Journal of Materials Processing Technology 209 (2009) 4502–4508

Contents lists available at ScienceDirect

Journal of Materials Processing Technology

journal homepage: www.elsevier.com/locate/jmatprotec

The influence of tool flank wear on residual stresses induced by milling aluminum alloy

Z.T. Tang[a,b,*], Z.Q. Liu[b], Y.Z. Pan[b], Y. Wan[b], X. Ai[b]

[a] *School of Mechanical and Electrical Engineering & Automobile Engineering, Yantai University, PR China*
[b] *School of Mechanical Engineering, Shandong University, PR China*

ARTICLE INFO

Article history:
Accepted 6 October 2008

Keywords:
Residual stresses
Flank wear
Cutting force
Cutting temperature
Aluminum alloy

ABSTRACT

The machining processes could induce residual stresses that enhance or impair greatly the performance of the machined component. Machining residual stresses correlate very closely with the cutting parameters and the tool geometries. In this paper, the effect of the tool flank wear on residual stresses profiles in milling of aluminum alloy 7050-T7451 was investigated. In the experiments, the residual stresses on the surface of the workpiece and in-depth were measured by using X-ray diffraction technique in combination with electro-polishing technique. In order to correlate the residual stresses with the thermal and mechanical phenomena developed during milling, the orthogonal components of the cutting forces were measured using a Kistler 9257A type three-component piezoelectric dynamometer. The temperature field of the machined workpiece surface was obtained with the combination of infrared thermal imaging system and finite element method. The results show that the tool flank wear has a significant effect on residual stresses profiles, especially superficial residual stress. As the tool flank wear length increases, the residual stress on the machined surface shifts obviously to tensile range, the residual compressive stress beneath the machined surface increases and the thickness of the residual stresses layer also increases. The magnitude and distributions of the residual stresses are closely correlated with cutting forces and temperature field. The three orthogonal components of the peak cutting forces increase and the highest temperature of the machined workpiece surface also increases significantly with an increase in the flank wear. The results reveal that the thermal load plays a significant role in the formation of the superficial residual stress, while the dominative factor that affects thickness of residual stresses layer is the mechanical load in high-speed milling aluminum alloy using worn tool.
Crown Copyright © 2008 Published by Elsevier B.V. All rights reserved.

1. Introduction

It is well known that machining processes create residual stresses on the surface of machined components. The machining residual stresses can have significant effects on component life by influencing fatigue strength, creep, and stress-corrosion-cracking resistance. In addition, machining-induced residual stresses can have detrimental effects on the component geometry and dimensional stability. Therefore, it is of considerable significance to optimize distributions of residual stresses by controlling the cutting conditions (Brinksmeier et al., 1982; Jacobus et al., 2000).

Machining residual stresses correlate very closely with the cutting parameters and the tool geometries. At present, numerous studies have been conducted by many researchers to determine relationships between the cutting conditions and residual stresses. Outeiro et al. (2002) studied the residual stress induced in turning of AISI 316L steel. Particular attention was paid to the influence of the cutting parameters, such as the cutting speed, feed and depth of cut. Patrik et al. (2004) investigated the influence of rake angle, cutting feed and cutting depth on residual stresses in hard turning AISI 52100, the results show that rake angle had the strongest influence on the residual stresses. The compressive stresses become greater with increased feed rate, while cutting depth had no obvious effect on residual stresses. Fuh and WU (1994) proposed the cutting speed, feed, tool nose radius and flank wear have the most significant effect on the residual stresses. Chen et al. (2004) developed a finite model to simulate the effects of tool flank wear and chip formation on residual stress when orthogonal cutting Ti–6Al–4V. Tonshoff et al. (2000) found that when turning hardened steels the residual stress magnitude on the surface shifts more toward the tensile region and into deeper depths with increasing flank wear length. Thiele et al. (2000) have found that tool-edge radius has a significant effect on surface residual stress and microstructure when finish hard turning

* Corresponding author at: School of Mechanical and Electrical Engineering & Automobile Engineering, Yantai University, PR China. Tel.: +86 531 88392045; fax: +86 531 88392045.
E-mail address: tangzhitao@gmail.com (Z.T. Tang).

0924-0136/$ – see front matter. Crown Copyright © 2008 Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.jmatprotec.2008.10.034

Table 1
Chemical composition of 7050-7451 (% in weight).

Zn	6.7
Cu	2.5
Mg	2.3
Zr	0.12
Fe	0.13
Si	0.12
Mn	0.10
Ti	0.06
Others	0.15

AISI 52100 steel. The residual stresses in the axial and circumferential directions were more compressive with larger edge radius. Jang et al. (1996) studied the effects of different machining parameters (cutting speed, feed rate, depth of cut and tool-edge radius) on surface residual stress when turning AISI 304 stainless steel. Tool-edge radius was found to have the most significant effect on residual stress, where larger radius resulted in higher surface tensile residual stress in cutting direction. The authors reported that the effect of edge radius on inducing tensile residual stress in stainless steels is more noticeable than in other steels, and attributed this to the low thermal conductivity of stainless steels. In addition to the efforts above, other models have been proposed for correlating the residual stress with some cutting parameter (Jang et al., 1996; Lin et al., 1997, 2000; Jacobus et al., 2001; Capello, 2005; Liu et al., 2004; Mohamed et al., 2007; Outeiro et al., 2006; Jiang et al., 2006; Pawade et al., 2008). These research results revealed that the cutting tool geometry is the dominant factor determining the residual stresses profiles.

