Study of some parameters on drilling of Al based Metal Matrix Composites – a review

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Abstract— Composite material in general, and metal matrix composites in particular, have been a main topic in research for the last 15 years. Metal matrix composites (MMC) have been found to be useful in a number of engineering applications and particle reinforced aluminum MMCs have received considerable attention due to their excellent engineering properties like high strength to weight ratio, high toughness, high impact strength etc. But these materials are generally regarded as extremely difficult to machine, because of the abrasive characteristics of the reinforced particulates. It is also acknowledged that their machining behavior is not fully understood. The work reviewed here investigated the drilling parameters like feed rate, drilling tool and its geometry, cutting speed and other parameters like influence of coolants, heat treatment etc.

Index Terms— Al-MMC, Composites, Drilling, Parameters.SiC

1 INTRODUCTION

Since the late 1980s there has been considerable interest in the development of materials with improved specific strength greater than that of ferrous-based materials, particularly in the transportation industries where fuel economy is a major consideration when designing components and selecting materials. Aluminum and magnesium alloys, plastics, carbon fibers and even ceramics are being used more frequently in road vehicle production. Nowadays, the notion of metal matrix composites (MMCs), a combination of a high-strength ceramic reinforcing a light metal alloy to deliver exceptional specific mechanical and physical properties, is becoming a reality. The properties of the resulting composite are generally controlled by three critical components: the matrix, the reinforcement and the interface. Many of the considerations arising from fabrication, processing and service performance of composites are related to processes taking place at the interface of matrix and reinforcement. Particulate metal matrix composites (PMMC) are economically cheaper in both raw materials and fabrications processes and have potential for applications requiring relatively large volume production

A persistent problem with particulate metal matrix composites (PMMCs) is that they are difficult to machine, due to the hardness and abrasive nature of the SiC or other reinforcing particles. The particles used in PMMCs are harder than tungsten carbide (WC), the main constituent of hard metal and even than the majority of the cutting tool materials. Polycrystalline diamond (PCD) is an exception, as its hardness is approximately three to four times that of the SiC. This is the reason why PCD is recommended by many researchers who have studied the drilling of these materials.

Drilling is a metal removal process and is important for the final fabrication stage prior to application. Because of the poor machining properties of MMCs, drilling MMCs is a challenging task for manufacturing engineers. Unlike machining of conventional materials, many problems are presented during drilling of MMCs. During drilling of MMCs, the cutting tool undergoes severe abrasive wear due to the presence of hard reinforcements and is considered highly unproductive.

These hard particles cause excessive tool wear even when machining with diamond tools. Drilling of MMCs pose many problems to the manufacturing engineers such as high drilling forces, tool wear and burr formation. In view of the growing engineering applications of these composites, a need for detailed and systematic study of their machining characteristics and machinability is envisaged. It is important to understand the drilling process in MMCs for choosing suitable tool materials, coolants and producing quality holes. Hence in this paper, a comprehensive review on various parameters like feed rate, drilling tool and geometry, cutting speed and some more parameters like application of coolant materials and heat treatment of work pieces is presented.

2 VARIOUS PARAMETERS AFFECTING THE PERFORMANCE

2.1 Feed Rate

Gul Tosun & Mehtap Muratoglu [1] had reported that as the feed rate increased, the cutting temperature also increased and this may cause weakening of the binding between the matrix and the SiCp, Paulo Davim & Conceicao Antonio [2] had suggested that at a constant cutting speed, the surface finish of the holes of the drilled samples deteriorates with increasing feed rate.Edith Morin et al. [3] had suggested that feed rate affects drilling forces and wear.Gul Tosun & Mehtap Muratoglu [4] had suggested that surface roughness decrease with increasing feed rate at each spindle-speed.

Basavarajappa et al. [5] had reported that feed rate is the main factor, which is influencing the thrust force. Ramulu et al. [6] suggested that the lowest surface roughness parameters occurred at the lowest feed rate. Basavarajappa et al. [8] also reported that the surface roughness value increases with increase in feed rate and decreases with increase in cutting speed.

