INTRODUCTION

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. Forging is an oldest shaping process used for the producing small articles for which accuracy in size is not so important. The parts are shaped by heating them in an open fire or hearth by the blacksmith and shaping them through applying compressive forces using hammers. Thus forging is defined as the plastic deformation of metals at elevated temperatures into a predetermined size or shape using compressive forces exerted through some means of hand hammers, small power hammers, die, press or upsetting machine. It consists essentially of changing or altering the shape and section of metal by hammering at a temperature of about 980°C, at which the metal is entirely plastic and can be easily deformed or shaped under pressure. The shop in which the various forging operations are carried out is known as the smithy or smith’s shop. A metal such as steel can be shaped in a cold state but the application of heat lowers the yield point and makes permanent deformation easier. Forging operation can be accomplished by hand or by a machine hammer. Forging processes may be classified into hot forging and cold forgings and each of them possesses their specific characteristics, merits, demerits and applications.

Higher strength-to-weight ratios often make forgings competitive with castings; not only because of their lighter weight, but also because forgings outperform castings. Materials science, also commonly known as materials science and engineering, is an interdisciplinary field which deals with the discovery and design of new materials. This relatively new scientific field involves studying materials through the materials paradigm (synthesis, structure, properties and performance). It incorporates elements of physics and chemistry, and is at the forefront of NANO science and nanotechnology research. In recent years, materials science has become more widely known as a specific field of science and engineering.
Hot forming processes are among the oldest and most important metal forming technologies and accounts for a large percentage of fabricated metal products. However, the metal industry today is very competitive and a metal former must carefully evaluate the costs of the operations necessary for converting each material into finished products. Therefore the industry continuously strives to lower the production costs of each operation. The die plays the most essential part in all types of hot forming operations, because it usually gives the object its final complex shape. Since the die usually is expensive to manufacture it has a major influence on the production costs of the products. Some metal workers even claims that a high-quality die with a long lifetime is the key for a successful and cost-effective production. Forming techniques such as hot forging and die casting are two popular ways of forming net and near net shaped components, since they are economical and high-speed methods. Also, modern statistical and computer based process design and simulations are becoming more important than ever in the struggle of reducing the production costs. Simply, because computer based process simulations can optimise the production, without using expensive tooling and testing.

Present research elevates the cost reduction of forged die materials compare cost effective with better compositions and mechanical, thermal properties comparisons.

Introduction to forging

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.

In modern times, industrial forging is done either with presses or with hammers powered by compressed air, electricity, hydraulics or steam. Some examples of shapes obtained now-a-days by forging process are- Crane hook, connecting rod of an IC engine, spanner, gear blanks, crown wheel, pinion etc.

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.

A. Some Important Forging Terms

1) Forging die: It may be defined as a complete tool consists of a pair of mating members for producing work by hammer or press. Die pair consists of upper and lower die halves having cavities.
2) Billet: A slug cut from rod to be heated and forged.
3) Blocker: Preform die or impression, used when part cannot be made in a single operation.
4) Cavity: The impression in upper and lower die.
5) Draft Angle: The taper on a vertical surface to facilitate the easy removal of the forging from the die or punch. Internal draft angles are larger (70-100), whereas external draft angles are smaller (30-50).
6) Fillet: It is a small radius provided at corners of die cavity to ensure proper and smooth flow of material into die cavity. It helps to improve die life by reducing rapid die wear.
7) Flash: The excess metal that flows out between the upper and lower dies which is required to accomplish a desired forging shape.
8) Gutter: A slight depression surrounding the cavity in the die to relieve pressure and control flash flow.
9) Parting Line: The location on the forging where excess material in the form of flash is allowed to exit from the forging during the forging operation.
10) Shrinkage: The contraction that occurs when a forging cools.
11) Sink: To cut an impression in a die.
12) Web: The thin section of metal remaining at bottom of a cavity or depression in a forging. The web may be removed by piercing or machining.

13) Die Closure: Refers to the function of closing together the upper and lower members of a forge die during the process of actually producing a forging.

**B. Classification of Forging Processes**

In forging, an initially simple part—a billet, is plastically deformed between two dies to obtain the desired final configuration. For understanding and optimization of forging operations, it is useful to classify this process in a systematic way. There are a large number of forging processes that can be classified as follows:

1) Classification based on Temperature of the work piece

   a) Hot forging (most widely used): Forging is carried out at a temperature above the recrystallization temperature of the metal. The recrystallization 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.

