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Technological Investigation of Effect of Machining Parameter on Tool Life

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ABSTRACT

Introduction. The machinability is typical criteria to be investigated and different authors suggested different parameters describing its quantification. Different parameters i. e. speed, feed, depth of cut, tool work-piece combination, machine types and its condition, cutting fluid, machinist expertise, etc. are contributing directly to the tool life. The selection of the tool for the machining impacts greatly on the economic viability of the machining in terms of energy usage and tooling costs. **The method of investigation.** The current research emphasis mainly on tool life investigation when machining the mild steel specimens ISRO 50, BIS 1732:1989 at constant cutting speed i.e. 200 m / min. In the industries the mild steel material is commonly used for various products manufacturing. Considering the high demands on productivity and surface finish, machining at 200 m / min is the preferred. The computerized numerical control machine (CNC DX-150) is used for the turning. The four corner insert (TNMG 120408) is used for different machining times i.e. 10, 15, 20 and 25 minutes respectively. The flank wear of the tool is measured with calibrated optical microscope. The temperature of the tool corner during machining is continuously measured for possible impact of temperature on bonding properties of the tool insert and impact on red hardness. **Results and discussion.** The plot of flank wear vs. machining time will give the value of tool life. The other quality output parameter, such as surface roughness, is measured after machining, indicating surface irregularities in root means square value. Efforts have been made to identify the relationship of tool life, machining time, the quantity of metal removed, surface roughness, and tool bit temperature.

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Introduction

The intensity of pressure and temperature is severe at the tool surface in contact with the chip and the work results in wear of the cutting edge of the tool. The end of the tool life is due to the pre-mature wear on a large scale or gradual wear as per the cutting conditions [1-3]. The expected wear is the gradual progressive wear of the cutting edge under normal conditions. It occurs when the cutting edges are gradually wearing and reaches a stage when undergo noisy operation and becomes less effective producing rough

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surfaces [4, 5]. Along with that certain other indicators are such as the reduction in cutting edge strength, increased tool forces and power consumption, increased cutting temperatures, loss of part dimensional accuracy, and eventually loss of productivity. So for ensuring better machining, control, and minimization of the tool wear is become a necessity [6, 7].

Tool wear is a complex phenomenon and it occurs by several processes or mechanisms, which involve abrasive wear, diffusion wear, corrosive wear, erosive wear, and fracture [8, 9]. Flank and crater wear are the most important measured forms of tool wear. Flank wear occurs at the tool flanks, where it contacts with the finished surface, as a result of adhesion and abrasion wear [10]. The increment is observed in the cutting forces with flank wear. It affects at the great extent to the mechanics of cutting. The region of the flank wear is known to wear land and is measured by the width of wear land [11-13]. The crater wear is mainly due to abrasion and diffusion. Normally speaking, tool flank wear is produced by the friction between the flank face of the tool and the machined surfaces. Its wear mechanism is very difficult [14]. Adhesive wear occurs when hard inclusions of work material or escaped tool particles scratch the flank and work-piece as they move across the contact area as well [15, 16].

Few researchers emphasize weight reduction of the tool as a measure of tool wear, but it has limitations because during machining tool bit is experiencing adhesion and abrasion phenomenon. The adhesion will result in sticking of metal particles of cut workpiece on the tool bit the weight of the latter will increase, and the actual wear will be difficult to determine. In addition, there are many software forecasting methods, but the suggested method can be chosen as it covers all aspects related to the actual processing conditions. The current research is mainly focused on flank wear measurement. It is commonly observed where the continuous chip is formed (usually in the ductile material). According to the norm ISO 3685:1993 for wear measurements, the major cutting edge is divided into four regions, as shown in Fig. 1. Tool wear is most commonly measured using the toolmaker microscope (with video imaging systems and a resolution less than 0.01 mm) or a stylus instrument similar to a profilometer (with ground diamond styluses) [17].

In general, the failure and wear of cutting tools depend on tool material and geometry, workpiece material, cutting parameters (cutting speed, feed rate, and depth of cut), cutting fluids, and machine-tool characteristics. Figure 2 shows a typical curve of the progress of flank wear land VB_B with cutting time for different cutting speeds [18].

