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Combined numerical and experimental determination of the convective heat transfer coefficient between an AlCrN-coated Vanadis 4 tool and Rhenus oil

Esmeray Üstünyagiz[a,*] , Chris V. Nielsen[a], Niels S. Tiedje[a] and Niels Bay[a]

[a]*Department of Mechanical Engineering, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark*

Abstract

Regardless of the field of application, the reliability of numerical simulations depends on correct description of boundary conditions. In thermal simulation, determination of heat transfer coefficients is important because it varies with material properties and process conditions. This paper shows a combined experimental and numerical analysis applied for determination of the heat transfer coefficient between an AlCrN-coated Vanadis 4 tool and Rhenus LA722086 oil in an unloaded condition, i.e. without the tool being in contact with a workpiece. It is found that the heat transfer coefficient in unloaded conditions at 80°C oil temperature is 0.1 kW/(m2·K) between the selected stamping tool and mineral oil. A sensitivity analysis of the numerical model was performed to verify the effects of mesh discretization, temperature measurement location and tool geometry. Among these parameters, mesh size and the thermocouple insert depth were identified as the critical parameters that affect the measured and calculated temperatures.

Keywords: Heat transfer, lubricant, numerical simulation, inverse analysis

1. Introduction

In metal forming about 90-95 % of the mechanical energy used in the process is converted to heat[1]. Some of the heat remains in the deformed region and some flows into the undeformed material. The remaining heat flows into the tooling and to the environment[2]. The temperature distribution in a forming process depends on the following points:

- The initial temperature of each part.
- Heat generation due to plastic deformation and friction.
- Heat transfer between the parts.
- Heat transfer between the parts and/or the lubricant and the environment.

Heat transfer across the interfaces depends on the heat transfer coefficient (HTC). For determination of the HTC in unloaded condition, Semiatin et al.[3] used two steel dies with different initial temperatures and brought them together under varying pressures. Burte et al.[4] used ring tests with pre-heated dies to compress 304 stainless steel rings. Two thermocouples were embedded in the lower die with different distances to the die-workpiece interface. The ring compression test was then simulated and the temperature history of the two nodes having the same location as the actual thermocouples was stored. The experimental temperature history was then used to match the numerical results with various HTCs. These studies concluded that the HTC at the contact interface in the free resting condition, i.e. without being subjected to load, is about 1 $kW/(m^2 \cdot K)$. Inverse methods are commonly used by many researchers to

[*] Corresponding author. Tel.: +45254728; fax: +45251960
E-mail address: esustu@mek.dtu.dk