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Investigation of kerf Characteristics in Abrasive Water Jet Machining of Inconel 600 using Response Surface Methodology

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ABSTRACT

Abrasive water jet machining (AWJM) has found its application in the manufacturing industries for machining hard materials with precision. A degree of high precision in machining of complex geometries makes AWJM valuable. The selection of optimum process parameters is important to the resulting quality of machined parts. In this study, an experimental investigation was conducted to evaluate the machinability of Inconel 600. A response surface methodology (RSM) is used to determine the influence of the AWJM process parameters on the considered performance characteristics, i.e., kerf top width (KTW) and taper angle. The analysis of variance is performed to obtain the contribution and influence of each process parameter on the considered responses. The value of R-Squared obtained for KTW and taper angle using regression model is 0.97 and 0.96 respectively. The optimum setting of the parameters for single and multiple response characteristics are obtained using the desirability analysis of RSM. The results obtained using desirability analysis of RSM is validated by conducting the confirmation experiments. The experimental confirmatory values obtained for the considered performance parameters KTW and taper angle as 27.138 and 0.125 respectively. The corresponding value of error obtained as 0.383 and 0.013 respectively. Further, an optimum set is obtained with KTW as 27.461 mm and taper angle as 0.582° for multiple response optimisation.

Keywords: Abrasive water jet machining; Taper angle; Kerf top width; Inconel 600; Response surface methodology

1. INTRODUCTION

Abrasive water jet machining (AWJM) is the significant process has some distinct benefits over the other modern machining processes. The process has large capability owing to its characteristics and applications in aerospace and automotive industry[1-3]. A literature reports different works of AWJM process which shows its capability of difficult-to-hard material for machining to meet the requirement of the industries. Few researchers have reported the influence of AWJM parameters using experimentation and evolutionary metaheuristic techniques. The brief summary of AWJM literature is shown in Table 1.

The literature reveals that different methods are applied to obtain the optimum setting of the process parameters on different materials. Furthermore, the influences of AWJM parameters on the performance of the process are reported. To the best of my knowledge, no work is reported that comprise of all the performance measurement, i.e., KTW and taper angle in a single study for any material. The present study investigate the influence of AWJM parameters, transverse speed (TS), abrasive flow rate (AFR), standoff distance SOD and water pressure (WP) during machining of the material Inconel 600 for the considered responses. The considered material for machining has different applications with constant growth. The desirability analysis is attempted to determine the optimum parameter setting for the single and multiple response characteristics.

2. EXPERIMENTAL DETAILS

The experiments are conducted on the AWJM havingan 850 D control system with cutting area of 4000 × 1800 mm^2. The experimental setup is shown in Fig. 1. The considered material Inconel 600 is a standard engineering material has high resistance to corrosion and heat, good strength, high workability. This material has wide application in aerospace, defence equipment, evaporator tubes, equipment for treatment abietic acid in the paper industry. The applications of Inconel 600 play an important role to develop the researcher's interest in the research to recognize material characteristics with respect to the parameters of the machining process. In the preliminary experiments, it is observed that the material Inconel 600 is not machined properly due its toughness. So, the WP is adjusted between 350 MPa - 400 MPa for Inconel 600 material, as it is found the feasible region in the preliminary experiments.

2.1 Experimental Procedure and Measurements

In this work, two performance characteristics like, KTW and taper angle are selected for investigation purpose. The process parameter KTW and kerf bottom width (KBW) are measured using digital vernier caliper. In the values of KTW and KBW, the size of circular specimen, i.e., 25 mm

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Table 1. Short summary of literature on AWJM process

