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ORIGINAL PAPER

Investigation on machining of a Ti–6Al–4V alloy using FEM simulation and experimental analysis

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Abstract

Titanium alloys have been attracting from the more industries, especially, industry aerospace due to their very important high strength to weight ratio. Furthermore, they were classified as difficult to machine materials due to low tool life in machining processes. In this study, a FE model has been developed to simulate the turning stage of Ti–6Al–4V alloy. A 3D model with thermo-mechanical coupling has been proposed to study the influence of cutting parameters and also lubrication on the performance of cutting tools. The constants of the Johnson–Cook constitutive model of Ti–6Al–4V alloy were identified using inverse analysis based on the process parameters of the orthogonal cutting. The predictive FE model has been validated based on an orthogonal cutting test. The investigations indicated that this approach estimates the resultant cutting forces with low prediction errors. Indeed, the predicted forces showed good agreement with the experimental data, with minimum and maximum error magnitudes of 2.8 and 8.7% for cutting force, and 1.3 and 6.8% for feed force, respectively.

Keywords Titanium turning · Cutting tools · FE simulation · Chip

1 Introduction

Metal chip removal machining was frequently used in the mechanical fabrication industry [1–4]. It makes it possible to obtain parts of complex shape characterized by a low roughness of the surface states at a fairly low cost, etc. Some alloys such as super alloys-based Cr, Ni and Ti were machined in a conventional manner and lead to rapid wear of the edges of cutting inserts for their high strength and abrasiveness, even at fairly high cutting speeds. Their low thermal conductivity therefore prevents the dissipation of the heat generated by the cutting, which causes a rapid increase in the heat increase of the workpiece [5–7]. This leads to early damage of the cutting insert and directly affects the final quality of the workpiece and its machined surface [8, 9]. Chip formation will affect machining temperature, cutting force, tool life and other cutting process parameters [10, 11]. The selection of appropriate cutting parameters therefore essentially improves the surface integrity induced by machining [12]. Vyas and Shaw and Hua and Shivpuri indicate that the titanium alloy chip segmentation was due to a crack initiation companioned by propagation inside the primary shear zone [13, 14].

In this context, it was interesting to propose a reliable 3D FE model which allows us a better understanding of the cutting insert-part interaction during the machining of this type of alloys. Numerical simulation of machining process and the residual stresses induced by the cutting operation have been investigated by many researchers [15–20]. Li et al. have set up an experimental plan to study the effect of machining parameters and the inclination angle of the cutting tool on the chips formation during the machining of the titanium alloy Ti–6Al–4V [10]. Chen et al. performed a numerical study to analyse the high-speed machining of titanium alloy Ti–6Al–4V using the Johnson–Cook material model coupled with a ductile failure criterion to analyse the process parameters effect on machining on the final morphology of the chips [21]. Takahashi et al. studied numerically analysed the effects of the rotational speed of the workpiece on the

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