TRIBOLOGICAL BEHAVIOR OF CERAMIC AND CARBIDE INSERTS IN INTERRUPTED AND CONTINUOUS TURNING OF HARDENED HIGH CHROMIUM CAST IRON

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ABSTRACT

The aim of the present study is to establish machining conditions in interrupted and continuous high speed turning of high chromium cast iron (21% Cr.), which is considered as one of high performance structural materials recently developed. Different tool materials such as ceramics and carbides were experimentally investigated during interrupted and continuous turning. For ceramic inserts, silicon nitride grade Kyon 2000 and aluminum oxide cold-pressed grade, K060 were used. Tungsten carbide, KC 850 and KC 950 were tested for carbide inserts. A comparative study between the proposed machining method and grinding based on the surface finish of machined components was also conducted. The results indicated that, for normal levels of cutting speeds, the tool wear of ceramic inserts is less sensitive to cutting speed. Failure of carbide inserts was noticed at high cutting speeds in continuous turning due to diffusion and adhesion wear. In case of interrupted turning, the wear resistance of carbide and ceramic inserts were enhanced significantly compared to continuous turning for all cutting speeds experimented. The wear mechanism of tools and hence the effect of machining conditions on their life were also discussed. In interrupted and continuous tests, high machining performance of Kyon 2000 ceramic inserts was achieved compared to other insert's materials. Flying and rotary tools were also recommended for high speed machining especially for tool materials having high thermal conductivity.

Keywords: Interrupted cut, Continuous cut, Ceramic inserts, Carbide inserts, Tool life

INTRODUCTION

Extensive research efforts had been done to enhance the performance of structural materials by improving their stiffness, strength, wear resistance, controlled thermal expansion in higher temperature applications. Because of their excellent structural performance, such materials play an important role in engineering design. Some industrial applications such as, drive shafts, components of braking systems, gun barrels and gears are developed from such materials. A widespread utilization of these new materials is limited by lack of knowledge about their properties and hence more details are required. For instance, solutions must be found to their disadvantages, such as, reduced ductility, low toughness, and problems in machining such as rapid tool wear [1-4]. In order to overcome these difficulties, most manufacturers try to produce parts close to final shapes and dimensions. In this case, machining operations are minimized. For some applications it is difficult to avoid such operations, therefore, the importance of generating new machine tools and tool materials capable of working these materials has been considered the main objective of recent technology. In recent years, there has been an increasing interest in automated machine tools for mass production. Therefore, machining conditions such as, cutting speed, depth of cut, and feed rate should be selected to achieve the maximum production rate. The prediction and

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monitoring of tool failures have been considered in modern manufacturing systems, to improve the product quality, increase productivity, and protect machine tool [5, 6]. The replacement of tools is traditionally scheduled according to a conservative estimation of the tool life. In this regard results of the experimental work concluded that, the replacement of the tool should occur when the wear land width reaches 0.25 to 0.5 mm for finishing cuts, 0.76 mm for medium to heavy roughing operations, and 1.02 mm for extremely heavy roughing cuts [10, 11].

For high production quality, the requirements for modern cutting tools include high wear resistance, fracture toughness, and chemical stability at high temperatures and forces. Ceramics, carbon boron nitride CBN and carbide tool materials are considered sufficient tools for precision cutting because of their hardness and chemical inertness, even at elevated temperatures. However, their capability to withstand mechanical and thermal shocks lead to make them suitable for most cutting operations [7-9].

EXPERIMENTAL WORK

Concentrated studies on the performance of different tool materials through high speed machining in continuous cut have been carried out. Less efforts were directed to the tool performance through interrupted cut of soft workpiece material. Recently, new strengthening and toughening techniques have been successfully developed for ultra hard and tough tool materials such as ceramic and carbide materials. Therefore, the present work is intended to evaluate the performance of such tool materials in machining very hard workpiece material such as hardened high chromium cast iron during interrupted and continuous machining. A comparative study is conducted to compare the performance of these methods and grinding based on generated surface roughness.

Cutting Tools

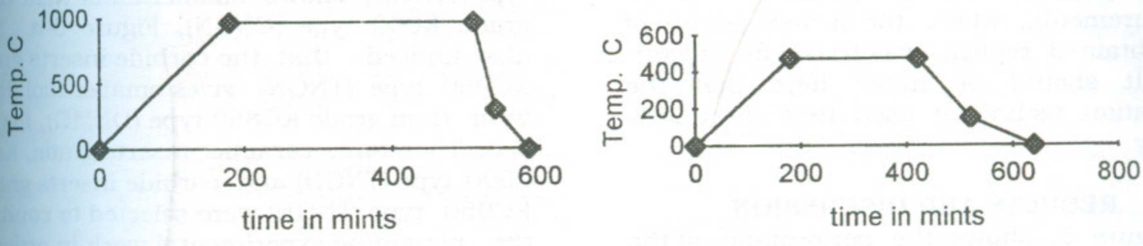
The experimental work was preliminary performed using tungsten carbide grade, KC 850, KC 950, silicon nitride ceramic grade Kyon 2000 and aluminum oxide cold-pressed ceramic grade K060 to investigate their performance in interrupted cuts. Inserts' types and codes according to Kennametal standard are; for carbide material Kenloc type (DNMG 15 04 08, 15 04 12, 15 04 16) and Kendex type (TNGN 16 04 08, 16 04 12, 16 04 16). For ceramic silicon nitride, Kendex type (TNGN 16 04 08, 16 04 12, 16 04 16) and aluminum oxide cold-pressed Kendex type (CNGN 16 07 08, 16 07 12, 16 07 16) are used.

Workpiece Preparation

The workpiece material was made from high chromium cast iron which was hardened and tempered before machining according to the thermal cycle indicated in Figure 1. The measured hardness is 60 RC. The chemical composition of the material is also shown in Table 1. The experimental work was conducted on center-lathe machine provided with special tool holders for movable tips. Interrupted turning was conducted through specimens having square cross-sectional area 50×50 mm after rounding their corners by grinding operation. Specimen shape and dimensions are shown in Figure 2. Continuous turning was conducted on cylindrical specimens having 50 mm diameter.

Table 1 The chemical composition of specimen's material.

C %	Si %	Mn %	S %	Ph %	Ni %	Cr %	Cu %
2.6	0.5	0.7	0.06	0.05	0.02	21	0.55



Hardening cycle

Tempering cycle

Figure 1 Thermal heat treatment cycle applied to high chromium cast iron workpieces.

