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MEASUREMENT AND SENSING OF CUTTING TOOL WEAR

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Abstract: Measurement of cutting tool wear is critical in metal cutting operations. In automated manufacturing, sensing of tool wear is of interest. In single point cutting tools, wear parameters are expressed in terms of wear land width and crater depth, which may not be the ideal or effective parameters to explain the wear related phenomenon in metal cutting. This paper deals with the measurement of wear by considering the three dimensional nature of the wear phenomenon. For this a special relocating fixture was designed and realized and the land and crater wear profiles were plotted in a single setup. From these profiles it was possible to compute other parameters, which could be used for wear quantification. For sensing tool wear, a pneumatic method of wear monitoring has been attempted. This paper gives the details of the measurement set-ups, measurement procedures, new parameter evaluation and their relationship with standard parameters as well as other wear related effects in metal cutting.

Keywords: Tool Wear, Sensing, Characterization, wear parameter.

1 INTRODUCTION

In understanding the manufacturing process, precise characterization and evaluation of cutting tool wear is important. The cutting tool wear, which takes place primarily in three different planes of the tool, is essentially a three dimensional phenomena. The conventional tool wear parameters - like the flank wear width (VB), the crater depth (KT) the distance of the maximum crater depth point from the cutting edge (Kd) and many others - are essentially linear measures and are inadequate in describing the complexity of worn tool topography.[1]. In the absence of rigorous mathematical models pertaining to the machining processes, physical significance of these parameters remains uncertain.

The international standard on tool wear criteria [2] includes parameters from flank wear and crater wear up to surface finish of the work-piece as potential parameters for monitoring tool wear. This only indicates the complexity of the issue in hand and our inability to arrive at a comprehensive parameter that will precisely characterize tool wear and tool life.

On the other hand, reliable simple and preferably on line tool wear measurement is essential for tool replacement decisions. While direct tool wear measurement techniques are usually off-line, in indirect techniques the correlation between the measured parameter and the cutting tool wear is poor.[3],[4] The multi-sensor approaches and the artificial neural network (ANN) based solutions make the measurement process complex and in practical environment, their reliability remains to be established.[5] In such a background the need for a simple wear measurement system assumes significance.

In this work, attempts are made to evolve a method for comprehensive tool wear characterization and a simple pneumatic wear measurement technique is proposed

2 TOOL WEAR CHARACTERIZATION

As seen earlier comprehensive characterization of tool wear remains an important issue in manufacturing. In this work, an attempt is made to completely digitize the entire wear region and with that the whole wear region is reconstructed. With this any realistic wear parameter, conventional or new could be evaluated. To facilitate this a special relocating fixture was designed so as to hold the insert and index it through the appropriate angle.

2.1 The Relocation Fixture

The relocation fixture consists of a frame, insert holding shaft, locating screws and the clamp. The insert holding shaft consists a pocket to receive the insert with provision for locating the insert.

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The locating arrangement is based on the 3-2-1 principle. Threaded pins with lock nut and hardened spherical ends are used for locating the insert in position. The located insert is then held in place by a diagonal spring-loaded clamp.

The insert holding shaft is held in a frame, with a ball bearing, with provision for indexing through a suitable angle. The flank and the rake face of the cutting tool insert are separated by an angle 90-α, where α is the clearance angle of the insert. To bring the wear topologies of these two faces to a single plane successively the insert holding shaft is to be indexed through an angle of 90+α. For implementation, an SNUN 120408 insert with 0° clearance angle was chosen. This necessitates indexing through an angle of 90°. This is felicitated by the two locating holes in the frame.
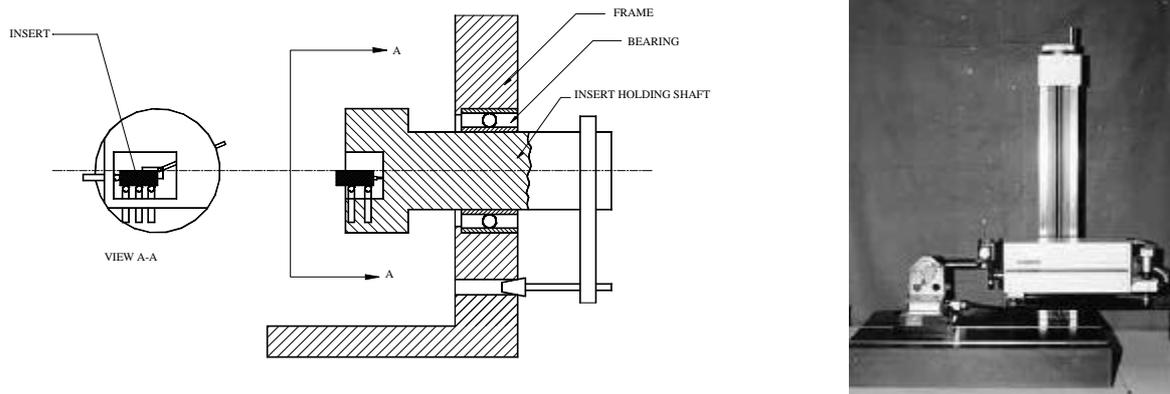

