STUDY THE INFULENCE OF MACHINING PARAMETERS ON THE INCLINATION OF FLANK WEAR LAND WITH CUTTING DIRECTION.

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ABSTRACT : *In this work an attempt is made to demonstrate the existence of the nonzero inclination of flank wear land with cutting direction. The wide usage of edge prepared tooling in modern manufacturing industry encouraged to conduct this study. The machining parameters like speed, feed, rake angle and clearance angle influence the flank inclination. The orthogonal turning experiments were carried out for the purpose and Analysis of Variance (ANOVA) tests show that the experimental data collected was statistically significant. Efforts made in this study may enhance understanding of basic mechanism present in the tool and work contact which helps to improve worn tool models or develop new one.*

Key Words: Flank Wear, ANOVA, Machining Parameters

1. INTRODUCTION

Growing use of hard turning, micro and nano machining technologies in modern industries encourage studying the different aspects of tool's micro geometry. Efforts are on to understand and improve the basic knowledge about physical phenomena and its characterisation of above mentioned techniques of machining. Machining with flank wear land typically represents the conditions prevailing in the micro and nano machining. Slip line field theory was used to describe the fundamentals of machining process which has potential to predict the material flow below tool edge and ploughing effects. These models consider different tool edge conditions such as sharp [1-5], rounded[6-11], chamfered [12-13], worn or flank wear [14-21].The machining performance is known to vary significantly with the progression of overall tool wear. This is because the flank wear of cutting tool alters the micro geometry of tool /configuration thus resulting in unexpected machining performance.

Shi and Ramlingam [14] developed a slipline model with a chip breaker and flank wear land. A nonzero inclination of flank wear land with respect to the cutting direction is assumed and the inclination angle is determined as a part of the problem solution. The work was based on the observation made by Thomsen and Kobyashi [22],who conducted experiments to studied the force variations due to flank wear and they found that when the tool flank was parallel to the cutting direction , the cutting force components are virtually constant and do not vary with the size of the flank wear in orthogonal cutting. Practically it was observed that the force components vary with flank wear during machining. This clearly indicates the flank wear land cannot be parallel to the cutting direction. S T Dundur and N S Das [15] developed the slip line model for the for worn tool by considering non zero inclination of flank wear land with cutting direction. They considered adhesion friction conditions at the interface of chip-tool and tool-work regions based on the frictional law suggested by Maekawa et al.[23]. Kountanya and Endres[16] studied the effect of flank wear of radiused tool under orthogonal cutting conditions. They captured images of evolving geometry of a flank worn, edge radiused tool. The boundary of the fresh tool was marked on them. These images throw some light on the inclination of flank wear land. Karpat and Ozel [17] developed a predictive model to determine the forces, stresses and temperature distribution in presence of tool flank wear. They combined the oblique moving band heat source theory with non-uniform heat intensity at tool chip interface and modified Oxley's[24] parallel shear zone theory with ploughing effects due to tool flank wear to predict cutting forces, stress and temperature distributions. Zhao et al.[18] studied the effect of degree of the flank wear on the orthogonal cutting process. They observed increase in tool flank wear produces slight increase in cutting forces but significant increase in thrust forces. Yu Long and

Yong Huang [19] proposed a slip-line field based force modeling approach is proposed to capture the worn tool cutting mechanism under the combined effects of both flank and crater wear in orthogonal cutting. Zhang, Zhen [27] have used the white light interferometry microscope to capture the included angle between tool's rake face and wear land. By discounting all the possible causes in the experimental setup that might change the rake face and cutting velocity direction, the nonzero angle was found between the tool's wear land and the cutting velocity direction. and found a inclination of 3.8^{o} under experimental conditions considered. This finding was used to develop a slip line model for blunt tool. J Wang,C Z Huang ans W G Song [21] have studied effect of flank wear on orthogonal cutting and found that tool flank wear results in a substantial increase in the force components and needs to be incorporated into the cutting performance predictive models. Above literature shows the flank wear significantly affects the machining process. The slip line models were developed based the non zero inclination of flank wear land. But there is very little experimental evidence to support this. The present work makes an effort to experimentally prove the presence of flank wear land inclination with cutting direction and to study influence of machining parameters on the flank wear land inclination.

