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Development of a powder metallurgical self cooling forging die with inner cavities

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Abstract

Powder metallurgy is known for its high potential for producing near net-shape products. A material utilization of up to 95 %, paired with comparably low energy costs, allows powder metallurgy to fulfil the requirements of modern manufacturing processes. By combining different powders, a wide range of products can be manufactured. An innovative powder metallurgical method currently being investigated at the Institute of Forming Technology and Machines (IFUM) within the subproject E3 of the Collaborative Research Centre 653 is the generation of controlled cavities inside a sintered part. For this purpose, a foreign element with a lower melting point than the base powder is embedded inside the green body. Depending on the sintering temperature, the foreign element can be firmly bonded with or melted out of the base powder, creating a defined cavity. Being attached to an external cooling system, the cavity can be applied as a closed circuit for circulating a cooling medium within the tool. The approach in this work is the development of a sintered forging die, equipped with an active temperature regulation which can react autonomously to process variations. The cooling temperature is controlled by measuring the operating temperature within the forging die. For measuring purposes, the cavities can also be used for integrating temperature sensors. The main aspect of these studies is the characterization of the compaction and melting behavior of the foreign material. Since the location of the foreign element within the base powder can differ due to the pressing force, the prediction of its final position based on the initial position and the process conditions is of high importance. For this aim, numerical simulations are employed to develop an optimized cooling layout. A numerical model is used to describe the compaction behaviour of the powder as an elastoplastic compressible continuum and its interdependency with the integrated elements. The studies also cover the influence of surface contours of the foreign elements (corrugated, plain) on their melting behavior as well as the resulting inner surface of the cooling channel.

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1. Introduction

Sub-project E3 arose from the Collaborative Research Centre 653 which mainly deals with “gentelligent components in their life cycle”. The aim of sub-project E3 is to develop a forging die which can “feel”, “learn” and “control” autonomous reactions to process variations. In the current early stage of the project (project start third quarter 2013) mainly preinvestigations and feasibility analysis were carried out. Furthermore, an outlook on future investigations is given (project end second quarter 2017).

Forging dies underlie high thermal and mechanical loads. Besides additional mechanical tool failures, varying temperatures also take influence on the gravure and as a consequence on the part accuracy. The thermal load of the tool is mainly influenced by forging temperature, forming rate, amount of friction, cycle time and heat flow caused by convection and radiation [1]. To counteract these thermal loads and hold the ground temperature steady, lubricants and spray cooling systems are applied [2].

The aim of this work is to provide a supplemental cooling system, besides a conventional spray cooling system, for thermal highly stressed areas by using internal cooling channels. The channels will accommodate the cooling medium which is pumped through the die body. The temperature of the cooling medium is regulated by means of an external recooling/heating aggregate. The channels can also be used for integrating temperature sensors. A possible solution is to apply fiberoptical sensors which enable continuous temperature measuring along the channels (Fig. 1). Based on the temperature measurements, the temperature of the cooling medium can be regulated in different directions (higher and lower).

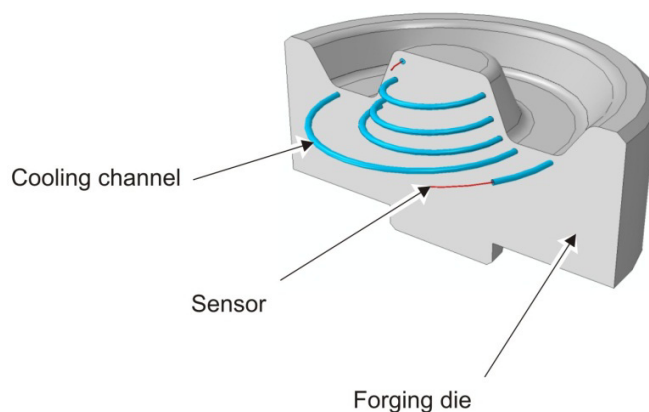


Fig. 1. Forging die with cooling channels and temperature sensor.

An effective temperature balance of forging tools results in an improved lifetime and higher part accuracy. A defined internal cooling system already exists for injection molding and pressure casting processes. The advantages are shorter cycle times, stable processes and higher accuracy [1]. These advantages have to be taken into consideration for designing the forging die, especially if highest accuracy is required. MUESSIG points out in his research when using a forging die equipped with drilled and milled cooling channels that the ground temperature of the die can be held constant by using tempered dies. Without a tempered die, failures can occur especially during starting times, process variations and after interruption, see Fig. 2 [1].

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