Machinability of a 53 % Silicon Aluminum Alloy

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Abstract

This paper presents the experimental results on the milling process of an Al-53 % silicon alloy using a polycrystalline cubic boron nitride PCBN diamond coated tool. The influence of different cutting parameters on material removal rate, roughness evolution milling forces, machine vibration and the surface quality of the machined material was measured during the experiments. Cutting forces were measured using Kistler table and digital acquisition system. Surface roughness and morphology were quantified using a confocal laser-digital microscope.

Keywords: Machinability of aluminum-silicon alloy, milling, diamond coated tools.

1. Introduction

The aluminum microstructure composite reinforced with high volume fraction silicon particles (AlSi) has been identified as a potentially suitable material system for space applications, because it has high thermal conductivity, low coefficient of thermal expansion and low density, references [1 – 3]. However, the hardness of silicon is higher than that of aluminum alloy. Thus, it is necessary to study the effect of Si on the machinability of the material.

The surface finish, which includes the topography and defects of the machined surface, has been studied in several studies. The surface roughness parameters are the basic indicators of the quality of the machined surface. The work of Ammula and Guo [4] showed that the feed rate has a major effect on the surface integrity compared to cutting speed and the depth of cut on 6061-T651 alloy. The surface roughness trends were often associated with the formation of the built-up-edge (BUE). Gómez-Parra et al., [5] showed that the increase in BUE caused a decrease in the roughness, Ra. Indeed, the presence of the BUE increases the radius of the tool nozzle, thereby improving the surface roughness. However, Iwata and Ueda [6] stated that BUE leaves cracks on the machined surface. Thus, it increases the surface roughness and deteriorates the resistance of the part. Li et al., [7] studied the effect of high cutting speed on the integrity of the 7075 aluminum alloy surface. Their results showed the positive effect of high cutting speed on surface integrity.

Andrewes et al., [8] treated experimental results on the machinability of silicon-reinforced aluminum and 65 % of silicon carbide (Al / Sip + SICP) during the milling process with a carbide tool. They measured cutting forces, wear, tool life, and the quality of the machined surface. They showed that if the same volume fraction of the silicon particles is replaced by silicon carbide while keeping the particle size, the flexural strength and the Vickers hardness are improved. Therefore, machinability becomes more difficult.

As reported by El-Gallab and Skladb [9], machining performance is a good indication of the workpeace machinability. During the machining operation, many parameters can affect the machining performance. Many studies have considered some variables as criteria of performance of machining. In summary, the most used criteria are Tool wear (tool life), integrity of the machined surface, cutting forces (power consumption), chip formation, and precision of the machined part.

The above review showed that there are still many missing information regarding the influence of machining parameters on the surface quality of Al alloys containing very high amounts of silicon. The present work has been defined in this context and has for main objective to determine the optimum machining parameters for an Al-53 % Si alloy.

2. Experimental Procedures

2.1. Workpiece Material: MS43 AlSi Alloy

The workpiece material is MS43, aluminum alloy with 53 % silicon. It was manufactured by extrusion then ultra-fast cooling and supplied by MDA Corporation, Quebec, Canada. MS43 is an aluminum alloy containing 53 % Si, 3.5 % C, 0.43 % O (wt %), with the rest Al. The bulk hardness of the MS43 was 54 ± 4 HRB, measured as Brinell Superficial Hardness using a 1/16 in. (1.59 mm) diameter ball and a 15 kg load. The microstructure of the MS43 consisted of the Al matrix and eutectic silicon particles. However, there were zones as well that consisted more dense than the global structure as shown in the Figure 1.

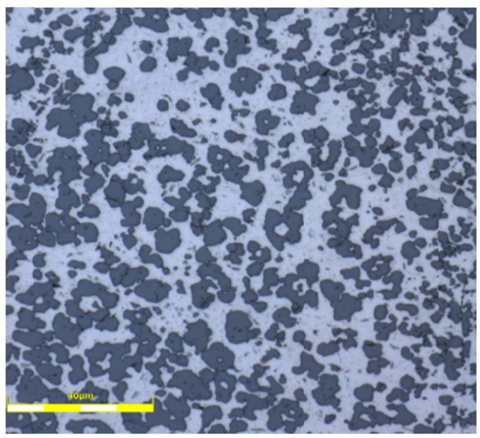

Figure 1. Micrographs of MS43 (53 volume % Si).

