Advanced Materials Research Vol 1043 (2014) pp 165-171
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doi:10.4028/www.scientific.net/AMR.1043.165

Submitted: 2014-08-13
Accepted: 2014-08-13
Online: 2014-10-20

# Experimental Investigation of Effect of Rotary Abrasive Jet Nozzle on Coating Removal Rate and Surface Finish

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**Keywords:** Swirling abrasive jet, Coating removal, Rotary abrasive jet nozzle, Horizontal striking angle.

**Abstract.** An abrasive jet machine can be used effectively for removing the existing coating on the surfaces .A rotating, variable angle abrasive jet nozzle has been designed to produce a swirling abrasive jet .The horizontal and the vertical striking angles of the abrasive jet nozzle has been adjusted as 50° ,40° respectively[1] . Investigations have been carried out to evaluate the effect of Garnet and $SiO_2$ abrasives and the speed of the rotation of the nozzle on coating removal rate. Coated Mild steel, Galvanized Iron and Aluminium were used as specimens for investigations. The rotary abrasive jet nozzle provides the swirling abrasive jet and intensifying the shearing action as the speed increases gradually and reached up to 355 rpm. The surface roughness of the coating removed samples for various rotary speed of the abrasive jet nozzle were observed and measured. The surface roughness was found to be more closely associated with the speed of rotation of the abrasive jet nozzle.

## Introduction

It is an essential process to remove the coatings, paints and cleaning of the components which are to be reconditioned and recoated [2, 3]. There are some methods followed by using abrasives such as $SiO_2$, $AlO_2$ and Garnet. If the above mentioned abrasives and non-abrasives are used with abrasive water jet machine with a stationary nozzle the work piece may tend to suffer damages [4] when the abrasives strikes the work piece [5].The damages caused during the coating removal process on the components are un desirable and effects the surface finish of the components. Also the process has some important parameters like striking angle, stand of distance, material removal rate, and rotational speed of abrasive jet nozzle and pressure of the abrasive water jet.

In the present work a rotary abrasive nozzle has been designed and developed [6]. Investigations have been carried out to evaluate the of effect of swirling abrasive jet, standoff distance on coating removal rate and surface roughness .In the previous works only an effort has been made to promote thermal performance [6] by using the revolving AJM nozzle .

## Experimentation

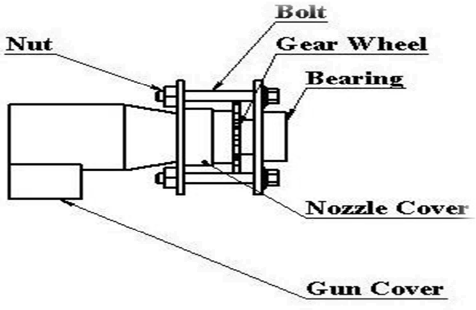


Fig. 1. Rotary abrasive jet machine

Fig. 2. Ejection of water in rotary machine

The work pieces of coated Galvanized Iron, Mild steel, Aluminium having the dimensions of 300mm X 300mm X 5mm were taken as specimens for experiments. Specimen was held vertically by using a frame. The vertical and horizontal angles are set with the help of a disk which has the angular divisions. The pressure of the water jet was controlled by the pressure valve. An electrical motor has been coupled with the abrasive jet nozzle by using a chain and sprockets arrangements as shown in Fig.1&2. The rotational speeds of the rotating nozzle were varied by using a regulator fitted on the control board. The Stand Off distances is changed as 190 mm to 150 mm in the step of 10mm. The horizontal and vertical striking angles were adjusted to 50°, 40° respectively. Garnet and $SiO_2$ of size of 600 grit sizes were used as abrasives. Water pressure and pump delivery were adjusted as 80 bar, 1,420 l/min. Experiments were conducted by varying the abrasive jet nozzle rotational speed as 0,295,325, 355 and 385 rpm. The surface roughness of coating removed surface has been evaluated by using surface analyser and the microstructure was obtained by using Scanning Electron Microscopy.