Authors	Workpiece Material	Process parameters	Performance parameters	Method/ Instrument	Effect of parameters / Observations
Caydus and Hascalic[4]	AA 7075 aluminium alloy	Transverse speed, water jet pressure, standoff distance, abrasive grit size and abrasive flow rate	*Ra*	Taguchi, ANOVA	They have conducted experimental investigation and developed models using ANN for the selected process parameters to predict the response *Ra*.
Fowler[5], *et al.*	Titanium alloy (Ti6Al4V)	Particle shape and hardness using different abrasives, i.e., garnet, glass beads, brown and white aluminium oxide and steel shot	*MRR, Ra*	Experimental and analytical, SEM	They have investigated the effects of particle shape and hardness with selected abrasives on *MRR* and *Ra* during machining of titanium alloy in abrasive water jet milling. The surface waviness was reduced as the traverse speed is increased whilst; *Ra* is not strongly dependent on traverse speed.
Srinivasu[6], *et al.*	Silicon carbide ceramics	Jet impinging angle, feed rate of the jet	*Kerf characteristics*	Experimental and analytical	They have conducted an experimental investigation to analyze the effects of the kinematic parameters on *kerf* during machining of silicon carbide ceramics and obtained three dimensional surface profiles.
Akkurt[7]	Brass-353, 99% pure aluminium, Al-6061, AISI 304, AISI 1030, cold working tool steel	Material type and thickness	*Drilling time*	Experimental, SEM	An experimental investigation was conducted on selected materials to study the effects of thickness and material type on the drilling time.
Ay[8]	Inconel 718 Nickel-Based Superalloy	Transverse speed	*Ra, Kerf taper ratio, kerf wideness*	Experimental, SEM, atomic force microscope (AFM)	The effects of selected transfer speed have been investigated on *Ra* and *kerf taper ratio* during machining of Inconel 718 nickel-based super alloy.
Zohoor and Nourian[9]	Hardox	Nozzle diameter, transverse speed, water pressure, abrasive flow rate	*Ra, kerf,* taper angle	Experimental and analytical, RSM	They have developed an algorithm to minimize the nozzle wear effect on the performance characteristics such as *Ra* and *kerf width* during machining of difficult-to-hard material using AWJM process.
Kechagias[10], *et al.*	TRIP 700 CR-FH and TRIP 800 HR-FH steel sheets	Material thickness, nozzle diameter, standoff distance, transverse speed	*Kerf width, Ra*	Experimental and analytical	They have investigated the influence of sheet thickness, nozzle diameter, transverse speed and standoff distance on the *kerf geometry* and *Ra* during machining of steel sheets.
Alberdi[11], *et al.*	CFRP composite	Water pressure, abrasive flow rate, standoff distance, thickness of plate	*Ra and* taper angle	Experimental and analytical, ANOVA	They have conducted an experimental investigation with different composite materials of varying thickness to study the behaviour of machinability in the composites.
Yue[12], *et al.*	Alumina ceramic	Water pressure, jet feed speed, abrasive mass flow rate, surface speed, nozzle tilted angle	*MRR*	SAO, RSM	They have conducted an experimental investigation to obtain the influence of considered process parameters on *MRR* while turning operation on alumina ceramic. They have obtained optimum parameters using sequential approximation optimisation (SAO) to enhance *MRR*.

Authors	Workpiece Material	Process parameters	Performance parameters	Method/ Instrument	Effect of parameters / Observations
Naresh Babu & Muthukrishnan[13] (2014)	Brass 360	Abrasive flow rate, pump pressure, standoff distance, feed rate	*Ra*	Experimental, RSM	They have investigated the effects of AWJM process parameters on *Ra* during machining of brass-360 material.
Li and Wang[14] (2015)	Titanium alloy	Depth of cut, water pressure	*Drilling time*	Experimental	They have performed two machining operations, i.e., drilling and slotting using an AWJM process while machining of titanium alloy to obtain the influence of depth of cut and water pressure on the *drilling time* of holes.
Santhanakumar[15], *et al.* (2015)	Ceramic	Abrasive grain size, abrasive flow rate, standoff distance, water pressure, jet traverse rate	*Ra,* taper angle	Experimental, Grey-Based RSM	They have attempted investigation using grey – based response surface methodology to obtain the influence of AWJM process parameters on *Ra* and taper angle while machining of ceramic tiles.
Pahuja[16], *et al.* (2016)	Titanium Graphite	Geometric variables (mixing tube aspect ratio and orifice bore size), water pressure, jet traverse speed and abrasive load ratio	*Taper ratio* and *surface quality*	ANOVA, Scanning electron and optical microscope	The mechanism of material removal is reported phase by phase for the considered material.
Ramula[17], *et al.* 2016	Metal Laminate-Titanium/ Graphite (Ti/Gr)	Transverse speed and Abrasive flow rate	kerf characteristics, entry damage and material removal rate	ANOVA	The researchers have reported the studied effects of the considered process variables on kerf character tics.
Shukla and Singh[18] (2017)	Aluminium alloy 6351 T6	Transverse speed, abrasive flow rate, standoff distance. Water pressure was considered as constant parameter.	*KTW and* taper angle	Experimental, PSO, FA, SA, CSA, BH, BBO, NSGA-II	They have attempted the experimental investigation to obtain the influence of AWJM parameters on the responses *KTW* and taper angle. They have applied selected optimisation techniques to obtain the optimum parameter setting.
Geethapriyan[19], *et al.* (2019)	Inconel 600	Water pressure, mass flow rate, transverse speed and standoff distance Abrasive with different size, i.e., 80 and 100.	*MRR* and *Ra*	Grey–Taguchi methodology	They have obtained optimum parameter setting of the considered process parameters for the multiple responses MRR and Ra with selected abrasive size.

