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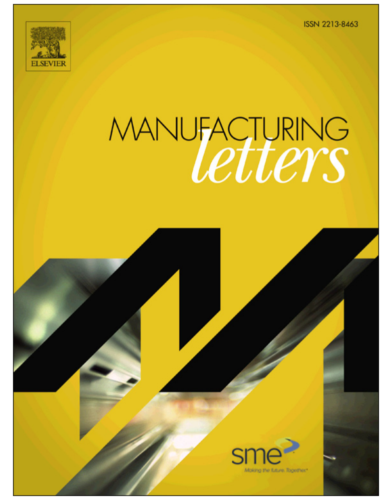

Letters

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Vivek Bajpai, Pankaj Kumar, Vivek Bajpai, Ramesh Singh, Pankaj Kumar, Vivek Bajpai

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BURR HEIGHT PREDICTION OF TI6AL4V IN HIGH SPEED MICRO-MILLING BY MATHEMATICAL MODELING

Dr. Vivek Bajpai[a], Pankaj Kumar[a], Vivek Bajpai[a], Ramesh Singh[b], Pankaj Kumar[a], Dr. Vivek Bajpai[a]

[a]Department of Mechanical Engineering, Indian Institute of Technology (ISM) Dhanbad, India

[b]Department of Mechanical Engineering, Indian Institute of Technology Bombay

KEYWORDS
High speed machining, burr formation in micro-milling, Ti6Al4V, Burr modeling

ABSTRACT

The current work is focused on high speed micro milling of Ti6Al4V. An analytical model has been developed to predict the exit burr height at high cutting speed. The model is validated at two cutting speeds: conventional (85m/min) and high speed (141m/min). Validation showed very small error in the prediction of burr height. The error in prediction of burr height was 3% and 7%. Further, the model was used to study effect of cutting speed on burr height. The burr height is reduced by 90% at 314 m/min compared to 79 m/min cutting speed.

1. INTRODUCTION

Ti and Ti6Al4V alloys are widely used in aerospace and biomedical fields due to its excellent material properties [1, 2]. However, poor machinability, excessive tool wear and burr formation pose additional challenges in micromachining of Ti-alloys. Micro-milling is a key machining process which could be used to create 3D free-form features and, hence, it is used in the manufacturing of micro-parts and micro-scale features in a wide range of engineering materials. Burr formation in micro-milling is the major problem. Burr reduces the quality of the machined product and deteriorates the performance, consequently, burr minimization and burr removal techniques are topics of extensive research. All the mechanical machining process leave burrs on the machined component. However, in micromachining processes, the burrs formed are significantly smaller than the macro- machining process. As a result, the removal of burrs from the small size components becomes very challenging [3]. It is suggested that the small ratio of axial depth of cut to the tool size reduces top burr size [4]. Z. Kou [5] presented a novel method to prevent burr formation in micro-milling process with supporting material method. Improved surface roughness and top burr minimization via process parameters has been achieved [6, 7]. Attanasio [8] analyzed effect of material microstructure on top burr size. A tool modification simulation was developed by Aurich [9] to shows the effect of helix angle on burr formation. Kim and Kang [10] observed that high speed milling not only yields higher material removal rate but also improves the machining accuracy and surface finish. The hinging mechanism for burr formation has been reported by Ravi et al. [11]. This paper is focused on the prediction of burr height of difficult-to-cut material Ti6Al4V in high speed micro-milling process to achieve better control over the micro-milling operation.

2. MATHEMATICAL MODELING OF BURR HEIGHT IN HIGH SPEED MICRO-MILLING OF TITANIUM ALLOY (TI6AL4V)

In the high speed micro-milling operation cutting area and feed per tooth to the radius of the cutter ratio are much smaller than the conventional milling operation. Luiz Carlos da Silva [12, 13] study the burr behavior in face milling of PH 13-8 Mo stainless steel and suggested the indirect method for measuring the height of the burr formed on the exit edge of the work-piece. The micro-milling of titanium alloy Ti6Al4V is a two-fold challenge; one due to unfavorable material properties for machining and another due to downscaling of the process [14]. Therefore prediction of burr characteristics is important to achieve better control over the micro-milling operation. The following section describes an approach to predict burr height for given cutting conditions.

2.1 Geometry of burr formation and mathematical formulation of burr height:

The geometry of burr formation in micro-milling is shown in Fig. 1. According to Ko and Dornfeld [16],
If we assume $d\theta$ and $d\beta$ are very small angles, where, θ and β are tool rotation angle and negative shear angle respectively, then from fig. 1(a) and from triangle $AA'B$ of fig. 1(b),

$$AA' = Rd\theta = l'd \qquad (1)$$

From fig. 1(b), PB is common in both triangles APB and A'PB, therefore, we can write,