Fig.1. The relocation fixture drawing and the relocation fixture during measurement

Most valuable data regarding tool wear, in the flank as well as the rake face, exist very close to the cutting edge. To facilitate data acquisition close to the cutting edge, a supporting block is provided, whose smooth top surface is in plane with the measurement plane. This facilitates the travel of the stylus from the top surface of the support block to the insert plane under consideration. The data pertaining to the supporting block and the subsequent transience can be eliminated in the software for the data processing.

The relocation fixture drawing and the photograph (without the support block) are shown in Fig.1

2.2 Experiments and Data Collection

Experiments were conducted on a high-speed lathe using ASTM 1040 steel as the work piece material and SNUN 120408 (TTS) insert as the cutting tool insert. Machining was carried out at 200 m/minute surface speed, 2 mm depth of cut and 0.1 mm/rev. feed. The machining was interrupted at appropriate intervals and the flank wear measurements were taken. The insert was then loaded on the relocation fixture and tracings were obtained on the flank and the rake faces. A stylus surface texture measuring machine was used to obtain the tracings. The readings are stored in the system and were later converted into data files using the built in utility to suit further data processing

Table 1. The machining time instants of measurement

Exp. No	Time in minute	VB in mm
1	0	0
2	1.1	0.18
3	3.82	0.25
4	13.71	0.31
5	22.95	0.48

The machining time and the flank wear values are given in the Table 1.

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2.3 Data Processing

Data points corresponding to the tracings were grouped together in terms of flank and the rake faces and a moving average was performed to eliminate the roughness variations. Since our interest is with regard too the gross shape variations in the insert due to wear this step is essential. The roughness-eliminated tracings were reconstructed in a computer and the gross tool shape was obtained. Since the data pertaining to the entire wear zone is available any relevant parameter like total reduction in volume, change in the surface area, flank wear land and the crater depth could be evaluated from the data.

2.4 Results

The wear zone plot, corresponding to the insert condition after 22.95 minutes of machining, is illustrated in the Fig.2. The wear zone comprises of the clear flank and crater zones. This facilitates the evaluation of any relevant parameter that is physically significant.
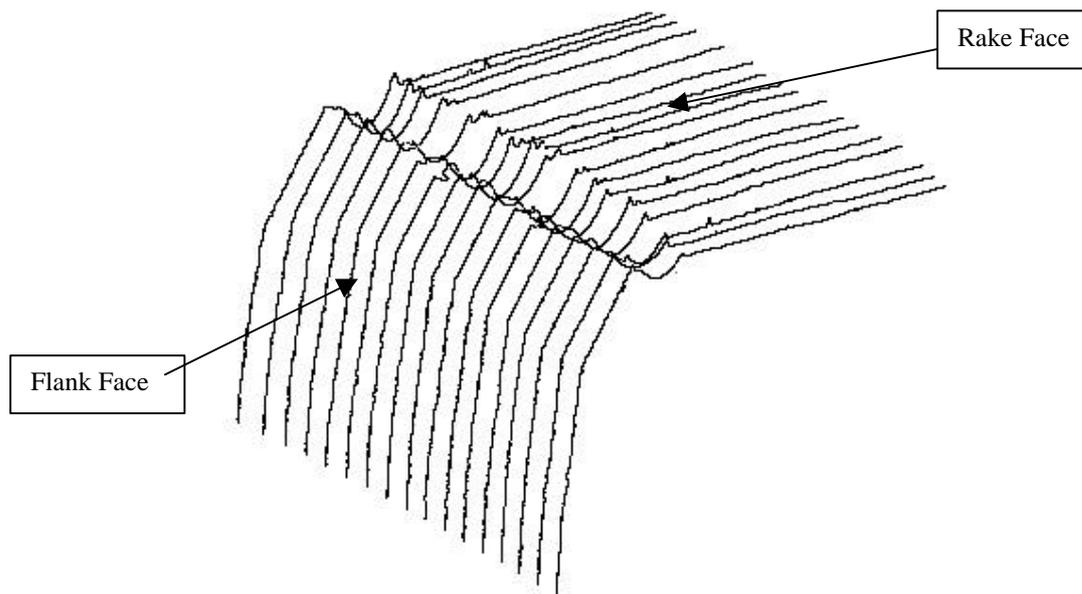

