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ACO APPROACH ON CUTTING PARAMETERS IN AWJM PROCESS FOR ALUMINIUM BASED ALLOY

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KEYWORDS:

Response surface methodology;
Ant Colony Optimization;
Material Removal Rate;
Surface Roughness.

ABSTRACT

For as far back as years we have watched a fast development in the improvement of harder, troublesome and multifaceted nature to machine metals and alloys. AWJM is one of the as of late created half and half, non traditional machining procedure in preparing different sorts of hard-to-cut materials these days. It is a practical technique for warmth touchy materials that can't be machined by procedures that produce heat while machining. Machining parameters assume the lead job in deciding the machine financial aspects and nature of machining It is an affordable strategy for warmth touchy materials that can't be machined by procedures that produce heat while machining. Machining parameters assume the lead job in characterizing the machine financial aspects and nature of machining .In this examination the result of Pressure, Abrasive stream rate, Orifice breadth, Focusing spout measurement and Standoff separation AWJM process parameters on MRR and SR of Aluminum 6061 composite which is machined by AWJM was tentatively performed and investigated. As per Response Surface Methodology structure, different examinations were led with the blend of info parameters on this compound.This paper presents the Prediction and Optimization of MRR and SR on Aluminium 6061 alloy using Single Objective Ant Colony Optimization.

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1.LITERATURE SURVEY

~~AWJC is the recently developed processes~~. Brittle materials similar to glass, ceramics and stones as well as composite materials and ferrous and non-ferrous materials can be machined by this technique. From the literature review of Adel A. Abdel-Rahman [1] in 2011 an elastic-plastic erosion model was implemented to build up an abrasive waterjet model for machining brittle materials. C. Ma, R.T. Deam [2] in 2006 reviewed that kerf geometry

have been measured by the use of an optical microscope. With these measurements, an empirical correlation for kerf profile shape under various traverse speed have been developed that fits the kerf shape well. H. Liu,J.Wang, N. Kelson, R.J. Brown Darker [3] in 2004 in their exploration Computational fluid elements (CFD) models for ultrahigh speed water jets and Abrasive waterjets (AWJs) are built up by the utilization of Fluent6 stream solver. Hashish [4] utilized disintegration model of Finnie to build up a model to foresee joined profundity of slice because of cutting and miss hapening wear for pliable materials just Hashish utilized this model to foresee profundity of slice because of cutting wear, while the forecast of profundity of slice because of disfigurement wear depended on Bitter's model. Yet, this model disregarded the variety in kerf width along the profundity of cut. Utilizing the equivalent altered disintegration model, Paul et al. [6] created logical model of summed up kerf shape for bendable materials considering variety in kerf width along its profundity. [7]A complex numerical model was likewise created by the Same writer for all out profundity of cut for paolycrystal-line weak materials representing the impacts of abrasive particle size and shape, yet overlooking variety of kerf width along the profundity of cut. Choi and Choi [8] built up a logical model for AWJM of fragile materials. Articulation created by them to anticipate volume of work material evacuated by a solitary abrasive Particle isn't as far as procedure parameters and besides includes consistent of proportionality.

2. EXPERIMENTAL WORK

2.1.Material

Aluminium 6061 alloy, an American element is a precipitation hardening aluminium alloy which is available in several forms such as tube, ingot, ribbon, wire, foil, bar, pipe and rod. It is one of the cheapest American element alloy. The important factor in selecting Aluminum 6061 alloy is their high strength to weight ratio, appearance, and their non magnetic properties. Some of the applications of Aluminium 6061 alloy include Marine fittings, aerospace maintenance, transport, bicycle frames, brake components, valves couplings etc. It is also applied in paint removal, surgery, peening, drilling turning etc. It has good surface finish and can be anodized. Its density is 2.7 g/cm^3 and its Modulus of Elasticity E = 80 GPa. The dimension chosen to cut the Aluminium 6061 alloy for this study is 150mm x 50mm x 50mm is depicted in figure 1.

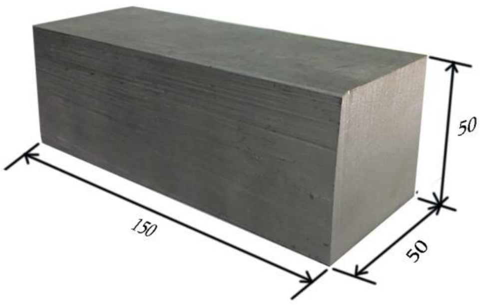

Figure 1 Aluminium 6061 alloy

2.2. RESPONSE SURFACE METHODOLOGY

RSM is a set of mathematical and statistical techniques which are useful for modeling and investigation of problems. In the present study five process parameters are chosen and varied in three levels as shown in Table 1.