The criteria recommended by ISO 3685:1993 to define the effective tool life for cemented carbides tools, HSS (high-speed steels), and ceramics are listed below: VB_{max} = 0.6 mm, if flank wear is non-uniform in Region B.

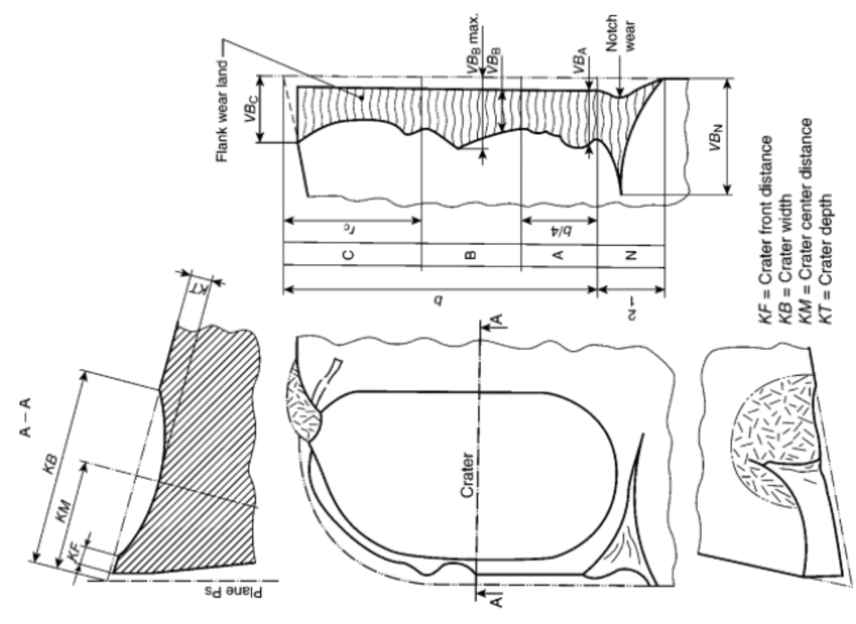


Fig. 1. Types of tool wear according to norm ISO 3685:1993

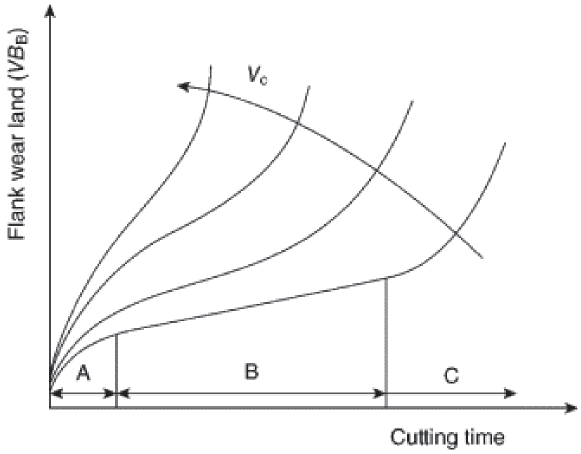


Fig. 2. Evolution of flank wear land VB_B as a function of cutting time for different cutting speeds

General recommendations used in industrial practice for the limit of flank wear VB_B for several cutting materials are given in Table 1.

Table 1

Recommendations used in industrial practice for a limit of flank wear VB_B (mm) for several cutting tool materials

Operation	HSS	Cemented carbides	Coated carbides	Ceramics	
				Al_2O_3	Si_3N_4
Roughing	0,35…1,0	0,3…0,5	0,3…0,5	0,25…0,3	0,25…0,5
Finishing	0,2…0,3	0,1…0,25	0,1…0,25	0,1…0,2	0,1…0,2

Methods

The experimental procedure involved turning of the Mild Steel specimens on Hx-150, Computerized Numerical Control (CNC) machine. The final diameters are calculated using analytical calculation performed in M.S. Excel for cumulative time for successive removal of layers in the form of a chip. Table 2 represents the initial and final diameters as output function as machining time. The variation of initial conditions i.e. diameter and length for all the experiments is intentionally given for achieving different values of metal removed from the given work.