Although an extensive study on machining residual stress and their correlation with cutting parameters and tool geometries are available. But most researchers focus on the residual stresses in turning and grinding all kinds of steel materials. Not much attention is paid to the residual stresses in milling aluminum alloy. Moreover, the mechanism of formation of the machining residual stresses is not well correlated to important machining physical phenomena such as the dynamic cutting forces and cutting temperature field. The objective of this paper is to investigate experimentally the effect of tool wear on residual stresses in the milling of aluminum alloy 7050-T7451. To be able to correlate the residual stresses with the thermal and mechanical phenomena developed during milling, the cutting forces and the cutting temperature field were measured, respectively. At last, the formation of the residual stresses can be explained by the thermo-mechanical coupling effects.

2. Experiment

2.1. Experimental material

High-strength wrought aluminum alloy 7050-T7451 is widely used for aerospace application because of its combination of high strength, stress-corrosion-cracking resistance and toughness. The chemical composition and the mechanical properties of the material are presented in Table 1 and Table 2, respectively.

Table 2
Mechanical properties of 7050-T7451.

Yield strength (MPa)	455
Tensile strength (MPa)	510
Elongation (%)	10
Hardness (HB)	135
Young modulus (GPa)	71.7

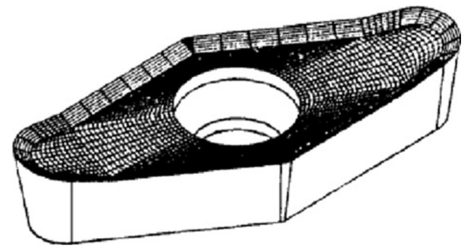

Fig. 1. Insert.

2.2. Experimental set-up

Milling tests were performed on a DECKEL MAHO DMU 70 V 5-axis universal machining center. Max power of the machine tool is 15 KW, and max spindle speed is 18,000 r/min. The workpiece was machined with superfine grain solid carbide inserts with 10,000 r/min spindle speed, 2 mm axial cutting depth, 10 mm radial cutting depth and 0.15 mm/z feed per tooth. The inserts VPGX2206EN-E10 (seen in Fig. 1) were mounted in corresponding arbor with a cutting diameter of 32 mm. The insert's rake and clearance angles are 25° and 6°, respectively. The tool flank wear was observed by a optics microscope (×100), seen in Fig. 2. In the experiment, the tool average flank wear length are 0.03, 0.07, 0.12, 0.17, 0.21, 0.26 mm, respectively. Dry cutting environment was used throughout the tests.

2.3. Residual stresses measurement

Residual stresses were measured by means of the X-ray diffraction method. Fig. 3 shows the used equipment, a portable stress analyzer from Stresstech Group's XSTRESS 3000. The main parameters of this apparatus are as follows: Cr tube (27 kV, 6 mA), 3 mm^2 measurement area, cross-correlation method for determining peak positions, Ni power calibration, 139.3° Bragg angle, ±6° ψ-oscillation, ±30° ϕ-oscillation. The location of the measurement point is at the center of the tool track. The stresses were measured parallel to the feed direction and perpendicular to the feed direction, respectively. In order to determine the in-depth residual stresses, the electro-polishing technique was used. The surface material was removed layer-by-layer using an electro-polishing machine Movipol-3 as shown in Fig. 4. The removed layer thickness can be determined using electronic digital micron indicator (seen in Fig. 5).

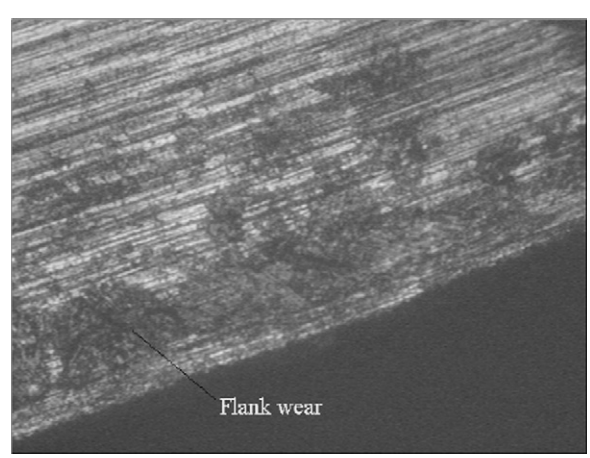

Fig. 2. Observation of flank wear.

Download English Version:

https://daneshyari.com/en/article/793467

Download Persian Version:

https://daneshyari.com/article/793467

Daneshyari.com