a}{\left(\frac{1}{2}\left(1 + \frac{S_{yring}}{Sydie}\right) - \frac{P_i}{S_{ydie}}\right) \cdot \sqrt{\frac{Sydie}{Syring}}}$$

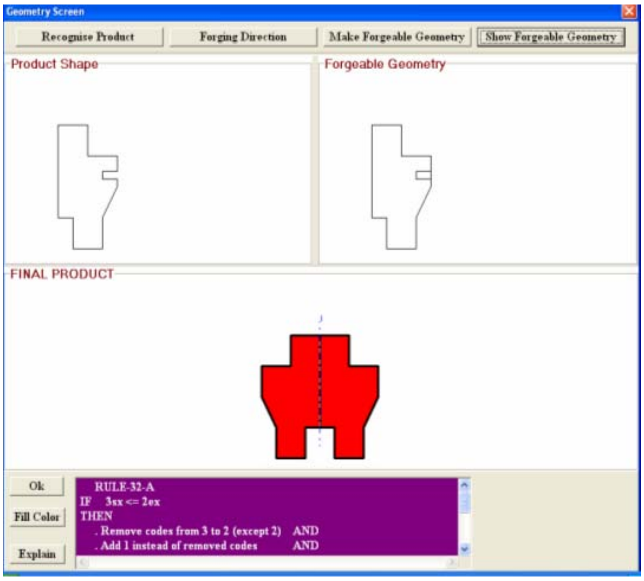
where a is the die insert inner radius, b is the die insert outer radius, c is the shrink ring outer radius and P_i is the inner pressure.

6. Case study

In this section, a rotationally axisymmetric part has been considered as a case study. The procedure of the analysis will be completed within several steps. These steps start with the drawing of finished product and continue with the transfer of geometry into DXF format, recognition of the product, development of the forgeable geometry, forging load calculation, die stress calculation and drawing of die assembly.

Within this knowledge based tool, generated DXF table is perceived and entities are extracted by pressing "*Recognise Product*" button, located at the top of the "*Geometry*" screen.

Once this button is pressed, "*Feature Recognition is Completed*" response appears and all data are recorded in database. As it is seen from Fig. 10, final product has unforgeable section for closed die forging operations. "*Make Forgeable Geometry*" button must be activated to eliminate the unforgeable area and to propose the forgeable product. Product shape, forgeable geometry and final product can be seen by pressing "*Show Forgeable Geometry*" button. Fig. 10 shows the geometry and presents reasoning strategy. "Explain" button is used for this purpose.



```
   RULE-32-A
IF    3sx <= 2ex
THEN
   . Remove codes from 3 to 2 (except 2)    AND
   . Add 1 instead of removed codes         AND
```

Fig. 10 Feature recognition screen

The next step is the calculation of forging load. Fig. 11 shows that geometry is divided into basic regions. Required load is calculated for each region individually and summation of them gives the total amount of load.

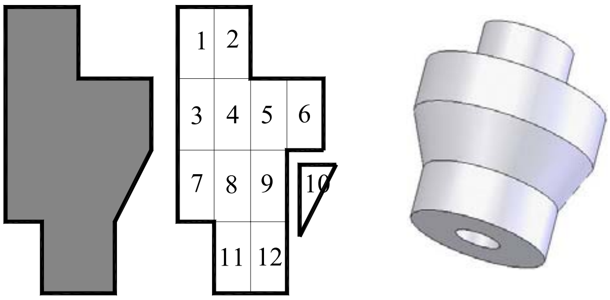
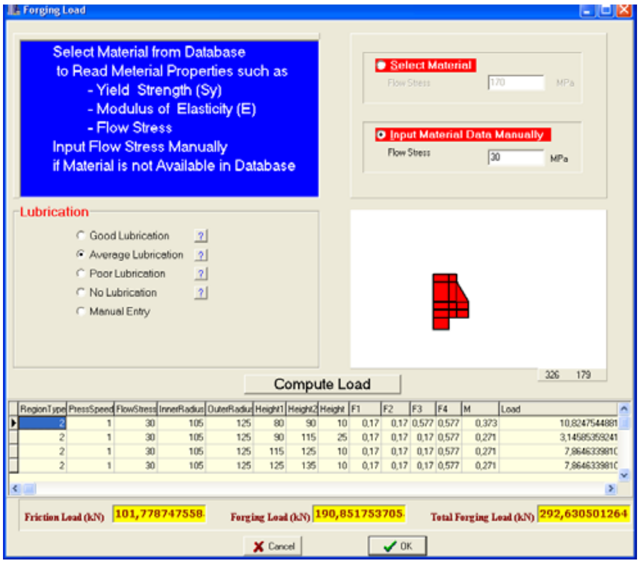


