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Study on Fabricated Toolpost Shaft Efficiency for Cold Cutting Machine

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Abstract

The study discussed on the fabrication of Cold Cutting Machine (CCM) toolpost shaft and the optimization of the fabricated toolpost shaft efficiency. CCM has been used in oil and gas industry for cutting on-site, thus it has to be mobile and spark free. The CCM toolpost shaft is functioning as the holder for the cutting tool and it is adjustable as the cutting process takes place. Thus the study is to re-design, fabricate and testing the new toolpost shaft for its cutting efficiency. The existing toolpost shaft was made as a reference for the fabrication of the new one. The shaft was fabricated in two new different sizes of cutting clearance and the original size of thread M10 as a constant. The pitch was altered in a range between 1 mm and 1.25 mm. Design of Experiment (DOE) Taguchi L9 orthogonal array was used to study the optimization process for toolpost shaft efficiency. The parameters include cutting clearance, coolant types and rotation speed at three different levels. It was found that for both depth of cut and machining time yields were strongly affected by the rotation speed and followed by cutting clearance. **Background/Objectives:** In industry, standardizing the toolpost shaft clearance is a major issue since their usage varies by different sizes of clearance. Hence, the study investigates the variety of clearance at toolpost shaft for its cutting efficiency in CCM. The re-design toolpost are fabricated by referring to the industry requirement. **Methods/Statistical Analysis:** The toolpost of CCM was fabricated by machining process. Then, the optimization of fabricated toolpost efficiency was done by using Design of Experiment Taguchi method and analyzed by using Analysis of Variance (ANOVA) analytical tool in MINITAB 15. **Findings:** CCM toolpost was successfully fabricated in two new sizes and fully functioning. The optimization of toolpost efficiency process yields were depth of cut and machining time. It shows that both of these efficiency yields were strongly affected by the rotation speed and cutting clearance. **Applications/Improvements:** Results from this study showed that the optimum of overall efficiency was found in the depth of cut for higher number of cutting in less time. This will increase productivity at the production line for the next pipe cutting.

Keywords: Cold Cutting Machine (CCM), Cutting Clearance, Machining Time, Toolpost Shaft, Toolpost Efficiency

1. Introduction

Cold Cutting Machine (CCM) is used to perform cutting and beveling oil and gas pipes since it does not generate flame, heat or sparks as it use pneumatic motor system. Hence, the CCM is the ideal cutting method as it eliminates the risk of ignition in explosive environment. The conventional cutting methods are time consuming as cutting and bevelling are carried out separately. CCM enables both cutting and bevelling processes to be accomplished simultaneously.

The main part of CCM includes low clearance split frame, tool slide and adjustable clamping pad extension[1]. The low clearance split frame ring consists of rotating ring and stationary ring. Each ring splits into two pieces. Tool slide is used as a holder to clamp the tool cutter in CCM. Its function is to clamp the tool cutter such as the parting tool and beveling tool. The low clearance slides are

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special order slides used when minimal radial clearance is required. The main parts of the tool slide consist of support tool, move tool and shaft. Different clearance sizes are used in cutting the pipes on oil and gas sites.

Previous study was done on the possibility of replacing the existing material used in CCM for the lightweight criteria materials such as aluminum alloys, Carbon Fiber Reinforced Plastics (CFRP), Glass Fiber Reinforced Plastics (GFRP) and titanium alloys[2]. It was found that weight reduction up to 33% was achieved by using aluminum alloy. The future work refers to a study done by[3] which they design and fabricate the new type dynamometer.

In this study, the work carried out was to determine the efficiency of the CCM toolpost. A machining process in CCM is similar to the turning machine. Thus cutting parameters of turning such as cutting speed, feed rate and depth of cut, cutting clearance, rotation speed and coolant types will be selected for investigation[4]. The yields for the CCM efficiency were measured by the depth of cut and machining time responses during cutting.

The new toolpost was fabricated in this experiment. The Two-Dimensional (2D) drawing was referred for materials and dimensional machining accuracy by using milling, turning and Computer Numerical Control (CNC). In addition, the fabrication on the parts of the split frame and gear such as clamp pads, gear housing and others by various machining processes which followed by testing and analysis[5].

