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Optimization MRR Of Stainless Steel 403 In Abrasive Water Jet Machining UsingAnova And Taguchi Method

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ABSTRACT
Stainlesssteel 403 is high-alloysteelwith good corrosion resistance and it'svery hard material. Abrasive water jet is an effective method for machining, cutting and drilling of stainlesssteel 403. In thispaperweoptimize the metalremoval rate of stainlesssteel 403 in abrasive water jet machining. The MRRisoptimize by usingthreeparameters water pressure, abrasive flow rate and stand-off distance and L_9 orthogonal array of Taguchimethod use to analyse the result. 9 experimentalrunsbased on L_9 orthogonal array of Taguchimethod.
Keywords- Abrasive water jet machine, stainless steel 403, garnet 80 mesh, L_9 orthogonal array of Taguchi method, water pressure, abrasive flow rate, stand-off distance, MRR, S/N ratio

I. INTRODUCTION

Abrasive Water Jet Machining is accepted effective technology for cutting various material as of its advantages over other non-conventional techniques such as No heat is generated in the cutting process, high machining versatility, minimum stresses on the work piece. Abrasive water jet machine is an industrial machine in which we can cutting of the any types of materials i.e. softer materials and harden materials. In the abrasive water jet machine, the water is supplied at a very high pressure from 20,000-60,000psi and provides the good cutting and surface finishing. In the abrasive water jet machine there is a orifice in which a nozzle fixed and through the nozzle water exit in the cutting stream formation, this nozzle is move in the x-y axis as like in CNC machine.

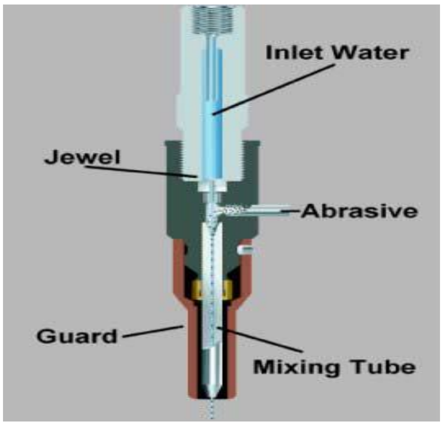

Fig. 1 Schematic of AWJM

The abrasive water jet machining process is also called cold method or cold cutting method and with the cold method we can cut the any desired shape of material.

Abrasive water jet cutting machine starts with a water pump. In the abrasive water jet machining, there is a mixture of garnet 80 mesh (abrasive) and water, which helps to cut the material simply and provides the good surfacefinishing. The abrasive water jet machine is more powerful than a pure water jet machine.

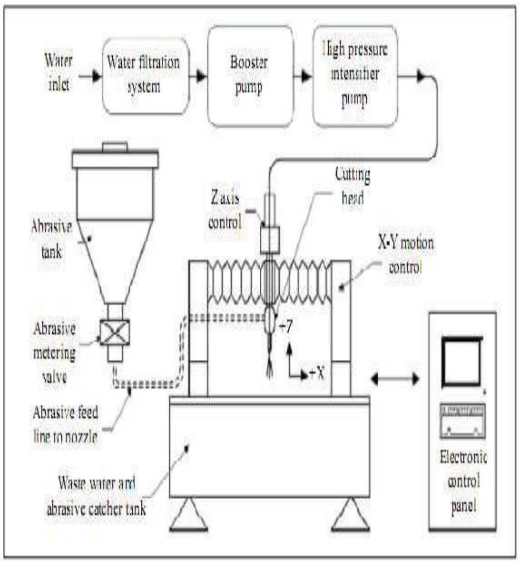

Fig. 2 Schematic of abrasive water jet machine

II. ABRASIVE WATER JET CUTTING MACHINE ELEMENT

Abrasive water jet cutting machines have four basic elements: pumping system, abrasive feed system, abrasive water jet nozzle and catcher.

- In abrasive water jet machine, two types of pump i.e. booster pump and high intensifier pump, they produced high velocity water up to 450mpa by using high power motor with 50 H.P.
- To mix the abrasives into this high-velocity water jet, the abrasive feed system supplies a controlled quantity of abrasives through a port (abrasive tank).
- In abrasive water jet machine there is water nozzle, in which the garnet and water are mixed together and flow in a cutting stream.
- An another element of abrasive water jet machine is catcher, in which the water and waste water are stored. This element is fixed at the bottom side of the machine.
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III. REVIEW OF LITERATURE

