"Comparative performance evaluation of Minimum Quantity Lubrication with and without vortex tube in turning of 250MDN"

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ABSTRACT

Maraging steels are evoked tremendous interest due to its extraordinary combination of structural strength and fracture toughness, at the same time ready to weld and heat-treated. Therefore, in the present study, an attempt has been made to investigate the effect of process parameters on performance characteristics in finish hard turning of MDN250 steel using coated carbide tool and there by optimization of turning of MDN250 steel by taguchi method. The cutting speed, feed and depth of cut were used as the process parameters whereas the surface roughness ware selected as performance characteristics. The L9 orthogonal array based on design of experiments was used to conduct experiments. The degree of influence of each process parameter on individual performance characteristic was obtained from Grey relation.

Keyword: - *Cutting fluids, Minimum Quantity Lubrication, Vortex tube, mixing chamber Turning, near dry machining.*

1.INTRODUCTION

Industries around the world constantly strive for lower cost solutions with reduced lead time and better surface quality in order to maintain their competitiveness. Traditionally, most ferrous metal parts are rough turned, heat-treated and finished by grinding. In recent years, hard turning which uses a single point cutting tool has replaced grinding to some extent for such applications. For successful implementation of hard turning, selection of suitable cutting parameters for a given cutting tool; work- piece material and machine tool are important steps. As Maraging steels falls in the group of hard material and are widely used in many sectors such as aerospace, military as well as for tools and dies due to its high strength in combination with good toughness. Due to the complex tool configurations/cutting conditions of metal cutting operations and some unknown factors and stresses, theoretical cutting force calculations failed to produce accurate results. Therefore, experimental measurement of the cutting forces became unavoidable. In Surface roughness is one of the important machinability factor in all areas of tribology and in evaluating the quality of machining operations. Achieving the desired surface quality is of great importance for the functional behavior of a part. Surface roughness is a measure of the quality of a product and a factor that greatly influences manufacturing cost. It can be generally stated that the lower the desired surface roughness the more the manufacturing cost and vise versa. In order to obtain better surface roughness and minimum forces in machining, proper selection of cutting parameters is crucial before the process takes place. There have been many studies concerning the effect of cutting parameters such as speed, feed, depth of cut, etc. and tool geometry on cutting forces and surface roughness while machining different materials.They observed that feed rate is the most significant factor affecting surface finish and cutting speed has very little influence on surface finish. The studied the machining of AISI D2 steel with PCBN tools using three levels of speed and feed rate for studying tool life and cutting forces. They concluded that 70 m/min speed is more suitable in machining of AISI D2 steel with PCBN tools material combination for highest acceptable value of tool life and volume of material removal. In the present work, turning experiments were conducted on a precision lathe with cecarbide cutting tools for the machining of maraging steel. The L9 orthogonal array based on design of experiments was applied to plan the experiments, by selecting three controlling factors namely, the cutting speed (v), feed (f) and depth of cut (d). The Taguchi analysis is applied to examine how these cutting speed,feed and depth of cut affect the surface roughness (Ra). An optimal parameter combination was then obtained using the experimental results. Furthermore, Grey relation analysis was also carried out to examine the most significant factors for the Ra in the turning process.

2. EXPERIMENTAL DETAILS

The turning experiments were carried out on a precision lathe setup using coated carbide cutting tools for the machining of maraging steel bar, which is 20 mm in diameter and 50 mm in length. The chemical composition and mechanical properties of the workpiece material are listed in below

Table -2.1 Chemical and Mechanical Properties

Chemical composition	Nickel	Molybdenum	Chromium	Titanium
Wt%	18	4.2	12.5	1.6
	Density (g/cm3)	Tensile strength (MPa)	Thermal conductivity (W/m.K)	Hardness HRC
Mechanical Properties	8.1	245	25.5	58

Coated carbide inserts, along with the tool holder (PSBNR 2525M-12) were used in the present investigation.In order to compromise experimental runs and experimentation cost and also to search for the optimal process condition through a limited number of experimental runs, Taguchi's L9 orthogonal array consisting of 9 sets of data was selected.The response variables measured were cutting force (Fz) and surface roughness.The average surface roughness (Ra), obtained on workpiece after first pass of machining with each tool, was measured with a Taylor Hobson Precision Surtronic 3+ selecting . MQL set-up and surface roughness measurements are shown below

