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EFFECT OF GRIT SIZE AND ABRASIVE TYPE ON SURFACE FINISH OF A MACHINED AL-SICP MMC

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ABSTRACT

Metal-matrix composites are a relatively new range of materials possessing several characteristics that make them useful in situations where low weight, high strength, high stiffness, and an ability to operate at elevated temperatures are required. Practical considerations for machining MMCp include selection of the cutting speeds, type of grinding wheel and surface roughness. This paper presents results from an ongoing investigation into the factors affecting the finish machining of an Al/SiC MMC. Diamond grinding wheels were used to machine an Al-SiCp (30 vol%) metal-matrix composite. The surface finish is significantly varying based on the coarse or finer grit grinding wheels. The effect of abrasive type on surface finish also studied. It was found that good surface finish can be achieved in terms of lower order grinding force components and low AE energy release. The performance of the different grit size diamond wheels and different abrasive wheels are compared.

Key words: *Metal Matrix Composites, Machining, Grinding and Surface Finish*

1. Introduction

Today's technological progress is due to sophistication in materials. As the technology becomes more and more advanced, the materials used have to be reliable and more efficient in performance. Materials should be light in weight, strong, tough, wear resistant and capable of withstanding extreme operating environments such as high temperature, pressure, cryogenic conditions, high vacuum, highly corrosive and in some cases electric, magnetic or irradiation fields. No individual material is capable of meeting these demands. For example, steel has been the most widely used engineering material due to its many advantages like high stiffness, high strength, ease of joining, high toughness and low cost; but has the disadvantage that it is heavy (7800 Kg/m^3) and is prone to corrosion. Aluminium is lighter (2700 Kg/m^3) and can be made as strong as steel but cannot be welded easily. Thus it is seen that the material system should preferably be designed for specific end use (tailor-made) necessitating a combination of desired properties. This has resulted in the development of advanced materials and composites form one class of such materials developed using modern innovative techniques. Composites represent a combination of at least two chemically distinct materials with a distinct interface separating the constituents. These are three kinds of them: Polymeric matrix (PMC such as FRP), Metal matrix (MMC) and Ceramic matrix (CMC) materials. Their high strength to weight ratio, enhanced resistance to environmental hazards, lower density, high fatigue resistance, wear resistance and related properties has widened the range of application leading to large scale substitution of conventional engineering materials for aerospace to consumer goods. The specific modulus (the ratio between the Young's modulus (E) and the density (ρ) or specific weight (w) of the material) and specific strength (the ratio between the strength (σ_{ult}) and the density (ρ) or specific weight (w) of the material) are high for composite materials compared to metals. This results in reduced space requirements and lower material and energy costs.

Metal matrix composites are either in use or being prototyped for the space shuttle, commercial airlines, electronic substrates, bicycles, automobiles, golf clubs and many other applications. The majority are aluminium matrix composites, a growing number of applications require the matrix properties of super alloys, Titanium, copper, magnesium. The term metal matrix composite (MMC) covers a wide range of scales and micro structures. Common to them all is a metallic matrix, which is normally contiguous. The reinforcing constituents are in most cases a ceramic, intermetallics or semi-conductors [1]. Particulate reinforced Al-metal matrix composite (PRAlMMC) is one of the important composites among the metal matrix composites, which have SiC particles with aluminium matrix is harder than tungsten carbide (WC), which pose many problems in machining. The aluminium alloy reinforced with discontinuous ceramic reinforcements is rapidly replacing conventional materials in various automotive and aerospace industries. Al-SiC-MMCs machining is one of the major problems, while resist its wide spread engineering application. It is found that surface finish is very poor while carbide tip tools are used for machining [2].Hence effective machining with generation good surface finish on the Al-SiC-MMC jobs during grinding operations is a challenge to the manufacturing engineers.

The hard reinforcement in a MMC provides them, the preferred higher wear resistance. However it is detrimental to cutting tools and forming dies. Heterogeneity and anisotropy of MMCs make their machining significantly different from that of conventional metals and alloys. The tool continuously encounters alternate matrix and reinforcement whose response to machining is entirely different and depends on diverse reinforcement and matrix properties. Fiber orientation/particle distribution, relative volume and size of reinforcement in MMCs cause severe force fluctuations posing fracture toughness and fatigue related machining problems. Accordingly the requirement on the part of the cutting tool changes continuously and it is this variation in the requirement of the tool that makes MMCs difficult to machine. Also conventional machining of MMCs is difficult due to the presence of comparatively high volume fraction of hard ceramic reinforcement which causes rapid abrasive tool wear during machining resulting in very short tool lives. Although the latest innovative manufacturing processes such as in-situ MMC development and Thixotropic processing can produce near net shape components, final machining and finishing processes like grinding are still required to fabricate MMC component to the required dimensional tolerance/surface texture. For effective machining of MMCs ultra hard tool materials like PCD and PCBN are necessary. PCD and PCBN tools are used for grinding MMCs. Trials were carried out with conventional silicon carbide grinding wheel also to explore the cutting requirements for the same while machining MMCs [4]

A burning phenomenon of a work piece is one of grinding faults that happen many times to the ground surface. The grinding burn is a discoloration phenomenon according to thickness of oxide layer on the ground surface. At the onset of grinding burns, a surface roughness deteriorates [5]. In view of these above mentioned machining problems, main objectives of the paper is to study the influence of different cutting parameters like cutting speed, feed rate, depth of cut on the machinability characteristics like surface finish during grinding of AL/SiCp-MMC. The surface finish for different sets of experiments were examined and compared for searching out the suitable parameter combination through highlighting the drawbacks and suggesting proper measures to be undertaken during machining performance which may overcome the machining barriers from Al-SiC_p-MMC.

