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Surface Texture Analysis in Turning of Mild Steel using Carbide Inserts

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ABSTRACT

Surface texture is influenced by the machining, cutting parameters. The MOTIF-method is a system for the evaluation of the primary profile and based on the envelope system and is suitable as an alternative to the mean line system. The MOTIF-method determines the upper points of the surface profile, which have an importance for the functional behavior. Roughness and waviness can be evaluated directly based on the diagram of the unfiltered profile. The effects of cutting speed, feed rate and depth of cut on surface texture analysis have been studied. The experiments were conducted to study the effect of machining parameters on turning of mild steel. The total set of experiments carried out is 27. The specimen was turned under different levels and R, Rx and Ar values were analysed. Results obtained concluded that the Feed rate is the significant factor.

Keywords: *Surface Texture; Mild Steel; Turning; MOTIFs; Waviness; Roughness.*

1.0 Introduction

The surface finish quality is important in field of manufacturing which influences the functioning of a component. The product quality depends very much on surface roughness and an increase in surface roughness leads to decrease the product quality. Surface roughness is an important design feature, such as parts subject to fatigue loads, precision fits, and fastener holes and so on. In terms of tolerances, surface roughness is one of the most crucial constraints for the machines and cutting parameters selection. The most common strategy involves the selection of conservative process parameters, which neither guarantees the achievement of the desired surface finish nor attains high metal removal rates.

The real geometry of a work piece has including their micro- and macro-geometrical deviations an effect on the one hand to the functional behavior and on the other hand to the real geometry marks of the whole manufacturing process.

Surface roughness and waviness measurements in industry are internationally widespread performed by stylus instruments. To separate roughness from waviness, the mean line system uses electronic filtering. The MOTIF-method (ISO 12085) offers an alternative evaluation to separate roughness and *waviness* by means of unfiltered profiles. The MOTIF-method is a graphical evaluation with the complete description of roughness and waviness with merely 7 parameters and the evaluation based on the upper envelope line. The MOTIF-method is a system for the evaluation of the primary profile and based on the envelope system and is suitable as an alternative to the mean line system. The MOTIF-method determines the upper points of the surface profile, which have an importance for the functional behavior. Roughness and waviness can be evaluated directly based on the diagram of the unfiltered profile.

The MOTIF-method finds out within these limits the horizontal and vertical properties of the essential profile irregularities without elimination of important profile points. It is very well suited for technical inquiries on unknown surfaces and processes, functions related to the envelope of the surfaces and profiles with very close wavelengths for roughness and waviness.

The objective of this experimental investigation is to ascertain the effects of cutting speed, feed rate and depth of cut in turning of mild steel and surface texture analysis. ANOVA has been used to accomplish the objective. In experimental investigations, statistical design of experiments, L27 orthogonal array has been used for conducting the experiments. Surface texture analysis—a brief review

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2.0 Literature Review

A considerable number of tribological studies have investigated the general effects of the speed, feed, and depth of cut, nose radius and others on the surface roughness. These studies have been briefly discussed for the variations observed experimentally. Mike Stewart [18] tribologist have demonstrated that an ideal bearing surface is a smooth one with relatively deep scratches-to hold and distribute lubricant, but quantifying and specifying these surfaces has always been a problem. The normalized abscissa and highest peak reference commonly used for plotting the bearing area curve limits its use for quantitative analysis, but when plotted on an absolute scale with a mean line reference, it becomes a powerful analytical tool for evaluating and specifying bearing surfaces. M. Dietzsch et al, [17] worked on surface roughness and waviness. Minodora Rîpă et al [19] worked for tribological characterisation of surface topography, analyses based on Abbott-Firestone Curve and concluded with useful information about some special functioning properties as bearing, sealing and lubricant retaining capabilities. Ulvi Seker et al [36] worked on ductile iron due to its enhanced strength, ductility and toughness, ductile iron has poor machining properties when compared to flake graphite cast iron. The results of machining tests of ductile irons (DIs) alloyed with Ni and Cu at various amounts to determine the effect of their microstructures and mechanical properties on cutting forces and surface roughness. In this study, among mach inability criteria, only cutting forces and surface roughness were investigated. G. Petropoulos et al [10] worked on the surface motif combination, ISO 12085:1996, a method of analyzing surface texture alternatively to the central line system ‗M'. It gives a graphical evaluation of surface profile using mainly six parameters without filtering waviness from roughness. Another functional roughness characterization is introduced by the DIN 4776 and ISO 13565-2 standards through the ‗'Rk'' parameters, which describe the shape of the relevant Abbott curves. This study presented the application of both the aforementioned methods in the analysis of turned textures carrying out turning tests for cutting conditions varied over a representative range. Yusuf Sahin and Riza Motorcu A. [39] developed a surface roughness model for turning of mild steel with coated carbide tools. The model was developed in terms of cutting speed, feed rate and depth of cut, using response surface methodology. S. Thamizhmanii et al [34], worked on the analysis of optimum cutting conditions to get lowest surface roughness in turning SCM 440 alloy steel by Taguchi method. G. P. Petropoulos [9] worked on complexity of machined surface profiles and the contemporary demands for functional characterization, multi- parameter analysis of roughness recommended by international surface metrology standards, as well as by research studies.