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Table 1. Levels of parameters used in experiment

Levels	Water Pressure	Abrasive Flow Rate (m_f)	Orifice Diameter (d_o)	Focusing Nozzle	Stand Off Distance
Low	3400	0.4	0.3	0.9	1
Intermediate	3600	0.55	0.33	0.99	2
High	3800	0.7	0.35	1.05	3

Based on response surface methodology, Box-Behnken design 46 sets of experimental design was selected and was shown in Figure 2. The parameters and its levels were selected based on the review of certain journals that have been acknowledged on AWJC on materials like 6063-T6 aluminum alloy [9], Metallic coated sheet steels [10] Metal Matrix Composites [11] and Ceramics [12].

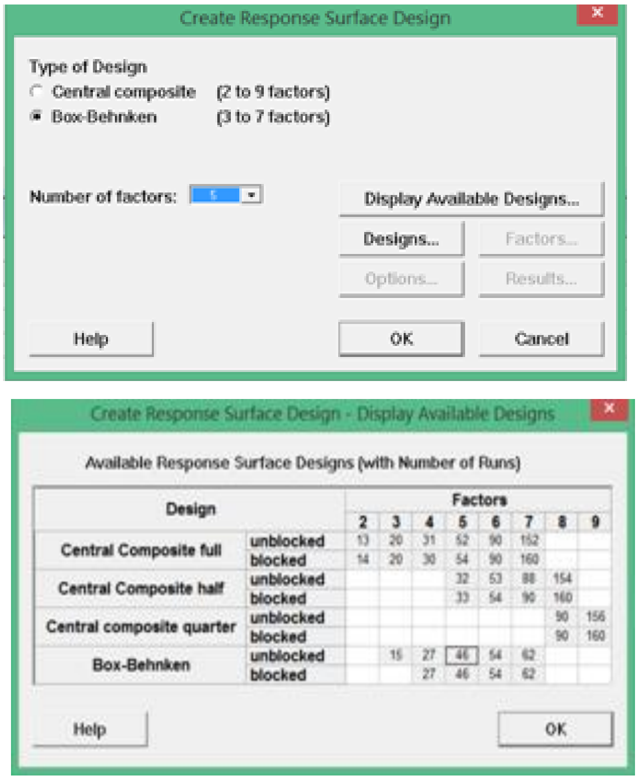


Figure 2 Selecion of Box-Behnken Design and No of Factors

3.DATA COLLECTION AND EXPERIMENTATION

The machine used to cut the American element Aluminium 6061 alloy was the AWJC machine is set with KMT ultrahigh pressure pump with the designed pressure of 4000bar, gravity feed type of abrasive hopper, an abrasive feeder system, a pneumatically controlled valve and a work piece table. The controller fixed in the control stand is used to adjust the SOD for different experiments. The abrasive water jet machine is programmed using numerical control code is to change the transverse speed and manage the supplement of abrasives. After the water is pumped at very high pressures resulting in high velocity of water jet of 1000 m/s as it comes out of focusing nozzle cuts the materials of the desired size and shape. The KMT abrasive water jet cutting machine with its mixing chamber is shown in figure 3.

