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A study on the effect of coolant parameters to surface roughness in external cylindrical grinding of 90CrSi steel using Taguchi method

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ABSTRACT

Grinding is one of the last operation performed which machine the work piece to obtain the high quality surface roughness and accurate dimension. It is an complex machining process and there are many processing parameters affect on the quality and productivity. Characteristic of grinding process is the removed material from the work surface in the phase of tine chips by many tiny abrasive particles of grinding wheel. There fore, it is difficult to evacuating chips and the most of energy converted to heat. To solve these problem require to using the suitable lubrication-coolant and the right lubrication condition. The optimum lubrication-coolant condition will ensure the machine quality and improve productivity. This study to investigate the optimization parameters of lubrication condition in cylindrical grinding 90CrSi harden steel using PV cutting oil.

Keywords*—Coolant-lubrication; external cylindrical grinding; taguchi method*

I. INTRODUCTION

Grinding process is one of the most important machining method to achieve final surface qualities and precessions. Grinding process directly effect to quality of the products. Therefore, there are numerous researchers interested in improving the performance and quality of grinding process [1]. For example, studies to optimizing grinding process parameters on material removal [2], on surface qualities [3-5], or minimizing grinding time and maximizing the volume of material removed rate [6, 7]. On the other side, the studies about influence of dressing parameters to wheel wear [8], to surface roughness [9] and topography of grinding wheels [10] have conducted. And, there have some studies to optimize the cost of grinding processes which present the cost function of grinding processes [11, 12].

More over, studying the effects of lubrication have focused. The lubrication have great effect on the surface qualities of products, the cutting force and temperature damaged to the ground surface. The researchers focus on finding the new lubrication liquid, lubrication method or determining the optimum parameters for lubrication in grinding process. Such as study about using the cryogenic LN_2 (liquid nitrogen) as an alternative coolant when grinding AISI 16 stainless steel by Sol-Gel (SG) alumina grinding wheel [13], or investigate the performance of two specifically designed fluids to reduces the quantities of oil and gas to very low (3ml/min and 0.2 kg/min) [14]. The study of D. Babic indicated that using high speed water mist jets seem to be cheap and effective way of cleaning the reducing specific energies [15].

The new lubrication method which applying the MQL (Minimum Quantity Lubricant) have studied. It have presented in study a system which use of two nozzles: first, oil is supplied as MQL, and then a flow of CO_2 at 238^oK is in charge of fixing the frozen oil on the surface of the abrasive grits, protect them from wear and improving sliding conditions where show the better surface quality of the component [16]. But the other study indicated that the effect of compressed cold air (CCA) and vegetable oil on the surface integrity and residual stresses of ground tool steel component show a good cooling efficiency only at small grinding depths [17]. More over, the study of Hadad to compare between MQL grinding performance to dry and fluid grinding process in terms of temperature distribution on the surface and subsurface of the work-piece, show the MQL despite the good lubrication, it can not meet the grinding cooling requirements compared with fluid grinding [18].

Until now, there haven't got any lubrication method which totally replace the fluid method. Regarding to determine the optimum parameters for lubrication the have got some study in internal grinding [19] or external grinding process [20].

This paper, presents a study to determine the optimum parameters of lubrication when grinding 90CrSi harden steel using PV Cutting oil by applying Taguchi method.

II. EXPERIMENTATION

In this research, the experiments were carried out by using PV Cutting oil in external cylindrical grinding process where it's parameter was described in table 1. This cutting oil is widely used in cutting processes with advantages as: safety, easy dissolve, stable emulsions, low foaming, good in cooling and corrosion protection.

Table 1. Parameters of PV Cutting Oil

Parameter	Method	PV Cutting Oil
Kinematic viscosity at 40°C	ASTM D445	46.5
PH in 5%, min	-	9.0
Density at 15°C	ASTM D1298	0.875
Flash point COC, °C, min	ASTM D92	220

The grinding system and measuring equipment are shown in the table 2.

Table 2. Grinding system and measuring equipment

Grinding machine	CONDO-Hi-45 HTS	Japan
Grinding wheel	Cn80MV1 400x40x203 35m/s	Viet Nam
Dressing tool	3908-0088C type 2	Russian
Surface roughness tester	Mitutoyo 178-923-2A, SJ-201	Japan

Work-piece material is 90CrSi harden steel to 62÷65 HRC with chemical composition in table 3. Work-piece dimension is ϕ25x180 mm.

