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MACHINABILITY OF SQUEEZE CASTING MMC_s A-390 REINFORCED WITH SiC AND AL_2O_3 PARTICULATES

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ABSTRACT:

Specimens of aluminum alloy matrix A-390 reinforced with 15 vol. % SiC and AL_2O_3 particulates were fabricated by squeeze casting. Multi layers coated carbide TK15, carbide ceramic and CBN were selected as tool materials. The machinability index of these materials was investigated through measuring tool wear, cutting forces, cutting temperature, dimensional accuracy, surface quality and chip formation.

The results indicated similar wear mechanisms for both cases of the reinforcement particulates. A relatively longer tool life was observed in case of aluminum oxide than that in case of silicon carbide reinforcement particulates. The increase of cutting speed, feed rate and depth of cut accelerated the tool wear. A sudden breakage of tool inserts occurred when the experiment started at high cutting speed. CBN inserts were the work suitable tool material for machining of composite materials. The present work manifested the empirical relations between tool life and cutting conditions for the used tools.

KEY WORDS

MMC_S, Machining, Tool Wear, Machinability index, Surface roughness, Cutting forces, Cutting temperature, Dimensional accuracy, Chip formation.

الملخص العربي

في الآونة الأخيرة ونظرا لأهمية المواد المركبة وزيادة استخداماتها فان مشاكل تشغيل هذة المواد هو موضع اهتمام العاملين في هذا المجال. لذلك يهدف هذا البحث إلى دراسة قابلية التشغيل للسبيكة A-390 المقواة بحبيبات من كربيد السليكون وأكسيد الالومنيوم والمصنعة بطريقة السباكة بالضغط. وقد استخدمت في هذا البحث عدد قطع من السيراميك و العدد المطلية بطبقات متعددة من الكربيدات وكذلك CBN وقد تم تقييم قابلية التشغيل من خلال قياس الآتي: التآكل في عدد القطع - قوى القطع - درجة حرارة القطع - دقة الأبعاد - جودة السطح - تكوين الرايش. وقد خلصت الدراسة إلى تشابه ميكانزم التآكل في عدد القطع عند قطع العينات المقواة بحبيبات كربيد السيلكون والمقواة بحبيبات أكسيد الألمونيوم. وقد لوحظ زيادة عمر الحد القاطع عند قطع العينات المقواة بحبيبات الألمونيوم بالنسبة للعينات المقواة بحبيبات كربيد السيلكون. وقد أوضحت الدراسة أن عدد القطع CBN هي انسب عدد القطع المستخدمة في قطع المواد المركبة نسبة لجميع مقاييس قابلية التشغيل المستخدمة في هذا البحث. وتضمن البحث العلاقات التجريبية بين عمر الحد القاطع وشروط القطع لعدد القطع المستخدمة.

INTRODUCTION

Composite materials have been developed primarily for applications requiring high stiffness, or strength, together with light weight. Many composites, however, have other attributes such as low thermal expansion and high thermal conductivity that make these composites dimensionally stable and resist thermal distortion [1, 2]. To satisfy tribological applications the search for new materials with specific properties has boosted the interest of designers and tribologists towards MMC materials. The design requirements of a light weight tribological element providing good frictional properties as well as high wear resistance, proved to be difficult to achieve through conventional materials. Aluminum composite materials are promising systems for structural applications because of the engineering reliability of aluminum and its alloys. These composites are competitive for many applications in aircraft, missiles, electric machinery, aerospace and spacecraft applications [3, 4].

In recent years, problems associated with machining composite materials have become a focus of attention. Current machining methods are limited largely to the grinding techniques. Such methods are costly and often induce damage that significantly affects the in-service performance of the machined component [5]. There is a considerable potential for other methods to improve the machinability of such materials. A program has been initiated to examine the various possibilities with an emphasis on turning methods.

An experimental study was conducted to evaluate the performance of cemented carbides, and Polycrystalline Diamond (PCD) inserts in cutting Graphite/Epoxy (Gr/Ep) composites [6]. Continuous and interrupted dry machining tests were made to cut woven fabric and tape Gr/Ep composites. It was found that continuous cutting mode at high cutting speeds significantly reduces the tool life of carbides. Machining of tape Gr/Ep reduces the tool life more than the machining of fabric work pieces. It was observed that a PCD inserts life was about 100 times of carbide inserts during continuous cutting at high speed [6].