S.Y.Ahmadi-Brooghani etl 2007 [4] has modelled and studied the effect of impact angle. A published literature [1] also has revealed that the horizontal and vertical striking angles are kept as 50º, 40° respectively the coating removal rate is increasing. Ciampini et al, 2003 [7] and Hlavac et al (2009) [8] also have analysed the effect of incident angle on cutting operation and it has been reported that the angle has an effect on quality of cutting process.

## Results and Discussions

**The effect of Standoff distance (SOD) on coating removal rate for Mild steel ,Galvanized iron and Aluminium specimens & The effect of rotational speed of abrasive nozzle on coating removal rate for mild steel specimen.** Experiments and Fig.3 reveals that 355 rpm is an effective speed which provides higher coating removal rate when compared to 295,325 and 385 rpm. When the SOD is kept below 170 mm as the gap between work piece and the nozzle is very small it was observed that some of the abrasive particles which are impinging on the work piece are bouncing back and blocking the jet which is travelling towards the specimen. Due to this the Coating removal time increases from 10.6 Sec to 13.3 for GI specimen. Arola et al., (2002) [9] also have selected and used SOD around this range to have better performance. When the SOD is increasing from 170 mm to 190 mm, the abrasive jet will be travelling more and losses its energy the velocity of reduces. As the kinetic energy of abrasives are getting reduces the coating removal rate begins to decrease with an increase in coating removal time form 10.6 sec to 12.6 sec.

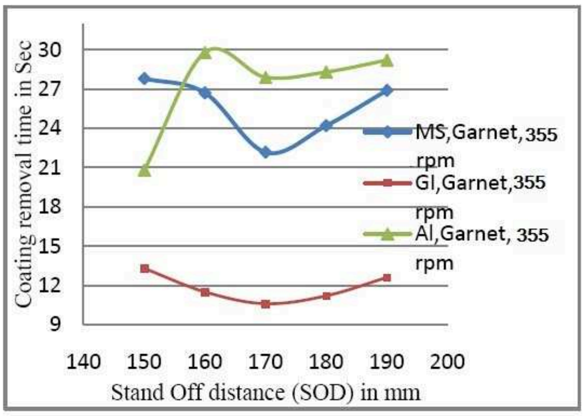


Fig .3 The effect of Standoff distance (SOD) on coating removal rate for Mild steel, Galvanized iron & Aluminium specimens

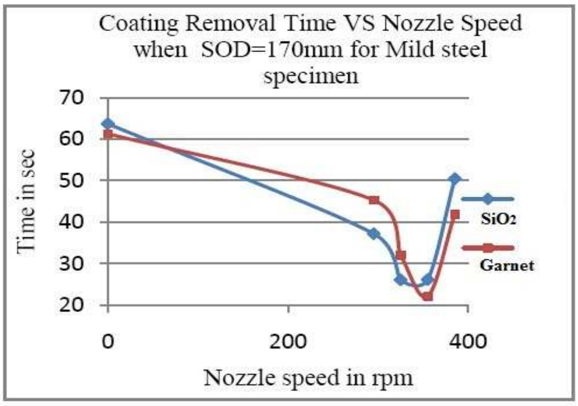


Fig .4. The effect of rotational speed of abrasive nozzle on coating removal rate for Mild steel specimen

Fig.4 shows the influence of nozzle speed on the coating removal rate when the stand-off distance (SOD) is 170 mm and mild steel is used as test material. It is observed that at a nozzle speed of 0 rpm the coating removal time is at its peak compared to the tested speed range. As the nozzle speed is increases to 355 rpm, the coating removal time is decreasing and has its minimum at this value. Above this value, the coating removal time is increasing again. The increase in coating removal rate up to 355 rpm due to the spinning action and shearing action of abrasive particles on the surface of the work piece. As the rotational speed increases above 355 rpm the abrasive particles are getting scattered and the coating removal becomes less effective. When garnet is used as abrasive material, the coating removal time at 355 rpm is 4 seconds faster than the time when SiO2 is used. However at different nozzle speeds $SiO_2$ may be more efficient if the coating removal time is considered as shown in the graph. Similarly the analysis has been carried out for Galvanized Iron, Aluminium specimens and the best conditions for higher coating removal have been taken.

