

# Effect of operating variables on different materials using Abrasive Jet Machining

<sup>1</sup>B.JOGA RAO, <sup>2</sup>S.H.V.PRAMODH, <sup>3</sup>G.ASHOK KRISHNA

<sup>1</sup>ASSOCIATE PROFESSOR, <sup>2,3</sup>U G SCHOLARS

<sup>1</sup>MECHANICAL ENGINEERING,

<sup>1</sup>GODAVARI INSTITUTE OF ENGINEERING AND TECHNOLOGY, RAJAHMUNDRY, INDIA

**Abstract :** The application of high speed stream of abrasive particles carried by a gas medium (air) through the nozzle is more obvious for the materials i.e., high sensitive and brittle using abrasive jet machine. In this present work, the parameters such as material removal rate (MRR), pressure and nozzle-tip-distance (NTD) were found with nozzle diameter 2 mm using AJM with a grain size of 20  $\mu\text{m}$  with sand as abrasive. The greater accuracy and surface finish was achieved with minimum diameter and maximum depth with carbide nozzle. Since negligible heat was induced while machining the surface (glass (G), fibre glass (FG) and GI sheet (GI)), the workplace is not subjected to thermal shocks. The maximum MRR with NTD 20mm for glass is  $21 \times 10^{-5} \text{kg/m}^3$  at a pressure of  $8 \text{kg/cm}^2$ , for the fiber glass with NTD 15 mm the MRR is  $10 \times 10^{-4} \text{kg/m}^3$  at a pressure of  $7 \text{kg/cm}^2$  and finally for the GI sheet with NTD 10 mm the MRR is  $27 \times 10^{-4} \text{kg/m}^3$  at a pressure of  $10 \text{kg/cm}^2$ .

**IndexTerms** – brittle, accuracy, homogenize, perspective.

## I. INTRODUCTION

Rapid technology development in the field of new materials and alloys with increasing strength, hardness, toughness, heat resistance and wear resistance have imposed many problems and difficulties during the machining by conventional means.

Machining intricate and complicated shapes of fragile components are accurate and economical forming of very hard. High strength materials which are being extensively used in aero plane and nuclear industries have forced the Scientist/Engineers and technologists to search for new techniques of machining which can rapidly provide an effective solution to these problems.

As a research and development for the last four decades several new machines were emerged. Among the new methods we are going to deal with “TUMBLING MACHINING”. The conventional techniques such as drilling, milling, turning, cutting, planing, shaping...etc., are well known and involves the use of mechanical power & man power between the workpiece and tool whereas in un-conventional machining process those above techniques are not applied because the man power is not involved. It can process through air, gas, water mediums.

## II. LITERATURE REVIEW

In this section, the experimental approach was discussed by the various researchers of abrasive jet machine. The researchers are conducted various tests at different parameters such as nozzle-tip distance NTD, carrier gas, air pressure, type of abrasives, mixing composition etc. are focused.

M L Neema and P C Pandey (1977) are together done a research on erosion of glass by abrasive jet. It was experimented on different glass pieces with various abrasives such as  $\text{Al}_2\text{O}_3$  &  $\text{SiC}$ . The abrasives with grain size varying between 10 to  $50 \mu\text{m}$  and mixed in some composition. It was considered that the abrasives play vital role to cut the glass that govern the metal removal rate. The mechanism of MRR with brittle materials is machined and analytical methods are proposed, and together they proposed an equation to calculate the MRR during indentation.

$$Q = k N d^3 v^{3/2} (\rho a / 12 \sigma_y)$$

Where, K is a constant, N is the number of abrasives, d refers the size of the abrasive particles,  $\rho a$  is the density of the abrasives, v is the velocity of the abrasive particles,  $\sigma_y$  is the yield stress of the material [1].

Dr A K Paul and R K Roy (1987) have done experimental studies on abrasive jet machine. MRR, Abrasive flow rate (AFR), and MRF at various pressures, grain size and nozzles diameter were calculated. Experimentation on glass specimen was conducted at various parameters and based on results drawn graphs for their perspective object. It was observed that with increase in grain size the MRR also increased.

