AN OVERVIEW ON CONVENTIONAL MACHINING OF METAL MATRIX COMPOSITES AND HARD-TO-MACHINE MATERIALS

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ABSTRACT

In today's world, because of the superior mechanical properties, Industrialist are looking for the advanced applications of metal matrix composites (MMCs). The use of MMCs provides better impact toughness to the products and strength and also lowers the material weight and cost. In this paper, a review on Metal Matrix Composites (MMCs) and machining of MMC along with few other hard-to-machine materials using various machining methods such as turning, drilling and milling is covered. This paper includes various prospects of MMCs, especially aluminium matrix composites, such as application, properties and issues in machinability of these materials. At the end, this paper concludes the identified gaps and unaddressed issues in machining of MMC along with few other hard-to-machine materials.

Keywords: MMC, Drilling, Conventional Machining, Burr Height

I. INTRODUCTION

In various ways, Metal Matrix Composites (MMC) are different from other composite materials. Metal matrix composites have made a breakthrough in the development of useful properties of metals and alloys in relation to the traditional approach of alloying and heat treatment. These composites, containing discontinuous or continuous reinforcements with whiskers, particulates or fibres are capable of providing properties cannot be achieved in monolithic alloys. The present scenario is that, the MMC have penetrated a wide range of applications. Further, Aluminium matrix composites are the most popular of all metal matrix composites and desirable for many engineering applications.

II. LITERATURE REVIEW

Suresh et al. (2012) [1]have used response surface methodology on AISI 4340 high strength low alloy steel to optimize surface roughness, machining force and tool wear.They concluded that, for minimizing the machining force, the combination of low feed rate, low depth of cut and low machining time with high cutting speed is beneficial.

Davim et al. (2001) [2]have used Pareto optimum solution on A356/20/SiCp-T6 material to optimise cutting forces, tool wear and surface finish. They concluded that when machining the PMMCs, the predominant wear mechanism is abrasive and the feed force increases with the flank wear of the drills. The torque is not sensitive to the tool wear increase. The optimal tool life is strongly affected by the tool wear and by the surface finish.

Basavarajappa et al. (2007) [3] have used response surface methodology on Al2219/15%SiCp to optimise effect of machining parameters on material, Surface finish and morphology. They concluded that with the increase in feed rate, Surface roughness increases and with the increase in cutting speed, Surface roughness decreases. For better surface finish, Conventional coated carbide tool performs better than multifaceted carbide drill.

Palanikumar (2011) [4] has used Taguchi's method on Glass fibre-reinforced polymer (GFRP) composite materials to optimise thrust force, work piece surface roughness. They conclude that feed rate is the more influential parameter than spindle speed; this is indicated by the analysis of grey relational grade. Feed rate followed by spindle speed is more important controllable factors based on the grey relational grade.

Aouici et al. (2012) [5]have used statistical analysis of variance (ANOVA) and response surface methodology (RSM) on AISI D3 cold work Steel to optimise surface roughness and cutting force. They concluded that cutting force is mostly affected by feed rate followed by depth of cut. The use of lower depth of cut value, higher cutting speed, while hard turning of AISI D3 hardened steel, ensures minimum cutting forces and better surface roughness.

Ramesh et al. (2012) [6] have used Response surface methodology on titanium alloy to optimise the surface roughness. They concluded that the most influencing parameter was identified as the feed. The order of importance was feed, followed by depth of cut and cutting speed. The feed was the most influential factor which affects the surface roughness. They have studied Different chip formations and 3-D response surface plots are plotted for cutting speed, feed, and depth of cut on surface roughness.

Suresh R et al. (2012) [7]have used Taguchi technique on AISI 4340 steel to optimise Cutting force and thrust force. They concluded that for minimizing the machining force, the combination of low feed rate, low depth of cut with high cutting speed is beneficial. Machining force initially increases with increase in feed rate and depth of cut and decreases with increase in cutting speed. The feed rate has highest influence on the specific cutting force, machining force and surface roughness.

Hessainia et al. (2013) [8] have used Response surface methodology on 42CrMo4 hardened steel to optimise surface roughness. They concluded that the feed rate is the dominant factor affecting the surface roughness, whereas vibrations on both directions have a low effect on it. The feed rate provides the primary contribution regarding the other working parameters and influences the surface roughness evolution, significantly.

Gopalakannan et al. (2013) [9] have used Response surface methodology on Al–SiCnano-composites material to optimise Surface roughness and feed rate. They concluded that the MRR first increases with an increase in pulse on time and then decreases with further increase in pulse on time. So the two main significant factors that affect the MRR are pulse current, pulse on time.