**Best conditions for higher coating removal rate for Mild steel, Galvanized Iron and Aluminium specimens & The effect of rotational speed of abrasive nozzle on surface roughness for Aluminum specimen.** Experiments have revealed that in most of the cases ,coating removal time is decreasing with the increase in coating removal rate when the standoff distance has become 170 mm [1] and the abrasive nozzle rotational speed is increased to 355 rpm .The Fig 4.5 shows the comparison of coating removal time between the Mild steel, Galvanised Iron ,Aluminium specimens .It is clear that the coating removal time and rate are depends on the process parameters, material , nature of the surface and type of abrasive [10]. From Fig.5 it is clear that the coating removal time is decreasing to 59.6 to 27.9 Sec when the garnet was used as abrasive for Aluminium specimen and the same trend was observed for mild steel and Galvanized Iron. This is due to the regular sharp edges of garnet which easily removes the coating with slicing and shearing action [5].

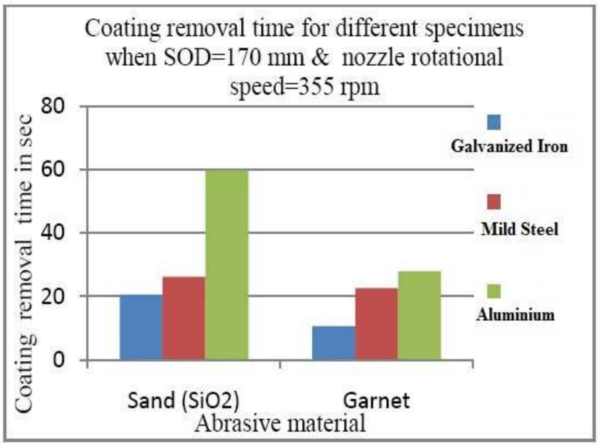


Fig.5 Best conditions for higher coating removal rate for Mild steel, Galvanized Iron & Aluminium specimens.

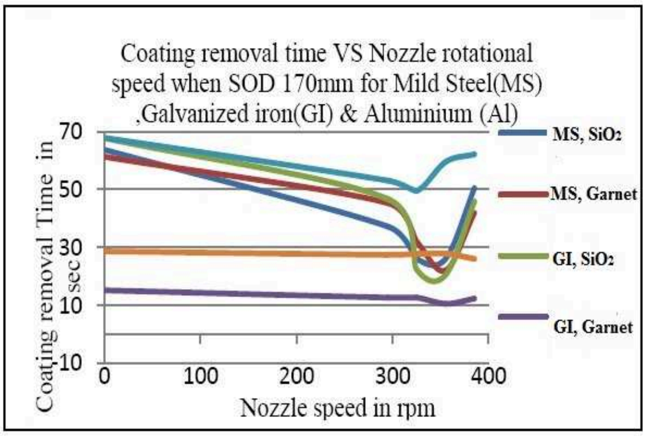


Fig.6.The effect of rotational speed of abrasive nozzle on surface roughness for an Aluminium specimen.

Fig.6. shows the relation between the coating removal time and nozzle rotational speed when the SOD is 170mm for Mild steel, Galvanized Iron and Aluminium specimens .The abrasives used are $SiO_2$ and Garnet. The coating removal time for Galvanized Iron is lesser than Mild steel & Aluminium as the bonding between coating and the base material is less due to the poor surface finish.

