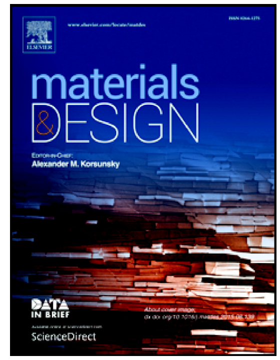
Accepted Manuscript



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PII: S0264-1275(18)30355-1
DOI: doi:10.1016/j.matdes.2018.04.069
Reference: JMADE 3882

To appear in: *Materials & Design*

Received date: 5 March 2018
Revised date: 12 April 2018
Accepted date: 27 April 2018

Please cite this article as: Stano Imbrogno, Sergio Rinaldi, Domenico Umbrello, Luigino Filice, Rodolfo Franchi, Antonio Del Prete , A physically based constitutive model for predicting the surface integrity in machining of Waspaloy. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Jmade(2017), doi:10.1016/j.matdes.2018.04.069

A physically based constitutive model for predicting the surface integrity in machining of Waspaloy

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Abstract
During machining, surface modifications are directly related to the process dynamic affecting the thermo-mechanical properties of the materials. The physics phenomena (such as dynamic recrystallization, hardening and recovery effects) are difficult to be experimentally evaluated during the cutting operations, therefore the simulations are very important tools to understand their evolution. Orthogonal cutting experiments were conducted on Waspaloy under different cutting parameters and lubri-cooling conditions. The machined surfaces were evaluated via optical microscope and the surface integrity was analysed in terms of microstructural changes and microhardness. The deformation mechanisms that occurred in chip formation and on the machined surface were investigated in order to build-up a physically based constitutive model. Subsequently, the developed material model was implemented via sub-routine in a commercial Finite Element software. The numerical prediction strategy was validated through comparisons with experimental outcomes (cutting forces, temperature and metallurgical changes) and employed to predict the variables of scientific interest (microstructural modifications and microhardness). The overall absolute error in predicting the principal cutting force, feed force and temperature were approximately equal to 5%, 9% and 7% respectively. Furthermore, the developed model permits to explore the metallurgical changes and their evolution during the machining process varying cutting parameters and lubri-cooling conditions.

Keywords: Material modeling; Waspaloy; machining; surface integrity.

1. Introduction

The aerospace industries have to guarantee extremely high reliability and duration of the manufactured artefacts, consequently, one of the most important topic of research into this sector regards the prediction of the aero-engine component failure. This latter is extremely hard to be estimated, mainly because a complete knowledge of the material changes happening during all the deformation history of the finished product cannot be obtained only via experimental analysis. Moreover, having a deep knowledge of the microstructural behavior of the material under large deformation process, can lead to the improvement of the mechanical properties. This improvement can be achieved optimizing the process parameters and consequently the thermo-mechanical routes of the worked material.

In the manufacturing of jet engines, the components produced by super alloys represent about 50% by weight. This broad contribution is mainly due to their superior mechanical performances under critical working conditions [1-3]. Although they have superior quality, they usually show poor machinability, indeed these materials are also known as “hard-to-cut” materials. Focusing on nickel-based alloys, the Waspaloy is mainly used in jet engines blades and structural components manufacturing thanks to its superior mechanical properties, high oxidation resistance, stiffness and strength to weight ratio [4]. In last decades, the researches focusing on this material are increasing, mainly because, many efforts are needed to adequately choose the process parameters and lubri-cooling conditions, select the correct tooling, control the machine shop and consequently reduce the work in process [5].

In this context, the numerical simulations lead a significant contribution in improving the product quality by optimization of the manufacturing process parameters, without performing costly experiments. Nowadays