An experimental work was conducted to study the capability of using commercially available solid WC twist drills to drill two types of particulate metal matrix composites PMMC; comral 85, a 20 vol. % micro-sphere reinforced 6061 AL and Duralcan 10 and 20 vol. % irregular shaped reinforcements. The drilling behavior was found to be dependent on the cutting parameters employed, the workpiece heat treatment condition and type of PMMC used. Abrasion was the principal wear mechanism. Increase in feed rate, rather than increased cutting speed, resulted in improved tool life and metal removal rates. Reinforcement shape had a greater effect on drilling behavior than its volume fraction [7]. In another work, the effect of workpiece heat treatment conditions on tool life was studied [8]. The results of this work indicated that annealing led to an increase in ductility and impact energy, but the decrease in hardness shortened the tool life and deteriorated the machinability. With normalising, hardness, ductility and impact energy increased; but the tool life shortened more and more. The maximum built-up edge (BUE) thickness occurred at lower cutting speeds when machining annealed specimens. The heat treatment operations applied did not bring about a considerable difference in cutting forces [8].

Fundamental studies on the machining of carbon fiber reinforced composites CFRP are carried out where machining parameters such as cutting speed, feed rate and depth of cut are varied [9]. Uncoated tungsten carbide and ceramic insert tool materials were used to machine the composite specimens. The result of this experimental work indicated that notch wear was the only type of tool wear. Excessive depth of cut increased notching of tungsten carbide and ceramic inserts.

Cutting temperature and Forces modeling in metal cutting are important for a multitude of purposes including thermal analysis, tool life estimation, chatter prediction, and tool condition monitoring. Numerous approaches have been proposed to model metal cutting temperature and forces with various degrees of success [10]. In addition to the effect of workpiece materials, cutting parameters, and process configurations, cutting tool thermal properties can also contribute to the level of cutting forces. For example, a difference has been observed in cutting forces between the use of high and low CBN content tools under identical cutting conditions. Huang et al [11] modifies Oxley's predictive machining theory by analytically modeling the thermal behaviors of the primary and the secondary heat sources. The model prediction is compared to the published experimental process data of hard turning AISI H13 steel (52 HRc) using either low CBN content or high CBN content tools. The proposed model and finite element method (FEM) predict lower thrust and tangential cutting forces and higher tool-chip interface temperature when the lower CBN content tool is used, but the model predicts a temperature higher than that of the FEM [11].

Statement of the problem

Poor machinability of the composite materials is the main problem that limits its industrial applications due to:

1- Hard particulates which leads to excessive tool wear.
2- Additional hardness due to cold work of the composite matrix which leads to dimensional and form errors, due to increased cutting forces.
3- Non homogenity of structure due to agglomeration of reinforcement particulates which leads to:

- Excessive forces, machine tool chatter and breakage of the cutting tools.
- Excessive tool wear which leads to dimensional and form errors.
- Excessive cutting temperature which leads to lower tool life.

EXPERIMENTAL WORK

The objective of this work is to achieve the economic machining conditions of such materials of poor machinability in order to attain the required shape, surface quality and dimensional accuracy at a reasonable cost.

Procedures:

1-Workpiece material

The selected workpiece material was Al-Si alloy A-390 (17% Si) used for pistons of internal combustion engines. Such an alloy has a low thermal expansion coefficient and high hardness due to the high content of Si. For manufacturing pistons; pressure die-casting, rough turning using carbide tools followed by finishing using diamond tools are adopted. Therefore, the workpiece material was fabricated from reinforcing particulates such as SiC and AL_2O_3 using squeeze casting technique to obtain metal composite specimens. A constant volume fraction of 15 vol. % and variable particle size of 30, 50, and 90 μm were used.

The reinforcing particulates were mixed with the molten matrix alloy inside a ladle which was heated in a specially designed electric furnace. The mixture was stirred using mechanical stirrer. After stirring for 15 minutes, the mixture was poured at 720 °C into specially designed die and punch set. The temperature of the molten metal was held at 720°C for 20 minutes in an induction furnace surrounding the die to achieve a uniform temperature distribution in the matrix. An optimum pressure of 20 tons was applied which was obtained from the preliminary tests conducted with different pressures ranging from 5 to 40 tons with a step of 5 tons applied to the punch until complete solidification of the composite material attained.

2-Selection of tool material

The selected tools were multi coated carbide inserts type Tk 15 (Widia Krupp), carbide ceramic inserts and polycrystalline CBN inserts (Kenna metal).

Tool geometry:

Rake angle -5°, clearance angle 5°, setting angle 60°, auxiliary setting angle 60° and r =0.4 mm.

Machining conditions:

-Variable cutting speed of 50, 79, 90, 112, 150, 183, and 200 m/min at a constant feed of 0.2 mm/rev and a depth of cut of 0.5 mm.

-Variable feed of 0.1, 0.2, 0.4 mm/rev at constant speed of 79 m/min and a depth of cut of 0.5 mm.

-Variable depth of cut of 0.25, 0.5, 0.75, and 1 mm at constant speed of 79 m/min and a feed of 0.2 mm/rev

Measurements

In order to investigate the machinability criteria at room temperature, the following parameters were measured in each experiment.