It is also observed that at a nozzle speed of 0 rpm the coating removal time is at its peak compared to the tested speed range. As the nozzle speed is increasing up to 355 rpm, the coating removal time is decreasing and has its minimum value of 10.6 Sec. Above this value, the time is increasing again. The increase in coating removal rate, when the rotational speed is increasing up to 355 rpm This is due to the can be the spinning action and shearing action of abrasive particles on the surface of the work piece which leads smooth shear off and removal of coating . The erosive process also helps the coating removal partially [11]. As the speed increases above 355 rpm the abrasive particles are getting scattered and the coating removal time is increasing with decrease in coating removal rate due to the separation of abrasive particles.Also it is clear that the coating removal rate is increasing with the use of garnet abrasives when compared to $SiO_2$ due to the sharp edges of the garnet particles and its weight.

**Effect of rotational speed of abrasive nozzle on surface roughness.** The surface roughness of the coating removed specimens was analysed and it was observed that Ra is decreasing with the increase in rotational speed of the abrasive jet nozzle up to 355 rpm. The Fig.8 & 9 shows the SEM image of Galvanized specimens when the abrasive jet nozzle speed is 355 rpm and 385 rpm respectively .The Fig 8 & 9 clearly shows that when the speed of rotation of the abrasive jet nozzle is kept between 295 to 355 rpm the surface texture is smooth due to the slicing, shear with spinning action of abrasives without ploughing [11] .The Fig 8 & 9 reveals that as the speed increases above the 355 rpm the abrasive jet particles are started to separate themselves from the jet and become scattered .This leads to the irregular distribution of abrasives particles and the surface roughness increases from 0.02 µm to 1.4 µm for Galvanized specimen if the Garnet is used as abrasive.

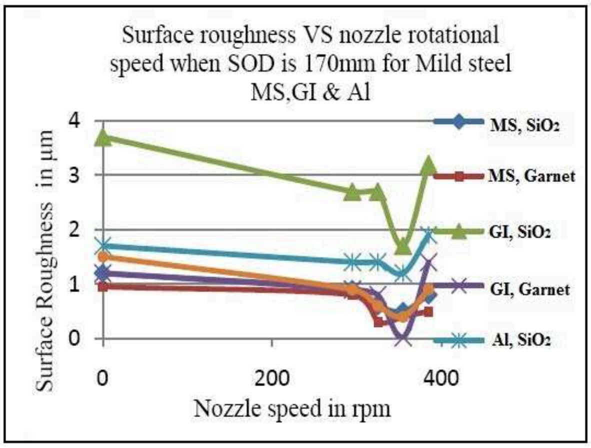


Fig.7 Effect of rotational speed of abrasive nozzle on surface roughness

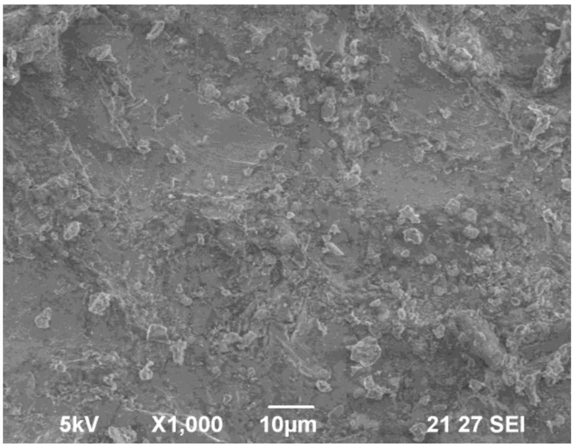


Fig .8 SEM image of GI specimen when the Garnet is used as abrasive and the abrasive jet nozzle speed is 355 rpm.

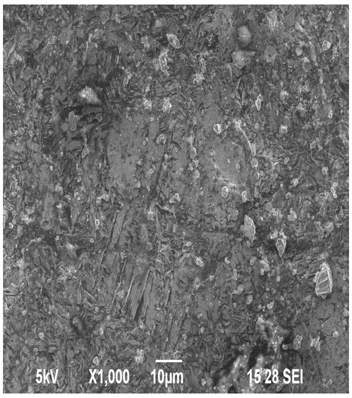


Fig.9.SEM image of GI specimen when the Garnet is used as abrasive and the abrasive jet nozzle speed is 385 rpm.

