COMPLEX FORGING DIE MACHINING FOR LUG DIE PREPARATION AND PARAMETERS OPTIMIZATION USING CAD/CAM TECHNIQUES

SHAIK ABZAL BASHA
M.Tech, CAD/CAM, A1 Global Institute of Engineering & Technology Arimadugu (Village), Markapur(M), Prakasam(Dist) -523316, A.P.

SK.MUNEER BASHA
M.Tech, Associate Professor (HOD), A1 Global Institute of Engineering & Technology Darimadugu (Village), Markapur (M), Prakasam (Dist)-523316. A.P.
Email: muni324@gmail.com

DR.CH.SREEDHAR Ph.D
Principal, A1 Global Institute of Engineering & Technology Darimadugu (Village), Markapur (M), Prakasam (Dist)-523316.A.P.

ABSTRACT:

Recent evolutions on forging process induce more complex shape on forging die. These evolutions, combined with High Speed Machining (HSM) process of forging die lead to important increase in time for machining preparation. In this context, an original approach for generating machining process based on machining knowledge is proposed in this paper. The core of this approach is to decompose a CAD model of complex forging die in geometric features. Technological data and topological relations are aggregated to a geometric feature in order to create machining features. Technological data, such as material, surface roughness and form tolerance are defined during forging process and dies design. These data are used to choose cutting tools and machining strategies. Topological relations define relative positions between the surfaces of the die CAD model. After machining features identification cutting tools and machining strategies currently used in HSM of forging die, are associated to them in order to generate machining sequences. A machining process model is proposed to formalize the links between information imbedded in the machining features and the parameters of cutting tools and machining strategies. At last machining sequences are grouped and ordered to generate the complete die machining process. In this paper the identification of geometrical features is detailed. Geometrical features identification is based on machining knowledge formalization which is translated in the generation of maps from STEP models. A map based on the contact area between cutting tools and die shape gives basic geometrical features which are connected or not according to the continuity maps. The proposed approach is illustrated by an application on an industrial study case which was accomplished as part of collaboration. In the present paper a component named as lug which is used in DTH hammers and act as a part of collate for holding digging bit. The complex shape of the model will form in forging because of high strength property of forging. Present working die has been modified under design considerations of die to achieve more production rate. The theoretical die model analyses is carried out with software tool ANSYS with impact load analyses .the practical work is has been compared to theoretical analyses and conclusions given for production rate.

Keywords: *Machining feature, CAD, CAM, machining process preparation, CAE.*

INTRODUCTION

Forging temperature is one of the basic considerations in forging processes. In warm forging, the metals are forged at temperatures about the re-crystallization temperature and below the traditional hot forging temperature. Warm forging has many advantages when compared to hot and cold forging. Accuracy and surface finish of the parts is improved compared to hot forging while ductility is increased and forming loads are reduced when compared to cold forging.

In this study, forging process of a part which is currently produced at the hot forging temperature range and which needs some improvements in accuracy, material usage and energy concepts, is analyzed. The forging process sequence design with a new pre-form design for the particular part is proposed in warm forging temperature range and the proposed process is simulated using Finite Element Method. In the simulations, coupled thermal mechanical analyses are performed and the dies are modeled as deformable bodies to execute die stress analysis.

Forging is a manufacturing technique in which metal is plastically deformed from a simple shape like billet, bar, ingot into the desired shape in one or more stages. Deformation takes place by means of applying compressive forces between the dies in machine tools like hammers, presses, horizontal forging machines, etc.

Virtually all metals have alloys that are forgeable, giving the designer the full spectrum of mechanical and physical properties of ferrous and non-ferrous alloys. The most common forging alloys include:

• Carbon, micro alloy and alloy steel forgings account for the greatest volume of forgings for a very wide range of applications.

• Stainless steels are widely used where resistance to heat and corrosion are required.

• Aluminum forgings are used in applications where weight of the component is an issue.

• Copper, brass and bronze forgings offer excellent corrosion resistance with high thermal and electrical conductivity.

• Iron, nickel and cobalt high temperature alloy forgings are preeminent for applications of cyclical and sustained loads at high temperatures.

CAM (Computer aided manufacturing)

Computer-aided manufacturing (CAM) is the use of computer software to control machine tools and related machinery in the manufacturing of work pieces. This is not the only definition for CAM, but it is the most common; CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, including planning, management, transportation and storage.[6][7] Its primary purpose is to create a faster production process and components and tooling with more precise dimensions and material consistency, which in some cases, uses only the required amount of raw material (thus minimizing waste), while simultaneously reducing energy consumption. CAM is now a system used in schools and lower educational purposes. CAM is a subsequent computer-aided process after computer-aided design (CAD) and sometimes computer-aided engineering (CAE), as the model generated in CAD and verified in CAE can be input into CAM software, which then controls the machine tool.

