IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 6, Dec-Jan, 2015
ISSN: 2320 – 8791 (Impact Factor: 1.479)
www.ijreat.org

Forging Die Design & Simulation

Nilkanth Velhal[1]

[1] **KTSL, MMIT, Pune, Maharashtra, India**

Abstract
Most of the Multi-national Companies want to establish their business in India, as India is one of the developing country. Forging Companies are contributing important role among these companies. As the number of two wheelers increasing, production of their parts also needs to be increase. If it is possible to design and simulate the part or component before its manufacturing, it will be useful to reduce rejection of parts due to its failure. So that it will be beneficial considering profit of that company
Keywords: *Connecting Rod, 3D Modelling, Simulation, Forge-3 Software.*

1. Introduction

Forging is a manufacturing process involving the shaping of metal using localized compressive force. Forging process is classified according to the temperature at which it is performed: "cold", "warm", or "hot" forging. Forged parts can range in weight from less than a kilogram to 580 metric tons. Most of the forged parts usually require further processing to achieve a finished part.
Currently in India Forging Dies are designed based on the geometry of product to be forged and forging the appropriate geometry on the forged component usually require multiple blows with multiple dies.
This leads to imperfect die in many cases and leads to heavy financial losses due to various manufacturing processes used to manufacture that failed die.
These losses can be avoided by designing the die on any 3D modelling software's available and then virtually stimulating the performance of the die on Forge-3 software by inputting various constraints and parameters required by the software.
By using such technique we can reduce failures occurring in die design by almost 90%.

1.1 Problem Definition

Currently the manufacturing process is time consuming and chances of failure are high. The designers have to 1st manufacture the dies and then tests are carried out. If the die fails to indent the required shape then heavy economic losses occurs.

We are going to design a forging die for manufacturing a connecting rod and stimulate the process virtually.
It will be advantageous for reducing the failures of forging dies by designing the dies 1st virtually in any 3d modelling software's and then testing these virtual dies by using stimulation software's such as Forge 3.

2. Forging

Forging processes are among the oldest and most important of materials-related technologies. The usefulness of the deformation processes that comprise metalworking technology is indicated by the wide variety of parts of simple and complex shape with carefully tailored mechanical and physical properties that are made routinely in industry. It is difficult to visualize what our lives would be like without such products. Today industry must continuously evaluate the costs of competitive materials and the operations necessary for converting each material into final products. Manufacturing economy with no sacrifice in quality is paramount. Therefore, "precision" method of forming, net and near-net shape processing, and modern statistical and design processes based on computer and control techniques have great importance than ever.
The term forging is applied to several processes in which a piece of metal is shaped to the desired form by plastic deformation of a simple starting form such as straight bar, billet and ingot. The energy which causes deformation is applied by a hammer, press, up setter either alone or in combination. The required shape is imparted by the tools that contact the work piece and by careful control of the applied energy.

2.1 Outline of Forging and Related Operations

- The Customer Details
- Product Design
- Technical Review with Customer
- Engineering Study of model and drawing
- Engineering Predevelopment review

- Cross functional team review
- Engineering analysis
- CAM generation
- Standardized tooling
- Die manufacturing
- Pre trail meetings
- Production Trial
- Part measurement
- Part submission

3. Die Material

DIE MATERIALS used for hot forging include hot-work tool steels (AISI H series), some alloy steels such as the AISI 4300 or 4100 series, and a small number of proprietary, lower-alloy materials. The AISI hot-work tool steels can be loosely grouped according to composition (see Table). Die materials for hot forging should have good harden ability as well as resistance to wear, plastic deformation, thermal fatigue and heat checking, and mechanical fatigue. Die design is also important in ensuring adequate die life; poor design can result in premature wear or breakage.

