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Effect of Process Parameter in Abrasive Water Jet Cutting Using Response Surface Method

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Abstract - This paper tells about the utilisation of Box-Behnken outline way to deal with arranging the examinations for abrasive water jet cutting with a general goal of streamlining the procedure to yield better surface quality. Abrasive water jet machining is a non–traditional method of evacuation of material by effect disintegration of the pressurised high speed of water and entrained high speed of coarseness abrasives on a work piece. A trial was led to assess the impact of process parameters on surface Roughness (Ra) of aluminium. The philosophy relied on upon Response surface method (BOX BEHNKEN) and analysis of variance (ANOVA) to enhance the procedure strategy parameter for suitable machining and to predict the perfect choice for each, pressure, standoff distance and Traverse rate. The combination generated in the Box-Behnken method by the design of expert software (DOE) test directed and with the assistance of ANOVA, it is found that these parameters affect machining qualities surface harshness (SR). The investigation uncovers that when all is said in done, the standoff distance has very little fundamentally influence while pressure and traverse speed has much influence on surface Roughness (SR). In this paper author use design of experiment software (DX10) for Response surface method.

Key Words: Abrasive Water Jet Machine (AWJM), optimization, Box-Behnken, ANOVA and Surface Roughness (SR).

1. INTRODUCTION

This While machining a component to achieve fine surface finish it is essential that provide the suitable combination of process parameter, at minimum cost. Surface completion produced on a workpiece in a machining operation has been considered as the whole of two autonomous impacts: ideal surface roughness and the natural roughness. The ideal surface roughness is the result of the geometry of the tool (in AWJM flexible tool abrasive) and the feed and natural roughness is caused by the irregularities in the machining operation. Ideal surface roughness is the best surface finish that can be achieved with a given apparatus shape and feed rate, and can be accomplished if the impact of natural surface finish is wiped out [1]. Numerous scientists have agreed that, it is a trademark that could impact the execution of the mechanical parts and the generation costs. Better surface completion is conceivable by controlling the process parameters required in machining [2]. As it were, measuring and portraying the roughness of machined surface is considered for assessing the procedure performance [3, 4].

In this study the optimization approach given by the Box–Behnken plan (BBD) of a response surface methodology (RSM) [5]. For applying the methodology, Design-Expert programming (Version DX10.0, Stat-Ease Inc., Minneapolis, USA), was utilised. On the premise of the BBD, the process parameters (pressure, standoff distance and traverse rate) in the cutting of aluminium could be advanced with a minimum number of test with a target of accomplishing better machined-surface quality bringing about overall cost advantage. Abrasive water jet machining makes utilisation of the standards of both abrasive jet machining and water jet machining. In abrasive water jet machining, a little stream of fine-grained abrasive particles are blended in reasonable extent, which in constrained on a workpiece surface through a nozzle with high velocity of water. The nozzle material also wears out because of disintegration brought about by the effect of abrasive particles passing through it and striking on the work surface. The attributes of the surface created by this strategy rely on upon numerous variables like jet pressure, jet velocity, Stand-off separation of the nozzle from the workpiece, Abrasive flow rate, Traverse rate, works materials. Non-contact of the instrument with the workpiece, no warmth influenced zone, low machining power on the work surface and capacity to machine the extensive variety of materials has expanded the utilisation of abrasive water jet machining over other machining processes. Numerous scientists have been completed on various parameters of AWJM Fecaier et al [6] and Ohlsson and Magnusson [7] examined the power parameters required during AWJ machining. Andreas and Kovacevic [8] examined the properties and structures of fast jets. Tikhomirov [9] took a shot at the conceivable feed rate depending on the standoff distance of the nozzle. Moser et al [10] examined the impact of abrasive grain size dissemination on abrasive waterjet machining process.

In addition the water carries the fine abrasive solid tool to cut the material usually by a shearing process [11]. Previously investigation [12] indicated that even through some efforts have been made to increase the material removal rate (MRR) and surface roughness. The AWJM is a non-contact, inertialess and speedier cutting process that offers some point of preference like restricted kerf width, unimportant warmth influenced zone, diminished waste material and adaptability to machining process in an alternate way[13].There are various related parameters and elements of AWJM procedure that can impact the surface nature of the AWJ machined surfaced [14]. MRR increases by expanding abrasive mass flow rate.

Expanding velocity is additionally built MRR. Full factorial design help for examination as no different blend requirements for affirmation test [15]. In this paper author talks about the utilisation of Box-Behnken outline way to deal with arranging the examinations for abrasive water jet cutting with a general goal of streamlining the procedure to yield better surface quality.