2. EXPERIMENTAL TEST

2.1 Materials

In this research work, commercially available IS 1239 mild steel pipes with a thickness of 4 mm were used for conducting orthogonal turning tests. The chemical composition of the steel being C%-0.2,Mn%-1.30,S%-0.040,P%-0.040 and hardness of HRC 30.

2.2 Cutting tool

A square HSS M2 grade tool bits manufactured by Miranda Tools were used to machine the MS pipes. The composition of tool (by %wt) is C-0.85%, W-8%, Mo-5% Cr-4% V-2% ,Co-0%. This HSS M2 grade is considered to obtain speedy wear on the flank face, as it has zero cobalt. To

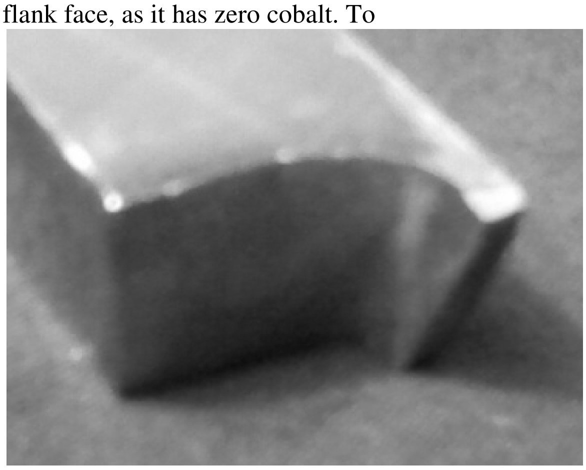

Figure 1: Photo of modified HSS tool bit

capture the two dimensional profile of the flank wear land, tool blanks are grounded on universal tool and cutter grinding machine to have similar geometry like grooving tool with required rake and clearance angles as shown in the Figure 1.

2.3 Machining parameters

Four machining parameters namely speed, rake angle, clearance angle and feed, which have major role in machining operation were selected for the experimental work. These parameters were considered at three levels. The Table 1 provides the details about the machining parameters.

2.4 Experimental equipment

The universal tool grinder is used to prepare the HSS tool blanks as per Central Composite Design (CCD) matrix. The orthogonal turnings of MS tubes were carried out on an all geared HMT precision lathe machine. The flank

Table1: Process parameters and their respective levels

Sl no	Parameters Description			Levels		
	Factors	Codes	Unit	High	Middle	Low
1	Speed	A	Rpm	245	151	54
2	Feed	B	mm / rev	0.036	0.03	0.024
3	Clearance angle	C	Degrees	15	10	5
4	Rake angle	D	Degrees	20	15	10

wear land inclination with cutting direction was measured using Nikon V-12B profile projector with the magnification of 20 X and resolution of 0.01mm.

2.5 Experimental design and procedure

Design of experiments (DOE) techniques applied to determine the individual and interactive effects of process parameters on the response. A popular second order response surface design, CCD was employed to determine the influence of machining parameters on the flank wear land inclination. As per CCD design matrix 31 experiments at three levels were conducted. The work pieces were prepared by skin turning to have a uniform diameter. Then tubes were supported at one end by a three jaw self-centering chuck keeping the minimum overhang to avoid bending due to machining forces. The tool was mounted along the axis of the tube. Machining was carried from free end under dry condition. The total contact between tool and work piece was kept identical by varying the machining length of work piece.

2.6 Measurement of Flank Wear Land Inclination

The tool blank on which flank wear land is formed was placed on the glass table of the profile projector and its shadow image projected on the screen. Then several points were picked along the edge of the rake surface. Then the inbuilt program of the profile projector fits a best line based on selected points. Similarly several points were picked along the wear land edge and again a best line was fit based on the selected points. Then profile projector control unit determines the angle between flank wear land and rake face of the tool (ϕ = ∠wsa) as shown in Figure 2 and same is displayed on the control box unit

