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Optimizing Die Life in Hot Forging: A Comprehensive Review of Improvement Methods

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Abstract

The wear investigation on die inserts utilized in the hot forging method to create a yoke-type forging – an element that makes up passenger car steering systems – is presented in this paper. To provide a quick and accurate wear examination of the forging tools (of complex forms), the investigation used an innovative reverse scanning technique that eliminates the need to remove the tools from the producing unit. The study is based on evaluations (scans) of forgings that are routinely gathered from the process and serve as a practical tool for testing and characterization. Apart from the industrial bending process, a new lubrication-cooling system has been developed to investigate the impact of lubrication quantity and duration on tool wear and to identify the optimal lubrication parameters to ensure forging process repeatability. Additionally, by offering a new forging and stabilizing procedure for the lubricating and cooling devices, the preliminary results demonstrate the potential for employing an expanded method to study the lifespan of forging tools, including those with complex shapes. The study's findings indicate that the inverse scanning approach allows for realistic real-time control over the forging tools' condition. Additionally, the apparatus is made to choose while offering the best tribological conditions for the procedure. Both suggested strategies ought to have a favorable effect on raising manufacturing output and lowering the cost of production.

Keywords: 3D reverse scanning, cooling-lubricating devices, wear, hot die forging

INTRODUCTION

The relatively low durability of forging castings, punches, and equipment used in industrial hot forging operations directly affects the cost, as well as the accuracy of forging manufacturing [1]. The primary and most prevalent damaging processes are thermal [5–7] and chemical–mechanical fatigue [8], mechanical fatigue cracking, abrasive wear, and plastic deformation [5, 6]. One of the most challenging production processes is hot die hammering. The tools are exposed to extremely high cyclic thermal loads during hot forging, with temperatures ranging from 80 to 800 °C and structurally reaching up to 1200 MPa. Because of this, the product's geometry is impacted by the wear of the forging tools and the remaining equipment, and any surface faults (cracks, blemishes) in the tools pass through to the forged goods [9], lowering its level of quality.

Analyzing tool wear is a very challenging process. The wide adoption of CAD/CAM/CAE and FEM tools [10] for the study and improvement of forging technologies, particularly for durability increase, is a result of many factors influencing the accuracy of the forging process, and therefore, the tool lifespan. These days, some R&D centers and scientific research organizations use a thorough method to evaluate the lifespan of the forging equipment [11, 12]. Typically, each factor's impact on the tool's durability is examined independently. A comprehensive study of the tool lifetime is made possible by the application of a systematized

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approach. Such an all-encompassing strategy means carrying out several tests. Unfortunately, these evaluations take a lot of time and are sometimes quite costly. For this reason, strategies that are fast, useful, and offer the most crucial information regarding deterioration are sought for or selected [9, 13].

RESEARCH METHODOLOGY

The study examines the damage of die inserts used in the creation of yoked forging, a crucial component of motor vehicle steering systems. There were two phases of this study.

To investigate and analyze how the amount and type of lubrication affected the forging tools' functionality, the first step was to design and build a unique lubrication and cooling device. In the study's second phase, the status of the die inserts utilized for complicated forgings was practically assessed employing the proposed 3D reverse scanning procedure (Figure 1(a-b)).

Figure 1. (a) The industrial forging process.

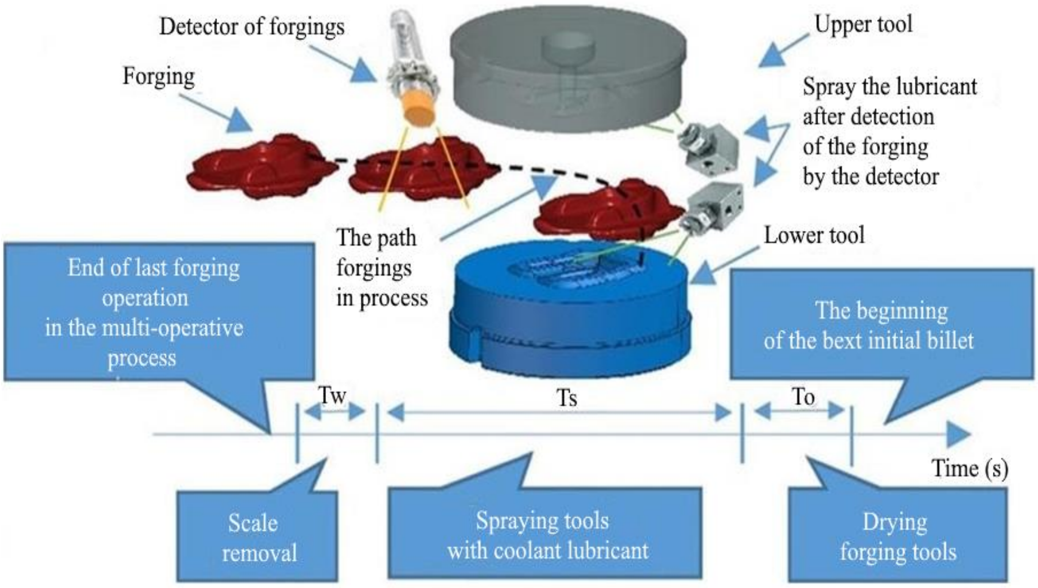

Figure 1. (b) The working cycle.