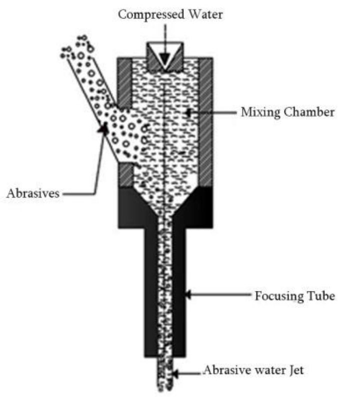


Figure 3 Experimental Setup of AWJM with Mixing Chamber

Table 2 Scheduling Matrix of the Experiments with the Optimal Model Data

Sl. No	Pressure (Bar)	Abrasive Flow Rate (Kg/min)	Orifice Diameter (mm)	Focusing Tube Diameter (mm)	Stand Off Distance (mm)	MRR mm^3/min	SR (μm)
1	3400	0.55	0.33	0.99	3	48.611	3.57
2	3600	0.55	0.33	0.9	1	53.639	2.08
3	3600	0.55	0.3	1.05	2	51.851	2.21
4	3600	0.55	0.33	0.9	3	50.835	2.55
5	3800	0.55	0.33	0.9	2	62.222	1.90
6	3600	0.55	0.33	0.99	2	51.851	2.19
7	3400	0.4	0.33	0.99	2	45.751	3.20
8	3600	0.7	0.35	0.99	2	53.639	1.80
9	3800	0.55	0.33	0.99	3	61.242	2.07
10	3800	0.55	0.3	0.99	2	62.222	2.05
11	3600	0.55	0.33	0.99	3	51.169	2.54
12	3400	0.55	0.33	1.05	2	47.716	3.08
13	3600	0.4	0.33	0.99	1	50.179	1.99
14	3600	0.55	0.33	0.99	2	52.910	2.17
15	3600	0.55	0.35	0.9	2	54.390	2.08
16	3600	0.55	0.3	0.9	2	51.851	2.79
17	3400	0.55	0.33	0.9	2	48.611	3.30
18	3600	0.55	0.33	0.99	2	52.910	2.19
19	3600	0.4	0.3	0.99	2	47.716	2.36
20	3400	0.55	0.35	0.99	2	48.309	2.95
21	3800	0.4	0.33	0.99	2	58.478	1.89
22	3600	0.7	0.33	0.99	3	54.773	2.25
23	3600	0.7	0.33	0.99	1	56.360	1.68
24	3600	0.4	0.35	0.99	2	49.226	2.29
25	3600	0.4	0.33	0.9	2	48.916	2.36
26	3600	0.55	0.35	0.99	3	51.169	2.50
27	3600	0.7	0.33	0.9	2	55.955	2.14
28	3400	0.55	0.33	0.99	1	49.226	2.65
29	3600	0.7	0.3	0.99	2	56.772	2.18
30	3600	0.55	0.33	1.05	1	50.835	1.90
31	3600	0.55	0.3	0.99	1	51.851	1.99
32	3800	0.7	0.33	0.99	2	64.814	1.70
33	3600	0.4	0.33	1.05	2	48.611	2.40
34	3600	0.55	0.3	0.99	3	52.199	2.68
35	3600	0.55	0.33	0.99	2	52.910	2.20

36	3800	0.55	0.33	1.05	2	59.829	1.99
37	3400	0.7	0.33	0.99	2	51.851	2.80
38	3600	0.55	0.35	1.05	2	51.169	2.34
39	3400	0.55	0.3	0.99	2	48.916	3.23
40	3600	0.4	0.33	0.99	3	48.309	2.69
41	3600	0.55	0.33	0.99	2	53.272	2.18
42	3600	0.55	0.35	0.99	1	52.552	1.80
43	3800	0.55	0.35	0.99	2	59.372	1.82
44	3600	0.7	0.33	1.05	2	56.772	2.03
45	3600	0.55	0.33	1.05	3	51.169	2.73
46	3800	0.55	0.33	0.99	1	61.242	1.72

For performing the experiments we have to design the combination of input parameters for each experiment and how many experiments has to be done. For this purpose using minitab software according to the Box-Behnken design of Response surface methodology design of experiments, with five input parameters, 46 experimental design is selected and performed experimentally and machining time is observed for all experiments as shown in Table 2. The MRR is calculated by the formula;

$$MRR = (m_f - m_i) / t$$

Where, m_f = mass of the material after machining, m_i = mass of the material before machining and t = Machining Time. The surface roughness for the machined Aluminium 6061 alloy is measured using Portable surface roughness tester in National College of Engineering, Tamilnadu, India.

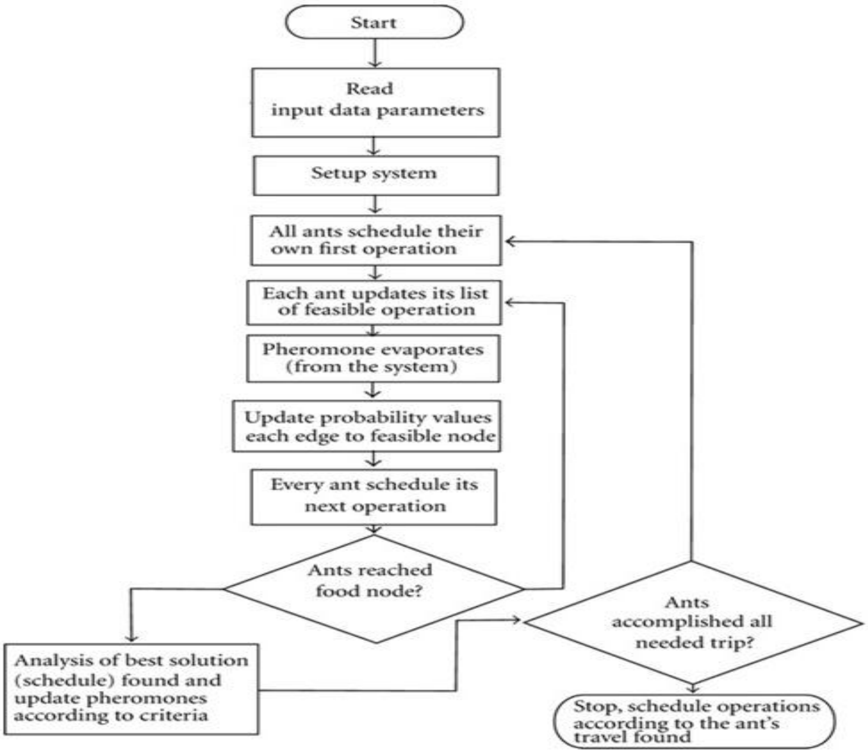
The mathematical model for the experimental data by cutting the Aluminium 6061 alloy using abrasive water jet machine for MRR and SR is developed using linear regression analysis through Minitab software. The developed regression equations are given below.