1- Tool wear.
2- Main cutting force component Fc.
3- Cutting temperature.
4- Dimensional accuracy.
5- Surface roughness.
6- Chip formation.

The experimental work was conducted on a 7.5 kW center-lathe providing a cutting speed range of 25 to 400 m/min. The tool flank wear was measured using a specially designed traveling device on which a microscope was mounted having X40 magnification. The microscope travel was measured by means of micrometer with an accuracy of 0.01 mm. Surface roughness was measured using a Talysurf 6. A two component tool force dynamometer was used to measure the cutting forces. A Williamson Viewtemp 2000 infrared camera (working distance of 400 mm and target diameter of 3 mm) was mounted on the lathe tool post and used for cutting temperature measurement. A micrometer of accuracy 0.01mm was used to determine the dimensional errors. In order to accelerate the tool wear all tests were conducted without coolant.

RESULTS AND DISCUSSIONS

Effect of Cutting Speed

Figs. 1, 2, and 3, represent the tool flank wear versus machining time for different cutting speeds using coated carbide, carbide ceramic and CBN inserts. It is clear that, the tool flank wear rises with the increase of the cutting speed and the machining time. Higher wear was noticed in case of coated carbide and ceramic inserts than in case of CBN inserts. Severe wear and tool nose breakage were noticed in case of coated carbide and ceramic inserts at cutting speeds of 112, 150, 183 and 200 m/min, at the start of machining, which means that these tool materials are not suitable for cutting composite materials. During machining, the generated heat is concentrated on the cutting zone, and due to the low thermal conductivity of ceramics and coated carbides, the temperature of tool nose, chip and machined surfaces were raised. These high temperatures lead to the tool nose failure through the effect of the abrasive action of reinforcement particulates and chip movements.

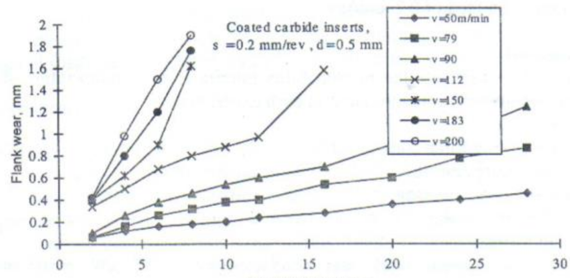


Fig. 1. Flank wear versus machining time at different cutting speeds using coated carbide inserts.

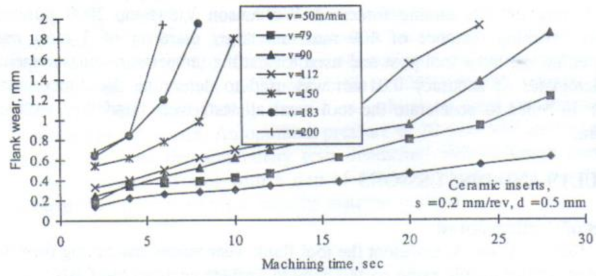


Fig. 2. Flank wear versus machining time at different cutting speeds using carbide ceramic inserts.

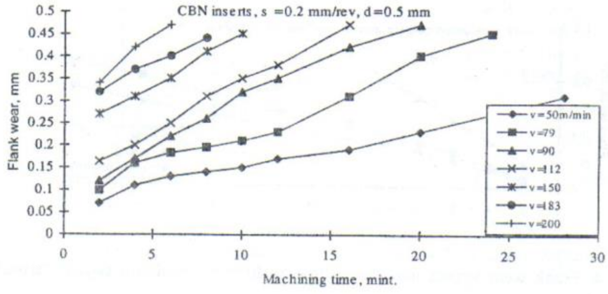


Fig. 3. Flank wear versus machining time at different cutting speeds using CBN inserts.

Effect of Feed and Depth of Cut

Figs. 4, 5, and 6, represent the tool nose flank wear versus the machining time for different feeds using coated carbide, carbide ceramic and CBN inserts respectively. The obtained results indicate that the tool wear increases with the feed and the machining time. Severe tool wear was noticed in case of coated carbide and carbide ceramic inserts compared to CBN. Similar results were noticed also in Figs. 7, 8 and 9, which represent the flank wear versus machining time for different values of the depth of cut. The increase of feed or depth of cut raises the cutting forces and hence the generated heat, which has a strong effect on tool nose specially in case of carbide ceramic and coated carbide tools that have low thermal conductivity. Under such conditions, the heat was stored in the cutting zone and raised the tool nose temperature, thus weakening the nose material. The tool nose was, therefore, lost through the effect of abrasive action of reinforcing particulates and the flow of hot machined chips.