To measure the condition of the forgings [14, 15] and the wear progress of the forging instruments [12, 16], there is a discernible expansion of interest in contactless measurement techniques using a measuring arm with integrated 3D scanners. For the purpose of a quick examination of the heavy parts without tool disassembly or production stops, such methods are very practical because they allow for high mobility and simple relocation of the testing stand within a production plant, directly into the tested object (for example, from a laboratory to a forging unit). Measuring arms are an approach to the coordination of measuring devices in applications that allow for low measurement precision, given their mobility and universality. Surface defect analysis used to assess the wear of nitride forging tools or hybrid varnishes is an example of a 3D scanning technology [12, 16]. The idea of a contactless measurement for checking the condition of tool wear during the trimming and cold hole-punching operations was examined by the authors in earlier works [14]. Based on observations of forgings that were periodically collected from the production line, the authors measured the wear of a few axisymmetric forging tools (of a simple shape). They also confirmed these measurements by quickly analyzing the tool's condition during brief scientific breaks [12]. Additionally, it should be remembered that a specific destructive mechanism cannot be determined by measuring certain geometric parameters during the usual quality control of the dies at the end of their work cycle. The amount of abrasive wear on the forging tools is seldom indicated by such obtained information. A Massey press with a nominal pressed force of 13 MN is used to carry out the yoke forging procedure. Every instrument is heated to roughly 200 and 250 degrees Celsius. WCL or Unimax steel is used to make die inserts. They have a hardness of 48–52 HRC with the heat treatment. The preparatory and finishing tools are lubricated with aqueous graphite to ensure that the material deformation is as consistent as possible within the whole volume. As a component of steering gear, yoke-type forgings (made of C45 steel) are a crucial safety component in a vehicle. Because of their repeatability, they need specific monitoring and attention during fabrication [17–20].

To increase the lifespan of these things, several methods and approaches are now used such as the introduction of new substances for tools (hot-working steel) and adjusting the friction conditions (lubrication system optimization).

The dosing pump's timing of operation is altered to regulate the liquid phase content of the cooling and lubricating mixture. To keep the lubrication settings stable, the gadget features an extra container filled with pure water. Additionally, the system has an anti-sedimentation mixer that helps maintain a stable graphite suspension in the water consistently. The apparatus operated quite satisfactorily under industrial situations according to preliminary tests [21–25].

RESULTS AND DISCUSSION

Both the novel system developed by the authors and the financing system already utilized at the foundry were used to conduct a comparative analysis. Unimax steel and 1.2344 steel (WCL) were selected as the two tool materials. Following initial testing, two fluid doses – 8 ml for lower tools and 12 ml for upper tools – as well as a blowout time of two seconds were selected for the new greasing system. The lubricating nozzles have been left in the same location to get similar characteristics of the way the system works. Figure 1 presents an overview of the variations of the Additionally, it is evident that strengthening the lubricating conditions for the tool – in the case of the WCL steel inserts (Figure 2– caused specific changes in the wear in particular tool locations. For instance, wear was seen in the places where the forging's "arms" were manufactured for the tool depicted in Figure 2, while no wear was visible in this area for the tool shown in Figure 2 (with the outdated lubricating system in use). This indicates the necessity for additional studies pertaining to other lubrication-related characteristics, as well as further optimization of the fluid dosage, direction, and frequency of application. The use of the novel lubricating device greatly decreased wear in the Unimax steel inserts as well, although it had no effect on the shift of the worn tool regions. Conversely, when comparing the types of tool materials used for the inserts, it is evident that Unimax steel Figure 2 provides superior wear protection than WCL steel Figure 2. The use of the new lubricating devices and the use of Unimax steel as the metal for the tool are the greatest solutions, according to the analysis of the given information.