Material Removal Rate = 195.719 - 0.360226 A + 99.1877 B + 1516.21 C + 364.430 D - 6.05121 E + 6.23441E-05 A*A - 1.34839 B*B - 802.864 C*C - 82.6080 D*D - 0.410467 E*E + 0.00196733 A*B - 0.102446 A*C -0.0265738 A*D + 0.000769113 A*E - 300.422 B*C + 15.6465 B*D + 0.470717 B*E - 438.266 C*D - 18.4785 C*E + 10.3697 D*E

Surface Roughness = 179.473 - 0.0589755 A + 6.28678 B - 132.385 C - 94.7475 D + 1.76521 E + 7.04007E-06 A*A - 2.89173 B*B + 32.5335 C*C + 19.3324 D*D + 0.0255693 E*E + 0.00175000 A*B + 0.00161011 A*C + 0.00528029 A*D - 7.12500E-04 A*E - 19.9095 B*C – 3.55958 B*D -0.216667 B*E + 113.234 C*D - 0.0302120 C*E + 1.16942 D*E

4. OPTIMIZATION OF MRR AND SR BY ANT COLONY OPTIMIZATION

ACO is a population based meta-heuristic for the solution of difficult combinatorial optimization problems. In ACO, each individual of the population is an artificial agent that builds gradually and randomly a solution to the particular problem. Agents figure solutions by moving on a graph based representation of the issues. At each step their moves define which solution components are added to the solution under process. A probabilistic model is connected with the diagram and is utilized to inclination the operators' decisions. To expand the likelihood that expected operators will construct great arrangements the probabilistic model is refreshed online by the specialists. Swarm insight that takes motivation from the social practices of creepy crawlies and of different creatures is a moderately new way to deal with critical thinking. Specifically, the universally useful enhancement strategy known as ACO is the most considered and the best, among various strategies and procedures which ants have enlivened. It takes motivation from the conduct of looking through nourishment of some subterranean insect species. These ants store pheromone on the ground so as to stamp some ideal way that ought to be trailed by different individuals from the state. ACO misuses a comparative instrument for taking care of enhancement issues. From the mid-nineties, when the first ACO calculation was proposed, ACO pulled in the consideration of expanding quantities of scientists and numerous effective applications are currently accessible. In addition, a considerable corpus of hypothetical outcomes is getting to be accessible that gives helpful rules to analysts and professionals in further uses of ACO. In this Ant Colony Optimization process, the Mathematical Modeling equation is considered as objective functions for MRR and SR. The table 3 shows the comparison between the Predicted Values of MRR and SR with the actual values and their corresponding error values is also shown in the same table.



An ordinary subterranean insect calculation is made out of the accompanying advances

Step 1: Initializing the Parameters and Pheromone Trails.

Step 2: Constructing Initial Population of Ants.

Step 3: Improving Each Solution to Its Local Optimum.

Step 4: Updating Pheromone Trail Levels.

Step 5: Repeating Steps 2–4 until a Pre-Specified Termination Condition is Reached.

5. IMPLEMENTATION OF ACO

Initially read all the input value i.e., taken through the experimentation. The weight age value which is given initially is zero. Again the weightage value will be given based on the influencing level of the parameters. 100 iterations are developed for finding the optimal path. Each ant updates its list of feasible operation. Each particle are allowed to move in their own path. At that time itself evaluation process is also done for finding the optimal ants path. Each particle reaches the target value but based on the iteration level choose the best value. The comparison between predicted and experimental values of MRR and SR using ACO for Aluminium 6061 alloy is depicted in Fig. 5.26 and 5.27 and Table 5.9 shows the predicted values are found very closer to the experimental values. The bar charts shows the variation between the experimental and optimization values using ACO. Fig. 5.28 shows the marching steps for maximization of MRR and Fig. 5.29 shows the marching steps for minimization of SR. It shows that, ACO optimization technique gives the better output when compared to experimental values. So it is the best technique for optimizing AWJM parameters.