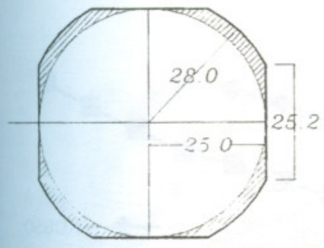


Figure 2 Specimen shape and dimensions for interrupted cut

Experimental Variables

Different machining conditions including cutting speed, feed rate, depth of cut and tool geometry were used to investigate the performance of selected tool materials in interrupted and continuous turning of hardened high chromium cast iron material. All experiments were conducted without coolant in order to accelerate the rate of tool wear using inserts tool geometry of 5^{0} negative rake angle and 30^{0} approach angle. The other machining conditions can be summarized as follows:

Cutting Speed

For both continuous and interrupted cuts the cutting speed was varied to include 79, 112, 148, 283 and 377 m/min. The depth of cut of 0.1 mm; feed rate of 0.08 mm/rev; and tool nose radius of 0.8 mm; were set constant during this part of experimental work.

Feed Rate

To study the effect of feed rate, at the selected cutting speed of 148 m/min; different feed rates of: 0.08, 0.1, 0.12, 0.14, 0.16, and 0.2 mm/rev; were tested using constant depth of cut of 0.1 mm and tool nose radius of 0.8 mm.

Depth of Cut

The effect of depth of cut was studied during interrupted turning at different cutting speeds of: 79, 112, 148, 283 and 377 m/min., using constant feed rate of 0.08 mm/rev; and nose radius of 0.8 mm. The depth of cut was varied between 0.1 and 0.6 mm.

Tool Geometry

The experimental work was extended to investigate the effect of tool geometry by changing the nose radius to include: 0.8, 1.2, and 1.6 mm; at constant cutting speed 112 m/min.; feed rate 0.08 mm/rev, and depth of cut 0.1 mm.

Grinding Conditions

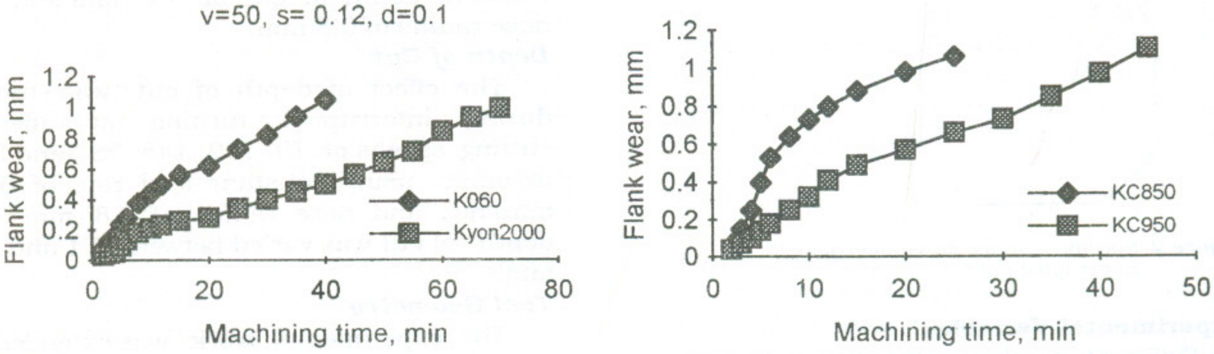
In order to evaluate the performance of the used tools as an alternative method that replaces grinding, experiments were conducted on a cylindrical grinding machine at the following conditions: grinding wheel speed 18 m/sec, feed rate 0.6 mm/rev and variable depth of cut from 0.001 to 0.09 mm, using A99 B80 J9 V grinding wheel.

Measuring Techniques

The experimental results of tool flank wear and surface roughness of specimens were recorded at different machining times. The tool flank wear was measured using especially designed traveling micro-scope of (40x) magnification. The micro-scope travel was controlled by a micrometer of 0.001 mm., least division. The surface roughness of machined specimens was recorded for different depth of cuts using a Self Curing Acrylic resin as a replica material to facilitate measurements, where the surface texture of the obtained replica was traced by Talysurf 10. It should be noted here that the replication technique used here is of 98% fidelity.

RESULTS AND DISCUSSION

Figure 3, shows the performance of the preliminary tests using the selected tool materials during interrupted turning of high chromium cast iron material. It is obvious that, the ceramic insert grade Kyon 2000 type (TNGN) shows smaller flank wear than grade K060 type (CNGN), Figure 3-a. It is also noticed that, the carbide inserts grade KC950 type (TNGN) gives smaller tool flank wear than grade KC850 type (DNMG), Figure 3-b. Therefore, ceramic inserts grade, Kyon 2000 type (TNGN) and carbide inserts grade, KC950 type (TNGN) were selected to conduct the remaining experimental work in order to investigate their performance under the selected machining conditions.



(a) (b)

Figure 3 Effect of machining time on tool flank wear during interrupted cut; (a) Ceramic inserts (b) Carbide inserts

Ceramic Inserts Tool

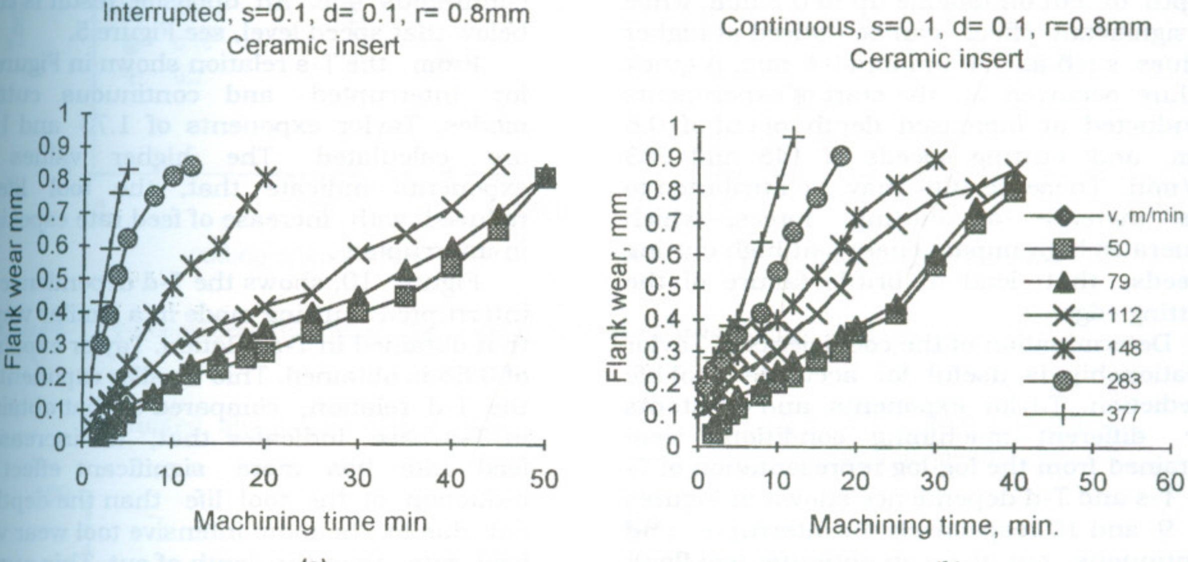
Effect of Cutting Speed on Tool Flank Wear