S. Thamizhmanii et al [33] studied the application of the Taguchi method parameter design to optimize the surface roughness, tool wear and cutting force by hard turning process. D. I. Lalwani et al [5], studied the effect of cutting parameters (cutting speed, feed rate and depth of cut) on cutting forces (feed force, thrust force and cutting force) and surface roughness. K. Palanikumar et al [15], worked on Fibre-reinforced plastic (FRP) composite materials This paper presented a study of influence of cutting parameters on surface roughness parameters such as Ra, Rt, Rq, Rp and R3z in turning of glass fibre reinforced composite materials. Empirical models were developed to correlate the machining parameters with surface roughness. J. Paulo Davim et al [13] , developed a surface roughness prediction models using artificial neural network (ANN) to investigate the effects of cutting conditions during turning of free machining steel. Chen Lu [4], studied the surface profile and roughness of a machined workpiece. W. Grzesik and Brol S. [38], worked on the surface profiles generated in longitudinal turning operations were characterized using continuous wavelet transform (CWT) and normalized fractal dimension T.H.C. Childs et al [35], worked on surface roughness, achievable mainly with cemented carbide but also with single crystal diamond round nosed turning and facing inserts, was experimentally studied, machining aluminium on engineering and precision lathes.

Adriana Carmen Cîrstoiu [2] worked on experimental determination of the influence of the cutting tool nose radius on surfaces roughness in case of external turning. A roughness evaluation by its correlation with Abbott-Firestone curve and statistical distribution of the amplitudes of roughness profiles was undertaken. By studying the bearing area ratio and the Abbott-Firestone curve, it was noticed that as the roughness decreases, the lift (bearing area ratio) increases. Adeel H et al [1] worked on experimental study is to optimize the cutting parameters using two performance measures, work piece surface temperature and surface roughness. E. Daniel Kirby [7] worked on lowest surface roughness, which usually requires the lowest possible feed rate and therefore a long cutting time. Khaider Bouacha et al [16] worked on experimental study of hard turning with CBN tool. The relationship between cutting parameters (cutting speed, feed rate and depth of cut) and machining output variables (surface roughness, cutting forces) through the response surface methodology (RSM) were analysed and modeled. The combined effects of the cutting parameters on machining output variables were investigated while employing the analysis of variance (ANOVA). The depth of cut exhibited maximum influence on cutting forces as compared to the feed rate and cutting speed. During tool–work piece interaction, it was found that the machined material hardness plays a dominant role in the variation of the cutting forces than cutting speeds. Also, the higher the feed rate and cutting depth, the higher the cutting force, whereas the higher the cutting speed, the lower the cutting force.

The depth of cut exhibits maximum influence on cutting forces as compared to the feed rate and cutting speed. It was also noted that the thrust force is the largest force component regardless the cutting conditions, and it is most sensitive to work piece hardness, negative rake angle and tool wear evolution. Esteves Correia A. and Paulo Davim J.

[8] worked on surface roughness using wiper inserts, which are increasingly being utilized in last year‘s. This study considered the influence of the wiper inserts when compared with conventional inserts on the surface roughness obtained in turning. It was possible to get surface quality in work piece of mechanics precision without cylindrical grinding operations.

Finish machining with wiper inserts provided a similar roughness when compared with machining with a low feed rate using conventional inserts. With high feed rate conventional inserts presented high values of surface roughness when compared with wiper inserts.

3.0 Experimental Work Details

The material used for conducting experiments is mild steel (IS: 2062-2006 Grade: E-250 (Fe410W) B). The experiment was carried out on lathe machine on mild steel (44mm diameter) with carbide tool and surface texture is measured by using instrument Surtronic 3+. The experiments were conducted according to the Taguchi design of experiment as per Table-1. The results of 27 tests are shown in table-2.

