Available online at www.sciencedirect.com
SCIENCE DIRECT®

Robotics and Computer-Integrated Manufacturing 21 (2005) 442–450

Robotics and Computer-Integrated Manufacturing

www.elsevier.com/locate/rcim

Burr size reduction in drilling by ultrasonic assistance

Simon S.F. Chang, Gary M. Bone*

McMaster Manufacturing Research Institute (MMRI), McMaster University, Hamilton, Ontario, Canada L8S 4L7

Received 30 August 2004; received in revised form 4 November 2004; accepted 5 November 2004

Abstract

Accuracy and surface finish play an important role in modern industry. Undesired projections of materials, known as burrs, reduce the part quality and negatively affect the assembly process. A recent and promising method for reducing burr size in metal cutting is the use of ultrasonic assistance, where high-frequency and low-amplitude vibrations are added in the feed direction during cutting. Note that this cutting process is distinct from ultrasonic machining. This paper presents the design of an ultrasonically vibrated workpiece holder, and a two-stage experimental investigation of ultrasonically assisted drilling of A1100-0 aluminum workpieces. The results of 175 drilling experiments with uncoated and TiN-coated drills are reported and analyzed. The effect of ultrasonic assistance on burr size, chip formation, thrust forces and tool wear is studied. The results demonstrate that under suitable ultrasonic vibration conditions, the burr height and width can be reduced in comparison to conventional drilling.

Keywords: Burr; Drilling; Metal cutting; Ultrasonic assistance; Ultrasonic assisted drilling; Vibration assisted drilling

1. Introduction

Conventional metal cutting methods produce undesired projections of material that result from plastic deformation, known as burrs. Burrs reduce the accuracy of the parts and subsequent assembly processes. Typically deburring accounts for up to 25% of the total production cost [1]. To reduce or even eliminate the deburring effort, the burr size must be reduced. In this paper, burr size reduction in drilling will be considered.

There are various methods to reduce the burr size. These include altering the cutting conditions and using suitable type of coolant. Dornfeld and Ko [2] showed that the influence of feedrate on burr size is not linear, and is dependent on other cutting conditions and on the material being machined. Varying the feedrate during drilling can also reduce burr size [3]. Special drill geometry, such as radial periphery drills, can produce smaller burrs than standard drills [4]. However, these special drill geometries are often expensive to manufacture. Using suitable coolant and tool coating to reduce the friction between the tool and the workpiece was found to produce smaller burrs [3]. However, coolants are expensive, hazardous to worker health, and pollute the environment. Kim et al. [5] have developed an empirical drilling chart to choose suitable cutting condition for different materials in order to reduce burr size. However, these drilling charts are only applicable to limited ranges of drilling. Drilling with a backup material can also reduce burr size [6]. However, this technique cannot be applied when the exit surface of the workpiece is not accessible.

A recent and promising technique to reduce burr size is known as ultrasonic-assisted (UA) drilling. The principle of this technique is adding high-frequency (1–200 kHz) and low peak-to-peak (pk–pk) vibration magnitude (2–26 μm) in the feed direction to the tool or workpiece. This cutting process is distinct from ultrasonic drilling. Ultrasonic drilling, also known as rotary ultrasonic machining, is a specific class of ultrasonic machining. Ultrasonic machining is a machining process where a tool is vibrated ultrasonically and feed axially

*Corresponding author. Tel.: +1 905 525 9140x27591; fax: +1 905 572 7944.
E-mail address: gary@mcmaster.ca (G.M. Bone).

0736-5845/$ - see front matter
doi:10.1016/j.rcim.2004.11.005