The tool flank wear versus machining time, for different cutting speeds, is shown in Figures 4-a and 4-b for interrupted and continuous turning respectively. From these results, it is clear that, the tool flank wear is increased at high cutting speeds in both interrupted and continuous cut. For low levels of cutting speeds 50 m/min, 79 m/min; and 112 m/min; small variations of tool flank wear with cutting speeds are clear. It can be seen also, that the tool flank wear is remarkably higher in case of continuous cut than that in interrupted cut at the range of cutting speeds up to 112 m/min.

Tool Life Analysis

Using the results shown in Figure 4, the tool life versus cutting speeds is shown in Figure 5. Small variation of the tool life with cutting speed up to 112 m/min; is clear. This observation may be due to the low cutting force and temperature generated under these machining conditions. It is noticed also that, the tool life in interrupted cut is longer than that for continuous cutting especially at low cutting speeds up to 112 m/min. These results can be attributed to, the tool flank wear at such relatively low cutting speeds which was affected mainly by the persistent heat and friction while the role of variable stresses at such low cutting speeds is insignificant. The actual machining time, in the case of interrupted cut, is less than the total machining time. It is considered as a ratio that can be represented by the length at which the tool is engaged with the workpiece (40% in the present study). This explains why the tool life in interrupted cut is longer than that for continuous cut.

It must be noticed that an opposite trend has been obtained at cutting speed greater than 112 m/min;. In such a case, the tool wear is higher in interrupted cut compared to continuous cut. At high levels of cutting speeds ceramic inserts are mainly affected by the expected high variable thermal, mechanical, and thermomechanical stresses which generates high impact energy and cyclic stresses as a result of the variation of the cutting depth, and cutting forces in the case of interrupted cut. These conditions besides the brittle nature of ceramic materials lead to brittle failure of the cutting edge that reduces the tool life.



(a) (b)

Figure 4 Tool flank wear versus machining time for variable cutting speeds in interrupted and continuous cutting

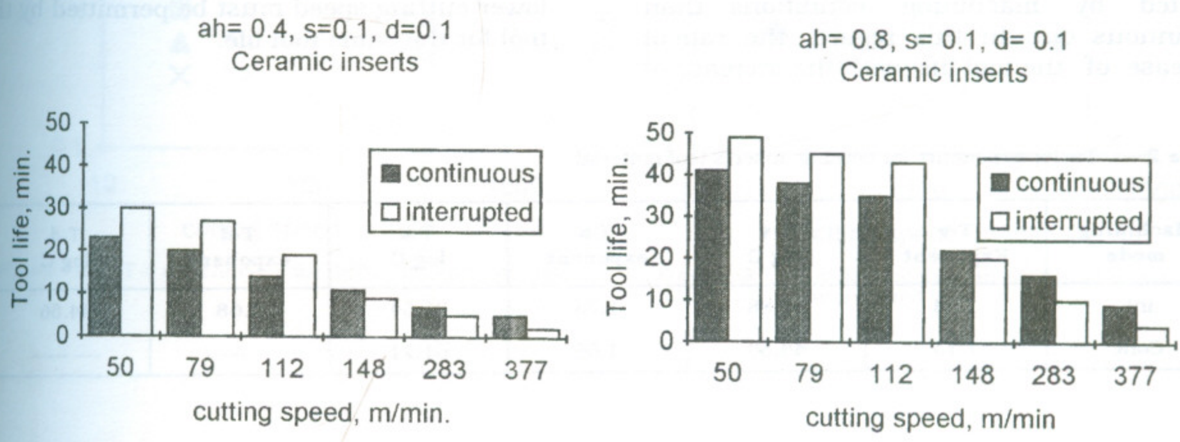


Figure 5 Tool life versus cutting speed for continuous and interrupted cuts at different flank wear

Taylor Coefficients

Figures 6-a and 6-b, show the logarithmic representation of tool life versus cutting speed T-v for different feed rates in interrupted and continuous cut for a tool flank wear of 0.8 mm;. Figure 7 shows (T-v) relation for different depth of cuts in interrupted machining mode. These figures can be used to determine the feed rate, the depth of cut and the corresponding cutting speed for the required tool life.

Figure 7 indicates a slight effect of the depth of cut on tool life up to 0.2 mm; while a significant effect can be noticed at higher values such as 0.4 mm and 0.6 mm. A quick failure occurred at the start of experiments conducted at increased depth of cut of 0.6 mm; and; cutting speeds of 148 and 283 m/min. These results may be attributed to the increase of cutting forces, which generates high impact energy, at high cutting speeds, that lead to brittle failure of the cutting edge.

Determination of the coefficients of Taylor relationship is useful for accurate tool life prediction. Taylor exponents and constants for different machining conditions were obtained from the log-log representation of T-v, T-s and T-d dependence shown in Figures 8, 9, and 10 respectively for interrupted and continuous cut using an optimum tool flank wear of 0.8 mm; Table 2. These results indicate that, the Taylor exponents in interrupted cut are higher than those in continuous cut. This observation means that, the tool life in interrupted cut is more affected by machining conditions than continuous cut. In this regard, the rate of decrease of the tool life with the increase of machining conditions (v, s, d) in interrupted cut is greater than that in continuous cut.

In the T-v relation shown in Figure 8, Taylor exponents of 1.88 and 1.15 are obtained for interrupted and continuous cut respectively. These values characterize the degree of variation of tool life with cutting speed. Trends representing the interrupted and continuous cuts intersect at a cutting speed of 130 m/min; and tool life of 25 minutes, beyond that level interrupted cutting has smaller tool life than that of continuous one. An opposite result is clear below that speed level, see Figure 5.

