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Parametric Optimization of Magnetic Abrasive Water Jet Machining Of AISI 52100 SteelUsing Grey Relational Analysis

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Abstract

Abrasive machining is one of the most non-conventional processes for finishing. It is widely used in industry to machine the materials like mild steel, aluminum, copper, titanium, glass, hard rock material, graphite, composite material, ceramics etc.Like in abrasive jet machining. This technique uses jet which contains abrasive material. Now a day water-magnetic abrasive machining is one of the new alternative concepts that the magnetic field (line of magnetic force) is used to precisely machine the surface of the work-piece. When it is a magnetic work-piece and the work-piece is magnetized and then become a new magnetic pole. On the country when it is non-magnetic it cannot be magnetized. In this research the precise processing phenomenon and the condition on abrasive machining of material by a high velocity of water and magnetic abrasive and other abrasive material whose hardness and grain size similar to magnetic abrasive are examined. And the final experiment result shows the comparison between effectiveness of the mixing of water and abrasive on the surface finish of the AISI 52100 steel materials.

Keywords: Optimization, Grey relational analysis, surface roughness, material removal rate.

I. Introduction

Dr. Norman Franz is regarded as the father of the water jet. He was the first person who studied the use of ultrahigh-pressure (UHP) water as a cutting tool. The term UHP is defined as more than 30,000 pounds per square inch (psi). Dr. Franz, a forestry engineer, wanted to find new ways to slice thick trees into lumber. In the 1950's, Franz first dropped heavy weights onto columns of water, forcing that water through a tiny orifice. He obtained short bursts of very high pressures (often many times higher than are currently in use), and was able to cut wood and other materials. His later studies involved more continuous streams of water, but he found it difficult to obtain high pressures continually. Also, component life was measured in minutes, not weeks or months as it is today. Dr. Franz never made a production lumber cutter. Ironically, today wood cutting is a very minor application for UHP technology. But Franz proved that a focused beam of water at very high velocity had enormous cutting power—a power that could be utilized in applications beyond Dr. Franz's wildest dreams.During the past few years, unprecedented progress has been made in the water jet machining. Now the generations go ahead creativity done in water jet machine by using abrasive. Abrasive machining is one of the most non-conventional processes for finishing. It is widely used in industry to machine the materials like mild steel, aluminum, copper, titanium, glass, hard rock material, graphite, composite material, ceramics etc. Like in abrasive jet machining. This technique uses jet which contains abrasive material. Now a day water magnetic abrasive machining is one of the new alternative concepts that the magnetic field (line of magnetic force) is used to precisely machine the surface of the work-piece. When it is a magnetic work-piece and the work-piece is magnetized and then become a new magnetic pole. On the country when it is non-magnetic it cannot be magnetized. In this research the precise processing phenomenon and the condition on abrasive machining of material by a high velocity of water and magnetic abrasive and other abrasive material whose hardness and grain size similar to magnetic abrasive are examined. And the final experiment result shows the comparison between effectiveness of the mixing of water and abrasive on the surface finish of the stainless steel material. Here also using aluminum oxide abrasive, comparing both final results of magnetic abrasiveand aluminum oxide abrasive for finishing on the work piece.

II. Experimental details

2.1 Work piece material

Here work piece AISI 52100 steel is having hardness of 61hrc for the experiment, known also as ball bearing steel, hardness range 61hrc to 66hrc.The Length of work piece was 500 mm and thickness of plate 30 mm.AISI 52100 steel is a high-carbon chromium alloy steel, which is used in a variety of mechanical applications. Mechanical properties of this material is elastic modulus 190-210Gpa, density 0.283 lbs/in, tensile strength 325,000psi, yield strength 295,000psi.

2.2 Abrasives

Aluminum oxide consists of blunt shaped grains and is very tough in its lowest refined form. It is produced in variety of refinements and by its versatility can be used to very hard to soft application, making it the very commonly used abrasive. Magneticabrasive consists of high hardness and very tough.