2. Experimental Design

2.1 Introduction

Metal matrix composites (MMC) consist of metals reinforced with one or more constituents (fibres, particles or whiskers) in continuous or discontinuous form. Machining of MMC’s is difficult owing to the material homogeneity, apart from hardness and abrasive nature of the reinforcing particles. Although near net shape manufacturing may be feasible, final finishing process like grinding is needed for achieving the desired dimensions and required surface finish. It is known fact that, there will be loading for a soft material like aluminum, but the dispersion strengthening of the composite due to presence of reinforcement enhances its machinability by reduced tendency to clog the wheel and consequently achieve improved surface quality.

2.2 Work material

It is noticed that, in MMCs the presence of hard abrasive particles in soft metal matrix present unusual machining problems. Therefore, a study on the influence of cutting parameters and process parameters on the achieved surface finish becomes relevant. The MMC material chosen for the study is aluminium alloy based MMC, reinforced with SiC particles. Details of the work piece material are given in table1

Table1: Work Material Specifications

Matrix	Reinforcement	Volume Fraction	Particle size	Processing route
Al2124 alloy	SiC particles	30 %	50μm	Powder metallurgy technique

2.3 Grinding wheels

Diamond is a very hard material. The wear of the diamond wheel is less compared to other conventional abrasive wheels. Silicon Carbide wheel cost is very less compared to other wheels. The grinding wheels used in the present investigation are:

1. Diamond wheel 120/140
2. Diamond wheel 170/200
3. SiC - 120 wheel

2.4 Experimental setup details

Experimental setup consisted of the Tool and Cutter Grinder (SCHUTTE WU3mS) with an auxiliary work table mounted on top of the existing work table which was driven by a variable frequency drive, so as to obtain different work speeds. A piezoelectric dynamometer (Kistler Type 9265A) was mounted on the auxiliary work table for measuring the tangential and normal components of cutting forces. The temperature at the grinding wheel-work piece interface was measured using an infrared pyrometer (tpi 377 type). Acoustic emission signals were captured using an acoustic emission sensor. The different pickups were connected to the data acquisition card (Adlink PCI-9812 PCI Bus Advanced Data Acquisition Card) mounted inside the PC, for receiving the signals, processing and storing in the database. The signals obtained from piezoelectric dynamometer were passed through a multi channel charge amplifier (Kistler Type 5019). The schematic diagram of experimental setup and photographic view are shown in figure1 respectively.

Acoustic Emission (AE) signal was passed through a 20dB preamplifier and signal conditioning unit, before passing on to the DAQ card. DC regulated supply of 16V was obtained from an Aplab regulated DC power supply (model 7152). For data acquisition and processing, Lab view software was utilized. Lab view is a graphical programming language with which a complete functional unit can be implemented to take over the function of an instrument. It consists of back end which is similar to a data flow block diagram and a front panel that can be configured for ease of operation. The following figure 2 shows the block diagram of the front panel used for the present work. After grinding, the surface finish was measured using a Mahr Perthen perthometer. Mahr perthometer allows the representation of characteristic curves, profile diagrams and measuring records as well as the carrying out statistical analysis.

