A REVIEW ON SPECIAL MATERIALS AND ITS PROPERTIES USED IN FORGING PROCESS WITH REFERENCE TO DIE MAKING MATERIALS

BOMMANA SHRAVAN KUMAR
Ph.D Research Scholar
Shri JJT University
Jhunjhunu, Rajasthan, India.
E-Mail: shravankumarbommana@gmail.com

Dr. S.CHAKRADHAR GOUD
Prof.and Principal
Dept. of Mechanical Engineering
Sri Sarada Inst. of Tech. and Science
E-Mail: cgsakki@yahoo.com

ABSTRACT

In modern times, industrial forging is done either with presses or with hammers powered by compressed air, electricity, hydraulics or steam. Forging process produces parts of superior mechanical properties with minimum waste of material. In this process, the starting material has a relatively simple geometry; this material is plastically deformed in one or more operations into a product of relatively complex configuration. Materials used in "High-Tec" applications, usually designed for maximum performance, and normally expensive. Forging is carried out at a temperature above the re-crystallization temperature of the metal. The re-crystallization temperature is defined as the temperature at which the new grains are formed in the metal. This kind of extreme heat is necessary in avoiding strain hardening of the metal during deformation. The steels used for hot forming is a special type of tool steel, made to withstand a combination of heat, pressure and abrasion and has been classified hot-work tool steel, AISI type H. All hot-work tool steels are used in a quenched and tempered condition. The most essential properties for these types of steels are high levels of hot strength, ductility, toughness, thermal conductivity, creep strength, temper resistance and also low thermal expansion. Steels that need to maintain its properties at high temperatures, e.g. hot-work tool steels, require having an increased temper resistance so that an appropriate strength can be achieved after tempering at 550 /650 °C.

Keyword: *Tool steels for forging, tool properties, die making applications.*

1.0 INTRODUCTION:

Forging is defined as a metal working process in which the useful shape of work piece is obtained in solid state by compressive forces applied through the use of dies and tools. Forging process is accomplished by hammering or pressing the metal. It is one of the oldest known metalworking processes with its origin about some thousands of years back. Traditionally, forging was performed by a smith using hammer and anvil. Using hammer and anvil is a crude form of forging. The smithy or forge has evolved over centuries to become a facility with engineered processes, production equipment, tooling, raw materials and products to meet the demands of modern industry. Forging process produces parts of superior mechanical properties with minimum waste of material. In this process, the starting material has a relatively simple geometry; this material is plastically deformed in one or more operations into a product of relatively complex configuration. Forging usually requires relatively expensive tooling. Thus, the process is economically attractive when a large number of parts must be produced and/or when the mechanical properties required in the finished product can be obtained only by a forging process.

Though forging process gives superior quality product compared to other manufacturing processes, there are some defects that are lightly to come if a proper care is not taken in forging process design. Defects can be defined as the imperfections that exceed certain limits. There are many imperfections that can be considered as being defects, ranging from those traceable to the starting materials to those caused by one of the forging processes or by post forging operations.

Advantages of forging

Some common advantages of forging are given as under.

1. Forged parts possess high ductility and offers great resistance to impact and fatigue loads.

2. Forging refines the structure of the metal.

3. It results in considerable saving in time, labour and material as compared to the production of similar item by cutting from a solid stock and then shaping it.

4. Forging distorts the previously created unidirectional fiber as created by rolling and increases the strength by setting the direction of grains.

5. Because of intense working, flaws are rarely found, so have good reliability.

6. The reasonable degree of accuracy may be obtained in forging operation.

7. The forged parts can be easily welded.

Disadvantages of forging

Few dis-advantages of forging are given as under.