Hot-work die steels are commonly used for hot-forging dies subjected to temperatures ranging from 315 to 650 °C (600 to 1200 °F). These materials contain chromium, tungsten, and in some cases, vanadium or molybdenum or both. These alloying elements induce deep hardening characteristics and resistance to abrasion and softening. These steels usually are hardened by quenching in air or molten salt baths. The chromium-base steels contain about 5% Cr (Table 1). High molybdenum content gives these materials resistance to softening; vanadium increases resistance to abrasion and softening. Tungsten improves toughness and hot hardness; tungsten-containing steels, however, are not resistant to thermal shock and cannot be cooled intermittently with water. The tungsten-base hot-work die steels contain 9 to 18% W, 2 to 12% Cr, and sometimes small amounts of vanadium. The high tungsten content provides resistance to softening at high temperatures while maintaining adequate toughness, but it also makes water cooling of these steels impossible.

Low-alloy proprietary steels are also used frequently as die materials for hot forging. Steels with ASM designations 6G, 6F2, and 6F3 have good toughness and shock resistance, with good resistance to abrasion and heat checking. These steels are tempered at lower temperatures (usually 450 to 500 °C, or 840 to 930 °F); therefore, they are more suited for applications that do not result in high die surface temperatures, for example, die holders for hot forging or hammer die blocks

3.1 Factors Considered For Selection of Die Material

- Properties of materials that determine their selection as die materials for hot forging are:
- Ability to harden uniformly
- Wear resistance (ability to resist the abrasive action of hot metal during forging)
- Resistance to plastic deformation (ability to withstand pressure and resist deformation under load)
- Toughness
- Resistance to thermal fatigue and heat checking
- Resistance to mechanical fatigue

For selection of Die material and considering section factors Chromium and Vanadium which are the deciding factors and from available materials it's beneficial to select H13 Die steel as a material for forging die.

4. Dies

4.1 Impression Dies

Dies for closed-die (impression-die) forging on presses are often designed to forge the part in one blow, and some sort of ejection mechanism (for example, knockout pins) is often incorporated into the die. Dies may contain impressions for several parts. Hammer forgings are usually made using several blows in successive die impressions. Such dies usually contain several different types of impressions, each serving a specific function.

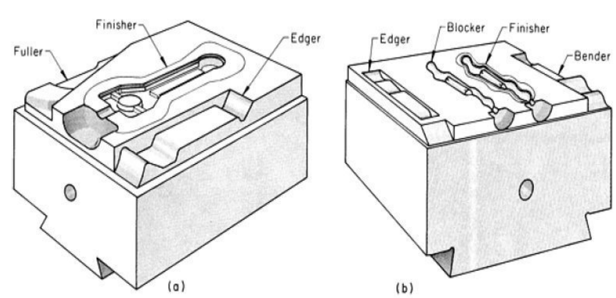

Fig.1. Impression Dies

4.2 Fullers

A fuller is a die impression used to reduce the cross section and to lengthen a portion of the forging stock. In longitudinal cross section, the fuller is usually elliptical or oval to obtain optimum metal flow without producing laps, folds, or cold shuts. Fullers are used in combination with edgers or rollers, or as the only impression before use of the blocker or finisher. Because fullering usually is the first step in the forging sequence, and generally uses the least amount of forging energy, the fuller is almost always placed on the extreme edge of the die, as shown.

4.2 Edgers

Edgers are used to redistribute and proportion stock for heavy sections that will be further shaped in blocker or finisher impressions. Thus, the action of the edger is opposite to that of the fuller. A connecting rod is an example of a forging in which stock is first reduced in a fuller to prepare the slender central part of the rod and then worked in an edger to proportion the ends of the boss and crank shapes.
The edger impression may be open at the side of the die block, or confined. An edger is sometimes used in combination with a bender in a single die impression to reduce the number of forging blows necessary to produce a forging.

4.3 Rollers

Rollers are used to round the stock (for example, from a square billet to a round, bar like shape) and often to cause some redistribution of mass in preparation for the next impression. The stock usually is rotated, and two or more blows are needed to roll the stock.
The operation of a roller impression is similar to that of an edger, but the metal is partially confined on all sides, with shapes in the top and bottom dies resembling a pair of shallow bowls. Because of the cost of sinking the die impressions, rolling is more expensive than edging, provided both operations can be done in the same number of blows.