Tool material

The cutting tool which is used for the present work was a carbide tip-KC5525. The basic properties of carbide tools have high hardness over a wide range of temperature; are very stiff (Young‘s modulus is nearly three times that of steel); have low thermal expansion compared with steel; relatively high thermal conductivity: and a strong tendency to form pressure weld at low cutting speed, these are weak in tension than in compression. Their high hardness at elevated temperature enable them to be used at much faster cutting speed (3 to 4 m/sec with mild steel)superior hot hardness and wear resistance. These can retain cutting hardness up to 700oC and have high wear resistance [14].

The tool used was cemented carbide insert type with tip radius 0.8mm. The work piece material was mild steel grade IS: 2062-2006 Grade: E-250 (Fe410W) B. Inserts used in this study can provide significant advantages in rough turning operations. The slightly higher cutting forces generated by the wiper insert is not a factor in a roughing operation. Consistent results in finishing operations are greatly influenced by the condition of the work piece material before the last pass is taken.

If chatter exists after the rough pass, it will continue to the finish pass and be very difficult to remove.

Thus, if a wiper insert is used in the turning operation prior to finishing, the work piece will have a superior surface for the final cut by the finishing tool.

This enhance surface before finishing will improve the ability of the finishing insert to hold size longer and cut more accurately. Using wiper inserts for roughing will improve surfaces for better finishing cuts, regardless if a wiper insert is used for the final finishing cuts.

Experimental plan and cutting conditions

Table 1: The Process Parameters and Their Levels

Process parameters	Levels		
	1	2	3
Speed (m/min) , V	62.17	98.09	154.74
Depth Of Cut (mm) , d	0.2	0.25	0.3
Feed (mm/rev) , f	0.2	0.3	0.4

The experimental work was carried out at DTU Metal cutting Lab, on a turning center. Cutting conditions were selected based on some preliminary investigations.

An L27 orthogonal array was selected for the present work.

The non-linear relationship among the process parameters can be revealed when more than two levels of the parameters are considered. Hence each selected parameter was analyzed at three levels.

The process parameters and their values at three levels are given in Table 1.

Twenty seven experiments were performed. For each experimental trial, a new cutting edge was used.

The version 13 of the Minitab was used to develop the experimental plan and same software was also used to analyze the data collected.

A systematic approach was used to reduce the cost and time of experiment and analyse the mean effect of the data collected from result graphs.

4.0 Analysis and Discussion

Table 2: Machining Data for Roughness and Waviness Motifs

S. No.	V	d	f	R (µm)	Rx (µm)	Ar (µm)
1	1	1	1	22.3	40.7	348
2	2	1	1	12	20.1	232
3	3	1	1	8.94	17	232
4	1	2	1	20.7	42.7	312
5	2	2	1	14.9	26	188
6	3	2	1	5.22	11.1	216
7	1	3	1	16.9	28.1	272
8	2	3	1	14.5	30.2	288
9	3	3	1	8.1	14.7	184
10	1	1	2	22.3	40.7	348
11	2	1	2	14.1	20.1	260
12	3	1	2	6.98	11.7	232
13	1	2	2	20.7	42.7	312
14	2	2	2	12.4	30.4	216
15	3	2	2	6.08	15	200
16	1	3	2	15.7	37.7	256
17	2	3	2	12.4	18.8	260
18	3	3	2	6.32	12.6	224
19	1	1	3	21.2	35.2	372
20	2	1	3	10.1	18.1	256
21	3	1	3	12.6	16.9	328
22	1	2	3	19.1	38.2	280
23	2	2	3	11.6	20.9	324
24	3	2	3	10.3	15.7	316
25	1	3	3	22.3	34.7	344
26	2	3	3	9.54	19.5	244
27	3	3	3	9.92	15.3	228

