INFLUENCE OF THE SEQUENCE OF TOOL EDGES USED ON LIFE TESTS OF SQUARED CEMENTED CARBIDE INSERTS

Janaína Aparecida Pereira, janaina_eng@yahoo.com.br
Fábio de Freitas Lima, fabiol7788@yahoo.com.br
Déborah Almeida de Oliveira, deborah@mecanica.ufu.br
Sérgio Abrão Retes Júnior, sergio.retes@gmail.com
Marcos Antônio de Souza Barrozo*, masbarrozo@ufu.br
Álisson Rocha Machado, alissonm@mecanica.ufu.br
Universidade Federal de Uberlândia, Faculdade de Engenharia Mecânica, Laboratório de Ensino e Pesquisa em Usinagem - Campus Santa Mônica - 38400-100 - Uberlândia – MG – Brasil
***** Faculdade de Engenharia Química

Abstract. *Machining experts some times come across with a question when using tool tips inserts: The use of one of the edges of an insert affects the performance of the others? Some of them comment that in squares inserts, for instance, the sequence of the tool edges used could affect their lives when machining. The reason for this is that worn edges would adversely affect the wear progress in the next adjacent edges. In order to avoid this, it is recommendable to index only the diagonal sequence for cutting edges. Based on this hypothesis and because there is no scientific information to support it, squared carbide inserts with negative rake angle were tested in turning of a microalloyed (HSLA) DIN 38MnSiVS5 steel grade. Tests were performed using all the possible edges sequences of one tool face in order to verify the possible influences in the tool edge lives. After using the upper face edges, the bottom face edges of the inserts were also tested. Tool wear and metal removal rate were monitored during machining. Statistically reliable results showed that there is no significant influence of a specific sequence of cutting edges on their tool lives, dismitifying the hypothesis for the cutting conditions tested.*

Keywords*: tool life, tool wear, turning, HSLA steel, sequence of indexable tool edges.*

1. INTRODUCTION

The tool life is defined by the time that it actually cuts (down time not considered) until it loses its ability to cut within a previously established criterion (FERRARESI, 1977). The criterion is normally based on the amount of wear developed.

In square indexable tools a doubt is raised on whether or not the sequence of the edges used affects the tool life test results. This is because a worn edge could affect the development of the wear of an adjacent cutting edge and therefore the use of only the diagonal edges would be recommended because they suffer less interference with respect to wear. In the literature there are several publications about the use of square or other insert shapes (Rogante, 2008; Wanigarathne et.al., 2005; De Melo, 2001), but in none of them this assertion is found or even considered this fact as a potential problem.

According to Machado et al. (2009) studying and understanding the processes of damages of the cutting tools are important because consistent and effective actions could be taken to avoid damages or to reduce the wear rate, extending the life of the cutting edges tools.

Three distinct types of damages of the cutting tools in machining are: breakage, wear and plastic deformation. These three types lead to changes in the tool geometry. The first two promote loss of mass, while plastic deformation promotes displacement of mass in the cutting tool. In normal cutting, that is, not using abusive cutting conditions, usually breakage and plastic deformation are avoided and wear predominates. The standard ISO 3685 (1993) defines tool wear as *"a change in its original form during the cut, resulting in gradual loss of material"*.

Several authors (Trent and Wright, 2000; König and Kloke, 1997; Diniz et al., 2001; Machado et al., 2009) classify the wear mechanisms as those that are more temperature dependant (plastic deformations, oxidation and chemical diffusion wear) and those that are less temperature dependant (attrition and abrasion wear).

If the wear on a cutting edge of a tool is to interfere in the wear development of the adjacent edge (either lateral or inferior) this surely will involve cracks, plastic deformation or/and chemical effects. However, those of mechanical futures (first two cited: spreading of cracks and plastic deformation) are more prone to interfere since cemented carbide tools does not suffer phase transformation, as in the case of high speed steels, and consequently will not be affected by high temperatures unless diffusion is so high that could reach the adjacent edges which is very unlikely to happen.