From the T-s relation shown in Figure 9, for interrupted and continuous cutting modes, Taylor exponents of 1.73 and 1.66 are calculated. The higher values of exponents indicate that, the tool life is reduced with increase of feed rate especially in interrupted .

Figure 10, shows the T-d dependence for interrupted cutting mode in a similar way to that obtained in T-s relation. Taylor exponent of 0.68 is obtained. This smaller exponent,for the T-d relation, compared to that obtained in T-s case, indicates that, the increase of feed rate has more significant effect on reduction of the tool life than the depth of cut due to, the more intensive tool wear with feed rate than the depth of cut. This results from the higher thermodynamic load per unit length of the cutting edge at high feed rate.The greater the forces acting on the tool, the higher cutting temperature, the more intensive tool wear was induced and hence lower cutting speed must be permitted by the tool for the same tool life.

Table 2 Taylor exponents for ceramic inserts tool material

Machining mode	T-v Exponent	T-v log C	T-s exponent	T-s log C	T-d exponent	T-d log C
int.	1.88	51.88	1.73	85.64	0.68	44.56
Cont.	1.15	43.50	1.66	61.21	--------	---------

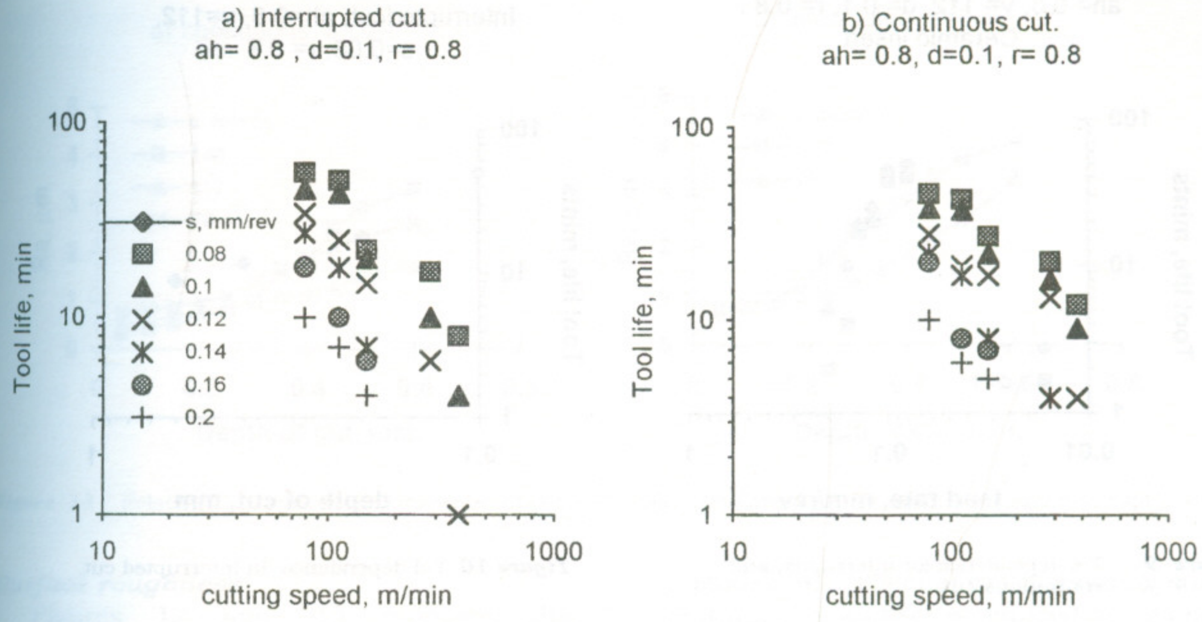


Figure 6 T-v dependence for different feed rates in interrupted and continuous cut

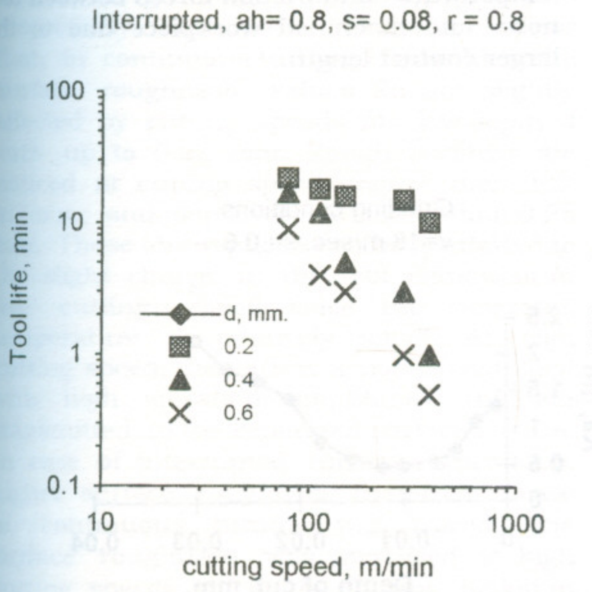


Figure 7 T-v dependence for different depth of cuts

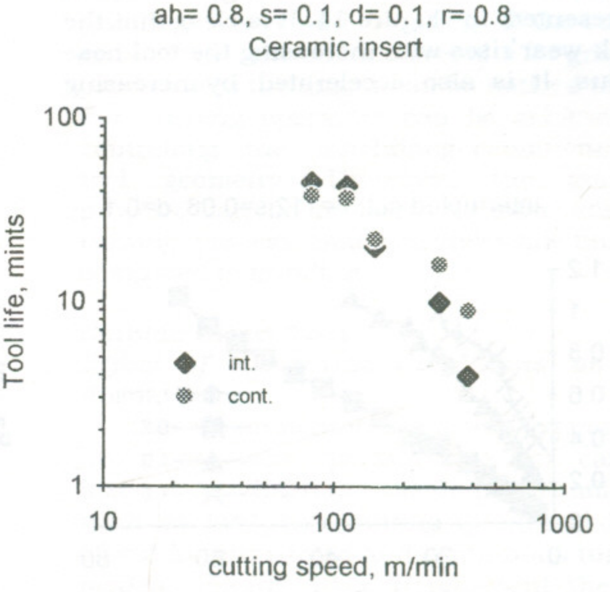


Figure 8 T-v dependence in continuous and interrupted cut.