For a robust design of experiment, Taguchi method was implemented to investigate the optimization of the machining process of CCM. The Taguchi method was developed by[6] from Japan in 1987. A study done by[7] was investigating the influence of cutting parameters in machining titanium alloys using Taguchi methods. Orthogonal arrays L9 are used to conduct a set of experiments to organize the parameters affecting the process and the levels[8].

2. Methodology

2.1 Methods and Materials

The study consists of two major parts namely fabrication of the toolpost and optimizing the machining efficiency. Fabrication of CCM's tool post shaft involved cutting M10 to the length of 110 mm and M14 to the length of 10 mm as shown in Figure 1 (a) and (b). Whereas, Figure 1 (c) shows the other halve of the shaft which was cut at a diameter of 15mm, 14mm and M14 to tighten the star wheel.

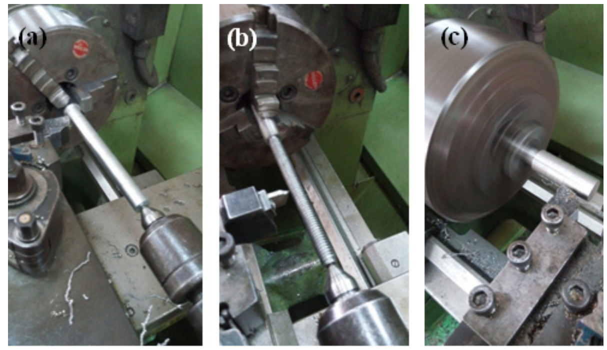


Figure 1. Fabrication of the CCM toolpost shaft.

The support and movable tool slide with 45° angles at its base, i.e., triangle shape as shown in Figure 2 (a) and (b) were fabricated by wire cut process. Figure 2 (c) showed the assembly of the two parts matched completely.

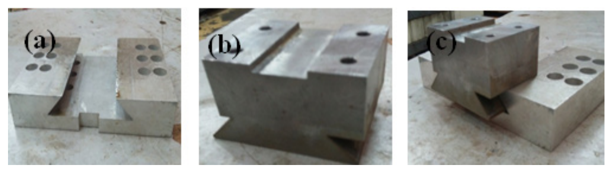
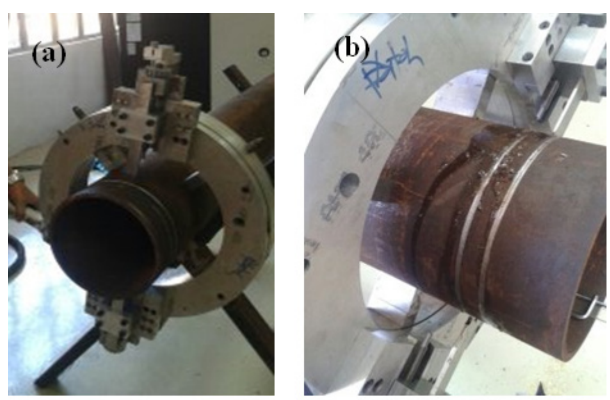


Figure 2. Fabrication of the support and tool slide.

2.2 Assemble and Testing

There are five parts altogether in toolpost assembly. This includes block, tool slide cover, shaft, move and support tool slide. They are all assembled in one complete assembly and attached to the CCM main frame. It was then ready for a trial run as shown in Figure 3. The cutting was carried out successfully and ready for the optimization part process.



(a) (b)

Figure 3. Trial cutting run. (**a**)Front view. (**b**) Side view.

2.3 Design of Experiment

The second part of the study was to optimize the efficiency of CCM by using the fabricated toolpost. Optimization was applying the design of experiment Taguchi methods. The number of parameters and its levels of the L9 orthogonal array are shown in Table 1. Three machining parameters were selected namely cutting clearance, coolant types and rotation speed. The two yields of optimization being measured are depth of cut and machining time.

