Optimization of Milling Parameters using Vegetable Oil by Measuring Vibration Signal

P.M.Arunkumar, T.Mohanraj, K.Ananthi, S.J.Abbhimanneu, R.Aravindh, T. Arul Praveen, S. Balaji, P.K. Dinesh, P. Leander Joseph

Abstract: This paper describes an on-line tool wear monitoring system for milling operation by optimizing the input parameters while machining 7075T6 aluminium composite material. The input parameters considered are Spindle speed, feed rate and depth of cut. Coolant is the major factor that affects the tool wear to greater extent. So the type of coolant (different types of vegetable oils) is also taken as an input parameter for optimization. The experiments are carried out with different spindle speed, feed rate, depth of cut and coolant and the vibration produced in X, Y & Z directions were measured. Taguchi mixed level design (L18) is taken for optimization process using S/N ratio and ANOVA (Analysis Of Variance) analysis. The results show that the coolant has the most significance while measuring the vibration.

Keywords: Tool condition monitoring, Parameter optimization, ANOVA

I. INTRODUCTION

In manufacturing industries low cost, high quality products with short manufacturing time are obtained with the use of Online tool condition monitoring techniques. Tool condition depends on the tool wear. Tool wear rate can be minimized by optimizing the input parameters. The output responses of machining process should be measured in order to optimize the input parameters. Vibration is an uncontrolled factor produced while machining. Based on the tool wear vibration is produced. The input parameters can be optimized by measuring the vibration produced (1). The input parameter which produces less vibration while machining is the optimized parameter.

Spindle speed, feed rate and depth of cut are the input parameters considered in most of the literatures (2).

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P.M.Arunkumar, Assistant Professor, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore

T.Mohanraj, Assistant Professor, Department of Mechanical engineering, Amrita Vishwa Vidyapeetham University, Coimbatore

K.Ananthi, Assistant Professor, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore

S.J.Abbhimanneu, UG scholar, Department of Mechatronics engineering, Sri Krishna College of Engineering and Technology, Coimbatore

R.Aravindh, UG scholar, Department of Mechatronics engineering, Sri Krishna College of Engineering and Technology, Coimbatore

T. Arul Praveen, UG scholar, Department of Mechatronics engineering, Sri Krishna College of Engineering and Technology, Coimbatore.

S. Balaji, UG scholar, Department of Mechatronics engineering, Sri Krishna College of Engineering and Technology, Coimbatore.

P.K. Dinesh, UG scholar, Department of Mechatronics engineering, Sri Krishna College of Engineering and Technology, Coimbatore.

P. Leander Joseph, UG scholar, Department of Mechatronics engineering, Sri Krishna College of Engineering and Technology, Coimbatore.

Type of cutting fluid is another important input parameter which affects the tool wear rate. Cutting fluids have more importance among machining factors due to their lubricant, cooling and chip removal properties (3). Many types of cutting fluids namely, straight oils, soluble oils, synthetic and semi synthetic are widely used in metal cutting processes. Bio-based cutting fluids have the potential to reduce the waste treatment costs due to their inherently higher biodegradability and may reduce the occupational health risks associated with petroleum-oil-based cutting fluids. The performance of four vegetable based oils (sunflower and canola oils with different extreme pressure additives) and two commercial cutting fluid (semi-synthetic and mineral) are evaluated for reducing surface roughness of workpiece, cutting and feed forces. It was concluded that vegetable based oils showed better performance than commercial cutting fluids (3). The effect of some straight biological oils (groundnut oil, coconut oil, palm kernel oil and shear butter oil) on cutting force during cylindrical turning were determined. Finally it is concluded that groundnut oil is the best among the four bio-oils investigated (4). Palm kernel, cottonseed oil, mineral oil-in-water emulsion cutting fluids are evaluated in turning of AISI 4340 steel with coated carbide tools. The result showed that based cutting fluids are better alternatives for machining AISI 4340 steel with coated carbide (5). The performance of stamping oil, hydraulic oil, jatropa oil, RBD palm oieln and palm fatty acid were tested in fourball tribometer under extreme pressure condition were studied. It was concluded that vegetable oils have high friction coefficient and low wear compared to commercial mineral oils (6). The effect of green cutting fluids (water vapour, gas, mixture of water vapour & gas and oil water emulsion) on cutting force, cutting temperature, chip deformation coefficient, rake face wear and tool flank wear were studied while turning ANSI 1045 steel with cement carbide tool P10. Compared to dry cutting the tool life was increased when mixture of water vapour & gas was used as lubricant (7). The effect of new vegetable based oil on surface roughness, hardness and part accuracy in reaming and tapping operation were investigated. vegetable oils used were reference mineral oil, Limnantes alba vegetable oil with and without additives. The result showed that better part accuracy, high micro hardness and lower surface roughness were obtained with vegetable oil (8). The effect of turning parameters (cooling condition, cutting speed, feed rate and depth of cut) on average roughness and average maximum height of profile were studied.

