OPTIMIZATION OF ABRASIVE WATER JET MACHINING PROCESS PARAMETERS USING RESPONCE SURFACE METHOD ON INCONEL -800

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Abstract

Abrasive water jet machining is classified a non-conventional machining procedure. Abrasive water jet machining uses water jet under high pressure as a tool, with added particles of abrasives. The most significant characteristic of the abrasive water jet cutting technology is cold cutting, which does not have a thermic effect on the material. The objective of the experimental investigation is to conduct research of the machining parametres' impact on surface roughness of the machined parts, and derive conclusions referring to the manner in which certain machining parametres affect surface roughness. Experimental investigation was conducted in the way that samples of two different materials were cut on the machine using different machining parametres. Measurement of different surface roughness parametres has been conducted after the cutting.

Aim of this project is the experimental study of the effect of inherent characteristics of the water jet flaring on straightness of throughout and effect of various process parameters on the major cutting performance measures in AWJ machining. In this project an attempt will be made for the quantitative taper angle analysis and establish the effect of various process parameters on straightness of the cut through experiments.

Keywords: *abrasive waterjet, ANOVA, INCONEL-800,MRR,SR.*

I. INTRODUCTION

Abrasive Water jet (AWJ) machine uses cold supersonic abrasive erosion to cut almost any materials both metals and non-metals and so it is also understood as a 'blast' erosion process in which the highly pressurized water is forced through a tiny areas resulting in formation of water jet. Abrasive garnet is mixed to this jet in the mixing chamber making it an Abrasive Water jet which erodes away the material. A considerable amount of work has been conducted in recent years to study the mechanism of AWJ cutting and to develop kerf geometry and surface roughness models for process control and optimization. These have involved the processing of ductile and brittle materials, leathers, woods and rubbers, as well as composites and layered composites. which are very difficult to machine It is interesting to note, however, that very little has been reported on the AWJ cutting of thin sheet steels.

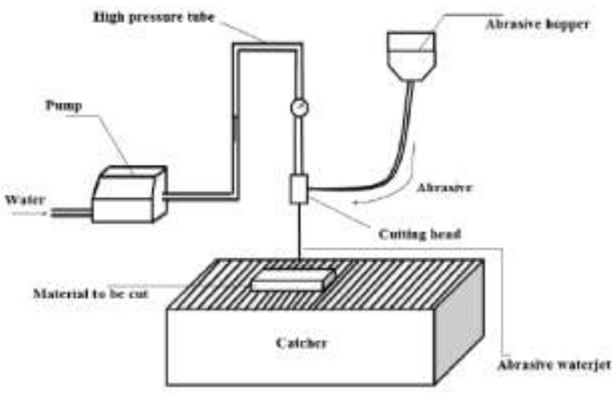


Figure1.1 AWJM Process

II. LITRATURE REVIEW

M. Chithirai Pon Selvan et al. [1]

In this research paper shows Abrasive water jet cutting is one of the non-traditional cutting processes capable of cutting wide range of hard to-cut materials. This paper assesses the influence of process parameters on depth of cut which is an important cutting performance measure in abrasive water jet cutting of stainless steel. The process variables considered here include traverse speed, abrasive flow rate, standoff distance and water pressure. Experiments were conducted in varying these parameters for cutting stainless steel using abrasive water jet cutting process. In order to correctly select the process parameters, an empirical model for the prediction of depth of cut in abrasive water jet cutting of stainless steel is developed using regression analysis. This developed model has been verified with the experimental results that reveal a high applicability of the model within the experimental range used.

Index Terms: Abrasive water jet, Garnet, Stainless steel, Depth of cut and Empirical model.

M. Chithirai Pon Selvan et al. [2]

In this research paper author investigated that effective technology for processing various engineering materials. This paper investigated the effects of process parameters on depth of cut in abrasive water jet cutting of cast iron. Four different process parameters were undertaken for this study; water pressure, nozzle traverse speed, abrasive mass flow rate and standoff distance. Experiments were conducted in varying these parameters for cutting cast iron using abrasive water jet cutting process. The influence of these process parameters on depth of cut has been studied based on the experimental results. In order to correctly select the process parameters, an empirical model for the prediction of depth of cut in abrasive water jet cutting of cast iron is developed using regression analysis. This developed model has been verified with the experimental results that reveal a high applicability of the model within the experimental range used.