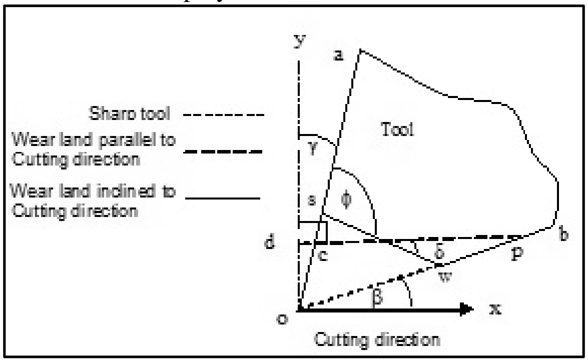

Figure: 2 Geometry of worn tool

screen. If flank wear land is parallel to cutting direction then the included angle between rake face and flank wear land (∠pca = pdy − aoy) will be equal to the

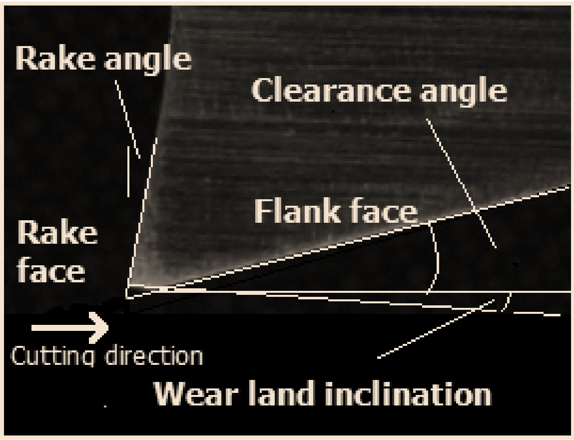

Figure: 3 Image of tool with flank wear land

90^0 minus rake angle (90^0-γ) as depicted in Figure 2. If it is not found to be equal to (90^0-γ) then it confirms, the flank wear land was not parallel to cutting direction but deviates from cutting direction by an angle δ [20]. The determined values of δ for different set of combination of machining parameters as per the design matrix are tabulated for the ANOVA analysis. In Figure 3 lines are drawn on the image of the worn tool to demonstrate the existence of flank wear land inclination with cutting direction. The Figure 3 shows the wear land is inclined in the opposite direction of the clearance angle. This is nature of angle was called as negative clearance angle.

3. Result and discussions

The data gathered by experiments is used to study the correlation between process parameters with the flank wear land inclination with cutting direction. Generally when the response function is unknown a second order model is applied.

In present study also a second order model developed to demonstrate the relationship between the process variable and response. The unknown coefficients are determined from the experimental data as presented in 2.The standard errors on estimation of the coefficients are tabulated in the column as 'SE coef'. The F ratios are calculated for 95% level of confidence and the factors having p-value more than 0.05 are considered insignificant. From the Table 2 it is evident that the following terms are significant - rake angle, square terms of

Table:2 Regression Coefficients for Flank Wear Land Inclination

Term	Coef SE	Coef	T	P
CONSTANT	-19.6	20.8	-0.943	0.360
A	-0.1	0.0	-1.404	0.179
B	2997.2	1520.1	1.972	0.066
C	-1.1	0.8	-1.260	0.266
D	-2.6	1.2	-2.227	0.029
A^2	-0.0	0.0	-1.507	0.151
B^2	-60192	25006.1	-2.407	0.029
C^2	0.0	0.0	1.158	0.264
D^2	0.1	0.0	2.608	0.0191
A*B	1.2	0.6	1.838	0.085
A*C	0.0	0.0	6.286	0.000
A*D	0.0	0.0	1.366	0.191
B*C	38.0	12.1	3.142	0.006
B*D	5.7	12.1	0.475	0.641
C*D	-0.1	0.0	-4.734	0.000
S = 1.450	**R-Sq = 91.3%**		**R-Sq(adj) = 83.7%**	

rake angle and feed, interaction terms between speed, feed and clearance angle and clearance angle and rake angle. The flank wear land inclination was consequence of collective effect of process parameters, as more interactive terms were found to be significant. The important coefficient value of ANOVA Table 2 is R^2, coefficient of determination is 91.3 %. This indicates the better fitting of the second order model with the observed data. The value of R^2_{adj} is 83.7%, which accounts for the number of predictors in the model describe the significance of the relationship. The normal probability plot of residuals shown in Figure 4 and