2. METHODOLOGY

It can be seen from the literary works that advancements and current practices in the region of procedure change prescribe utilizing RSM for expressing the output parameters (responses), in terms of input variables.

2.1 Response Surface Methodology (RSM)

RSM is a gathering of measurable and numerical techniques that are valuable for the demonstrating and investigating engineering issues. In this method, the principle target is to advance the response surface that is affected by different process parameters. RSM likewise evaluates the relationship between the controllable input parameters and the output response surfaces. The outline technique of RSM is as per the following

- Designing of a progression of examinations for satisfactory and solid estimation of the response of interest.
- Developing a scientific model of the second request response surface with the best fittings.
- Finding the ideal arrangement of test parameters that create a most extreme or least estimation of response.
- In the last step represents the immediate and intuitive impacts of process parameters through two or three-dimensional plots.

2.2 Design of Experiments for RSM

RSM plans permit us to gauge connection and even quadratic impacts, and in this way give us a thought of the (nearby) state of the response surface under scrutiny. Box-Behnken plans and focal composite outlines are proficient plans for fitting second order polynomials to response surfaces since they utilize the generally little number of perceptions to evaluate the parameters. Rotatability is a sensible premise for the determination of a reaction surface outline. The motivation behind RSM is the improvement and the area of ideal is obscure before running the investigation, it bodes well to utilize a configuration that gives the break even with the accuracy of estimation in all bearings. For such purposes, Central Composite Design (CCD) -spherical or face cantered and Box – Behnken outline are the regularly utilized exploratory configuration models for three level three variable investigations.

2.3 Box – Behnken design

Box and Behnken proposed three level outlines for fitting reaction surfaces. These outlines are framed by joining 2k factorials with inadequate block designs. It can be seen that the Box-Behnken configuration is a spherical design with all focuses lying on a sphere radius. Likewise the Box – Behnken design does not contain any point at the vertices of the cubic district made by the upper and lower limits for every variable.

3. EXPERIMENT DETAILS

3.1 Material

In this investigation, the work piece material aluminium was used with the following main properties: Tensile Strength 90 MPa, Modulus of elasticity 69 GPa, and Density 2.71 g/cm3. The abrasive used was garnet with mesh size of 80 and hardness of 7.5 Mohs.

3.2 Equipment

The equipment used for machining the samples was Abrasive Water Jet Machine of model 2652 OMAX Jet Machining Centre equipped with OMAX High- Pressure Pump with the design pressure of 345MPa (50,000 psi) and the nozzle diameter was 0.85mm. The OMAX variable speed, high-pressure pump is an electrically driven, variable speed, positive displacement, crank shaft drive triplex pump designed for use with the OMAX precision jet machining system and other applications requiring high pressure water required by the OMAX jet machining system to operate. The pump control panel provides a keypad display screen, and pumps start/stop controls. When the pump is attached to an OMAX jet machining centre, controls sheared between the Jet machining centre controller and the pump.

3.3 Experimental Design

The experimental layout for the machining parameters using RSM was used in this study. This consists of three control parameters and three levels, as shown in table1. Thus in this study, Author observed the values of surface roughness to see the dependencies of process parameter.

3.4 Selection of Process Parameters

Process parameters for the study had three levels as given in Table 1. The levels were fixed based on the preliminary experiment-trials, discussion with expert operator of AWJ machine and also the available literatures.

Table -1: Process parameter with level

Level	Process parameter		
	Pressure (MPa)	Standoff distance (mm)	Traverse rate (mm/min)
L1	150	1.5	90
L2	220	2.5	150
L3	290	3.5	210

4. RESULTS AND DISCUSSION

The results of surface roughness gained by an optical Profilometer MicroProf (FRT) mentioned in table no.2. The contour is plotted between two process parameter and surface roughness at a time with the help of Design of Expert Software (DoE DX10). Also the 3D surface analysed by author which obtained from DoE software.