With these comments a conclusion is that only statistically supported practical experiments could dismiss this supposition. Aiming to clarify such hypothesis the present work was developed where several tool life tests in turning operation using square carbide inserts were carried out varying the sequence of the tool edge indexed. As work material the microalloyed steel DIN 38MnSiVS5 was used.

2. EXPERIMENTAL PROCEDURE

Cylindrical bars with 100 mm of diameter and length of 500 mm of DIN 38MnSiVS5 HSLA steel with average hardness of 256 HV was used as work material. Its composition is shown in Tab.1.

Table 1: Chemical composition of the DIN 38MnSiVS5 HSLA steel used in the tests

Composition	*% C*	*% Si*	*% Mn*	*% P*	*% S*	*% Cr*	*% Ni*	*% Mo*	*% Al*	*% Cu*
Max.	0.360	0.600	1.30	0.000	0.020	0.100	0.000	0.000	0.0100	0.000
Min.	0.400	0.750	1.50	0.025	0.040	0.200	0.150	0.050	0.0250	0.200

Composition	*% Sn*	*% Ti*	*% V*	*% B*	*ppmH*	*% N2*
Max.	0.0000	0.0100	0.0800	0.0000	0.00000	0.0130
Min.	0.0300	0.0300	0.1300	0.0004	3.00000	0.0200

The micrography of the material is shown in Figure 1, comprising mostly by perlite and ferrite.

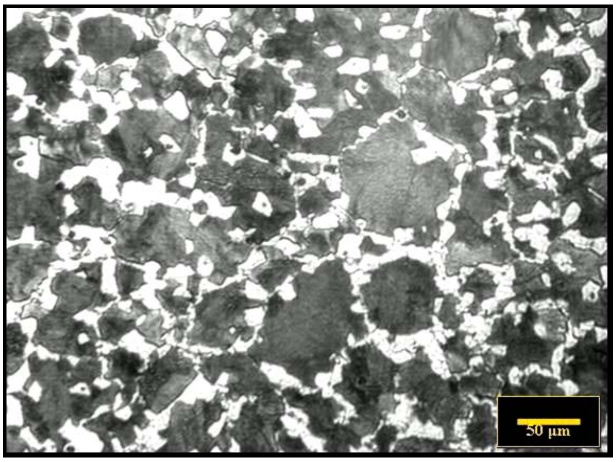

Figure 1. Micrography of the DIN 38MnSiVS5 HSLA steel used in the tests (etched with 2% Nital)

The turning tests were carried out in a Multiplic 35 D lathe manufacture by Industrias Romi S.A., with 11 KW of power, variable spindle speed from 3 to 3000 rpm and equipped with a GE Fanuc Series 21i – TB CNC control.

The tools used were SNMG 120404-PM, square negative rake and 0^o clearance carbide inserts with eight cutting edges available, ISO grade P35 coated with TiCN/Al2O3/TiN on the clearance face and with TiCN/Al_2O_3 on the rake face (the TiN layer was microblasted off) (Sandvik Coromant grade GC4235), with integrated chip breaker, recommended for semi-finishing to medium rough cuts. The tool holder was a DSBNR 2525 M12 (ISO designation). When one of the inserts is clamped on it the following geometry results: back and side rake angles = -6^0; relief angle = 6^o; approach angle = 75^o (side cutting edge angle = 15^o); end cutting edge angle = 15^o.

Tool wear was measured after each pass using a SZ6145TR - Olympus stereo microscope and the Image-Pro Express image analyzer software. In order to measure it the insert needed to be taken off the tool holder and placed on the microscope reference table every time.

Constant roughing cutting conditions (V_c = 250m/min, doc = 2mm, f = 0,2mm/rev) were used for the machining tests and the end of tool life criteria were those recommended by the ISO 3685 (1993) standard (VB_B = 0.3 mm; VB_{Bmax} = 0.6 mm; KT = 0.06 + 0.3 f and VN e VC =1.0 mm, the one that is first reached). In the present investigation the maximum flank wear, VB_{Bmax}, always prevailed and the value of 0.6 mm was then taken as the limit of the tool life.

