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Different methods of forging; applications and obstacles

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Abstract: Forging is a manufacturing process that consists of shaping the metal using localized compression forces. The blows are delivered with a hammer (often an electric hammer) or a die. In this paper, different methods of forging (multi-directional forging, hot forging, near-beta forging, multi-axial forging, direct powder forging, warm forging and ring forging) are discussed. The main problems that may be encountered by users are investigated. In some cases, the problems are being solved by researchers in which the process is presented. Afterwards, one of the main applications of forging process, blade forging, is discussed. Furthermore, forging process's effect on mechanical properties of components has been investigated. In this review paper, readers could find important information about forging process and get familiar with some forging methods and their impact on the properties of the components. And readers also can develop some ideas about how to solve the main obstacles of forging process.

Keywords: Forging, MDF, Hot forging, Ring forging, Blade forging

1. Introduction

Forging is a process where bulk deformation is reached by application of force. In forging process, the constraining dies and they are generally made from steel. The process is generally easy due to simple case of upsetting between flat plates, but variation in section thickness and significant lack of symmetry makes it difficult in several ways. Although stamping operations are done on thin sheets, but forging is a process made from billets with several inches thick. Reducing high utilization of materials and considerable reduction in machining cost are main advantages of forging. In some cases, the ductility and strength of material could be controlled by forging. Also, complex shapes could be produced by forging. Even in materials which is possible to produce by injection molding, by using forging thicker components could be achieved. As the matter of fact, in ordinary plates the first option for economic production is injection molding, but when the component is so thick or has lots of variation in section thickness, forging process must be used. There are lots of obstacles in forging process. The springback still remains the major problem in forging.

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The usual lack of symmetry and section thickness variation lead to this severe problem. Crystalline materials show less springback, thus they are much easier to forge [1]. While forging may be one of the most ancient of metal working techniques, it remains today one of the most important manufacturing processes embracing primary processes such as the reduction in size of large cast ingots (~1 m diameter), to the net-shape microforming of electronic components (<1 mm) [2].

In this paper, the forging process for different applications is investigated. Furthermore, different types of forging are explained and obstacles and problems that could be confronted, are illustrated. Engineers could use this paper to get a general view about forging process and know the major problems in forging process and how to solve them.

2. Main Types of Forging

2.1. Multi-Directional Forging

Multidirectional training is a progressive and modern way of producing forged parts with a complex shape (See Figure 2-1). It is possible to make products that are not possible with other technologies. The use of multiple forging produces less waste material than conventional machined forgings [3].

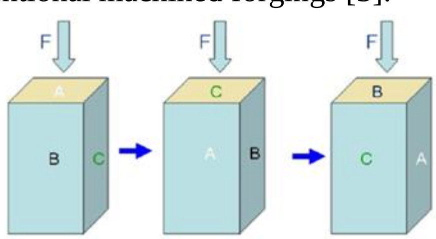

Figure 2-1. Schematic of multidirectional forging[3]

Figure 2-2 shows a conventional product by forging it in a multidirectional manner. Generally, this technology produce "T" shaped pipes, exhaust pipes and other slabs of complex shape. These forgings have greater strength than the machined parts [4].

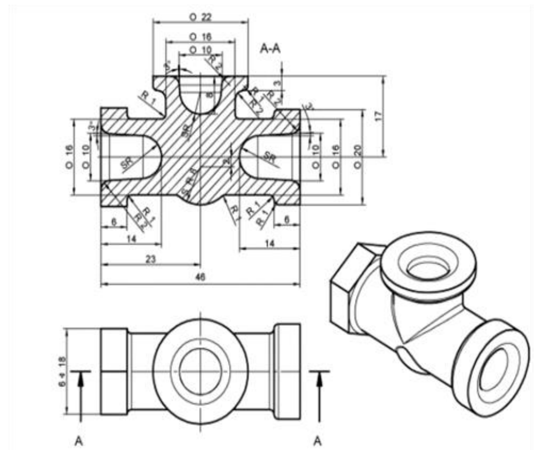

Figure 2-2. Simple forging part made by multidirectional method[4]

2.2. Hot forging

Hot forging of medium carbon steels (0.3-0.6% C) is often used as a first step in the manufacture of mechanical components such as plates, shafts and shafts. Generally the entire production cycle consists of hot forging, annealing or normalization, intermediate machining, quenching, tempering and final machining, Figure 2-3 [5].