Index Terms: Abrasive mass flow rate, abrasive water jet, cast iron, empirical model, garnet, nozzle traverse speed, regression analysis, standoff distance, water pressure.

Dr. N. Mohana Sundara Raju et al. [3]

In this research paper author formulate that effective technology for processing various engineering materials. Surface roughness of machined parts is one of the major machining characteristics that play an important role in determining the quality of engineering components. This paper assesses the influence of process parameters on surface roughness (Ra) which is an important cutting performance measure in abrasive water jet cutting of cast iron. Taguchi's design of experiments was carried out in order to collect surface roughness values. Experiments were conducted in varying water pressure, nozzle traverse speed, abrasive mass flow rate and standoff distance for cutting cast iron using abrasive water jet cutting process. The effects of these parameters on surface roughness have been studied based on the experimental results.

Index Terms: Abrasive water jet, cast iron, garnet, water pressure, mass flow rate, traverse speed, standoff distance.

Dr. G. D. Acharya et al. [4]

In this research paper author worked out Abrasive water jet machining (AWJM) is an emerging machining technology option for hard material parts that are extremely difficult-to-machine by conventional machining processes. A narrow stream of high velocity water mixed with abrasive particles gives relatively inexpensive and environment friendly production with reasonably high material removal rate. Because of that abrasive water jet machining has become one of the leading manufacturing technologies in a relatively short period of time. This paper reviews the research work carried out from the inception to the development of AWJM within the past decade. It reports on the AWJM research relating to improving performance measures, monitoring and control of process, optimizing the process variables. A wide range of AWJM industrial applications for different category of material are reported with variations. The paper also discusses the future trend of research work in the same area.

Index Terms: Abrasive water jet machining, Process parameter, Process optimization, Monitoring, Control.

III. METHODOLOGY

Experimental Setup

The Abrasive Water Jet Machining has been conducted on SL-V50 AWJM 3 - axis machine with CNC programming at Ram Engineers, vatva GIDC, Ahmedabad. The machine used for samples was Water Jet Model: DWJ1525-FA which is equipped with SL-V50 pressure pump with the designed pressure of 290MP. 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 3000 mm x 3000 mm. Sapphire orifice was used to transform the high-pressure water into a collimated jet, with a carbide nozzle to form an abrasive water jet. Set up of an abrasive water jet cutting process.

Figure: 2.1: DWJ1525-FA AWJM

Response Surface Methodology

Response surface methodology (RSM) is a collection of mathematical and statistical techniques for empirical model building. By careful design of experiments, the objective is to optimize a response (output variable) which is influenced by several independent variables (input variables). An experiment is a series of tests, called runs, in which changes are made in the input variables in order to identify the reasons for changes in the output response.

I. RESULTS OF DOE

Obtain results are shown in table 3.1

Table 3.1–Experimental Results

Sr. No.	SOD	TS	AFR	SR	MRR
1	3	90	250	3.476	1.66667
2	3	90	250	3.471	1.766667
3	4	100	200	3.668	1.8222
4	4	80	300	3.282	1.782352
5	3	90	250	3.45	1.566667
6	2	100	200	3.352	1.440741
7	2	100	300	3.127	1.7102
8	3	90	250	3.564	1.866667
9	3	80	250	3.172	1.382352
10	4	90	250	3.433	1.6333
11	4	80	200	3.209	1.382352
12	3	90	250	3.566	1.566667
13	3	100	250	3.44	1.740741
14	2	90	250	3.346	1.566667
15	3	90	300	3.472	1.566667
16	2	80	300	2.937	1.5676
17	3	90	200	3.675	1.466667
18	2	80	200	2.929	1.882352
19	3	90	250	3.56	1.55
20	4	100	300	3.567	1.7222