Figure 1. Experimental setup of AWJM process.

is accumulated for ease in calculation of taper angle. The schematic view of KTW, KBW and taper angle is shown in Fig. 2. The performance parameter taper angle is calculated by the following relation given in Eqn. (1).

$$taper\quad angle = \tan^{-1}\frac{w_t - w_b}{2t} \tag{1}$$

where w_t is the *KTW*, w_b is the *KBW* and t is the thickness of the workpiece.

3. RESPONSE SURFACE METHOD

A response surface method (RSM) is used to build the regression models using the experimental results. The experiments are the series of runs for the independent variables which is used to find the influence on the responses. The RSM method reduces number of experiments without degrading the actual purpose and thus reduces the cost of experiments. The second order equation for obtaining the values of models using "Design Expert 10" is

$$y = b_0 + \sum_{i=1}^{n} b_i x_i + \sum_{i,j=1}^{n} b_i x_i x_j + \sum_{i=1}^{n} b_i x_i^2 \pm \varepsilon \tag{2}$$

where y is the value of response, x_i and x_j is the value of machining parameter, b_i is the regression coefficients and ε is the error during the experiment. The second term in Eqn. (2) signifies the linear effect, whereas the third term signifies the higher order effects. By using a least square technique, the values of the coefficient can be obtained[13,20,21].

A central composite second order quadratic design with 31 experimental runs is used to conduct the experimentation in the present work. The process parameters with levels for Inconel 600 are given in Table 2. Using the experimental results for the considered material as given in Table 2, the final regression models obtained for the considered characteristics, i.e., *KTW and* taper angle are given in Eqns. (3)-(4).

$$\begin{aligned} KTW &= 5.75798 + 0.028611x_1 + 0.99628x_2 + 0.012874x_3 \\ &+ 9.00021\times10^{-3}x_4 + 4.35291\times10^{-4}x_1x_2 + 3.35299\times10^{-5}x_1x_3 \\ &- 3.58005\times10^{-6}x_1x_4 + 8.92665\times10^{-5}x_2x_3 \\ &- 7.78265\times10^{-5}x_2x_4 - 7.67756\times10^{-7}x_3x_4 - 2.00726\times10^{-4}x_1^2 \\ &- 0.15023x_2^2 - 1.72861\times10^{-5}x_3^2 - 1.08448\times10^{-6}x_4^2 \end{aligned} \tag{3}$$