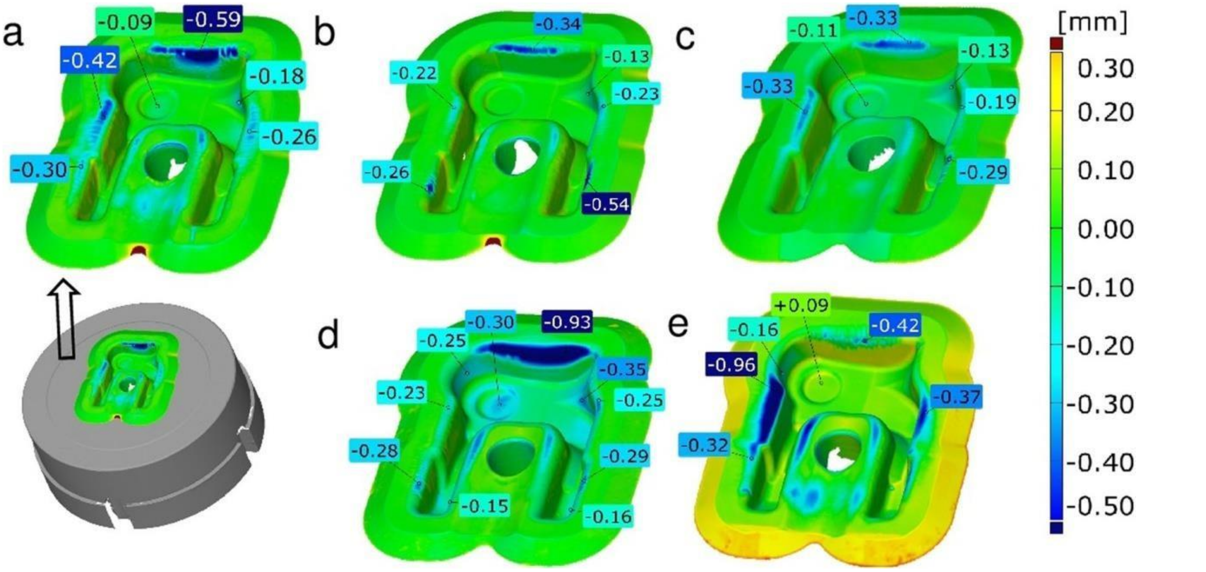

Figure 2. Scanning results for a WCL insert after 9000 forgings with the old lubrication system.

The complex and partially extended reverse scanning approach was used to track the wear history of a single die insert Figure 2. Up till now, the process has been effectively applied to uniaxial structures with significant material loss values and generally fundamental forms [12]. Such an examination is considerably more difficult in the case of a yoke-type forging. The forging's non-repeating shape and the scanned object's small size compared to the measuring accuracy of the scanners currently in use, such as the RS3 scanner integrated with the 7520si ROMER Absolute measurements arm (scanning system accuracy according to the B89.4.22 standard equals 0.053 mm), are two of the explanations. The technique used by the study's authors involves using a scanner in the shape of the tools for determining the increasing wear of the chosen forging tool.

Referred to as the scan of the 100th forging, it exhibits chosen scans of the forgings (every 2000 items) in the form of a change in the determined surface's shape. The findings show the instrument is gradually wearing down. An analysis at the interval equivalent to the frequency with which the forgings are gathered is made feasible by such a simulation of the wear path. The acquired findings are consistent, indicating that it is possible to do a suitable study of the increasing wear of forging tools, including those with challenging forms. Underfills are shown by the appearance of "blue" patches in the stem portion of the forging, which can be seen by an exhaustive local study of what was found.

This may indicate problems committed during the forging process, such as inadequate lubrication (not absorbed lubricant), which might lead to the Rebinder effect [10]. The study that applies to the evaluation of the volume change occurring during the die wear process is the amplification of the technique for evaluating the wear of forging tools based on the measurement of the steel forgings. By observing the volume changes in the forging process, this method allows for a comprehensive and worldwide description of mineral loss. To compute the volume changes based on the scans of the subsequent forgings compared to the scan of the 100th conventional forging, the analysis employs an algorithm that allows for the calculation of the volume in the chosen sections of the forging. In fact, minimum quadrangular prisms with a base of 0.01 mm may be used to fill the spaces thanks to the Poly Works utility.

CONCLUSION

Two unique solutions used in the commercial method of creating a yoke-type forging are covered in this article. One of these is the 3D reverse scanning method, which uses periodically collected and examined forgings to ensure ongoing (practical and quick) control of the state of the forging tools of complex shapes performed during this procedure, as well as a detailed reconstruction of the history of tool wear without the need to dismount the tools from the machine room. The development and construction of a system of lubrication that guarantees a precise dosage and application frequency of the lubricating agent, whose introduction into the industrial forging operation provides repeatable and stable tribological conditions resulting in an additional increase of the tool life, is the other suggested solution. For both the selected device fragment and the entire die insert, both solutions have been used in the analysis of die insert wear (differing in the number of produced forgings and the tool material, as well as in reference to the use of the old lubricating system and the one designed by the authors). The measurement of the forging volume variances in the final forging operation, regarding the die insert, after the same number of forgings produced, has been used to validate the results. The validity of the lubricating system’s insertion into the exact forging process has been verified, and the measurement results have shown a very high degree of agreement. The employment of Unimax steel as the tool material and an innovative lubrication device, which ensures improved and reproducible lubricating conditions, is the best way to increase tool longevity, according to the conducted analyses. The test results that have been treated as given are obviously significant to the industry. It appears that each of the suggested solutions offers quantifiable and useful perks, and that more research in this field is essential.

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