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THE RELATIONSHIPS BETWEEN CERAMIC TOOL LIFE AND DIFFERENT MACHINING PARAMETERS

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ABSTRACT

With the increasing use of ceramic tool materials in applications, has come an increasing need for experimental data to assign the behavior of the life of these tool materials. Experimental results during turning operation show that it is possible to increase cutting tool life substantially by a proper variation of the cutting parameters used in this work.

The tool lives (tool flank wear land length) of three different ceramic materials, namely; Silicon carbide (Sic), Alumina (Al_2O_3) and partially stabilized zirconia (PSZ) in addition to, Titanium carbide and high speed steel tools are investigated in this work. Also, The effect of varying the cutting speed, feed rate and tool rake angle on tool life of each tool material is studied.

It was found that the Sic cutting tool showed the highest tool life among all materials tested in this work. It was also noticed that increasing the cutting speed has led to an increase in tool life for ceramic tools only. However, increasing the feed rate and tool rake angle resulted in a reduction in tool life in all materials examined in the present study. Further analysis conducted on SiC tool material to examine the effect of the interaction of cutting parameters on the tool life.

KEY WORDS

Machining parameters, Ceramic, Tool Life, Tool flank wear

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1- INTRODUCTION

One of the most important factors that has a great effect on the machining output (response) is the tool wear. The rate of the tool wear which determines the tool life depends on many parameters. These parameters include; workpiece and tool materials, tool geometry, cutting speed, feed rate, depth of cut and the presence or absence of a lubricant during machining.

As products become more sophisticated, complex geometries and higher strength materials are required to meet higher specifications. On the other hand, products must be manufactured to a higher quality standard, at a reduced cost and within a tighter schedule. Therefore, tougher materials must be machined and better cutting tools must be used in order to save production costs while maintaining tighter tolerances and decreasing manufacturing lead times. Even though better cutting tools have appeared in the market in recent years such as low binder content submicron-sized cemented carbide tools, ceramics tools and cubic boron nitride (CBN) tools, which can machine hard materials [1,2], tool life is still a major problem which causes delays and also increase direct and indirect manufacturing costs. Machining of hard material can replace certain grinding operations and could reduce manufacturing costs significantly. Previous studies have shown that rough grinding can be replaced by machining with equivalent surface roughness characteristics [3-13]. The machining of hard materials is therefore very important but tool life is still very limited in practice and avenues must be found to increase this critical parameter of cutting process. Some other studies [3,4] concentrated on chemical and mechanical tool wear of ceramics in steel machining

For a given material, cutting speed, feed rate, and depth of cut are the most important parameters influencing the cutting process efficiency and cutting tool life. Tool performance is usually examined in terms of crater wear and flank wear. The wear may be attributed to mechanical or thermal mechanisms, or to some extent to the combination of both [14]. In recognition of the complex factors affecting the surface wear generation under various cutting conditions, the key question to address is: Which tool will last longer than the other or in some other words which tool has the maximum tool life among all materials tested at different cutting conditions.

The main objective of this work is to investigate in a comprehensive manner the effects and interacts of three cutting parameters (cutting speed, feed rate and tool rake angle) on the tool life for five different tool materials.

2- EXPERIMENTAL WORK

Turning experiments were conducted on a center lathe machine at different cutting speeds and feed rates. The cutting speed values ranged from 0.5 to 2.5 m/s while the feed rate ranged from 0.05 to 0.315 mm/rev

2-1 Cutting Tool Materials

In this work five different cutting tool materials were chosen to widen the field of research. These materials include three different ceramics: reaction bonded silicon carbide (Sic), 2500VPN, sintered alumina (Al_2O_3), 1930VPN, and partially stabilized zirconia (PSZ), 1400VPN, beside two other cutting tool materials: Titanium carbide (C70), 1171VPN and high speed steel (HSS), 650VPN. The rake angle was adjusted to the desired value using a grinding wheel followed by measurements using a rake angle gauge. Table 1 shows some specifications of the five different materials used in this research.

Table 1: Specifications of the tool materials used

	Density (g/cm^3)	Flexural strength (Mpa, 20^o)	Hardness, Hv
Sic	3.1	325	2500
Al_2O_3	3.78	360	1930
PSZ	6.05	1000	1400
Titanium carbide	11.5	1150	1171
High speed steel	8.3	2500	650

2-2. Workpiece Material

In the present investigation, carbon steel was used as the workpiece material. This material was chosen because of its importance in industry. The chemical composition in weight percent of this material is given in Table 2.