Traditionally, CAM has been considered as a numerical control (NC) programming tool, wherein two-dimensional (2-D) or three-dimensional (3-D) models of components generated in CAD software are used to generate G-code or M-code etc, which may be company/controller specific, to drive computer numerically controlled (CNC) machines. In modern day Controllers, CNC Machines, simple designs such as bolt circles or basic contours do not necessitate importing a CAD file for manufacturing operation.

Computer-integrated manufacturing (CIM) is the manufacturing approach of using computers to control the entire production process. This integration allows individual processes to exchange information with each other and initiate actions. Through the integration of computers, manufacturing can be faster and less error-prone, although the main advantage is the ability to create automated manufacturing processes. Typically CIM relies on closed-loop control processes, based on real-time input from sensors. It is also known as flexible design and manufacturing.

The term "computer-integrated manufacturing" is both a method of manufacturing and the name of a computer-automated system in which individual engineering, production, marketing, and support functions of a manufacturing enterprise are organized. In a CIM system functional areas such as design, analysis, planning, purchasing, cost accounting, inventory control, and distribution are linked through the computer with factory floor functions such as materials handling and management, providing direct control and monitoring of all the operations.

LITERATURE SURVEY

In the study of Garat, Bernhart and Hervy et al.., [25], hot forging die for a nut was investigated in order to increase its life time. In the paper, brittle failure phenomenon of tools is addressed and the influence of process parameters like billet length, billet initial temperature or tool design are studied. Service life prediction considering fatigue is made using the universal slope method proposed by Manson.

Kim, Lee, Kim, Kim et al.., [26] studied the estimation method of die service life based on wear and the plastic deformation of dies in hot forging processes. Two methods are suggested for estimating the service life of hot forging dies by plastic deformation and abrasive wear, and these are applied to predict the product quantity according to two main process variables, forming velocity and initial die temperature for a spindle component. Through the applications of the suggested methods, the thermal softening of dies due to the local temperature rise led to the reduction of the service life of hot forging dies by plastic deformation more than by abrasive wear.

Brucelle and Bernhart et al.., [27] described the methodology that has been applied to gain understanding of the thermo mechanical stress field in a cemented carbide punch used for the manufacture of airbag container type parts. The stresses are the result of a combination of purely mechanical stresses due to the forging process, and thermo mechanical stresses induced by the thermal cycling of the punch surface during successive hot forging and waiting periods. In the paper, the importance of a simultaneous use of numerical simulation (process simulation and thermo mechanical stress calculation) and experimental testing (laboratory and industrial tests) is highlighted.

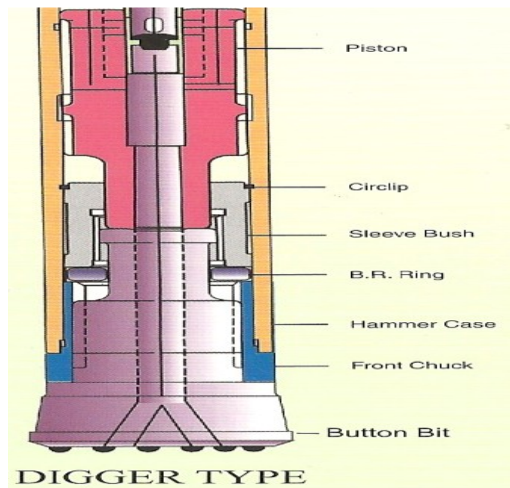
In the study of Jeong, Kim, Kim, Kim and Dean et al.., [28], experiments and numerical analyses were performed under various conditions, two kinds of surface treatment, two lubricants, different initial billet temperatures and different loads, to investigate the effects on thermal softening and the amount of heat transfer. Carbon Nitride (CNx), ion-nitride and no surface treatment for the dies were used and oil-based and water-based graphite were used as lubricants.

Experiments were also performed to take the heat- transfer coefficient into account with the combination of surface treatments and lubricants. The coefficients determined were then used in a finite element model for the analysis of the backward extrusion process, the results produced were compared with experiments.