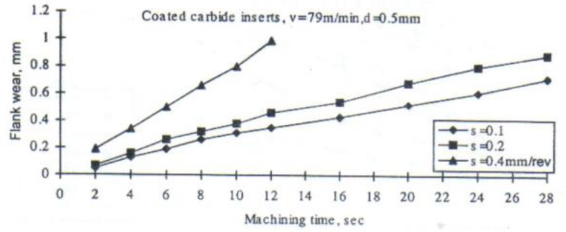


Fig 4. Flank wear versus machining time at different feeds for coated carbide inserts.

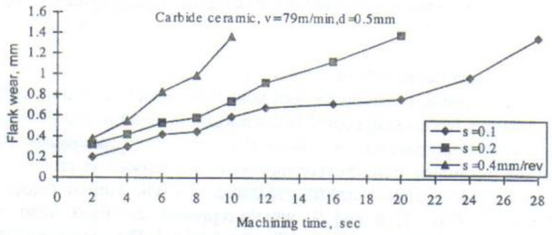


Fig. 5. Flank wear versus machining time at different feeds for carbide ceramic inserts.

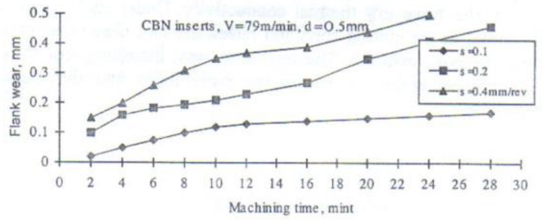


Fig 6. Flank wear versus machining time at different feeds for CBN inserts.

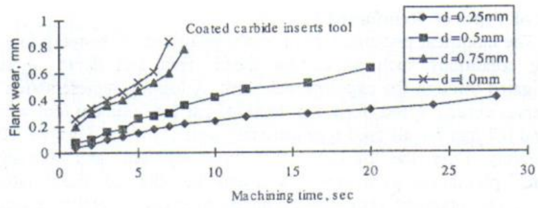


Fig. 7 Flank wear versus machining time at different values of the depth of cut for coated carbide inserts.

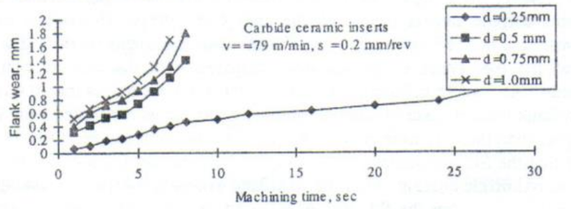


Fig 8 Flank wear versus machining time at different values of the depth of cut for carbide ceramic inserts.

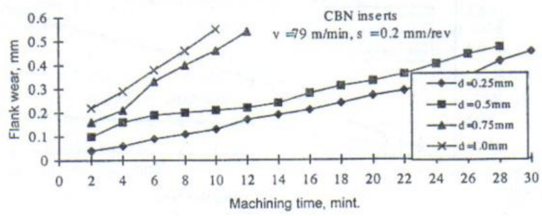


Fig. 9 Flank wear versus machining time at different values of the depth of cut for CBN inserts.

Effect of Types of Reinforced Particles

The empirical phormulu describe the relationships between tool life and cutting conditions such as cutting speed, feed and depth of cut were investigated through the experimental work. A log-log representation for tool life versus cutting speed, feed and depth of cut for optimum tool wear of 0.3 mm and 0.7 mm for all used tool materials were shown in Figs. 21, 22 and 23 respectively. From the log-log curves the coefficients and constant of the empirical phormulas were investigated and the obtained results tabulated in Table 1. The obtained results show an approximately parallel trends for the used tool materials. This means that, Fig. 10 represents the tool flank wear versus the machining time in machining the matrix and composite specimens, reinforced with AL_2O_3 and SiC particulates. Coated carbide inserts tools were used to conduct these tests. The results showed a reasonable performance for the coated carbide inserts in cutting the matrix specimens. However a high flank wear was noticed during cutting of composite specimens reinforced with either of the two types of particulates compared with the case of matrix specimens. At small machining times where the flank wear less than 0.4 mm the tool flank wear in case of cutting composite specimens reinforced with SiC was higher than those reinforced with AL_2O_3. This is result can be attributed to the fact that the SiC particulates have a higher hardness than that of AL_2O_3 w. r. t the Al oxinitride coating. After the wear land excealed 0.4 mm the coating is totally removed so that the SiC and AL_2O_3 particulates have almost the same effect on the wear of the tungsten carbide substrate.