Table 2: Chemical composition of carbon steel

Element	C	Si	Mn	P	S	Cr	Mo	Ni
Weight percent	1.03	0.12	0.16	0.006	0.024	0.057	0.002	0.045
Element	Cu	Sn	Al	Co	Zn	Ca	Fe	
Weight percent	0.14	0.01	0.001	0.008	0.002	0.002	89.393	

3. RESULTS AND DISCUSSION

Fig. 1 shows the relationship between the cutting speed, v (m/s) and tool life, T (min) at constant feed rate of 0.18mm/rev for different tool materials. It can be seen from this figure that the silicon carbide tool which has the highest hardness (2500Hv) among the group of tool tested, started with a minimum tool life of about 20min and

then the tool life increases gradually with increasing the cutting speed. For the high speed steel (650 Hv hardness, it can also be seen from Fig. 1 that its tool life started with almost the same tool life of Sic at minimum cutting speed. However, the behavior is in contrast to that of the Sic tool. It can be seen that the tool life decreases with increasing the cutting speed. This could be attributed in terms of the low hardness of high speed steel compared with Sic at high temperature. By increasing the cutting speed the overall temperature increased and affects the tool material. For Al_2O_3 tool (hardness 1930 Hv), it can be seen from Fig. 1 that the cutting speed-tool life relationship follow the same trend as for the Sic tool mentioned above. But the tool life magnitude is lower than that of Sic. It can also be seen from the same figure that the PSZ tool shows a similar relationship but lower magnitude is also observed for this material compared with Sic and Al_2O_3.
All these results could be interpreted in terms of the hardness where the hardest material shows a longer tool life. For Titanium carbide cutting tool material (1171 Hv) it can be seen from Fig. 1 that its tool life is not sensitive to the variation of cutting speed. Contour plots in Fig. 1 was developed using a computer program and it could be used to determine the value of the average surface roughness, Ra, for a given cutting speed.

Fig. 2 shows the relationship between the tool life T(min) and feed rate f(mm/rev) for different cutting tool materials. It can be seen that the Sic tool material shows the highest tool life value at minimum feed rate of (0.05 mm/rev), by increasing the feed rate the tool life decreases gradually with feed rate until about 0.175 (mm/rev). After that the tool life shows lower sensitively to the variation of feed rate. For Al_2O_3 tool material, the results show the same trend but in a lower magnitude. However the results for the other three materials (PSZ, Titanium carbide and high speed steel) show the same trend while the tool life value for them all are close to each others but in a much lower magnitude. It can be said that high hardness for Sic and Al_2O_3 is responsible for the high tool life compared with the other three materials. The reduction in tool life with increasing the feed rate could be interpreted in terms of microchipping of the tool during cutting which reduce the tool life.

Fig. 3 shows the relationship between tool life and tool rake angle for the three ceramic materials, Titanium carbide and high speed steel. It can be seen that the tool life of all cutting tool materials investigated in this research decreases with increasing the tool rake angle. It can also, be seen that the Sic tool has the highest tool life among this group of materials, followed by the Al_2O_3 tool material. Despite that the other three tool (PSZ, Titanium carbide and high speed steel) materials follow the same trend, the results are not consistent with their hardness and require further investigation.

Further analysis was conducted on Sic tool material as it shows the maximum tool life among the group of materials tested in the present work. Fig. 4 shows the interaction between the cutting speed and feed rate on the tool life of the Sic cutting tool material. It can be seen that in all feed rates conducted in this work, a gradual increment of tool life is obtained by increasing the cutting speed. It also can be seen that by decreasing the feed rate, the tool life decreased except for the two higher values of feed rate (0.25 and 0.318) where the results of varying the cutting speed show the same tool life. The contour plot in this figure could be used to determine the value of tool life at any interaction between the cutting speed and feed rate.

Fig. 5 shows the interaction between cutting speed and tool rake angle with their effect on the tool life for Sic material. It can be seen that the trend for all rake angles used in this research is almost the same in the whole range of the cutting speed used in the present investigation and the values of the results of the tool life are close to each others.
The contour plot in Fig. 5 is used to determine the value of the tool life at any interaction between the cutting speed and the rake angle.

Fig. 6 shows the interaction between the feed rate and tool rake angle with their effect on the tool life. It can be seen that increasing the feed rate has led to the reduction of tool life until about 0.25mm/rev feed rate. However increasing the feed rate to 0.3 mm/rev leads to either an increase in the tool life value or non sensitivity to this increase of feed rate.
The contour plot in Fig.6 is used for determining the value of the tool life at any interaction between the feed rate and tool rake angle.

4. CONCLUSION

The life of ceramic tools and two other cutting materials were studied at different machining parameters.

1- It was found that the Sic ceramic (2500VPN) exhibits the highest tool life among all cutting tools tested in this research.