The sequence of machining tests followed a particular order of the cutting edges according to Figure 2. This sequence was:

1) First, the Edge 1 was tested;
2) Test of Edge 2 after testing edge 1;
3) Test of Edge 3 after testing edges 1 and 2;

4) Test of Edge 4 after testing edges 1, 2 and 3.
5) Test of Edge 3 after testing edge 1 (only if statistical influence was detected in the previous tests);

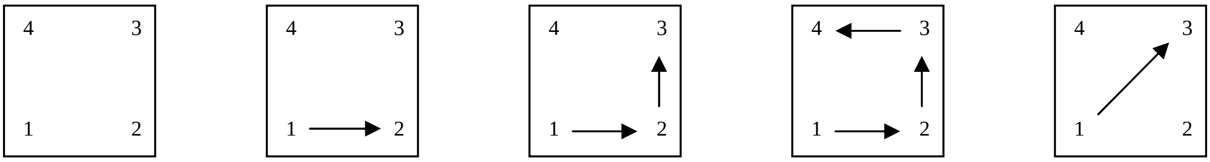

Figure 2. Sequence for testing the upper edges of the square cemented carbide insert

After completing the sequence described, with all the upper surface edges worn from previous tests the bottom surface edges were also tested. This new sequence allowed not only to check again the horizontal sequence of Figure 2 tested but also to verify possible influences of vertical sequence of edges. Figure 3 shows these new sequences as indicated by the arrows.

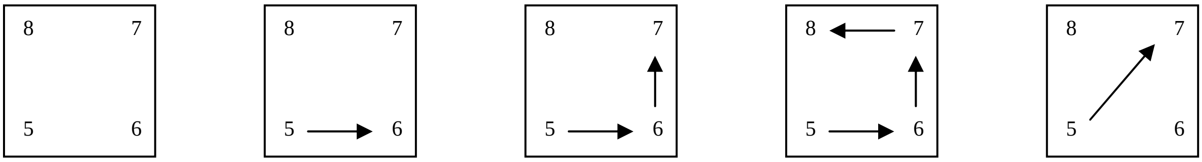

Figure 3. Sequence for testing the bottom edges of the square cemented carbide insert

All the tests were replicated twice and the tool life result considered was the average calculated from these three tests (one test plus two replicas).

3. RESULTS AND DISCUSSIONS

The data analysis was performed with the help of the Statistica 7.0 software, using analysis of variance (ANOVA) with a significance of 5 %.

3.1. Comparison between consecutive upper edges

Table 2 shows the results of the average, variance and standard deviation of the tool lives obtained when the upper edges were used and Table 3 shows the *p* value calculated from the ANOVA.

Table 2. Average tool lives of the upper edges

Edges	*Average Tool Life*	*Variance*	*Standard Deviation*
Edge 1	1101.600	53720.800	231.777
Edge 2	977.800	3533.200	59.441
Edge 3	1064.250	38114.917	195.230
Edge 4	1298.500	142133.667	377.006

Table 3. Comparison of the tool lives of the upper edges

Comparisons between edges	*F*	*p-value*	*F critical*
A1 e A2	1.338460195	0.280680787	5.317655063
A2 e A3	0.904874345	0.373158825	5.591447848
A3 e A4	1.217719695	0.312088951	5.987377584
A4 e A1	0.940429878	0.36447344	5.591447848

According to the p-values results it can be said with 95 % confidence that there is no difference between the tool lives obtained for the four upper edges tested in a increasing sequence order because all the p-values are higher than 0.05.

Figure 4 shows diagrammatically the average tool lives with their respective standard deviations for each upper edge of the square cemented carbide insert.

