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Development of cryogenic assisted machining strategy to reduce the burr formation during micro-milling of ductile material

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ABSTRACT

Micro-milling is an inevitable machining process for the fabrication of products with complex shapes and high dimensional accuracy. However, this process usually needs post-processing operations to remove the burrs formed from the ductile materials. This research work focuses on the development of a micro-milling strategy to suppress the formation of burrs during machining and hence avoid post-processing operations, consequently reducing the cost of the products. During micro-milling, a LN_2 jet was positioned ahead of the tool movement loci resulting in a change of microstructure at the top layer of the workpiece surface, enhancing its mechanical properties with the subsequent reduction of excessive plastic flow during the shearing process. Micro-hardness tests were performed below the top layer to conform the speculation and evaluate the effect of cryogenic treatment and a significant increase in micro-hardness was found. The experimental results reveal a significant decrease in the burrs formation due to the cryogenic treatment with an enhanced machining quality in terms of cutting forces, chip morphology and surface roughness.

1. Introduction

Considering the vast application of the small size and highly precise products in the current industrial scenario, fabrication is a challenging task. Several manufacturing processes such as electrochemical, electric discharge, laser-assisted, etc. [1–3] are applied to make these types of components. Considering the negative impacts of the afore-mentioned methods resulting in micro-structural alterations at the workpiece surface and causing changes in mechanical properties, the trend in manufacturing industries is shifting towards the application of machining with micro-sized tools to fabricate such components [4,5]. This method of machining has been proven to be relatively successful to produce parts with better stiffness, higher production capacity with considerable cost [6]. Theoretically, micro-machining is the down-scaling of the tool size and subsequent reduction of the parameters from the conventional macro-scale machining processes. However, with the reduction of tool edge radius, it becomes comparable to the cutting thickness and in some cases to the grain size of the workpiece material. This leads to the development of factors such as size effect, minimum uncut chip thickness and hence ploughing effect [7]. These factors during micro-machining especially with the ductile materials greatly affect the quality of the production in terms of surface integrity and formation of burrs [7–9]. Several researchers have reported the formation of burrs during micro-machining that is more prominent during the machining of ductile materials [10,11]. This issue of micro-machining needs to be addressed effectively to improve the machining quality.

As per the definition provided by ISO-13715, the overhanging residual material at the edge of the machined surface can be called burrs. Generally, depending on the position of the burrs over the workpiece surface, burrs can be classified as entrance burr, exit burr, side burr, and top burr [12,13]. To get a final burr-free product, two approaches are used by the industries and the researchers. The first one is the post-processing approach in which, the burrs formed during machining are removed by using some technique suggested by several researchers [14–16]. For instance, Yang et al. [17] performed an experimental study by using laser-assisted deburring to remove burrs formed during the micro-milling. Although this methodology is simple and more flexible in terms of its application, however, during the deburring processes, the

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