Table 3: ACO Output for Aluminium 6061 Alloy

Sl. No.	**Experimental MRR (mm^3/min)**	**ACO MRR (mm^3/min)**	**Error MRR**	**Experimental SR (µm)**	**ACO SR (µm)**	**Error SR**
1.	48.6111	47.9981	1.261029	3.57	3.629448	1.66521
2.	53.6399	53.89948	0.483931	2.08	2.052654	1.31471
3.	51.8519	52.02173	0.327529	2.21	2.21491	0.22217
4.	50.8352	51.61877	1.541393	2.55	2.556073	0.23816
5.	62.2222	61.12602	1.761718	1.9	1.912224	0.64337
6.	51.8519	52.39634	1.04999	2.19	2.139035	2.32717
7.	45.7516	46.42029	1.461566	3.2	3.207438	0.23244
8.	53.6399	54.47808	1.562605	1.8	1.846499	2.58328
9.	61.2423	60.85731	0.628634	2.07	2.075111	0.24691
10.	62.2222	61.24672	1.567736	2.05	2.092022	2.04985
11.	51.1696	52.9081	0.397525	2.54	2.523314	0.65693
12.	47.7164	46.89207	1.727561	3.08	2.965218	1.72669
13.	50.1792	49.68762	0.979649	1.99	2.007254	0.86704
14.	52.9101	52.03832	1.647663	2.17	2.143079	1.2406
15.	54.3901	52.84914	1.833163	2.08	2.036159	1.10774
16.	51.8519	53.37032	0.928379	2.79	2.794609	0.1652
17.	48.6111	50.48887	0.862842	3.3	3.306147	0.18627
18.	52.9101	52.03832	1.647663	2.19	2.143079	2.14251
19.	47.7164	47.18854	1.106244	2.36	2.362273	0.09631
20.	48.3092	48.47637	0.346042	2.95	3.000737	1.7199
21.	58.4785	57.75582	1.235805	1.89	1.874164	0.83788
22.	54.7731	55.4384	1.214647	2.25	2.274614	1.09396
23.	56.3607	56.11858	0.42959	1.68	1.697695	1.05327
24.	49.2264	49.85001	1.26682	2.29	2.225795	1.80371

25.	48.9168	48.24699	1.369284	2.36	2.342467	0.74292
26.	51.1696	52.4905	2.581416	2.5	2.462171	1.51316
27.	55.9552	55.30182	1.167684	2.14	2.126749	0.61921
28.	49.2264	49.485	0.525328	2.65	2.60138	1.83472
29.	56.7721	57.02717	0.449288	2.18	2.166991	0.59674
30.	50.8352	50.74913	0.169312	1.9	1.940351	2.12374
31.	51.8519	53.30268	2.79793	1.99	2.0196	1.48744
32.	64.8148	63.20658	1.481254	1.7	1.635423	2.79865
33.	48.6111	49.67144	2.181271	2.4	2.410688	0.44533
34.	52.1999	51.48421	1.371056	2.68	2.642767	1.38929
35.	52.9101	52.44663	0.875958	2.2	2.156667	1.96968
36.	59.8291	59.07648	1.25795	1.99	1.933054	2.86161
37.	51.8519	49.10504	3.297511	2.8	2.818416	0.65771
38.	51.1696	51.55253	0.748354	2.34	2.387491	2.02953
39.	48.9168	48.00835	1.857133	3.23	3.248848	0.58353
40.	48.3092	49.57698	2.624303	2.69	2.690763	0.02836
41.	53.2725	52.75546	0.970557	2.18	2.155011	1.14628
42.	52.5526	51.61327	1.787409	1.8	1.806023	0.33461
43.	59.3724	57.67025	2.866904	1.82	1.806223	0.75698
44.	56.7721	57.28646	0.906008	2.03	2.029598	0.0198
45.	51.1696	52.10677	1.831498	2.73	2.737519	0.27542
46.	61.2423	61.79289	0.899035	1.72	1.726355	0.36948

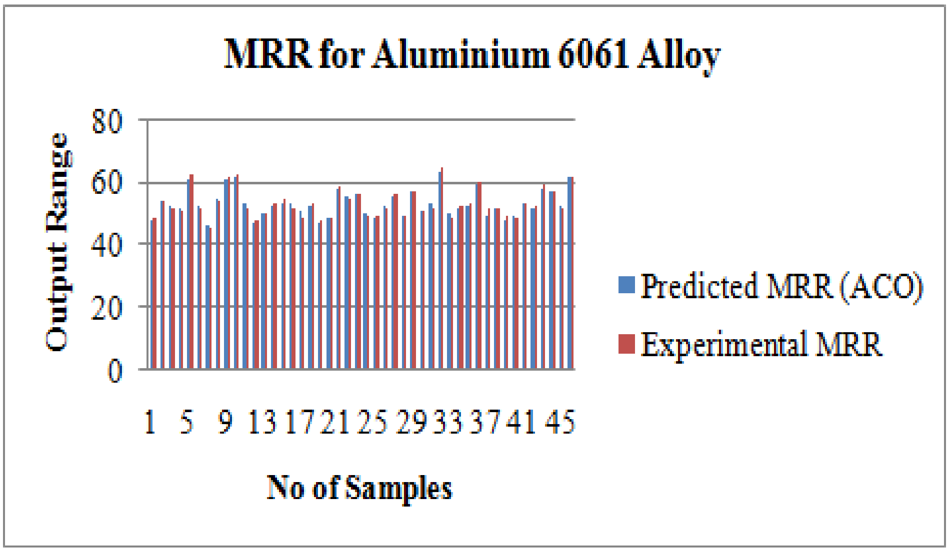


Fig. 4: MRR Comparision between Experimental and ACOValues for Aluminium 6061 Alloy