Table -1: Design of Experiment

Run no.	Process parameter			
	Pressure (MPa)	Standoff distance(mm)	Traverse speed (mm/min)	Surface roughness(μm)
1	290	3.5	90	3.8
2	150	2.5	150	8.87
3	220	3.5	150	6.14
4	150	3.5	90	7.64
5	220	3.5	150	6.16
6	290	3.5	210	4.26
7	220	3.5	150	6.15
8	220	4.5	90	6.1
9	150	4.5	150	9.86
10	220	4.5	210	6.43
11	220	3.5	150	6.14
12	220	3.5	150	6.13
13	290	4.5	150	4.13
14	290	2.5	150	4.03
15	150	3.5	210	9.89
16	220	2.5	210	6.2
17	220	2.5	90	5.2

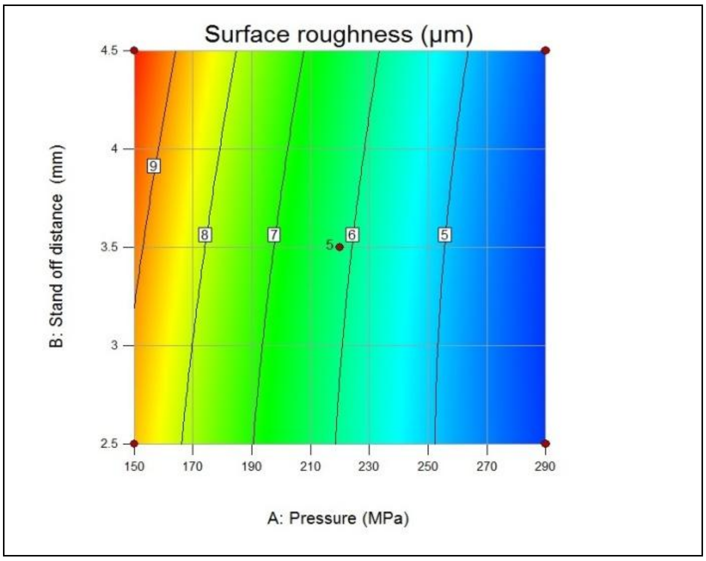

Fig -1: Contour plot among pressure, standoff distance and surface roughness

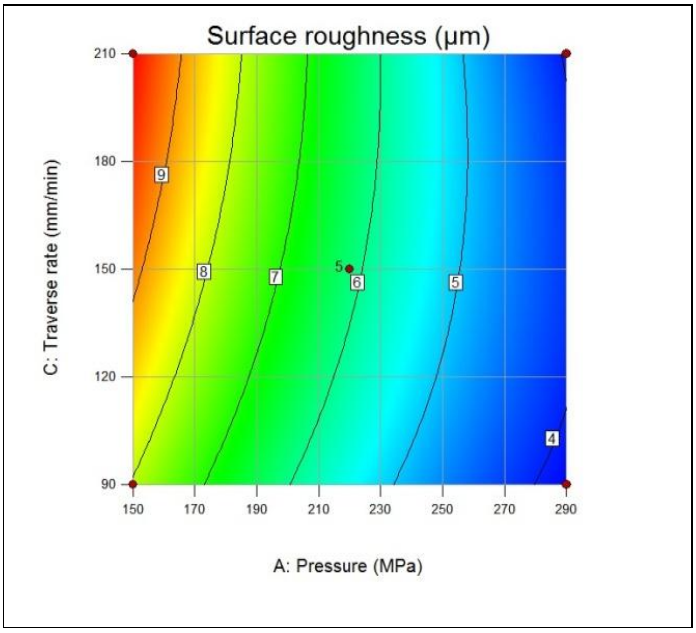

Fig -2: Contour plot among pressure, traverse rate and surface roughness

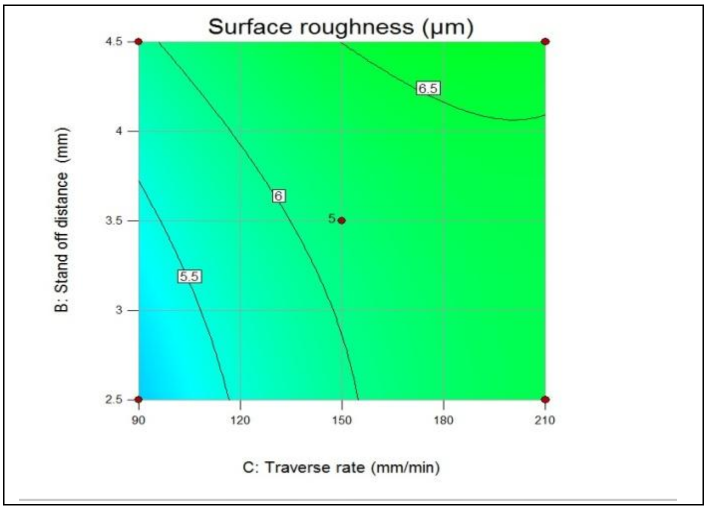

Fig -3: Contour plot among traverse rate, standoff distance and surface roughness