In the study of Lee and Jou et al.., [29], the experimental techniques, wear model and numerical simulation method was combined to predict the wear of warm forging die. The non-isothermal ring compression test was adopted to estimate the friction coefficient in different temperatures and the on-line temperature recording system was setup to correct the heat transfer coefficient of the interface. The wear coefficients in different temperatures were acquired from high temperature wear experiment. Additionally, the Archard wear theory and a FEM code were used to analyze the warm forging of automotive transmission outer-race and predict the die wear condition.

In the study of Kim, Yagi, Yamanaka et al.., [30], a history of practical use of FE simulations in forging area was briefly reviewed. Then, practical use and benefits of FE simulations in forging area were discussed with examples. Finally, key points for successful and effective use of FE simulations were explained followed by current issues for better use of the FE simulation as a must tool in the forging industry.

DTH HAMMERS



The lugs are used in B.R ring and acts as collate

Design of impression-die forgings and tooling

Forging dies are usually made of high-alloy or tool steel. Dies must be impact resistant, wear resistant maintain strength at high temperatures, and have the ability to withstand cycles of rapid heating and cooling. In order to produce a better, more economical die the following rules should be followed:

1. The dies should part along a single, flat plane if at all possible, If not the parting plan should follow the contour of the part.

2. The parting surface should be a plane through the center of the forging and not near an upper or lower edge.
3. Adequate draft should be provided; a good guideline is at least 3° for aluminum and 5° to 7° for steel
4. Generous fillets and radii should be used
5. Ribs should be low and wide
6. The various sections should be balanced to avoid extreme difference in metal flow
7. Full advantage should be taken of fiver flow lines
8. Dimensional tolerances should not be closer than necessary the dimensional tolerances of a steel part produced using the impression-die forging method are outlined in the table below. It should be noted that the dimensions across the paring plane are affected by the closure of the dies, and are therefore dependent die wear and the thickness of the final flash. Dimensions that are completely contained within a single die segment or half can be maintained at a significantly greater level of accuracy. A lubricant is always used when forging to reduce friction and wear. It is also used to as a thermal barrier to restrict heat transfer from the work piece to the die. Finally the lubricant acts as a parting compound to prevent the part from sticking in one of the dies.

Press forging

Press forging is variation of drop-hammer forging. Unlike drop-hammer forging, press forges working slowly by applying continuous pressure or force. The amount of time the dies are in contact with the work piece is measured in seconds (as compared to the milliseconds of drop-hammer forges). The main advantage of press forging, as compared to drop-hammer forging, is its ability to deform the complete work piece. Drop-hammer forging usually only deforms the surfaces of the work piece in contact with the hammer and anvil; the interior of the work piece will stay relatively un deformed. There are a few disadvantages to this process, most stemmingfrom the work piece being in contact with the dies for such an extended period of time. The work piece will cool faster because the dies are in contact with work piece; the dies facilitate drastically more heat transfer than the surrounding atmosphere. As the work piece cools it becomes stronger and less ductile, which may induce cracking if deformation continues. Therefore heated dies are usually used to reduce heat loss, promote surface flow, and enable the production of finer details and closer tolerances. The work piece may also need to be reheated.

Press forging can be used to perform all types of forging, including open-die and impression-die forging. Impression-die press forging usually requires less draft than drop forging and has better dimensional accuracy. Also, press forgings can often be done in one closing of the dies, allowing for easy automation.

Upset forging

Upset forging increases the diameter of the work piece by compressing its length. Based on number of pieces produced this is the most widely used forging process. Upset forging is usually done in special high speed machines; the machines are usually setup to work in the horizontal plane to facilitate the quick exchange of work pieces from one station to the next. The initial work piece is usually wire or rod, but some machines can accept bars up to 25 cm (10 in.) in diameter. The standard upsetting machine employs split dies that contain multiple cavities. The dies open enough to allow the work piece to move from one cavity to the next; the dies then close and the heading tool, or ram, then moves longitudinally against the bar, upsetting it into the cavity. If all of the cavities are utilizes on every cycle then a finished part will be produced with every cycle, which is why this process is ideal for mass production. A few examples of common parts produced using the upset forging process are engine valves, couplings, bolts, screws, and other fasteners. The following three rules must be followed when designing parts to be upset forged:

1. The length of unsupported metal that can be upset in one blow without injurious buckling should be limited to three times the diameter of the bar.
2. Lengths of stock greater than three times the diameter may be upset successfully provided that the diameter of the upset is not more than 1.5 times the diameter of the stock.
3. In an upset requiring stock length greater than three times the diameter of the stock, and where the diameter of the cavity is not more than 1.5 times the diameter of the stock, the length of unsupported metal beyond the face of the die must not exceed the diameter of the bar.