4.4 Flatteners

Flatteners are used to widen the work metal, so that it more nearly covers the next impression or, with a 90° rotation, to reduce the width to within the dimensions of the next impression. The flattener station can be either a flat area on the face of the die or an impression in the die to give the exact size required.

4.5 Benders

A portion of the die can be used to bend the stock, generally along its longitudinal axis, in two or more planes. There are two basic designs of bender impressions: free-flow and trapped-stock.

In bending with a free-flow bender either one end or both ends of the forging are free to move into the bender. A single bend is usually made. This type of bending may cause folds or small wrinkles on the inside of the bend.

The trapped-stock bender usually is employed for making multiple bends. With this technique, the stock is gripped at both ends as the blow is struck, and the stock in between is bent. Because the metal is held at both ends, it is usually stretch edger bending. There is a slight reduction in cross-sectional area in the bend, and the work metal is less likely to wrinkle or fold than in a free-flow bender.

Stock that is to be bent may require preforming by fullering, edging, or rolling. Bulges of extra material may be provided at the bends to prevent the formation of kinks or folds in free-flow bending. This is particularly necessary when sharp bends are made. The bent pre form usually is rotated 90° as it is placed in the next impression.

4.6 Splitters

In making fork-type forgings, frequently part of the work metal is split so that it conforms more closely to the subsequent blocker impression. In a splitting operation, the stock is forced outward from its longitudinal axis by the action of the splitter. Generous radii should be used to prevent the formation of cold shuts, laps, and folds.

4.7 Blockers

The blocker impression immediately precedes the finisher impression and serves to prepare the shape of the metal before it is forged to final shape in the finisher. Usually, the blocker imparts the general final shape to the forging, omitting those details that restrict metal flow in finishing, and including those details that will permit smooth metal flow and complete filling in the finisher impression.

4.7 Finisher

The finisher impression gives the final overall shape to the work piece. It is in this impression that any excess work metal is forced out into the flash. Despite its name, the finisher impression is not necessarily the last step in the production of a forging. A bending or hot coining operation is sometimes used to give the final shape or dimensions to a forged part after it has passed through the finisher impression and the trimming die.

A blocker may be a streamlined model of the finisher, used to provide a smooth transition from partially finished to finished forging. Streamlining helps the metal flow around radii, reducing the possibility of cold shuts or other defects. Sometimes, the blocker impression is made by duplicating the finisher impression in the die block and then rounding it off as required for smooth flow of metal. When this practice is used, the volume of metal in the blocker preform is greater than will be needed in the finisher impression. Also, the blocker impression is larger at the parting line than is the finisher impression. The excess metal causes the finisher impression to wear at the flash land--where the excess metal must be extruded as flash--and around the top of the impression. With wear, the finisher will produce forgings that cannot be properly trimmed or that are out of tolerance. The impression must be reworked more frequently, or the die must be scrapped prematurely.

It is better practice to make the blocker impression slightly narrower and deeper than the finisher impression, with a volume that is equal to, or only slightly greater than, that of the finisher. The use of a blocker impression having this narrower design minimizes die wear at the parting line in the finisher impression. Moreover, it eliminates the occurrence of the type of lap that is likely to be produced in a finished forging made from a blocker preform of the rounded, finisher-duplicate sort described above, namely, the lap made when the finisher shaves excess metal from the sides of the blocker preform. An added benefit of the narrower design is that it allows for some wear of the blocker impression.

Forging of parts that include deep holes or bosses can cause trouble in the finisher. For producing such parts, the blocker sometimes serves as a gathering operation: A volume of metal that is sunk to one side of a forging in the blocker impression can be forced through to the other side in the finisher impression, filling a high boss. Use of a blocker impression, in addition to promoting smooth metal flow in the finisher impression, reduces wear.