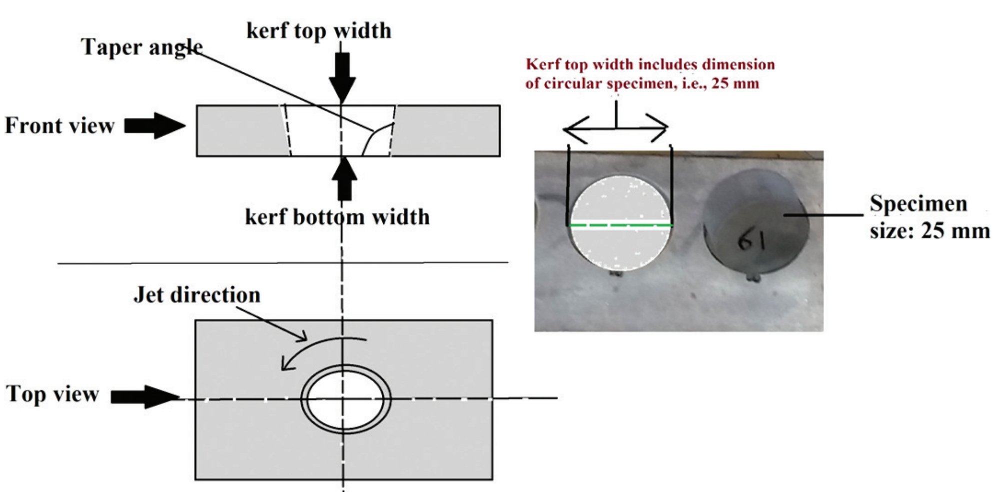

Figure 2. Schematic view of *KTW* and *taper angle.*

Table 2. Experimental design matrix and results for Inconel 600 material

No.	Transverse speed (mm/min) (x_1)		Standoff distance (mm) (x_2)		Abrasive flow rate (gm/min) (x_3)		Water pressure (bar) (x_4)		*KTW*[#] (mm)	Taper angle (°)
	Coded	Actual	Coded	Actual	Coded	Actual	Coded	Actual		
1	1	87.5	-1	1.5	-1	300	-1	3625	27.1247	0.2130
2	0	75	-2	1	0	350	0	3750	27.1680	0.1749
3	1	87.5	-1	1.5	-1	300	1	3875	27.2034	0.2717
4	-1	62.5	-1	1.5	1	400	-1	3625	27.2280	0.4403
5	0	75	0	2	-2	250	0	3750	27.2529	0.4940
6	-1	62.5	-1	1.5	-1	300	-1	3625	27.2642	0.3531
7	-1	62.5	-1	1.5	-1	300	1	3875	27.2666	0.5068
8	2	100	0	2	0	350	0	3750	27.2673	0.3983
9	1	87.5	-1	1.5	1	400	1	3875	27.2727	0.1248
10	1	87.5	-1	1.5	1	400	-1	3625	27.2740	0.4306
11	1	87.5	1	2.5	-1	300	-1	3625	27.3210	0.4554
12	-1	62.5	-1	1.5	1	400	1	3875	27.3333	0.3819
13	0	75	0	2	2	450	0	3750	27.3389	0.5218
14	0	75	0	2	0	350	-2	3500	27.3439	0.6898
15	1	87.5	1	2.5	-1	300	1	3875	27.3708	0.5435
16	-1	62.5	1	2.5	-1	300	-1	3625	27.3993	0.3966
17	-2	50	0	2	0	350	0	3750	27.4194	0.5909
18	0	75	0	2	0	350	0	3750	27.4359	0.6812
19	1	87.5	1	2.5	1	400	1	3875	27.4411	0.4994
20	-1	62.5	1	2.5	1	400	-1	3625	27.4458	0.5915
21	-1	62.5	1	2.5	-1	300	1	3875	27.4530	0.7932
22	0	75	0	2	0	350	2	4000	27.4582	0.6821
23	0	75	0	2	0	350	0	3750	27.4597	0.7043
24	1	87.5	1	2.5	1	400	-1	3625	27.4668	0.7891
25	0	75	0	2	0	350	0	3750	27.4678	0.7475
26	0	75	0	2	0	350	0	3750	27.4686	0.6812
27	0	75	2	3	0	350	0	3750	27.4692	0.6716
28	0	75	0	2	0	350	0	3750	27.4720	0.7123
29	0	75	0	2	0	350	0	3750	27.4730	0.6812
30	-1	62.5	1	2.5	1	400	1	3875	27.4754	0.6390
31	0	75	0	2	0	350	0	3750	27.4768	0.7345

[#]Specimen circular size of 25 mm is added in the measurement of *KTW* for ease of taper angle computation.

$$\begin{aligned} taper\ \ angle = & -43.33526 + 0.18255x_1 - 0.57177x_2 + 0.061894x_3 \\ & + 0.014253x_4 + 5.09140\times10^{-3}x_1x_2 + 3.57443\times10^{-5}x_1x_3 \\ & - 3.95186\times10^{-5}x_1x_4 + 7.43378\times10^{-4}x_2x_3 \\ & + 3.94253\times10^{-4}x_2x_4 - 1.30346\times10^{-5}x_3x_4 - 4.06085\times10^{-4}x_1^2 \\ & - 0.32512x_2^2 - 2.40474\times10^{-5}x_3^2 - 9.98714\times10^{-7}x_4^2 \end{aligned} \tag{4}$$

3.1 Experimental Results and Analysis

In this segment, the analysis of variance is reported for the experimental results obtained for material Inconel 600 in AWJM process.

3.1.1 ANOVA Analysis and Effects of Process Parameters on KTW

The analysis of variance (ANOVA) is used to check the adequacy of the developed regression models for *KTW* and taper angle of the considered Inconel 600 material. The ANOVA results for the quadratic model on the *KTW* are given in Table 3. It is revealed from Table 3 that the value obtained for model F-value is 37.49 which show that that the regression model is significant. "Prob > F" represent that the regression coefficient is zero and the obtained regression model is true. The values obtained "Prob > F" is less than 0.0500 indicate model terms are significant. In the present model for *KTW* the terms A, B, C, D, AC are significant. The value observed greater than 0.1000 implies that the model terms are not significant. "Lack of Fit F-value" represents the obtained regression models is poor or not in terms of data fit. The "Lack of Fit F-value" is found to be 4.67 implies its significance. "Pred R-Squared" represents how well the new observation can be predicted using generated regression model. The value of "Pred R-Squared" is in reasonable agreement with the "Adj R-Squared" (it

Table 3. ANOVA analysis of *KTW*

Source	Sum of squares	Degree of freedom	Mean square	*F* Value	*p*-value *Prob > F*	
Model	0.33	14	0.024	37.49	< 0.0001	significant
TS	0.02	1	0.02	31.88	< 0.0001	
SOD	0.17	1	0.17	266.24	< 0.0001	
AFR	0.021	1	0.021	32.89	< 0.0001	
WP	0.011	1	0.011	17.93	0.0006	
TS and SOD	1.18E-04	1	1.18E-04	0.19	0.6707	
TS and AFR	7.03E-03	1	7.03E-03	11.13	0.0042	
TS and WP	5.01E-04	1	5.01E-04	0.79	0.3864	
SOD and AFR	7.97E-05	1	7.97E-05	0.13	0.727	
SOD and WP	3.79E-04	1	3.79E-04	0.6	0.45	
AFR and WP	3.68E-04	1	3.68E-04	0.58	0.4561	
Residual	0.01	16	6.31E-04			
Lack of fit	8.95E-03	10	8.95E-04	4.67	0.0362	significant
Standard deviation	0.025				R^2	0.9704
Mean	27.36				Adj R^2	0.9445
C.V. %	0.092				Pred R^2	0.8444
PRESS	0.053				Adeq Precision	19.196

is a modified R-squared value which improves or reduces with the addition of predictor's terms) i.e. the difference is less than 0.2.