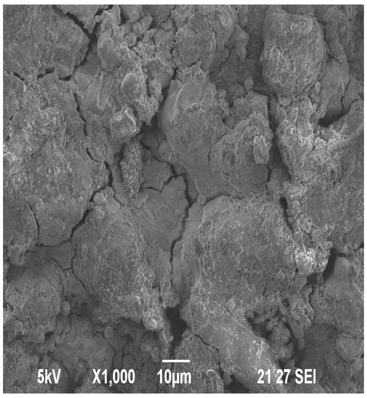


Fig.10. SEM image of MS when the SiO2 used as abrasive and the abrasive jet nozzle speed is 355 rpm.

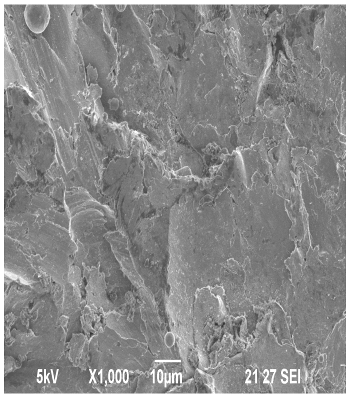


Fig.11. SEM image of MS specimen when the Garnet is used as abrasive and the abrasive jet nozzle speed is 355 rpm.

Fig.10 & 11 shows the SEM image of a Mild steel coating removed specimens by using $SiO_2$ and Garnet respectively.As the garnet exhibits the smooth and sharp edges ,the coating has removed without much of impact on the specimen and the abrasives are found to be slides away along with the coating material .As a result the surface roughness becomes smooth and decreasing. As the $SiO_2$ interacts more with the contact area of the specimen, the surface area of specimen is subjected to more impact and the surface roughness for Mild steel has increased to 0.8 µm and 1.7 µm.

**Fuzzy Model**

A mamdani maxi-min fuzzy model is created from the experimental readings. Five Linguistic variables are given to input parameters namely standoff distance and rotation. They are Very low, Low, Medium, High, Very high. Two Linguistic variables are given to input parameter abrasive namely sand and garnet. Three Linguistic variables are given to input parameter work piece namely Mild steel, Aluminium and Galvanized iron. A total of nine Linguistic variables are given to output parameters Time taken and surface roughness. They are Lowest, Lower, Low, under medium, Medium, Upper medium, high, higher, highest. Thus the range of input and parameters are divided according to these linguistic terms so that the value of each input and output parameter can be converted to its corresponding linguistic terms. Based on the experimental readings a total of 150 rules are created. Triangular membership functions are used for converting experimental values to corresponding linguistic fuzzy values. Using Mat lab Simulink software the model is simulated and output values are generated from it. It is found that predicted values are very well matching with the experimental values. This model can be used for future research work Mamdani maxi-mini model.

