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MEASUREMENT OF FLANK WEARS USING EDGE DETECTION METHOD

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Abstract

In machining of parts, the rate at which inserts wear plays a crucial role in terms of economics of the cutting tools and hence understanding the inserts wear is of utmost importance. Turning tool wear monitoring is vital in metal cutting industry in terms of dimensional accuracy, shape deviations and overall surface quality. This paper reports a novel edge detection technique which is based on canny algorithm, for the measurement of flank wear of bonded and brazed tools in turning operation.A standard 2^4 full factorial experimentation has been designed to analyse the experimentally observed data. The photograph of the used tools was taken and edge detection technique was used for finding the boundaries within these images. The edge detection algorithm Canny was used for this purpose. Input to the programme was in the form of photograph. The input indexed image was converted to gray scale. MATLAB 14.0was used for the measurement of the flank wear of the tools bysuccessfully implementing the canny algorithm.The results of the tool wear obtained from the edge detection technique are experimentally validated with those obtained from the regression models. This study shows that edge detection technique can be effectively used for the wear measurement of tools. This technique can defiantly be used in the manufacturing industries for tool wear monitoring and measurement.

I. INTRODUCTION

Turning operation is one of the most important and widely used subtractive manufacturing methods. In machining of parts, the rate at which inserts wear plays a crucial role in terms of economics of the cutting tools and hence understanding the inserts wear is of utmost importance. [1] Turning tool wear monitoring is vital in metal cutting industry in terms of dimensional accuracy, shape deviations and overall surface quality. Traditional wear measurement technique includes: Indirect and direct wear measurement. Direct wear measurement technique applies direct approach of tool wear quantity. Offline technique like optical microscope is used for direct measurement of tool wear. Normally, most of the offline tool wears measurement techniques are time consuming.[2] Cutting tool monitoring review indicates that tool wear condition can be successfully monitored by many direct measurement techniques such as machine vision.[3,4,5,6,7] Deep learning models can be effectively used for image processing provided sufficient data is available for the training purposes. White light interferometry [8, 9, and 10] can be used for measuring both types of wear. Indirect tool measurement involves measurement of various process parameters which have a correlation with tool wear. Indirect wear measurement includes, correlating wear with the changes in the parameters such as temperature, surface finish and force.[11] The surface irregularities due to tool wear can also be a criterion of determination of possible tool wear. Decimated wavelet transform decomposes the surface image of the given work piece to the sub- mages, which ultimately indicates the cutting tool wear.[11]Thechange in the original boundary indicates wear of the inserts. This worn boundary of the inserts helps find the probability functions which can accurately relate the worn boundary with original boundary with the aid of Bayesian Inference.[11, 12] Cutting tools wear can also be measured with the aid of two-dimensional matrices feature in MATLAB software, thus the method helps in monitoring any change in the insert shape. [13, 14] In turning operation, turning tool is subjected to two types of wear: crater wear and flank wear [11]. The severity of the cutting tool can easily be quantified with flank wear as compared to crater wear of the tool. Another tool that can be used for measuring the flank wear is unitary methodology. [15]The intent of this work is to develop a reliable method for predicting the flank wear of the turning tool. In Image processing images taken are treated as two dimensional signals by applying already set signal processing methods. Flank wear of the turning tools can be effectively measured by using edge detection methods. In edge detection technique the boundaries of objects within images are detected. Boundaries of the images are detected by detecting discontinuities in the image boundaries due to brightness. Edge detection is specifically used for image segmentation and data extraction in areas such as image processing, computer vision, and machine vision. Many edge detection algorithms are used. The algorithms that can be used are sobel, Canny, Prewitt, Roberts, and fuzzy logic methods. Canny algorithm which is rarely used earlier has been used for wear measurement in this experimentation.

II. METHODOLOGY

Today, image processing system is therapidly growing technologies, with its applications in many areas in the field of engineering and computer sciences. The methodology adopted in this work is explained here.