The influence of AWJM process parameters on KTW is depicted in Figs. 3 (a)-3(f). As the TS increases the performance characteristic KTW is decreased. The negative effect of TS on KTW is because of the smaller quantity of particles strikes on the workpiece material with the increase of nozzle TS. It is observed from Fig. 3 (a) that as the SOD increases the value of KTW increases. This shows that SOD has the prominent influence on KTW. This occurs due to the fact that as the SOD increases the impact of abrasives on the workpiece material increases which tends to tear off the upper portion the workpiece material. It reveals from Fig. 3 (b), as the AFR increases the performance characteristics KTW increases. As the AFR increases, the number of particles impinges on the material increases which erode the target surface. It is observed from Fig. 3 (e)-3(f) that with the increase of WP the response *KTW* increases. The similar trend is obtained for the material hybrid aluminim 7075 metal matrix composite by Sasikumar[22], *et al.* As the WP increases during machining, the abrasive particle present in the water jet breaks down into smaller fragments due to its brittle nature. Furthermore, the kinetic energy of the abrasive particles increases due to an increase of WP which increases the value of KTW of the target material.

3.1.2 *ANOVA Analysis and Effects of Process Parameters on* Taper angle

The ANOVA results for the quadratic model on taper angle are reported in Table 4. It is revealed from Table 4 that the obtained F-value is 28.66 which show that that the regression model obtained is significant. The model terms, i.e., A, B, AB, AD, CD are significant as "Prob > F" is less than 0.05. The "Lack of Fit F-value" is found to be 4.69 implies its significance. The value of "Pred R-Squared" shows good agreement with the "Adj R-Squared" i.e. the difference obtained is less than 0.2.

The influence of AWJM process parameters on taper angle are depicted in Figs. 4 (a) - 4(f). It is revealed from the Fig. 4 (c), as the TS increases the performance characteristic taper angle increases. In the literature, Sasikumar[22], *et al.* have obtained similar trend for the response kerf taper (mm/mm) with respect to transverse speed. This occurs when the TS increases; it reduces the number of particle impact on the workpiece. The effects of TS on taper angle with respect to SOD, AFR and WP are shown in Figs. 4 (a) - 4(c). It is observed from Fig. 4 (a) that as the SOD increases the performance characteristics taper angle increases. It happens when the increase of KTW occurs due the scatter impact of abrasive particles on the target surface material. Furthermore, as the SOD increases the kinetic energy of the particle impacting on the target material surface gradually decreases from high to low which reduces the kerf bottom width. It reveals from Fig. 4 (f), as the AFR increases the performance characteristics taper angle increases. This occurs when the AFR increases; the erosion of material increases the KTW and KBW of the target surface. It is observed from Fig. 4 (c) that with the increase of WP the performance characteristics taper angle is found improved. The kinetic energy of the abrasive particles increases due to an increase of WP which plays a significant role in improving the taper angle.

4. DESIRABILITY ANALYSIS

In this section, desirability analysis using RSM is attempted for the experimental results of material Inconel

