Applications and Fundamentals of CAD/CAM in Forging Industry: A Review

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Abstract— **Forging is an age-old manufacturing process in which desired shape of component is obtained by applying impact load on the metal. Most of the small and medium scale industries work on traditional trial-and-error method to design dies and forged components. With the advent of CAD/CAM in forging industry, process modelling has greatly reduced the lead time and errors to produce the product. The cost of CAD/CAM interface in the long run is very less as compared to actual failures of the die and shutdowns in the shop floor. Small and medium scale industries must gracefully accept this change and progress with technological advancements to keep pace with global market, otherwise it may be too late for such industries to sustain at global level.**

Keywords— Forging, CAD/CAM, Lead time, Flash less forging, Die stresses.

Nomenclature	
σ	*Stress*
ε	*Strain*
Q	*Strength index*
e	*Strain hardening exponent*
σ_{TFS}	*Total flow stress*
i_y	*Initial yield*
i_{sh}	*Isotropic hardening*
V_{PF}	*Visco plastic flow*
F_t	*Flash thickness*
a	*Area of forging*
d	*Diameter of forging*

I. Introduction

Forging is an age-old manufacturing process in which desired shape of component is obtained by applying impact load on the metal. Most of the small and medium scale industries work on trial-and-error method to design a forged component. The various forging processes are hot forging, cold forging, open die forging, and closed die forging. The industries following traditional forging process faces lot of challenges like die failures, underfill, wastage of material in the form of flash and uneven die load distribution. This causes wastage of time and economic resources to design a forging die and subsequently the forged component. With the advancement of CAD/CAM facilities in the forging industry, die design process has improved a lot. Taking into considerations the hardships faced by small scale forging manufacturers, a study has been planned to focus on the latest developments in CAD/CAM or process modelling that may be suitable for such manufacturers to sustain at global level.

II. MATERIALS AND METHODS

The data base was searched from science direct and Google scholar using the keywords “forging” and “CAD/CAM”. The science direct is an online library of scholarly articles published by Elsevier. The research papers from journals having impact factor (web of sciences) were selected for this review. Few research papers from the conferences that were relevant to the topic were also shortlisted for this study. The papers were selected for two forging processes i.e., cold forging and hot forging. These two forging processes were chosen as they are commonly used in most of the small and medium scale industries.

III. Literature Review

Forging die design is a complex task and requires lot of experience in the relevant field. With the advancement of technology and advent of CAD/CAM facilities in forging, many die related issues can be resolved before actual manufacturing of the die. CAD/CAM interface is being used to study the die filling, non-linear behavior of the material, die loads, stresses to predict the life of the die and design optimization to produce the best quality product at minimum cost. Die life and stresses predict the maximum number of components that can be produced by that particular die before it needs replacement or repair in the form of machining. Such analysis is very important from economic consideration by an entrepreneur [1-3]. CAD/CAM is computer aided design and computer aided manufacturing in which computer simulation is used to design and manufacture a product with ease and minimum possible errors. Not only die filling, or die loads are predicted correctly with CAD/CAM, it can also be used to produce flash less forgings. In Flash less forging, there is no wastage of material in form of flash around the forged component. The concept of flash less forgings is applicable to both hot and cold forging processes. Near net shape forging was used by researchers to manufacture gears by cold forging [4]. The gears of different shape and size can be produced with the help of forging processes. The different types of gears include spur gears, helical gears, herringbone gears, straight bevel and spiral bevel gears. The other types of gears are hypoid and worm gears. The use of process simulation and numerical modelling was used to predict the die stresses of ring gear. The results were further compared during the actual production of gear by cold forging orbital process. The authors also analyzed the stresses in the perform, and the punch. The stresses were high and numerical simulations helped to change the design of the product during early product life cycle to reduce failures [5]. The parameters of cold forging die design were programmed using programming language. The major parameters included dimensions of the billet, working temperature, and speed of extrusion for die design. The authors claimed that user can further extend the program database to any other forging process as well [6]. CAD/CAM has drastically changed the methodology of the forging process. Now the dies could be designed and manufactured with minimum errors and maximum profitability [7]. The forging process involves number of tools. These tools could also be designed for cold forging process using CAD/CAM interface [8]. The finite element method was used in cold forging to design a bevel gear at reduced cost with better quality at much shorter lead time [9]. The simple cold working equation of metals is given by [10-12].

$$\sigma = Q\varepsilon^{e} \qquad (1)$$

This equation defines the relation of stress and strain during plastic flow of the material. This equation defines the non-linear deformation and behavior of the material during forging process. It is also very important to understand the plastic flow deformation mechanism of the forging process. The total flow stress during plastic deformations is given by [12-15]

$$\sigma_{TFS} = i_y + i_{sh} + V_{PF} \qquad (2)$$

The total flow stress of the material depends upon initial yield, isotropic hardening and Visco plastic flow of the material. Not only in cold forging, process modelling has helped to produce flash less forgings and high-quality die designs for hot forging dies also. Flash less forging for hot forging die design was also studied with the help of finite element analysis. In this study, researchers designed and developed a closed cavity to produce near net shaped connecting rod. This led to 40 % material savings, which directly means reduced cost of the product. FEA also resulted in shorter lead times, better quality of the die and improved overall product. Process modelling provided more information about load distribution and flow of material at different stages of the forging process [16]. The flow of material depends upon the design of land and gutter size, billet dimensions, friction and heat transfer between billet and dies [17]. The hot forging process may consume lot of time and iterations to produce the actual product. Considering the time involved in this tedious work, an expert system was developed to produce flash less forged gears which helped in overall decision making and planning to produce the best quality product in the market [18]. The most important aspects of such flash less forgings are reduced machining costs and lead times [19-20]. Not only the problems and die related issues were resolved by CAD/CAM interface, the capacity to manufacture connecting rods was also increased with the help of process modelling softwares [21]. A study analyzed the importance of CAD/CAM for precision forging of connecting rods, gears and other parts [22]. Despite having numerous benefits of CAD/CAM and technological advancements in forging, the small-scale manufacturers are not keeping pace with these updates. There are many challenges faced by small-scale manufactures. The calculation of flash is one of these parameters. The different authors and die designers have calculated the flash thickness as per their expertise and requirement [23-24].