The proposed MFR equation is

$$\text{MFR} = \text{MRR (g/min)} / \text{AFR (g/min)}$$

It was shown a graphical form for every operation done on AJM in a laboratory [2].

Iain Finnie (1960) discussed on erosion of surfaces by solid particles which means the AJM setup was operated with the help of fluid stream. The experiment was observed that when fluid impacts with solid particles on to the workpiece the erosion was

imparted on the surface. It was analysed the erosion between the brittle and ductile materials at different parameters. An equation was also proposed when the particles impacting of mass  $M$  carried with fluid stream, can be calculated as

$$Q = C_f (\Theta) M v^n$$

Where,  $C$  &  $n$  are constants,  $\Theta$  is the impingement angle [3].

Sarkar and pandey (1980) developed an equation to calculate the MRR for AJM

$$Q = x Z d^{3/2} (\rho/12H_w)^{3/4}$$

Where,  $Z$  is the particles imparting per unit time,  $D$  is the mean diameter of abrasive grain,  $\rho$  is the density,  $V$  is the velocity of abrasive particles, and  $x$  is a constant. He improvised the equation proposed by the neema and pandey [4].

Bhaskar Chandra kandapal (2011) conducted experimentation on the glass plate and the ceramic plate with the silicon carbide and alumina particle at different parameters and plotted graphs between the parameters such as NTD, MRR and pressure. These are compared with the theoretical values. According to this paper the as NTD increases the MRR also increases. [5]

El-Domiaty et al (2009) was conducted an experiment on the glass plates with various abrasives such as sand, silicon carbide at different pressures and various parameters with air stream. In this experimentation the nozzle kept at constant at one position throughout the machining process and the nozzles were changed of different sizes. [6]

Manabu wakuda, Yukihiko et al (2003) studied on alumina and ceramics with the various abrasives particles such as silicon carbide, aluminium oxide, diamond dust. By using the abrasive the research has proceeded on the ceramics and alumina to identify the material response and impact of the material after machined. [7].

Matthew W. Chastanger explained the paper on the edge consistent and precise shape is more important while machining the mechanical components. It was stated that machining edges must be accurate and shape obtained is in precise manner so as to calculate the theoretical values and plotting the graphs will me more accurate. The SEM micrographs of AJM are describes the edges of the specimen [8].

Alireza Moridi et al (2010) has presented an experimental study of the different parameters such as NTD, Nozzle, air pressure, grain size, abrasive particles on the cutting performance measures such as kerf, groove depth, taper angle. In this paper the experimental study made on the grooves and u-shaped cutting. According to the alireza moridi the groove depth cutting is increased with abrasive flow rate when more particles are impinged on the surface and it leads to the more metal removal rate [9].

### III. MATERIALS AND METHODS

As we know that the un-conventional machining process has an immense impact on the material study, and the materials such as brittle & ductile materials are easily machined as no heat is imparted on the material. There are many methods and materials to improve the machinability by approaching the various parameters. Every material has their own properties and structures based on the parameters that they induced in it.

In this machining process different materials such as Glass, Fibre Glass and GI sheet are considered to find MRR at an optimized pressure at a fixed NTD. All these materials contain special characteristics on their own way. As it was observed from the literature most of the experiments were conducted on abrasive jet machine with glass. But In this present work machining was done on both ductile and brittle materials.

The experimentation was conducted on various materials at different factors such as NTD, Grain size, Pressure. Many other scholars on AJM projects have their own methods to approach the operation, but the new method that have been used is tumbling machine apparatus to mix the abrasive particles and compressed air in appropriate proportion to cut the workpiece with precise and accurate dimensions.

The compressor is used to compress the atmospheric air at certain prescribed pressure and allows us to do certain operations. From this compressed air the AJM was operated with help of tumbling apparatus. This tumbling apparatus operates between the required pressures and shakes the equipment with the help of motor and cam mechanism. The use of this tumbler in AJM setup plays a vital role and mixing proportion of the gas & abrasives particles are in mixed in certain ratio to cut the difficult-cut-materials. The power produced over tumbler pushes the mixed proportion to the machining chamber and helps to cut the material very easily.

