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Experimental Investigation of MRR during Grinding of Aisi H11 under Dry, Wet and Cryogenic Treatment Condition using Taguchi Technique

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Abstract: Grinding is defined as metal cutting operation by using multi point cutting tool. Material is removed in the form of micro-sized chips by shearing and ploughing with the help of abrasive grits in grinding wheel. In present paper investigation to optimize the effect of input parameters to maximize the MRR in surface grinding of AISI H11 hot work steel material under different working conditions (dry, wet and cryogenic treated) and process parameters (wheel speed, depth of cut and feed rate) using aluminium oxide grinding wheel. Minitab software is used to apply Taguchi L_{27} orthogonal array to set up the experimental design. It is concluded that the maximum material is removed using cryogenic treated grinding wheel at speed 2000 rpm, feed rate 15 mm/rev and depth of cut 0.20mm.

Keywords: Feed Rate, Wheel Conditioning, Depth of Cut, Surface grinding and Material Removal Rate.

1. INTRODUCTION

Now-a-days, there is a tremendous use of grinding process especially in mechanical field. It is mainly used for removal and surface generation to provide the finishing of any kind of materials like steel, aluminium alloys and the other elements. Machining is the process of surface removal from the work piece in the form of chips to attain high accuracy and surface finishing thus, increasing its performance and long-life. The removal of surface material can be done by using single point cutting tool, multi point cutting tool and by abrasive action. The operations during Single point cutting tool are turning, boring, shaping and planning etc while multi point cutting tool operations include milling, drilling, tapping, reaming, and hobbing, broaching and sawing operations. Abrasive operations are grinding, lapping, honing and super finishing operations. Surface Grinding produces flat and angular surfaces of the work piece in the horizontal plane. The work is attached to the table by magnetic forces and ground by either a transverse or rotating movement of the table. A horizontal spindle is used to adjust up and down allowing the edge or the face of the wheel to contact the work. An abrasive is a material which is used for polishing and grinding operations. It must in pure form and should contain uniform properties of toughness, hardness and resistance to fracture which is useful in manufacturing grinding wheels. Abrasive are based upon the following two groups namely as natural and artificial or manufactured. Size of grain or grit plays a vital role while considering the surface finish and material removal rate. For better finishes, we use small grain size whereas, for larger material removal rates we use larger grit sizes. Moreover, smaller grain sizes are used to cut harder material while larger grain sizes are used to cut softer material. The degree of strength with which the bond binds up the abrasive grains from being the torn from the wheel by an external force is known as grade of the abrasive grinding wheel. The degree of hardness and softness or the grade of a wheel, depending upon the type of bond, is determined by the amount of bond material of grinding wheel.

II. CRYOGENIC TREATMENT

The process of reducing temperature of a component to very low level below −190 °C (−310.0 °F) for a long time period is known as cryogenic treatment. The common fluid for cryogenics process is liquid nitrogen (LN2). The energy of motion is removed because cryogenic treatment removes the built in kinetic energy of atoms. The atom remains together due to normal attraction between them. In heat treatment of steel some amount of austenite is present after heat treatment process. The austenite present in steel is converted into martensite by cryogenic treatment process. Additional effects are the production of martensite and the precipitation of Eta type carbides. We now know that this rapid quenching produces a metastable phase in steel called martensite. This transformation process is rapid and diffusion less. The martensite reaction occurs as the FCC austenite converted to a BCT (body centered tetragonal) martensite .Carbon atoms are trapped in interstitial sites during the rapid transformation. Eta carbides were molecular in size, form

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a crystal structure intermeshed with the martensite. They can only be seen at the types of magnifications produced in electron microscopy by using x-ray diffraction. The addition of martensite will increase the hardness and increase wear resistance, but reduce the toughness. Eta-carbide is recognized to be strong and tough and the fine particles of cementite should increase wear resistance without sacrificing toughness. The residual stresses are removed in all metals like aluminium, copper etc by using cryogenic treatment process. Cryogenic treatment has wide application as it improves, tool life as well as transmission of musical signals. Cryogenic treatment has some benefits such as it improves thermal properties, electrical properties, component life, flatness and strength. It reduces coefficient of friction, electrical resistance and failure due to cracking. It has been found and proved wear resistance is improved or enhanced by cryogenic treatment process of many alloy steels to great extent cryogenic process has been widely adopted as a reduction of cost and performance enhancing technology. Cryogenic treatment is mainly use as enable technologies, when its stress relieving benefits are utilized to permit the fabrication (or machining) of critical tolerance parts. The process of cryogenic treatment widely used where the sub-zero cryogenic temperatures down to –300ºF to become a refine micro-structure the material. Cryogenic treatment process assists additional transformations in metals.