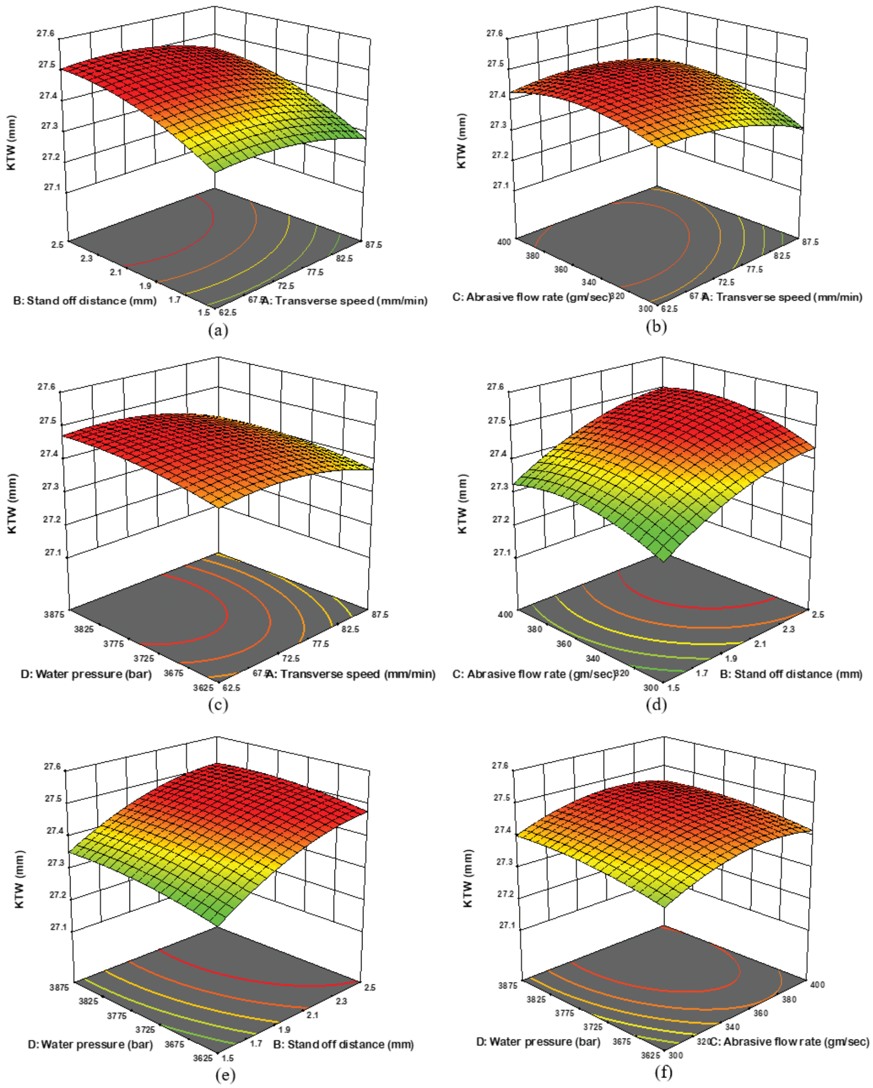

Figure 3. (a)-(f) 3D surface plots for KTW.

600. In the desirability analysis both the single and multiple responses, characteristics are considered. It is observed from literature that the multi response optimisation has found applications in path finding in network[23], energy conservation systems[24] and sustainable design for energy supply systems[25]. It determines the optimum set of the considered process parameters on the performance characteristics.

A maximum level is set for KTW characteristic which is required to be optimised. The obtained optimum process parameters are TS as 67.263 mm/min, SOD as 2.491 mm, AFR as 352.339 gm/min and WP as 3804.362 bar for the response KTW as 27.521 mm with the desirability value as 1. The obtained value of the desirability is 1 which indicates its significance in the improvement of the response KTW. The 3D surface plot of KTW as depicted in Fig. 5 is obtained from the desirability analysis for the process parameters TS and SOD with the constant value of AFR and WP as 353.339 gm/min 3804.36 bar, respectively.

A minimum level is set for taper angle characteristic which is required to be optimised. The obtained optimum process parameters are TS as 87.5 mm/min, SOD as 1.5 mm, AFR as 400 gm/min and WP as 3875 bar for the response taper angle as 0.138 with the desirability value as 0.981. The 3D surface plot of taper angle as depicted in Fig. 6 is obtained from the desirability analysis for the process parameters TS and SOD with the constant value of AFR and WP as 400 gm/min 3875 bar, respectively.

Table 4. ANOVA analysis of *Taper angle*

Source	Sum of squares	Degree of freedom	Mean square	*F* Value	*p*-value *Prob> F*	
Model	0.98	14	0.07	28.66	< 0.0001	significant
TS	0.056	1	0.056	23	0.0002	
SOD	0.37	1	0.37	151.65	< 0.0001	
AFR	7.31E-03	1	7.31E-03	3	0.1026	
WP	2.39E-04	1	2.39E-04	0.098	0.7584	
TS and SOD	0.016	1	0.016	6.65	0.0202	
TS and AFR	7.99E-03	1	7.99E-03	3.28	0.0892	
TS and WP	0.061	1	0.061	25.02	0.0001	
SOD and AFR	5.53E-03	1	5.53E-03	2.27	0.1517	
SOD and WP	9.72E-03	1	9.72E-03	3.98	0.0632	
AFR and WP	0.11	1	0.11	43.55	< 0.0001	
Residual	0.039	16	2.44E-03			
Lack of Fit	0.035	10	3.46E-03	4.69	0.036	significant
Standard Deviation	0.049				R^2	0.9617
Mean	0.54				Adj R^2	0.9281
C.V. %	9.22				Pred R^2	0.7983
PRESS	0.21				Adeq Precision	18.949

