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Effect of Gas Laser Beam applied during Machining of Metal Matrix Composites Reinforced by Sic Particle

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Abstract. This paper presents a study of Laser Assisted Machining (LAM) when turning the AlSi9Mg alloy reinforced with 20 vol.% particles of SiC. Due to hard ceramic reinforcing, components are difficult to machine using conventional manufacturing processes. The applied LAM process was used to heat the cutting zone. The aluminum matrix becomes softer and easer in plastic deformation, which leads to the reduction of pushing force of the SiC particles on the clearance face of a cutting tool, with is the reason of its wear. This research was carried out for tungsten carbide inserts. The results obtained with the laser assisted machining were compared with results obtained in conventional turning.

Introduction

The reinforcement of metallic alloys with ceramic particles has generated a new family of material called metal matrix composites (MMCs). Aluminium, titanium and magnesium alloy are used as matrix elements, while silicon carbide (SiC) and alumina (Al_20_3) are popular reinforcements.

The commonly used lightweight materials, e.g. aluminum alloy composites are still of great interest in the field of automotive, aerospace, electronics and medical industries [1-4]. They have outstanding properties like high specific strength, low weight, high modules, low ductility, high wear resistance and high thermal conductivity. As a consequence of the applications of metal matrix composites (MMCs), the machining process has become a very important subject for investigation. The reinforcing materials are characterized by harder and stiffer features than the matrix. This material belongs to the group which is difficult to machine, like tungsten carbide [5], hardened steel [6], Waspaloy [7] or Inconel 718 [8, 9] and therefore machining is much more difficult in comparison with conventional materials like steel [10]. However, due to hard ceramic reinforcing components in MMC, they are difficult to machine using conventional manufacturing processes due to heavy tool wear. As a consequence, hybrids machining processes, e.g. electro discharge machining (EDM), laser [4], numerical method [11-13] and other techniques [14-16], are becoming more popular for the MMC machining. The most LAM hot processes still require further investigations to get all optimum parameters.

The work reported here investigated the effectiveness of laser assisted machining process to machine MMC. A different defocus of laser beam was used to heated the cutting zone. The laser

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irradiation makes the aluminum matrix softer and easer in plastic deformation, which leads to the reduction of pushing force of the SiC particles on the primary flank face of the cutting tool. This phenomenon is the main reason of increasing tool wear.

The collected results and observations on composite materials and their laser processing may be interesting in the context of similar technological processes, e.g. production of nanocomposites [17] or protective coatings by ESD with subsequent laser machining [18, 19], which is of great importance in the case of hydraulic seals of heavy machines [20] . This work can also inspire the further development of experimental data analysis, such as DOE [21] and image analysis [22].

Experimental details

Composite AlSi9Mg (aluminum with 9.2% silicon, 0.6% magnesium, 0.1% iron), reinforced with silicon carbide particles, was the material selected for this study. The SiC particles in the machined composite workpieces were about 20% in volume and about 8-15 μm in diameter. The workpieces had a cylindrical shape of 25 mm length and 38 mm in diameter. The workpieces were painted by absorptive coating each time to increase laser absorption.

Investigation on the wear of SNMG 120408 MS Kennametal tool in the machining of MMC was carried out by turning. The tool was a commercially available physical vapor deposition (PVD) TiCN coated KC5510 tungsten carbide inserts with a fine-grain substrate, with rake angle of 5^o, clearance angle of 5^o, cutting edge angle of 75^o, minor cutting edge angle of 15^o, nose radius of 0.8 and cutting edge inclination angle of 6^o.

Laser assisted machining was carried out with a 2.6 kW continuous wave (CW) CO_2 laser (2.6kW Trumpf, type TLF2600t). After each trial, the machined surface roughness was measured using a Hommel T1000 profilometer with a diamond stylus type instrument set to a 0,8 mm cut-off length and a tracing length of 4.8 mm. Three readings were taken at random points on the machined surface and averaged after each test. Tool wear was measured on the primary flank face by an optical microscope. The measurements of tool wear (VB_c) and machined surface roughness (*Ra*) were carried out at regular intervals during a 44 s machining period.

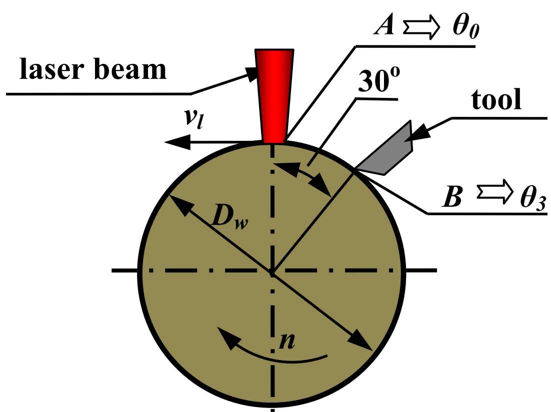

Figure 1. Scheme of the experimental set-up. Designations: A - heating area by laser beam,

B – zone of machining, θ_0, θ_3 - areas of temperature measurement, D_w- workpiece diameter.