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Turning experiment was carried on AISI 1050 steel under dry cutting, wet cutting and MQL. The result showed that feed rate and cooling condition has great influence on surface roughness (9). Tool condition monitoring was done using multiple sensors like acoustic emission sensor, force sensor, vibration sensor and spindle power sensor and the result was analysed under sensor fusion and non-fusion level. The better result was obtained with different sensor fusion technique(10). Selection of optimization method is very important in tool condition monitoring. It determines the number of experiments to be taken for optimization. Taguchi optimization method is the most effective method to optimize the machining parameters, in which a response variable can be identified (11).

II. EXPERIMENTAL SETUP

The experiment was carried out in CNC vertical milling machine (LMILL 55). Work piece used is 7075-T6 aluminium composite material. Carbide tool with XDHT-090308 HX PA120 insert is used. Accelerometer is used to measure vibration produced while machining in X, Y & Z direction. The sensor signals are acquired using Data Acquisition System and is integrated with the computer using LabVIEW software. The Accelerometer is fixed on the work piece using a glue. Once the machining starts, the vibration produced is measured by the Accelerometrer. The vibration signals are acquired by the DAQ system and using signal conditioning unit the analog signals are converted to digital signals and the values are stored in computer. Photograph of the setup is shown in the Figure 1. The vegetable oils considered for this study are

1. Groundnut oil
2. Castor oil
3. Cotton seed oil
4. Palm oil
5. Rapeseed oil
6. Neem oil

Fig. 1 Experimental set up

The vegetable oils used are natural oils without any additives. Viscosity of the cutting fluid is one of the important parameter to determine the effectiveness of the cutting fluid (3). The viscosity of all the vegetable fluids are determined at different temperatures using Saybolt viscometer and the results are presented in the table 1.

Table. 1 Properties of cutting fluids

S.NO	CUTTING FLUID	DENSITY (gm/cubic meter)	KINEMATICVISCOSITY(centi stokes)
1	Groundnut oil	940	2.74
2	Castor oil	940	52.71
3	Cottonseed oil	980	2.89
4	Palm oil	860	20.71
5	Rapeseed oil	960	5.92
6	Neem oil	900	3.22

III. MILLING CONDITIONS AND EXPERIMENTAL DESIGN

Experiments are conducted for different values of input parameter like spindle speed, feed rate, depth of cut and coolant. The flow rate of the coolants was kept constant. The milling factors and their levels are shown in the table 2. The experimental design for three cutting parameters (speed, feed rate, depth of cut) with 3 levels and one parameter (cutting fluid) with six level are organised using Taguchi mixed level system (L18 orthogonal array shown in table 3). The S/N ratio is calculated for the measured vibration and for optimisation, among the three S/N characteristic smaller the better option is opted for cutting force.