Fig-1 Experimental set-up with MQL

Fig-2 Surface roughness measurement

3.Design of Experiment by Using Taguchi Method

Dr. Genichi Taguchi is regarded as the foremost proponent of robust parameter design, which is an engineering method for product or process design that focuses on minimizing variation and sensitivity to noise. When used properly, Taguchi designs provide a powerful and efficient method for designing products that operate consistently and optimally over a variety of conditions. MINITAB provides both static and dynamic response experiments in a static response experiment; the quality characteristic of interest has a fixed level. The goal of robust experimentation is to find an optimal combination of control factor settings that achieve robustness against (insensitivity to) noise factors. The table below shows the L9 orthogonal array of Taguchi method to carry out experiments three input parameters are selected and each parameter has been different in three levels as low, medium and high. In this thesis L9 orthogonal array used with total 18 number of experiment performed to analyze the characteristics of machining parameters.

Table 3.1 Levels selected for experiment are shown below.

Process Parameters	**Level 1**	**Level 2**	**Level 3**
Speed(rpm)	750	0.20	1.5
Feed(mm/rev)	500	0.18	1.2
Depth of cut(mm)	350	0.16	0.9

4. RESULTS AND DISCUSSION

L9 orthogonal array used with, total 18 numbers of experiments performed and calculated the mean of 18 experiments for the Surface roughness (Ra) and the results are discussed.

Table-4.1 Observational Data For MRR

Expt No.	**v(rpm)**	**f(mm/rev)**	**d(mm)**	**Ra(μm)**	**SNRA1**	**Ra*(μm)**	**SNRA1***
1	750	0.2	1.5	0.897938	0.93507	0.457938	6.78387
2	750	0.18	1.2	0.874235	1.16744	0.434235	7.24550
3	750	0.16	0.9	0.756669	2.42188	0.316669	9.98789
4	500	0.2	1.2	0.878975	1.12047	0.438975	7.15120
5	500	0.18	1.5	0.827777	1.64173	0.387777	8.22836
6	500	0.16	0.6	0.819244	1.73173	0.379244	8.42163
7	350	0.2	0.9	0.842947	1.48399	0.402947	7.89504
8	350	0.18	0.6	0.833466	1.58224	0.393466	8.10186
9	350	0.16	1.5	0.874235	1.16744	0.434235	7.24550

5. Taguchi Analysis

Taguchi recommends the use of the Signal to Noise (S/N) proportion to measure the quality characteristics deviating from the desired values. The main principle of measuring quality is that to minimize the fluctuation in the product performance in response to No is factors Noise factors are those that are not under control of the operator of an item and the Signal factors are those that are sector controlled by the operator of the item to make use of its intended functions.The types of Signal to Noise (S/N) proportion 1.Smaller is better:In cases where requirement is to minimize the occurrences of some undesirable product characteristics such as torque ,overcut quality, thrust force etc. need compute the following S/N ratio, η = -10 log [(1/n) * ∑ (yi2)]

2. Nominal is better: Here we have a fixed signal values and the variance around this value can be considered as the result of the noise factors, η= 10log [Mean2/variance]

3. Larger is better: In the set types of engineering problems maximum is expected to be desirable

Table 5.1 Response Table for Signal to Noise Ratios

Level	Speed	Feed	Doc
1	1.411	1.774	1.849
2	1.498	1.464	1.152
3	1.508	1.180	1.416
Delta	0.097	0.594	0.697
Rank	3	2	1

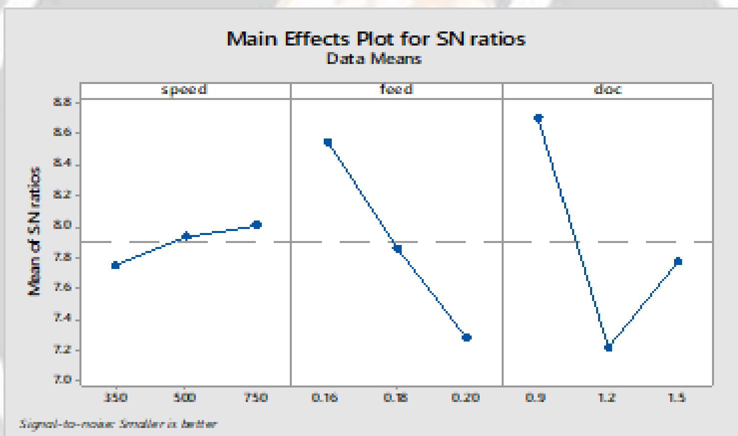

Fig-3 Main Effects Plot (Ra) for SN ratios

From S/N ratio graph fig (3) the greater average SN ratio corresponds to the minimum Ra. From the SN response graph, it is concluded that the optimum parametric combination for Ra is speed 750 rpm, feed at 0.16 mm/rev and depth of cut at 0.9 mm