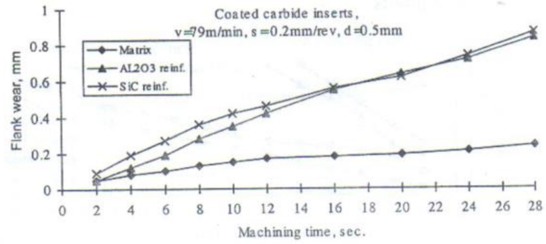


Fig 10. Flank wear versus machining time in machining matrix , and composite specimens reinforced with AL_2O_3 and SiC particulates with coated carbide tools.

Effect of Particle Size

Fig. 11, represents the tool flank wear versus machining time for different reinforcing particle sizes of 30, 50, and 90 μm. Coated carbide tools were used to conduct these experiments. The results show that the tool flank wear increases with the larger particle size. The higher cutting temperature accelerates the tool wear mechanism. The large particulates generally produced higher wear rate than the small particulates.

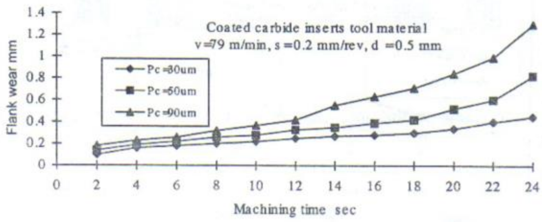


Fig. 11. Flank wear versus machining time for different particles size of SiC.

Surface Roughness

The average surface roughness Ra was measured using Talysurf 6 in the longitudinal feed direction. The variation of average surface roughness Ra versus cutting speeds at a constant feed of 0.2 mm/rev and depth of cut 0.5 mm is shown in Fig. 12. The results indicate a significant effect of cutting speeds on surface roughness at higher levels of cutting speeds specially in case of coated carbide and ceramic inserts. These results can be explained by the presence of built-up edge at these levels of cutting speeds where its formation and growth changes the tool geometry and depth of cut. This leads to a higher vibration which is transmitted to the machined surfaces causing a rough surface texture. The value of cutting speed at which the built up edge disappears can be investigated after the peak point of the curve trained. This value varied according to the used tool material, where the obtained results indicate that these values are 150 and 183 m/min in case of ceramic and coated carbide inserts respectively. In case of CBN inserts the obtained curve has no peak point, which means that the zone of formation, growth and disappearance of built up edge lies out the range of used cutting speeds in the experimental work. These results can be attributed to the capability of the generated heat in cutting zone to rise the temperature of built up edge to the recrystallization temperature. The generated heat during cutting operation depends on cutting speed, friction between tool and chip and value of tool wear. A higher tool wear was recorded in case of ceramic than that of coated carbide and CBN inserts. So the generated heat in case of carbide ceramic is higher than that in case of coated carbide and CBN tools. Hence, in case of carbide ceramic the recrystalliztion temperature of built up edge was reached corresponding to a cutting speed smaller than that of the other used tool materials

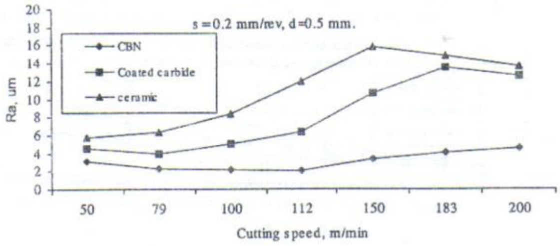


Fig. 12. Average surface roughness R_a versus cutting speed

Cutting Forces and Temperatures

The cutting force component F_c versus the feed for CBN, coated carbide and carbide ceramic inserts is shown in Fig.13. The cutting forces increase with the feed. Higher cutting forces are obtained in case of carbide ceramic and coated carbide inserts than CBN. These results are noticed also in Fig. 14, which represents the cutting temperature versus the feed. Higher cutting temperatures were obtained at larger feeds when using carbide ceramic and coated carbide inserts. Lower cutting temperatures were noticed when using CBN than the other used inserts due to lower frictional force. These results are related to the cutting forces that depend on the tool geometry and friction between the tool and machined specimens. The increase of tool nose dimensions raises the friction force and the generated heat through the cutting zone. These factors increase the cutting forces and the cutting temperature. The generated heat softens the specimen matrix material and hence decreases its cutting resistance, which tends to decrease the cutting forces. However, the cutting force followed the stronger effect of increase. This fact explains the phenomena of low variation of cutting force with feed rates and tool usage distance which shown in Fig. 15, for carbide ceramic and coated carbide tool materials.

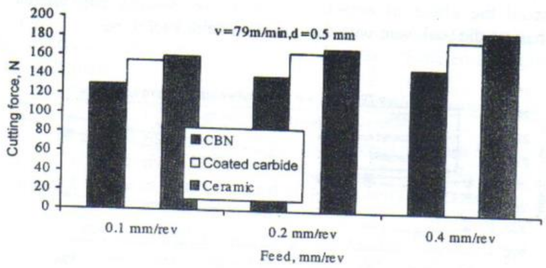


Fig 13. Cutting force versus feed rate for constant cutting speed of 79 m/min and depth of cut 0.5 mm.