Automatic hot forging

The automatic hot forging process involves feeding mill-length steel bars (typically 7 m or 24 ft long into one end of the machine at room temperature and hot forged products emerge from the other end. This all occurs very quickly; small parts can be made at a rate of 180 parts per minute (p pm) and larger can be made at rate of 90 p pm. The parts can be solid or hollow, round or symmetrical, up to 6 kg (12 lbs), and up to 18 cm (7 in.) in diameter. The main advantages to this process are it's high output rate and ability to accept low cost materials. Little labor is required to operate the machinery. There is no flash produced so material savings are between 20 - 30% over conventional forging. The final product is a consistent 1050 °C (1900 °F) so air cooling will result in a part that is still easily mach able (the advantage being the lack of annealing required after forging). Tolerances are usually ±0.3 mm (±0.012 in.), surfaces are clean, and draft angles are 0.5 to 1°. Tool life is nearly double that of conventional forging because contact times are on the order of 6/100 of a second. The downside to the process is it only feasible on smaller symmetric parts and cost; the initial investment can be over $10 million, there large quantities are required to justify this process. The process starts by heating up the bar to 1200 to 1300 °C (2200 to 2350 °F) in less than 60 secondsusing high power induction coils. It is then decaled with rollers, sheared into blanks, and transferred several successive forming stages, during which it is upset, preformed, final forged, and pierced (if necessary). This process can also be couple with high speed cold forming operations. Generally, the cold forming operation will do the finishing stage so that the advantages of cold-working can be taken advantage of, while maintaining the high speed of automatic hot forging. Examples of parts made by this process are: wheel hub unit bearings, transmission gears, tapered roller bearing races, stainless steel coupling flanges, and neck rings for LP gas cylinders.[1] Manual transmission gears are an example of automatic hot forging used in conjunction with cold working.[2]

Roll forging

Roll forging is a process where round or flat bar stock is reduced in thickness and increased in length. Roll forging is performed using two cylindrical or semi-cylindrical rolls, each containing or more shaped grooves. A bar is inserted into the rolls and when it hits a stop the rolls rotate and the bar is progressively shaped as it is rolled out of the machine. The work piece is then transferred to the next set of grooves or turned around and reinserted into the same grooves. This continues until the desired shape and size is achieved. The advantages of this process are there is no flash and it imparts a favorable grain structure into the work piece. Examples of products produced using this method include axles, tapered levers and leaf springs.

Net-shape and near-net-shape forging

This process is also known as precision forging. This process was developed to minimize cost and waste associated with post forging operations. Therefore the final product from a precision forging needs little to no final machining. Cost savings are gained from the use of less material, and thus less scrap, the overall decrease in energy used, and the reduction or elimination of machining. Precision forging also requires less or a draft, 1° to 0°. The downsize of this process is it's cost, therefore it is only implemented if significant cost reduction can be achieved.

Equipment

The most common thought of forging equipment is the hammer and anvil. The principles behind the hammer and anvil are still used today in drop-hammer equipment. The principle behind the machine is very simple, raise the hammer and then drop it or propel it into the work piece, which rests on the anvil. The main variations between drop-hammers is in the way that the hammer is powered; the most common being air and steam hammers. Drop-hammers usually operate in the vertical position. The main reason for this is because excess energy (energy that isn't used to deform the work piece) that isn't released as heat or sound needs to be transmitted to the foundation. Moreover, a large machine base is needed to absorb the impacts. To overcome some of the shortcomings of the drop-hammer the counterblow machine or impact or is used. In a counterblow machine both the hammer and anvil move and the work piece is held between them. Here excess energy becomes recoil. This allows for the machine to work horizontally and consist of a smaller base. Other advantages include less noise, heat and vibrations. It also produces a distinctly different flow pattern. Both of these machines can be used for open die or closed die forging .A forging press, often just called a press, is used for press forging. There are two main types: mechanical and hydraulic presses. Mechanical presses function by using cams, cranks or toggles to produce a preset (a predetermined force at a certain location in the stroke) and reproducible stroke. Due to the nature of this type of system difference forces are available at different stroke positions. Mechanical presses are faster than their hydraulic counterparts (up to 50 strokes per minute). Their capacities range from 3 to 160 MN (300 to 18,000 tons). Hydraulic presses use fluid pressure and a piston to generate force. The advantages of a hydraulic press over a mechanical press areits flexibility and greater capacity. The disadvantages are that they are slower, larger and more costly to operate. The roll forging, upsetting, and automatic hot forging Processes all use specialized machinery.