2.3 Nozzle

Cutting head consists of orifice, mixing chamber and focusing tube or insert where water jet is formed and mixed with abrasive particles to form abrasive water jet. Water carried through the pipes is brought to the jet former or cutting head. The standoff distance between the mixing tube and the target material is typically 0.010 to 0.200 inch. Larger standoff (greater than 0.080 inch) can cause a frosting to appear atop the cut edge of the part. Many Water jet systems reduce or eliminate this frosting by cutting under water or using other techniques.

2.4Measurement of surface roughness and material removal rate

The surface roughness of the samples was measured with Mitutoyo make Surface roughness tester (SJ-110) and the material removal rate measured by the theoretical calculation.

2.5Design of experiment

In this study, four controllable variables, namely, abrasive grain size, water pressure, tip distance, pole distance has been selected. In the machining parameter design, three levels of the cutting parameters were selected, shown in Table 1.

Table1.Factors with levels value

Factors	Level 1	Level 2	Level 3
Abrasive grain size(μn)	80	100	120
Pressure(Mpa)	225	235	245
Tip distance(mm)	11	14	18
Pole distance(mm)	10	15	20

As per table 1, L9 orthogonal array of "Taguchi method" has been selected for the experiments in MINITAB 15. Each 9 experiments will carried out with abrasives. Surface roughness and material removal rate has been selected as response variables. All these data are used for the analysis and evaluation of the optimal parameters combination. Experiment result as shown in Table2.

Table2. Experimental results.

Sr. no	Abrasive grain size (μn)	Pressure (Mpa)	Tip distance (mm)	Pole distance (mm)
1	80	225	11	10
2	100	235	14	10
3	120	245	18	10
4	80	235	18	15
5	100	245	11	15
6	120	225	14	15
7	80	245	14	20
8	100	225	18	20
9	120	235	11	20

III. Methodology

3.1 Grey relational analysis method

In the grey relational analysis, experimental results were first normalized and then the grey relational coefficient was calculated from the normalized experimental data to express the relationship between the desired and actual experimental data. Then, the grey relational grade was computed by averaging the grey relational coefficient corresponding to each process response. The overall evaluation of the multiple process responses is based on the grey relational grade. [4]

3.2 Data preprocessing

In grey relational generation, the normalized data corresponding to Lower-the-Better (LB) criterion can be expressed as:

$$Xi(k) = \frac{\max yi(k) - yi(k)}{\max yi(k) - \min yi(k)} \quad (1)$$

For Higher-the-Better (HB) criterion, the normalized data can be expressed as:

$$Xi(k) = \frac{yi(k) - \min yi\,(k)}{\max yi(k) - \min yi(k)} \quad (2)$$

Where xi (k) is the value after the grey relational generation, min yi (k) is the smallest value ofyi (k) for the kth response, and max yi (k) is the largest value of yi (k) for the k^{th} response.

An ideal sequence is x0(k) (k=1, 2) for two responses. The definition of the grey relational grade in the grey relational
analysis is to show the relational degree between the twenty-seven sequences (x0(k) and *xi*(k), i=1, 2, . . . , 27; k=1, 2). The grey relational coefficient ξi(k) can be calculated as:

$$\xi i(k) = \frac{min\Delta + \theta max\Delta}{\Delta i(k) + \theta max\Delta} \quad (3)$$

Where Δi = | X0 (k) – Xi (k) | = difference of the absolute value x0 (k) and xi (k); θ is the distinguishing coefficient 0 ≤ θ ≤ 1; minΔ = ∀j min ϵ i∀kmin= | X0 (k) – Xi (k) | = the smallest value of Δ0i; and maxΔ = ∀jmax ϵ i∀kmax = largest value of Δ0i. After averaging the grey relational coefficients, the grey relational grade γi can be computed as

$$yi = \frac{1}{n}\sum_{k=1}^{n} \xi i\ (k) \qquad (4)$$

Where n = number of process responses. The higher value of grey relational grade corresponds to intense relational degree between the reference sequence x0 (k) and the given sequence xi (k). The reference sequence x0 (k) represents the best process sequence. Therefore, higher grey relational grade means that the corresponding parameter combination is closer to the optimal. [5]