2- Increasing the cutting speed leads to a gradual increase in tool life for Sic, Al_2O_3 and PSZ. However, the Titanium carbide tool shows slight sensitivity to the variation of cutting speed
However the high speed steel cutting tool shows a gradual reduction in tool life by increasing the cutting speed.

3- The results of tool life at different cutting speed for all cutting tool materials are consistent with the hardness.

4- The tool life for all cutting tool materials tested in this research is decreased by increasing the feed rate.

5- The results show that increasing the rake angle results in a gradual reduction in tool life for the five different materials examined in the present work.

6- Contour plots were developed for determining the tool life at any interaction between the cutting parameters

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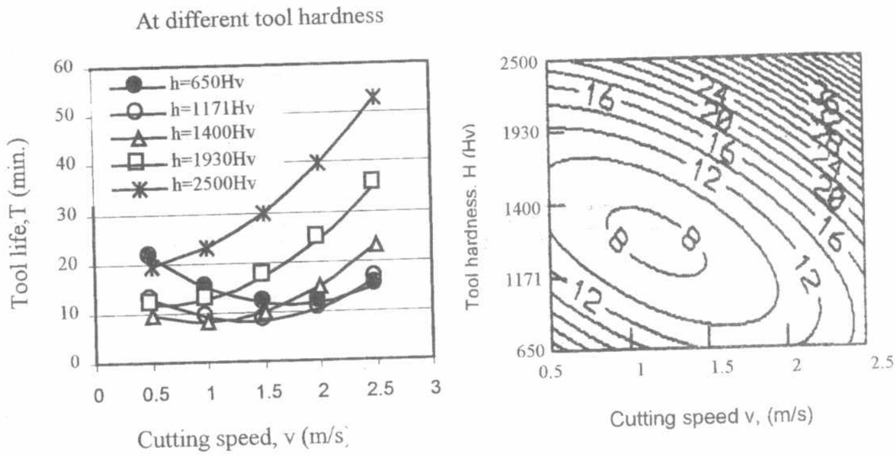

Fig. 1 Relationship between tool rake angle and tool life for different tool hardness at feed rate=0.18mm/rev and tool rake angle=-10°

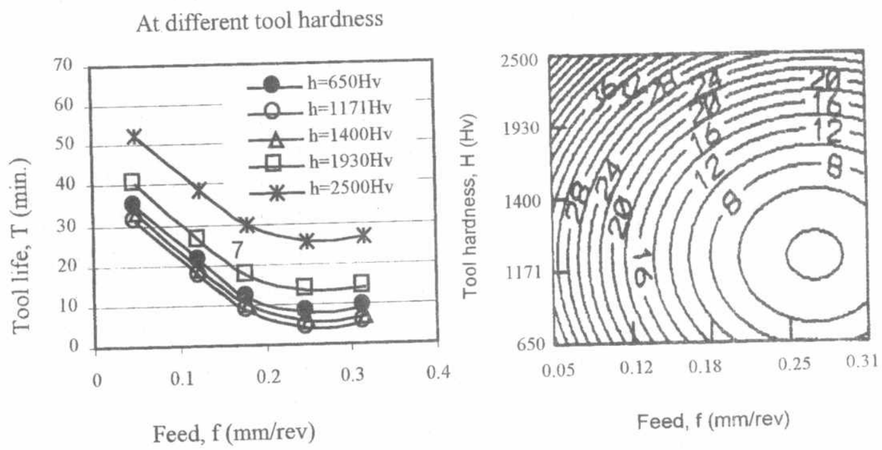

Fig. 2 Relationship between feed rate and tool life for different tool hardness at cutting speed=1.5m/s and tool rake angle=-10°

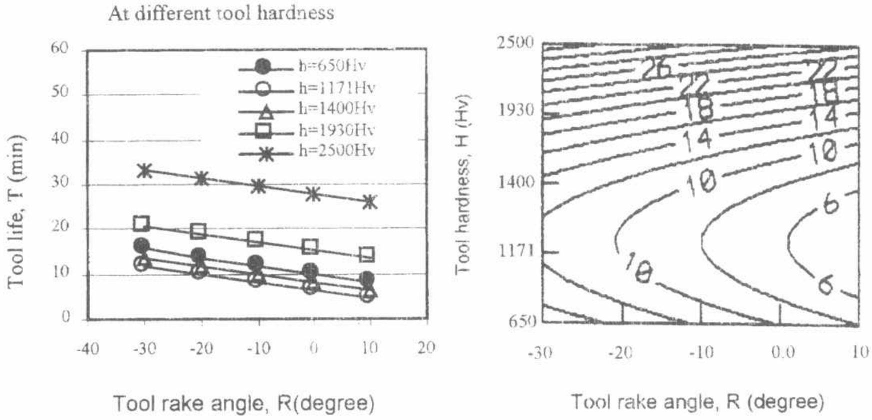

Fig. 3 Relationship between tool rake angle and tool life for different tool hardness at cutting speed=1.5m/s and feed rate=0.18mm/rev