Fig.2. Worn tool profile

3 TOOL WEAR SENSING

The need for a simple system to measure the too wear parameter, say the most widely measured flank wear, accurately without much disturbance and interruption to the machining process cannot be over emphasized. In the present work, a new pneumatic sensing technique is proposed.

As the cutting tool wear takes place, the cutting edge, which is otherwise straight, under goes discontinuity particularly at the inner end of the primary and the secondary flank wear region. A template matching the primary and the secondary cutting edges of an un-worn insert is held in close contact with the insert cutting edges. With a new insert, the template will perfectly match with the cutting edge proper, with no gap in between the two. However, with the worn insert, a definite gap along the portion of the cutting edge in contact with the workpiece develops and it progressively increases as the wear develops.

The progressive increase in the gap could be successfully measured using a backpressure measuring system.

3.1 The Fixture Design

A fixture to facilitate aligning the insert and the template and to measure the gap with a pneumatic gauge was designed and realized. The fixture consists of a square block with a pocket to accommodate the insert. The 'L' shaped template, with a fillet radius matching the insert nose radius and with generous clearance angle at the inner walls, is pressed against the insert by spring loaded clamps at two directions. Just below the wear zone of the insert, a threaded nipple is attached. The nipple is in turn connected to a pneumatic gauge. To ensure an airtight chamber for the gap, a vertical spring-loaded clamp with provision for unrestricted flow of air, is used.

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Figure 3 shows the drawing of the fixture and the photograph of the fixture and the pneumatic gauge.

3.2 Experiments

The new insert was first positioned in the fixture and the initial pneumatic gauge reading was obtained. Experiments were conducted on a high-speed lathe using ASTM 1040 steel as the work piece material and SNUN 120408 (TTS) insert as the cutting tool insert. The machining was suitably interrupted at appropriate intervals and the primary and the secondary flank wear measurements were taken, using the tool makers microscope. The insert was then positioned in the fixture, and the corresponding pneumatic gauge readings were noted down. Table 2 indicates the pneumatic gauge reading corresponding to the different primary and secondary flank wear values.
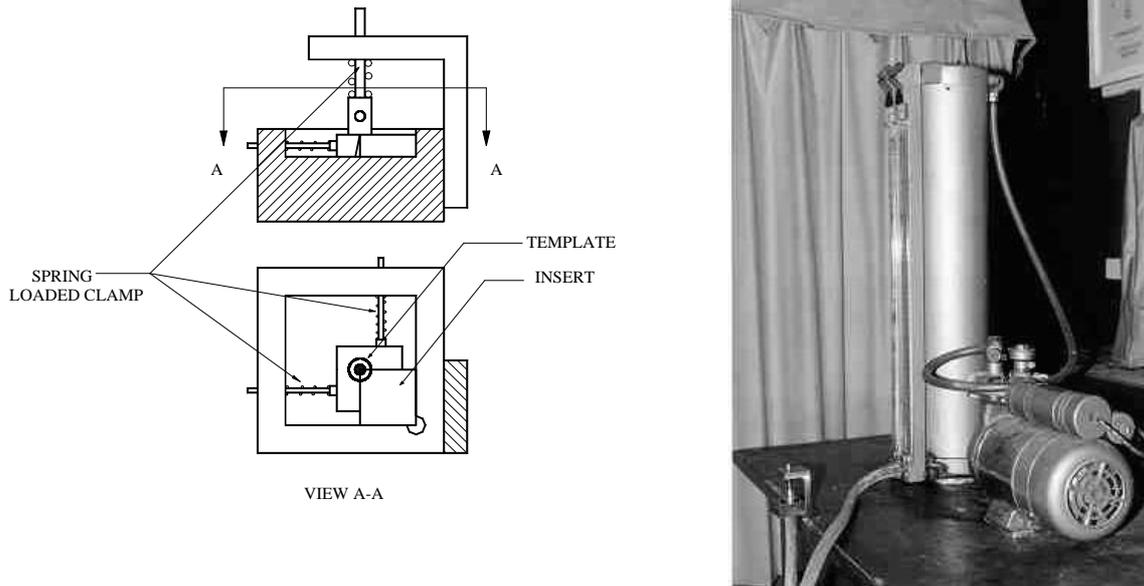