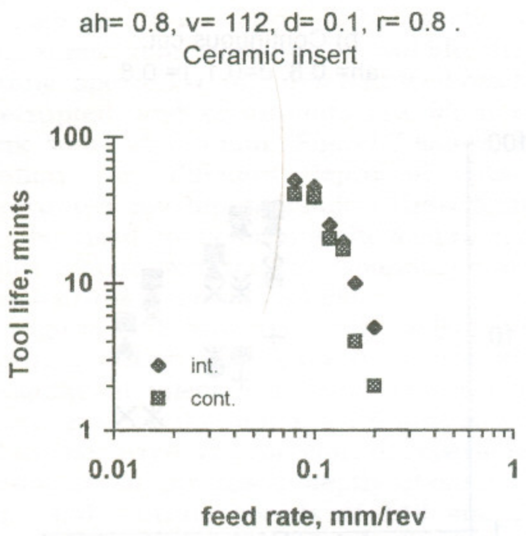


Figure 9 T-s dependence for interrupted and continuous cut.

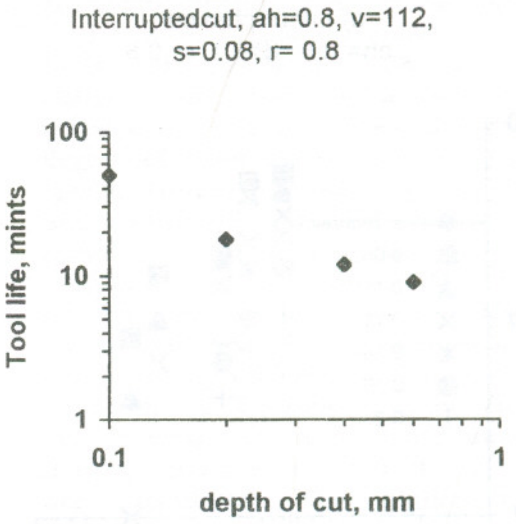


Figure 10. T-d dependence in interrupted cut.

Effect of Nose Radius

The effect of tool nose radius on flank wear at different machining times is represented in Figure 11. It is clear that the flank wear rises with increasing the tool nose radius. It is also accelerated by increasing machining time. These results may be attributed to the increase of cutting temperature and friction forces between tool nose and machined workpiece due to the larger contact length.

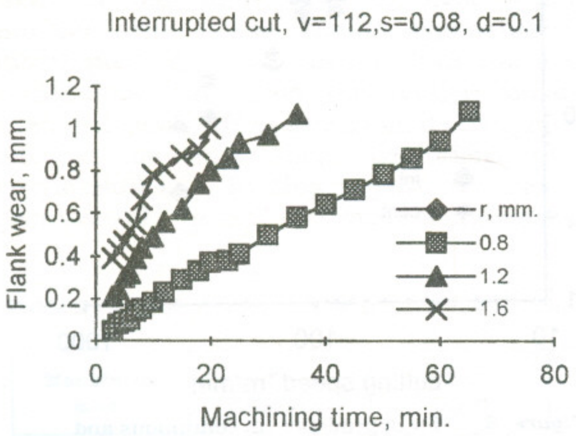


Figure 11 Effect of nose radius on tool flank wear

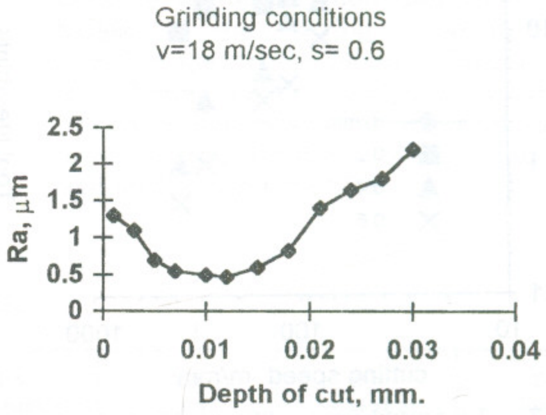


Figure 12 Relationship between grinding depth of cut ansd surface roughness Ra

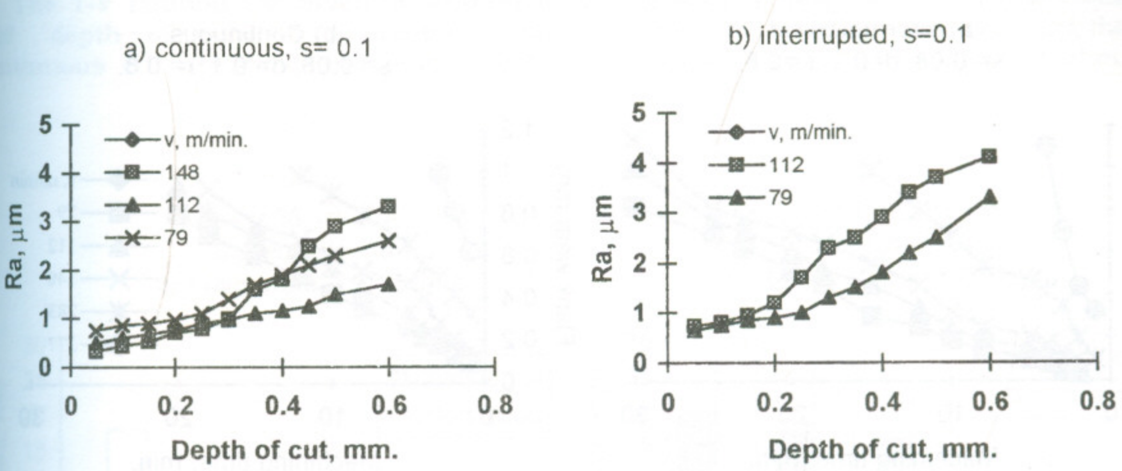


Figure 13 Relationship between turning depth of cut and surface roughness Ra for continuous and interrupted turning

Surface roughness

Figures 12 and 13, represent the relationship between the depth of cut and surface roughness parameter Ra measured at the surface of the Self-Curing Acrylic replica, for grinding and turning operations respectively. From these results it is clear that, in continuous turning Figure 13-a, the surface roughness values Ra are slightly affected by cutting speeds for low depth of cuts up to 0.25 mm. Rough surfaces are noticed at cutting speed greater than 112 m/min.; and depth of cut more than 0.25 mm. These observations can be attributed to the slight change in the tool flank wear at low cutting speed since the generated temperature is relatively small. At high cutting speed, the cutting action is combined with high vibration amplitudes that are transmitted to the generated surface texture. In case of interrupted turning Figure 13-b, higher surface roughness than that in case of continuous turning was traced. The surface roughness was increased at high cutting speeds since, the cutting action in interrupted cut is combined with high impact force at the beginning and end of the engagement between the tool and workpiece. This induces higher vibration levels that are transmitted to the machined surface texture. In case of grinding operation Figure 12, the obtained results showed that, at lower depth of cut, the generated surface roughness includes the effect of pre-machining surface texture. Their effect is reduced by increasing the depth of cut to a certain limit at which the effect of pre-machining disappeared. An increase in surface roughness is noticed at higher depth of cut owing to the increase of grinding forces and blunting of the cutting grits. From the obtained results for grinding process and turning, it can be noticed that, a fine turning operation can be achieved by controlling the machining conditions and tool geometry. Therefore, the grinding process can be replaced by more efficient turning process that produces fine finishes compared to grinding.

