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A Review on Abrasive Water Jet Machining (AWJM) of Aluminium Matrix Composites (AMCs)

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***Abstract*--- Abrasive Water Jet Machining (AWJM) is an unconventional material processing technique that is widely used in industries now. In various product applications, high strength with lower weight is desirable nowadays. Aluminium Matrix Composites (AMCs) are having high strength to weight ratio, better tribological properties and good corrosion resistance and hence their demand increases now days. In present review, study the effect of various AWJM process parameters, like, jet pressure, transverse speed and stand of distance nozzle diameter and abrasive grain size on kerf width, kerf angle and surface roughness presented.**

***Keywords*--- AWJM; AMCs; Process Parameters**

LIST OF ABBREVIATIONS

AWJM: Abrasive Water Jet Machining
AMC: Aluminium Matrix Composites
AJM: Abrasive Jet Machining
WJM: Water Jet Machining
KE: Kinetic Energy
JP: Jet Pressure
TS: Traverse Speed
SOD: Stand-off Distance
ND: Nozzle Diameter
AGS: Abrasive Grain Size
KA: Kerf Angle
SR: Surface Roughness
MRR: Material Removal Rate
AFR: Abrasive Flow Rate
DOC: Depth of Cut
KW: Kerf Width

I. INTRODUCTION

AWJM is widely used in industries for machining of various non-metallic and metallic materials [1]. The heat is not generated during the process and can cut almost a broad spectrum of materials like metals, non-metals composites and ceramics [2]. Surface finish after AWJM is fair enough to be accepted as compared to other processes. The material up to 200 mm thickness can be cut using this AWJM process. It is combination of two processes principle which is AJM and WJM [3]. The process work on the principle of erosion of the material[4]. Hard abrasive particles are merged to the pressurized high velocity water jet stream which results in increase in Kinetic Energy of the abrasives. This results in removal of material from targeted workpiece [5]. Fig. 1 shows the setup of AWJM process. It consists of Water pump, High pressure tube, abrasive hopper, cutting head and a catcher.
The parameters are Jet Pressure (JP), Traverse Speed (TS), Stand-off distance (SOD), Nozzle Diameter (ND) and Abrasive Grain size (AGS) [7-10].

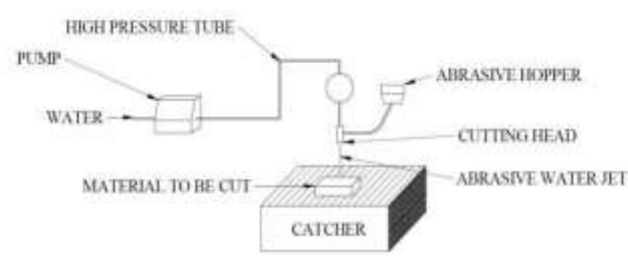

Fig. 1 : AWJM PROCESS, Shailendra [6]

Parameter Definitions:

- Jet Pressure : Pressure at which the jet impact on workpiece surface

- Traverse Speed: Speed of linear movement of nozzle
- SOD: The distance of nozzle tip from the workpiece surface

Composite materials consist of two or more than two different materials with different chemical, physical and mechanical properties [11]. By producing composites, the required properties can be achieved which can't be achieved by using constituting material individually. Composites are used in industries due to its improved properties like high strength to weight ratio, better tribological properties and good corrosion resistance [12]. Composite materials can be classified Polymer Matrix Composites, Metal Matrix Composites and Ceramic Matrix Composites. The composites can be prepared by addition of reinforcement material in matrix (base of the composite). In composites, the matrix as continuous phase which holds the reinforcement and control strength at high temperature [13]. The reinforcement can be of any of the following: Al_2O_3, SiC, Si_3N_4, B_4C, BN, TiC, TiB_2, ZrO_2, B_4C, WC, fly ash, etc. [14]. The application of composites is as found Automobile Sector, Aerospace and Aircraft industry, Sports and Recreations, Electrical transmissions as shown in Fig. 2 [15-16, 31-32].

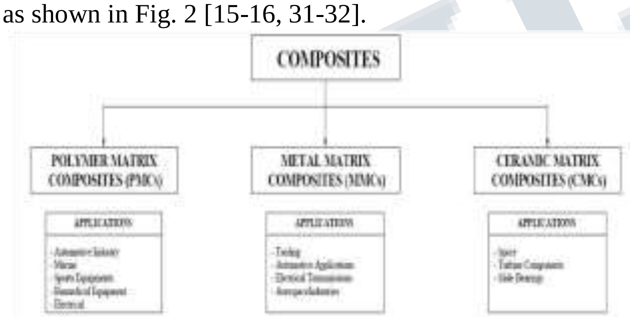

Fig. 2: Types of Composites

II. LITERATURE REVIEW ON AWJM OF MMCS

A brief review of AWJM on AMCs is done in the following section to identify and study process parameters and their effects on various output parameters.