CONSTANT PARAMETER

Abrasive type	Garnet
Abrasive Size	90 Mesh
Orifice diameter	0.40 mm
Nozzle diameter	1.3 mm
Work piece thickness	10 mm

Analysis of Variance for SR

Source of Variation	DOF	Sum of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Percentage Contribution (% C)
Stand of distance	2	0.2060	0.09795	18.69	39.38%
Traverse speed	2	0.2899	0.13975	27.81	57.62%
Abrasive flow rate	2	0.02216	0.00908	2.71	5.42%
Error	13	0.0521	0.01605	1	1.17%
Total	20				
R-Sq = 95.65%					

Analysis of Variance for MRR

Source of Variation	DOF	Sum of Squares (SS)	Mean Square (MS)	Variance Ratio (F)	Percentage Contribution (% C)
Stand of distance	2	10206.73	5103.365	5.06045	10.12%
Traverse speed	2	40281.48	20140.70	19.9713	39.93%
Abrasive flow rate	2	47494.86	23747.43	23.5477	47.09%
Error	13	2016.96	1008.48	1	2.86%
Total	20				
R-Sq = 97.14%					

RESULT AND DISCUSSION:

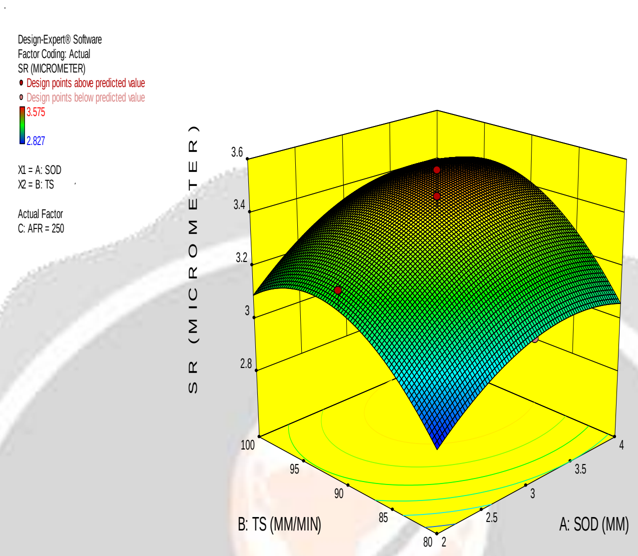
The effects of five process parameters ie, Abrasive flow rate, Traverse speed and standoff distance and their effects on material removal rate and surface roughness is analyzed and studied using the experimental values.

Surface roughness is one of the most important quality control parameter for assessing a production process. In the present investigation it was found that the machined surface is smoother near the jet entrance and gradually becomes rougher towards the jet exit. This is due to the fact that as the particles moves down they lose their kinetic energy and their cutting ability deteriorates. By analyzing the experimental data of the selected material, it has been found that the optimum selection of the three basic parameters, i.e., abrasive mass flow rate, nozzle traverse speed and nozzle standoff distance are very important on controlling the process outputs such as material removable rate , surface roughness. The effect of each of these parameters was studied while keeping the other parameters as constants as shown Table

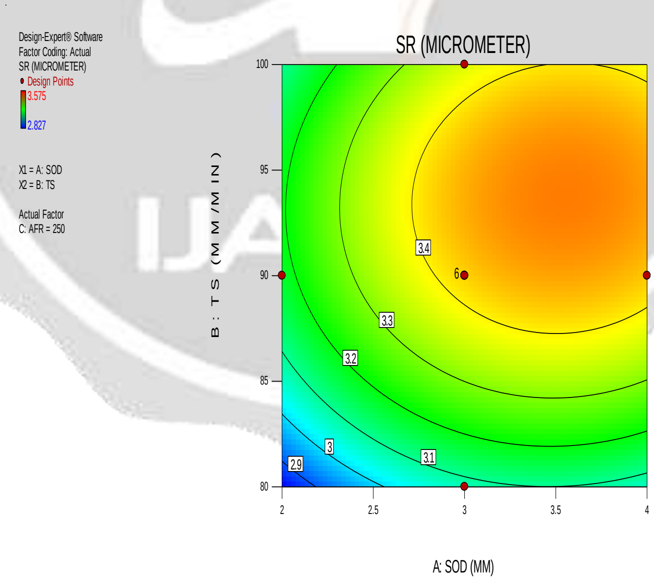
Effects of Process Parameters on Surface Roughness:

Effect of Traverse Speed on Surface Roughness:

Traverse speed didn't show a prominent influence on surface roughness. For decreasing of the machining costs every user try to choose the feed rate of the cutting head as high as possible, but increasing the traverse speed always causes increasing of inaccuracy and surface roughness. But with increase in work feed rate the surface roughness increased. This is due to the fact that as the work moves faster, less number of particles are available that pass through a unit area. Therefore, less number of impacts and cutting edges are available per unit area, which results a rougher surface. The relationship between the traverse speed and the surface roughness is shown in fig.



3D SURFACE PLOT



CONTOUR

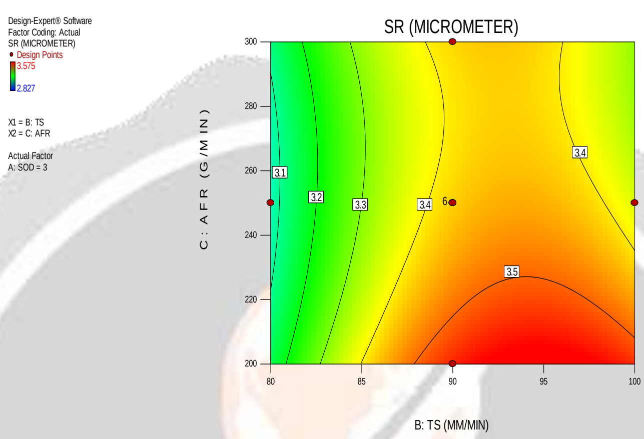
Effect of Standoff distance on Surface Roughness:

Surface roughness increase with increase in standoff distance. This is shown in fig. Generally, higher standoff distance allows the jet to expand before impingement which may increase vulnerability to external drag from the surrounding environment. Therefore, increase in the standoff distance results an increased jet diameter as cutting is initiated and in turn, reduces the kinetic energy of the jet at impingement. So surface roughness increase with increase in standoff distance. It is desirable to have a lower standoff distance which may produce a smoother surface due to increased kinetic energy. The machined surface is smoother near the top of the surface and becomes rougher at greater depths from the top surface.

Effect of Abrasive flow rate on Surface Roughness:

It can be seen that the roughness slightly decreases with increase of abrasive flow rate. This is attributed to the fact that an increase in abrasive flow rate results in more particles impinging on the cutting surface and increasing the depth of smooth. The findings indicate that the selection of high abrasive flow rate can improve this cutting performance measure.

It needs a large number of impacts per unit area under a certain pressure to overcome the bonding strength of any material. With the increase in abrasive flow rate, surface roughness decreases. This is because of more number of impacts and cutting edges available per unit area with a higher abrasive flow rate. Abrasive flow rate determines the number of impacting abrasive particles as well as total kinetic energy available. Therefore, higher abrasive flow rate, higher should be the cutting ability of the jet. But for higher abrasive flow rate, abrasives collide among themselves and loose their kinetic energy. It is evident that the surface is smoother near the jet entrance and gradually the surface roughness increases towards the jet exit.