4.7 To manufacture a CONROD One need design following dies:

1. Roller die
2. Flattener die
3. Blocker die
4. Finisher die
5. Piercing Die
6. Trimming die

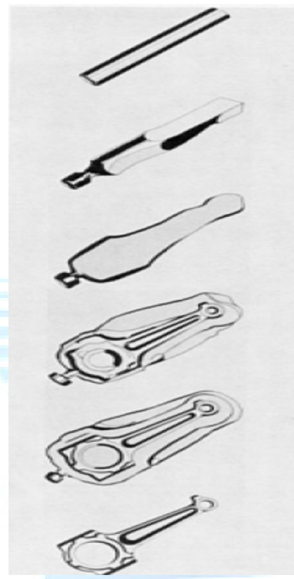

Fig.2. Various operations on a billet.

5. Customer Requirements

Requirements are as follows:

- Material-S48C (JIS G 4051).
- After forging HARDEN & TEMPER to 235-275 BHN.
- Forging to be close trimmed and shot blasted.
- Forging must be straight & free from twist.
- Inspect 100% for hairline crack by magnaflux test.
- Finally the forging should be stress relieved.

6. Software

6.1 Software used in Designing of Dies:

CAD software:	AUTOCAD 07 CATIA V5 UG-NX4
CAD CAM software:	UG-NX4
Analysis software:	FORGE 3

6.2 AutoCAD 2007

AutoCAD is a software application for computer-aided design (CAD) and drafting. The software supports both 2D and 3Dformats. The software is developed and sold by Autodesk, Inc., first released in December 1982 by Autodesk in the year following the purchase of the first form of the software by Autodesk founder John Walker. AutoCAD is Autodesk's flagship product and by March 1986 had become the most ubiquitous microcomputer design program in the world, utilizing functions such as "polylines" and "fitting". Prior to the introduction of AutoCAD, most other CAD programs ran on mainframe computers or minicomputers, with each CAD operator (user) working at a graphical terminal or workstation.

6.3 CATIA V5 R19

CATIA (Computer Aided Three-dimensional Interactive Application) (in English usually pronounced /kəˈtiə/) is a multi-platform CAD/CAM/CAE commercial software suite developed by the French company Dassault systems. Written in the C++ programming language, CATIA is the cornerstone of the Dassault Systems product lifecycle management software suite.
CATIA competes in the high-end CAD/CAM/CAE market with Creo Elements/Pro and NX (Unigraphics).

6.4 UG-NX4

NX, also known as NX Unigraphics or usually just U-G, is an advanced CAD/CAM/CAE software package developed by Siemens PLM Software.
It is used, among other tasks, for:
•Design (parametric and direct solid/surface modelling)
•Engineering analysis (static, dynamic, electro-magnetic, thermal, using the Finite Element Method, and fluid using the finite volume method).
•Manufacturing finished design by using included machining modules.
NX is a direct competitor to Creo Elements/Pro and CATIA.

6.5 FORGE 3

FORGE 3 from Transvalor, France used for process validation, die stress analysis, to estimate forging load, grain flow, tool life, material yield and design optimization and do virtual simulation of forging process. The engineering center is well equipped with latest hardware & software to continuously upgrade the techniques of product development.

- Metal flow simulation software Forge-3, 2D and 3D for Virtual Manufacturing.
- Virtual manufacturing.
- Prediction of Forming Load Energy .
- Feasibility study on part manufacturing.
- Die stress analysis.

Fig.3. 3D model of connecting rod which is to be manufacture

7. Details from 3D Model

- MW = Model weight=1.63 Kg
- Lmax = Maximum forging length=248mm
- Wmax=Maximum forging width=93mm
- PA=Plan area of forging=8937 millimeter square
- Weight for 0.1mm thickness=0.007 Kg