Carbide Insert Tool

Effect of Machining Conditions on Tool Flank Wear

The experimental work was extended to investigate the performance of carbide inserts at different machining conditions such as feed rate, cutting speed, and depth of cut in interrupted and continuous turning modes. Figure 14-a, b represent the tool flank wear versus machining time for different cutting speeds in interrupted and continuous cutting respectively. Accordingly, in case of continuous turning, a significant effect of cutting speed is noticed since the carbide inserts do not withstand high cutting speeds.

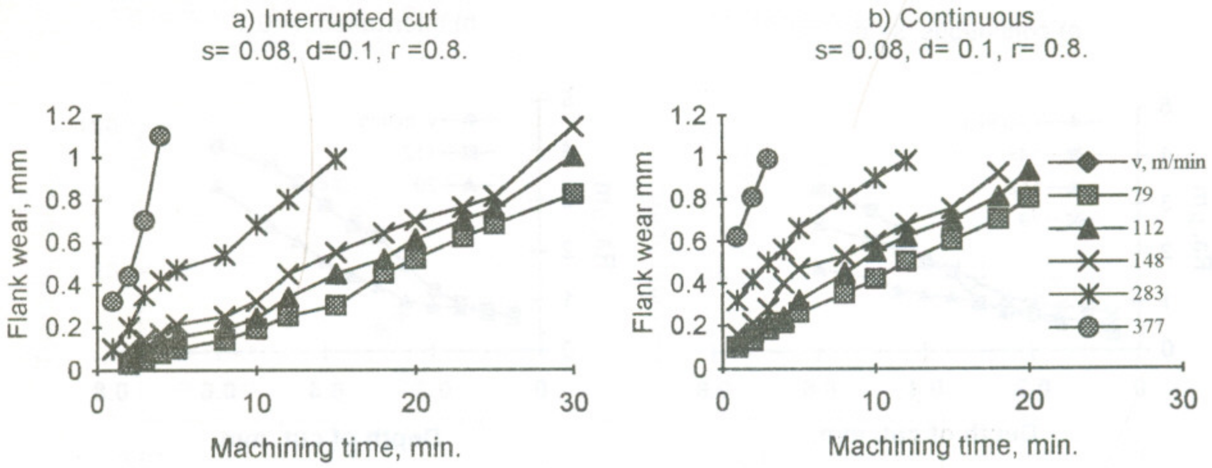


Figure 14-a Tool flank wear versus machining time at different cutting speeds for interrupted and continuous cuts.

Tool Life Analysis

Figure 15, represents the tool life versus cutting speed for different tool flank wear of 0.4 mm and 0.8 mm. These results indicate that, the tool life has a slight variation with cutting speed up to 148 m/min; while a significant effect is noticed beyond this level. This trend is attributed to the adhesion and diffusion wear resulting from higher contact stresses and hence high generated heat. A significant effect of machining mode on tool life can be noticed in Figure 15. The tool life is improved significantly in case of interrupted cut compared to the continuous cut for all investigated machining speeds. These results can be related to, the adhesion and diffusion effects during the cutting action. Because the carbide material has high hardness and toughness, they resist the impact load and cyclic stress generated during interrupted cut. Under such conditions, the insert tip is engaged with material through a part of the machining cycle depending on the dimensions of workpiece. In this case the insert tool receives heat during contact and looses some of their heat to the surrounding atmosphere, during non-cutting cycle. This cools the cutting edge before starting the new cutting cycle. In case of continuous cut the cutting edge is in continuous contact with the workpiece throughout all the machining time. Therefore the heat was accumulated in the cutting zone, and the cutting temperature increases. These conditions, lead to an accelerated tool wear in the case of continuous turning than that in interrupted one due the adhesion and diffusion actions. In order to reduce the effect of diffusion wear for high thermal conductivity tool materials, the flying and rotary cutting tools are therefore recommended in high speed machining.

Taylor Coefficients

The log-log representation of T-v, and T-s are plotted in Figures 16 and 17 respectively. Taylor exponents and constants are indicated in Table 3. It is generally clear that Taylor coefficients in interrupted cut are greater than those obtained in continuous cut. However the greater value of Taylor exponent of T-v relation means that, the tool life is affected by cutting speed in continuous cut more than that in interrupted cut due to, the increase of temperature at higher cutting speeds. Consequently the rate of decrease in tool life with the increase of cutting speed in continuous cut is more than that with interrupted cut. These results are in agreement with those obtained in Figure 15. The increase of Taylor constants in interrupted cut compared to continuous cut explains why the tool life in interrupted cut is longer than that in continuous cut?

The T-v relation for different feed rates and depth of cuts in interrupted and continuous cut are shown in Figure 16-a, b, c and d, respectively. These results can be used as a guide when selecting the suitable cutting conditions for a given tool durability.

