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A Review: Enhancement of Forging Die Life by Alloy Material and Surface Treatment

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ABSTRACT

This article provides a summary of years' worth of work done to improve the longevity of forging dies. The service life of the die in the forging process is crucial for both financial and finishing quality of productions. The dies are exposed to high contact pressures and temperatures during warm and hot forging. To extend the life of a die, it is essential to choose the right substance, hardness, and coating. According to recent studies, ceramic dies and different surface treatment methods can increase die life at a reasonable expense in some applications. Due to their improved wear and fatigue resistance, surface treatments are necessary to extend the in-service lifespan of hot forging dies.

Key words: HotForging Process, Forging Die, Die life, Die Material, Surface Coating

I. INTRODUCTION

The metal forming process known as forging involves applying forces to the material such that the stresses induced in the material are greater than the yield stress and less than the ultimate stress. This causes the material to deform plastically, which can then be used to alter the shape of the component.Metal is pressed, pounded, or squeezed under intense pressure to form forgings, which are highly durable parts. This manufacturing method is known as die forging. Forging holds a unique position among all manufacturing processes because it creates parts with excellent properties. Additionally, forging produces superior-quality goods with the least amount of material loss.

Forging involves delivering an impact force or a gradual load to the material to cause deformation. Forging is divided into two categories: press forging and hammer forging. Press forging involves progressive loads, whereas hammer forging involves impact loads.Forging is divided into three categories: open die forging, impression die forging, and flashless forging depending on the character of the material flow and the constraint on flow imposed by the die/punch.

An open die forging process called upsetting involves subjecting the billet to horizontal flow by the flat die and punch. Friction causes a non-uniform material movement across the thickness. While the material in the centre flows easily, the material near the die is prevented from flowing. In impression die forging, the work component is imprinted with shapes by the punch and the die. In this procedure, the flow is more constrained. Additionally, flash is created as the extra metal moves out of the cavity. Flashless forging is a process in which the work piece's movement inside the die chamber is completely restricted. There is no surplus material, so there are no flash shapes. Forging without flash requires a great degree of accuracy.Important factors include final product volume and die cavity design.

Due to their capacity to maintain their hardness at high temperatures while possessing sufficient strength and toughness to resist the stresses imposed during forging, hot work die steels are primarily used in hot and warm forging. Other materials like ceramics, carbides, and super alloys have also found some cost-effective applications, though these uses are constrained by the prices and design requirements. Vanadium enhances wear and thermal fatigue characteristics, while molybdenum increases resilience to thermal softening. Because they are not thermal shock robust, tungsten alloy steels shouldn't be briefly cooled with water.

It has been noted that the die life is shorter for titanium alloy casting than it is for their metals. Here is due to its low hot working temperature and poor forgeability. As is common knowledge, one of the main materials used in the casting industry is titanium alloy. They are employed in industrial, medical, architectural, and aerospace uses. The technique chosen to increase die life was to change the material of the die. For a reasonable die life, the right substance choice is essential.

II. METHODS OF IMPROVING FORGING DIE LIFE

1) Change in die material

It has been noted that the die life is shorter for titanium alloy casting than it is for their metals. This is as a result of its low hot working temperature and poor forgeability. As is common knowledge, one of the main materials used in the forging industry is titanium alloy. They are employed in industrial, medical, architectural, and aerospace uses. The technique chosen to increase die life was to change the material of the die. For a reasonable die life, the right substance choice is essential.

The EN24 die substance was swapped out for DIN2714 as part of this task. The industry's latest preferred die material is EN24. A Cr-Ni-Mo-V alloy with exceptional hardness and wear resistance is DIN 2714. [1]

Table 1: forging cycle (EN24) [1]

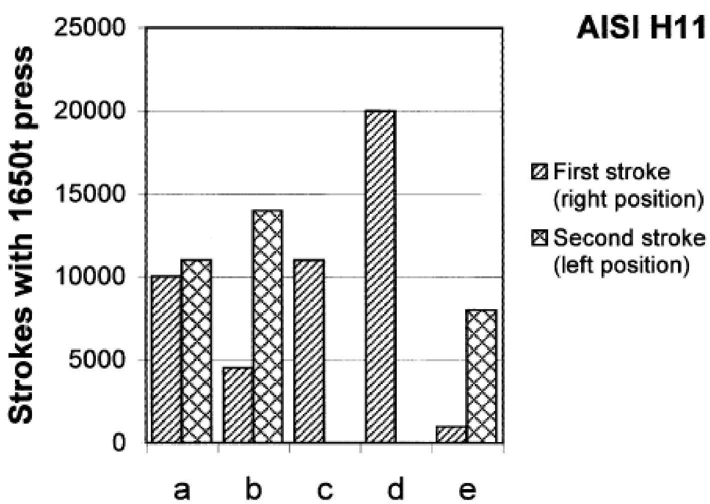
Job	Die material	Number of forging cycles Completed
TITANIUM	EN24	132 84 99 120 294
		Total = 729