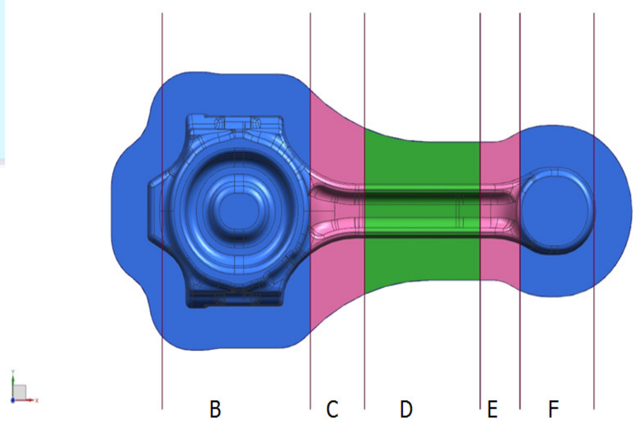

Fig.4. Approximate Partitions of the prepared 3d model is done

7.1 3D model Roller Dies after calculating Dimension of billet for each pass

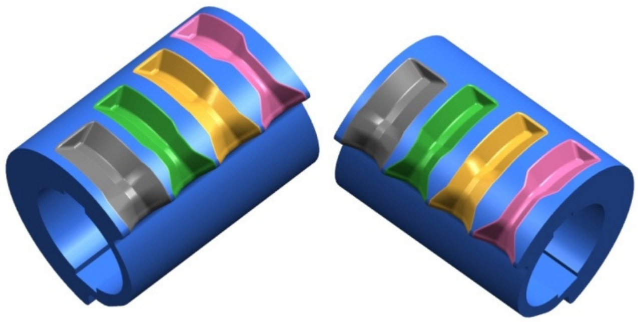

Fig.5. Roller Die

8. Flatner, Blocker and Finisher Die

8.1 Flatner

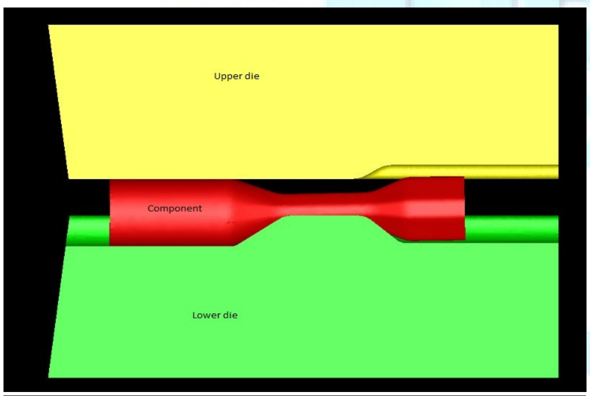

Fig.6. Flatner Die

8.2 Finisher

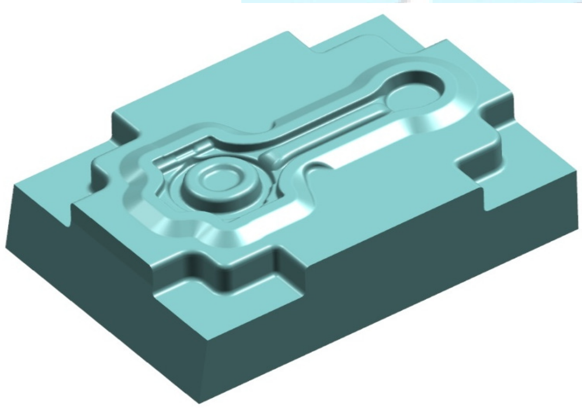

Fig.7. Finisher Die

8.3 Simulation Results From FORGE 3 Software

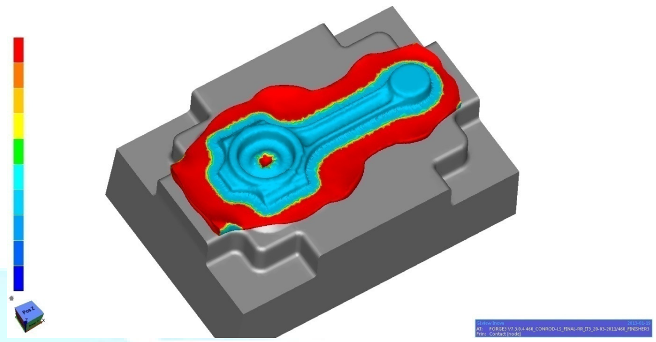

Fig.8. Finisher Die

In figure no. 8 Blue colour indicates Die is completely filled by material and die is in completely in contact with the component after application of force. If Die is not completely in contact with material due to forging defects then at that part colour of forged component is RED shown by FORGE 3 analysis tool. In Fig.8 forged part having red colour is nothing but Flash which will remove in Trimming operation. And circular red spot is part where upper die is not in fully contact with component. But this part is going to remove in piercing Operation. This analysis is useful to identify defects in forged component before its manufacturing.

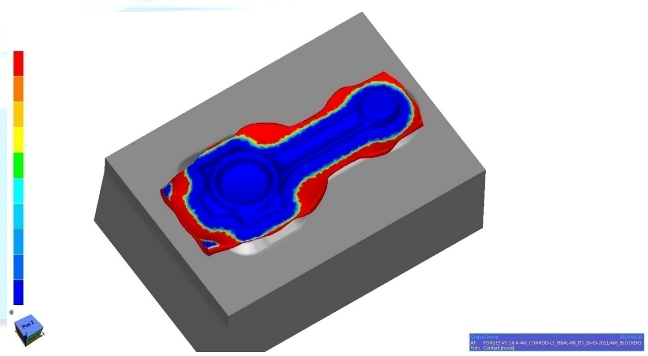

Fig.9. Blocker Die

9. Trimming & Piercing Die

Trimming is the removal of flash that is produced on the part during the forging operation. Trimming may also be used to remove some of the draft material, thereby producing straight sidewalls on the part. It is usually performed by a top die and bottom die that are shaped to the contour of the part. The top die acts as a punch to push the part through the lower die containing the cutting edge. If the top die does not follow the contour of the part, the part may be deformed during the trimming operation. An operation similar to trimming is punching, in which excess material on an internal surface is removed. To ensure accurate cuts, punching and trimming operations are often performed simultaneously.

10. Manufactured Connecting Rod

