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Multi-objective Optimization on Abrasive Water Jet Machining of AA6082 using Teaching Learning Based Optimization

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Abstract:

An evolutionary algorithm provides an efficient and systematic method of generating and equating the machining parameters in order to attain optimal machining. An optimal solution is to reduce the numerous objectionable values and to exploit the most substantial enviable effect. Many practical assessment problems include numerous and contradictory objectives, which required to be optimized concurrently while regarding several complex constrictions. Aluminium alloys are widely used in various automotive sectors due to their superior properties and high strength. In this study, AA6082 aluminium alloy was investigated its machinability using the abrasive water jet cutting process. Teaching Learning Based Optimization (TLBO) was used to optimize the experimental parameters by varying the parameter influences such as abrasive feed, stand-off distance and transverse speed. The effect of depth of cut, hardness and surface roughness was investigated by forming a multi-objective optimization by Assignment of Weights method.

Keywords:*AA 6082, Abrasive Water Jet Cutting, Assignment of Weights, Depth of cut, Hardness, Surface Roughness, Teaching Learning Based Optimization.*

I. INTRODUCTION

At the present time, innovative machining methods are extensively used for elucidating numerous issues in manufacturing processes that include machining great strength materials, improved surface structures, adept of high levels of accuracy, a decrease of surplus and lesser production time. Amongst the several advanced machining techniques, abrasive water jet machining (AWJM) has established more attention from researchers (Yuvaraj et al, 2020). The surface finish shaped by conventional machining is normally uniform. Hence, the surface finish of the machined surface can simply be characterized by measuring the surface roughness of any point of the machined surface (Saravanan, S et al, 2019).

Ravi Kumar et al (2018) has investigated the effect of AWJM parameters on aluminium composites was tested out at various standoff distance, tungsten carbide and transverse distance. Multi Response Optimization based on desirability was used to estimate the set of input parameters by maximizing the material removal rate and minimizing the surface roughness. Shukla and Singh (2017) have made an experimental investigation on abrasive water jet machining on the material aluminium alloy using the Taguchi methodology and evolutionary optimization techniques. Machining variables such as mass flow rate, transverse speed and standoff distance was considered for optimization. Yusup et al (2014) have used artificial bee colony to enhance machining constraints such as standoff distance water pressure and traverse feed rate for surface roughness and formed the effects with regression calculation, artificial neural network and genetic algorithm.

Gnanavelbabu et al (2018) have investigated the effect of process features like, mesh size, water pressure, traverse speed and abrasive flow rate of abrasive water jet machining on hybrid aluminium alloy composites for the predisposed the output of surface roughness. Barletta et al (2007) have investigated tube internal surface finish on an aluminium alloy AA6082 through a fluidized bed assisted abrasive jet machining. Taguchi's experimentation was used to examine the effect of abrasive jet speed, abrasive mesh size and machining cycle on surface roughness and material removal rate. Joel and Jeypoovan (2019) have investigated the abrasive water jet machining with AA6082 on surface roughness.

In this study, AA6082 aluminium alloy was examined on the abrasive water jet cutting process. Teaching Learning Based Optimization was implemented to optimize the experimental parameters by varying the process influencing factors such as abrasive feed, stand-off distance and transverse speed. The effect of depth of cut, hardness and surface roughness was investigated by forming a multi-objective optimization by Assignment of Weights method.

II. MACHINING OF AA6082

Aluminium alloy 6082 is strong anti-corrosion material with the good yield strength of the 6xxx series Aluminum alloys and it is also called as a structural alloy because of its applications. The mechanical properties of AA6082 Aluminum Alloy are Young's modulus of 71 GPa, Yield strength of 280 MPa and Ultimate tensile strength of 250MPa. Because of its high strength, AA6082 is extensively used in the building of the high-stress presentation of trusses, cranes, bridges and predominantly used in the automobile sector.