$$F_t = 0.015\sqrt{a} \qquad (3)$$

$$F_t = 0.016d \qquad (4)$$

The other problems of small-scale industries highlighted by researchers are lack of development with respect to new materials, lead times and unnecessary costs. Due to lack of development the survival of such forging industries is at risk [25]. The small and medium scale industries are facing not only technological challenges but they are also short of skilled manpower [26].

IV. RESULTS AND DISCUSSION

Forging Industry is mainly based on trial-and-error method. Forging is very tedious process and needs lot of skill and experience in the relevant field. The design of flash land and gutter is very complex and depends upon the expertise of the die designer. Moreover, the forging loads cannot be calculated manually for upsetting, blocker and finisher operations. Most of the time is wasted in die designing and making necessary try outs to produce the actual component. The savings in time by using CAD/CAM interface has been found to be from days to weeks depending upon the type of the product to be designed. Flash is one of the major concerns of the forging industry which increases the cost of the product. It is the extra material that flows out of the die cavity. Too less billet size may cause the problem of under fill and unnecessary stresses in the component. It can ultimately result in premature die failures. With the advancement of CAD/CAM in the forging industry die designers can design defect free dies having enough durability. Die failures in the production hammer and press means shutdown of the shop floor activities. No production means no profit and delayed consignments to the customers. CAD/CAM in the forging industry has proved to be a boon for the design engineers and ultimately production team which means reduced inspection and high-quality product. The CAD/CAM interface has enhanced the capabilities of the die designer's manifold. Now die designers can simulate the product before its actual manufacturing. The dies and the product can be visualized with the help of CAD/CAM softwares. This means no or very little die design errors. There are various commercial softwares available in the market for simulating the flow of the material during different forging operations like upsetting, blocker and finisher operations, and during different extrusion processes. This means that product may be designed at shorter lead times. Lead time refers to the time when the order is placed and shipment is ready for the use of customers. Some of the advantages of the CAD/CAM interface in the forging industry have been explained with the help of flow chart given in the figure 1.

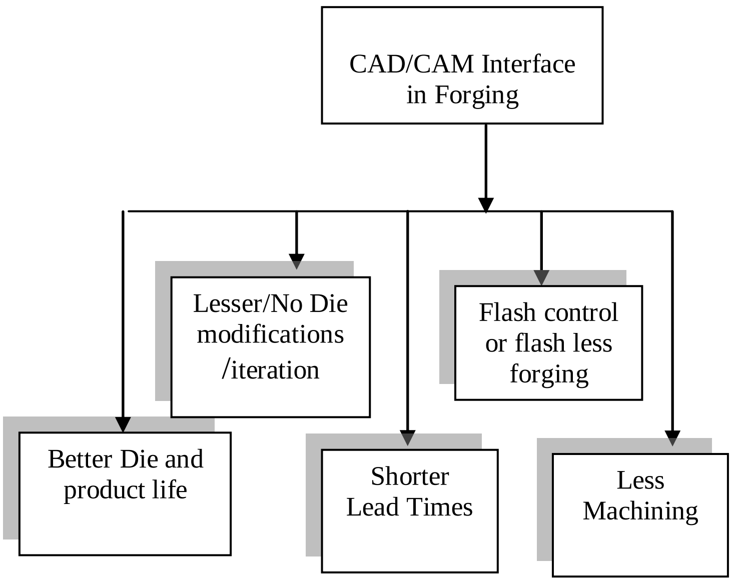

Fig1 Advantages of CAD/CAM in Forging Die-Design

The finite element simulations can also help the die designers to simulate the flash around the forged component. Iterations of the die design and simulation of the material flow around the component can help the designers to achieve near net shape forgings or flashless forgings. Flashless forgings or near net shape forgings means reduced billet size or volume of the component. It means reduced cost of the product to the company as well as to the customers. Flashless forgings also mean no or little machining. There are also no costs that are involved for trimming punch and trimming die. This is all possible because of CAD/CAM interface in forging. If the load distribution of the upper die and bottom die is uniform during the hammer or press operations, the die life is increased manifolds. The load distribution between different operations can also be simulated with the CAD/CAM softwares. This means increased die as well as product life. The grain flow distribution of the material during different stages of the forging operations can also be accurately predicted and modeled using CAD/CAM.

V. Conclusion

Forging process is one of the most important manufacturing processes to reshape metals. There is long list of the components that can be designed and manufactured with the help of forging process. Forging finds applications in engine blocks, aircraft frames, crankshafts, gears, industrial tools, hand tools, pipe line fittings, fixtures, valves, ship, boat building, turbines, and bearings. CAD/CAM interface has successfully changed the working environment of forging industries. With the help of process modelling, the component can be simulated before it is actually produced in the shop floor. Process modelling has greatly reduced the lead time to produce the components. The cost of CAD/CAM interface in the long run is very less as compared to actual failures and shutdowns in the shop floor. Small and medium scale industries must gracefully accept the change and progress with technological advancement to keep pace with global market, otherwise it may be too late for them to sustain at international level.

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