1. Rapid oxidation in forging of metal surface at high temperature results in scaling which wears the dies.

2. The close tolerances in forging operations are difficult to maintain.

3. Forging is limited to simple shapes and has limitation for parts having undercuts etc.

4. Some materials are not readily worked by forging.

5. The initial cost of forging dies and the cost of their maintenance is high.

6. The metals gets cracked or distorted if worked below a specified temperature limit.

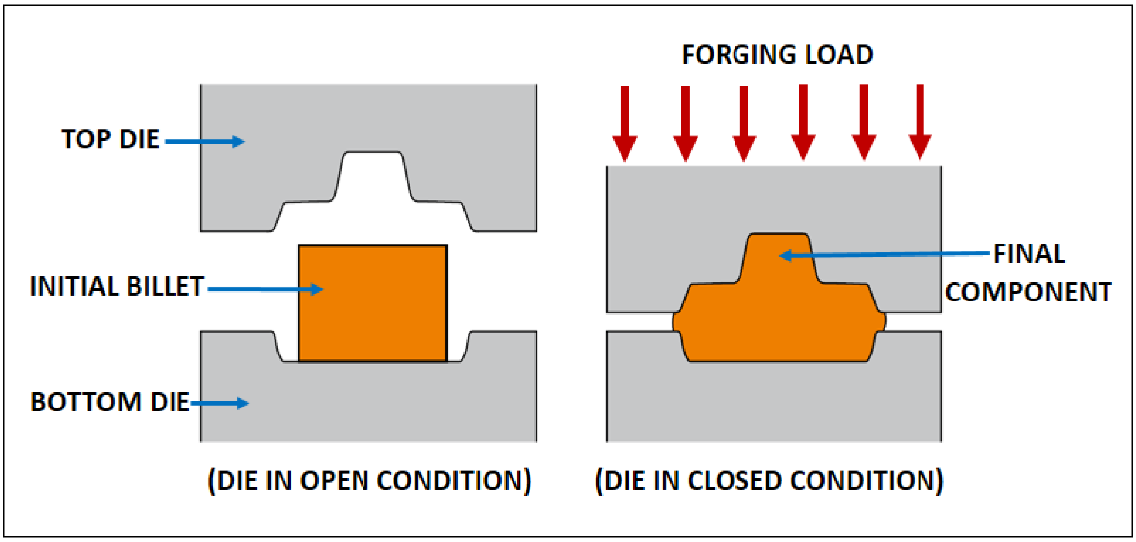
7. The maintenance cost of forging dies is also very high.

1.2 Applications and objectives of forging

Almost all metals and alloys can be forged. The low and medium carbon steels are readily hot forged without difficulty, but the high-carbon and alloy steels are more difficult to forge and require greater care. Forging is generally carried out on carbon alloy steels, wrought iron, copper-base alloys, aluminium alloys, and magnesium alloys. Stainless steels, nickel based super-alloys, and titanium are forged especially for aerospace uses. Producing of crank shaft of alloy steel is a good example which is produced by forging. Forging processes are among the most important manufacturing techniques utilized widely in manufacturing of small tools, rail-road equipments, automobiles and trucks and components of aeroplane industries. These processes are also extensively used in the manufacturing of the parts of tractors, shipbuilding, cycle industries, railroad components, agricultural machinery etc.

1.3 Closed-die Forging Process:

The forging process is deployed aiming at transforming the simple part geometry, into the desired final shape by controlling plastic deformation. In closed die forging (also known as impression die forging), the die imparts pressure on the material through the interface which results in the generation of cavity shaped component. The hot forging criteria together with closed die condition, can produce a higher degree of deformation with reasonable geometrical accuracy, making it a preferred process for mass production of parts with complex shape. A typical arrangement of closed die forging is shown in Figure below:



1.4 Process Variables in Closed-die Hot forging (CDHF)

The physical phenomena defining a complex closed die hot forging operation are generally difficult to express in terms of quantitative relationships. A typical closed die hot forging process comprises many input variables that may be clubbed into the following groups.