Figure 1 shows the scheme of a laser assisted machining set-up used during the present study. Surface temperatures were measured with a two RAYTEK pyrometers (model:MA2SC and S5XLT). One of these measured temperatures in A area (Fig.1) and the second in B area (Fig.1) at the same time. Emission was set in the software to the value of ε = 0.3 based upon primarily made calibration tests.

The constant parameters were the following: cutting speed (v_c = 107 m/min), depth of cut (a_p = 0.1 mm), feed (f = 0.04 mm/rev), emissivity (ε = 0.3), cutting time (t = 0.73min) and workpiece diameter (d_w = 38mm). Several others parameters were the following variables: laser power (P = 0.26÷2.34 kW), laser beam diameter (d_l = 2÷4mm).

Results and discussions

In Figure 2 the effect of laser power on the temperatures in *A* and *B* areas are shown. It was noticed that the temperature (θ_0) in *A* zone (Fig.2a) insignificantly increases with the increasing power of laser beam. The increase of laser power more than three times causes small a increase of temperature to about 200ºC. In the case of the temperature (θ_3) in *B* area (Fig.2b), increasing power of laser by approximately 1kW had distinct effect on increased temperature in this area. On the other hand, increasing power of laser beam above 1 kW practically did not change temperature (θ_3) in *B* area. It can be brought out of appearance plasma in area heated by laser beam which in this conditions intensively absorbs the energy of laser radiation.

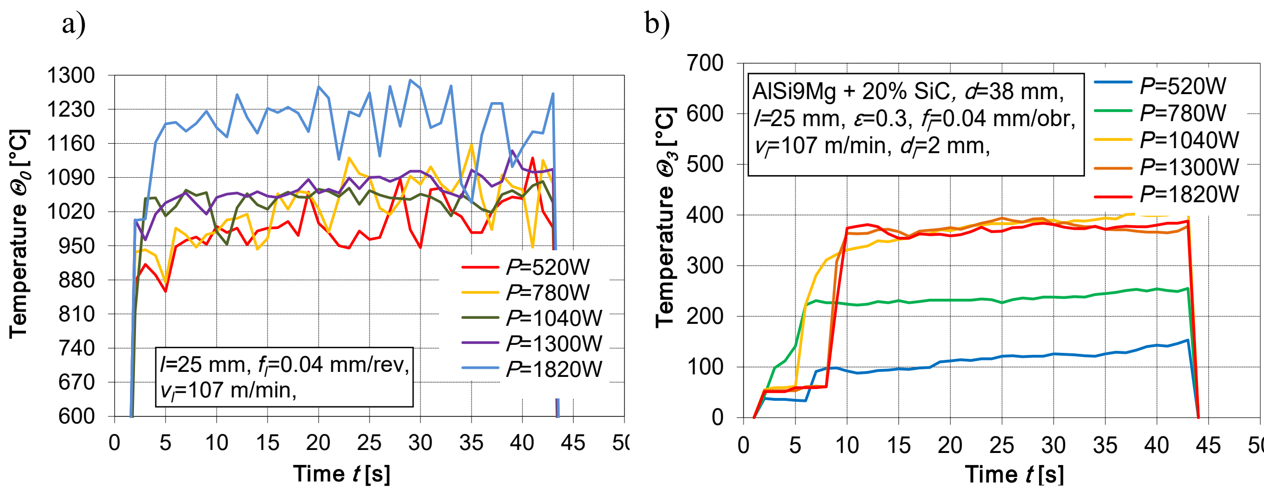

Figure 2. Comparison of measured temperatures with different power of laser beam, a) measured from θ_0 area, b) measured from θ_1 area

Tool wear and surface finished in laser-assisted machining

In comparison with conventional cutting, laser assisted machining increases tool wear but only for 2mm of laser beam diameter, which is depicted in Figure 3. It can be caused by the softening effect of laser heating on the aluminum matrix which reduces the pushing forces of SiC particles on the cutting tool. This effect was observed for severe cutting tool wear in the conventional machining of this composite. Figure 3 shows that 4 mm of laser beam diameter was not sufficient to provide suitable power of laser to soften the matrix and finally wear of wedges had comparable value for conventional and hot assisted machined cutting.

Turning with laser heating improves machined surface roughness in comparison with conventional turning but surface quality decreases with the increase of a laser power beam. In low range value (to 1kW) of laser power, LAM improved surface roughness in both 2mm of laser beam diameter and 4mm of laser beam diameter.