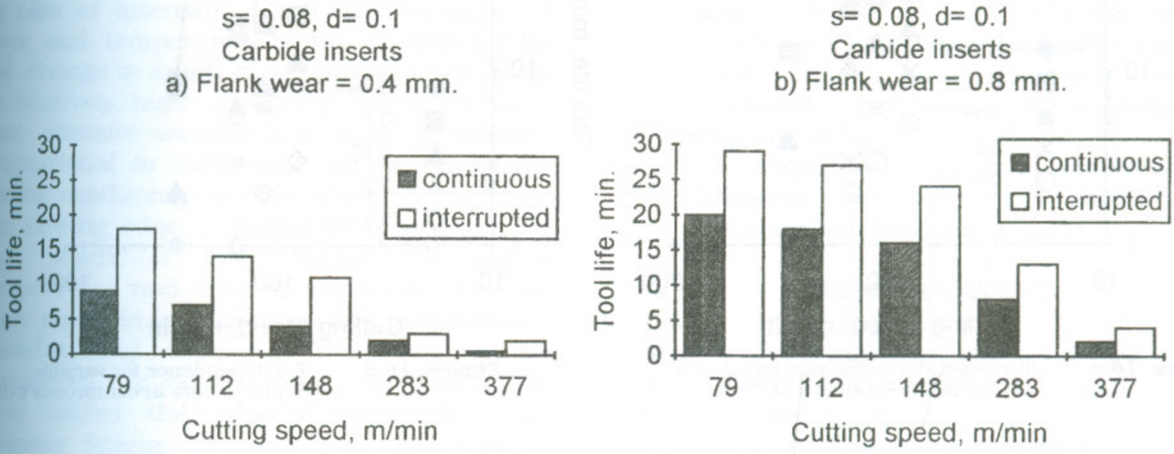


Figure 15 Tool life versus cutting speed for continuous and interrupted cut at different flank wear.

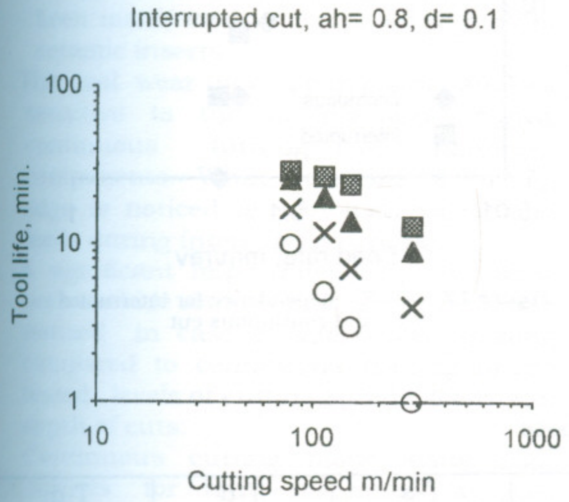


Fig. 16-a T-v dependence for different feed rates in interrupted cut .

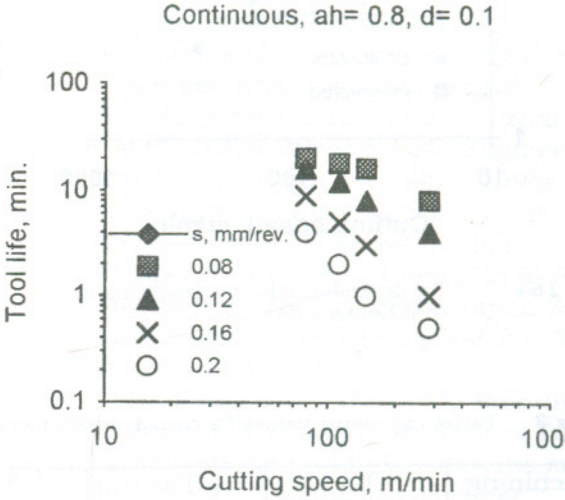


Figure 16-b. T-v dependence for different feed rates in continuous cut

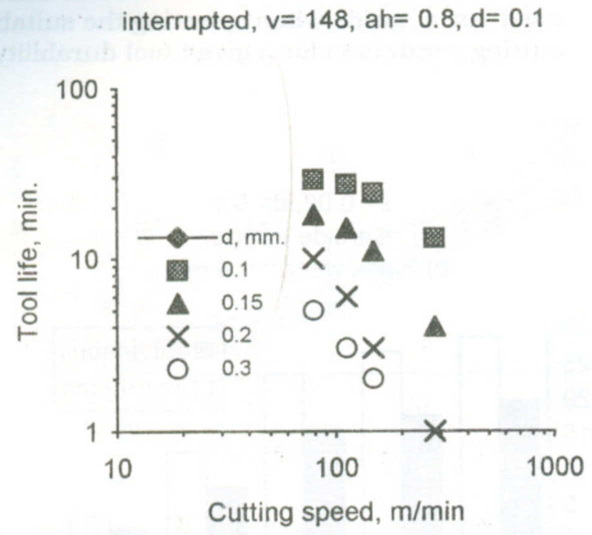


Figure 16-c T-v dependence for variable depth of cut in interrupted cut.