It was investigated the effect of different cutting processes on pure Al and Al 6061 aluminium alloy of 20 mm thickness. The cutting processes were saw cutting, milling, plasma, submerged plasma, laser, wire EDM, oxy fuel and Abrasive water jet [17].

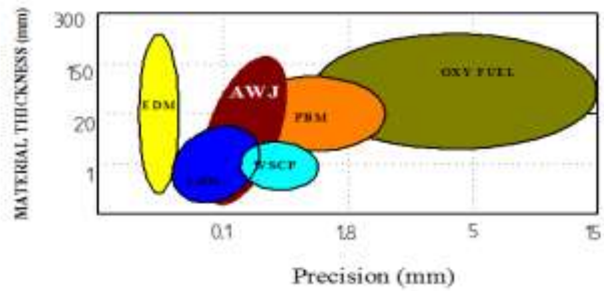

Fig. 3 : Different Cutting Methods, Akkurt [17]

Fig. 3 shows the comparison of AWJ with alternate cutting methods. It was also observed that AWJ did not have any adverse effect on microstructure and can be used in industries where there is no change in microstructure of material and material hardness is essential and study of the output of AWJM on kerf characteristics of hybrid Al 7075 AMCs [Al 7075 + (5%, 10%, 15%) TiC + (5%, 10%, 15%) B4C]. Input parameters were JP (240, 260, 280 MPa), TS (30, 60, 90 mm/min) and SOD (1, 2, 3 mm) and Output response were Top kerf width, Kerf angle (KA) and Surface Roughness (SR) [18]. When TS increased, top kerf width and SR decreased and KA increased. With increase in JP provided better surface finish and decrease in KA. Lower SOD provided smaller kerf width and KA as well resulted in good surface finish. With increase in TS, the SR increased and it was observed that the effect of AGS (80, 120) on KA, MRR (Material Removal Rate) and SR [19]. Input parameters were JP, SOD and TS. It was deduced that particle size had no influence on MRR at high pressure but at lower pressure the coarse resulted in high MRR at lower TS and high SOD. The fine particles resulted in better surface finish and minimum KA. It was experimented with Hybrid AA6061- (5, 15% vol) B_4C- (5, 10% vol) CNT composites. The output responses were KA, SR and MRR. Study revealed that with an increase in reinforcement there was an improvement in KA. A decrease in reinforcement lead to lower SR whereas increase in reinforcement resulted in increase in MRR. SCR (Smooth Cutting Region) was found at higher reinforced composites [20] and studied the effect of TS (60, 80, 120, 150, 200, 250 mm/min) on Ti-6Al-4V alloy. The output responses were kerf geometries and micro-structural features. Three cutting zones identified which were: (i) IDR (Initial Damage Region) (ii) SCR (Smooth Cutting Region) and (iii) RCR (Rough Cutting Region). It was observed that with increase in TS, the kerf width got narrowed. There was not considerable effect on SR. The TS appeared to be a significant parameter for soft cutting region [21].

Experimental investigation carried out with hybrid AMCs, i.e. AA7075 matrix with (5, 10, 15 vol. % $ZrSiO_4$) and (5 vol. % hBN) reinforcements. The inputs were Abrasive Grain Size, AFR, JP & TS. A kerf characteristic was the output response. High pressure resulted in to minimum KA and SR. Lower TS provided minimum kerf taper angle. Fine particles provided better surface finish. The TS found to be the most effecting parameter for KA & SR [22] performed experiment on AA2014 using SiC as abrasive and parameters as TS, JP, Mass Flow Rate and SOD. L9 orthogonal design was used for selected parameter at three levels. It was revealed that JP was the most effecting parameter for depth of cut followed by TS & AFR[23].

It was investigated the effect of abrasive grain size (80, 100, 120), AFR, JP and work TS on AA6061- (5-15 vol.%) B_4C- (15 vol.%) hBN hybrid AMCS. It was found that the finer particles produced a smoother surface. An increase in reinforcement resulted in increase in SR. The TS proved to be most dominating parameter affecting the SR. With elevation in abrasive flow rate and mesh size, SR decreased [24]. [25] Investigated the cutting ability of AWJM on Aluminium 6061 by varying AFR, water JP and TS of jet on DOC. The effect of AFR was negligible on DOC.