As decrease tool wear (Fig.3) as well increase surface roughness (Fig.5) during higher values of laser power can be explained by the fact that fusion surface causes appearance of plasma which intensively absorbs laser radiation. The result was that the thin layer of composites was heated so deeper layers of workpiece were not soft enough.

Abrasion of the deposited workpiece material on both primary and secondary flank faces results in the grooves on the flank face (Fig. 4).

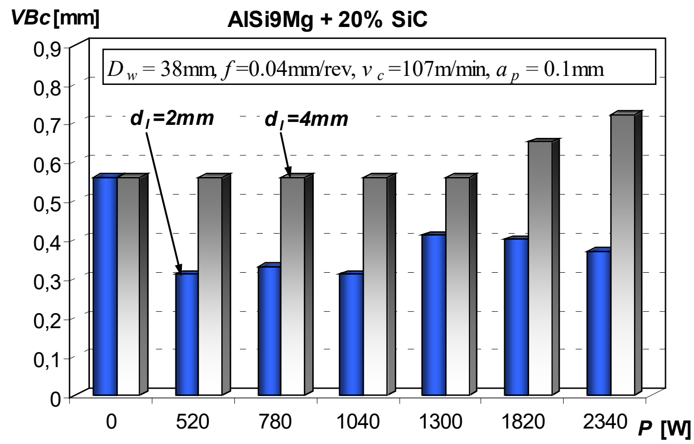

Figure 3. Tool wear after conventional cutting and laser-assisted hot cutting of AlSi9Mg+20% SiC MMC with diference laser beam diameter

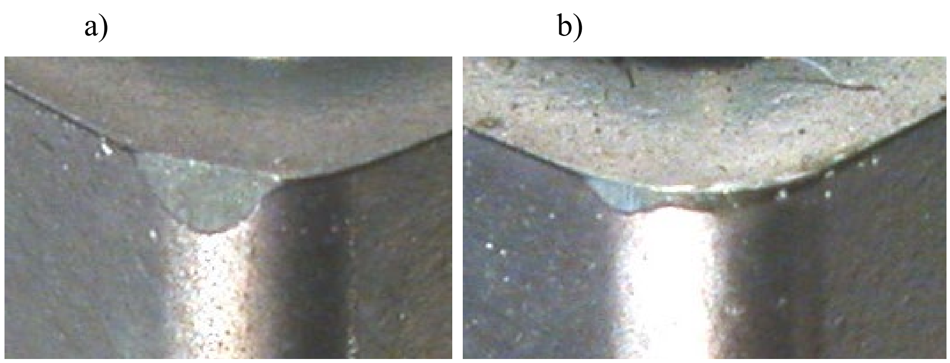

Figure 4. The images of KC5510 inserts after: a) conventional turning, b) with laser assisted machining. Parameters: v_c = 107m/min, f = 0,04mm/rev, a_p = 0,1mm, t_s = 0,73min

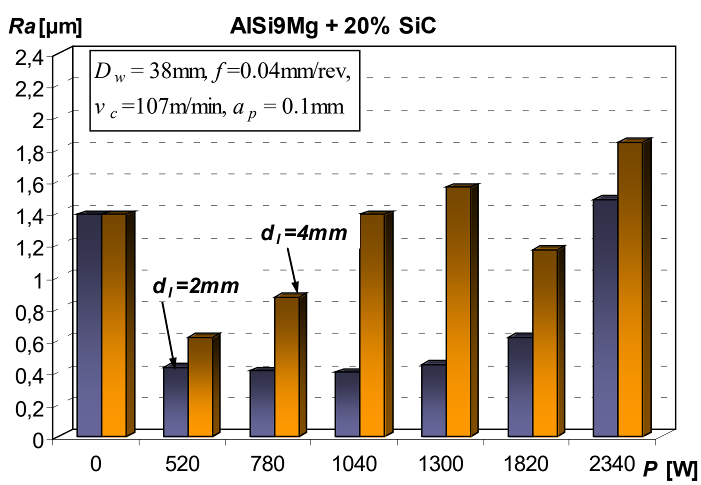

Figure 5. Comparison of machined surface roughness between conventional and LAM turning

Summary and conclusions

The results of the experiment show how laser assisted machining improved tool wear resistance and machined surface quality in comparison with conventional cutting. Hence, it is necessary to understand the whole processes during laser assisted machining for this material through further investigation. Conclusions derived from this study are as follows:

1. Laser- assisted machining is a very effective method (in low range value to 1kW) of laser power) in the machining of SiCp/Al composite.
2. LAM of MMC was studied to prove tool life increase by using a CO_2 laser to heat spot on a workpiece.
3. In the low value of laser power, the laser-assisted hot machining of SiCp/Al composite improves the machined surface.

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