Fig 1: Roughness and Waviness Motifs (ISO 12085)
V=62.17, d=0.2, f=0.2

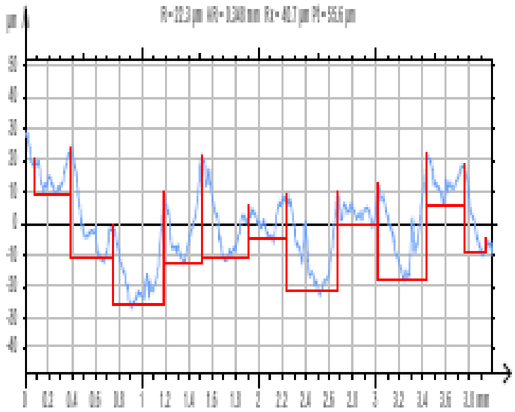


Fig 2: Roughness and Waviness Motifs (ISO 12085)
V=98.09, d=0.2, f=0.2

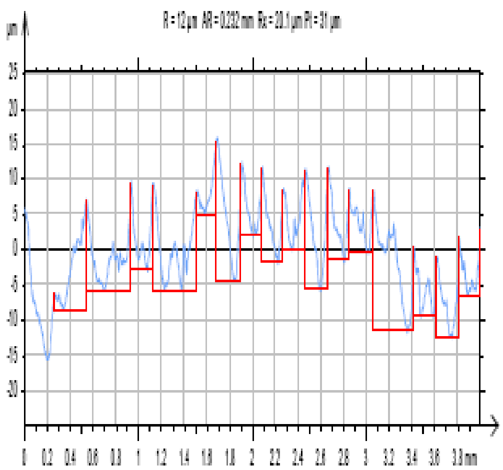


Fig 3: Roughness and Waviness Motifs (ISO 12085)
V=154.74, d=0.2, f=0.2

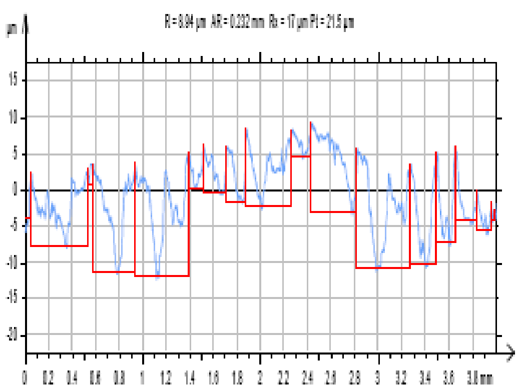


Fig 4: Roughness and Waviness Motifs (ISO 12085)
V=62.17, d=0.25, f=0.3

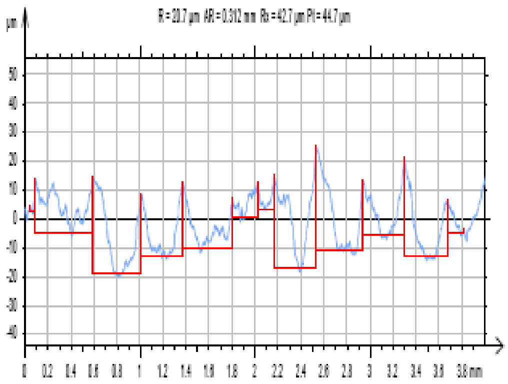


Fig 5: Roughness and Waviness Motifs (ISO 12085)
V=98.09, d=0.25, f=0.3'