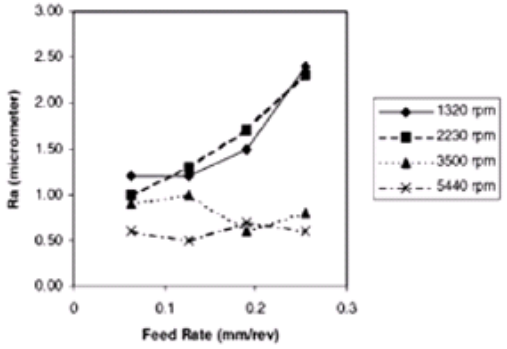

Fig.1. Surface roughness as a function of feed rate under different cutting speeds reported by Ramulu et al. [6]

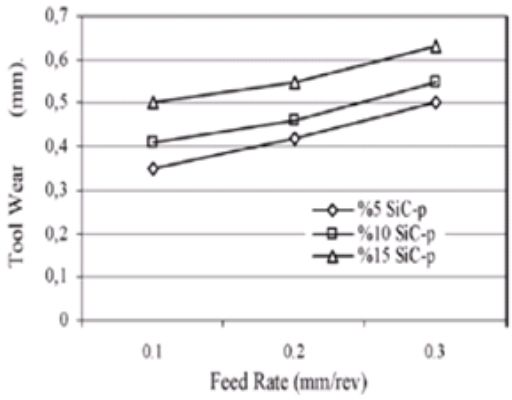

Fig.2. Tool wear as a function of feed rate at constant cutting speed reported by Tamer ozben et al. [11].

Coelho et al. [10] had investigated the various cutting parameters and selection of cutting tools for drilling of Al based MMCs and reported that the low feed rates produced rapid flank wear on the tool. Tamer ozben et al. [11] reported that the tool wear increase with feed rate at a constant cutting speed. Tool wear further increased by increasing the percentage of Sicp as shown in Fig.2.

2.2 Drilling Tool and its Geometry

Gul Tosun & Mehtap Muratoglu [1] were reported that as the point angles of HSS and TiN coated HSS drills increase, the damage zone increased. However, with increasing point angles of solid carbide drills, the damage zone decreased.

From the report of Gul Tosun & Mehtap Muratoglu [4], by increasing the point angles of all the drills, the surface roughness decreased. Hard-carbide tools produce a better surface finish compared to that achieved when using the HSS and the TiN coated HSS drills.

Ramulu et al. [6] suggested that drilling forces were significantly influenced by tool materials. HSS drills are unsuitable for drilling MMCs because of very high tool wear, poor drilled-hole quality, and higher drilling forces induced.

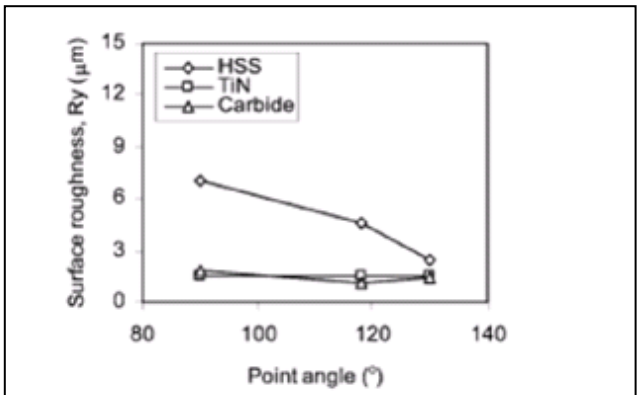

Fig.3. Effect of point angles of various drills on the surface roughness reported by Gul Tosun & Mehtap Muratoglu [4]

Basavarajappa et al. [8] reported that burr formation is less when multifaceted carbide drill is used when compared to conventional coated carbide drills. Conventional coated carbide drilling is preferred in applications that require a good surface finish. Coelho et al. [10] had reported that HSS is not a suitable tool material. PCD tipped drilling tools were effective over a wide range of operating conditions.

2.3 Cutting Speed

Edith Morin et al. [3] studied the thrust forces; torque and flank wear for several feed rates and cutting speeds and reported that cutting speed has no significant effects on drilling force and wear over a range of speed. Ramulu et al. [6] had evaluated the drilling characteristics in terms of drilling forces, tool wear, surface finish etc. and reported that the lowest surface roughness parameters occurred at the lowest feed rate with highest cutting speed. Basavarajappa et al. [5] had analyzed the drilling characteristics and suggested that the surfaced finish increases with increase in speed, or the surface roughness decreases with increase in spindle speed as shown in Fig.4.

