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Quality optimization for aluminum precision forging processes in completely enclosed dies of long forging parts by prediction and avoidance of thin flash generation

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Abstract

The technology of flashless precision forging enables the manufacturing of complex shaped high strength parts by a cost and material efficient process. Due to geometrical tolerances and complex thermal expansions of the tool elements, small gaps must exist between punches and dies even in precision forging processes. In hot precision forging processes material flows into these gaps unintendedly and the so called thin flash generates. The generation of thin flash in a forging process complicates workpiece positioning in subsequent forming processes and leads to positioning and tolerance defects in subsequent cutting operations.
In this paper, the investigation of thin flash generation in a precision forging process of an aluminum long part using finite elements analysis (FEA) and corresponding forging trials is described. For this purpose, the forging processes were varied by use of different preforms with equal volumes but different mass distributions, while the geometrical parameters of the final part were not varied. The forging processes were analyzed by FEA with focus on the value of the form-filling simultaneity depending on the preform geometry. Afterwards, corresponding forging trials were carried out for validation. The experimentally forged parts were analyzed concerning the amount and location (part area) of the generated thin flash to validate the FEA results. The results of the experiments and the FEA showed good agreement concerning the part areas were thin flash generation was predicted by FEA and actually occurred in experiments. It was shown, that the preform geometry strongly influences the generation of thin flash. Preforms with higher values of form-filling simultaneity showed less thin flash generation while preforms with lower values of form-filling simultaneity showed significantly increased thin flash generation. Based on the results, it is very likely that by using a preform geometry, which would lead to a complete simultaneous form-filling, thin flash generation could be completely avoided under ideal technical conditions.

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Keywords: Forging; aluminum; FEA; thin flash generation; prediction

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1. Introduction and state of the art

The technology of forging is generally used for the production of parts with a high strength in production processes with output in high quantities [1]. Flashless precision forging enables the manufacturing of complex shaped high strength parts by a cost and material efficient process. An increased material utilization, an increase of geometrical and surface part tolerances, a reduction of the die wear, the elimination of a subsequent trimming step, as well as a reduction of subsequent cutting operations are main advantages of precision forging processes [2, 3].

Aluminum forged parts provide good mechanical properties, combined with a perfect flow line distribution and a high accuracy. Therefore, they fulfill the requirements of lightweight [4, 5]. Hybrid parts made of two different steels or steel and aluminum will be forged in the near future [6]. Behrens et al. successfully showed flashless forging of complex shaped steel parts [7].

In flashless precision forging processes of steel and aluminum as well, the forging tools include die gravures that almost completely enclose the work piece. Punches move into the dies and carry out the forming of the work piece. Due to geometrical tolerances and complex thermal expansions of these tool elements small gaps must exist between punch and die. In hot forging processes material flows into these gaps unintendedly and the so called thin flash generates [2].The generation of thin flash in a forging process complicates workpiece positioning in subsequent forming processes and leads to positioning and tolerance defects in subsequent cutting operations. Tool concepts to prevent the flash generation with moveable flash gaps were investigated by Behrens et al. [8]. In aluminum forging, the generation of thin flash is more likely as in steel forging. Thin flash generation in aluminum forging is not predictable yet nor is it preventable with existing tool concepts. Some parameters have an influence on thin flash formation, e.g. gap size, and can change during the production of a batch. This complicates the prediction of thin flash [2]. Hence, a flashless hot forging of aluminum parts is not possible nowadays. Knowing the amount and exact location of thin flash generation, could provide the possibility to design a completely flashless forging process in the future.

This paper describes the investigation of a precision forging process for an aluminum long part by finite elements (FE) simulations and experimental forging trials considering the amount and location of thin flash generation. The forging process under investigation was varied by use of different preform geometries with equal volumes but different mass distributions, while the geometrical parameters of the final part were not varied. By use of different preforms, the material flow in the form-filling process can deliberately be influenced. The form-filling behavior, and thus the value of form-filling simultaneity is depending on the geometrical relation of the used preform for a specific final-forged part. Therefore, the value of form-filling simultaneity can be influenced by variation of the geometry of the preform. The research hypothesis is, that by achieving a time-simultaneous form-filling in every area of the final part, thin flash generation in precision forging processes can be completely avoided. For an invariable final-part geometry an adjustment of the preform geometry concerning an increased value of form-filling simultaneity is expected to lead to a significant reduction of the occurring amount of thin flash, while preform geometries with decreased value of form-filling simultaneity are expected to lead to a higher amount of thin flash generation. The investigation of this hypothesis is the research goal of this paper. Therefore, a given reference preform related to a specific final geometry was on the one hand changed to provoke a higher value of form-filling simultaneity (less thin flash), and, on the other hand changed to provoke a lower value of form-filling simultaneity (more thin flash). FE simulations with focus on the value of form-filling simultaneity depending on these three preform geometries were carried out for the same final part geometry. Corresponding forging trials were performed to analyze the amount and location of the thin flash generation in different final part areas.

2. Investigation of a precision final forging process of an aluminum long part using different preform geometries by FEA and experiments

2.1. FE simulation setup

In this research paper, the analysis of a one step precision forging process of an aluminum long part is presented. Therefore, FE simulations of this process were carried out. In this chapter, the simulation model and its parameters are described.

The simulations were done by use of the FEA-software FORGE NXT 1.0 using the press kinematics of a hydraulic press