III. DEEP CRYOGENICS

The process used to improve desired structural and metallurgical properties of a material by ultra-low temperature processing. The ultra-cold temperatures (-320°F, -196°C, or 77°K) are attained to using computer controls, along with insulated treatment chamber and liquid nitrogen (LN_2). Nitrogen is the gas that contains 78.03% of the air. The liquid form is the product of air separation, compression and liquefaction. What this cut down to is that deep cryogenic systems.

IV. LITERATURE REVIEW

Over the last few decades, there has been great optimization in research on grinding due to its ever increasing application in manufacturing industry. Also the grinding process requires main attention to understand it because of its complexity. High performance grinding was essentially to attain high dimensionally accuracy and surface reliability of ground component at optimum cost efficiency. The main motives of this paper are to state of the fine art technology of high efficient of grinding at high wheel speeds with more efficient abrasives.

[1] Monici et. al. studied the method of cutting fluid to enhance the efficiency of process and explained that efficiency of aluminium oxide (Al_2O_3) grinding wheel is not better than CBN grinding wheel used along with neat oil.
[2] Guo et. al. have researched on both the parameters as well as wheel wear for the performance of grinding of plated CBN wheel on a nickel alloy to obtain particular model. Further, this model in comparison to aluminium oxide wheel based model for comparison of optimizes result.
[3] Atzeni et. al. have researched the speed of cutting and feed per grain and its effects on roughness of surface after grinding process. The resulting data have statistically processed to form a relationship among kinematics parameters and surface roughness. It also shows that the roughness is mainly affected by the feed per grain and a minimum degree of the cutting speed.
[4] Fathallah et. al. has studied the use of sol-gel grinding wheel for much better surface integrity of AISI D2 steel. It's cooling by liquid nitrogen in comparison to the conditions using aluminium oxide and cooling with oil-based.
[5] Ramdatti et. al. have used the Taguchi techniques to form an optimal setting of grinding process parameters resulting in an optimal value of rate of materials removal and roughness of surface when machining EN-8, EN-39 and cast iron.
[6] Lee et. al. has researched in process of grinding for roughness of surface, force of grinding and tool wear. It is found that the magnitude of force of grinding and tool wear decreases significantly at low air temperature, which could result in longer tool life.
[7] Mane et. al. has investigated for surface finishing enhancement of grinding process using compressed air. Also, it is found that air helps to increase the surface finishing of machined surface.
[8] Pawan Kumar et. al**.** has studied the abrasive grinding tool effect on EN24 steel surface by process of parameters such as depth of cut, grinding wheel speed and table speed. Depth of cut, grinding wheel speed and table speed were considered using methods of response surface for developing empirical model. To determine the machining parameter optimization by using response surface methodology to minimize the roughness of surface and maximize the rate of material removal in grinding surface process.
[9] Deepak Kumar et. al**.** has developed an experiment for hot work steel AISI H11 of its grinding using different environment and process parameters. It is concluded that using compressed gas, there is a major increase in rate of material removal by increase in depth of cut and decrease in rate of feed, using Al_2O_3 grinding wheel.
[10] Naresh kumar et. al. investigated the C40E steel by working on cylindrical grinding. For this experiment work, he used taguchi method to study the depth of cut, feed rate and speed of wheel, as input process parameters. It is

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concluded that speed of grinding wheel, feed rate has a significant effect on roughness of surface while depth of cut has the least effect on roughness of surface.