Table 1. Taguchi L9 parameters and their levels

Parameters	Levels		
	1	2	3
Cutting clearance/mm (A)	1.00	1.25	1.50
Coolant types (B)	Water	Mobile cut	Belling X10
Rotation speed/ms^{-1} (C)	10	20	30

3. Results and Discussion

The fabricated toolpost was successfully assembled and run. Problems encountered during the trial run were successfully overcome and amended accordingly. The optimization of 9 run experiment was later conducted. The 9 run was replicated three times. The Taguchi L9 was analyzedby using the MINITAB 15 statistical software for the two yields, i.e., depth of cut and machining time respectively.

3.1 Depth of Cut

The statistical analysis tool of MINITAB 15 by using Analysis of Variance (ANOVA) with the confidence level of 95% ($P < 0.05$) is tabulated in Table 2. Based on the ANOVA data, the cutting clearance and rotation parameters were significant which indicate the p-value less than 0.05. In conclusion, the parameters strongly influence the experiment whereas the coolant types were not significant.

Table 1. ANOVA for depth of cut yield

Source	DF	Seq SS	Adj SS	F	P
Cutting clearance	2	0.164217	0.082109	610.17	0.02
Coolant	2	0.000062	0.000031	0.23	0.813
Rotation	2	0.340151	0.170075	1263.86	0.01
Residual error	2	0.000269	0.000135		
Total	8	0.504699			

The main effects plot for means in Figure 4 indicated the effect of parameters on the experiment. The large differences between the maximum and the minimum values show the parameter has a great effect on the experiment. The effect value for the cutting clearance is 0.8122-0.4856 = 0.3266. On the other hand, the effect value for rotation parameter is 0.4677 from 0.8933-0.4256. As for coolant parameter, the highest value is set 1 and 2 (0.6356) and the lowest is set 3 (0.6300). The range between both set noted the lowest range which is 0.0056, but the coolant parameter effect is not significant.

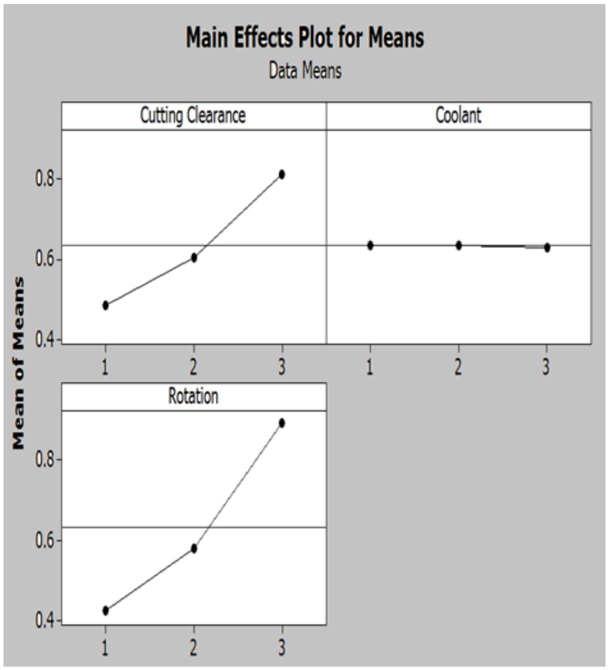


Figure 4. Main effects plot for means (depth of cut).

The depth of cut is aimed for larger-the-better characteristics. The depth of cut represent the maximum value in cutting clearance (A) in level 3, coolant (B) in level 1 and rotation (C) maximum value in level 3. Thus, the cutting clearance effect's value is 5.309. The next significant parameter in the plot graph is rotation speed which has the effect of 6.748. In Figure 5, the main effects plot for SN ratios show the significant parameters of cutting clearance and rotation in level 3. This shows that the depth of cut is with the larger-the-better result. It can be concluded that based on the analysis for depth of cut, the optimum process for the design of experiments is A3 C3 B1.