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Table. 2 Milling factors and levels

MILLING PARAMETERS	UNIT	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5	LEVEL 6
Spindle speed	Rpm	1000	1500	2000	-	-	-
Feed rate	mm/rev	0.05	0.075	0.1	-	-	-
Depth of cut	Mm	0.5	1.0	1.5	-	-	-
Type of cutting fluid		1-Groundnut oil	2-Castor oil	3-Cotton seed oil	4- Palm oil	5- Rapeseed oil	6- Neem oil

Table. 3 Taguchi L18 Orthogonal array and measurements

EX. No.	CUTTING FLUID	SPINDLE SPEED (rpm)	FEED RATE (mm/rev)	DEPTH OF CUT (mm)	VIBRATION IN 'X' DIRECTION	VIBRATION IN 'Y' DIRECTION	VIBRATION IN 'Z' DIRECTION	RESULTANT VIBRATION	S/N Ratio for vibration
1	1	1000	0.05	0.5	0.0033740	0.0287000	0.0002740	0.0288989	30.7824
2	1	1500	0.075	1.0	0.0033420	0.0286900	0.0004030	0.0288868	30.7860
3	1	2000	0.1	1.5	0.0033130	0.0285940	0.0003480	0.0287874	30.8160
4	2	1000	0.05	1.0	0.0033840	0.0286080	0.0004460	0.0288109	30.8089
5	2	1500	0.075	1.5	0.0033787	0.0284200	0.0003409	0.0286222	30.8660
6	2	2000	0.1	0.5	0.0032359	0.0284302	0.0002560	0.0286149	30.8682
7	3	1000	0.075	0.5	0.0034401	0.0285550	0.0004130	0.0287644	30.8229
8	3	1500	0.1	1.0	0.0033912	0.0283024	0.0002970	0.0285064	30.9012
9	3	2000	0.05	1.5	0.0033920	0.0282320	0.0003866	0.0284377	30.9221
10	4	1000	0.1	1.5	0.0032708	0.0271998	0.0005912	0.0274021	31.2443
11	4	1500	0.05	0.5	0.0032554	0.0273308	0.0005437	0.0275293	31.2041
12	4	2000	0.075	1.0	0.0031951	0.0270857	0.0004540	0.0272773	31.2840
13	5	1000	0.075	1.5	0.0033270	0.0268760	0.0006660	0.0270893	31.3440
14	5	1500	0.1	0.5	0.0031640	0.0270730	0.0003085	0.0272590	31.2898
15	5	2000	0.05	1.0	0.0032190	0.0268530	0.0004716	0.0270494	31.3569
16	6	1000	0.1	1.0	0.0033220	0.0267660	0.0005961	0.0269779	31.3798
17	6	1500	0.05	1.5	0.0032880	0.0267780	0.0006278	0.0269864	31.3771
18	6	2000	0.075	0.5	0.0031960	0.0267550	0.0003953	0.0269481	31.3894

IV. RESULTS AND DISCUSSIOIN

S/N ratio and Analysis of Variance (ANOVA) are used for analysis of experimental results. The purpose of ANOVA is to determine which input factor significantly affects the vibration. In order to optimize the input parameter Taguchi's the lower- the better quality characteristic (S/N ratio) is considered for vibration. The values of S/N ratio for cutting force are shown in table 3.The main effects of plots for S/N ratio for vibration is depicted in figures 2-5.

From the S/N analysis in figure 2, the optimal milling parameters are coolant- rapeseed oil (level 5), 2000 rpm of spindle speed (level 3), 0.1 mm/rev of feed rate (level 3) and 0.5 mm of depth of cut (level 1). Rapeseed oil has greater influence on vibration and it reduces the vibration at higher spindle speed and feed rate.