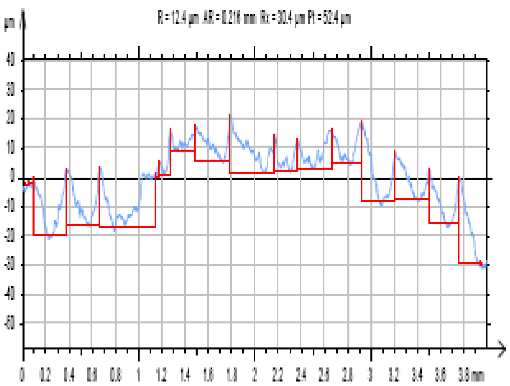


Fig 6: Roughness and Waviness Motifs (ISO 12085)
V=154.74, d=0.25, f=0.3

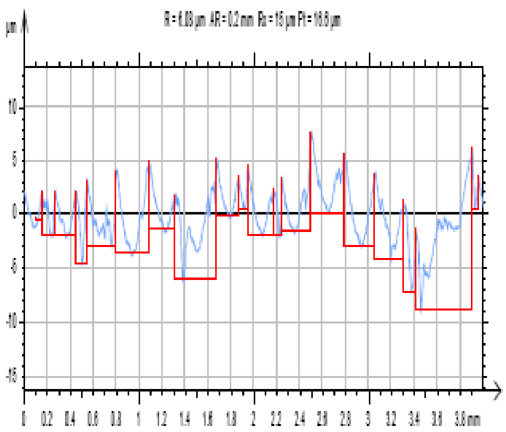


Fig 7: Roughness and Waviness Motifs (ISO 12085)
V=62.17, d=0.3, f=0.4

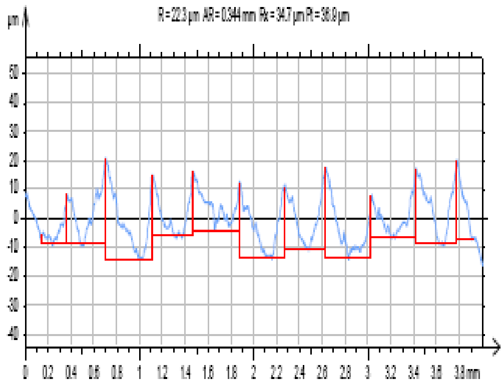
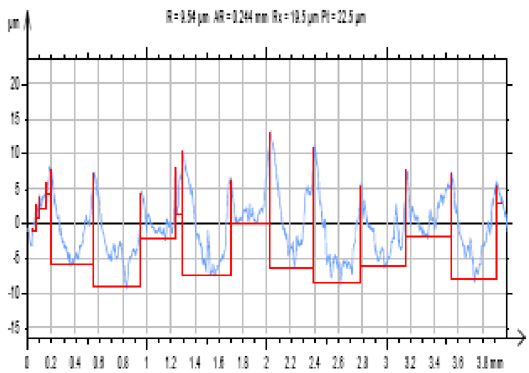
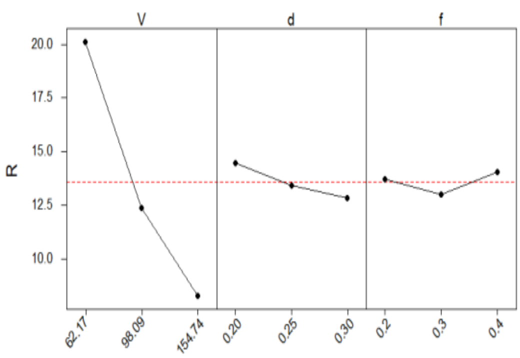


Fig 8: Roughness and Waviness Motifs (ISO 12085)
V=98.09,d=0.3, f=0.4



Roughness and Waviness Motifs (ISO 12085) for "R" Parameters R (Average depth of roughness motifs) decrease with increase in cutting speed and depth of cut. R decrease up to 0.30mm/rev. and then increase with increase in feed.

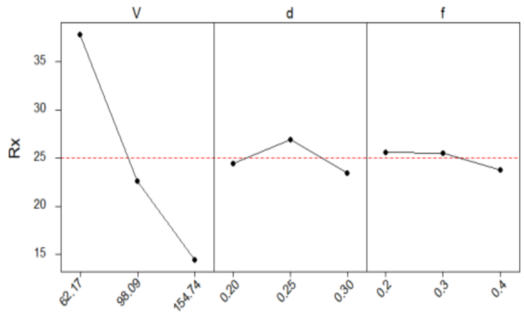
Fig 9: Main Effects Plot - Data Means for R



Roughness and Waviness Motifs (ISO 12085) for "Rx" Parameters

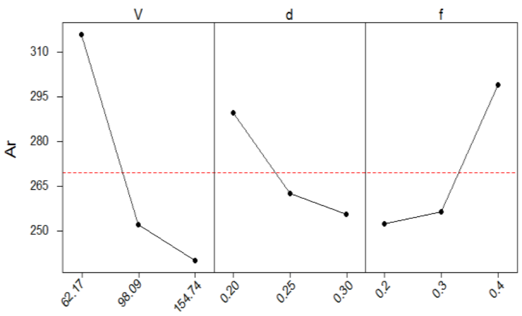
Rx (Maximum depth of roughness motifs) decreases with increase in cutting speed.

Fig 10: Main Effects Plot - Data Means for Rx



Roughness and Waviness Motifs (ISO 12085) for ―Ar‖ Parameters

Fig 11: Main Effects Plot - Data Means for Ar



Ar (Average spacing of roughness motifs) decreases with increase in cutting speed and depth of cut whereas Ar increases with increase in feed.

5.0 Conclusions

The conclusions drawn from the results and graphs display clearly that Feed rate is the significant

factor. Optimum values of Rx are 154.74 m/min, 0.4mm/rev and 0.3mm. Optimum values of Ar are 154.74 m/min, 0.2mm/rev and 0.3mm. Optimum values of R are 154.74 m/min, 0.3mm/rev and 0.3mm.

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