M.Sreenivasa Raoet.al studied the effect water pressure, traverse speed and stand-off distance on mild steel in abrasive water jet machining. In this research they have taken one output parameter i.e. surface roughness.They have cut the mild steel at different water pressure, traverse speed and stand-off distance with using the Taguchi method L9. By analyzed they have found that the optimum value of the different parameters water pressure, traverse speed and stand-off distance, at which the surface roughness will be decrease.[1]

Prof.KamleshH.Thakkaret.al studied the effect of traverse speed, stand-off distance and abrasive flow rate on abrasive water jet machining of mild steel 250. They have cut the mild steel at different traverse, stand-off distance and abrasive flow rate by using the Taguchi method L9. By analyzed they have found that the optimum selection of the three basic parameters, i.e., traverse speed, abrasive flow rate and standoff distance is at the minimum surface roughness and maximum metal removal rate. The effect of each of these parameters is studied while keeping the other parameters considered in this study as constant.[2]

M. ChithiraiPonSelvanet.al studied the different parameters in abrasive water jet machining of aluminium with dimensions of the sheet 150×100×60mm. They have cut the aluminium with the variable parameters water pressure, traverse speed, abrasive flow rate and stand-off distance using Taguchi method L9 and the garnet 80 mesh is used in the form of abrasive. By analyzed they have found that the effect of surface roughness with respect to these four variable parameters. As the jet pressure increases, the surface becomes smoother.[3]

P. K. Kinnellet.al have studied in abrasive water jet machining of aluminum 7475 with taking parameters traverse speed, stand-off distance and jet pressure. They have taken aluminium plate with thickness 3mm to find the effect of material removal rate and fatigue life. They have find out that the error bars were determined by the result of the four samples. By analyzedin the graph the number of cycles where the machined surface has failed is approximately 46,000, as shown by the red line, however for the machined surface the failure was approximately between 39,000 and 49,000. And that results in a reduction of material removal rate as the water jet has to overcome the residual compressive stress.[4]

Probal Kumar Daset.al studied about the changing different parameters such as water pressure, abrasive flow rate, traverse speed and stand-off distance. To analysis the effect of depth of cut at changing these parameters. In this research they have cutting of the borosilicate glass with changing these parameters with using the Taguchi method L27 and find out that Testing of the estimated depth of cut model and validation of the optimum result indicate their practical adequacy. Finally, SEM study of the cut wall gives a possible material erosion mechanism of amorphous material.[5]

John Kechagiaset.al studied for quality characterization of abrasive water jet machining of TRIP sheet steels with dimension 10×10cm^2 by using the Taguchi method L18. They have find out that signal to noise (S/N) ratio represents the response of the data observed in the Taguchi design of experiments. Both, the arithmetic mean roughness and the mean kerf width was characterized as “the smaller the better” quality characteristics since lower values are desirable.[6]

Chuanzhen Huanget.al studied the material removal rate effect in the abrasive water jet machining process with changing in the input parameters such as water pressure, jet feed speed, abrasive mass flow rate and nozzle tilted angle. They obtained that if cutting of the alumina ceramic then increase the MRR with the increasing water pressure and mass flow rate.[7]

Jun WANGstudied the effect of depth of cut in multi-pass cutting and single pass cutting in the abrasive water jet machining. Jun Wang have cut the alumina ceramic in both cutting form with four controlled parameters i.e. water pressure, nozzle traverse speed, nozzle stand-off distance and abrasive flow rate. He found that in single pass cutting nozzle oscillation cutting creates a scanning cutting action by the particles that not only reduces the particle interference, but also clears the target surface and in the multi-pass cutting the number of passes may be not endlessly increased to increase the total depth of cut for thick materials.[8]

Hakan Tozanet.al investigated vibration emission for the abrasive water jet machining. They have taken the stainless steel AISI 309 and experiment on this material with control parameters abrasive flow rate 250-400 g/min. and traverse speed 100mm/min. They found that the shapes of curves are approximately the same, frequency spectrum of vibration (and acoustic) emission has approximately the same course. [9]

GulayCosansu and Can Cogun investigated the effect of colemanite powder used as an abrasive in abrasive water jet machine when perform at the different materials such as aluminum 7570, marble, glass, Ti6Al4V and composite selected as sample materials in the experiment. They have studied what is the effect of output parameters such as surface roughness, surface waviness and kerf taper angle when used a mixture of colemanite powder and garnet as an abrasive. The experiments of Al7075 with colemanite powder were started at 80 mm/min traverse rate and 5 g/s abrasive flow rate. They found that increase in abrasive flow rate also reduces the jet deflection sand burr formation at the jet exit region. That is mainly due to the improved cutting ability of the jet with increasing amount of abrasive impinges to the work surface in unit time.[10]

IV. EXPERIMENTAL WORK

(A) MATERIAL

Stainless steel – Grade 403 plates were used as the specimens in this study.Stainless steel is the most common form of steel because it provides material properties that are acceptable for many applications. Stainless steel is very hard material which is very difficult to cut by another machining process but it's simply cut in abrasive water jet machining in a small time.