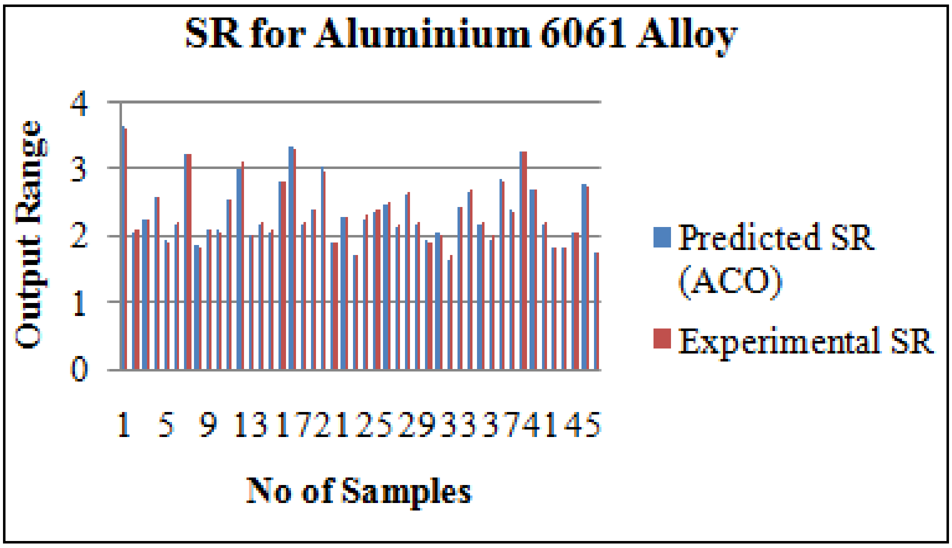


Fig. 5: SR Comparision between Experimental and ACOValues for Aluminium 6061 Alloy

Table 4. Comparison of RSM and ACO Least Mean Square Error for MRR and SR

S. No.	Error MRR using RSM	Error MRR using ACO	Least Mean Square Error MRR using	Least Mean Square Error MRR using	Error SR using RSM	Error SR using ACO	Least Mean Square Error SR using RSM	Least Mean Square Error SR using ACO
1	0.1408	1.261029			0.2212	1.66521		
2	0.2238	0.483931			1.6436	1.31471		
3	1.4558	0.327529			1.3945	0.22217		
4	0.2555	1.541393			0.1816	0.23816		
5	0.6981	1.761718			1.2036	0.64337		
6	0.4197	1.04999			0.6072	2.32717		
7	2.5640	1.461566	**0.12714**	**0.126567**	0.8620	0.23244	**0.178674**	**0.148385**
8	0.5063	1.562605			1.9564	2.58328		
9	0.2935	0.628634			0.1639	0.24691		
10	0.1206	1.567736			1.3936	2.04985		
11	1.5439	0.397525			1.2712	0.65693		
12	1.5214	1.727561			1.0154	1.72669		
13	0.7272	0.979649			0.4000	0.86704		
14	0.1460	1.647663			1.7969	1.2406		

15	0.0703	1.833163			2.0043	1.10774		
16	0.5543	0.928379			2.5200	0.1652		
17	0.0852	0.862842			0.3448	0.18627		
18	0.1370	1.647663			2.1219	2.14251		
19	1.9075	1.106244			0.1430	0.09631		
20	0.8991	0.346042			1.0961	1.7199		
21	1.6190	1.235805			0.3656	0.83788		
22	0.0915	1.214647			0.9955	1.09396		
23	0.1398	0.42959			0.6616	1.05327		
24	1.0022	1.26682			0.3950	1.80371		
25	1.1660	1.369284			1.3097	0.74292		
26	0.62	2.581416			0.3586	1.51316		
27	0.2609	1.167684			0.8818	0.61921		
28	0.9057	0.525328			0.12	1.83472		
29	0.8216	0.449288			0.6940	0.59674		
30	0.0345	0.169312			2.3964	2.12374		
31	0.1900	2.79793			0.0238	1.48744		
32	0.0646	1.481254			0.5658	2.79865		
33	1.3903	2.181271			0.4587	0.44533		
34	0.0673	1.371056			0.8340	1.38929		
35	0.4284	0.875958			0.1396	1.96968		
36	0.2758	1.25795			1.8687	2.86161		
37	0.5606	3.297511			1.0053	0.65771		
38	0.7906	0.748354			0.9944	2.02953		
39	0.3611	1.857133			1.2478	0.58353		
40	0.5167	2.624303			0.7667	0.02836		
41	0.7113	0.970557			2.4859	1.14628		
42	0.9396	1.787409			2.1756	0.33461		
43	0.9916	2.866904			0.2032	0.75698		
44	0.0727	0.906008			0.6171	0.0198		
45	0.7709	1.831498			0.0011	0.27542		
46	0.9002	0.899035			1.1921	0.36948		

