Experimental Study on Surface Integrity, Dimensional Accuracy, and Micro-Hardness in Thin-Wall Machining of Aluminum Alloy

Gururaj Bolar, Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal, India
Shrikrishna N. Joshi, Department of Mechanical Engineering, Indian Institute of Technology Guwahati, Guwahati, India

ABSTRACT

This article presents an experimental investigation into the influence of process parameters viz. feed per tooth, axial depth of cut on milling force, surface finish, wall deflection and micro-hardness during thin-wall machining of an aerospace grade aluminum alloy 2024-T351. Results revealed that the process parameters significantly influence the surface finish and dimensional accuracy of machined thin-walls. High feed rate promoted the formation of built-up-edge (BUE). Combination of high feed and axial depth of cut aided in catastrophic failure of tools. Surface damages such as material plucking, material shearing, material adhesion and deformed feed mark layer formation were observed. Axial depth of cut negatively influenced the wall deflection leading to loss of dimensional accuracy. Interestingly, the micro-hardness at the machined surface was found to be lower than that of the bulk material hardness. These results will be useful in selection of suitable process parameters for quality and precise machining of thin-wall parts.

KEYWORDS

Axial Depth of Cut, Built-Up-Edge, Chatter, Feed Rate, Milling Force, Surface Roughness, Tool Diameter, Wall Deflection

INTRODUCTION

Precision machining of thin-wall components is an important aspect in modern day aircraft industries. During the machining of monolithic thin-wall components, 90-95% of the material is machined from the initial blank. During machining of deep pockets and high aspect ratio ribs, use of long end mills becomes inevitable. As the machining progresses, rigidity of these parts reduce and these components become susceptible to wall deflection and damage due to the vibration between the tool and the workpiece. The deflection of the thin-wall during the machining process is illustrated by Figure 1. For the chosen milling parameters, the material to be cut is ABCD, however, under the action of milling force, the wall deflects causing the material A’B’C’ to remain uncut. As the cutter moves away in the feed direction (Y-direction), the wall recovers elastically and the material remains uncut which causes the shape of the wall to be thicker at its top and thinner at its base. Thus, to achieve good quality surface finish and accurate wall dimensions, proper selection of tool and cutting process parameters is essential.

Literature reveals important research works on experimental as well as analytical and finite element method (FEM) based numerical modeling of thin wall machining to predict the cutting forces and part deflection during thin-wall machining process. Ratchev et al. (2004) developed an
analytical model to predict the cutting force for static machining error compensation of low rigidity components. In this model, an infinitesimal segment of the helical teeth was approximated to an oblique cutting process and changes of the immersion angles of the engaged teeth was considered for cutting force calculation. The values predicted by the flexible force model were used as input conditions for a FEM based deflection model (Ratchev et al., 2004). Wan and Zhang (2006) worked on an approach to predict static form errors in peripheral milling of thin-walled structures using FEM. A cutting force model was developed, and the deflection was predicted using the developed model. Aijun and Zhanqiang (2008) proposed an analytical deformation model suitable for static deformations prediction of thin-walled plate with low rigidity. Part deformations were predicted using a theoretical deformation equations model which was established based on reciprocal theorem where the linear load acts on thin plates. The form errors in peripheral milling of thin-walled workpieces were studied numerically and experimentally by Kang and Wang (2013). An efficient flexible iterative algorithm (FIAL) for surface form error prediction was developed. Ning et al. (2003) conducted numerical investigations to study the part deformation in thin-walled components. They noted that part deformation increases with the decrease in wall thickness and increase in cutting force. Rai and Xirouchakis (2008) provided an comprehensive overview on FEM based milling model and associated tools, which considered the effects of fixturing, operation sequence, tool path and cutting parameters to predict the thin-wall deflections and elastic–plastic deformations during machining. The model predicted the deformation for various features like steps, slots, pockets which are often encountered in thin-wall component machining. The model was further utilized to understand the thermo-mechanical aspects of machining and its influence on part quality by carrying out transient milling simulations (Rai and Xirouchakis, 2009). Gang (2009) utilized commercial FEM based software to develop a three-dimensional (3-D) FEM model of a helical tool and a thin-walled part as a cantilever. The obtained results were compared with the experimental values and the results predicted by the developed model were found to be accurate.

Wang and Sun (2014) developed an error prediction and compensation tool for milling of blisk blades. FEM based tool was used to carry out the simulations. The error due to deflection was predicted and corrected using deformation error compensation scheme. Li et al. (2015) carried out 3-D FEM simulation to predict the deformation of thin-wall made of 45 steel. The machining deformation
Implementing a Cohesive Zone Interface in a Diamond-Coated Tool for 2D Cutting Simulations
www.igi-global.com/article/implementing-a-cohesive-zone-interface-in-a-diamond-coated-tool-for-2d-cutting-simulations/106958?camid=4v1a

3D Printing and Actor-Network Theory
www.igi-global.com/chapter/3d-printing-and-actor-network-theory/168213?camid=4v1a