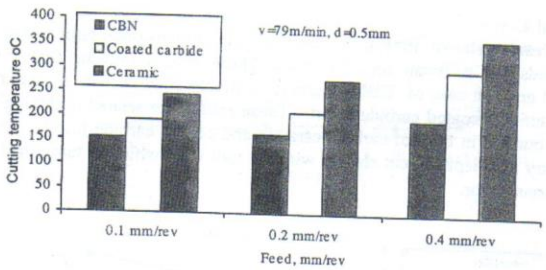


Fig 14. Cutting temperature versus feed for different tool insert materials.

Effect of Tool Usage

Fig. 15, represents the cutting forces versus tool usage or tool travel. It was noticed that the cutting force increases with tool usage. Small variation in its values is evident for small distance of tool usage. High fluctuation of cutting forces was noticed after a longer distance of tool usage. These results are related to the change of tool geometry with the increase of tool usage. A relatively small difference (less than 10 %) in cutting forces is recorded in case of carbide ceramic and coated carbide inserts. The variation of cutting forces with tool usage is very small in case of CBN inserts (about 3 %) compared to other inserts. These results are related to the fact that CBN inserts tool material can withstand the effect of abrasive action of reinforcing particulates that slowly enhances the tool wear with machining time or tool usage.

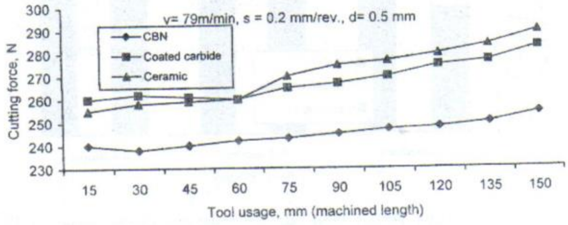


Fig. 15. Cutting force versus tool usage (machined length).

Dimensional Error

The results shown in Fig.16 represent the dimensional error versus cutting speeds for different tool materials. These results indicate that the dimensional error in case of CBN inserts is relatively smaller than in case of carbide ceramic or coated carbide inserts. These results are related to the high tool wear obtained in case of carbide ceramic and coated carbide inserts. The tool geometry and depth of cut change with the tool wear which in turn affects the dimensional error.

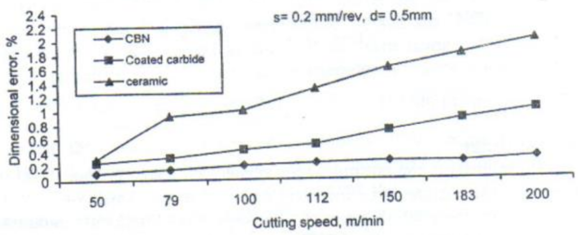


Fig. 16 .Dimensional error % versus cutting speeds

Relative Cost Increase Ratio

Fig. 17 shows the relative cost increase ratio (RCIR) versus cutting speeds for different tool materials. The RCIR was calculated according to the following formula.

$$RCIR = \frac{\textit{Cost of machining composite specimen} - \textit{Cost of machining matrix specimen}}{\textit{Cost of machining matrix specimen}}$$

The results of Fig. 17 indicate that, for cutting speeds between 50 to 200 m/min the use of CBN inserts increases the RCIR from 50% to 200%. The corresponding values in case of coated carbide inserts increased from 190% to 850% while that for carbide ceramic inserts are from 380% to 1400%. This means that the carbide ceramic and coated carbide inserts tool materials are not economical for machining the composite specimens. Reasonable cost was noticed in case of CBN inserts relative to the other tool materials.

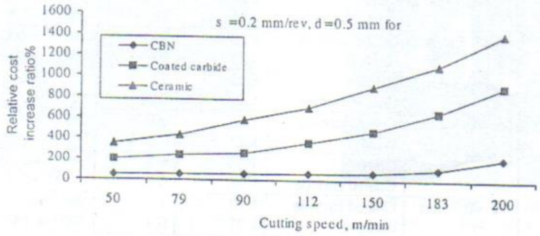


Fig. 17. Relative cost increase ratio versus cutting speeds for different tool materials.

Chip Formation and Types of Wear

A continuous chip was obtained when machining the matrix specimens and abrasive wear is the only type of wear noticed due to the action of Si content which scratches the tool nose as shown in Fig. 18-a, b.

Broken discontinuous chips were obtained when machining composite specimens at high cutting speeds as shown in photograph Fig. 19-a. Severe abrasive tool wear and broken tool nose were noticed at high cutting speeds as shown in the microscopic photographs Figs. 19-b, c, d.