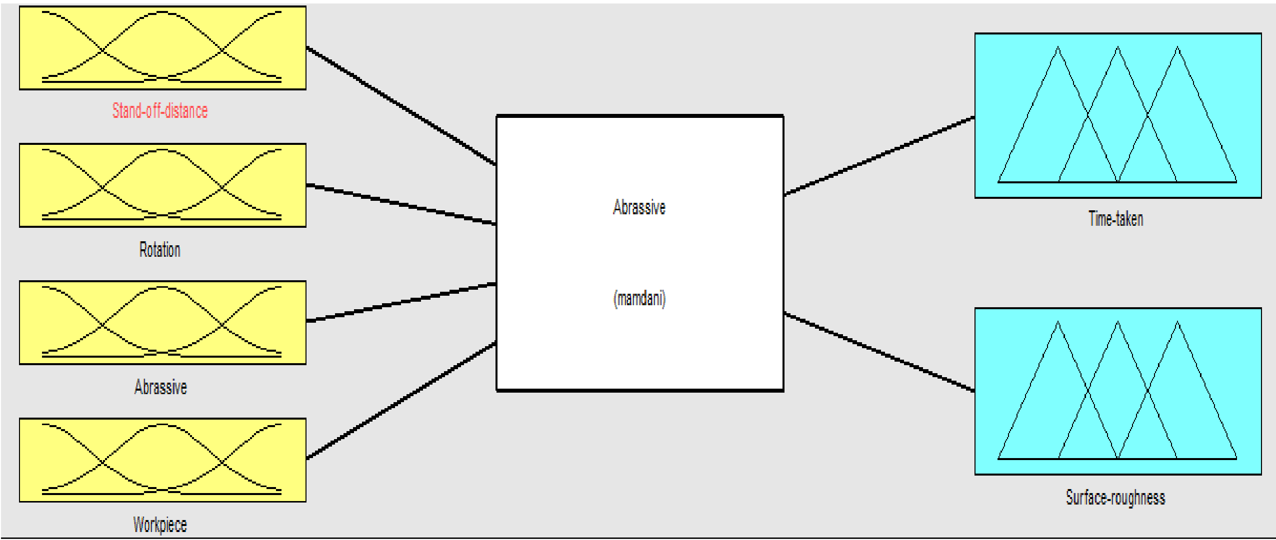


Fig.12 .Mamdani fuzzy model

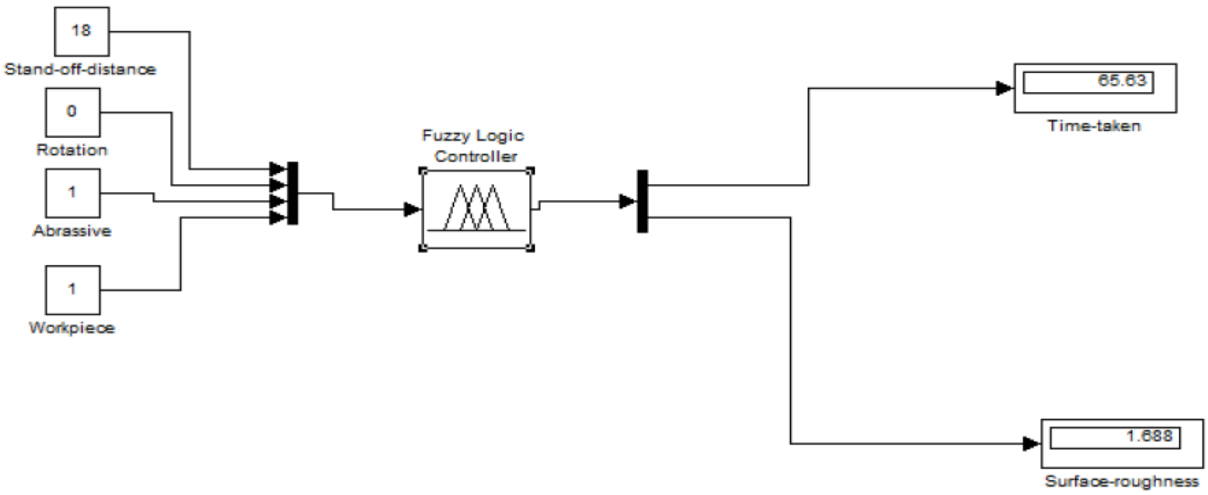


Fig.13 Simulated model

The above is the simulated model shows when the SOD is 180mm, the abrasive is $SiO_2$, speed of rotation is 0 rpm and specimen is mild steel, output values generated from the simulated model and it is found out that the values are closer to the experimentally obtained values.

## Conclusion

A rotating abrasive jet nozzle has been designed and developed for providing a swirling abrasive jet. Experiments were conducted with GI, Aluminium and Mild steel specimens by varying the abrasive nozzle rotational speed and standoff distance .The coating removal time, surface roughness and the microstructure of specimens were studied for various experimental conditions. The experiments revealed that rotational speed is the one of the parameter which is influencing the surface roughness of the work piece and coating removal rate.

