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Numerical Investigation for the Design of a Hot Forging Die with Integrated Cooling Channels

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Abstract

Ongoing research at the Institute of Forming Technology and Machines (IFUM) within the scope of sub-project E3 of the Collaborative Research Centre 653 deals with the generation of controlled cavities inside a sintered hot forging die. The primary objective of sub-project E3 is to develop a forging die which can “feel”, “learn” and “control” autonomous reactions to process variations. The current project stage aims at developing a hot forging die with integrated cooling channels.

This paper presents the findings of numerical investigations carried out to analyze the hot forging die made of tool steel powder and equipped with internal cooling channels. Two different geometric variations have been numerically investigated in order to study the stress states within the die under process boundary conditions.

Keywords: powder metallurgy; cooling system; thermo-mechanical simulations; hot forging; numerical simulations

1. Introduction

Powder metallurgy has gained a significant importance in the metal processing industry in the recent years. It is known for its high potential for producing near net-shape products. Higher percentage of material utilization and comparably lower energy costs allows powder metallurgy to fulfil the requirements of modern manufacturing

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processes. The Collaborative Research Centre 653 “gentelligent Components in their Lifecycle” aims at devising methods and techniques for manufacturing machine tools that can control themselves. The primary objective of sub-project E3 is to develop a forging die which can “feel”, “learn” and “control” process variations. In the ongoing project stage, the objective is to develop a hot forging die with integrated cooling channels as well as slots for fiber optic temperature sensors and a stab to induce a cooling effect in the die center and mandrel by conduction. Figure 1 shows the schematic of such a forging die.

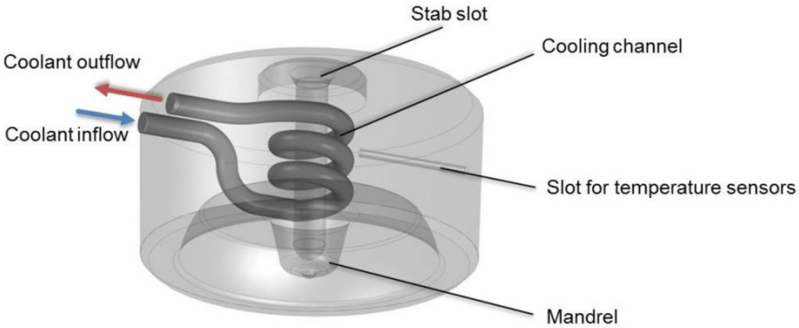

Figure 1: Forging die with integrated channels

Forging dies undergo high thermal and mechanical loads. Besides mechanical tool failures, variations in temperature also influence the die curvature and consequently part accuracy. The thermal load of a tool is mainly influenced by the forging temperature, forming rate, amount of friction, cycle time and heat flow caused by convection and radiation [1]. Lubricants and a spray cooling system help against these thermal loads to keep the basic temperature steady [2]. A supplementary cooling system based primarily on the concept of internal cooling channels in the areas with high thermal stresses is the focal point of this work. The channels will accommodate the cooling medium whose temperature is to be regulated by means of an external temperature control system. Temperature sensors can be integrated by application of fiber optic sensors hence enabling continuous temperature measurement along the length of the die. Based on these measurements, the temperature of the cooling medium can be regulated as per requirements.

Previous works by the authors present the preliminary work in this regard [3]. The present work deals with a numerical analysis of two different geometric variations of the said die in order to study the mechanical strength of the die, in particular the cooling channels, under operating conditions. Figure 2 presents concept diagrams for both of the variations. Left (Model A) is a die with integrated channels only whereas the right-side figure shows the variation with an additional vertical stab slot at the center (Model B). As mentioned earlier, this slot is designed with an aim to further extend the cooling effect to the mandrel by means of a high conductivity insert. The slot for the temperature sensors as shown in Figure 1 is omitted in the numerical analysis during this work but will be considered for the future investigations once the design of cooling channels is finalized.

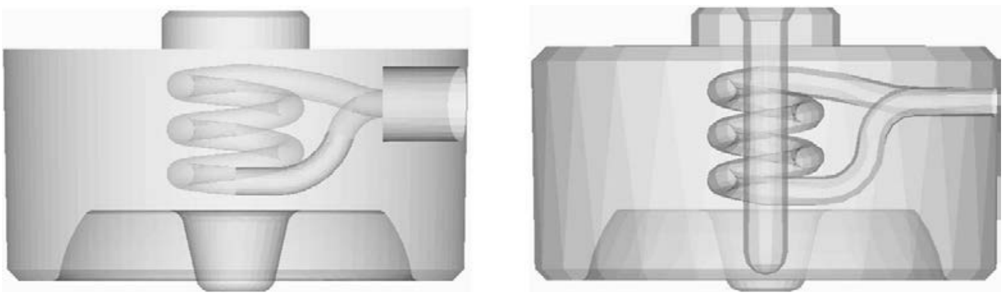

Figure 2: Geometric variations of the forging die; Model A (left) and Model B (right)