[11] Kumar et. al. to investigated the rate of material removal behaviour of AISI H11 hot work steel under working condition such as compressed gas, dry and wet and concerned parameters like feed rate, speed of wheel and depth of cut. The results concludes that silicon carbide (Sic) grinding wheel used as grinding cutting tool and MRR increased with increased in depth of cut and decreased in rate of feed by using compressed gas condition.

[12] Pranali P. Patil et al. have studied input of various concerned parameters likes depth of cut, speed of grinding wheel and rate of feed, cutting speed, material hardness, grain size conditions. It has also observed that Al2O3 and Sic mostly used wheel grinding and to optimize rate of material removal and surface finish during the grinding process. Taguchi method is used for optimizing the machine stiffness and specific grinding energy.

V. EXPERIMENTAL PROCEDURE

The set up of experiment was formed on standard high power Surface grinding machine manufactured by Kwality machinery Export Company. The same Aluminium oxide grinding wheel was while whole process. Their specifications were "AA46/54 K5 V8" and manufactured by Carborundum universal limited company. The wheel dimensions were 200 x 13.31 x 75mm. The material selected for workpiece was AISI H-11 steel. In the beginning of experiment work, The AISI H-11 hot work steel plate blank has been heated up to a temperature of 1025^0C for about 30 minutes soak time followed by quenching process in a 500^0C hot salt bath and then tempered in two cycles with maximum temperature of 450^0C and 2 hours of soak time to obtain a final hardness of 45 HRC. The AISI H-11 steel is mostly used for the manufacture of blades and machine dies. The following table-I shows the chemical composition of work piece material.

Table-I Chemical composition of AISI H11 steel (wt %)

C%	Cr%	Mo%	Vo%	Si%	S%	Mn%	P%	Fe%
0.35	5.26	1.19	0.5	1.01	0.002	0.32	0.016	90.31

The size of a rectangular workpiece 304 mm × 110 mm × 24 mm is taken under consideration. The proper cleaning of workpiece was done by the pressurized air jet to remove dust or unwanted particles. The grinding experiments were conducted on AISI H11 hot work tool steel under the three different environments of dry, wet and cryogenic treated. In wet grinding cooling consists of 25% coolant oil in water, applied directly at the inter-face of grinding wheel–work material at 6.56/min. For dry grinding there is no coolant is used. During the experiments, cuts were made of 110mm length. The experiment set up is represented as a schematic diagram in figure 1. To measure the weight of the workpiece, a digital weighing machine was used before and after each cut of machining to the machine time.

$$\mathbf{MRR = (W_{wi} - W_{wf})/ t \quad gm/sec}$$

Where, $W_{wi} =$ initial weight of work piece
W_{wf} = final weight of work piece
t = Machining time

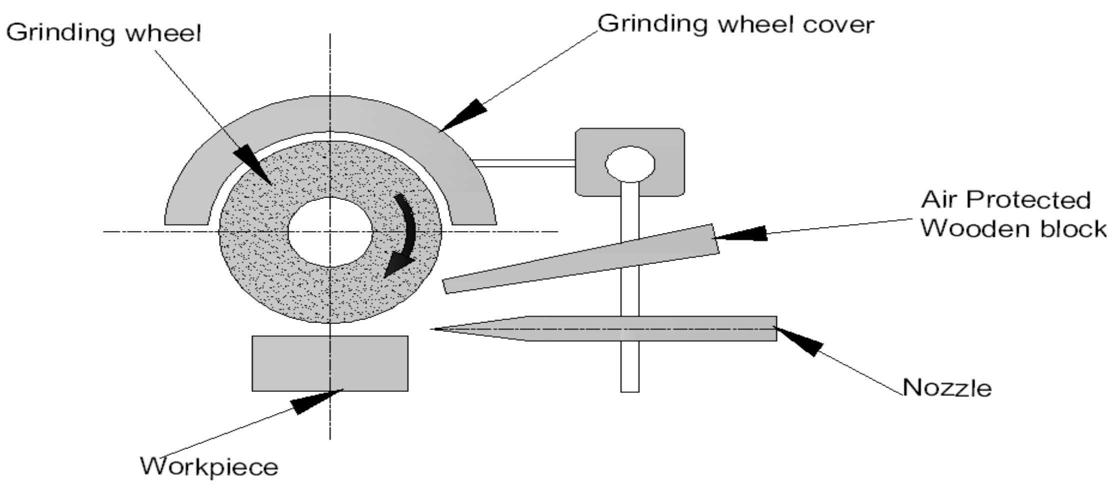

Figure 1.1 Schematic diagram of present work

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To investigate the effect of parameters of grinding, we perform 27 experiments by combining four parameters each having three levels. A Minitab 17 software was used in taguchi L_{27} orthogonal array, where we obtain different sets of input machining parameters are assigned in the below table-II