Table 3. Chemical composition of 90CrSi steel

Steel grade: 9CrSi						
C	Si	Mn	Cr	P	S	Co
0.85-0.95	12-1.6	0.3-0.6	0.95-1.25	≤0.03	≤0.03	≤1

Experiment design

To evaluate the effect of the coolant on the grinding process and determine the optimum coolant parameters, the grinding and dressing condition had been kept constant during the grinding process. The coolant parameter were chosen as input parameters to investigated are flow rate, coolant pressure and concentration of lubricating fluid with three different level as shown in table 4.

Table 4. Coolant parameters and control levels

Symbols	Controlled parameters	Level 1	Level 2	Level 3
F	Flow rate (l/min)	5	10	15
P	Coolant Pressure (at)	1	1.5	2
C	Concentration (%)	2	3	4

The experiments were desinged by Taguchi method for optimizing the input parameters using L_9 orthogonal array. The result of experiment design by Minitab software are describled in table 5.

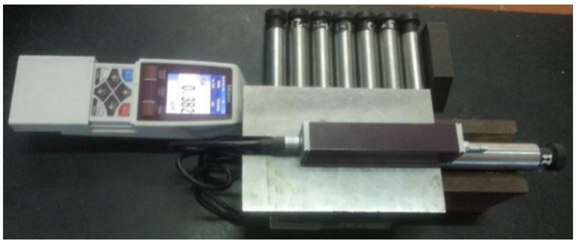

Figure 1. Surface Roughness Test

III. RESULT AND DISCUSSIONS

In the grinding test, the surface roughness of work-piece are measured by Mitutoyo Surface Roughness tester (SJ-201, Japan) (Figure 1). The experimental plans and the output results and their response are shown in Table 5.

Table 5. Experimental plans and output response

Test	Flow rate (l/min)	Coolant Pressure (at)	Concentration (%)	Surface Roughness (Ra)			SNRA	MEAN (µm)
				Trail 1	Trial 2	Trial 3		
1	5	1	2	0.491	0.487	0.455	6.4126	0.477667
2	5	1.5	3	0.382	0.388	0.365	8.4396	0.378333
3	5	2	4	0.422	0.415	0.425	7.5208	0.420667
4	10	1	3	0.286	0.275	0.280	11.0454	0.280333
5	10	1.5	4	0.315	0.332	0.325	9.7871	0.324000
6	10	2	2	0.427	0.428	0.431	7.3575	0.428667
7	15	1	4	0.342	0.338	0.325	9.4971	0.335000
8	15	1.5	2	0.410	0.412	0.405	7.7653	0.409000
9	15	2	3	0.315	0.302	0.312	10.1807	0.309667

For achieve the minimum of surface roughness, the testing results were analyzed by the criterion for evaluation "Smaller is better $SN=10\log[1/n(\sum y_i^2)]$" has been used. By using ANOVA in Minitab 18, the analysis of Variance (ANOVA) for SN ratios is shown in Figure 2. The specific percent contribution of the input parameters are show clearly in Figure 3. From the figure, the concentration of lubricant fluid is the most effect on surface roughness (about 61%), the flow rate contribute about 36% and the coolant pressure has least contribution with 2%.

Analysis of Variance for Means

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Flow rate (F)	2	0.012170	0.012170	0.006085	55.71	0.018
Coolant Pressure (P)	2	0.000774	0.000774	0.000387	3.54	0.220
Concentration (C)	2	0.020927	0.020927	0.010463	95.79	0.010
Residual Error	2	0.000218	0.000218	0.000109		
Total	8	0.034089				

Figure 2. Analysis of Variance for means of SN ratios for Surface Roughness (Ra)

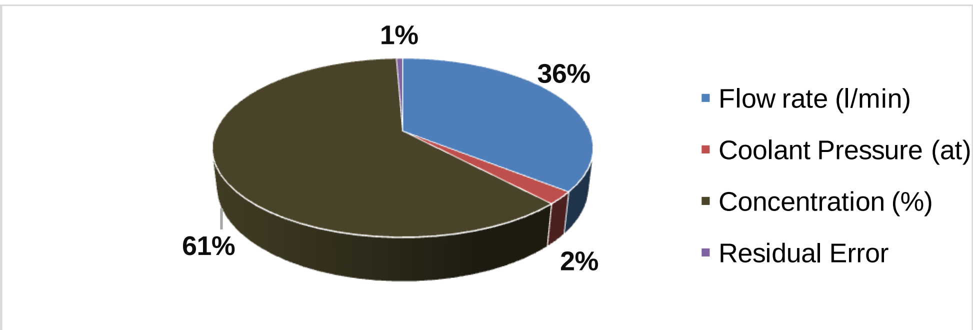

Figure 3. Percentage contribute of parameters to surface roughness (Ra)

Base on the analysis result in Figure 2, the P-value also descibes that flowrate (F) and concentration (C) of lubricant fluid have significant effect on the surface roughness and the coolant pressure (P) has not significant effect.