Granular and powder chips were obtained at a moderate cutting speed of 150 m/min for coated carbide tools as shown in photograph Fig. 20-a. Abrasive wear is the type of wear noticed at this condition as shown in photograph Fig. 20-b.

Theoretical Work

The empirical relations between tool life and cutting conditions for the used tools were investigated on the base of the experimental results. A log-log representation for tool life versus cutting speed, feed and depth of cut for optimum tool wear of 0.3 mm and 0.7 mm were shown in Figs. 21, 22 and 23 respectively. The coefficients and constants of the empirical relations were investigated from the log-log curves and the results were tabulated in Table 1. The obtained results indicate an approximately parallel curves trend. This means that the used tools were subjected to the same type of tool wear mechanism which is abrasion wear as mentioned before.

Table 1: Empirical tool life relations for the used tools.

Form of relation	Optimum tool wear	Tool material	Coefficients		Relation
			Exponent	Constant	
$TV^n = C_1$	$V_b = 0.3$ mm	CBN Coated carbide	1.37 1.33	40×10^3 70	$TV^{1.37} = 40\times10^3$ $TV^{1.33} = 70$
	$V_b = 0.7$ mm	Coated carbide ceramic	1.33 1.27	200 90	$TV^{1.33} = 200$ $TV^{1.27} = 90$
$TS^x = C_2$	$V_b = 0.3$ mm	CBN Coated carbide	1.43 1.38	5 0.22	$TS^{1.43} = 5$ $TS^{1.38} = 0.22$
	$V_b = 0.7$ mm	Coated carbide ceramic	1.38 1.37	0.9 0.3	$TS^{1.38} = 0.9$ $TS^{1.37} = 0.3$
$Td^y = C_3$	$V_b = 0.3$ mm	CBN Coated carbide	1.43 1.38	6 0.5	$Td^{1.43} = 6$ $Td^{1.38} = 0.5$
	$V_b = 0.7$ mm	Coated carbide ceramic	1.38 1.37	1 0.3	$Td^{1.38} = 1$ $Td^{0.3} = 0.3$

General empirical relations

General empirical relations between tool life in minutes with cutting speed in m/min, feed in mm/rev and depth of cut in mm were assumed on the following form:

$T = CV^{-n} S^{-x} d^{-y}$

The values of coefficients n, x, y and constant C were obtained from the logarithmic representation of the individual parameter with the tool life. The following relations were obtained:

$T = 1.48\times10^3 V^{-1.37} S^{-1.43} d^{-1.43}$ for CBN tool material ($V_b = 0.3$ mm.)

$T = 19.9 V^{-1.33} S^{-0.84} d^{-1.37}$ for coated carbide tool material ($V_b = 0.7$ mm.)

$T = 7.3 V^{-1.33} S^{-0.81} d^{-1.38}$ for coated carbide tool material ($V_b = 0.3$ mm.)

$T = 8.2 V^{-1.27} S^{-0.9} d^{-1.37}$ for ceramic tool material ($V_b = 0.7$ mm.)

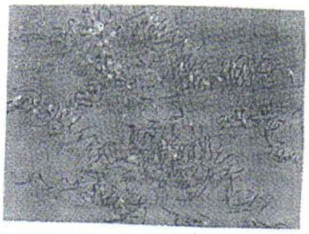


Fig. 18-a. Shape of chip for machining the matrix specimen at a cutting speed of 112 m/min, feed of 0.2 mm/rev and depth of cut 0.25 mm using a coated carbide tool.

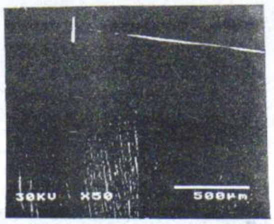


Fig. 18-b. Tool nose wear for machining the matrix specimen at a cutting speed of 112 m/min, feed of 0.2 mm/rev and depth of cut 0.25 mm using a coated carbide tool.

Fig. 19-a. Shape of chip for machining the composite specimen at a cutting speed of 183 m/min, feed of 0.2 mm/rev. and depth of cut 0.25 mm using a coated carbide tool.

Fig. 19-b. Tool nose wear for machining the composite specimen at a cutting speed of 183 m/min, feed of 0.2 mm/rev and depth of cut of 0.25 mm using a coated carbide tool.

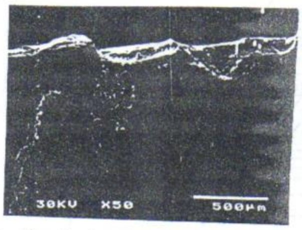


Fig. 19-c. Tool nose wear for machining the composite specimen at a cutting speed of 183 m/min, feed of 0.2 mm/rev and depth of cut of 0.25 mm using a carbide ceramic tool.