In this abrasive jet machining process, the dry air is sucked through compressor which is then filtered by using air filters. The pressure and flow rate of the compressed air can be regulated by using pressure gauge. After that the compressed air is passed into the abrasive sand mixer with the help of hosepipe. In this chamber, abrasive particles are fed. To homogenize abrasive particles and compressed air, single induction motor by using cam mechanism was used. Finally, the high pressure air with abrasive particles strikes the workpiece through nozzle so that the material to be removed. The schematic layout of AJM is shown below figure1.

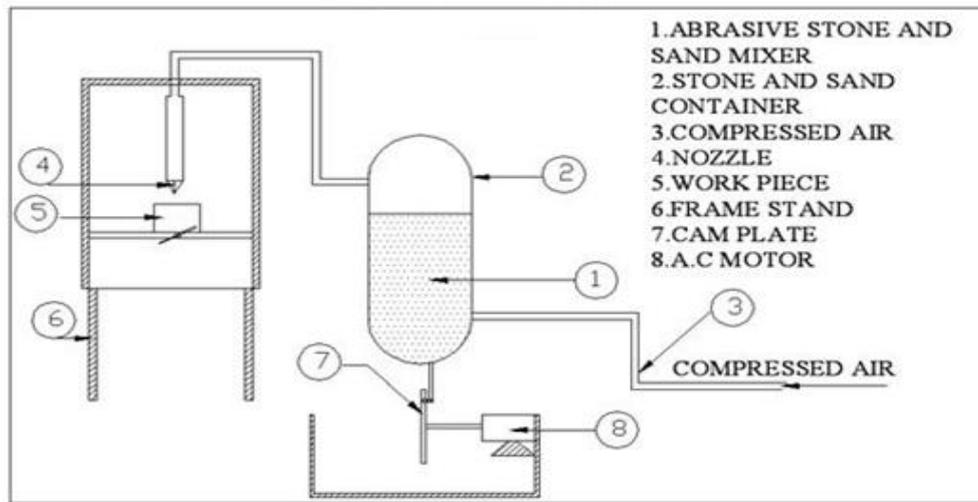


Fig1: schematic layout of abrasive jet machine

IV. RESULTS AND DISCUSSION

In conventional process, drilling and cutting of glass, fibre glass and GI sheet cannot be machined effectively but Tumbling Machining process has created a revolution in machining of these delicate materials. Abrasive Jet Machining presented the best performance when all the possible drawbacks are eliminated comparing to the present mode. In this process, compressed air and abrasives are used to drill and cut the materials in required dimension by varying the pressure.

A brief review of the experimental approach was conducted in this paper. It was followed by the analysis of various parameters such as MRR, NTD, nozzle, grain size, types of abrasives. These experimentations were done on AJM with variable pressure ranging from 6-10 kg/cm<sup>2</sup> at NTD of 10 to 20 mm with the variation of 5. For every pressure, time taken to remove the material was noted down. From this result, MRR is calculated using the relation.

$$Q = k N d^3 v^{3/2} (\rho_a / 12 \sigma_y)$$

Where, K is a constant, N is the number of abrasives taking a quiet time, d refers the size of the abrasive particles, ρ<sub>a</sub> is the density of the abrasives, v is the velocity of the abrasive particles, σ<sub>y</sub> is the yield stress of the material

The below figure are shown which are machined on AJM.

The experimentation was conducted on glass, fibre glass and GI sheet at various pressures and at different NTD that are represented in figure 2, 3 and 4 below.