The speed, feed, depth of cut of the machining are chosen as per the CMTI book for specified workpiece tool combination [19]. The input-output variables are as shown in figure 3. Based on the initial and final

Table 2

Machining time as a function of initial and final diameters

Sr. No.	Initial Diameter, mm	Final Diameter, mm	Length, mm	Time, Min.
1	46,0	20,0	235,0	25,15
2	50,0	33,5	235,0	20,22
3	33,5	19,5	215,0	9,929
4	50,0	32,0	165,0	15,20

diameters of the workpiece, the program with preparatory and miscellaneous command i.e. G Code and M Code is prepared as given in Appendix 1.

After machining, corner 1 of the TNMG120408 tool gets weared-out for 10 minutes, corner 2 for 15 minutes, corner 3 for 20 minutes, and corner 4 for 25 minutes.

The machining set-up in the CNC machine is shown in figure 4, indicating the fixing of the workpiece on a chuck. The jaw of the chuck is machined first for firm grip and also the tailstock support is given to make the machining vibration-free. The temperature of the corner of the tool insert is continuously measured at the interval of one minute [20].

The flank wear VB_{max} of the insert is measured with the help of calibrated optical microscope rmm3 series (radical scientific equipment's made) integrated with computer interface as shown in figure 5. The instrument has the facility to plot a line in a magnified view of the tool insert corner image and the length of the line can be measured. In this way, the flank wear VB_{max} is measured for each four corners.

Figure 6 is the measurement of the surface finish of the machined sample using surface roughness tester. The instrument is calibrated first and it is capable to give roughness average value in micrometer. For the measurement different combinations of the slip gauges and V-block is used [21, 22].

Results and Discussion

Based on the machining and subsequent output parameters quantification following are the remarks.

Flank Tool Wear Rate (VB_{max})

The flank wear (VB_{max}) is first identified in a magnified view of the digital microscope (figure 7) and with the help of interface with a computer, it is measured and summarized in table 4.

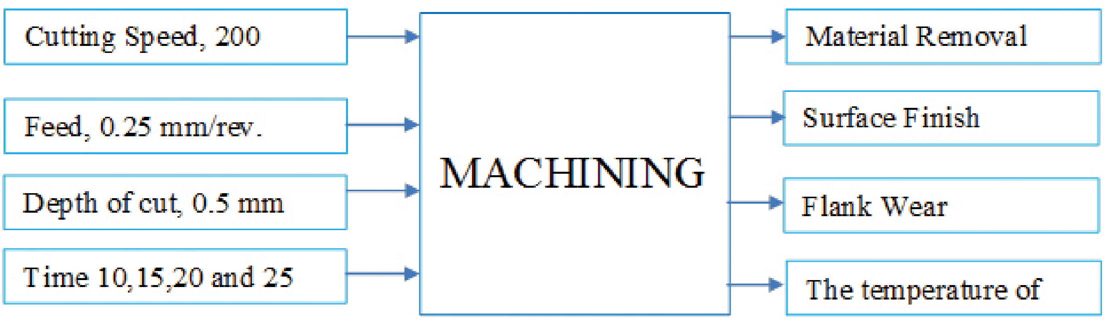
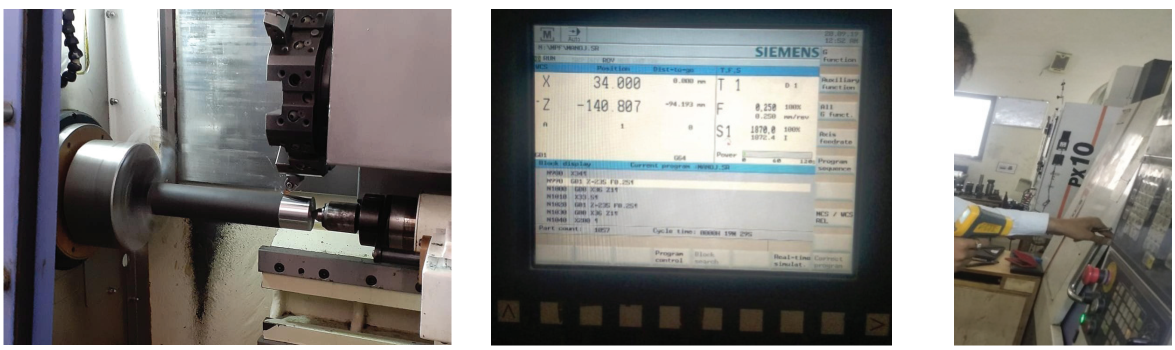
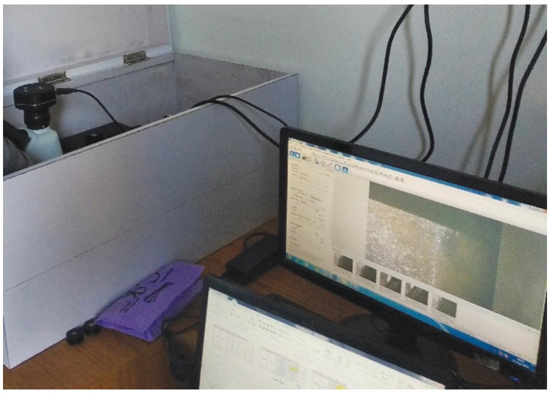