The Model S3015 Abrasive Water Jet cutting machine with gravity feed abrasive hopper (Fig 1) was offered with 3000 mm x 1500 mm on x and y movements are operated by pneumatically. It transverse speed varies from 10 mm/min to 45 mm/min with the water pressure of 320MPa. In this examination, AA6082 was taken as a block of size 500 mm x 50 mm x 50 mm for considered for conducting the research in Abrasive Water Jet cutting machine.

Fig. 1. Abrasive water jet cutting machine

A three machining parameters of traverse speed, abrasive feed and standoff distance, three design level matrix was prudently selected and tabulated in Table 1.

Table 1. Machining Parameters and Levels

S.No.	**Process parameters**	**Unit**	**Notation**	**Levels**		
				-1	**0**	**1**
1	Abrasive feed	g/min	A	250	300	350
2	Stand-off distance	mm	B	2	3	4
3	Nozzle transverse speed	mm/min	C	24	36	44

Figure 2.Machined Work samples

The L9 orthogonal array was created through the design of experiments and experimental results were tabulated in table 2. Figure 2 shows the investigational trials of 9 samples measuring 50mm x 50mm x 10mm.

Table 2. AA6082 Experimental Results

Exp No	**Abrasive feed (g/min)**	**Stand-off distance (mm)**	**Nozzle transverse speed (mm/min)**	**Hardness (BHN)**	**Surface Roughness (Ra)**	**Depth of Cut (mm)**
1	250	2	28	90.33	4.25	5.352
2	250	3	36	93.15	4.31	4.400
3	250	4	44	98.92	4.97	3.762
4	300	2	36	91.45	4.26	5.280
5	300	3	44	96.14	4.78	4.515
6	300	4	28	93.25	4.26	6.423
7	350	2	44	92.25	4.69	5.267
8	350	3	28	89.26	4.74	7.493
9	350	4	36	94.36	4.53	6.159

III. TEACHER-LEARNING-BASED OPTIMIZATION

The teacher-learning-based algorithm is a type of metaheuristic algorithm inspired by a teaching and learning process. The TLBO was presented by Rao et al (2011) to solve controlled mechanical application problems. It was stimulated by passing on the information inside a classroom atmosphere where students first achieve information from a teacher and by shared interaction among their self (Crepinsek et al, 2012). TLBO algorithm is a population-based metaheuristic algorithm in which the class students are reflected as population. The subjects thought on the class are considered as design parameters for the optimization problem and student's outcome was preserved as the suitability value of a solution for the optimization problem.

This algorithm consists of two phases namely, Teacher phase and Learner phase [Rao et al]. In Teacher phase, the knowledge of the students enhanced by the teacher. In this teacher phase, the best output acts as a teacher. Other outputs were enhanced by moving their locations near to the location of the teacher by considering the mean value of the parameters. The knowledge of the students with their mutual interface conducted in the student phase.

The pseudo-code of the TLBO as follows:

```
Representation of process parameters.
Initialization of process parameters within its limits from the levels.
Evaluation of machine outputs i.edepth of cut, hardness and surface roughness.
Selection of Best Teacher and calculation of the mean value of parameters.
Teacher’s phase.
Learners phase.
Replacement stage.
Repeat the iteration till the stopping criteria.
```

In this, two students are randomly selected and response is compared and the students would move towards better solutions. Leading benefit of TLBO algorithm over further metaheuristic algorithm is to use only governing parameters rather than algorithm-based parameters (Waghmare, 2013).Regression equations for the output responsewere created based on experimental values in Table 2through the MatLab as follows,

$$\text{Hardness}=96.6473-0.0544*A+0.6926*B-0.1342*C-.0000*A*B+0.0010*A*C+0.0445*B*C;$$

$$\text{Surface Hardness}=2.7722+0.0171*A+0.2083*B-0.1173*C0.0048*A*B+0.0001*A*C+0.0373*B*C;$$

$$\text{Depth of cut}=0.8198+0.0344*A+0.6096*B-0.1149*C-0.0048*A*B-0.0002*A*C+0.0113*B*C;$$

Many practical assessment problems include numerous and contradictory objectives, which required to be optimized concurrently while regarding several complex constrictions. In practical conditions, solving a specified problem typically demands the efficient and simultaneous study of more than single objective function transfer to multi-objective optimization [Huang et al, 2006]. The determination of multi-objective optimization techniques used to invent the greatest compromise result. Resulting in theimperativepartsoftheresult maker and favouriteevidence [Eskelinen and K. Miettinen, 2012].