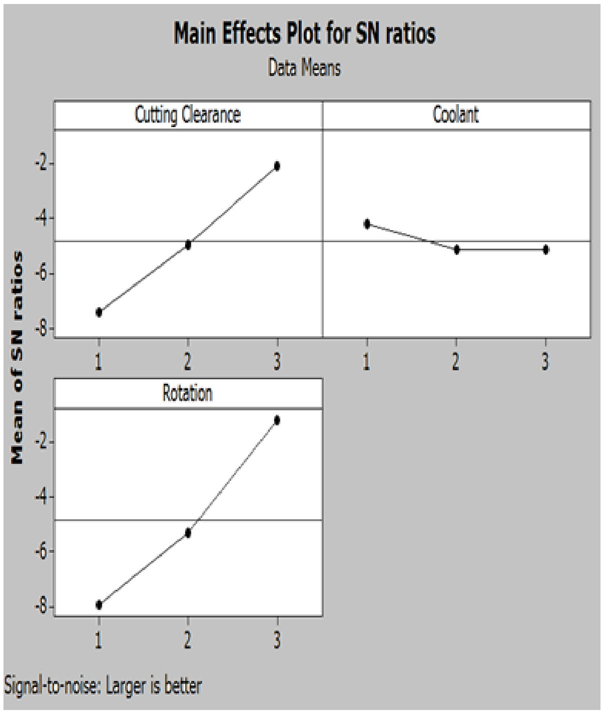


Figure 5. Main effects plot for SN ratios (depth of cut).

3.2 Machining Time

The Design of Experiment (DOE) was analyzedby using statistical tool ANOVA with the confidence level of 95% (P < 0.05). Table 3 shows the analysis of variance for means machining time. The rotation speed is significant parameters where these factors strongly influence the experiment, but the cutting clearance and coolant types are not significant. The value of P for rotation speed is below than P<0.050, meanwhile P-value for cutting clearance and coolant were considered not significant as they have the value of P>0.050. P value (P>0.050) the parameter should be rejected and never be accepted.

Table 3. ANOVA table for machining time

Source	DF	Seq SS	Adj SS	F	P
Cutting clearance	2	2080.1	1040.1	2.50	0.286
Coolant	2	366.6	183.3	0.44	0.694
Rotation	2	27117.2	13558.6	32.62	0.030
Residual error	2	831.4	415.7		
Total	8	30395.2			

The main effects plot for means in Figure 6 indicated the effect of parameters on the experiment. The large differences between the maximum and the minimum values show the parameter has a great effect on the experiment. The rotation speed has the effect value of 134.1. For the cutting clearance, the highest value is at set 3 (131.96) and the lowest value is set 2 (96.72). This means the range between both set noted at the second higher which is 35.24. Lastly, for coolant, the highest value is set 3 (118.30) and the lowest is set 2 (102.72). The range between both set noted at the lowest range, which is 15.58. In conclusion, the cutting clearance and coolant parameters were not significant.

Figure 6. Main effects plot for means of machining time yield.

The machining time is aimed for smaller-the-better characteristics. The smaller represent the maximum value in cutting clearance (A) in level 2, coolant (B) in level 2 and a rotation speed (C) maximum value in level 1. Thus, it is best to get the rotation effect's value 16.26. In Figure 7, the main effects plot for SN ratios show the significant parameters of rotation speed in level 1. This provides evidence that the machining time is the smaller-the-better result. It can be concluded that based on the analysis of machining time, the optimization process for design of experiments is C1 A2 B2.

Figure 7. Main effects plot for SN ratios (machining time).

In optimizing the efficiency of the fabricated toolpost, rotation speed was greatly affecting both the depth of cut and machining time yields. This was followed closely behind by cutting clearance and coolant parameters.

4. Conclusion

The fabrication of the toolpost parts such as shaft, block, tool slide cover, move the tool slide and support tool slide were successfully carried out. The overall fabrications of the CCM parts were completed as per drawing successful and several problems encountered were successfully solved. The best cutting clearance for CCM was analyzed through the depth of cut yield. It was shown that for optimum depth of cut, the cutting clearance must be at 1.5 mm and the rotation speed must be set at 30. On the other hand, the efficiency of the fabricated toolpost was determined by the machining time yield. There smallest rotation speed in a second is the optimum result i.e., 30 rotations. Thus, the optimum of overall efficiency of the fabricated toolpost was based on both yields; depth of cut and machining times. The best cutting result was found in the depth of cut for the high number of cutting in less time. This will increase productivity at the production line for the next pipe cutting. Machining time relies on the air pressure apply. Shorter time is better for industry since time saving will help in reducing costs.

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