Table 1. Chemical compositions of SS-403

Element	Fe	Cr	Mn	Si	C	P	S
%	86	12.3	1.0	0.5	0.15	0.04	0.03

Table 2. Properties of stainless steel 403

Density (g/cm^3)	Tensile strength (mpa)	Yield strength (mpa)	Fatigue strength (mpa)	Shear modulus (mpa)	Elongation at break (%)	Hardness Rockwell
7.8	485	310	275	76	25	80

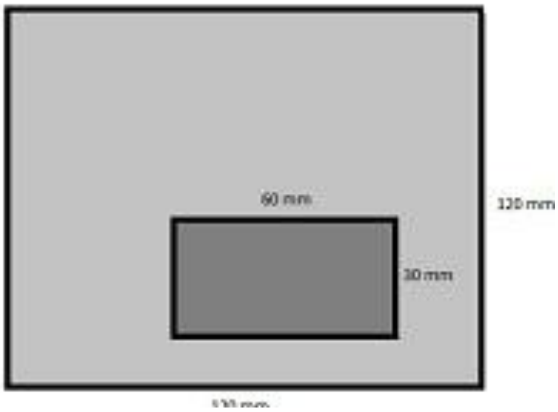

Fig. 3 Diagram of SS 403 plate

(B) GARNET 80 MESH

Garnet abrasive is composed of natural Almandite garnet grains that are known for their natural hardness, durability and abrasive characteristics. Garnet abrasive is extensively used in all renowned water jet cutting machines around the world. The highest purity garnet and highly accurate sizing of grains are produced using the world's best processing methods. The garnet 80 mesh is suitable abrasive for cutting purpose in abrasive water jet machine. The maximum use of garnet 80 mesh abrasive as compare to other abrasives i.e. tungsten carbide, aluminium oxide, silicon carbide in water jet machining process.

(C) EQUIPMENT

The equipment used for machining the samples was Water Jet Model: Maxiem-1530 with 30 H.P. pump direct vane. The machine is equipped with a gravity feed type of abrasive hopper, an abrasive feeder system, a pneumatically controlled valve and a work piece table with dimension of 120 mm x 120 mm. Set up of an abrasive water jet cutting process is shown in figure.

Table 3 Equipments of the water jet machine: Model-1530

Bed length	3000 mm×1500 mm
Nozzle diameter	.75 mm
Weight (tank empty)	1814 kg
Operating weight (with water in tank)	7121 kg
Height	3200 mm
X-Y travel	3061 mm×1575 mm
Z- axis travel	305 mm
Table size	3708 mm×1740 mm
Voltage	480 mm

Fig. 4 Setup of abrasive water jet machine

DESIGN OF EXPERIMENT

Design of experiments (DOE) is a powerful tool that can be used in a variety of experimental situations.For present work, Stainless steel 403 has been selected as work material.

The chemical composition and properties of stainless steel 403is shown in Table 1 and Table 2.The length and width of these 09 workpieces is 120mm and 120mm respectively. The tests were carried out on abrasive water jet machine with using the garnet 80 mesh in the form of abrasive. The control parameters are water pressure (WP), abrasive flow rate (AFR), and stand-off distance (SOD), and the responses considered is metal removal rate (MRR).The metal removal rate is calculated by using the formula.

$$MRR = \frac{W_i - W_f}{t * \rho}$$

Process variables and their levels have been shown in Table 4, whereas the design of experiment based on Taguchi's L9 Orthogonal Array method is shown in Table 5. The obtained values of responses are then compared with predicted values of regression equations. Minitab 17 version statistical software is used to generate regression equations and for analysis of obtained data Taguchi Method is used.