Table-II the values of machining input parameters are assigned at various levels

Factor	Level-1	Level-2	Level-3
Wheel Conditioning (A)	Dry	Wet	Cryogenics Treated
Speed (B) R.P.M	1000	1500	2000
Feed Rate (C) mm/rev	15	20	25
Depth of cut (D) mm	0.1	0.15	0.2

Number of experiments was performed by using taguchi L_{27} Orthogonal array on surface grinding machine as shown in Table-III.

Table-III Experimental results using L_{27} (3^4) orthogonal array

S. No.	Wheel Conditioning (A)	Speed (B) rpm	Feed Rate (C) mm/rev	Depth of Cut (D) mm	Material Removal Rate (gm/min)
1	Dry	1000	15	0.1	0.047
2	Dry	1000	20	0.15	0.253
3	Dry	1000	25	0.2	0.159
4	Dry	1500	15	0.15	0.379
5	Dry	1500	20	0.2	0.193
6	Dry	1500	25	0.1	0.074
7	Dry	2000	15	0.2	0.397
8	Dry	2000	20	0.1	0.078
9	Dry	2000	25	0.15	0.117
10	Wet	1000	15	0.1	0.06
11	Wet	1000	20	0.15	0.314
12	Wet	1000	25	0.2	0.135
13	Wet	1500	15	0.15	0.213
14	Wet	1500	20	0.2	0.318
15	Wet	1500	25	0.1	0.031
16	Wet	2000	15	0.2	0.575
17	Wet	2000	20	0.1	0.145
18	Wet	2000	25	0.15	0.152
19	Cryogenic Treated	1000	15	0.1	0.071
20	Cryogenic Treated	1000	20	0.15	0.37
21	Cryogenic Treated	1000	25	0.2	0.17
22	Cryogenic Treated	1500	15	0.15	0.455
23	Cryogenic Treated	1500	20	0.2	0.187
24	Cryogenic Treated	1500	25	0.1	0.048
25	Cryogenic Treated	2000	15	0.2	0.52
26	Cryogenic Treated	2000	20	0.1	0.06
27	Cryogenic Treated	2000	25	0.15	0.14

VI. RESULTS AND DISCUSSIONS

As maximum material removal rate is desired, the “larger is better” quality characteristic for material removal rate has been taken. Main effects plot and interaction plot for S/N ratio of material removal rate are shown in figure-I and figure-II.

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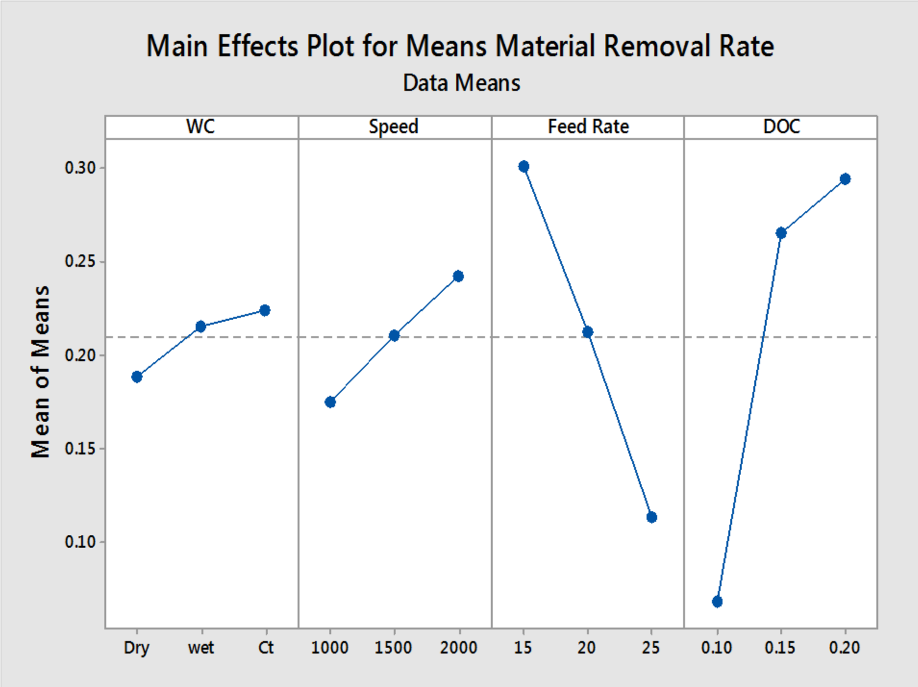