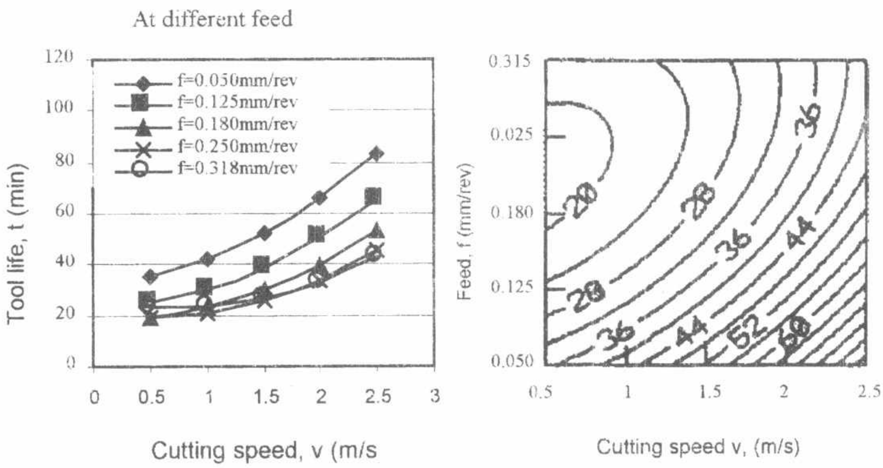

Fig. 4 Relationship between cutting speed and tool life for different feed rate at tool rake angle=10^o for Silicon carbide cutting tool

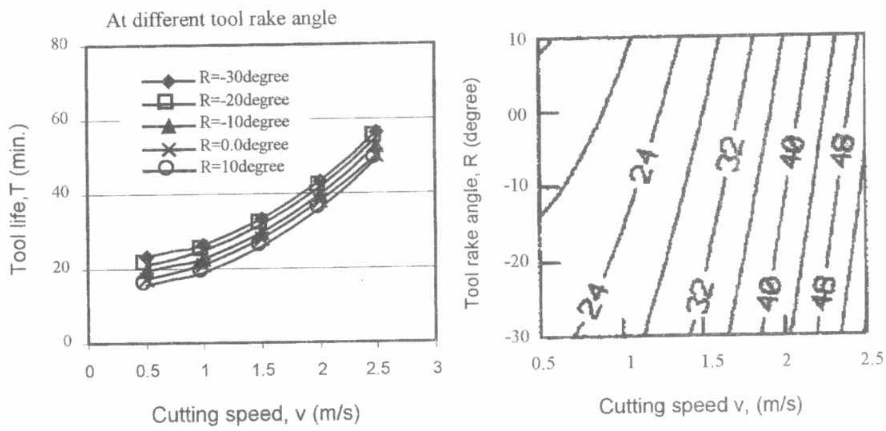

Fig. 5 Relationship between cutting speed and tool life for different tool rake angle at feed rate=0.18mm/rev for Silicon carbide cutting tool

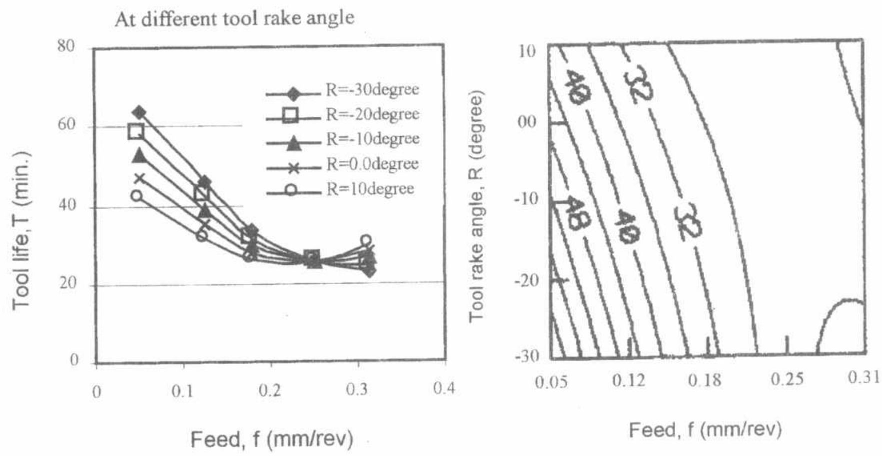

Fig. 6 Relationship between feed rate and tool life for different tool rake angle at cutting speed=1.5m/s for Silicon carbide cutting tool