Fig. 11 Geometry division for load calculation

Flow stress of the material is taken about 30 MPa at room temperature condition. Fig. 12 shows forging load print screen diagram with average lubrication condition. In Fig. 12, it is shown that total forging load is calculated about 292.6 kN and experimental result, which is almost the same with theoretical result, is obtained about 295 kN.

Load calculation is also verified with Deform program. Metal flow at different stroke and load values are shown in Fig. 13.



Select Material from Database
to Read Meterial Properties such as
- Yield Strength (Sy)
- Modulus of Elasticity (E)
- Flow Stress
Input Flow Stress Manually
if Material is not Available in Database

○ Select Material
Flow Stress 170 MPa

● Input Material Data Manually
Flow Stress 30 MPa

Lubrication
○ Good Lubrication
● Average Lubrication
○ Poor Lubrication
○ No Lubrication
○ Manual Entry

326 179

RegionType	PressSpeed	FlowStress	InnerRadius	OuterRadius	Height1	Height2	Height	F1	F2	F3	F4	M	Load
2	1	30	105	125	80	90	10	0,17	0,17	0,577	0,577	0,373	10,8247544881
2	1	30	105	125	90	115	25	0,17	0,17	0,17	0,577	0,271	3,14585359241
2	1	30	105	125	115	125	10	0,17	0,17	0,17	0,577	0,271	7,864633981
2	1	30	105	125	125	135	10	0,17	0,17	0,17	0,577	0,271	7,864633981

Friction Load (kN) 101,778747558
Forging Load (kN) 190,851753705
Total Forging Load (kN) 292,630501264