Figure 4 present the respond table for signal to noise ratios for the surface roughness. It indicates the influences of input parameters on the surface roughness by the ranks of its effect in sequence are the concentration, the flow rate and the coolant pressure.

Response Table for Signal to Noise Ratios

Smaller is better

Level	Flow rate (F)	Coolant Pressure (P)	Concentration (C)
1	7.458	8.985	7.178
2	9.397	8.664	9.889
3	9.148	8.353	8.935
Delta	1.939	0.632	2.710
Rank	2	3	1

Figure 4. Response table for signal to noise ratios (Smaller is better)

The Main effects plot for SN ratios for surface roughness is presented in figure 5. As in the mention above, the smaller value of surface roughness is better in grinding process. In this figure, the large S/N ratio means a smaller surface roughness. Therefore, as desrcibe by plot of each parameter in the figure, it was found that the optimum values of the input parameters for surface roughness are flowrate 10 l/min (level 2), concentration 3% (level 2) and coolant pressure 1 atm (level 1).

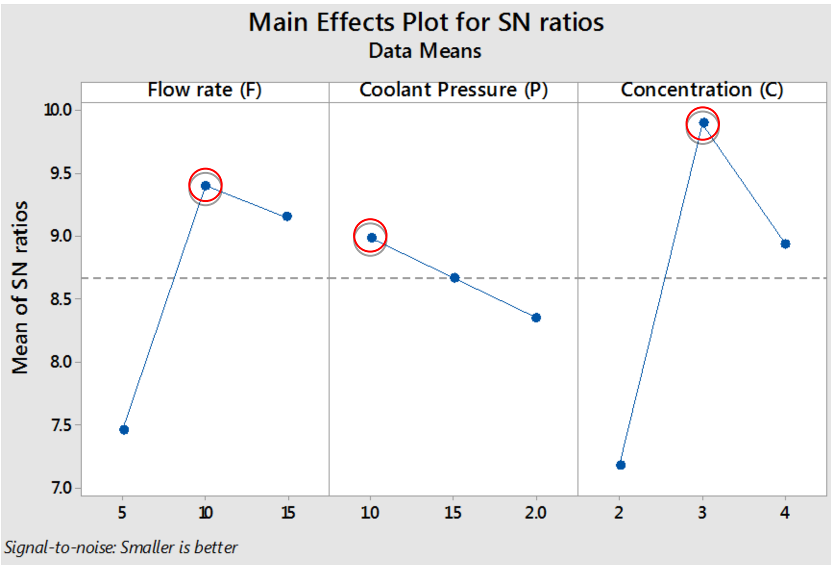

Figure 5. Main effect plot for SN ratios

An analys using Minitab 18 to predict the surface roughness respective optimum parameters of lubricant has been proceed. As the result which is shown in figure 6, the predict optimum value of the surface roughness is 0.284 µm.

Predicted values

Prediction

S/N Ratio	Mean	StDev	Ln(StDev)
10.9356	0.284037	0.0087846	-4.84671

Figure 6. Predicted values of surface roughness at optimum lubricant parameters

To verify the optimum input parameters, a test using the optimum values was conducted. The surface roughness of testing was 0.295 µm, compare to predict surface rougness, the error was only 3.87%. Its mean that the experiment work is satisfied.

IV. CONCLUSIONS

In this study, the optimum lubricant parameters in external cylindrical grinding are determined. The experiments were designed by using Taguchi technique, the result are analysed by Minitab 18 indicated the effect of coolant parameters on the surface roughness. The optimum values of lubricant parameters to get the minimum surface roughness in sequence of its effect are the lubricant concentration of 3%, the flow rate at 10 l/min and the coolant pressure of 1 at. In addition, the optimum values of input parameters with predict value of surface roughness was successful verified by an experiment and the error was 3.87%.

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