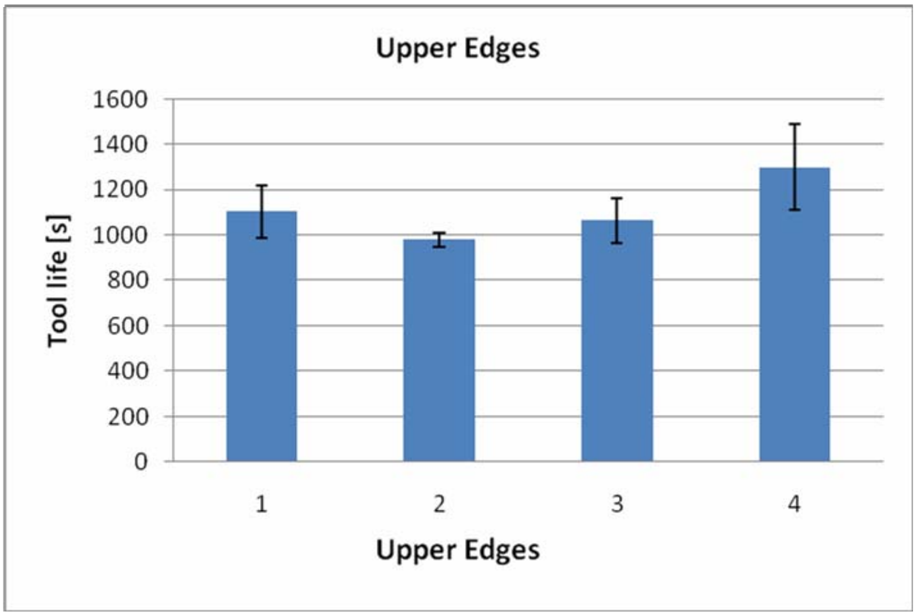

Figure 4. Average tool life for each upper edges of the square insert

The bottom and consecutive edges followed the same methodology used to compare the upper edges, and the results of the average, variance and standard deviation are shown in Table 4. Table 5 shows the *p* value calculated from the ANOVA.

Table 4. Average tool lives of the bottom edges

Edges	*Average Lifetime*	*Variance*	*Standard Deviation*
Edge 5	1161.500	21703.000	147.319
Edge 6	997.500	29546.917	171.892
Edge 7	1009.000	154490.917	393.053
Edge 8	1015.000	31464.250	177.382

Table 5. Comparison of the tool lives of the bottom edges

Comparisons between edges	*F*	*p-value*	*F critical*
A5 e A6	1.991812995	0.20784304	5.987377584
A6 e A7	0.007846213	0.932299205	5.987377584
A7 e A8	0.053776403	0.824324466	5.987377584
A8 e A5	1.247125815	0.306816554	5.987377584

Again, according to the p-values results it can be said with 95% confidence that there is no difference between the tool lives obtained for the four bottom edges tested in a increasing sequence order because all the p-values are higher than 0.05.

Figure 4 shows diagrammatically the average tool lives with their respective standard deviations for each upper edge of the square cemented carbide insert.