Figure-I Main Effect for Means Material Removal Rate (Larger is better)

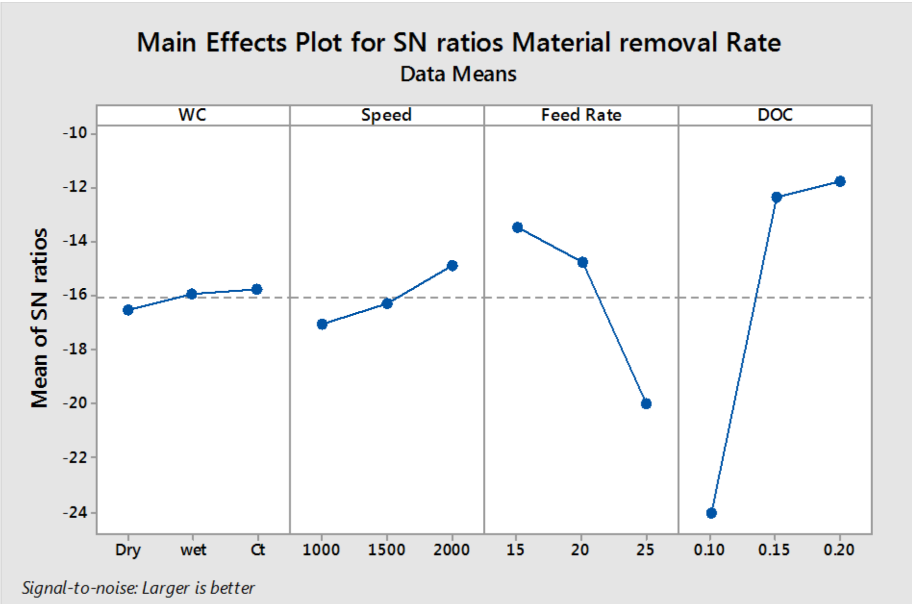

Figure-II Main Effects Plot for SN ratios Material Removal Rate (Larger is better)

Taguchi method was used to analyze the results of material removal rate based on larger is better criteria. The purpose of ANOVA was to investigate which of the process parameters significantly affect the performance characteristics. Table-IV shows the responses of various parameters at different levels.

Table-IV Response table for means for material removal rate

Level	Wheel Conditioning (A) (Wc)	Speed (B) (RPM)	Feed Rate (C) (mm/rev)	Depth of cut (D) (mm)
1	0.18859	0.17544	0.30189	0.06822
2	0.21589	0.21089	0.21311	0.26589
3	0.22456	0.24267	0.11400	0.29489
Delta	0.03600	0.06722	0.18789	0.22667
Rank	4	3	2	1

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It is clear that depth of cut has the highest rank signifying highest contribution to the material removal rate followed by feed rate and speed. Wheel conditioning has the lowest rank and was observed to have insignificant affect on the material removal rate.

VII. CONCLUSION

In this paper, it was concluded that cryogenic treatment Al_2O_3 grinding wheel gives maximum material removal as compared to dry and wet grinding process.

1. AISI H11 hot working steel provides maximum material removal during the grinding process with optimum grinding parameters such as: speed 2000 rpm, feed rate 15 mm/rev and depth of cut 0.20mm.
2. Depth of cut and feed rate are most dominate factor.

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