METHODS AND MODELS

CAD/CAM/CAE in Forging

The ever-increasing costs of material, energy and especially manpower require that forging processes and tooling should be designed and developed with minimum amount of trial and error with shortest possible lead times. Therefore, to remain competitive, the cost-effective application of computer aided techniques, i.e. Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Engineering (CAE) and especially, Finite Element Analysis (FEA) and Finite Volume Analysis (FVA) based computer simulation, are an absolute necessity. [6] Since the late 1970s, the use of computer-aided techniques in the metal forming industry has increased considerably.

3-D models of the forgings preform and finish dies can be created using CAD/CAM software, and parameters like the dimensions, shrinkage factors, etc. can easily be changed when necessary. Additionally the designer can observe the defects that may occur during forging by the help of these programs, which will reduce cost and time considerably.

Finite Volume Method (FVM) is a widely used tool for forging process simulations. The method has been used for many years in analyzing the flow of materials in liquid state. However, in recent years, some codes for computer simulation of solid state metal forming operations, like MSC. Super forge , have been established on the basis of this method. In FVM, the grid points are fixed in space and the elements are simply partitions of the space defined by connected grid points. The finite volume mesh is a "fixed frame of reference".

The material of a billet under analysis moves through the finite-volume mesh; the mass, momentum, and energy of the material are transported from element to element. The finite volume solver, therefore, calculates the motion of material through elements of constant volume, and therefore no remising is required.

In the Finite Element Method (FEM), the deformation zone in an elastic-plastic body is divided into a number of elements interconnected at a finite number of nodal points. The actual velocity distribution is then approximated for each element. A set of simultaneous equations is then developed representing unknown velocity vectors. From the solution of these equations, actual velocity distributions and the stresses are calculated. Because of the severe element distortion common in metal forming operations, re-meshing is necessary to follow the gross material deformation.

To be able to successfully apply the finite element method to the metal forming operations, the following requirements should be fulfilled:

1- The physical problem should be well-defined for the application of simulation.

2- The idealization of this problem should be done correctly: Simplifications and assumptions should be reasonable. Unnecessary details should be eliminated.

3- The idealized problem should have the correct spatial dis-crystallization: Type of elements used, topology of element mesh, and the density of element mesh should be constructed according to the nature of problem.

4- Boundary conditions of the physical model should be investigated and applied in the simulation: friction, heat transfer, machines, dies etc.

5- Correct material laws and parameters should be used in the simulation: flow curve, anisotropy, failure, etc.

6- Numerical parameters used in the simulation should be chosen accordingly: penalty factors, convergence limits, increment sizes, re-meshing criterion etc.

7- The simulation should be "economical": Computation times and the time required to prepare the model should be reasonable, storage requirements of the model and the results should also be within physical limits.

8- The results should be evaluated carefully and checked whether they are reasonable or not. Finite Element simulation of the forging process is complicated by the large displacement and the large strains that the material is subjected to. Because of the large displacements, the relationship between the strain and the displacement becomes nonlinear. There are other causes of nonlinearity in forging problems.

DESIGNING PROCEDURE

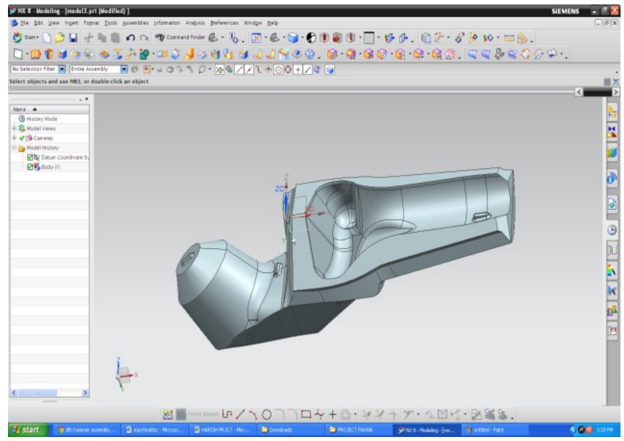


Fig: shows the component taken as step file conversion of existing part for die design.