Table-5.2 Response for Signal to Noise Ratios

Level	**Speed**	**Feed**	**Doc**
1	7.747	8.552	8.704
2	7.934	7.859	7.214
3	8.006	7.277	7.769
Delta	0.258	1.275	1.490
Rank	3	2	1

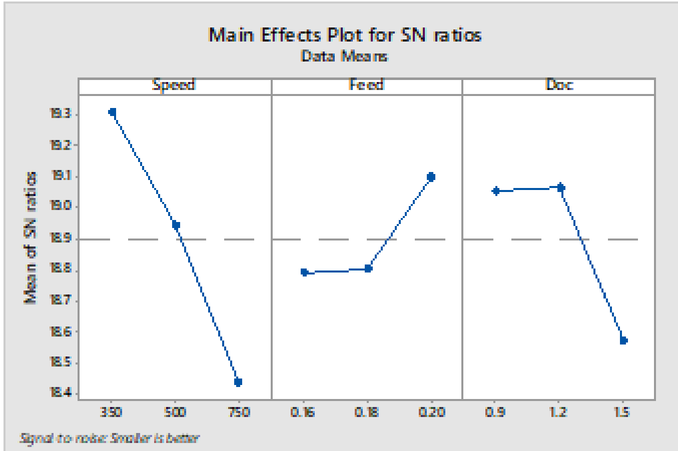

Fig-4 Main Effects Plot (Ra*) for SN ratios

From S/N ratio graph fig (4) the greater average SN ratio corresponds to the minimum Ra. From the SN response graph, it is concluded that the optimum parametric combination for Ra is 750 RPM, Feed 0.16 mm/rev and depth of cut is 0.9 mm

6. Grey Relational Analysis (GRA) Method

In the time of 1980, dim system hypothesis was presented by teacher Deng Ju-long from china Gray analysis utilizes a particular idea of data. It characterizes circumstances with no data as dark, and those with consummate data as white. Be that as it may, neither of these idealized circumstances ever happens in real world. Actually, circumstances between these extremes are escribed as being grey, hazy or fuzzy. Gray analysis is widely used for measuring the degree of relationship between sequences by grey relational grade. Grey relational analysis is applied by several researchers to optimize control parameters having multi-responses through grey relational grade.

6.1 Generation of Grey Relation

The use of full method with grey relational analysis to optimize the turning operations, with multiple performances characteristics includes the following steps

1. Identify the performance characteristics and surface roughness to be evaluated.

2. Conduct the experiments based on the arrangement of the taguchi method.

3. Normalize the experiment results of Ra.

4. Select the optimal level of surface roughness parameter.

6.2 Data Processing

In grey relational analysis, the data pre-processing is the first step performed to normalize the random grey data with different measurement units to transform to dimensionless parameters. Thus, data pre-processing converts the original sequences to a set of comparable sequences. Different methods are employed to pre-process grey data depending upon the quality characteristics of the original data. The original sequence and pre-processed data are represented by $x_0^{(0)}$ (k) and $x_i^{(0)}$ (k) , i=1,2,….m; k=1,2,………,n respectively where m is the number of experiments and n is the total number of observations of data. Depending upon the quality characteristics, the three main categories for normalizing the original sequence are identified as follows:

If the original sequence data has quality characteristic as “ Larger-the-better” than the original data is pre-processed as “ larger-the-better”

$X_i^*(k)$ ……………Eq (1)If the original sequence data has quality characteristic as “larger-the-better” than the original data is pre-processed as “Smaller-the-better”

$X_i^*(k)$ ……………...…Eq (2)However, if the original data has a target optimum value (OV) then quality characteristic is “nominal-the better” and the original data is pre-processed as “ nominal-the-best”:

$X_i^*(k)$……………..Eq (3)Also, the original sequence is normalized by a simple method in which all the values of the sequence are divided by the first value of sequence.Where max $x_i^{(0)}(k)$ and min $x_i^{(0)}(k)$ are the maximum and minimum values respectively of the original sequence $x_i^{(0)}(k)$.Comparable sequence $x_i^*(k)$ is the normalized sequence of the original data.