Sahoo et al. (2013) [10] have used Taguchi's L9 orthogonal array on Al/SiCp MMC to optimise Feed rate. They concluded that Cutting speed is found to be the most significant parameter for flank wear followed by feed. Depth of cut has the insignificant effect on flank wear. Mathematical models for flank wear and surface roughness are statistically significant

Taskesen et al. (2013) [11]have used Grey relational analysis on B4C reinforced Al-alloy to optimise thrust force, torque and surface roughness. They conclude that Flank wear of the cutting tool was found to be mostly dependent upon particle mass fraction, followed by feed rate, drill hardness and spindle speed, respectively. Grey relational analysis indicated that drill material was the more influential parameter than feed rate and spindle speed.

Karabulut (2015) [12] have used Taguchi method and neural network on AA7039/Al2O3 metal matrix composites material to optimise surface roughness and cutting force. ANOVA technique is also used. They concluded that the analysis results showed that material structure was the most effective factor on surface roughness and feed rate was the dominant factor affecting cutting force. ANOVA results show that the most effective control factor for surface roughness, with a percentage contribution of 85.24%, was the type of material. The feed rate and cutting speed affect the surface roughness by 7.12% and 5.05% respectively. The depth of cut has the least effect on surface roughness.

Suresh et al. (2012) [13] have used response surface methodology on AISI 4340 high strength low alloy steel to optimize surface roughness, machining force and tool wear.They concluded that, for minimizing the machining force, the combination of low feed rate, low depth of cut and low machining time with high cutting speed is beneficial.

Gallab et al. (1998) [14] have used Dry turning test on Al:SiC particulate metal-matrix composites to optimise Rake angles. They concluded that for the roughing operations, Polycrystalline tools with zero rake angle and large tool nose radii are recommended. The main tool wear mechanism is abrasion and micro-cutting of tool material grains, manifested as grooves on the tool face parallel to the chip flow direction.

Hayajneh et al.(2009) [15] have used Artificial neural network modeling on aluminum/alumina/ graphite hybrid composites to optimise Cutting speed ,Cutting feed ,volume fraction of the reinforced particles and thrust force. They concluded that ANN is an excellent analytical tool, if it is well trained, can be used for other machining processes. The models for the thrust force and cutting torque were identified by using the alumina (Al2O3) particles contents, graphite (Gr) particles contents, cutting feeds (F) and spindle speeds (N) as input data and thrust force and cutting torque as the output data.

Rajmohan et al. (2012) [16]used Taguchi's method on hybrid mmc to optimise Surface finish, thrust force, tool wear, and burr height in the drilling of composites. They concluded that, the factors which affect the drilling process are feed rate and the type of drill. The tested parameters, the feed rate shows strongest correlation to the thrust force, surface roughness, tool wear and burr height (exit).

Rajmohan et al. (2013) [17] used Microstructure and mechanical characterization on hybrid aluminium matrix composites to optimise strength and hardness. They concluded that the better strength and hardness are achieved with Al/10SiC−3mica composites. The increase in mass fraction of mica improves the wear loss of the composites. Mica reinforced composites exhibits less wear loss and higher density compared with the ceramic reinforced composites.

Taskesen et al. (2013) [18] have used grey relational analysis on boron carbide reinforced metal matrix composites to optimise Feed rate and spindle speed. They concluded that the weight fraction of the B4C resulted in a considerable increase in the thrust force. Average surface roughness of drilled hole decreased with increasing particle content for carbide tools and increased for HSS tools. TiAlN coated carbide drills showed the best performance with regard to the surface roughness.

Davim (2003) [19]have used Taguchi's method on MMC to optimise Correlation between cutting velocity, feed rate and cutting time. Feed rate is the cutting parameter which has greater influence on surface roughness and specific cutting pressure followed by cutting velocity and cutting time. To analyze interaction in the holes surface roughness, the interaction cutting velocity/feed is the most important.

Kumar et al. (2012) [20]have used Optimization of drilling parameters on Al6061–SiC composites to optimise Hardness, Ultimate tensile strength and feed rate. They concluded that the experimental results showed that the density of the composites increase with increased SiC content. The wear resistance of the composites is higher than that of base alloy. Hardness of the composites was found to increase with increased filler content. The ultimate tensile strength properties of the composites are found to be higher than that of base matrix.