i. Product variables

ii. Material variables

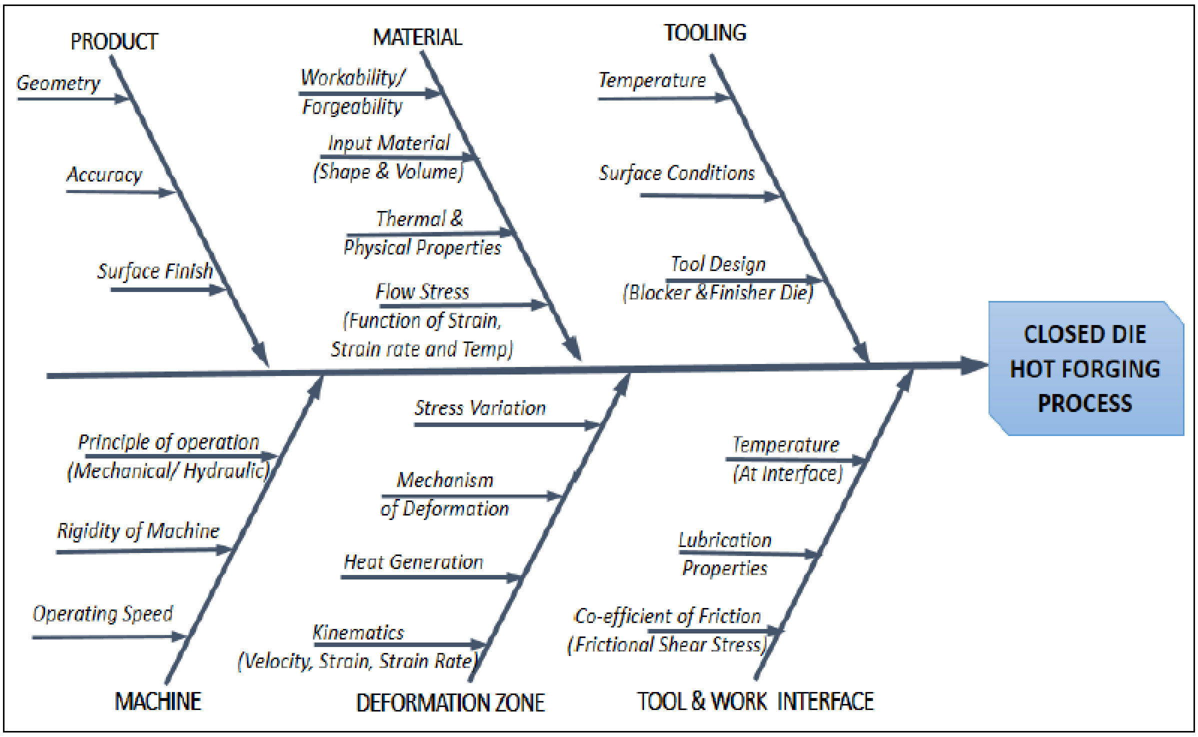
iii. Tooling parameters

iv. Machine parameters

v. Deformation zone characterisation

vi. Tool and work interface behaviour

Each variable group could further be sub-divided into a set of parameters. A schematic diagram showing the broad parameters that can affect a complex CDHF process is illustrated



2.0 Major Factors influencing the Metal Flow (review)

2.1: Forging Temperature

In general, increasing the hot forging temperature (which is far above the re-crystallization temperature of the material) reduces the flow stress, the strain hardening coefficient and hence the resistance of the material to deform. It is expected that, the forging load requirement would go down.

It should also be noted that, additional heat is generated during the process due to the plastic deformation and friction. Indeed, an appreciable fraction of the mechanical energy involved during the process is converted to heat. This can contribute to an increase in temperature if the strain rate is reasonably high.

2.2: Flow Stress

The flow stress refers to the instantaneous value of stress, under the given condition of temperature which is required for continuous deformation or flow of material. This is the most vital material variable in the metal forming analysis. For a given material, the flow stress $(\bar{\ })$ is a function of degree of deformation or strain (ϵ), rate of deformation or strain rate ($\dot{\epsilon}$) and temperature of deformation (T).

$$\bar{\sigma}=f(\varepsilon,\dot{\varepsilon},T)$$

As has been mentioned, at the temperature of forging the strain hardening is low; hence the rate of deformation or strain rate has a far greater effect on flow stress. The increase in strain rate, increase the values of flow stress, in most cases.

2.3: Friction and Lubrication

The forging load applied to the die is transmitted to the work piece through the die interface. So, frictional conditions at the interface is vital to the metal flow. It can influence the metal flow, die stress and increase the requirement of forging load.

Appropriate lubricants are used during metal forming operation to reduce friction, forging load and die wear, so as to improve the metal flow in the lateral direction.

2.4: Forgeability of the Material

The forgeability of a metal refers to the ability to undergo deformation without causing defects such as discontinuities or crack. The common tests for forgeability include upsetting and hot-twist. The test is recommended to be performed at similar operating condition as experienced in forging, such as temperature, strain rate. The forgeability also depends on material characteristics such as tendency for grain growth, oxidation and so on.