Fig.3 The pneumatic measurement system the sketch and during measurement

3.3 Results and Discussion

Figure 4 plots the pneumatic gauge reading Vs the primary wear and the secondary flank wear values. The high value of R^2, more than 0.9 in both the cases indicate a very good correlation between the pneumatic gauge reading and the respective flank wears.

Table 2. The tool wear and the pneumatic gauge reading

Primary Flank Wear in mm	Secondary Flank Wear in mm	Pneumatic Gauge Reading mm of water
0,075	0,135	38,8
0,075	0,14	38,7
0,11	0,16	38,5
0,13	0,2	38
0,15	0,24	37,4
0,16	0,24	36,9
0,195	0,29	36,2
0,23	0,3	36,4
0,305	0,32	35,7
0,36	0,32	35,1

However, the pneumatic gauge reading is also influenced by the depth of cut and the clearance angle of the insert. The depth of cut influences the length of the gap, and thereby the pneumatic gauge readings. Hence the pneumatic gauge readings are to be calibrated against the various values of depth of cut. On the other hand, the clearance angle of the insert influences the

relation between the flank wear land and the gap between the template and the cutting edge. As the clearance angle increases, with in the limits of the pneumatic gauge range, for a fixed flank wear, the gap increases and hence the sensitivity of the pneumatic gauge.

The pneumatic gauge reading is the combined measure of primary flank wear, secondary flank wear and the wear at the nose region. In the absence of excessive rubbing conditions the said three wears develop together. This is the reason for high correlation between the pneumatic gauge reading and the primary and the secondary wear parameters independently.
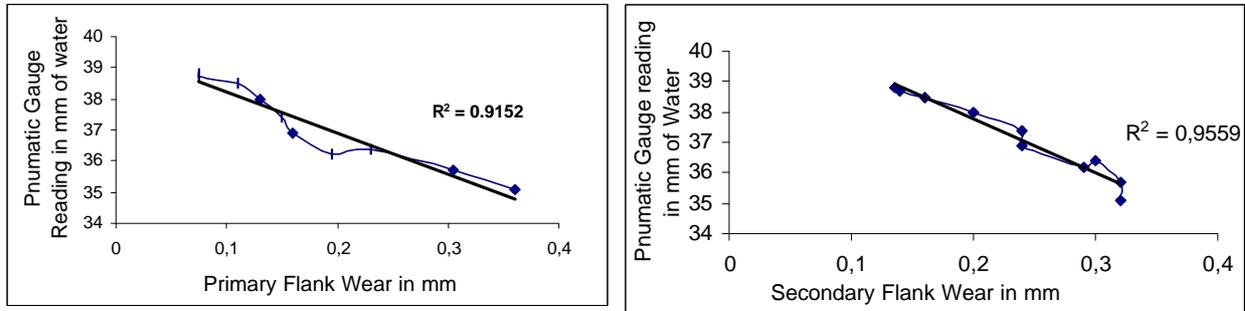

Fig 4. Pneumatic Gauge reading Vs. primary and secondary flank wear

4 CONCLUSION

Attempts were made to comprehensively characterize tool wear. The entire wear profile was successfully digitized. This facilitates evaluation of appropriate wear parameter. Further attempts are to be made to evolve conventional and new tool wear parameters, from the digitized data. Further studies to correlate new parameters and the physical variables of the machining system will be of interest.

The pneumatic sensing of tool wear is a simple sensing technique. In this technique, the pneumatic gauge really measures a composite parameter, which is related to the combined effect of primary and the secondary flank wear and the nose wear. This technique has potentials of on-site implementation.

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