2.2. Properties of Tool and Physical Vapor Deposition (PVD) Coating

The cutting tools used for the milling were 3.175 mm diameter manufactured by Harvey tools [10]. The chemical composition of the PVD amorphous diamond coating improves lubricity and wear resistance. The characteristics of the tool are shown in the Table 1.

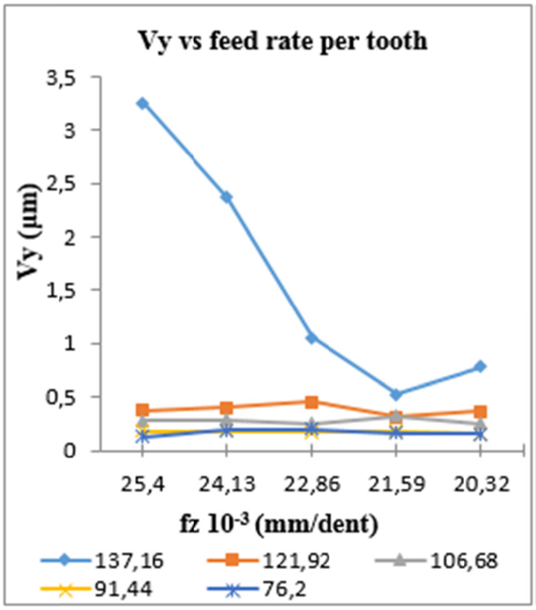

Figure 8a. Vy vs feed rates per tooth.

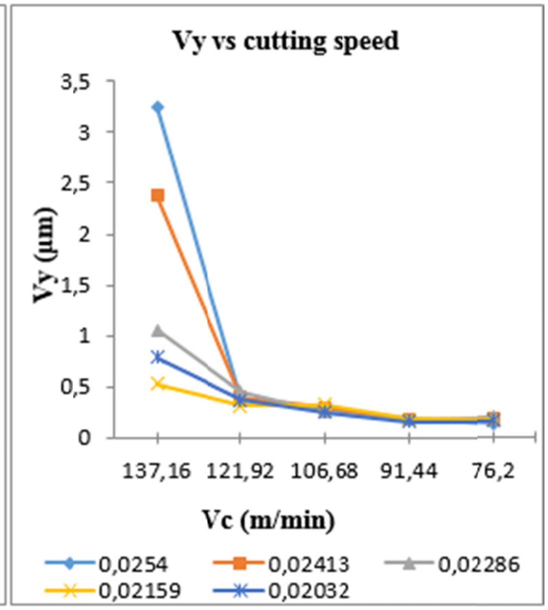

Figure 8b. Vy vs cutting speed.

4. Conclusions

This study led us to conclude that the cutting forces and the vibration increase with the cutting parameters. The signals of force and vibration are very high with the cutting speed 137.16 mm/min and 0.0254 mm/tooth. The force and vibration signals become stabilized for cutting conditions consisting of a cutting speed of 121.92 mm/min and a feed rate per tooth of 0.02286 mm/tooth. For the cutting force, depending on the axis of the displacement of the tool, the hardness of the workpiece increases continously. Above 137.16 mm/min and 0.02286 a force that varies between 18 and 33 N will be produced while for 121.92 mm/min the material can be machined with 0.0254 mm/tooth without having high cutting forces (less than 16 N). The variation of the cutting parameters greatly influences the surface roughness; in fact the increase in cutting speed increases the surface roughness.

Waves and roughness spikes were observed on the machined surfaces, they were caused by the vibration generated because of the severe cuts parameters. To have a better roughness (around 1.5 µm), the cutting parameters must not exceed 106.68 mm/min and 0.02159 mm/tooth.

5. References

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