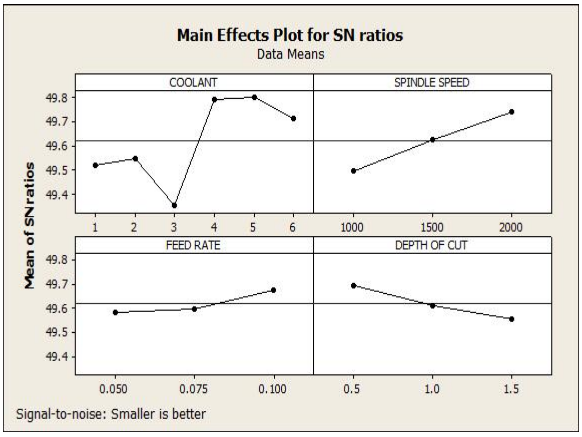

Fig. 2 Main effects of plots for Vibration in X direction

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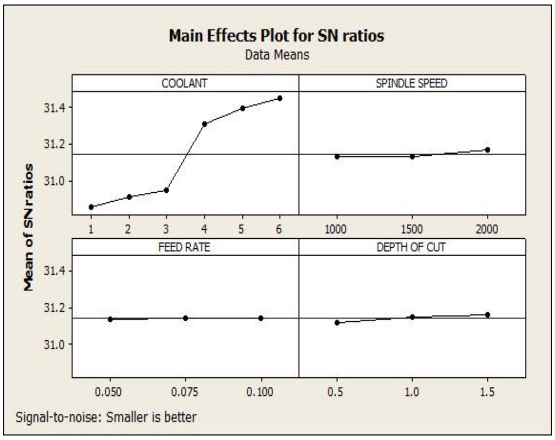

Fig. 3 Main effects of plots for Vibration in Y direction

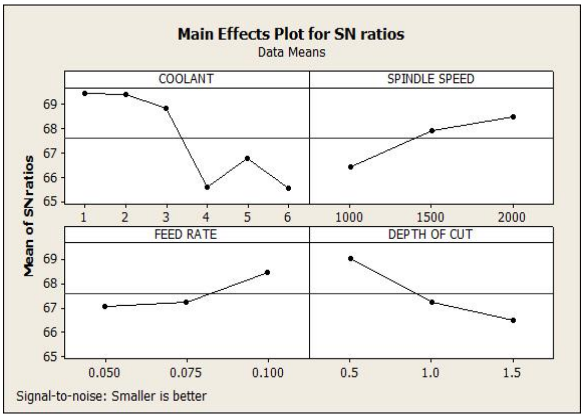

Fig. 4 Main effects of plots for Vibration in Z direction

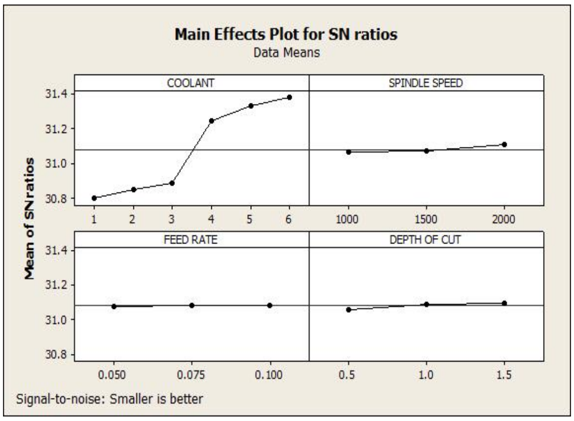

Fig. 5 Main effects of plots for resultant Vibration

This result is in agreement with the literature (12). From S/N analysis in figure 3, the optimum milling parameters considering vibration produced in Y direction are neem oil as coolant (level 6), 2000rpm of spindle speed (level 3), 0.075mm/rev of feed rate (level 2) and 1.5mm of feed rate (level 3). The S/N analysis for vibration produced in Z direction (figure 4) shows that groundnut oil as effective coolant (level 1), 2000 rpm as spindle speed (level 3), 0.1mm/rev as feed rate (level 3) and 0.5mm as depth of cut in reducing the vibration in Z direction. Groundnut oil was effective in reducing the vibration at higher spindle speed and feed rate. This result is in agreement with literature (4). From S/N analysis in figure 5, the optimal milling parameters for minimal vibration are coolant- neem oil (level 6), spindle speed- 2000rpm (level 3), feed rate- 0.075mm/rev (level 2) and feed rate- 1.5mm (level 3).From this it was clear that Neem oil for above mentioned input parameters show less vibration.