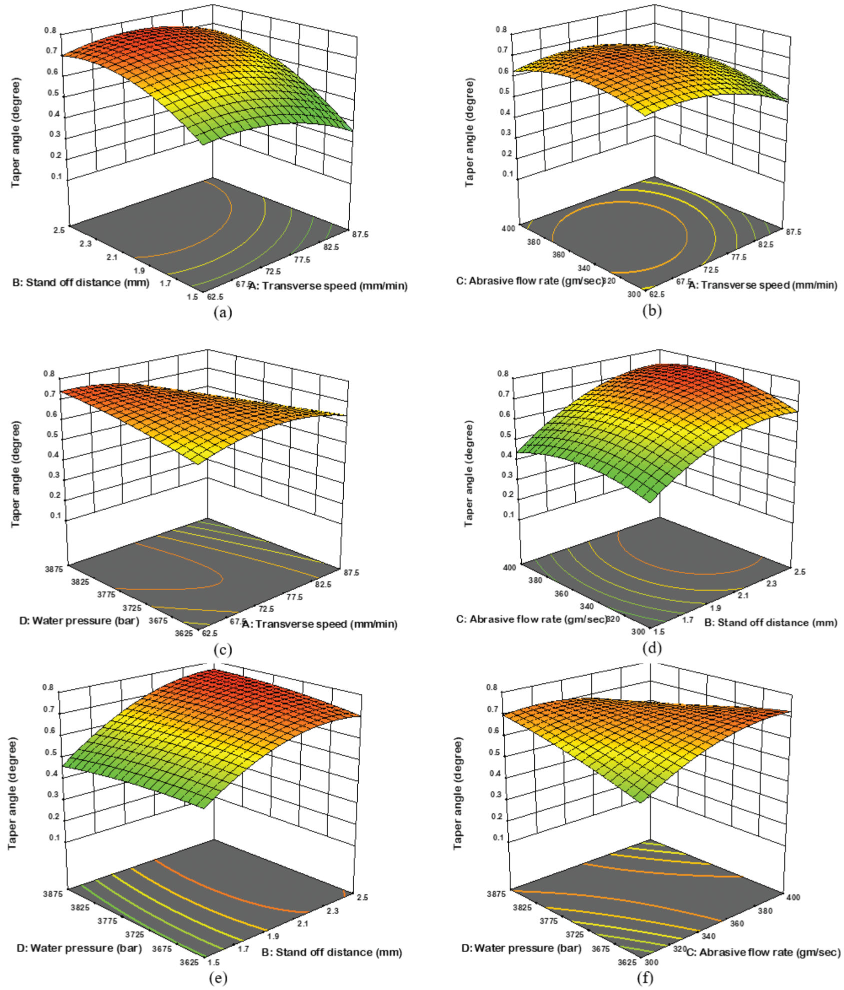

Figure 4. (a)-(f) 3D surface plots for *taper angle*.

4.1 Desirability Analysis for Multiple Response Optimisation

The limits and goals for each process parameter are established for considered responses, i.e., KTW and taper angle in order to obtain their impact on desirability. A minimum or maximum level is set for each response characteristic which is required to be optimised. The obtained optimum process parameters are TS as 87.5 mm/min, SOD as 2.5 mm, AFR as 400 gm/min and WP as 3875 bar. The corresponding response values obtained for KTW as 27.461 mm and taper angle as 0.582° with the desirability value as 0.696. The value of the combined desirability is 0.594 which indicates its significance in the improvement of the considered responses. The value of the combined desirability is nearly equaled to 0.7 is due to the fact that the considered multiple responses which reduce desirability overall mean value. The 3D surface plot of desirability as depicted in Fig. 7 is obtained from the desirability analysis for the process parameters TS and SOD with the constant value of AFR and WP as 400 gm/min and 3875 bar respectively. The results obtained for multiple response optimisation using desirability analysis is validated by conducting the confirmation experiments. The experimental confirmatory values obtained for the considered performance parameter KTW as 27.441 mm and taper angle as 0.519°.

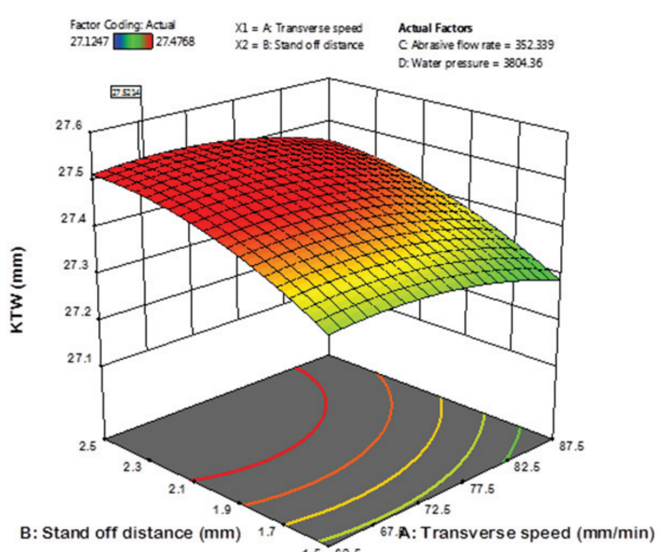

Figure 5. 3D Desirability *KTW* plot.