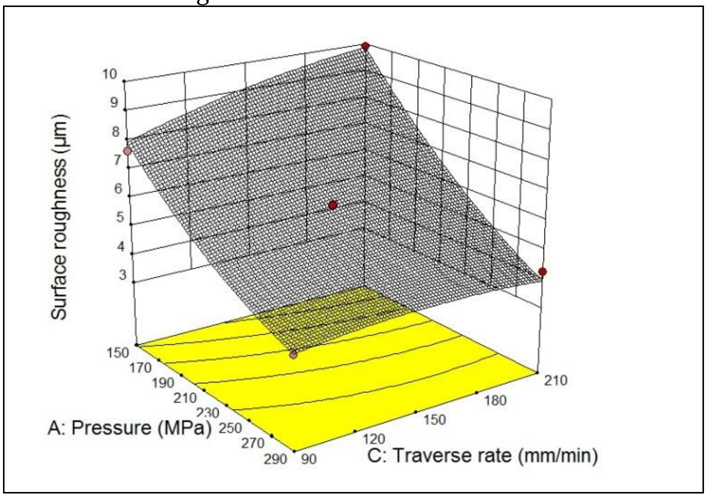

Fig -4: 3D Surface among pressure, traverse rate and surface roughness

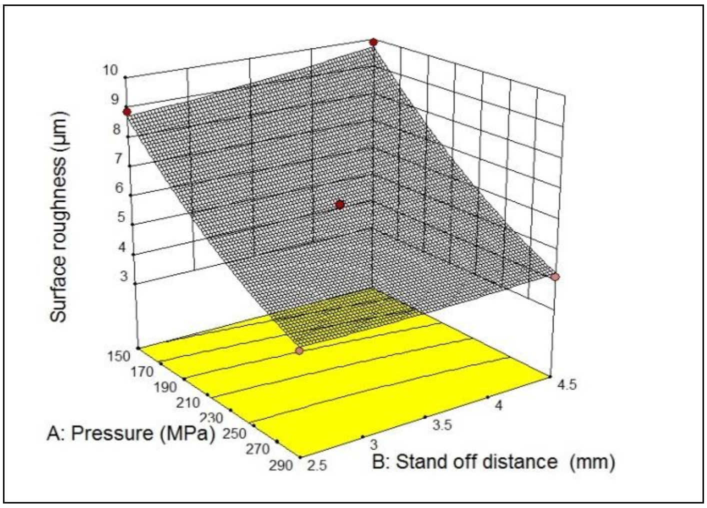

Fig -5: 3D Surface among pressure, standoff distance and surface roughness

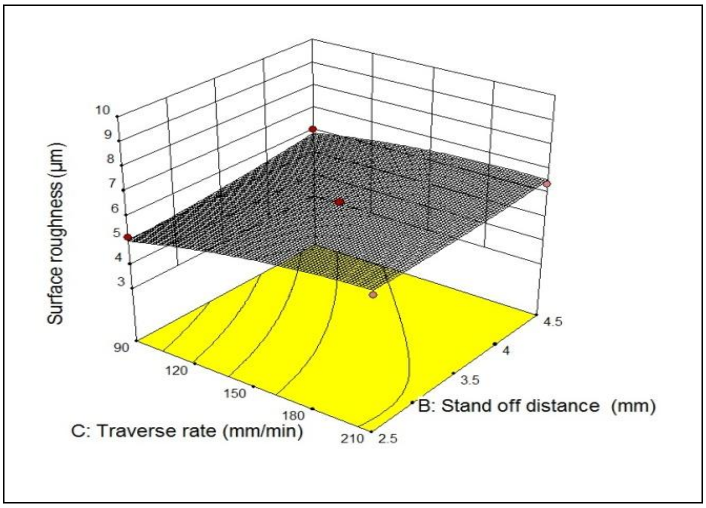

Fig -6: 3D Surface among standoff distance, traverse rate and surface roughness

3. CONCLUSIONS

The author observed that the pressure and traverse rate has much effect on surface roughness than standoff distance. Even though the effect of standoff distance is less but can't negotiate. When pressure increases surface quality improve as surface roughness decreases. As traverse rate increases surface quality decreases as surface roughness increases. Standoff distance of lesser than one millimetre produce poor surface finish in the starting cutting region near the top surface but as standoff distance increases greater than two to three millimetre surface roughness again increases. In this paper author has taken standoff distance one to three hence we only found that as standoff distance increases surface quality decreases.

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