Barnes et al. (2000) [21] have used Taguchi's method and ANOVA on Aluminum/SiC Metal Matrix Composite to optimiseDrill wear, Hole diameter and Surface roughness. They concluded that in the drilling performance, the application of through toolcoolant (even at low pressure) produced a significant improvement. In agreement with otherwork, the wear observed at some locations increased when usingconventional cooling relative to dry drilling.

Horvath et al. (2011) [22] have used Response surface method (RSM) on Aluminum alloys to optimise Surface roughness, Feed rate Surface height and standard deviation. They concluded that the cutting speed and feed have the largest influence on surface roughness. Also the interactions of these factors also significantly affect surface roughness. The harder hyper-eutectic alloy has better finish turning and lower roughness values.

III. REVIEW IN TABULAR FORMAT

AUTHOR	OPTIMIZATION TECHNIQUES	Material	QUALITY CHARACTERISTICS
Suresh et al. (2012)	RSM.	AISI 4340 high strength low alloy steel	Surface roughness, Machining force and Tool Wear
Davim.et al. (2001)	Pareto Optimum Solution	A356/20/SiCp-T6 MMC	Cutting Forces, Tool Wear and Surface Finish
Basavarajappa et al. (2007)	RSM	Al2219/15%SiCp MMC	Surface finish and Morphology.
Palanikumar (2011)	Taguchi's method	Glass fibre-reinforced polymer (GFRP) composite	Thrust Force, Surface Roughness
Aouici et al. (2012)	ANOVA & RSM	AISI H11 steel hardened to (40; 45 and 50) HRC	Surface Roughness, Cutting Force
Ramesh S et al. (2012)	RSM	aerospace titanium alloy (gr5)	Surface Roughness
Suresh R et al. (2012)	Taguchi Optimization	AISI 4340 steel	Cutting force, Thrust Force
Hessainia et al. (2013)	RSM	42CrMo4 hardened steel	Surface Roughness
Gopalakannan et al. (2013)	RSM	Al–SiCnano-composites	Surface roughness, Feed Rate
Sahoo et al. (2013)	Taguchi	Al/SiCp MMC	Flank Wear,

	Optimization		Surface Roughness
Taskesen et al. (2013)	Grey relational analysis	B4C reinforced Al-alloy	Thrust Force,Torque Surface Roughness.
Karabulut (2015)	Taguchi Optimization and ANOVA	AA7039/Al2O3 MMC	surface roughness and cutting force
Suresh et al. (2012)	RSM	AISI 4340 high strength low alloy steel	Surface Roughness, Machining Force Tool Wear.
Gallab et al. (2008)	Taguchi Optimization	Al:SiC particulate MMC	MRR Surface Roughness
Hayajneh et al. (2008)	ANN	mixture of aluminium powder as a matrix and alumina (Al2O3) and graphite (Gr) powders as reinforcements	Thrust force Torque
Rajmohan et al. (2012)	Taguchi method with grey relational analysis	Hybrid Metal Matrix Al356/SiC-mica composites	Thrust Force, Surface Roughness, Tool Wear, Burr Height
Rajmohan et al. (2013)	Microstructure and mechanical characterization of the composites	Mica and SiC ceramic particles incorporated Al 356 alloy	Wear Loss Strength Hardness
Taskesen et al. (2013)	Grey analysis and ANOVA	B4C reinforced MMC	Thrust Force, Torque Surface Roughness
Davim (2012)	Taguchi Optimization	Al2O3, SiC, B4C, MMC	Tool Wear, Cutting Pressure Surface Roughness
Kumar et al. (2012)	They have used Optimization of drilling parameters of hybrid metal matrix comp	Al6061–SiC MMC	Hardness, Ultimate Tensile Strength, Feed Rate
Barnes et al. (2000)	Experimentally studied with SEM images	Al-SiC MMC	Drill wear, Hole diameter and Surface roughness
Horvath et al. (2011)	Response surface method (RSM)	AS12 eutectic alloy AS17 hyper-eutectic alloy	Surface roughness Feed rate Surface height

IV. CONCLUSION

This paper gives a review of the literature so as to understand the complex mechanism of machining MMCs and hard-to-machine materials by conventional method. The review of available literature shows that conventional machining of metal matrix composites is mainly focused on experimental investigation into the process characteristics and its benefits. This review found that, optimization of the Burr height, Over-Cut and Temperature for the conventionally machined MMCs can be done keeping the process parameters viz. Speed, Depth of Cut and Diameter.

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