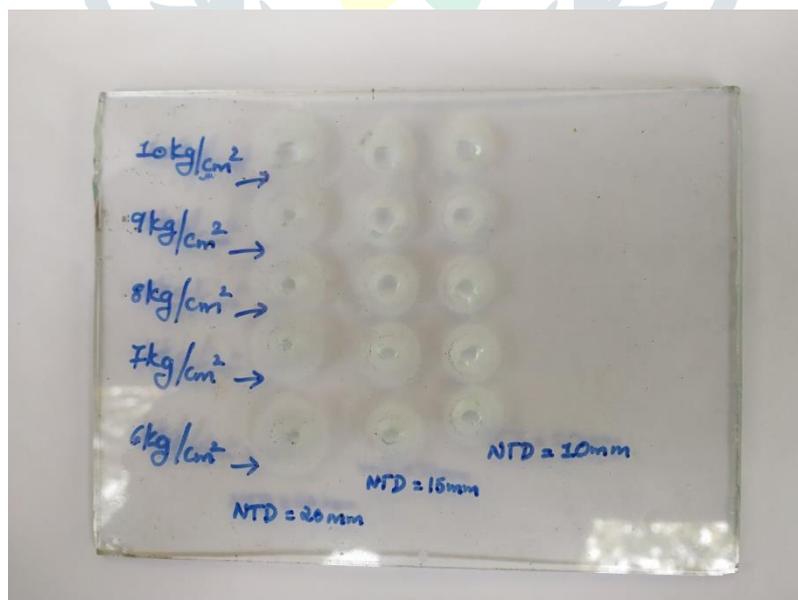


Fig 2: fibre glass machined on AJM at various Pressures and at different NTDs

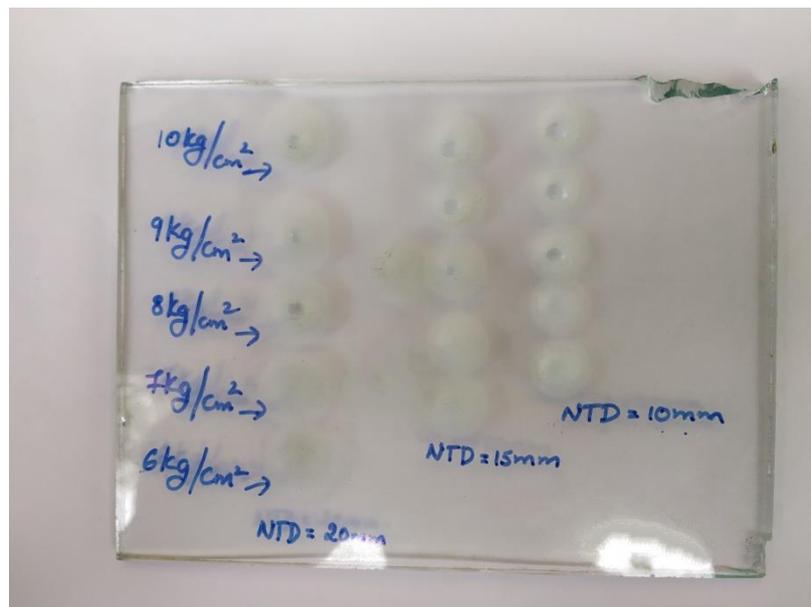


Fig 3: glass workpiece machined on AJM at various Pressures and at different NTDs

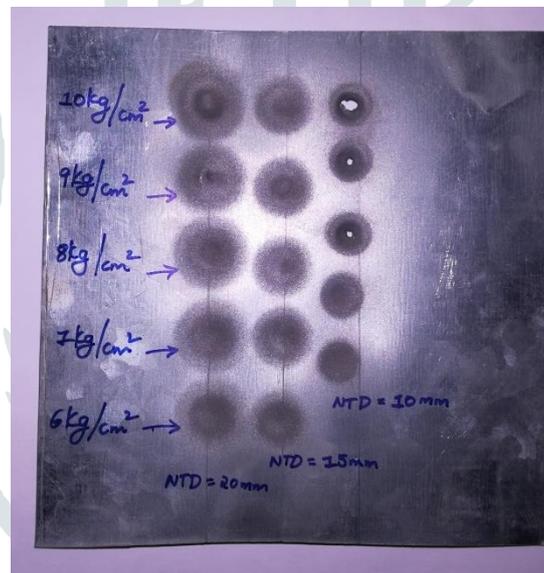


Fig 4: GI sheet machined on AJM at various Pressures and at different NTDs

The below graph fig 5, 6 & 7 relates between MRR and Pressure at different NTDs (20, 15 & 10 mm). From the graphs it was observed that as NTD decreases the MRR increases similarly, as pressure increases, MRR also increases significantly. The glass at a pressure of  $10 \text{ kg/cm}^2$  has the highest metal removal rate at a NTD of 20 mm because the glass is brittle nature and marginal MRR is observed during experimentation at a pressure of above  $7 \text{ kg/cm}^2$  and at NTD 20 mm. So the time taken to cut the material is least (40 seconds) which is the faster removal rate than the other materials such as GI sheet and Fibre glass. While fibre glass maximum MRR is noticed at a pressure of  $7 \text{ kg/cm}^2$  at NTD of 15 mm. Lastly, for the GI sheet highest MRR is obtained at a pressure of  $10 \text{ kg/cm}^2$  at NTD of 10 mm due to more shear strength of the ductile material (GI sheet), NTD is decreased and considerable material removal is noticed at a pressure of  $8 \text{ kg/cm}^2$ .