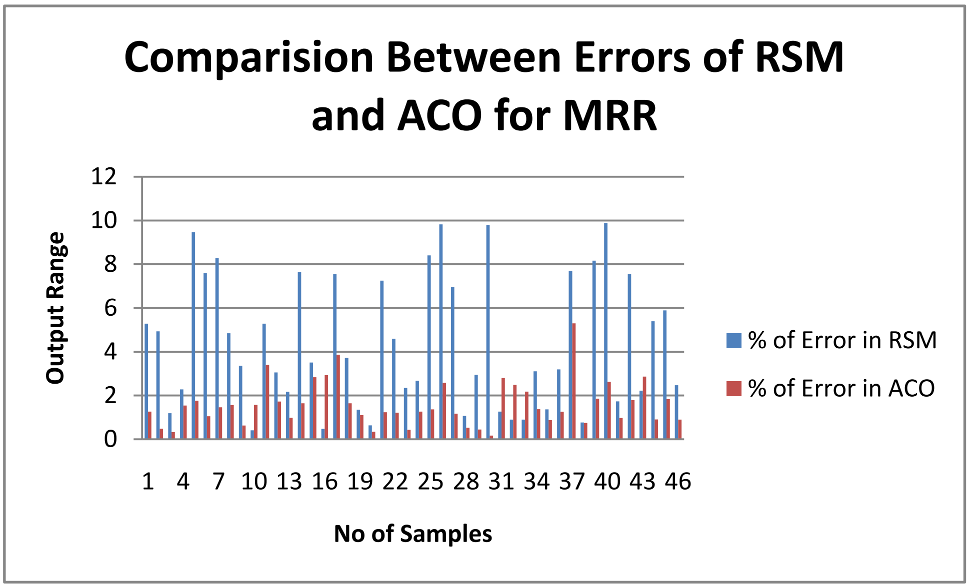


Figure 6: Bar Chart on RSM and ACO Error Values for MRR

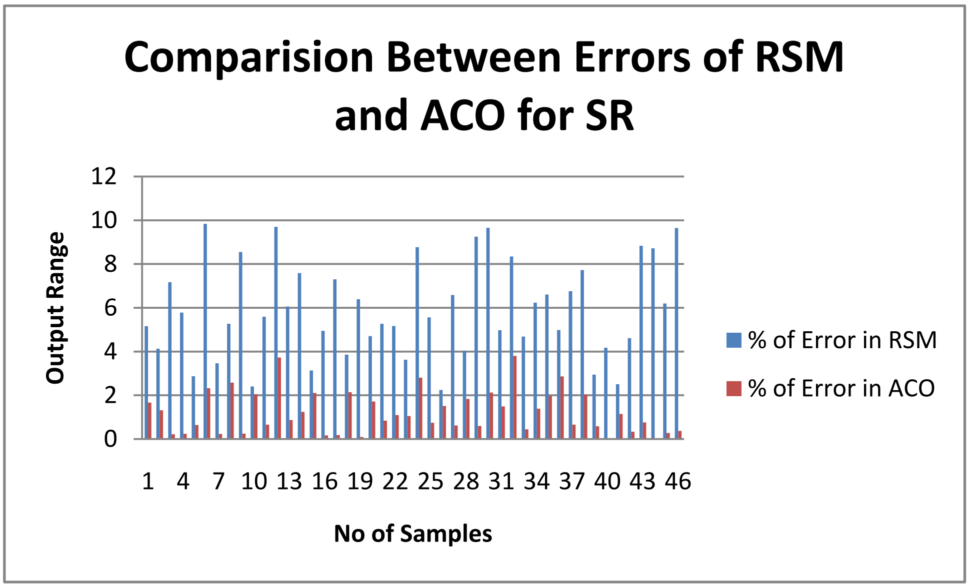


Figure 7 Bar Chart on RSM and ACO Error Values for SR

Figure 8 and 9 demonstrates the walking ventures for most extreme material evacuation rate and least surface unpleasantness and found that the upgraded estimation of MRR and SR utilizing Single Objective Ant Colony Optimization is appeared in table 5.