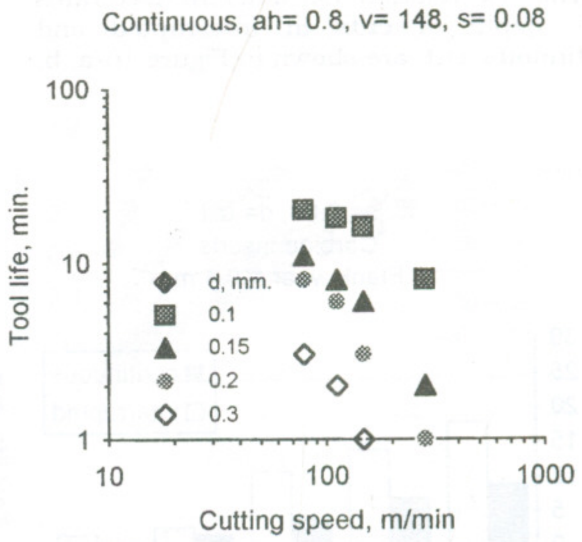


Figure 16-d T-v dependence for variable depth of cuts in continuous cut

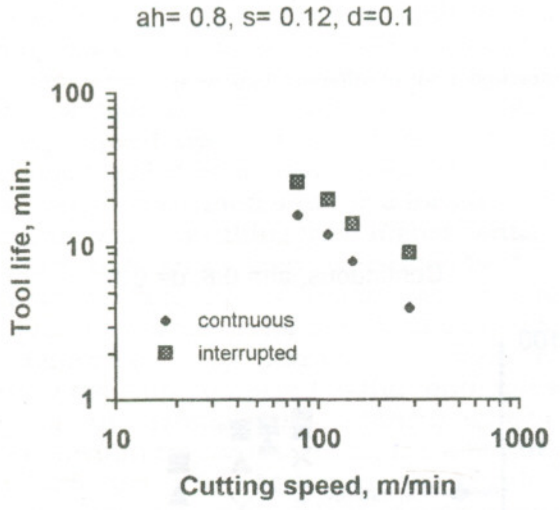


Figure 16-e T-v dependence for interrupted and continuous cuts

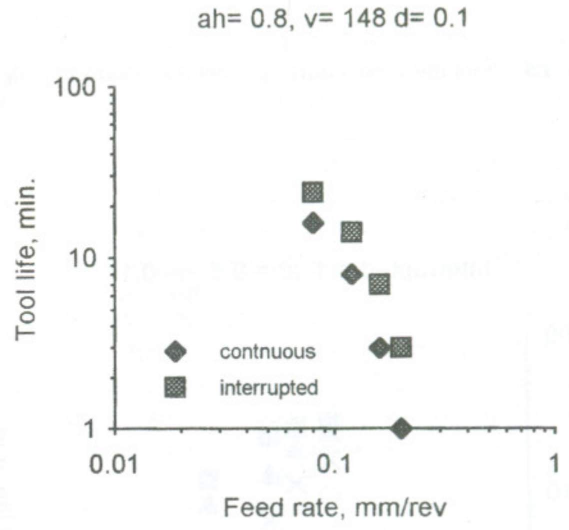


Figure 17 T-s dependence for interrupted and continuous cut

Table 3 Taylor exponents values for carbide insert tool material

machining mode	T-v exponent	T-v Log C	T-s Exponent	T-s log C	T-d Exponent	T-d log C
int.	1.33	28.99	0.97	40.50	0.65	44.17
cont.	1.41	18.38	0.93	28.50	0.62	27.83

Tool Wear Pattern

The results of the present work provides the tool wear mechanisms acting during machining of hard materials. It could be seen that the variations of force and temperature exert additional stresses on the cutting edge. In case of interrupted cut such variation of force and temperature is directly affected by the change in depth of cut during machining at relatively high speeds. It is also known that abrasive and diffusion wear are directly proportional to both time and temperature during machining. In case of interrupted cut, the cutting edge is subjected to variation of the depth of cut, hence the mean temperature and time of contact are smaller than those in continuous cut. Accordingly, abrasion and diffusion wear can not be considered to be the main mechanism of wear within the zone of interrupted cut. However fatigue wear in such case may be the predominant mechanism.

CONCLUSIONS

From the obtained results, the following points are concluded:

1. In interrupted and continuous turning tests, high cutting performance of ceramic inserts grade Kyon 2000 has been manifested as compared with other ceramic inserts.
2. The tool wear of ceramic inserts are less sensitive to the cutting speed during continuous turning of hardened components. While breakage of cutting edge is noticed at very high speeds and feeds during interrupted turning.
3. A significant improvement in tool life of both carbide and ceramic insert tools was noticed in case of interrupted turning compared to continuous turning for the tested levels of cutting speeds, feeds and depth of cuts.
4. Continuous cutting mode using high speeds for hard machined surfaces significantly reduces tool life of carbides inserts.
5. The flying and rotary cutting tools are recommended for high speed machining for tool materials of high thermal conductivity.
6. Fine turning by a single point tool at optimum cutting conditions could fully substitute the grinding process on the basis of surface finish of machined component and rate of metal removal.
7. The T-v dependence for different feed rates and depth of cuts are represented for ceramic and carbide inserts which can be used as a guide for selecting the machining conditions for a given tool edge durability
8. In interrupted cut both abrasion and diffusion wear can not be considered as the main mechanisms of wear.

NOMENCLATURE

CBN	carbon born nitride
ah	tool flank wear, mm
d	depth of cut, mm
r	nose radius, mm
Ra	center line average surface roughness, μm
T	tool life, min.
RC	Rockwell hardness number
V	cutting speed, m/min
s	feed rate, mm/rev.
C	Taylor constant
n	Taylor exponent

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السلوك الترايبولوجى للقم السيراميكية والكربيدية فى الخراطة المتقطعة والمستمرة لخامات الحديد الزهر المقسى والغنى بالكروم

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ملخص البحث

نظرا للتطور السريع فى مجالات التصنيع وهندسة المواد فان الحاجة الى معدات اكثر كفاءة تستطيع التعامل مع الخامات الحديثة ذات المواصفات الميكانيكية والفيزيقية العالية مثل المتانة والصلادة والجساءة هى محور اهتمام العاملين فى هذا المجال. ان احد مشاكل استخدام الخامات الحديثة فى مجال تصنيع المعدات هو صعوبة التشغيل لذلك يلجأ بعض العاملين فى مجال الإنتاج الى البعد عن عمليات التشغيل. ولكنة فى اغلب الأحيان لأبد من اجراء عمليات التشغيل المختلفة للحصول على درجات دقة مرتفعة. ونظرا لتواجد خامات ذات صلادة عالية مثل الكربيدات والسيراميك وكذلك التطور الكبير فى ايجاد انواع منها تقاوم الصدمات فان محاولات استخدامها فى تشغيل الخامات الصلدة هو محور اهتمام العاملين فى هذا المجال. يهدف هذا البحث الى اختبار الأنواع المناسبة والمتوفرة فى الأسواق المحلية من اللقم المصنعة من خامات السيراميك والكربيدات فى تشغيل عينات

مصنعة من الحديد الزهر المحتوى على نسبة ٢١٪ كروم بعد تقسيته حيث ان الصلادة المسجلة بمقياس روكول سى هى ٦٠ . وامتد البحث الى اختبار عمر الحد القاطع للقم القطع المناسبة خلال ظروف التشغيل المختلفة باستخدام القطع المستمر والمتقطع ودراسة امكانية استبدال عمليات التجليخ باخرى اكثر كفاءة مثل الخراطة او التفريز. وقد توصل البحث الى ان اللقم المصنعة من السيراميك مثل Kyon 2000 واللقم الكربيدية مثل KC 950 هى افضل الأنواع التى تم اختبارها وان التآكل فى الحد القاطع للقم المصنعة من السيراميك لأيعتمد على سرعة القطع فى مجال السرعات المعتادة. اما اللقم الكربيدية فانها تنهار فى حالة استخدام سرعات قطع مرتفعة فى الخراطة المستمرة وان مقاومتها للانهيار تتحسن فى حالة القطع المتقطع. وبالنسبة للقم السيراميك فان عمر الحد القاطع فى حالة القطع المتقطع اكبر من القطع المستمر حتى سرعة قطع ١١٢ متر/ دقيقة وبعدها يحدث تحسن لعمر الحد القاطع فى حالة القطع المستمر عن القطع المتقطع. كذلك يمكن استبدال عمليات التجليخ بعمليات الخراطة.