Fig. 3. Input-Output variables for machining



a *b* *c*

Fig. 4. Machining set-up of the workpiece and temperature of the tool bit insert measurement:
a – workpiece holding on a chuck and turning; *b* – CNC Program; *c* – temperature measurement of tool bit by infrared gun



a

b

Fig. 5. Digital microscope for measurement of flank wear on tool insert (10x):
a – set-up of the insert on digital microscope; *b* – insert positioning for the measurement of VB_{max}

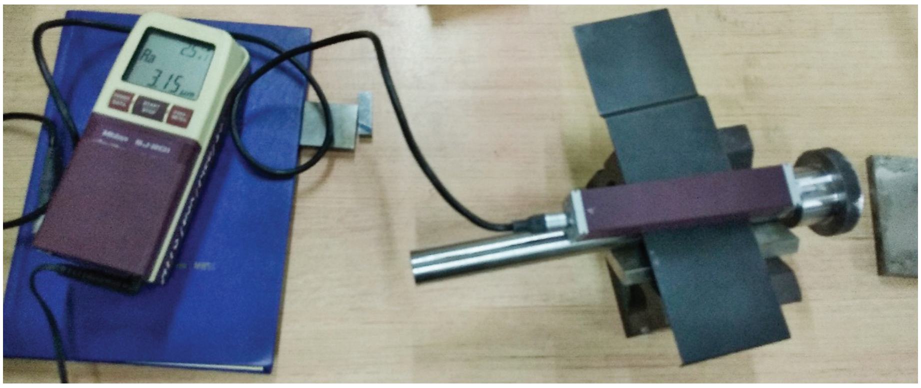


Fig. 6. Surface roughness measurement

As per ISO: 3685, tool wear is corresponding to the time for wear of tool in the form of flank wear of 600 microns, by linear interpolation the tool life is 68 minutes for mild steel and TNMG 1604208, work-piece tool combination. The plot of the same is shown in figure 8. The linear interpolation is matched with the scatter plot with an R^2 value of 0.9837 indicating assuming it as linear is an accurate forecast. The value indicates that the confidence level of 98.37 for the forecast.

The surface finish of the machined workpiece

The surface finish of the machined specimen is measured on a transverse direction of four marks at 90° on its periphery with the help of Mitutoyo SJ-201 surface roughness tester. The values of the same are given in table 3.

The temperature of the tool bit during machining

As an additional measure, the temperature at the insert corner during machining is measured with the help of the HTC MT 6 Digital Infrared Thermometer. The plot of temperature vs. time is drawn and shown in figure 9. For all the experiments the temperature value of the tool insert at any instant does not exceed 80° C, so we can say that the red hardness point is not reached but at the elevated temperature (higher than the room temperature) the softening of any metal is occur and resulting into higher wear than the designated value.

The summary table of the research work is shown in table 4. The data obtained show that flank wear and average surface roughness value and temperature is the function of the mass removed by machining at constant cutting conditions i.e. speed, feed and depth of cut.