Fig.10. Billet after Roll forging.

Fig.11. Billet after flatter impression

Fig.12. Billet after Blocker impression

Fig.12. Billet after Finisher impression

Fig.13. Billets after Trimming Operation

ISSN: 2320 – 8791 (Impact Factor: 1.479)
www.ijreat.org

Fig.13. Billets after Piercing Operation
(Connecting Rod)

6. Conclusion

Although the design criterions imposed challenging problems which however were overcame by me due to availability of good reference books. The selection of choice raw materials helped me in machining of the various components to very close tolerance and thereby minimizing the level of wear and tear.

By using stimulation it is easy to reduce the failure chances of the dies manufactured by about 90 % and thus reduced the financial losses which occur because of these failures.

The various dies which were manufactured by company for forging connecting rod gave satisfactory results.

Acknowledgments

The author thanks foMr. Mahesh Gade, Engineering Design Head, KTSL. and the management for giving me the opportunity to work in their esteemed organization. His ideas at certain crucial points have helped us greatly.The author also thanks Prabal Kumar Bhumkar, Sandeep Ram Shinde and Abhijeet Vijay Hake for their great time and support for supporting me. The author also thanks Prof. R. S. Patil, HOD Mechanical Engineering Department MMIT, Lohgaon and Dr. P. J. Awasare, Principal, Marathawada Mitra Mandal's Institute of Technology who directly or indirectly helped me.

References

[1] Evaluation of a sudden brake warning system: Effect on the response time of the following driver, Applied Ergonomics Volume 41, Issue 4, July 2010.
[2] "ASM Handbook of Forming and forging", S.L. Semiatin, 9th Edition.
[3] "Process Design in Impression Die Forging" by T. Altanand M. Shirgaokar, ERC/NSM, NSM Laboratory, Ohio State University.
[4] "Selection of Forging Equipment" by Taylan Altan and Manas Shirgaokar, The Ohio State University.
[5] "Product design for forging" - Published by forging industry association.