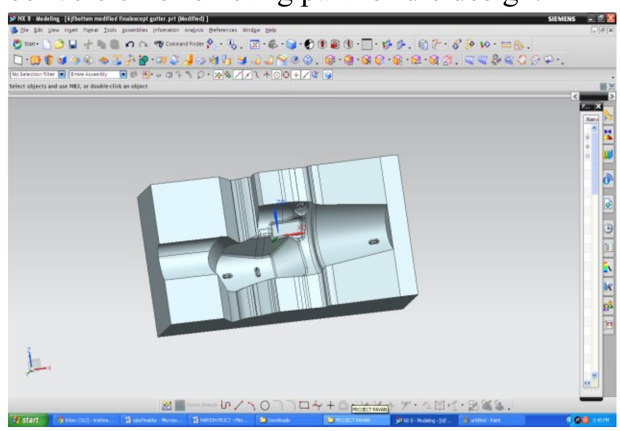


Fig: shows the bottom die cutting and usage at present

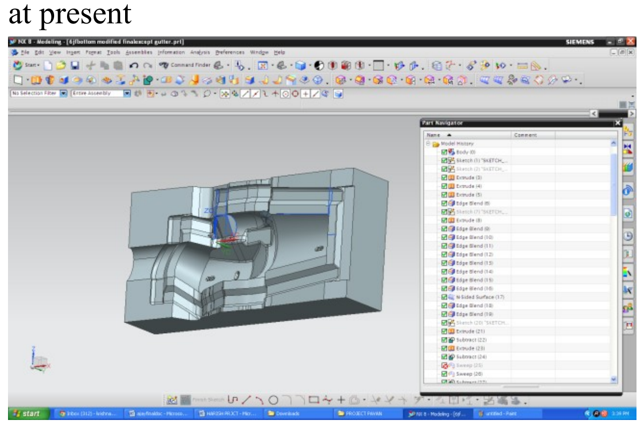


Fig: shows the design of rectified bottom die with metal flow gutter for manufacturing with model tree.