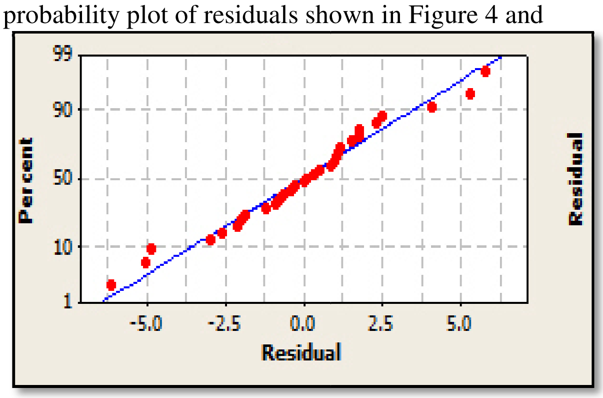

Figure 4: Normal Probability Plot of Residuals

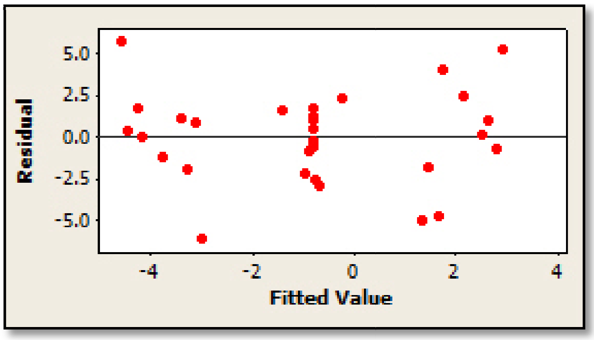

Figure: 5 Plot of Residuals and Predicted values

residuals verse fitted values plot shown in Figure 5 were used to check the sufficiency of the second order model. All the point in normal probability plot of residuals lay close to the line; it implies that the data were normal. There is no noticeable pattern or unusual structure present in the data as depicted in Figure 5. It means a reasonably well fitted regression model can be developed with the observed values. The ANOVA Table 3 for flank wear land inclination shows the p value for lack of fit is insignificant, this indicates the Second order model is statistically significant for analysis of flank wear land inclination.

Table 3 ANOVA for Flank Wear Land Inclination

Source	**DF**	**Seq SS**	**ADj SS**	**ADj MS**	**F**	**P**
Regression	14	326.74	326.74	23.338	2.52	0.040
Linear	4	164.57	46.40	11.601	1.25	0.030
Square	4	36.7	36.7	9.118	0.98	0.044
Interaction	6	125.69	125.69	20.949	2.26	0.050
Residual Error	16	148.41	148.41	9.275		
Lack-of-Fit	10	107.33	107.33	10.733	1.57	0.301
Pure Error	6	41.08	6.846	6.846		
Total	30	475.14				

The main effect of machining parameters on the response is shown in Figure 6 The flank wear land inclination shows a linear relationship with clearance angle. Its value decreases with the rise in the values of rake angle. The feed and speed show a little effect on the formation of flank wear land inclination.