2.5: Shape factor of Component and Die

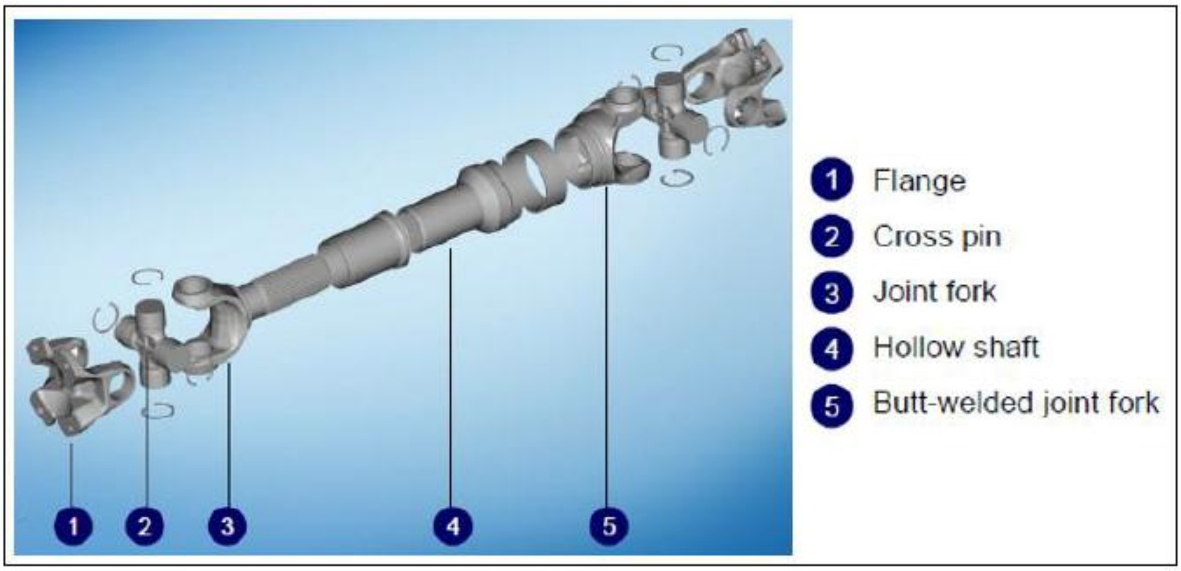
The metal flow in the die cavity is greatly influenced by the geometry of component and die. The simple shaped parts are easier to forge, compared to the complex shapes. The components having higher surface area per unit volume can be termed as a complex shape for forging. These parts with increased surface area are more critically affected by friction and temperature variation. As a result, forging load tends to increase for complete filling of the die cavity.

2.6: Die Temperature

Preheated dies are generally used in the hot forging process to avoid chilling effect at die and work piece interface which hinders the metal flow at surfaces. The heated dies also facilitate die filling and reduce forging pressures. Typically, the die is heated in the range of 250-400 oC, based on complexity of work piece.

3.0 Case study of complex works in forging

The propeller shaft and inter-axle shaft may contain several flange yokes at the universal joint. A typical arrangement of the assembly and its components are shown in Fig



As has been mentioned in the foregoing, a number of process parameters and material characteristics are involved in the closed die hot forging operation that can influence the attributes of a product. Attempts were made in earlier times to adopt analytical techniques to analyse their effect; however, they had many limitations and the predictions were most of the time found unsatisfactory. With the advent of numerical methods the situation improved. Subsequently, in combination with computational techniques, the predictive capability showed appreciable enhancement. Equally important, such analysis can be completed rapidly and therefore optimisation, even on-line, is possible.

4.0 Parameters survey:

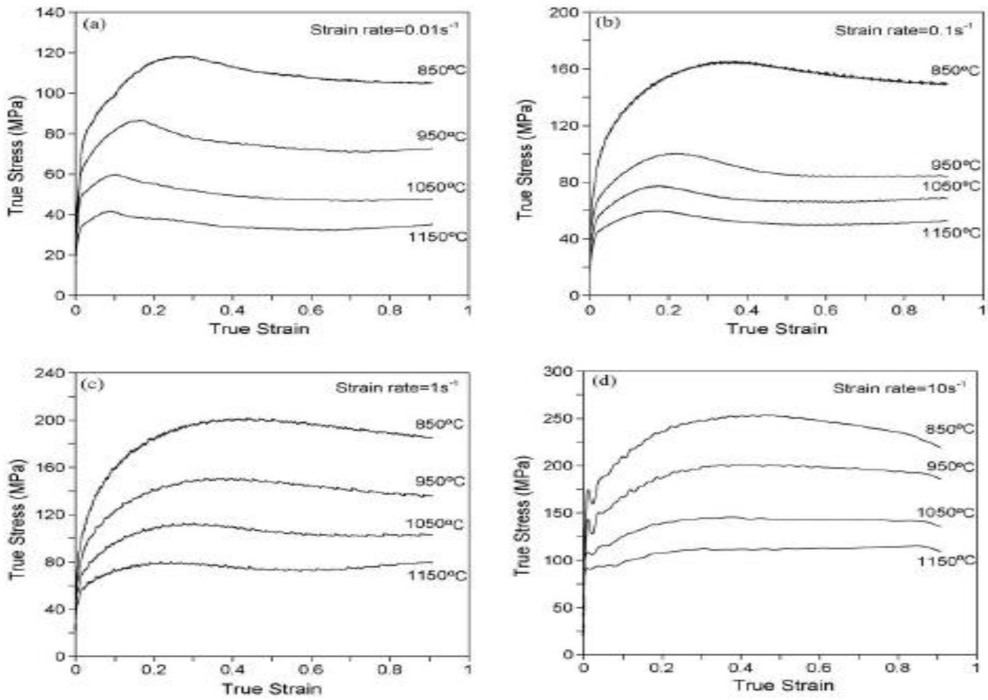
The broad objective of this chapter is to provide requisite background information relating to the proposed study from literature. The identified areas of the survey include:

- Closed die hot forging (CDHF) process and the process parameters

- Approaches for Analysis of the closed die forging process

- Finite Element (FE) Analysis for CDHF process.

Closed Die Forging Process and Process Parameters: The closed die hot forging process is most suitable for generating complex shaped work parts with reasonable profile accuracy. The process is quite complex from the analysis point of view as there exist several parameters, that can influence the process. These parameters in broader terms can be classified into two categories: design and process parameters. The design parameters include the preform shape design and die design. The preform shape design is primarily dependent upon the number of stages involved. The die design includes parameters such as flash thickness, flash width, draft angle, corner and fillet radius, input billet geometry etc.



Effect of temperature and strain rate on flow stress (Material: 42CrMo steel)

From the above review, it can be observed that both the design and process parameters exert appreciable influence on the hot forging process.

Approaches for Analysis of the Closed Die Forging Process : Several methods, developed over time, exist for analysing the metal forming processes. The historical development, is summarised in the work by Osakada. The methods can be broadly divided into Analytical Methods and Numerical methods.

The main objective of such analysis is to:

- Establish a kinematic relationship between the undeformed part and formed part, so that the metal flow during the process can be predicted.

- Predict the process output parameters such as load, stress, strain, temperature etc.

Finite Element Analysis for CDHF Process: Among the numerical methods, the finite element modelling technique is found to be adopted by many researchers for analysis of closed die forging process, in order that complex shapes could be handled. The development of hardware to support the high speed computing along with availability of reliable commercial software codes can be considered as a prime reasons for the adoptability of FE Method. The method of calculation is automated, in the available commercial simulation codes (e.g. DEFORM). The FE modelling software is normally used in conjunction with a CAD (Computer Aided Design) software, for accurate modelling of component and die. These models are imported into the FEM software for further processing such as discretization, application of boundary condition and computational analysis work. The solver used for analysis of CDHF process should be able to model both deformation and thermal analysis, as the actual processing is done at elevated temperature.

5.0 CONCLUSIONS

Hot die forging process is one of the major parts of closed forging for complex shapes manufacturing. The above paper describes about the parameters that have to be consider for hot die forging. Parameters described above will give a clarity about forging process and parameters to be consider for flow process of forming.

6.0 REFERENCES

[1] Maity, K.P., Rout, A.K. and Majhi, K., "computer –aided simulation of metal flow through curved die for extrusion of square section from square billet", Scientific/Industrial journal, (2009)

[2] Ameed, A. S., Hwyyin, R. N. and Kadhim, H.K., "Three- Dimensional Analysis of Extrusion in Complex Die by Using Upper Bound theory", Engg. & Tech. Journal, 29 (4) (2011): pp.639-50.

[3] Gao-yong, L., Jia, Z. and Xiao-yan, Z., "Numerical simulation of extrusion process of X5214 aluminum alloy profile", Journal of Central South University Technology, 39 (4) (2008): pp.748−54.

[4] Zhou, J., Li, L., and Duszczyk, J., "3D FEM simulation of the wholecycle of aluminium extrusion throughout the transient state and thesteady state using the updated Lagrangian approach", Journal of Materials Processing Technology, 134 (2003)

[5] Bogale, K., "Extrusion Dies Design and simulation", Degree thesis, Plastic Technology (2011).

[6] Chaubey, S., "Modeling and Design of Die Profile of Extrusion of square section from round billet through non-linear converging Dies", (2011).