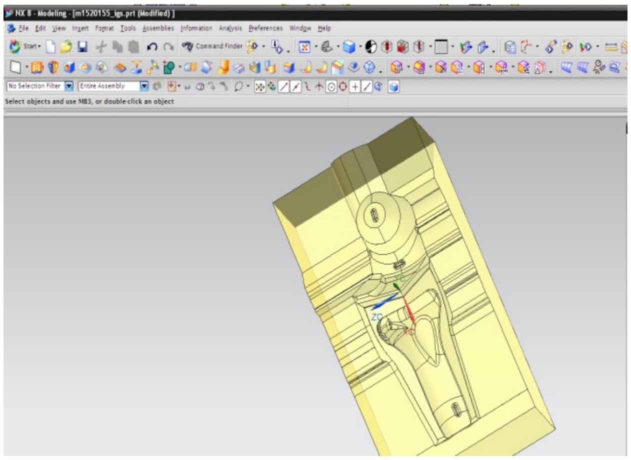


Fig: shows the top die part with out changing any design as per parting line

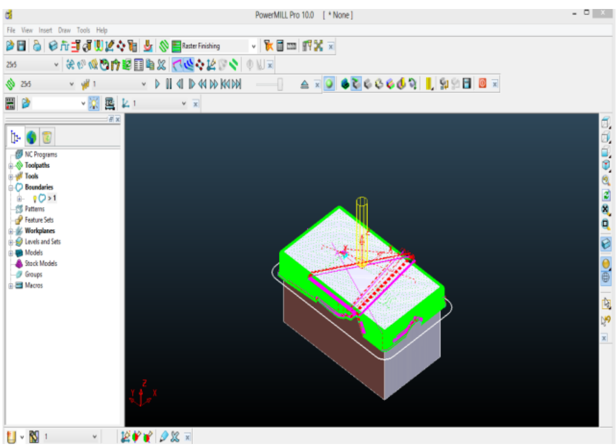


Fig: shows del-cam tool path

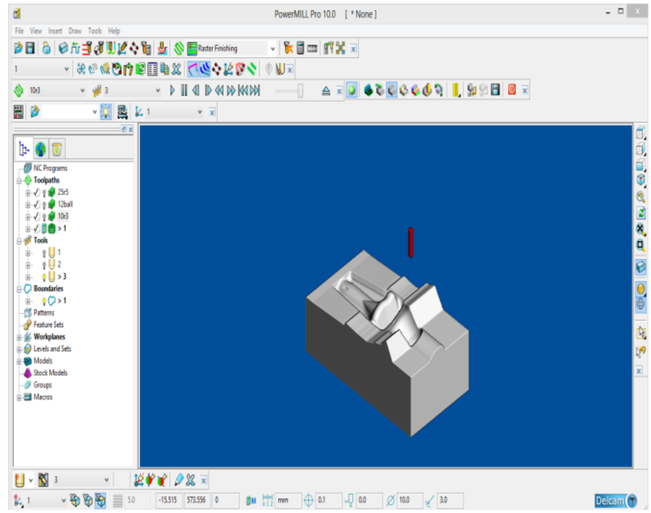


Fig shows the tool path simulation

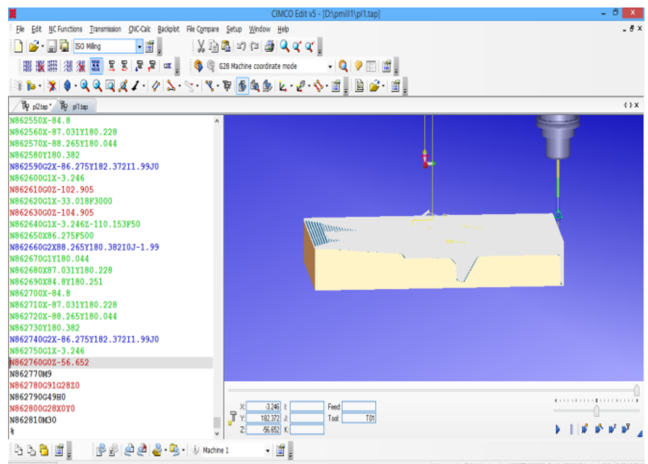
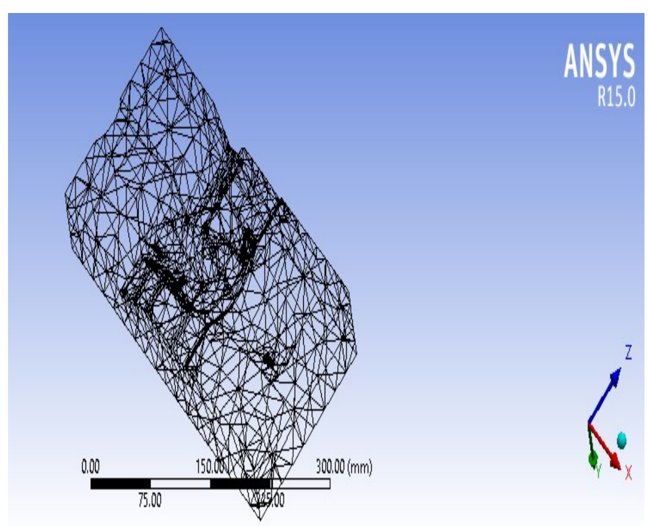