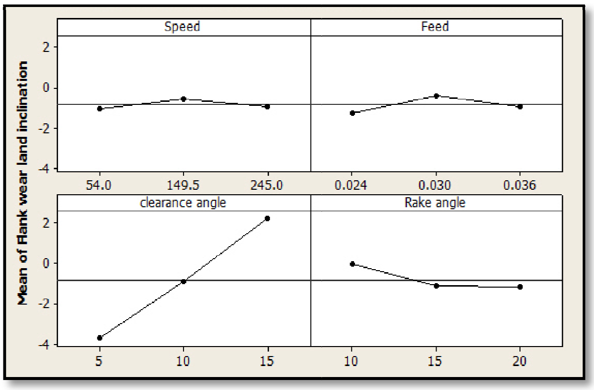

Figure: 6 Main effect plots for Flank Wear Land Inclination

The contour plots are utilized to explain the interaction between different process parameters. The Figure 6 shows the interaction effect of clearance angle and speed for flank inclination. For higher values of clearance angle and speed the inclination value is zero or positive, it means flank face wears in the same direction as that of clearance face. At lower values of the clearance angle, contact between the flank face and work piece becomes more resulting in to higher negative inclination angle the same is demonstrate in the figure. At higher speed the strength of tool reduces because of higher cutting temperature. Under this condition when tool rubs over the work piece surface more flank wear takes place which may result into higher negative wear land inclination .Figure 7 depicts the interaction effect of clearance angle and feed. At low feed rate the clearance angle will govern formation of the negative flank wear land inclination and vice versa is also true. This contour plot shows lower values of negative flank wear land angle at higher values of feed and clearance. The 8 shows the interaction between rake and clearance angle with flank inclination. The pattern of contour depicts that the variation in flank wear land inclination is the result of combined effect rake and clearance angle. At higher values of rake angle and clearance angle the flank wear land angle has higher positive value.

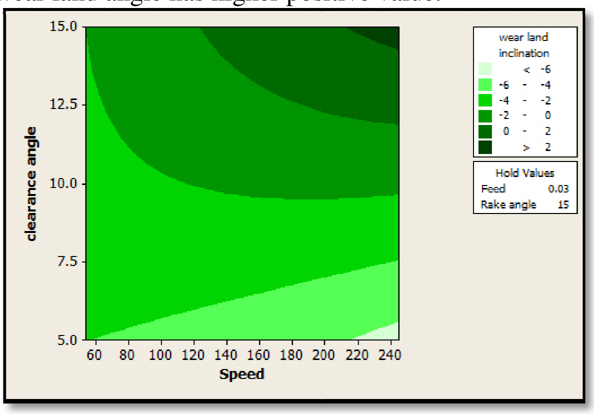

Figure:7 Contour plot of Flank Wear Land Inclination vs Clearance angle, Speed

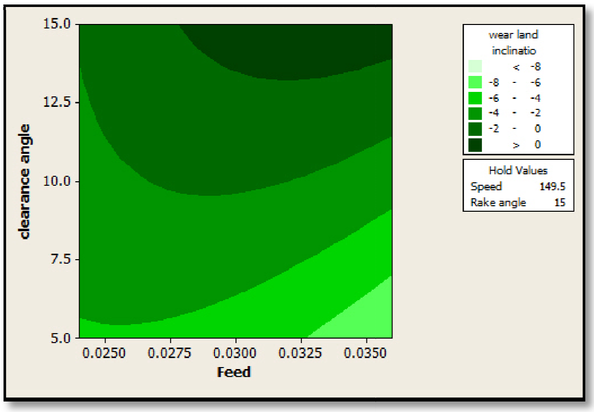

Figure:8 Contour plot of Flank Wear Land Inclination vs Clearance angle, Feed

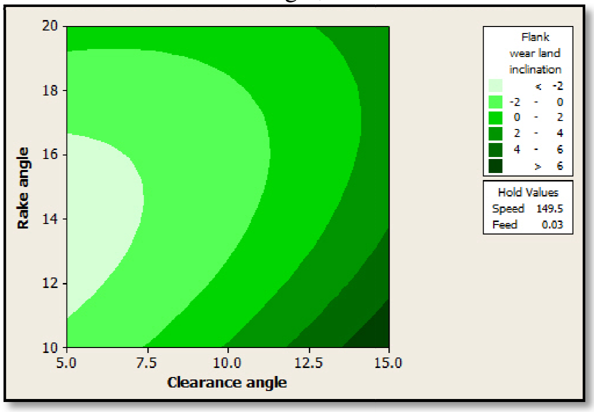

Figure:9 Contour plot of Flank Wear Land Inclination vs Clearance angle, Rake angle

This substantiates, for better performance of machining higher values of rake and clearance are recommended.

4. CONCLUSIONS

The orthogonal machining experiments were conducted by modifying the HSS M2 grade tool blanks as grooving tools, to enable the profile projector to capture the profile of flank wear land. The observed data confirms presence of non zero inclination of flank wear land with cutting direction. Analysis of Variance (ANOVA) demonstrates the correlation between machining parameters and flank wear land inclination. The geometric parameters of the cutting tool, rake and clearance angles have great influence compare to other machining parameters namely speed and feed. Inclusion of flank wear land inclination in cutting models may improve the basic knowledge about physical phenomena of edge prepared tools. The authors are working in this direction.

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