The coating removal rate increases linearly with the nozzle rotation speed up to 355rpm. This is due to the impingement of the abrasive particles on the work piece is occurring with a swirl and higher shear rate .Also it was observed that rotation of nozzle causes an efficient mixing of abrasive and water. The coating removal rate by using SiO2 and Garnet was compared and it was found that the Garnet was more effective than the sand as it producing smoother surface and higher coating removal rate.

The surface roughness of coating removed specimens were compared and it was found out that the surface roughness of Galvanized Iron was better than the Aluminium and Mild steel after removing coating .This is due to the nature of bonding existing between coating and specimen and the abrasives are sliding a way with the removed coated particles.

The study of microstructure by using SEM reveals that, when the abrasive jet nozzle speed is between 295 to 355 rpm and 355 rpm to 385rpm the surface roughness is increasing and leads to poor surface condition. As the abrasive jet nozzle speed reaches 355 rpm the surface condition improved and the surface roughness has decreased .When the SOD is increasing from 150 to 160 mm and from 180 to 190 mm, it was noticed that there are many cavities and scratches on the specimen due to the increase in kinetic energy and decrease in kinetic energy respectively [12]. This problem was solved when the SOD is kept as 170 mm.

## References


[1] D.S.Robinson Smart, 2012.Experimental Investigation of effect of abrasive jet nozzle Position and angle on coating removal Rate. International journal of manufacturing System.1

[2] Raykowski, A., M. Hader, B. Maragno and J.K. Spelt, 2001. Blasting cleaning of gas turbine Components: Deposit removal and substrate Deformation. Wear, 249: 126-131.

[3] D.P.Weston, P.H.Shipway, S.J.Harris, 2005.Coating removal from an Industrial polypropylene Blend by cryogenic blasting: the development Substrate damage. International journal of Wear, 258:392-401.

[4] S.Y.Ahmadi-Brooghani etl, 2007.Modeling of Single-Particle Impact in Abrasive Water Jet Machining, World Academy of Science, Engineering and Technology, Vol: 1 2007-12-20.

[5] G.Fowler, I.R.Pashby, P.H.Spipway, 2009.The Effect of particle hardness and shape when Abrasive water jet milling titanium alloy Ti6A14V, International journal of Wear, 266:613-620.

[6] Z.X.Yuan, Y.Y.Chen, J.G.Jiang, C.F.Ma, 2006.Swirling effect of jet impingement on heat Transfer from a flat surface fto CO2 stream, International journal of Experimental, Thermal and Fluid sciences, 31:55-60.

[7] Ciampini, D., J.K. Spelt and M. Papini, 2003. Simulation of interference effects in particle Streams following impact with a flat surface: Part I. Theory and analysis. Wear, 254: 237-249

[8] L.M.Hlavac, I.M.Hlavacova, L.Gembalova, J.Kalicinsky, S.Fabian, J.Mestanek, J.Kmec, V.Madr, 2009.Experimental method for the Investigation of the abrasive water jet cutting Quality, Journal of materials processing Technology, 209:6190-6195.

[9] Arola, D., M.L. McCain, S. Kunaporn and M. Ramulu, 2002. Water jet and abrasive water jet Surface treatment of titanium: a comparison of Surface texture and residual stress. Wear, 249: 943-950.

[10] Hashish, M. and J. Stewart, 2000. Observations on precision turning with AWJ. Proceedings of 15th International Conference on Jet Cutting Technology, Sept. 6-8, Ronneby, Sweden, pp: 367-380.

[11] J.Wang, 1999.Abrasive water jet machining of polymer matrix composites cutting performance, Erosive process and predictive models, Int. J. Adv. Manul. Technol. 15, 757-768.

[12] Oka, Y.I., H. Ohnogi, T. Hosokawa and M. Matsumura, 1997. The impact angle dependence of erosion damage caused by solid particle impact. Wear, 203/204: 573-579.

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