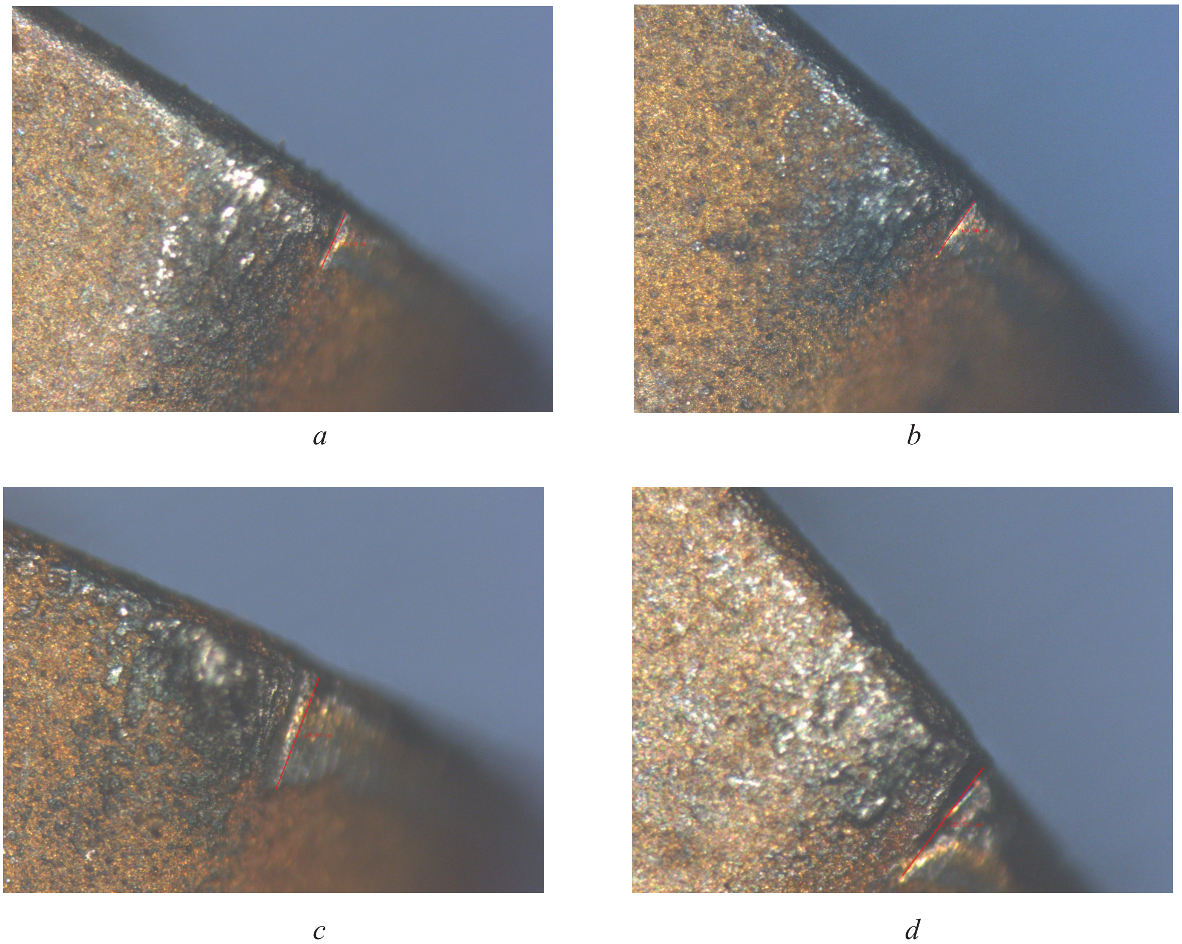


Fig. 7. Flank wear of the tool insert at different machining time:
a – flank wear VB_{max} after 10 Min. machining; *b* – flank wear VB_{max} after 15 Min. machining; *c* – flank wear VB_{max} after 20 Min. machining; *d* – flank wear VB_{max} after 25 Min. machining