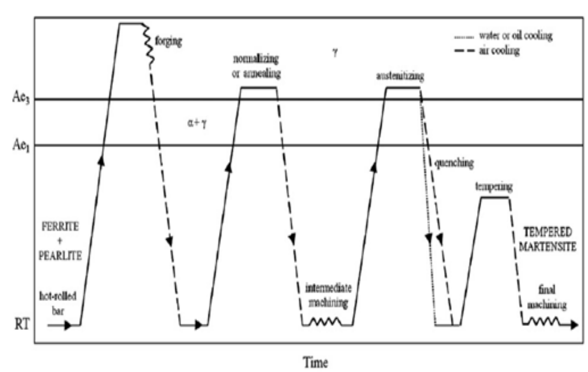

Figure 2-3. Typical production cycle of hot forged quenched and reinforced steel components of microalloyed steel at warm temperatures[5]

2.3. Near-beta forging process

From the perspective of damage tolerance design, beta forging with a laminar microstructure is a better form of treatment than conventional (alpha + beta) forging, because of its excellent high temperature properties and toughness to break. Unfortunately, ductility and thermal stability are relatively low and, therefore, forged titanium parts are often discarded. This is one of the main reasons why forging beta found some practical applications in the production of aircraft components in China. For the same reason, special attention was paid to the optimization of the mechanical properties of titanium alloys in the phase field (alpha + beta) [6].

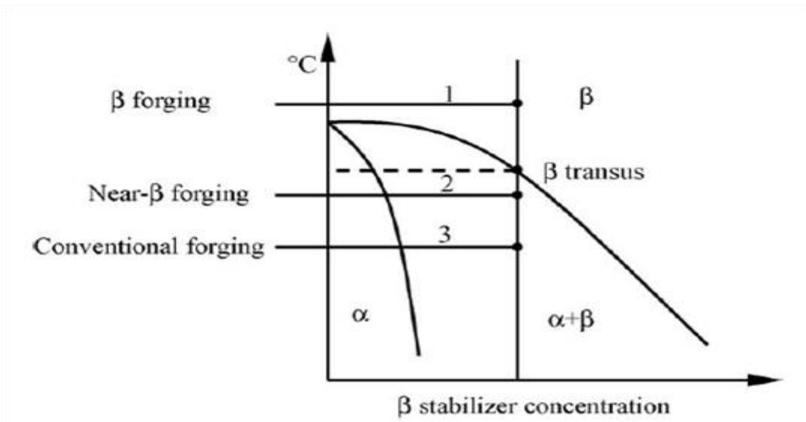

Figure 2-4. Phase diagram of titanium alloys[6]

2.4. Multi-axial forging (MAF)

Another deformation path that is capable of conferring severe plastic deformation (SPD)[7] in a channel die is multi-axial forging (MAF). In this technique, the sample is compressed in a channel die to a fixed strain, deformation is removed, rotated 901, reinserted into the channel matrix and pressed at the same deformation. If the channel die is open in one direction, as in Ref. [7] the amount of deformation step must be controlled to the desired amount so that this process can be repeated [8].

2.5. Direct powder forging

In this process, the encapsulated powder and vacuum is heated to a formation temperature and forged directly into the final form, by the use of a high formation charge for a very short time. Direct forging powder is an economical process and energy-saving compared to the conventional powder metallurgy process. Similarly, readily available conventional press machines can be used for the forging powder. Low prior particle boundary precipitation leads to less heating time. Due to large plastic deformation, existing prior particle boundary networks are broken and therefore, this weaken the impact of prior particle boundary [9].

2.6. Warm forging

Warm forging tools have a rather short life time, which depends on the forging process conditions, the design of the tool, the heat treatment (specific to the tool material), the shape of the forging preform, manufacturing, and etc. [10] To improve the durability of tools used in hot and warm forging processes, changes caused by various failure mechanisms in the surface layer of the tool during its service must be accurately identified. [11]

2.6. Ring forging

A very limited number of researches were carried out in the field of forming the magnesium alloy ring forming process, particularly in the study of the hot ring forging process. Zhang and Huang [12] reported that an AZ31 alloy ring was successfully fabricated by a hot ring forging process which was a two-stage non-isothermal process. In their study, the authors found that in the central region of the ring, a fine and relatively homogeneous microstructure was obtained and the mechanical response of the ring from different tensile directions differed considerably. However, some subjects remained unknown, like the microstructure, the development of the texture and its effects on the mechanical properties of the ring under various processing conditions [13].

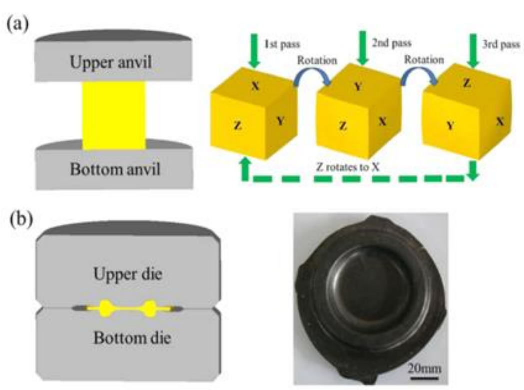

Figure 2-5. Hot ring forging (a) pre-forging (b) finish die forging

Pre-multidirectional forging and finish die forging are two main stage of hot ring forging process, as shown in Fig. 2-5(a) and (b). For hot ting forging, four different pre-multidirectional forging temperatures and the corresponding finish die forging temperatures were used.