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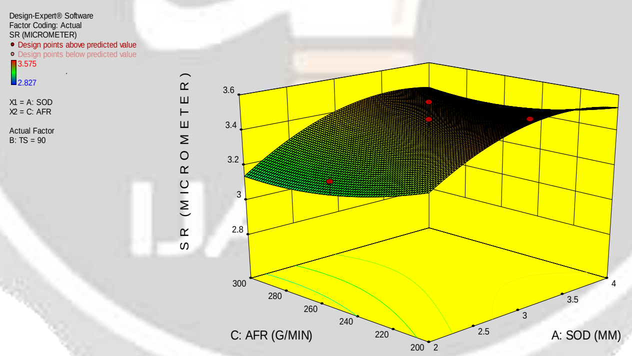
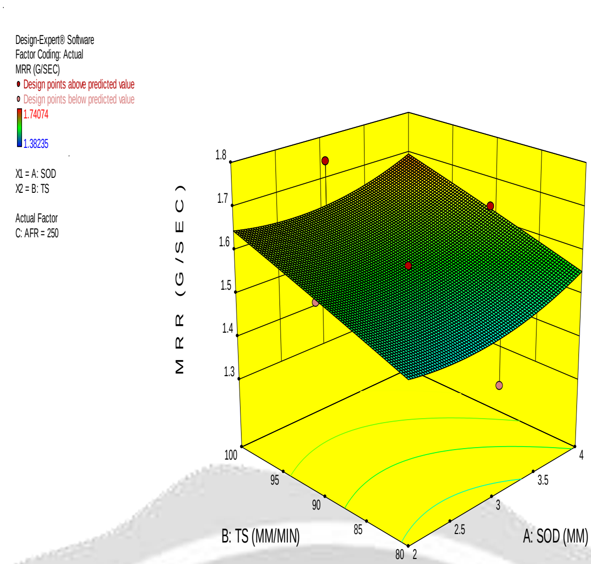


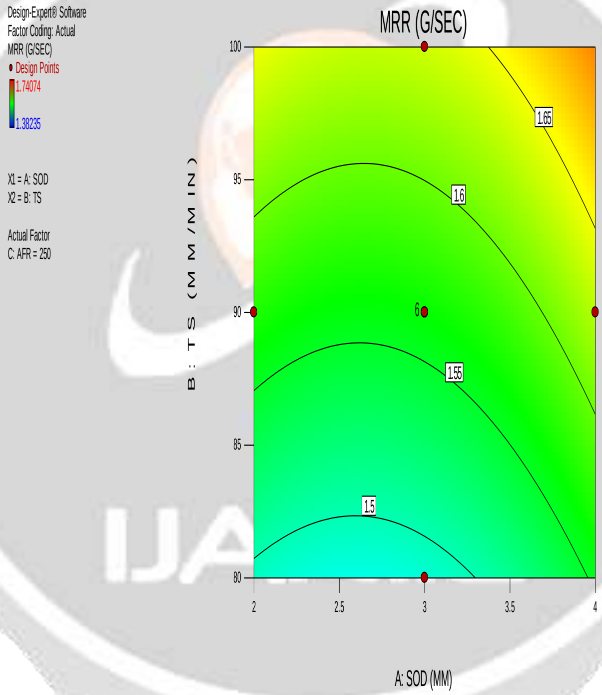
3D SURFACE PLOT

Effects of Process Parameters on Material Removal Rate:

Effect of traverse speed on MRR:

A number of experiments were carried out to find the relation between the traverse speed and MRR. During these tests the traverse speed is varied from 80 to 100 mm/min. and the testes were repeated for abrasive flow rates of 200 and 300 g/min. Figure shows the test results and their trend curves. It shows that MRR increase with the increase of traverse speed. The trend is of a polynomial function with high regression ratio R2