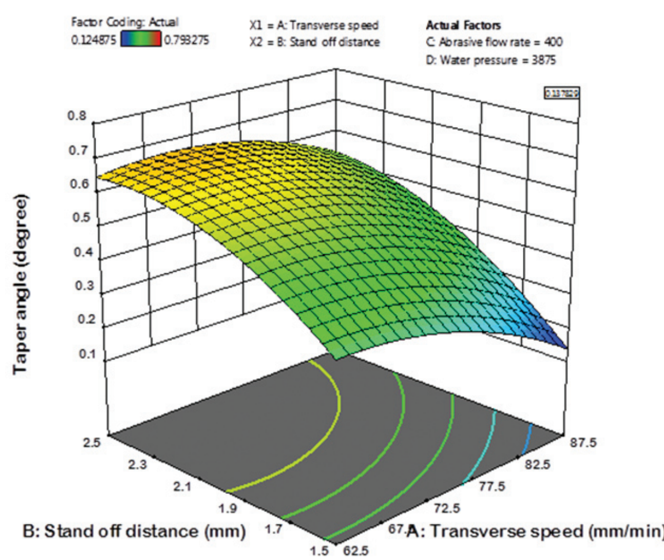

Figure 6. 3D Desirability *taper angle* plot.

Table 5. Confirmatory test results for desirability analysis

Response	Transverse speed	Standoff distance	Abrasive flow rate	Water pressure	Response value	Confirmatory test result	Error
KTW (mm)	67.263	2.491	352.339	3804.362	27.521	27.138	0.383
Taper angle (°)	87.5	1.5	400	3875	0.138	0.125	0.013

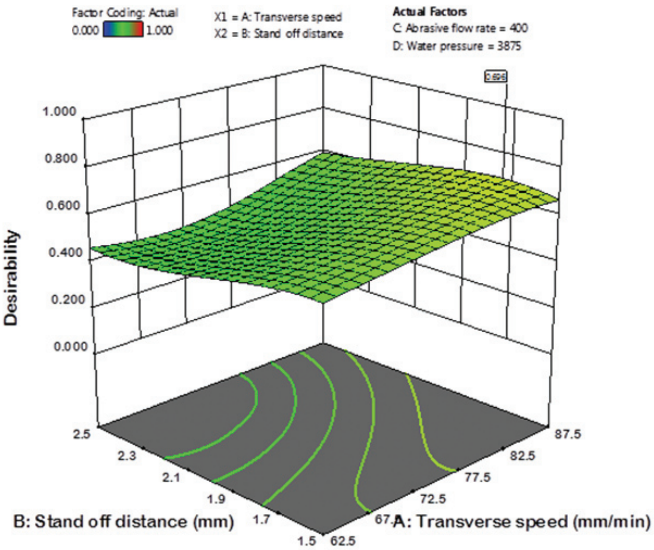

Figure 7. 3D Desirability plot for multiple responses.

5. CONFIRMATORY TEST RESULTS

The optimal parameter setting is determined using RSM desirability analysis for the considered performance parameters. However, the end step is to confirm the obtained optimum values. The results obtained using desirability analysis of RSM is validated by conducting the confirmation experiments. The experimental confirmatory values obtained for the considered performance parameters *KTW* and taper angle as 27.138 and 0.125 respectively. The corresponding values of errors obtained are 0.383 and 0.013 respectively. The confirmatory values are depicted in Table 5.

6. CONCLUSIONS

In this work, AWJM process is considered for parameters optimisation using desirability approach of RSM. An experimental investigation is conducted using L31 array design of experiments. The study comprise of two responses, i.e., KTW and taper angle. AWJM process has proved its capability for machining Inconel 600 under accepted region with KTW as 27.521 mm and taper angle as 0.138° obtained using desirability approach.The effects of parameters viz. TS, SOD, AFR and WP are reported through machining of material Inconel 600. Due to the toughness of the considered material, it was found that WP has least significant effect in the considered range of 3500 bar to 4000 bar on the response KTW. Similarly, the process parameter SOD has high influence on the response taper angle. Furthermore, a desirability analysis of multiple responses is attempted to see the combined effects of process parameters of AWJM on the considered responses. An optimum set was obtained with KTW as 27.461 mm and taper angle as 0.582° for multiple response optimisation. The finding of the current research is useful to the manufacturing engineers in selecting the optimum combination of parameters for AWJM process to obtain desired responses.

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