   Advantages: High strain rates and hence easy flow of the metal, Re-crystallization and recovery are possible, Forces required are less.

**FORGING TEMPERATURES**

A metal must be heated to a temperature at which it will possess high plastic properties to carry out the forging process. The metal work piece is heated to a proper temperature so that it gains required plastic properties before deformation, which are essential for satisfactory forging. Excessive temperatures may result in the burning of the metal. Insufficient temperatures will not introduce sufficient plasticity in the metal to shape it properly by hammering etc. Moreover, under these conditions, the cold working defects such as hardening and cracking may occur in the product.

The temperature to start the forging for soft, low carbon steels is 1,250 to 1,300°C, the temperature to finish forging is 800 to 840°C. The corresponding temperatures for high carbon and alloy steels which are hard in nature are 1100 to 1140°C and 830 to 870°C. Wrought iron is best forged at a temperature little below 1,290°C. Non ferrous alloys like bronze and brass are heated to about 600 to 930°C, the aluminium and magnesium alloys to about 340 to 500°C.

Forging temperature should be proper to get good results. Excessive temperature may result in the burning of the metal, which destroys the cohesion of the metal. Insufficient temperature
will not introduce sufficient plasticity in the metal. The forging operation in metal is if finished at a lower temperature, it may lead to cold hardening and cracks may develop in it. However, excessive heating of the forgeable part may result in oxidization and hence material is wasted. The temperature of heating steel for hand forging can be estimated by the colour of heat and which color of the light emitted by the heated steel. For accurate determinations of forging temperatures of the heated part, the optical pyrometers are generally used.

**BACKGROUND OF THE WORK**

The forging industry is facing drastic challenges and growing competition to keep costs down and quality high. The avoidance of conditions that cause internal defects is important from a production and cost containment perspective. It is often difficult to determine the root cause of an internal defect after the material has undergone various heat treatments and deformations. The objective of the present work is to perform a systematic study of several types of internal defects that can be occasionally found in forged products and characterize the defect surface prior to and after high temperature heat treatment.

Hot working tool steels are frequently used to make forging dies. These are high performance alloy steels, which can withstand substantial mechanical and thermal stresses encountered in forging processes. Producing forging dies is technically a demanding process, at all stages of its evolution and manufacturing. During use the forging dies can fail due to variety of failure modes, such as, wear, cracking and mechanical & thermal fatigue.

The demand on more efficient hot-work industry increases and since much of the efficiency derives from the tool and its life-time, the “Computational Engineering” becomes extremely important. Component and die design are closely linked, where Computer Aided Design (CAD) and Finite Element (FE) stress calculations are potential means to minimise delay and to increase the tool lifetime. Models of the tool steels behaviour is needed in the FE calculations and the results from the numerical simulation in this study show that it is possible to use the nonlinear kinematic and isotropic hardening model to simulate the behaviour of a tool during use.

**SCOPE OF STUDY**

The objective of this paper is to evaluate in service performance of these forging dies. This performance evaluation will be based on industrial data of time to failure of the forging dies. The time to failure shows a significant variability around its average value. Keeping in view both the average value and dispersion in the die life the nature of their failure rate will
be explored and appropriate reliability characterization will be provided. Using the parameters of the fitted reliability models a strategy is outlined to have a comparative evaluation of forging tools produced by two competing die manufactures or die materials and/or heat treatments.

Reliability analysis of tool life data is done for a variety of forging dies. Various modes of failure and their underlying damage mechanisms are discussed. Important features of the damage processes are identified, and approaches to minimise the tool damage are highlighted. Major focus of the paper is on the reliable life modelling of these metal-forming tools, and to discuss some possibilities to enhance their life.

**PROBLEM STATEMENT**

This thesis mainly aims at improving the die material and its performance, and that problem was encountered in several steps. The first step was to identify the life-limiting factors of a hot forming die and, since, the conditions of a die varies a lot depending on the application, two different hot forming dies from two different hot forming techniques, hot forging and die casting, was investigated. Several damage mechanisms were found on the dies, such as; wear, oxidation and plastic deformation, but common for both techniques and dies were that thermal fatigue was found to be the most detrimental damage mechanism. By adding of composite materials with inclusion of NANO materials in fabrication of die part to check wear behaviours one of the most important factors of die life in forging.