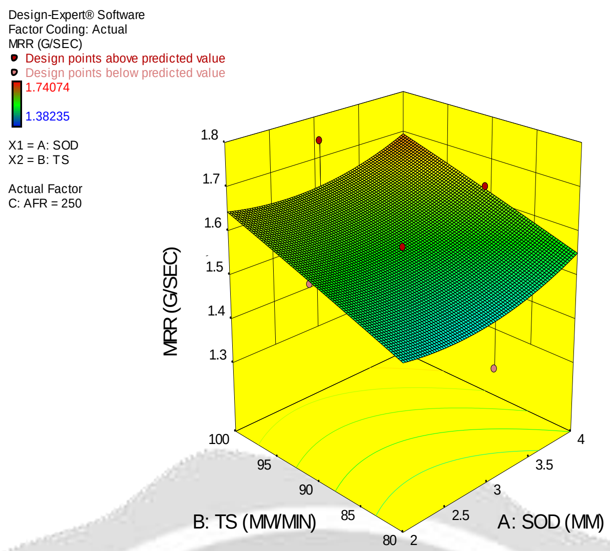


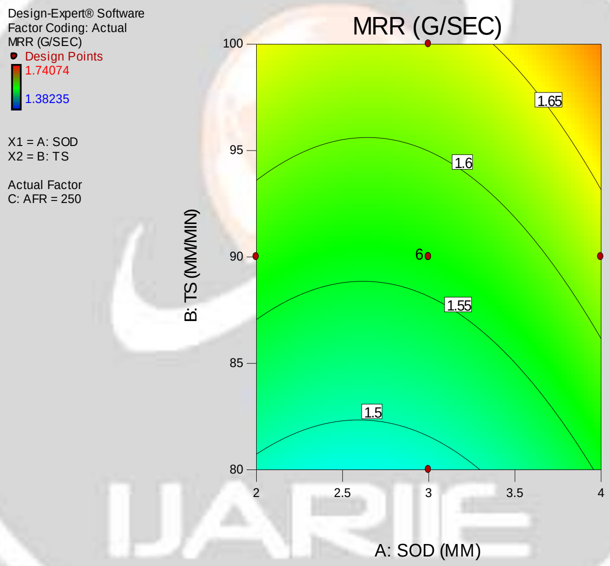
Effect of abrasive flow rate on MRR:

number of experiments were carried out to find the relation between the abrasive flow rate and MRR. During these tests the abrasive flow rate varied from 200 to 300 g/min. and the testes were repeated for two traverse speeds. Figure shows the test results with their trend curves. It shows that MRR increases with the increase of abrasive flow rate. The trend is of a polynomial function with high regression ratio R2

Effect of stand of distance on MRR:

The MRR values were tested at three different stand-off distances. The tests were repeated at three different traverse speeds. The test results are illustrated in Figure . The tests show that the MRR values are nearly increasing at different stand-off distances. Therefore, it is concluded that the standoff distance are increasing with increasing on MRR value.





Validation of Predictive model through experiment

In order to check the adequacy of the models for the surface roughness of Straight cut, analysis have been carried out by comparing the model predicted value with the corresponding experimental value and it has been found that at:

Traverse Speed = 80mm/min

Abrasive flowrate =200g/min

SOD=2mm

surface roughness of Straight cut according to predictive model is 2.929 micrometer whereas actual found to be 2.827 micrometer which is in close resemblance. The predictive model develop for the surface roughness of Straight cut can give adequate predictions for the range of the experimental conditions used in this study.

Desirability=SR MODEL/SR OPTIMUM

= 2.827/2.929

=96.51 %

SUMMARY:

So many investigations had done on AWJM process. MRR or production is improved by improving the traverse speed but major problem with increasing traverse speed is that surface roughness and kerf quality are decreased. Types of abrasive and abrasive flow rate are also affect the MRR. By increasing abrasive flow rate MRR is increased but it decrease the surface roughness.

CONCLUSION:

This paper presents optimization of the process parameters on abrasive water jet machining for Inconel 800H material by taking Material removable rate (MRR) and surface roughness (SR) as responses. The following conclusions can be drawn for effective machining of Inconel alloy 800H by AWJM process as follows:

 Traverse Speed (S) plays a major role on influencing material removable rate (MRR) observed in ANOVA F test. Then the major contribution on MRR is abrasive Flow Rate which is about 30%. We also observed that Standoff distance is sub significant in influencing MRR.

 The confirmation experiments were conducted using the optimum combination of the machining parameters obtained from regression analysis. The recommended parametric combination for optimum material removal rate is S3R3H3 and the optimum response value of MRR is 1.87 grams/min

 In case of surface Roughness Standoff distance and Transverse speed plays major significance of about 47% and 37% respectively. Abrasive flow rate is having sub significance influence on SR.

 The confirmation experiments were conducted on Surface roughness with S3R1H1 levels as obtained from regression analysis. The optimal response values for Surface roughness are 2.87µm.

 These test results provides us a greater detail in selecting significant parameters on output parameters such as MRR, SR while machining Inconel 800 H material on abrasive water jet

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