A new forging die made to DIN2714 specifications was created and compared to EN24. In the instance of forging titanium alloy, the comparison was based on the number of forging cycles completed without failure. Tables 1 and 2 demonstrate the number of forging cycles completed using EN24 and DIN2714, respectively. The lifespan of dies is significantly influenced by the hardness of the die substance. The hardness of DIN2714, 360 HB, is higher than that of EN24. [1]

Table 1: forging cycle (DIN2714) [1]

Job	Die material	Number of forging cycles Completed
TITANIUM	DIN2714	480 660 600
		Total = 1740

2) PVD coatings and duplex treatment



Number of strokes with AISI H11 hot forging die after various surface treatment in two-step forging of steel components: a. Tenifernitriding b. duplex treatment c. Tenifernitriding, insert only d. duplex treatment, insert only e. BALINIT FUTURA coating only. [2]

In the production of steel components, the duplex treatment applied unquestionably increased the service life of hot forging dies, particularly in the second stroke when cutting-off flash and calibrating the final size. We need to increase the plasma-nitrided diffusion depth to 150-200 µm and use a 6 8-µm-thick FUTURA coating in order to succeed in the first stroke, where the most aggressive wear occurs during the forging of hot billets at 1100Cº. [2]

3) Layers combining hardfacing and nitriding

The enhanced wear resistance of these layers results from the combination of advantageous materials during hardfacing and nitriding treatment. On examples of hot-work tool steel (H11), tests were carried out. [4]

These samples received three layers of hardfaced coating, each composed of two different materials (Robotool 46 and HardfaceVMolc powder wires). In order to achieve a diffusion layer without a whitish zone of nitrides on the surface, samples of both materials were then nitrided using ZeroFlow gas nitriding technology. The characteristics of hardfaced layers and hardfaced layers that had undergone nitriding treatment were the subject of the following investigation. [4]
The experiments that were run included tribological tests, observations of the microstructure, measurements of microhardness as a function of distance from the surface, and X-ray diffraction measurements of stresses in the surface layer. The findings of the tests conducted indicate that hybrid layers that combine hardfacing and nitriding may be useful for extending the life of tools used in hot forging processes. [4]

Hardfacing of forging dies using fluxcovered electrodes can be effectively replaced by the FCAW-S method, which uses self-shielded powder wires and is distinguished by high precision in layer bead (pass) laying and high efficiency of the hardfacing process. [4]

Based on the findings, it can be said that plasmanitriding of AISI-H13 steel enhanced the material's surface characteristics. Approximately 1300 HV0.1 of surface hardness is attained after 8 to 10 hours of plasma-nitriding at 470°C. [7]

The substance had a hardness of roughly 550 HV0.1 when it was received. Under the stated experimental circumstances, plasma nitriding this material produced a diffusion layer only, not the white nitride layer. Therefore, plasma nitriding in these circumstances was a diffusion-controlled procedure. Hot-forging dies with plasma nitriding have maximal lives that are more than eight times longer than those of the dies that were originally received. [7]

4) The surface treatments

The same circumstances were used to examine a single layer of aluminium titanium nitride (AlTiN), a special multilayer coating known as TOKTEK (trademarks of the Teknoplasma, Industry and Trade Corporation), nitriding, and the weld overlay coating of the contact surface of the hot forging dies. After that, the outcomes were compared to the die that had been received (uncoated). [5]

In this study, four different kinds of surface-treated dies and an untreated die were compared in terms of polishing life, die service life, and die cost per part. Following analysis of the actual forging methods used in this work, the following conclusions were drawn.