Table 4: Process variables and their levels for abrasive water jet process stainless steel 403

Factors	Level 1	Level 2	Level 3
Water pressure (psi)	35000	40000	45000
Abrasive flow rate (gm/min)	250	300	350
Stand-off distance (mm)	2	4	6

Table 5: Design of Experiment for abrasive water jet machine of stainless steel 403

Sr.no.	Water pressure	Abrasive flow rate	Stand-off distance	MRR	S/N ratio
1	35000	250	2	4.063	12.1769
2	35000	300	4	3.162	9.9992
3	35000	350	6	2.670	8.5302
4	40000	250	4	3.899	11.8191
5	40000	300	6	3.283	10.3154
6	40000	350	2	4.993	13.9672
7	45000	250	6	4.051	12.1512
8	45000	300	2	5.795	15.2611
9	45000	350	4	4.967	13.9219

V. RESULTS AND DISCUSSIONS

Figure 5 depict the factor effect on metal removal rate.The higher the signal tonoise ratio, the more favorable is the effect of the input variable on the output The graph shows that, the optimum value levels for best metal removal rate (maximum) are at a water pressure 35000 psi, abrasive flow rate 250 gm/min, and stand-off distance 2 mm.The plot shows the main effect plot of MRR at different parameters i.e. Water pressure, Abrasive flow rate and Stand of distance in Abrasive water jet machining process of stainless steel 403.

S = 0.0465558 R-Sq = 99.95% R-Sq (adj) = 99.78%

Table 6: Analysis of Variance for S/N ratios (MRR)

Source	DOF	Adj SS	Adj MS	F-value	P-value
Water pressure	2	4.03824	2.01912	931.57	0.001
Abrasive flow rate	2	0.06492	0.03246	14.98	0.063
Stand-off distance	2	3.95103	1.97552	911.45	0.001
Error	2	0.00433	0.00217		
Total	8	8.05853			

Table 7: Response Table for Signal to Noise Ratios – larger is better (MRR)

Level	Water pressure	Abrasive flow rate	Stand-off distance
1	10.24	12.05	**13.80****
2	12.04	11.86	11.91
3	**13.78****	**12.14****	10.34
Rank	1	3	2

******indicates higher S/N Ratio

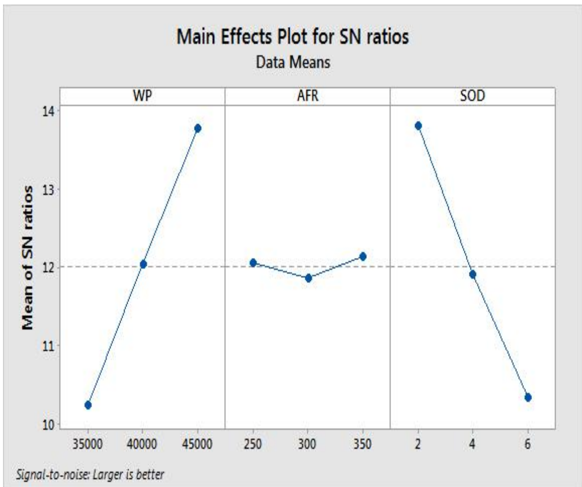

Fig 5 Main Effect Plot of S/N ratios for MRR

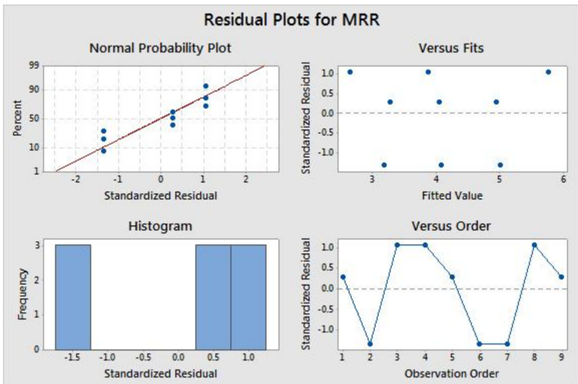

Fig 6 Residual Plots for MRR

For validation, the predicted values obtained by regression equation for metal removal rate are compared with the experimental values.Also, the optimum set of parameters obtained from analysis is shown in Table 7. And the optimum S/N ratio is 12.0524

The Regression Equation for metal removal rate for abrasive water jet machine of stainless steel 403
MRR = 4.0981 -0.7998 WP35000 - 0.0398 WP40000 + 0.8396 WP45000- 0.0938 AFR250- 0.0181 AFR300+0.1119 AFR350 + 0.8522 SOD2 - 0.0888 SOD4 - 0.7634 SOD6

Table 8: Optimum control parameter level

Response	Water pressure	Abrasive flow rate	Stand-off distance
MRR	35000	250	2

VI. CONCLUSION

Metal removal rate (MRR), the water pressure (WP) was the most influencing factor for stainless steel 403 work material followed by stand-off distance and abrasive flow rate.

So, to achieve the maximum removal rate of stainless steel 403, employ water pressure 35000 psi, abrasive flow rate 250 gm/min and stand-off distance 2 mm.

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