Experimental Planning

The aim of the study was to measure the insert wear during the turning operation. Trials were conducted on a HMT TL 20 lathe. Aluminium 6061workpieceswas used. Aluminium 606 It has good mechanical properties, good weld ability and is used for general-purpose machining. The dimensions of Aluminium 6061 alloy work pieces include 250 mm in length with an external diameter of 50 mm. The shank material was mild steel with a cross section 16 mm square and having triangular shaped carbide inserts. Carbide insert used are of 16 mmside with internal sides of 14 mm. The insertsTPKN2204P30was used and has got the specificationas: Inscribed circle (IC) of 9525 mm,Insert thickness of 3mm andNose radius of 0.8 mm. The cutting edge condition is of negative land and shape of the selected inserts was equilateral triangle. The tool geometry designated was of Side rake angle - 5º and back rake angle of 5º The End clearance angles of 5º with Side clearance angle of 5º and Side or End cutting edge angle was of 15º. The turning process parameters were selected by a comprehensive literature survey. Pilot experiments were conducted for selecting the appropriate levelsof cutting parameters likedepth of cut, cutting speed, feed rate and the coolant flow rate required in this experimentation. [16, 17] The selected cutting conditions for performing experimentation are specified in the Table 1.

Experimental Design

The experimental design was planned by using Design of Experimentation (DOE) [15]. The methodology has been used to analyse the experimentally observed data. A standard 2^4 full factorial experimentation was designed. The independent parameters viz. cutting speed, Feed rate, Depth of cut (X3) and Coolant flow rate were selected. The conventional brazed and bonded tools were used for this experimentation and measurement of wear of these tools was taken into consideration. The edge detection technique used for tool wear measurement has been explained in subsequent topics.

Tool Wear Measurement

Here, wear measurement of the tools used in this experimentation was carried out through image processing. It is a method of converting the images of wear into its digital form and then performing somekind of operations on it, for getting an enhanced image. This is basically done for extracting some important information. The method adapted is type of signal dispensation. Here input is a digital image and output is also an image or characteristics that are associated with the input image. In this type of signal processing system, an input image was treated as two dimensional signals.Set signal processing methods was applied to these images.Edge detection technique was used for measurements of the flank wear of the cutting tools. The photograph of the used tools was taken and edge detection technique was used for finding the boundaries within these images. The edge detection algorithm Canny was used for this purpose.The advantage of using canny algorithm is that it reduces the amount of data to be processed. Input to the programme was in the form of photograph as shown in the figure 1. Gray scale is usually the preferred format for image processing. The input indexed image was converted to gray scale. MATLAB 14.0 was used for the measurement of the wear. Output being the last stage represented an altered image or final report of the image analysis. The sample results of the measurement of flank wear of turning tools for some trials are shown in the Figure 2.

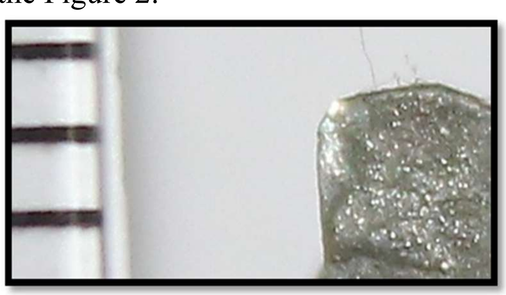

Figure 1: Input Image of Flank Wear

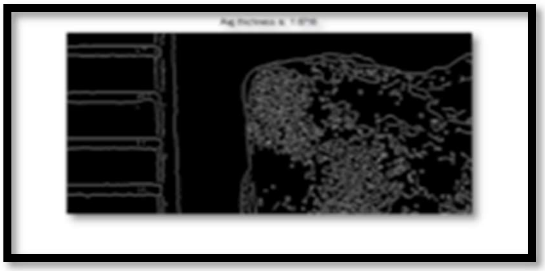

Figure 2: Flank wears of Turning Tools

III. RESULTS

The results of wear measurement by using edge detection technique are presented here.The primary aim of this study was to measure the tool wear during the turning operation. Carbide inserts TPKN2204P30 was used.Aluminium 6061 alloy work pieces having 50 mm diameter were used. Chemical composition of the Aluminium 6061 alloy work pieces are shown in the Table 2. Fresh carbide inserts were used for every turning operation in order to ensure similar working conditions. Machining time for all the specimen was around 5 minutes with the input cutting conditions represented in the Table 3 and Table 4. Conventionalbrazed tools and adhesively bonded tools were used in this experimentation. Total 16 trials on each turning tools with two replications and three repetitions were conducted. The edge detection canny algorithm was used for this purpose. The input indexed image was converted to gray scale. MATLAB 14.0 was used for the measurement of the wear. The results of measurements of insertswear for adhesively bonded tools and brazed tools respectively were shown in Table 3 and Table 4. This study shows, application of edge detection for the measurement of cutting tools wear in the turning operations.