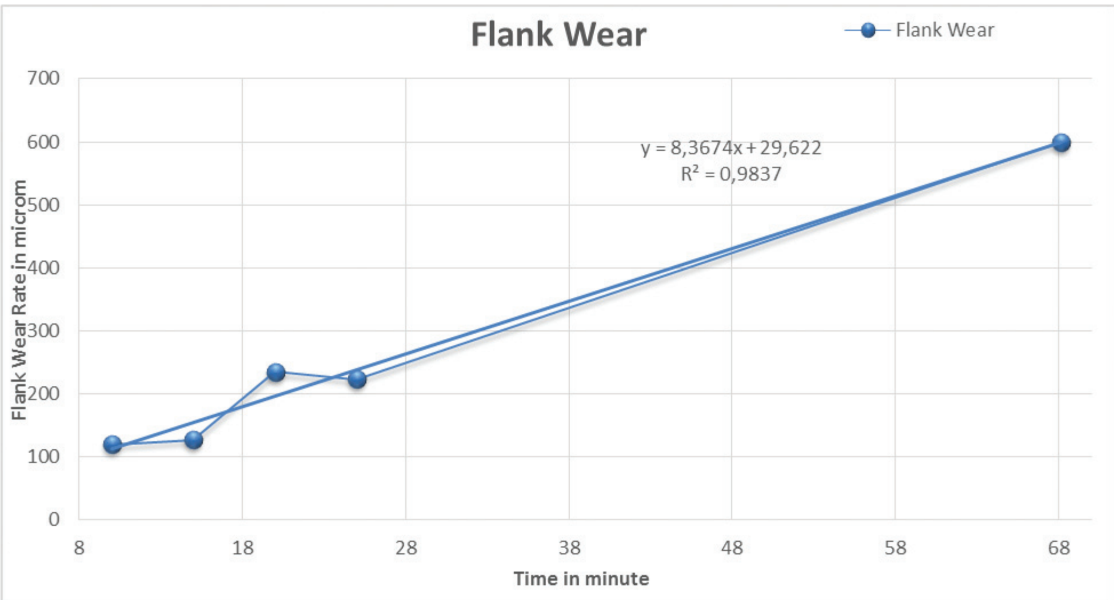


Fig. 8. Plot of flank wear vs. machining time

Table 3

Roughness measurement of the machined workpiece

Roughness Average, Ra Value, µm				
Surface Roughness	25 Min.	20 Min.	15 Min.	10 Min.
1	4,08	3,15	2,95	3,04
2	4,00	3,07	2,84	2,95
3	4,07	3,06	2,87	3,08
4	4,07	3,12	2,97	3,08
Average	4,055	3,1	2,9075	3,0375