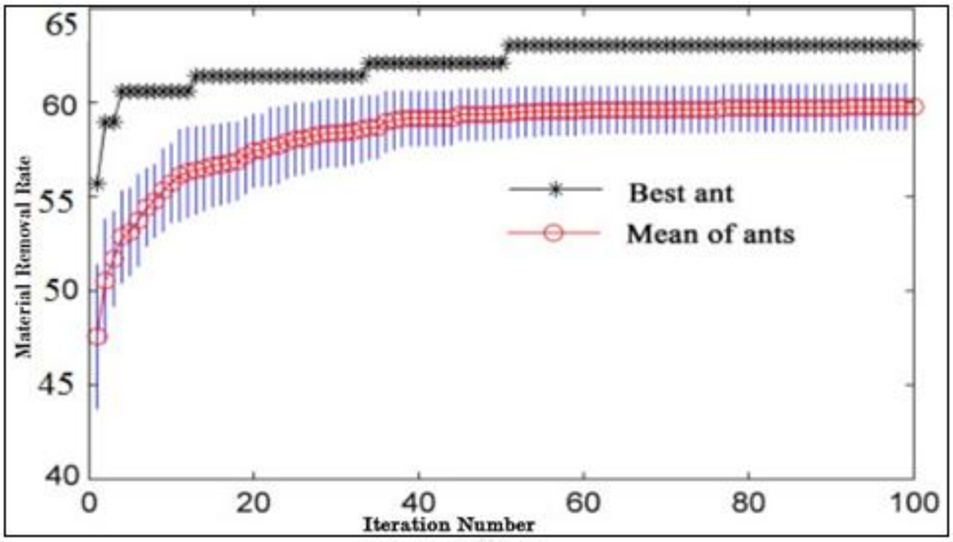


Fig. 8: Marching Steps for Maximization of MRR

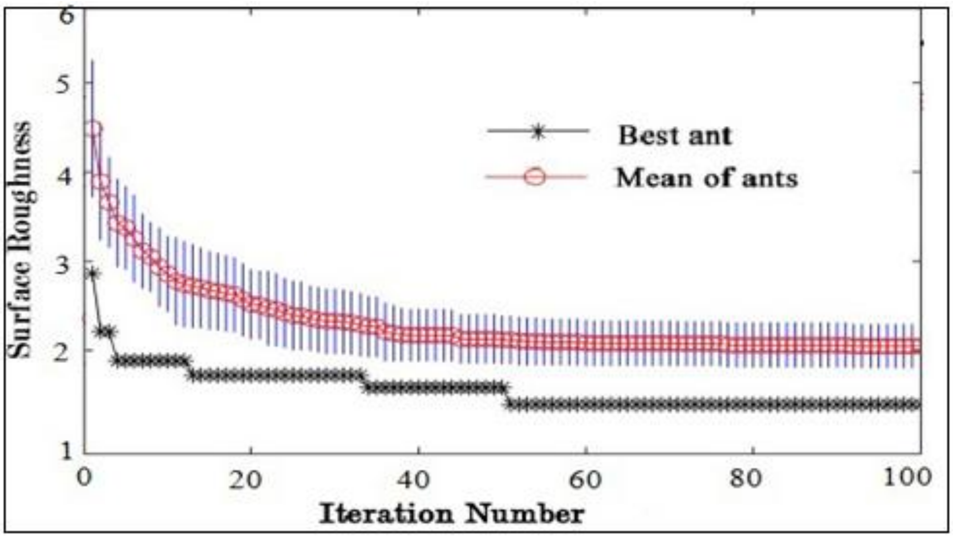


Fig. 9: Marching Steps for Minimization of SR

6. EXPERIMENTAL VALIDATION

The enhanced parameters acquired for the most extreme MRR and least SR as the age advances the arrangements are moving toward ideal. An approval of trial is directed utilizing the ideal procedure parameters. It is seen that MRR got from approval analyses is nearer to the streamlined MRR and SR got utilizing ACO intelligent tool. It infers the practical applicability of the use of ACO for optimizing the AWJM process parameters to obtain maximum MRR and minimum SR. The below Table 5 shows the experimental values and optimized values through ACO of MRR and SR for Aluminium 6061.

Table 5 Optimized Value of MRR and SR using Ant Colony Optimization

S.N.	**Pressure Bar**	**Abrasive Flow Rate Kg/min**	**Orifice Diameter mm**	**Focusing Nozzle Diameter mm**	**Stand Off Distance mm**	**Material Removal Rate mm^3/min**		**Surface Roughness µm**	
						Ex	**ACO**	**Ex**	**ACO**
1.	3755	0.66	0.32	0.94	2	58.23	58.77	---	
2.	3757.15	0.7	0.35	0.94657	1	---		1.53	1.5

7. CONCLUSION

In this paper, using linear regression analysis a mathematical model is developed for Aluminium 6061 Alloy through Abrasive water jet machining process by Minitab software is done. At that point the forecast of material expulsion rate and surface unpleasantness for Aluminium 6061 Alloy by cutting through Abrasive water jet machining process by the tool named ACO is done which illustrates that the experimental values are closer to the predicted values. The error comparison between RSM and ACO is also studied which shows the least MSE is very less in ACO while compared with RSM. Additionally the Prediction and Optimization of Material Removal Rate and Surface unpleasantness on Aluminum 6061 alloy utilizing Single Objective Ant Colony Optimization is introduced in this paper and found that the optimized value of MRR and SR is 58.23 mm^3/min and 1.5 µm.

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