6.3 Grey Relation Grade

Next step is the calculation of the deviation sequence, $\Delta i(k)$from the reference sequence of pre-processes data $x_i^*(k)$. The grey relational coefficient is calculated from the deviation sequence using the following relation:

$0<\gamma\{X_o^*(k),X_i^*(k)\}\leq 1$……………..Eq(4)

Where the deviation sequence of the reference sequence $x_i^*(k)$ and comparability sequence $x_i^*(k)$.

ξ is the distinguishing coefficient, $\xi\epsilon[0,1]$. The distinguishing coefficient ξ value is chosen to be 0.5. A grey relational grade is the weighted average of the grey relational coefficient and is defined.

GRA for Surface roughness with MQL(Ra) and with MQL an Vortex Tube (Ra^*)

Table-6.1 Input Data for GRA and Grey Relational Coefficients

Expt No.	**Ra**	**Ra^***	**WT1**	$WT1^*$
1	0.897938	0.458	0	0
2	0.874235	0.434	0.004771	0.010174
3	0.756669	0.317	0.028432	0.060715
4	0.878975	0.439	0.003817	0.008136
5	0.827777	0.388	0.014121	0.030146
6	0.819244	0.379	0.015838	0.033814
7	0.842947	0.403	0.011068	0.023624
8	0.833466	0.393	0.012976	0.0277
9	0.874235	0.434	0.004771	0.010174
MAX	0.897938	0.4579	1	1
MIN	0.756669	0.3167		

Table-6.2 Deviation Sequence and Grade

Sr.No.	A1	AVG	GRG	Rank	Sr.No.	A1*	AVG*	GRG*	Rank*
1	1	0.938784	0.954778	1	**1**	0.989258	0.935204	0.956545	1
2	0.995229	0.955473	0.94663	2	**2**	1	0.958498	0.945168	3
3	0.971568	0.96309	0.942957	4	**3**	0.967774	0.95124	0.948684	2
4	0.996183	0.962473	0.943253	3	**4**	0.989258	0.971931	0.938729	5
5	0.985879	0.979799	0.934998	7	**5**	0.978516	0.972122	0.938638	6
6	0.984162	0.968863	0.940192	5	**6**	0.978516	0.960535	0.944186	4
7	0.988932	0.984246	0.932903	8	**7**	1.010742	0.995706	0.927546	9
8	0.987024	0.972336	0.938536	6	**8**	0.978516	0.972332	0.938538	7
9	0.995229	0.989928	0.930239	9	**9**	0.978516	0.988205	0.931045	8

7.CONCLUSIONS

In present work, experimental investigation had been reported on machining performance on Maraging Steel on lathe machine using Minimum Quantity Lubrication. The MRR, TWR and Ra are studied with various parameters are Speed, Feed and depth of cut. Regression analysis had been utilized for predicting the relationship between response characteristics (MRR, TWR, and Ra) and process parameters. Taguchi's L9 orthogonal array used to design the experiments for developing the correlation between process parameters and response parameters. L9 orthogonal array was used with total 9 experiments performed to analyse the machining characteristics. The analysis of experimental work was performed using MINITAB 18 statistical software. Grey relation analysis method used to optimize the parameters. Surface roughness of maraging steel with rotation of tool up to 750 rpm possible, which gives better result compared to 500 rpm and 350 rpm.Using GRA (Grey Relational Analysis) optimal process parameters were obtained. The Grey Relational Grade is best at setting are 750rpm speed ,0.20mm3/rev feed and 1.5mm depth of cut. Turning of maraging steel(250MDN) with MQL and Vortex tube process gives low surface roughness as compared to only.

8. ACKNOWLEDGEMENT

The completion of this undertaking would not have been possible without the guidance of Prof.S.S.Sarnobat, Production Engineering Department, D.Y. PatIl College of Engineering, Akurdi, Pune.

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