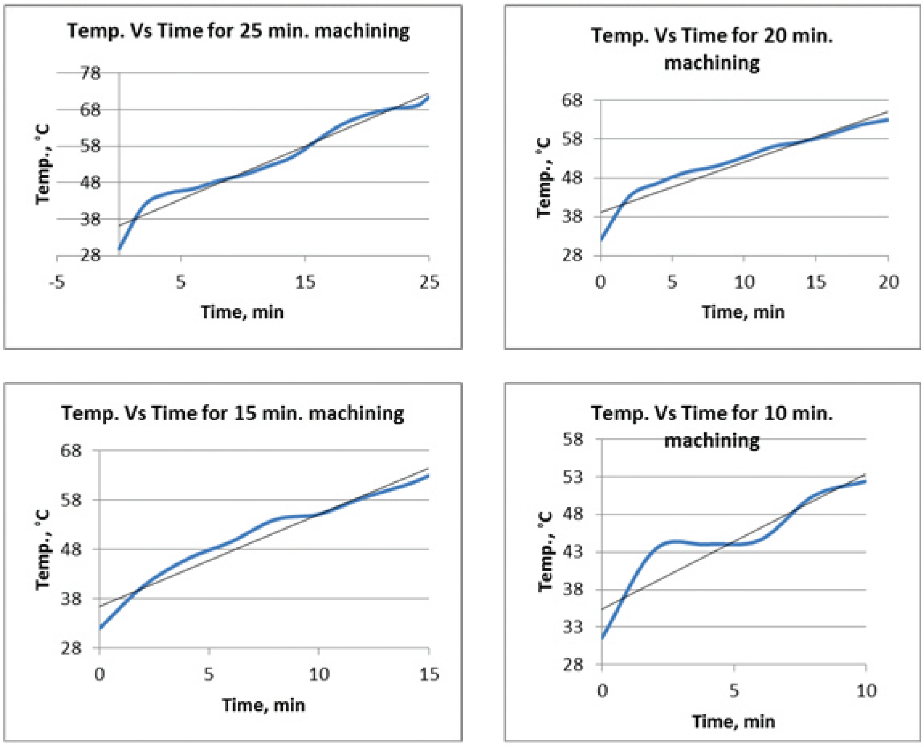


Fig. 9. Temperature vs. time plot at the corner of the insert during machining

Table 4

Summary table of all parameters of the research work

Initial Dia., mm	Final Dia., mm	Length, mm	Machining Time in Min.	Volume Removed in mm^3	Average Surface Roughness in µm	Mass Removed in kg	Temp. in °C	Flank Wear in µm
46	20	235	25	316 719,7	4,055	2,486249	71,5	222,872
50	33,5	235	20	254 289,3	3,1	1,996171	63	234,967
33,5	20	215	15	121 959,6	2,9075	0,957383	52,4	119,423
50	32	165	10	191 275,9	3,0375	1,501516	63	126,943

Conclusion

The method of the tool wear measurement and subsequence quantifying machinability which is very difficult to ascertain as per the number of authors is a key finding of this paper. Before the experimentation, it was an earlier presumption that the tool wear, temperature, and surface roughness is a function of machining time if cutting parameters are constant. But after experimentation, it is found that the said parameters are a function of the quantity of metal removed. The corresponding evidence is shown in table 4. The temperature variation trend of the tool insert during machining is also observed and it is almost linear with an R^2value of higher than 0.90.

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Appendix 1

CNC Program for the experimental work

```
N10 G90 G53 G64
G71 G95;
N20 M03:
N30 G96 S200
LIMS=1370 M03;
N40 T1;
N50 M16 D1;
N60 M08;
N70 G00 X51.5 Z2;
N80 X49.5;
N90 G01 Z-235
F0.25;
N100 G00 X51.5 Z2;
N80 X49;
N90 G01 Z-235
F0.25;
N100 G00 X51 Z2;
N110 X48.5;
N120 G01 Z-235
F0.25;
N130 G00 X50.5 Z2;
N140 X48;
N150 G01 Z-235
F0.25;
N160 G00 X50 Z2;
N170 X47.5;
N180 G01 Z-235
F0.25;
N190 G00 X49.5 Z2;
N200 X47;
N210 G01 Z-235
F0.25;
N220 G00 X49 Z2;
N210 X46.5;
N220 G01 Z-235
F0.25;
N230 G00 X48.5 Z2;
N240 X46;
N250 G01 Z-235
F0.25;
N260 G00 X48 Z2;
N270 X45.5;
N280 G01 Z-235
F0.25;
N290 G00 X47.5 Z2;
N300 X45;
N310 G01 Z-235
F0.25;
N320 G00 X47 Z2;
N330 X44.5;
N340 G01 Z-235
F0.25;
N350 G00 X46.5 Z2;
N360 X44;
N370 G01 Z-235
F0.25;
N380 G00 X46 Z2;
N390 X43.5;
N400 G01 Z-235
F0.25;
N410 G00 X45.5 Z2;
N420 X43;
N430 G01 Z-235
F0.25;
N440 G00 X45 Z2;
N450 X42.5;
N460 G01 Z-235
F0.25;
N470 G00 X44.5 Z2;
N480 X42;
N490 G01 Z-235
F0.25;
N500 G00 X44 Z2;
N510 X41.5;
N520 G01 Z-235
F0.25;
N530 G00 X43.5 Z2;
N540 X41;
N550 G01 Z-235
F0.25;
N560 G00 X43 Z2;
N570 X40.5;
N580 G01 Z-235
F0.25;
N590 G00 X42.5 Z2;
N600 X40;
N610 G01 Z-235
F0.25;
N620 G00 X42 Z2;
N630 X39.5;
N640 G01 Z-235
F0.25;
N650 G00 X41.5 Z2;
N660 X39;
N670 G01 Z-235
F0.25;
N680 G00 X41 Z2;
N690 X38.5;
N700 G01 Z-235
F0.25;
N710 G00 X40.5 Z2;
N720 X38;
N730 G01 Z-235
F0.25;
N740 G00 X40 Z2;
N750 X37.5;
N760 G01 Z-235
F0.25;
N770 G00 X39.5 Z2;
N780 X37;
N790 G01 Z-235
F0.25;
N800 G00 X39 Z2;
N810 X36.5;
N820 G01 Z-235
F0.25;
N830 G00 X38.5 Z2;
N840 X36;
N850 G01 Z-235
F0.25;
N860 G00 X38 Z2;
N870 X35.5;
N880 G01 Z-235
F0.25;
N890 G00 X37.5 Z2;
N900 X35;
N910 G01 Z-235
F0.25;
N920 G00 X37 Z2;
N930 X34.5;
N940 G01 Z-235
F0.25;
N950 G00 X36.5 Z2;
N960 X34;
N970 G01 Z-235
F0.25;
N980 G00 X36 Z2;
N990 X33.5;
N1000 G00 X100
Z50;
N1010 M09;
N1020 M30;
%
```