Table 1 Cutting Conditions for Aluminium 6061 Work Pieces

Input Factors	Mean Level	Upper Level	Lower Level
Cutting Speed,m/min	150	188	112
Feed Rate, mm/rev	0.10	0.15	0.05
Depth of Cut, mm	0.475	0.70	0.25
Coolant Flow Rate, ml/sec	34	48	20

Table 2 Composition of Aluminium 6061 Alloys

Si %	Fe%	Mn%	Cu %	Mg %	Cr %	Zi %	Ni %	Ti %	Aluminium
0.40-0.8	0.7	0.15	0.15-0.40	0.8-1.2	0.04-0.35	0.25	-	0.15	Balance

Table 3 Flank Wear for Adhesive Bonded Tools for Aluminium - 6061

Tool No.	Cutting speed m/min	Feed Rate mm/rev	Depth of Cut mm	Coolant Flow Rate ml/sec	Wear (mm) Adhesive Bonded Tools					
					Replication 1			Replication 2		
					1	2	3	1	2	3
1	112	0.05	0.25	20	0.19	0.19	0.18	0.19	0.18	0.19

2	188	0.05	0.25	20	0.24	0.25	0.25	0.23	0.26	0.25
3	112	0.15	0.25	20	0.38	0.34	0.35	0.37	0.34	0.36
4	188	0.15	0.25	20	0.53	0.56	0.53	0.53	0.55	0.54
5	112	0.05	0.7	20	0.48	0.41	0.43	0.44	0.45	0.43
6	188	0.05	0.7	20	0.69	0.66	0.64	0.63	0.68	0.68
7	112	0.15	0.7	20	0.98	0.94	0.97	0.96	0.96	0.97
8	188	0.15	0.7	20	1.66	1.59	1.63	1.65	1.61	1.64
9	112	0.05	0.25	48	0.18	0.19	0.18	0.17	0.19	0.19
10	188	0.05	0.25	48	0.22	0.22	0.23	0.23	0.21	0.23
11	112	0.15	0.25	48	0.33	0.34	0.33	0.35	0.34	0.31
12	188	0.15	0.25	48	0.57	0.49	0.48	0.55	0.49	0.50
13	112	0.05	0.7	48	0.35	0.35	0.36	0.36	0.35	0.37
14	188	0.05	0.7	48	0.54	0.58	0.59	0.55	0.57	0.59
15	112	0.15	0.7	48	0.71	0.63	0.65	0.70	0.64	0.65
16	188	0.15	0.7	48	1.59	1.61	1.56	1.58	1.62	1.56

Table 4 Flank Wear for Brazed Tools for Aluminium - 6061

Tool No.	Cutting speed m/min	Feed Rate mm/rev	Depth of Cut mm	Coolant Flow Rate, ml/sec	Wear (mm) Brazed Tools					
					Replication 1			Replication 2		
					1	2	3	1	2	3
1	112	0.05	0.25	20	0.31	0.28	0.28	0.29	0.27	0.31
2	188	0.05	0.25	20	0.32	0.39	0.41	0.35	0.39	0.38
3	112	0.15	0.25	20	0.39	0.45	0.39	0.39	0.42	0.42
4	188	0.15	0.25	20	0.70	0.73	0.66	0.72	0.71	0.66
5	112	0.05	0.7	20	0.63	0.59	0.61	0.62	0.62	0.62
6	188	0.05	0.7	20	0.79	0.80	0.79	0.80	0.78	0.80
7	112	0.15	0.7	20	1.45	1.60	1.47	1.48	1.58	1.46
8	188	0.15	0.7	20	1.80	1.82	1.78	1.79	1.81	1.80
9	112	0.05	0.25	48	0.26	0.24	0.25	0.24	0.26	0.25
10	188	0.05	0.25	48	0.32	0.33	0.31	0.34	0.33	0.29
11	112	0.15	0.25	48	0.38	0.45	0.37	0.40	0.42	0.38
12	188	0.15	0.25	48	0.58	0.56	0.50	0.57	0.55	0.52
13	112	0.05	0.7	48	0.46	0.47	0.46	0.46	0.46	0.47
14	188	0.05	0.7	48	0.73	0.72	0.78	0.76	0.73	0.74
15	112	0.15	0.7	48	0.95	1.05	1.05	0.98	1.02	1.05
16	188	0.15	0.7	48	1.68	1.62	1.58	1.63	1.62	1.63