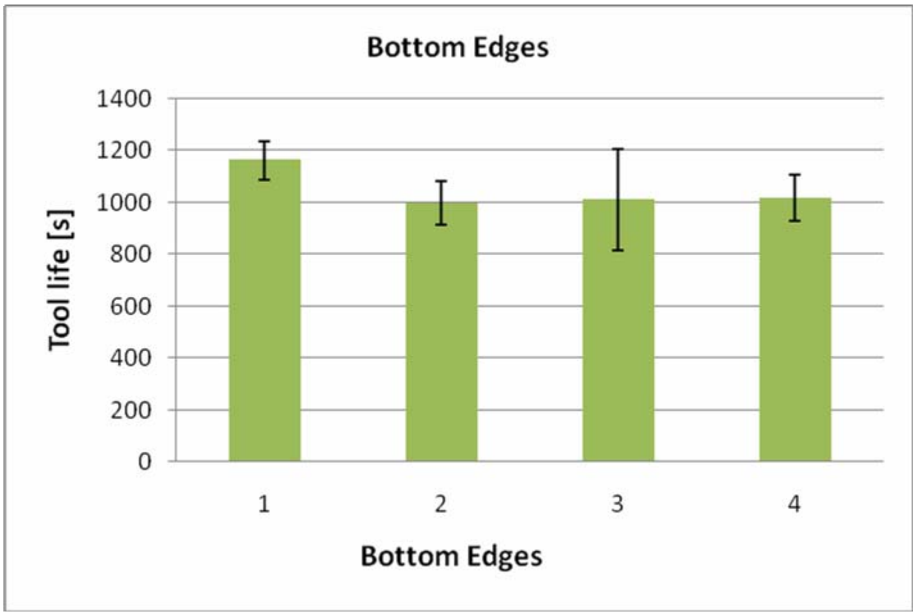

Figure 5. Average tool life for each bottom edges of the square insert

After comparing the tool lives generated by consecutive upper edges and then, the consecutive bottom edges, the tool lives obtained for the upper edges were compared against the tool lives of the next adjacent bottom edges. Table 6 shows the *p* value calculated from the ANOVA for these tests. It is observed that again there are no statistical differences between the tool lives obtained for the upper edges and their respective bottom edges as indicating by the p-values, with 95 % of confidence.

Table 6. Comparison of the tool lives obtained from upper and bottom edges

Comparisons between edges	*F*	*p-value*	*F critical*
A1 e A5	0.439079454	0.528773546	5.591447848
A2 e A6	0.424361618	0.535561681	5.591447848
A3 e A7	0.057241257	0.818873708	5.987377584
A4 e A8	1.291503114	0.299114351	5.987377584

Table 7 shows the result of p-values for comparisons between the tool lives obtained by diagonal cutting edges of both upper and bottom surfaces of the square insert. Although a difference between the results from edges 2 and 4 was observed for a confidence of 90 % ($p < 0.1$), for a confidence of 95 % this does not hold true (p-value is higher than 0.05). The same happens for the other diagonal edges compared. No difference is therefore seen among the tool lives.

Table 7. Comparison between diagonal edges

Comparisons between edges	*F*	*p-value*	*F critical*
A1 e A3	0.065912842	0.804765735	5.591447848
A2 e A4	3.631651873	0.098379402	5.591447848
A5 e A7	0.72537266	0.427066928	5.987377584
A6 e A8	0.06300486	0.810183216	5.987377584

As could be observed in all the tables shown before, the p values allow saying with 95 % of confidence that there are no differences between the tool lives obtained from consecutive adjacent and diagonal cutting edges both of the upper and of the bottom surfaces of the square insert tested. There are also no differences between the tool lives from cutting edges dwelling vertically close to each other, that is, tool lives of the upper edges compared to the tool lives of next adjacent bottom edges.

If an influence is to occur the expectation would be much higher when comparing tool lives from the upper and from the next adjacent bottom edges (1 against 5, 2 against 6 and so on, see Table 6) because they dwells much closer to each other than any two adjacent upper or bottom edges (1 against 2, 2 against 3, 5 against 6 and so on, see Tables 3 and 5).

This expectation is based on possible thermal and/or mechanical effects that would have influenced the tool lives of two adjacent cutting edges. A thermal damage or eventually cracks of mechanical origins would affect much more the closer next adjacent vertical edges than the next adjacent horizontal either upper or bottom cutting edges. The distance between two adjacent vertical cutting edges (insert's thickness) is much smaller than the distance of two adjacent horizontal cutting edges (insert's cutting edge length).

After analyzing these results, further tests to check influences on tool lives obtained when using only the diagonal cutting edges (edge 1 against 3 without testing edge 2 and 5 against 7 without testing edge 6, see Figures 2 and 3) was discarded. If no statistically confident influence was observed in adjacent consecutive cutting edges let alone will have between the further away adjacent diagonal cutting edges.

The results are valid only for the cutting conditions and for the tool-work material pair tested and it has to be pointed out that they are subject to experimental errors inherent to the machining test and also the fact that the statistical tools used for the analysis take into account the number of samples tested (n) which seems to be small to adequately represent the phenomenon studied. The standard deviation is relatively high and could be improved if further tests were carried out. However, machining tests demand great volume of work material, high number of cutting tools and long machine times those contributing to raise test costs.

4. CONCLUSIONS

The results allow the following conclusion with 95 % of confidence to be drawn:

Within the cutting conditions tested and using the same tool-work material pair in dry turning, tool life tests of a cutting edge in a square insert are not influenced at all by another previous test carried out using another cutting edge of the same insert, regardless the sequences of cutting edges considered (horizontal or vertically).

5. ACKNOWLEDGMENTS

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