3. Main application and effect

3.1. Blade forging

As it is shown in Fig. 2-6, there are four stages in deformation of blade forging process: upsetting, heading, busting and final forging stage. As the first three preforming operations applied, a cylindrical billet is formed with a head. The piece is cooled afterwards in room temperature air, the surface is peeled off, the blanks are then sand blasted and heated to the forging temperature with a soaking time for even distribution of the temperature in the volume of material. The forging operation is then performed to form the final product [14].

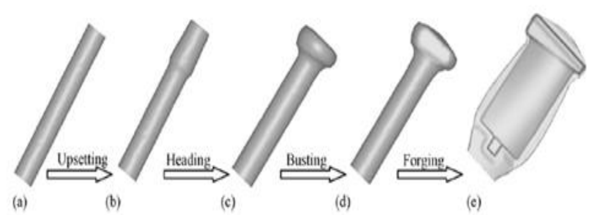

Figure 2-6. Blade manufacturing stages (a) initial billet, (b) upsetting perform, (c) heading preform, (d) busting preform, (e) final forging.

In some studies, hot forging is used to determine temperature related errors and the effect of shape and position of the preform. Deformation of die profiles during blade forming is also studied. The microstructural structure of material of blades is another significant field of study. In another approach, Soltani et al. [15] used both flow and solid approach to simulate forging and proposed a hybrid scheme. Increment in techniques for forging makes it easier to produce accurate ring-type components. A different type of incremental forging operation is ring rolling. The microforging is a zone of great potential, especially in electronics and medical devices, but research to improve the quality of bracelet is very rare. The behavior that happens after forging is a vague subject. In some studies residual stress that results from forging process is considered.

The influence of press behavior, although it is important in processes such as net-shape forging, also received little attention, but Ou et al. [16] considers the elasticity of the press in a study of the optimization of forging turbine blades. It is possible that the continuous re-meshing in three dimensions required for incremental forging modeling and perhaps the need to include anisotropic or orthotropic models in the microforging analysis have discouraged further research in these areas. But these kinds of problems offer the greatest value potential for original research in forging practical operations [2].

3.1. Hot forging effect on mechanical properties

Both cast iron and hot forged alloy and composite materials were subjected to microstructural studies, micro hardness and tensile strength tests (See Figure 3-1). The results show that due to both cast and hot forging conditions, the microhardness, yield and tensile strength of the developed composites became higher than matrix alloy. The increase of the silicon nitride content in the matrix alloy leads to an improvement in the microhardness yield and the tensile strength of the composites. On the contrary, the process of increasing content of silicon nitride in the matrix alloy lead to lower ductility of the cast and the forged composite. The hot forging alloy and its composites have more microhardness, tensile strength and higher ductility compared to cast composites for a given reinforcing content [17].

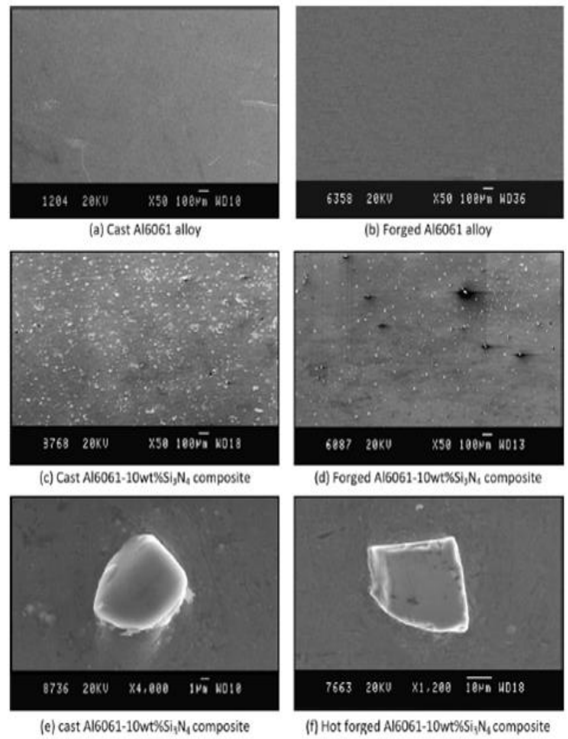

Figure 3-1. SEM of cast and hot forged composites

4. Conclusion

This study is focused on some of forging methods and their impact on the properties of the components. Also, in some parts the obstacles and problems that may be confronted by users are being discussed and solved. From general point of view, in most cases forging affect directly or indirectly the mechanical properties of the component. But, this technique could be better used, if for each application the perfect method is being selected. The process is almost easy in every way but thickness variations and lack of symmetry makes it hard. But beside all the problems and obstacles, the forging is widely used in mechanical and industrial processes.

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