Fig. 12 Program output for total forging load

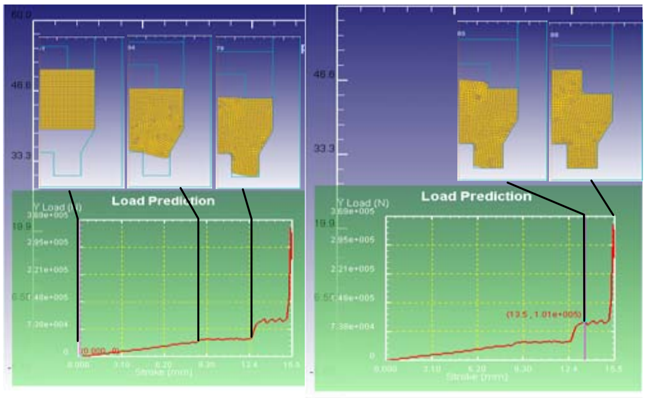
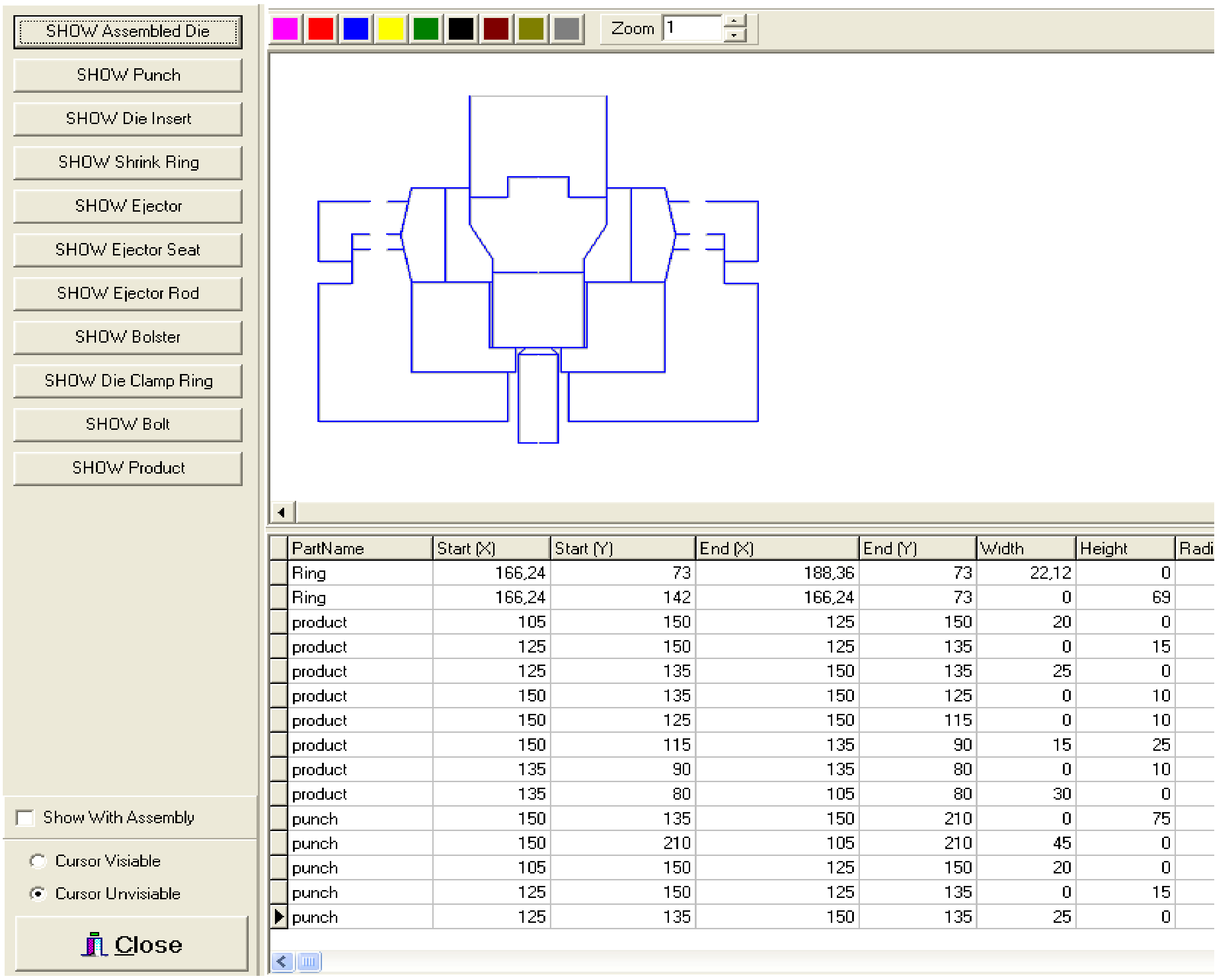


Fig. 13 Die filling and load calculation

Die is completely filled with 304 kN. As it is seen, calculations, experimental result and FEM simulation results are very close and verifies to each other.

After calculation of the forging load, corrected die radius, dimensions of the die insert and shrink ring are calculated. Drawing of die assembly forms the final step of the program. "Die Drawing" pull down menu enables the user to see the die assembly. Fig. 14 shows the print screen of die drawing.