IV. Results and discussions

A level average analysis was adopted to interpret the results. This analysis is based on combining the data associated with each level for each factor. The difference in the average results for the highest and lowest average response is the measure of the effect of that factor. The greatest value of this difference is related to the largest effects of that particular factor. Data preprocessing of each performance characteristic and the experimental results for the grey relational according to formulas (1),(2),(3) and (4) are given in Table 3 and 4.

Table 3 Normalize value of SR, Fc and Ff for dry, wet and solid lubricant environment.

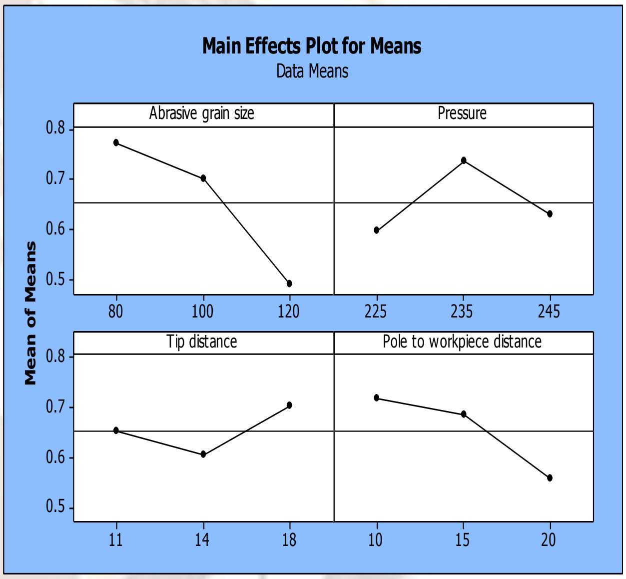
Experiment No	Normalize value of MRR	Normalize value of SR
1	0.58930875	1
2	1	0.661519
3	0.891671648	0
4	0.983953686	0.943372
5	0.657584243	0.889318
6	0	0.494208
7	0.723971935	0.612613
8	0.454330932	0.803089
9	0.219928893	0.603604

GRC of MRR	GRC of SR	GRG	Grade No.
0.5490	1	0.7745	3
1	0.5963	0.7981	2
0.8219	0.3333	0.5776	7
0.9689	0.8982	0.9335	1
0.5935	0.8187	0.7061	4
0.3333	0.4971	0.4152	9
0.6443	0.5634	0.6038	5
0.4781	0.7174	0.5978	6
0.3906	0.5577	0.4741	8

Table 4 Calculation of GRC and GRD

In grey relational analysis higher the grey relational grade of experiment says that the corresponding experimental combination is optimum condition for multi objective optimization and gives better product quality. Also form the basis of the grey relational grade, the factor effect can be estimated and the optimal level for each controllable factor can also be determined. From Table 4. It is found that experiment 4 has the best multiple performance characteristic among 9 experiments, because it has the highest grey relational grade of 0.9335

The main effects plot of grey relational grade vs. process parameter can generated by Minitab 15 statistical software to find out optimum parameter combination, is shown in graph 1.



Graph 1. Mean effect plot of grey relational grad Vs.abrasive grain size, water pressure, tip distance, pole to workpiece distance

From the graph 1. It is conclude that the optimum condition for surface roughness is meeting at abrasive grain size (A1), pressure (B2), tip distance (C3) and pole to work piece distance (D1).

I. Conclusion

It is concluded that the application of magnetic abrasive in water jet machining has proved to be a feasible alternative to aluminium oxide and other abrasives, if it can be applied properly. There is a considerable decrement in surface roughness and quality of product produced.

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