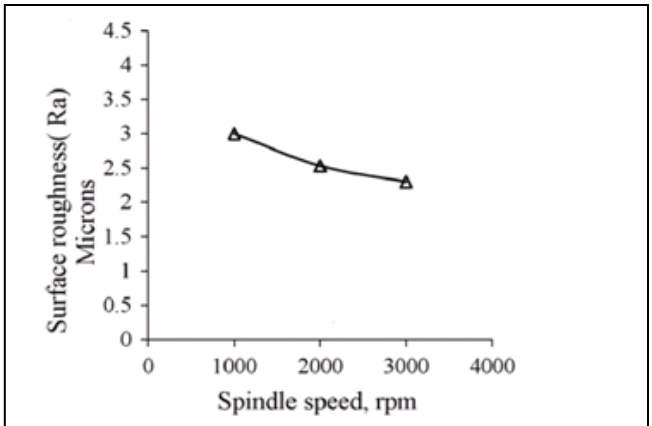

Fig 4. Variation of surface finish with spindle speed as reported by Basavarajappa et al. [5]

Tamer ozben et al. [11] reported that the cutting speed is the most significant machining parameter on cutting tool wear and the tool wear increases with cutting speed as shown in Fig. 5.

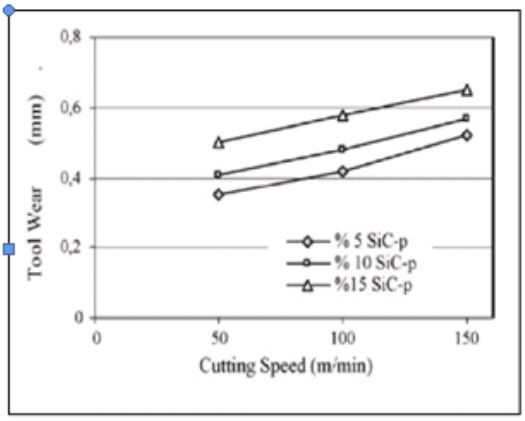

Fig.5. Tool wear as a function of cutting speed at constant feed rate reported by Tamer ozben et al. [11].

Basavarajappa et al. [8] also investigated the influence of various cutting parameters on the drilling performance of Al based metal matrix composites and suggested that the surface roughness value decreases with increase in cutting speed. Coelho et al. [10] had investigated the various cutting parameters for drilling of Al based metal matrix composites and proved that the cutting speed was not a significant matter affecting tool life.

2.4 Other Parameters

Gul Tosun & Mehtap Muratoglu [1] investigated the effect of different heat treatment conditions of the work pieces like as received, solution treated, solution treated and aged for 4 hrs and 24 hrs. and reported that the carbide tools with peak aged is showing better performance and the comparative graph is given by the author, which is shown in Fig.6.

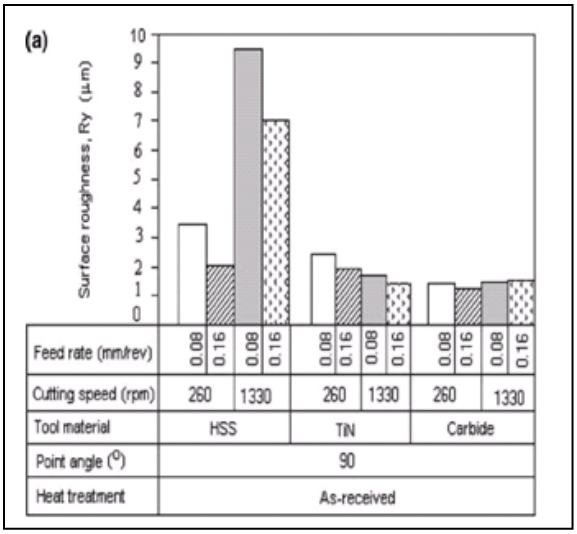

Fig.6. Effect of different heat treatment processes under various cutting parameters as reported by Gul Tosun & Mehtap Muratoglu [1]

Stuart barnes & Ian R.Pashby [7] investigated the effect of the coolant application method on the performance of the drilling operations on an aluminium / Sic metal matrix composites using TiN coated carbide tools and reported that the application of through – tool coolant produced a significant improvement in the drilling performance. They also suggested that the results obtained with conventional coolant were similar to those obtained when drilling dry Basavarajappa et al. [8] investigated the various parameters and reported that the inclusion of graphite as an additional reinforcement in Al/SiCp reinforced composite reduces the thrust force.

CONCLUSION

A comprehensive review on the effect of various parameters on drilling of MMC was presented in this paper. The review of the literature indicates that the research progress with the drilling of Al based MMC was scarce. The effect of feed rate, cutting speed, cutting tools, heat treatment and application of the coolant were reviewed and the results shows that the trend can be confirmed with more number of experimental and theoretical modeling. Hence it can be concluded that more research is required particularly on drilling of MMC. Furthermore the focus on development of predictive models will be useful in predicting the drilling performance of MMC. Hence it is believed that this review will provide the necessary guidelines for future research on drilling of Aluminium based metal matrix composites

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