Each part of the die can be seen individually only by pressing related button of left sided ones. Lower right hand side of the screen presents the dimensions of each part In this section, dimensions of the whole assembly can be seen by checking the "Show With Assembly" check box. Making empty of this box enables the user to see the part geometry and only its dimension.



Zoom 1

☐ Show With Assembly

○ Cursor Visiable

● Cursor Unvisiable

PartName	Start (X)	Start (Y)	End (X)	End (Y)	Width	Height	Radi
Ring	166,24	73	188,36	73	22,12	0	
Ring	166,24	142	166,24	73	0	69	
product	105	150	125	150	20	0	
product	125	150	125	135	0	15	
product	125	135	150	135	25	0	
product	150	135	150	125	0	10	
product	150	125	150	115	0	10	
product	150	115	135	90	15	25	
product	135	90	135	80	0	10	
product	135	80	105	80	30	0	
punch	150	135	150	210	0	75	
punch	150	210	105	210	45	0	
punch	105	150	125	150	20	0	
punch	125	150	125	135	0	15	
punch	125	135	150	135	25	0	

Fig. 14 Drawing of die assembly screen

7. Conclusion

In this paper, a study on knowledge-based reverse engineering tool for axisymmetric forging dies has been performed. Apart from the previous studies, a holistic approach for rotational axisymmetric parts was carried out.

Closed die forging is a very complex forming process from the point of view of the mechanics of deformation or metal flow. It is difficult to analyse, because of such factors as nonsteady state and nonuniform metal flow, the variable interface friction, and heat flow between the material being deformed and the dies, all of which present a real challenge to the evaluation.

In the present study, geometric design of near net shape forging operations are developed by modifying final component shape to a forgeable geometry using some certain rules. After the identification of geometry, the design rules have been stored in the knowledge base in such a way that every industry (designer) can define and add its own values.

In order to determine the forging load and die stress values *Upper Bound Elemental Technique* (UBET) was used and verified by FEM. Although many researchers have investigated the forging load, there is no exact empiric solution which can be applicable to all axisymmetric forgings. Due to the complexity of its nature, instead of considering the whole part, subdivision of the geometry, prediction of load for each part and summing them to find final load gives the more accurate results. It is seen that, geometry decomposition in correct way takes an important place in the prediction of forging load. UBET subdivision incorporates a substantial degree of generality in the generation of its velocity fields. At this point, this study differs from the previous studies in that, elemental regions are taken into account so that each element contacts to each other or to die completely.

Yield stress of forging material plays an important role in plastic deformation. When the punch pressure becomes equal to the yield stress of forging material, the deformation from elastic to plastic starts and simple compression continues until the workpiece touches the die insert. At this stage radial pressure applied to the die insert increases with an increase in the punch pressure.

Since the flash gutter formation is not allowed, an important feature of completely closed dies was found that volume constancy must be maintained between the die cavity and forging workpiece. Size determination of the die insert was carried out after several calculations. Outside diameter of each section of finished product was recorded, and then, geometry correction factors such as; elastic die expansion, thermal die expansion, thermal product contraction and spark gap are evaluated and added to the finished product size.

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ŽINIŲ BAZE PAREMTAS AŠIAI SIMETRINIO KALIMO ŠTAMPO, SKIRTO GALUTINEI FORMAI ARTIMAI DETALEI GAMINTI, ATVIRKŠTINIO PROJEKTAVIMO BŪDAS