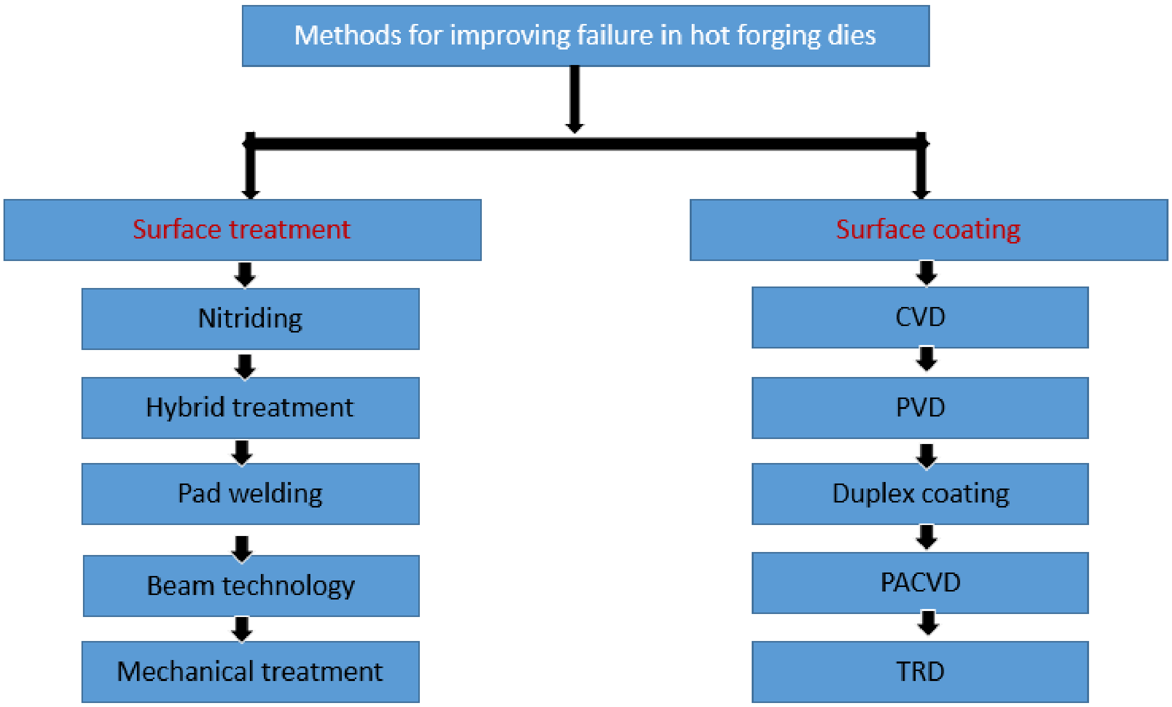
Weld overlay coated dies produced the best outcomes for die service life. The findings revealed an increase of 892% when compared to dies as received. The outcomes outperformed TOKTEK coatings, which took second place, by 206%. [5]
The dies can be categorised as weld overlay coated, layered TOKTEK coated, single layer AlTiN coated, plasma nitrided, and as received dies, going from best to worst. With the exception that it is the same for AlTiN and TOKTEK coatings, this spectrum also applies to the die polishing life. When determining the type of coating to be applied, the total quantity of forging must also be taken into account. [5]

The total quantity of forging must exceed the figure determined as the break-even point. When surface preparation techniques are used correctly, die life is significantly improved while product costs are significantly reduced.

The surface treatment technique and the total quantity of forging determine how much money can be saved on die life and product costs.

Alternative die materials, like ceramics and carbides, which are used in forging tooling mainly for their ability to maintain hardness at high die surface temperatures, have seen some success in certain applications. The use of alternative die materials has been studied in studies that have been published in the press. Additionally discussed were methods for surface treatment like nitriding, weld overlays, and ceramic coatings. [8]

5) Methods of hot forging tools (dies)



Fir. 2 Current methods for preventing failures in hot forging tools

Surface treatment and surface coating are two different kinds of surface engineering techniques needed to increase the durability of hot forging tools.

Numerous techniques, including nitriding, hybrid treatment, pad welding, beam technique, and mechanical treatment, are used to implement this technique. Another research introduces nitriding as one of the most affordable and widely used technologies for implementing thermochemical surface treatment. [6]

6) Frederick W. Taylor determined a relationship between cutting speed (V) and tool life (T)

This formula of: V x Tn = C [9]
Equation A.1: Taylor's Tool Life Formula

This formula determines the tool life and is dependent upon the constants n and C. Graphed on a log-to-log graph this relationship provides the user with a linear relationship and an approximate time length till tool failure. This basic form of Taylor's original study can be expanded to include more effecting variables and take on the form:

V x Tn x fn1 x dn2 = C [9]

Equation A.2: Expanded Taylor's Tool Life Formula

In this expanded version, (f) represents the feed rate, and (d) represents the depth of cut. Both are raised to individual constants. Using this basic strategy a forging die life formula can be created.

As an example:Nf = P + Td n1 + Twp n2 + Vn3 + Hn4 + tn5…… [9]
Equation A.3: Example of Die Life Prediction Formula

(P) = Forging Load
(Td) = Temperature of Die
(Twp) = Temperature of Workpiece
(V) = Velocity of Dies
(H) = Hardness Ratio of Dies
(t) = Forging Process Length
(Nf) = Cycles till Failure [9]

7) Improving die life and material utilization during hot forging Through finite element simulation

The project entails examining how effective die stresses are initially impacted by friction, work part temperature, die temperature, and forging press stroke speed. We look at the temperatures of the die surfaces, the sliding speeds between the die and the workpiece, and the contact pressures. Transvalor Forge2009 software was used to replicate the forging die after it had been modelled using Unigraphics NX6 solid modelling software. A forged differential cover with a 6-inch diameter was the subject of the evaluation. The findings of a few simulation iterations revealed that it was possible to reduce the stress values during forging operations by 20% while also minimising die wear. [10]

CONCLUSION

The forging industry has expressed a strong interest in improving the tooling used in hot forging processes due to new demands on high productivity and expense reduction in forging processes.The businesses gain significantly from even minor advancements in this area.When surface preparation techniques are used correctly, die life is significantly improved while product costs are significantly reduced. The surface treatment technique and the total quantity of forging determine the amount of die life and product cost savings.The methods of increasing durability are classified into two basic groups: surface treatment (nitriding, hybrid procedure, padwelding, beam technology, and mechanical treatment) and surface coating (CVD, PVD, duplex coating, PACVD, and TRD). Based in material a new forging die made to DIN2714 specifications was created and compared to EN24 and other surface treatment methods to improve the life of forging die.

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