[26] Studied the machinability of B_4C reinforced AMCs with AWJM. Specimen manufactured using SC (Stir Casting). The input parameters considered AGS (80, 100, 120), AFR, TS (60, 90,120 mm/min) and JP (125, 200, 275 MPa). Observations indicated that 80 mesh size abrasives, high pressure, high flow rate and lower TS produced best results among other parameter combinations. Increment in water JP and AFR resulted into higher DOC. Increase in TS produced lower DOC. With 80 mesh size the DOC was higher and with 120 mesh size abrasives produced lower DOC[26].

Experimental study carried out for the material AA2024-B_4C-TiC with AWJM process. Output responses were SR, MRR and KA. The input parameters were JP, SOD and TS. With an increase in SOD, TS and water JP, there was an increase in MRR. Scanning Electron Microscope was used for observation of machined surface and erosion directions [27]. Effect of material thickness, TS and AFR for AWJ cutting of Aluminium material was done and in experimental investigation it found that the SR increased with increase in TS and it reduced with increase in AFR. The increase in material thickness resulted into the increase in SR, specially at bottom portion[28]. Experimentations with AA2618/20% SiC particles and A356/35 % SiC and machining was done by three processes which were Abrasive Water Jet, Laser Cutting and Electro Discharge Machining. The EDM process was very slow. In laser cut machining the burr observed at the exit whereas there were no such burr observed in AJM [29]. It was experimented with AA6082 matrix with (2, 4, 6, 8, 10%) WC reinforcement. It was concluded that MRR is influenced very much by traverse speed Roughness is influenced by % of WC reinforcement[30]. The above literature is summarized in following table (Table 1).

TABLE I. LITERATURE REVIEW SUMMARY

Author(s)	***Material***	***Input Parameters***	***Output Responses***	***Remarks***
KSKSasikumar	AA7075+ TiC+ B4C	- JP - TS - SOD	- Kerf top width, - KA and - SR	-KW decreased with increase in TS and SOD - KW increased with increase in JP
S. Thirumalai	AA6351 + SiC + B4C	- JP - SOD - TS	- KA - MRR - SR	- Grain size has no influence on MRR - Finer abrasive produced good surface finish - Coarse particles produced lower KA
A. Gnanavelb abu	AA6061 + B4C + CNT	- AGS - Abrasive Flow Rate (AFR) - JP - TS	- KA - SR - MRR	-Increase in Reinforcement resulted in decrease in KA and increase in MRR -Decrease in reinforcement led to lower SR
R. Rethan Raj	AA7075 + ZrSiO4 + hBN	- AGS - AFR - JP - TS	- KA - SR	-TS found to be the most dominant parameter for KS and SR.

R. Shibin	AA2014	- TS - JP - SOD - AFR	- DOC - MRR	-The JP was most significant parameter for DOC.
A. Gnanvelba bu	AA6061 + B4C + hBN	- AGS - AFR - JP - TS	- Kerf Characteristics, - SR	- TS found to be the most significant parameter for SR.
Prabhuswa my N R	Aluminium 6061	- AFR - JP - TS	- DOC	-The effect of AFR on DOC was Negligible
M. C. Kalai Selvan	Al2024 + B4C	- JP - TS - AGS - AFR	- DOC	- Fine particles provided lower DOC.
P. Ganesan	AA2024 + B4C + TiC	- JP - SOD - TS	- SR - MRR - KA	- MRR increased with increase in TS, SOD and JP.
DerzijaBegic - Hajdarevic	Pure Aluminium	- Thickness - TS - AFR	- SR	- Increase in material thickness resulted into increase in SR at bottom portion.

III. CONCLUSIONS AND FUTURE SCOPE

AWJM is used widely in industries as it is more advantageous as compared to other material processing techniques. It has many advantages such as almost any hard and difficult to be machined materials can be cut using AWJM and also it has no thermal effect on the cutting edges. It is used in industries where no thermal damage to the material required. The most dominant parameters widely used are JP, TS and SOD which affect the output entities such as kerf characteristics, SR and MRR. Increase in reinforcement resulted in increase in Surface Roughness and decrease in Kerf Angle. The value of surface roughness decreased with increase in jet pressure whereas surface roughness increased with increase in traverse speed and stand-off distance. With increase in jet pressure kerf angle reduced. Increase in traverse speed and stand-off distance resulted in larger kerf angle.

Further scope in the area is that the process is applicable to almost all the materials so any other material or composites can be selected for experimental as well as review work.

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