Reziumė

Naudojant štampus, kuriais galima gaminti detales, kurių forma artima galutinei formai, taupomos medžiagos, spartėja gamyba, gerėja gaminių kokybė. Kalimo operacijoms atlikti reikia turėti nemažą patirties ir laikytis tam tikros operacijų sekos. Šiame darbe normomis besiremiančiai sistemai, skirtai projektuoti štampams, kuriais galima gaminti detales, kurių forma artima galutinei formai, ir jai pritaikytai žinių bazei plėtoti naudojama EXFOR sistema. Ši sistema leidžia, štampą, skirta gaminti detales, kurių forma artima galutinei formai, projektuoti atvirkštiniu būdu, naudojant visiškai užbaigtos gaminamos detalės geometriją, įvertinant jos atskirus techninius elementus, galimą kalimo būdu suformuoti geometriją, skaičiuoti medžiagas ir kalimo apkrovas. Kalimo apkrovos, kurių reikia, kad visos įdubos būtų visiškai užpildytos, skaičiuojamos naudojant stichinį viršutinės ribos (UBET) metodą. Šiame etape taip pat nustatyta kalimo jėga ir energija, reikalinga gaminiui pagaminti. Štampe atsirandančios įražos skaičiuojamos po šio etapo. Vėliausiai nustatoma štampo forma. Šiam tikslui pasiekti įvertinamos šiluminės deformacijos, atsirandančios dėl ruošinio ir štampo temperatūrų skirtumo, tamprusis ir terminis štampo plėtimasis, terminis gaminio susitraukimas ir jo apsauga nuo kibirkščiavimo.

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KNOWLEDGE BASED REVERSE ENGINEERING TOOL FOR NEAR NET SHAPE AXISYMMETRIC FORGING DIE DESIGN

Summary

Near net shape forging is quite important with the meaning of material saving, shortening the design time and quality improvement of forged products. Forging operations require high level of experience and therefore some certain procedures should be followed. In this paper, the application of a rule based system to the near net shape axisymmetric forging die design, and development of knowledge base for it, is carried out (EXFOR). This system enables the reverse engineering tool for forging die design from final component geometry by incorporating the feature recognition, forgeable geometry, material and forging load calculation. The required forging load is calculated by using Upper Bound Elemental Technique (UBET) so as to fill the die cavity completely. The power and energy requirements for making the finished forging are also determined at this stage. Die stress calculation comes after this process and the final section covers die shape determination. For this purpose, amount of thermal shrinkage due to temperature difference between workpiece and die, elastic die expansion, thermal die expansion, and thermal product contraction and spark gap are taken into account.

Нецип Фазил Иилмаз, Омер Еиециоглу

ПРОЕКТИРОВАНИЕ ОСИ СИММЕТРИЧНОГО КУЗНЕЧНОГО ШТАМПА ПРЕДНАЗНАЧЕННОГО ДЛЯ ИЗГОТОВЛЕНИЯ ДЕТАЛЕЙ БЛИЗКОЙ К ИХ КОНЕЧНОЙ ФОРМЕ ОБРАТНЫМ МЕТОДОМ С ИСПОЛЬЗОВАНИЕМ БАЗЫ ЗНАНИЙ

Резюме

Метод ковки детали до близкой к ее конечной форме является важным фактором при экономии материалов, сокращении времени производства и улучшении качества изделия. Ковка требует большого опыта и соблюдения определенной поочередности операций. В этой статье для усовершенствования системы, которая опираются на нормы, предназначенные для проектирования кузнечного штампа, изготовляющего детали близкой к их конечной форме, и усовершенствования базы знаний использовалась EXFOR система. Эта система позволяет приспособить обратный метод проектирования кузнечного штампа, предназначенного для изготовления деталей близкой к их конечной форме используя геометрию полностью завершенной детали, оценивая ее разные технические элементы: геометрию, материалы и расчет нагрузки. Необходимые нагрузки для ковки определены используя метод верхней стихийной границы (UBET) при условии, заполнения металлом всех впадин. На этом этапе проектирования также определяется сила и энергия, необходимые для изготовления детали. Усилия, действующие в штампе, определены после завершения этого этапа. Позднее всего устанавливается форма штампа. Для этой цели учитываются тепловые деформации, возникающие из-за температурной разницы между заготовкой и деталью штампа, упругое и тепловое расширение штампа, тепловое сжатие изделия и его защита от искр.

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