Fig shows 3d simulation of tool path



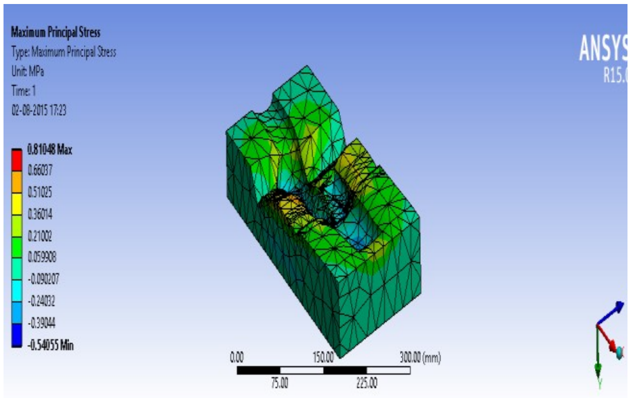


Fig principal stresses

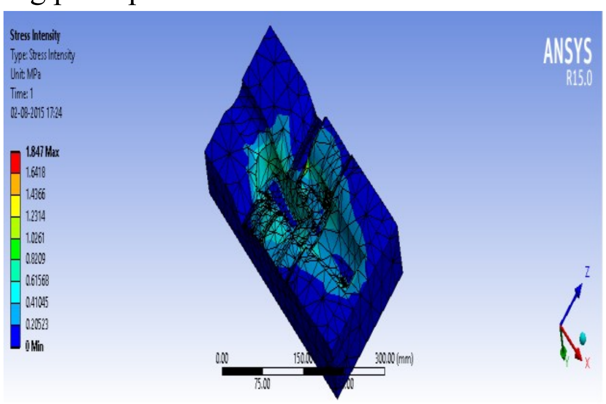


Fig Stress intensity

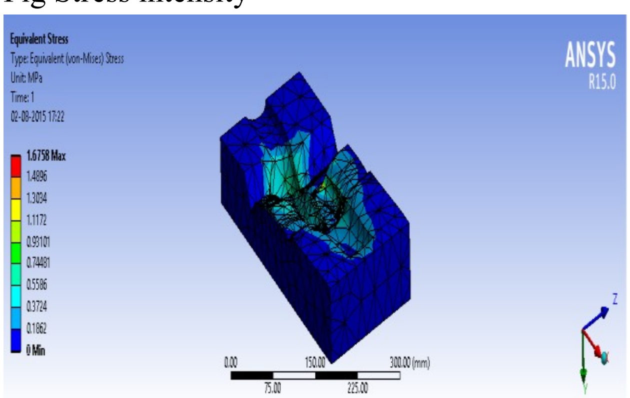


Fig: Equivalent stresses

CONCLUSIONS

From the present project the following conclusions are made by comparison of work from practical study.

1. By modifying the die design life of the die has been increased i.e production quantity increased when compared to before die.
2. Accuracy increased with less amount of wear in bottom die .
3. Theoretical analysis carried out has approximately reached the practical point of production.
4. The difference between cad analysis and practical study variation is below 10% of total production which is negotiable.
5. This project reveals the depth study about forging of complex closed dies with respect to industrial approach.

FUTURE SCOPE

1.Under this study of complex die forging various components can make such differences in design.

2. Design requirement study can be done by changing the production variations which raises practical problems.

3. Forging is a huge market era which finds different process of metal forming processes.

REFERENCES

[1] S.E. Rusinoff, "Forging and Forming Metals", (1952), American Technical Society, Chicago.

[2] T. Altan, H. J. Henning, "Closed-Die Forging of Round Shapes Flash Design and Material Savings", Metallurgia and Metalforming, March, p. 83, 1972.

[3] "DIN STANDARD 7523 Design of Drop and Press Forgings", September 1986, Part 2.

[4] S. Babu, D. Riberio, R. Shivpuri, "Material and Surface Engineering of Precision Forging Dies", The Ohio State University, June 1999.

[5] S. Kalpakjian, "Manufacturing Processes for Engineering Materials", (1991) Addison-Wesley.

[6] T. Altan, G. Ngaile and G. Shen, "Cold and Hot Forging-Fundamentals and Applications", March 2004.

[7] MSC Superforge 2005.

[8] V. Bhavin Mehta, Ibrahim Al-Zkeri, Jay S. Gunasekera, "Evaluation of MSC.SuperForge for 3D Simulation of Streamlined and Shear Extrusion Dies", Ohio University, Athens, Ohio, USA, 2000.

[9] _sbir, S. S., "Finite Element Analysis of Trimming", M.S. Thesis, 2002, p.24, Middle East Technical University, Ankara.

[10] Gökler, M.I., "Computer Aided Sequence and Die Design for Hot Upset Forgings", Ph.D. Thesis, University of Birmingham, England, 1983.

[11] Kazancı, B., "Design and Analysis of Hot Upset Forgings with Non- Circular Cross-Sections", M. Sc. Thesis, Middle East Technical University, Ankara, Turkey, 2002

[12] Mogulkoç, T., "Finite Element Analysis of Piercing Operation on Forging Machines", Middle East Technical University, Ankara, Turkey, 1999.

[13] Elmaskaya, D., "Finite Element Analysis of Effects of Tapered Preforms in Cold Upsetting", Middle East Technical University, Ankara, Turkey, 1997.

[14] Dogan, Ö., "Finite Element Analysis of Effects of Tapered Preforms on Final Product in Cold Upsetting", M. Sc. Thesis, Middle East Technical University, Ankara, Turkey, 2000.

[15] Alper, E., "Computer Aided Design of Axi-Symmetric Press Forgings", M. Sc. Thesis, Middle East Technical University, Ankara, Turkey, 1989.

[16] Kutlu, A, E., "Analysis and Design of Preforms for Non-Axisymmetric Press", M. Sc. Thesis, Middle East Technical University, Ankara, 2001.

[17] Karagözler, A, B., "Analysis and Preform Design for Long Press Forgings with Non-Planar Parting Surfaces", M. Sc. Thesis, Middle East Technical University, Ankara, Turkey, 2003

[18] Gülbahar, S., "Preform Design for Forging of Heavy Vehicle Steering Joint", M. Sc. Thesis, Middle East Technical University, Ankara, 2004.

[19] Civelekoglu, B., "Analysis of Forging For Three Different Alloy Steels", Middle East Technical University, Ankara, Turkey, 2003.

[20] Karacaovalı, H., "Analysis of Roll-Forging Process", Middle East Technical University, Ankara, Turkey, 2005.