Venkata Rao et al (2019) made a multi-objective optimization of abrasive water jet machining process using Jaya algorithm and PROMETHEE Method. DurgaPrasada Rao et al (2019) have investigated the three outputs, surface roughness, material removal rate and kerb equations using a multi-objective optimization algorithm called elitist non-dominated sorting genetic algorithm on carbon fibre-reinforced polymer machining. AbhishekTiwari et al (2015)usedenhanced through the non-dominated sorting genetic algorithm for maximizing the metal removal rate and minimizing the surface roughness.

In this study, Assignment of Weight method was used to make the multi-objective optimization ofmaximizing depth of cut, hardness and minimizing the surface roughness on abrasive water jet machining. AA6082 aluminium alloy was examined on the multi-objective optimization with Teaching Learning Based Optimization. The influencing factors such as abrasive feed, stand-off distance and transverse speed were analyzed for the response of depth of cut, hardness and surface roughness[23-25].

Combined Objective Function (COF) =f (max(hardness), max(depth of cut), min(surface roughness))

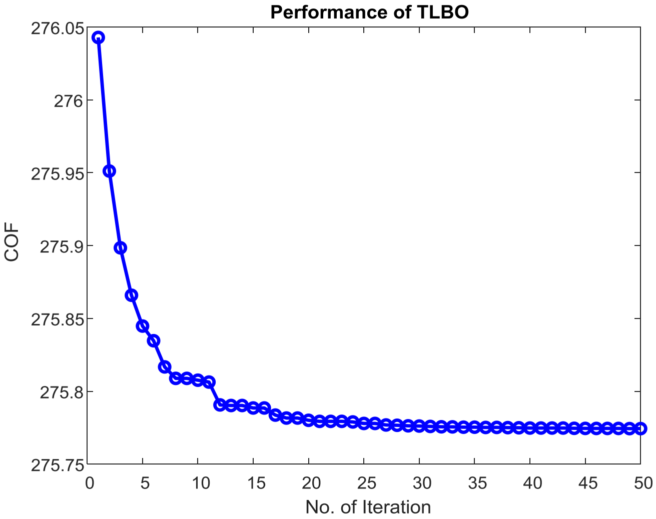

Fig. 3.Combined Objective Function results of AA6082

On the execution of TLBO, 20 students were taken as samples and 50 iterations were conducted to optimize the maximizing depth of cut, hardness and minimizing the surface roughness. The parameters are abrasive feed, standoff distance and traverse speed were analyzed.The results show, maximizing depth of cut at 6.1632 mm, maximum hardness at 87.5489 BHN and minimizing the surface roughness at 5.5968. The results were obtained under the machining conditions of 350g/min abrasive feed rate, 2 mm of stand-off distance and 28 mm/min as a nozzle transverse speed.

IV. CONCLUSION

In this study, multi-objective optimization Teaching Learning Based Optimization with Assignment of Weight method was used to make the multi-objective optimization of maximizing depth of cut, hardness and minimizing the surface roughness on abrasive water jet machining.AA6082 aluminium alloy was examined on the multi-objective optimization with influencing factors such as abrasive feed, stand-off distance and transverse speed were analyzed for the response of depth of cut, hardness and surface roughness. The results were obtained under the machining conditions of 350g/min abrasive feed rate, 2 mm of stand-off distance and 28 mm/min as a nozzle transverse speed.

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