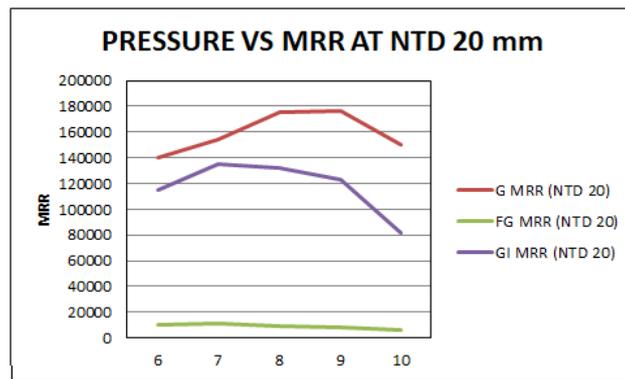


Fig 5: graph between Pressure and MRR at NTD 20mm

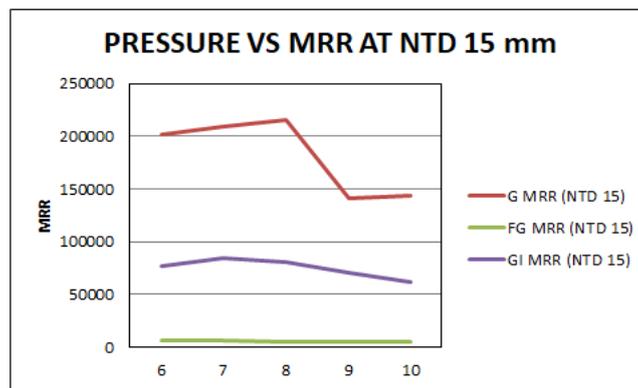


Fig 6: graph between Pressure and MRR at NTD 15mm

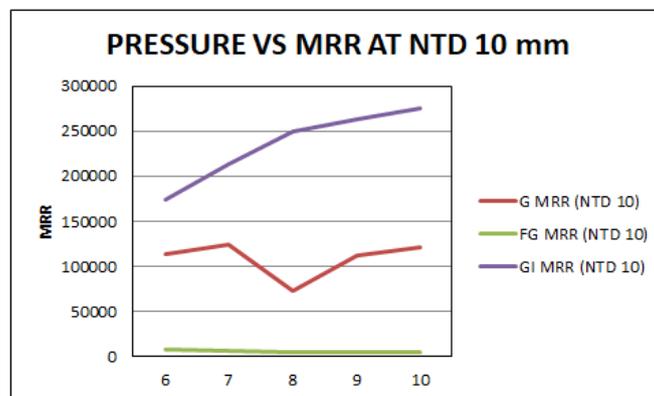


Fig 7: Graph between Pressure and MRR at NTD 10mm

**V. CONCLUSION**

The effect of various operational parameters showed the optimized values for better MRR on the selected materials. NTD is the major criteria and depends on hardness and toughness of the material. During experimentation it was observed that minimum pressure requirement is noticed to remove the material for different materials particularly when sand used as an abrasive material. The highest MRR is observed for Glass, Fiber Glass and GI Sheet at a pressure of 10kg/cm<sup>2</sup>, 7kg/cm<sup>2</sup> & 10kg/cm<sup>2</sup> at NTDs of 20, 15 & 10 mm respectively. Compared to brittle materials, ductile materials require less NTD due to its Shear strength and hardness. This experimentation reveals with more than 10 kg/cm<sup>2</sup> pressure ductile materials can be easily drilled with 10 mm NTD.

**VI. FUTURE SCOPE**

High toughness materials like TITANIUM can also be used for the machining with high pressure and less NTD.

## VII. ACKNOWLEDGEMENT

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