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Tribological Modeling in Hot Stamping Processes: Prediction of Tool Wear and Tool Lifetime on Industrial Scale

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Abstract

Severe abrasive wear is an unwanted phenomenon which occurs widely during hot stamping processes due to extreme process conditions like high temperatures and the absence of lubrication. Abrasive wear is a form of tool wear in which material is removed from the tools, changing the geometrical characteristics of the tools. In a longer term, abrasive wear can negatively affect the shape of formed parts and can influence the heat transfer between the tools and the sheet. Therefore, it is important to develop advanced tools to predict and control abrasive wear during hot stamping processes. More recently an advanced friction model for hot stamping processes has been introduced to accurately describe frictional behavior of 22MnB5-AlSi. This study aims to further extend the advanced friction model of 22MnB5-AlSi into an abrasive wear prediction tool by evaluating a number of abrasive wear models. Three dimensional tool scans of an industrial part are used to calibrate the abrasive wear models. This resulted in a multi-dimensional abrasive wear model as a function of temperature, pressure, strain and the cumulative sliding distance in contact between the tool and the sheet. The abrasive wear distribution and tool lifetime predictions are evaluated based on an industrial part from Volvo Cars. The abrasive tool wear locations are properly identified on the dies and a good correlation in tool wear severity could be made. However, the evolution of abrasive wear in less severe areas should be further investigated to increase the prediction capability of the proposed tool wear model.

1 Introduction

Hot stamped parts in body-in-white applications are of a great interest due to their superior mechanical properties [1]. A commonly used material in direct hot stamping process is the ultra-high strength steel 22MnB5 with an aluminum silicon (+AlSi) coating to improve its corrosion resistance. For the tooling, tool steel material with a coating layer to improve wear and frictional behavior is often utilized, which together with the 22MnB5 (+AlSi) form the most commonly used tribology system for hot stamping processes in the automotive industry. However, one of the known issues during hot stamping processes is abrasive tool wear, a form of tool wear in which material is removed from the tools [2,3].

Tool wear occurs due to extreme process conditions during hot stamping with very high temperatures and the absence of lubrication, leading to material removal from the tools affecting the geometrical characteristics and the tribological conditions [3]. In a longer term, abrasive wear can negatively affect the shape of formed parts and can negatively influence the heat transfer between the tools and the sheet during e.g. the quenching process. These unwanted phenomena cause a disturbance in the production process, as the tooling needs to be repaired or replaced after a certain process duration [1]. Hence, developing advanced models to predict abrasive tool wear in forming simulations can benefit significantly to achieving a better understanding of the process and to optimize the tool lifetime. That is, by knowing the locations and severity of abrasive tool wear, the tool lifetime can be predicted and adaptions can be made to elongate the tool life.

To describe the frictional behavior in forming simulations of hot stamping processes, an advanced friction model has been introduced by TriboForm [4]. This friction model can predict friction under different process conditions such as pressure and temperature and can substitute the conventional constant Coulomb friction modelling in hot stamping simulations [4,5]. More recently, the model was extended to describe galling effects in hot stamping processes, a form of adhesive tool wear where fractured debris from the sheet coating is transferred and adhered to the tool surface [6,7].