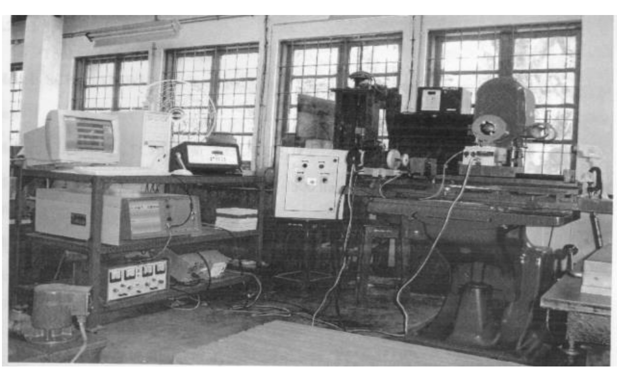

Fig.1 Photographic View of the Set-up

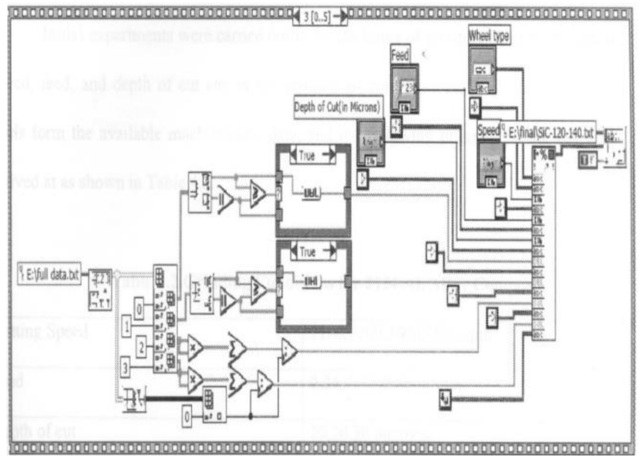

Fig.2 Virtual Instrumentation Block Diagram

3. Results & Discussion

The performance index in any manufacturing system can be broadly classified into two classes: system performance index and process performance index. In order to maintain the desired performance level, it is necessary to monitor performance indicators such as cutting force components, acoustic emission signal emanating from cutting tool, cutting temperature. The performance of cutting tool can be evaluated by monitoring any of these indicators apart from surface quality of the machined part. Depending on the requirement, either one or more of these indicators are monitored.

Grinding trials on Al2124/SiCp metal matrix composite were carried out using silicon carbide (SiC), PCD wheels. The performance of the grinding wheel was assessed in terms of grinding force components, acoustic emission signal characteristics and surface finish of ground surfaces. Diamond 120 &170 grinding wheels were used to find the significance of grit size and SiC 120 wheel was used to find the effect of abrasive type.

3.1 Effect of grit size on surface finish

The effect of grit size on surface finish with an increase in speed is monitored during grinding is shown in fig 3. For the same machining conditions, the variation in machining surface finish is observed with diamond 120/140 wheel and diamond 170/200 grit wheel. One of the problems associate with grinding of MMCs is the frequent loading of the wheel by the softer aluminium. This limits the depth of abrasive penetration with finer grit and consequent reduction in the force. Despite of the reduction in the grinding forces with finer grit, higher order acoustic emission has been observed.

This can be observed because of increased proneness to wheel loading with finer grit and it results rise in temperature. This leads to poor surface finish. A progressive rise in temperature with wheel speed observed in case of coarser grit can be attributed to sustained grinding performance and better surface finish. Diamond 120/140 grinding wheel exhibits good performance at a wheel speed of 1000mpm in terms of lesser grinding forces, lower AE rms and good surface finish. Compared to diamond 120 wheel the temperature values are relatively high especially at higher wheel speeds while machining with 170/200 wheel. With increase in table speed and wheel speed the surface finish has deteriorated in almost all cases. Above a grinding depth of 20µm there is a increase in surface roughness. At 1000 mpm wheel speed, 0.2 mpm table traverses and less than 20µm depth of cut, the machining is good.

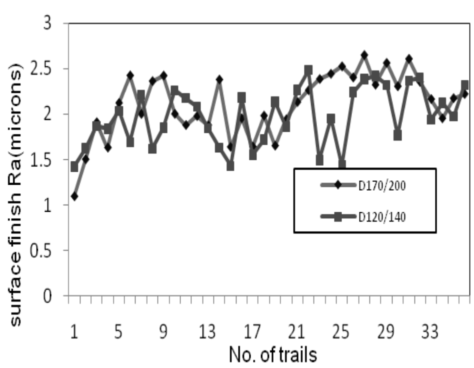

Fig. 3 Comparison of Surface Finish Values for Different Grit Size

3.2 Effect of abrasive type on surface finish

The effect of abrasive type on surface finish with an increase in speed is monitored during grinding is shown in fig 4. For the same machining conditions, the variation in machining surface finish is observed with diamond 120/140 wheel and SiC 120/140 grit wheel. The SIC 120/140 wheel is performed better in terms of surface finish as compared diamond 120/140. The rise in temperature with wheel speed has resulted increase in acoustic emission. The wide difference in thermal proportion between aluminium matrix and reinforcing SiC particles could have resulted in larger energy release from the metal matrix. Good surface finish is obtained at 1000mpm and 1400mpm.

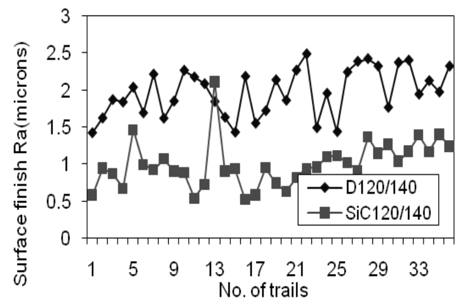

Fig. 4 Comparison of Surface Finish Values for Different Abrasive Wheels

4. Conclusions

The effect of grit size and abrasive wheel type on surface finish of ground surface is observed during machining process. Referring to the illustrations on performance of diamond grinding wheels 120/140,170/200, Silicon carbide120/140 grinding wheel, it is concluded that Diamond 120/140(coarse grit) grinding wheel performs effectively as compared to Diamond 170/200 (finer grit) resulting good surface finish. The SIC 120/140 wheel gives better values of surface finish as compared to diamond coarse grit wheel.

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