Appendix 2

MS Excel program for fixing minimum diameter on the basis of time for 15 minutes machining

Pass	L	Length	Diameter	Speed(RPM)	Feed (mm/min)	Time	Time (sec)	Cumulative time
1	165	165	49,5	1286,101	321,53	0,51	30,79	0,51
2	165	330	49	1299,224	324,81	0,51	30,48	1,02
3	165	495	48,5	1312,618	328,15	0,50	30,17	1,52
4	165	660	48	1326,291	331,57	0,50	29,86	2,02
5	165	825	47,5	1340,252	335,06	0,49	29,55	2,51
6	165	990	47	1354,51	338,63	0,49	29,24	3,00
7	165	1155	46,5	1369,075	342,27	0,48	28,92	3,48
8	165	1320	46	1383,956	345,99	0,48	28,61	3,96
9	165	1485	45,5	1399,164	349,79	0,47	28,30	4,43
10	165	1650	45	1414,711	353,68	0,47	27,99	4,90
11	165	1815	44,5	1430,606	357,65	0,46	27,68	5,36
12	165	1980	44	1446,863	361,72	0,46	27,37	5,82

The End Appendix 2

Pass	L	Length	Diameter	Speed(RPM)	Feed (mm/min)	Time	Time (sec)	Cumulative time
13	165	2145	43,5	1463,494	365,87	0,45	27,06	6,27
14	165	2310	43	1480,511	370,13	0,45	26,75	6,71
15	165	2475	42,5	1497,929	374,48	0,44	26,44	7,15
16	165	2640	42	1515,761	378,94	0,44	26,13	7,59
17	165	2805	41,5	1534,024	383,51	0,43	25,81	8,02
18	165	2970	41	1552,731	388,18	0,43	25,50	8,44
19	165	3135	40,5	1571,901	392,98	0,42	25,19	8,86
20	165	3300	40	1591,549	397,89	0,41	24,88	9,28
21	165	3465	39,5	1611,696	402,92	0,41	24,57	9,69
22	165	3630	39	1632,358	408,09	0,40	24,26	10,09
23	165	3795	38,5	1653,558	413,39	0,40	23,95	10,49
24	165	3960	38	1675,315	418,83	0,39	23,64	10,89
25	165	4125	37,5	1697,653	424,41	0,39	23,33	11,27
26	165	4290	37	1720,594	430,15	0,38	23,02	11,66
27	165	4455	36,5	1744,164	436,04	0,38	22,70	12,04
28	165	4620	36	1768,388	442,10	0,37	22,39	12,41
29	165	4785	35,5	1793,295	448,32	0,37	22,08	12,78
30	165	4950	35	1818,914	454,73	0,36	21,77	13,14
31	165	5115	34,5	1845,275	461,32	0.36	21,46	13,50
32	165	5280	34	1872,411	468,10	0,35	21,15	13,85
33	165	5445	33,5	1900,358	475,09	0,35	20,84	14,20
34	165	5610	33	1929,151	482,29	0,34	20,53	14,54
35	165	5775	32,5	1958,83	489,71	0,34	20,22	14,88
36	165	5940	32	1989,437	497,36	0,33	19,91	15,21

Conflicts of Interest

The authors declare no conflict of interest.