Formulation of Regression Analysis Model

Regression analysis, a statistical and analytical modelling method was used for evaluating the performance of bonded and brazed tools in terms of tool wear. Their performances on tool wear were studied by varying cutting speed, feed rate, and depth of cut and coolant flow rate. The observed optimalvalues of tool wear calculated from model werecompared with the measured values of tool wear. Table 5 and Table 6 shows the regression analysis models of tool wear for bonded tools and brazed tools.

Table 5: Optimization of Regression Model for Bonded tools

Regression Model for Bonded tools				
Term	**Min**	**Max**	**Coefficient**	**Optimal Solution**
Constant	-	-	0.5906	-
Cutting speed (m/min)	112	188	0.1557	188
Feed rate (mm/rev)	0.05	0.15	0.2323	0.05
Depth of Cut (mm)	0.25	0.7	0.2677	0.25
Coolant flow rate (ml/sec)	20	48	-	-
Tool Wear (mm)	0.146 mm			

Table 6: Optimization of Regression Model for brazed tools

Regression Model for brazed tools				
Term	**Min**	**Max**	**Coefficient**	**Optimal Solution**
Constant	-	-	0.74	-
Cutting speed (m/min)	112	188	0.1212	112
Feed rate (mm/rev)	0.05	0.15	0.2612	0.05
Depth of Cut (mm)	0.25	0.7	0.3288	0.25
Coolant flow rate (ml/sec)	20	48	-	-
Tool Wear (mm)	0.186 mm			

The regression analysis model for the tool wear of bonded tools is:

$$Tw_{bonded} = 0.5906 + 0.1557 *X_1 + 0.2323*X_2 + 0.2677*X_3 +0.0882*X_1*X_2 +0.0978 *X_1*X_3 +0.1194*X_2*X_3$$

Where, X_1 = Cutting speed (m/min)

X_2 = Feed rate (mm/rev)

X_3 = Depth of Cut (mm)

X_4 = Coolant flow rate (ml/sec)

Twbonded = Tool wear of adhesive bonded tools (mm)

The coefficient of correlation [R] between the flank tool wear observed and predicted by the regression model is 0.982 with $R^2 = 96.55$ and $R^2_{adjusted} = 94.25$

Also the regression analysis model for the tool wear of brazed tools (Twbrazed) is:

$$Tw_{brazed} = 0.74 + 0.1212 *X_1 + 0.2612*X_2 + 0.3288*X_3 + 0.1575*X_2*X_3$$

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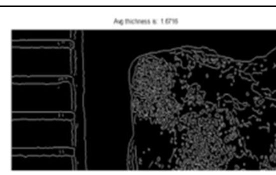
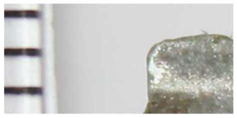
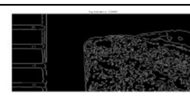
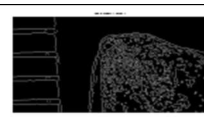
Here the coefficient of correlation [R] between the flank tool wear observed and predicted by the regression model is 0.977 with $R^2 = 95.54$ and $R^2_{adjusted} = 93.32$.The results indicate better correlation between the experimental and predicted values of the flank wear of these tools.

IV. CONCLUSIONS

In the wear measurement of the bonded tools and conventional brazed tools automatic calibration system was implemented successfully.Total cutting tools wear area of inserts (mm^2) is shown in the Table 7. Most of the measured values of flank wear for the bonded tools and brazed tools are found have close agreement with the results obtained from the regression models.This study shows that edge detection technique can be effectively used for the wear measurement. It also helps in understanding the overall condition of the tools. This technique can defiantly be used in the manufacturing industries for tool wear monitoring and measurement.

Table 7: Tool Wear Measurement with Edge Detection Technique

Sr. No.	Wear Zone Captured by Camera	Flank Wear Zone Image	Total Wear Area of Inserts (mm^2)
1			0.942
2			0.961
3			0.312
4			0.354
5			0.716

6			0.594
7			0.782
8			0.254
9			0.224
10			0.321

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