V. ANALYSIS OF VARIANCE

Another analysis for understanding of the importance of coolant, spindle speed, feed rate and depth of cut on vibration is ANOVA. The ANOVA result in table 4 clearly shows that coolant is the only parameter which influence the vibration in X direction. ANOVA for vibration in Y direction (Table 5) shows that coolant influences by 99.09 % and spindle speed influence by 0.9 %. Coolant and depth of cut influences the vibration in Z direction by each 50% (Table 6). The other parameters do not have any influence. The ANOVA for Resultant vibration (Table 7) shows that coolant and spindle speed influence the vibration by 99.09 % and 0.9%. The other parameters do not have any influence on resultant vibration. For Vibration in all the directions the type of coolant has the maximum contribution of 100%. This is followed by the depth of cut (50%) for vibration in Z direction. So the type of coolant is the only input parameter which significantly affects the vibration produced while machining.

Table. 4 ANOVA for vibration in X direction

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F	P	P%
COOLANT	5	0.0000001	0.000000	21.37	0.001	100
SPINDLE SPEED	2	0.0000000	0.000000	20.82	0.002	0
FEED RATE	2	0.0000000	0.000000	3.48	0.099	0
DEPTH OF CUT	2	0.0000000	0.000000	6.10	0.036	0
ERROR	6	0.0000000	0.000000			0
TOTAL	17	0.0000001				100

Table. 5 ANOVA for vibration in Y direction

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SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F	P	P%
COOLANT	5	0.0000110	0.0000022	330.92	0.000	99.09
SPINDLE SPEED	2	0.0000001	0.0000000	4.15	0.074	0.9
FEED RATE	2	0.0000000	0.0000000	0.14	0.873	0
DEPTH OF CUT	2	0.0000000	0.0000000	3.69	0.090	0
ERROR	6	0.0000000	0.0000000			0
TOTAL	17	0.0000111				100

Table. 6 ANOVA for vibration in Z direction

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F	P	P%
COOLANT	5	0.0000001	0.0000000	4.12	0.057	50
SPINDLE SPEED	2	0.0000000	0.0000000	3.15	0.116	0
FEED RATE	2	0.0000000	0.0000000	0.91	0.452	0
DEPTH OF CUT	2	0.0000001	0.0000000	3.99	0.079	50
ERROR	6	0.0000000	0.0000000			0
TOTAL	17	0.0000002				100

Table. 7 ANOVA for Resultant vibration

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F	P	P%
COOLANT	5	0.0000110	0.0000022	337.86	0.000	99.09
SPINDLE SPEED	2	0.0000001	0.0000000	4.97	0.053	0.9
FEED RATE	2	0.0000000	0.0000000	0.19	0.833	0
DEPTH OF CUT	2	0.0000000	0.0000000	3.26	0.110	0
ERROR	6	0.0000000	0.0000000			0
TOTAL	17	0.0000111				100

VI. CONCLUSION

This study focuses on optimizing the input parameter for milling considering the vibration developed during machining using vegetable oil as coolant. Taguchi mixed level system was used and 18 experiments were carried out with different spindle speed, feed rate, depth of cut and coolant. S/N ratio and ANOVA analysis were done and the result showed that

- Minimum vibration in X direction was obtained with the spindle speed of 2000 rpm, feed rate of 0.1mm/rev, depth of cut of 0.5 mm along with the rapeseed oil is a coolant
- The optimal parameter for vibration in Y direction was spindle speed of 2000 rpm, feed rate of 0.075 mm/rev, depth of cut of 1.5 mm along with neem oil as cutting fluid.
- When vibration in Z direction is considered, groundnut oil reduces the vibration with higher spindle speed and feed rate. Vibration is increased when depth of cut increases
- For the minimal resultant vibration, Neem oil with spindle speed 2000rpm, 0.075 mm/ rev feed rate and 1.5mm depth of cut is used

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