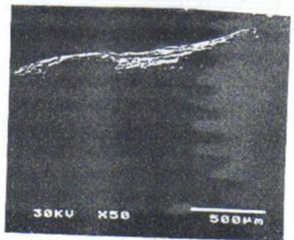


Fig. 19-d. Tool nose wear for machining the composite specimen at a cutting speed of 183 m/min, feed of 0.2 mm/rev and depth of cut of 0.25 mm using a CBN tool.

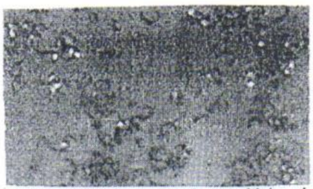


Fig. 20-a. Shape of chip for machining the composite specimen at a cutting speed of 150 m/min, feed of 0.2 mm/rev. and depth of cut 0.25 mm using a coated carbide tool.

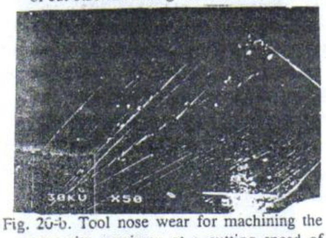


Fig. 20-b. Tool nose wear for machining the composite specimen at a cutting speed of 150 m/min, feed of 0.2 mm/rev and depth of cut of 0.25 mm using a coated carbide tool.

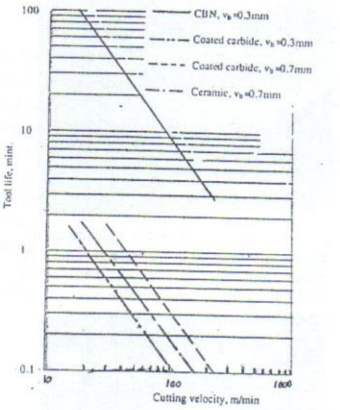
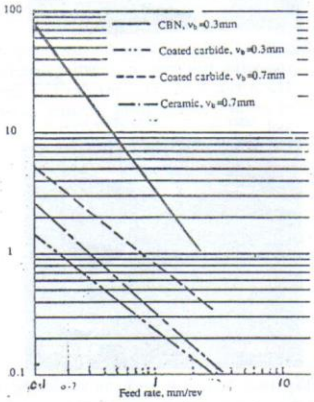


Fig. 21. Tool life versus cutting velocity for several kinds of used tool materials.



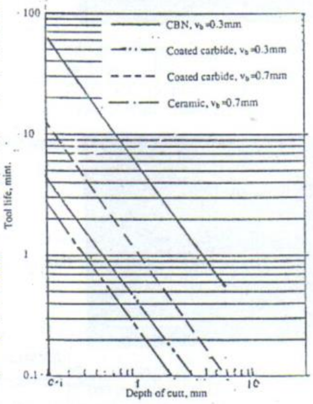


Fig. 22. Tool life versus feed for several kinds of used tool materials

Fig. 23. Tool life versus depth of cut for several kinds of used tool materials

CONCLUSIONS

From the present work, it can be concluded that:

1- A similar tool wear mechanism is obtained for all of the used tool materials (Abrasion) in both cases of reinforced workpiece matrix using silicon carbide and aluminum oxide particles.

2- The tool wear of coated carbide tools in the case of machining composite specimens reinforced with AL_2O_3 is less than that of machining composite specimens reinforced with SiC for flank wear less than 0.4mm due to higher hardness of SiC. For tool flank wear more than 0.4mm the coating is totally removed, so that the SiC and AL_2O_3 particulates have almost the same effect

3- Lower surface roughness values and more accurate dimensions are obtained when using CBN inserts, while high roughness and inaccurate dimensions are encountered when using coated carbide or carbide ceramic tool materials.

4- Sudden tool failure occurred when the experiments were carried out at high cutting conditions when machining composite specimens using coated carbide and carbide ceramic tools.

5- Considerable variation in average surface roughness Ra was noticed at high cutting speeds in case of coated carbide and ceramic tools while small variation was noticed in case of CBN tools.

6- The increase of cutting speed from 50 to 200 m/min increases the relative cost ratio from 50% to 200% in case of CBN, from 190 to 850% in case of coated carbide and from 380 to 1400% in case of carbide ceramic tools.

7- For a cutting speed range from 50 to 200 m/min, dimensional error of 0.1 to 0.3% was noticed in case of CBN tools, of 0.1 to 1% in case of coated carbide and 1to 2% in case of ceramic tools.

8- The increase of reinforcing particle size or cutting conditions accelerates the tool flank wear.

9- Empirical relations between tool life and cutting conditions for the used tools were investigated on the base of experimental results.

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