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COATED CARBIDE CUTTING TOOLS PERFORMANCE IN HIGH SPEED MACHINING PROCESSES

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Abstract:-

High-speed machining (HSM) has emerged as a key technology in rapid tooling and manufacturing applications. The present work studies the effect of cutting parameters (cutting speed, feed and depth of cut) in turning process applied on C-60 steel using multi- coated carbide cutting tools at high cutting speeds. The influence of cutting parameters on a cutting forces, tool wear and surface roughness are analyzed. The importance of orthogonal force components to surface finish and tool wear are explored. The results show that cutting forces has a very strong correlation with surface finish and that increased spindle speeds lead to far superior surface finish .Tool wear measurements demonstrated the capability of such coated carbide tools in turning steel with reasonable low tool wear (i.e. high tool life). Forces measured resulted in relatively low values. The cutting component (F_c) is the largest of all. For the different cutting conditions studied, the feed rate has the greatest influence on force and tool wear.

Key words:-Coated carbide tools, high speed machining, cutting forces, Flank wear.

أداء عدد القطع الكاربيدية المطلية في عمليات التشغيل عند السرع العالية

ملخص البحث:-

إن عمليات التشغيل عند السرع العالية هي تكنولوجيا جديدة تم إدخالها حديثا في العمليات الإنتاجية نتيجة للتطور الحاصل في مجال عدد القطع. في هذا البحث تمت دراسة استخدام سرع القطع العالية في عملية الخراطة عند ظروف القطع المختلفة (سرعة القطع , التغذية , عمق القطع) على قوى القطع , تآكل أداة القطع والخشونة السطحية للسطح المنتج._أوضحت النتائج بان قوى القطع بالاتجاهات الثلاثة لها تأثير كبير على قيم الخشونة السطحية حيث أن زيادة سرعة القطع تؤدي إلى تحسن كبير في قيم الخشونة لسطحية . كذلك أوضحت النتائج قابلية هذه العدد في قطع الفولاذ عند سرع عاليه وبقيم تآكل قليلة (عمر أداة قطع عالي). تلعب قيم معدل التغذية الدور الرئيسي في التأثير على قيم قوى القطع ومعدل الثاكل الحاصل في الأداة.

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1:- Introduction:

The challenge of modern machining industries is focused mainly on the achievement of high quality, in terms of work piece dimensional accuracy, surface finish, high production rate, less wear on the cutting tools, economy of machining in terms of cost saving and increase the performance of the product .In general, the most important point in machining processes is the productivity, achieved by cutting the highest amount of material in the shortest period of time using tools with the longest lifetime. Combining all the parameters involved in the machining process to maximize productivity is, nevertheless, a very complex task and becomes much more difficult when working at high speed cutting when machining the steels [1].

Development of new cutting tool materials and availability of machine tools with high rotational speeds have made it possible to increase material removal rate. But at a high cutting speed tool wear occurs more intensively and causes the requirement of frequent tool changing. Again, tool changing time increases machine downtime and reduce the productivity of machining .One of the important cutting tool improvements in recent years has been the introduction of hard surface coatings on substrates such as carbide. Hard coating such as TiN, TiC and AL_2O_3 have been used. High-speed machining is constantly increasing in importance. These new techniques can be applied in place of conventional machining methods for manufacturing of various components at low cost or even making entirely new type products, e. g. machined from brittle materials.

Machining of steels using multilayer coated carbide tools at high cutting speeds has certain advantages compared to the traditional machining processes. The cutting force information is important to part accuracy, tool wear and heat generations that may cause part thermal damages. Tool wear effects on cutting forces may limit the tool life and change the thermal conditions of the cutting tool [2].

Different researchers have carried out investigations on tool wear and tool life at high cutting speeds. M. Nouilati [3] studied the machining performance of a series of commercially available coated tungsten based cemented carbides, with 55^o diamond shape during finish turning of AISI 1018 steel under dry conditions. For comparison, uncoated cemented tungsten carbide was also tested under the same cutting conditions. The coated tools exhibited superior wear resistance over the uncoated tool. Jianwen Hu.et al[4] ,develop an analytical model for cutting force simulations in finish hard turning by a worn tool, which includes both chip formation and flank wear-land contact forces. The results show that the wear-land is the most significant factor and generally does not alter the effects from other parameter, however, amplifies the tool nose radius effects dramatically. Yong Huang [5] addresses these issues by formulating an oblique chip formation force model through the extension of a two-dimensional (2D) mechanistic force model while considering the effect of tool geometry complexities. The coefficients of the mechanistic force model are estimated by applying a genetic algorithm in overcoming the lack of explicit normal equations. The model-predicted forces match well with experimental results in the turning of hardened 52100 bearing steel. Tugrul Ozel [6] experimentally studied the effects of cutting edge geometry, workpiece hardness, feed rate and cutting speed on surface roughness and resultant forces in the finish hard turning of AISI H13 steel. Cubic boron nitrite inserts with two distinct edge preparations were used. The results show that the effects of workpiece hardness, cutting edge geometry, feed rate and cutting speed on surface roughness are statistically significant.

1-1:- Coated carbide cutting tools:

The machining of hard and chemically reactive materials at higher speeds is improved by depositing single or multi layer of hard coating material on carbide cutting tool to combine the beneficial properties of coating and traditional tool materials. The effect of coatings layer can be summarized as follow [3]:-

1. Reduction in friction, in generation heat, and in cutting forces which allow the use of high cutting speeds and feed,

2. Reduction in the diffusion between the chip and the surface of the tool, especially at higher cutting speeds (the coating acts as a diffusion barrier)

3. Prevention of galling, especially at lower cutting speeds.

1-2:- Cutting forces measurement:-

Cutting forces measurement in metal cutting is important for thermal analysis, tool life estimation, chatter prediction, and tool condition monitoring purposes. Significant efforts have been devoted to understanding the force profiles in metal cutting along with mathematical approach. In turning operation the resultant force is divided into three components, feed force F_f, radial force F_r and cutting force F_c as shown in figure (1). Usually, in finishing operations the radial force, Fr, is the smallest of all, since the depth of cut is very small, compared to the other force components. Force measurement in metal cutting is essential requirement as it is related to machine part design, tool design, power consumptions, vibrations, part accuracy etc. It is the purpose of the measurement of cutting force to be able to understand the cutting mechanism such as the effects of cutting variables on the cutting force, the machinability of the work piece, the process of chip formation, chatter and tool wear [7]. It has been observed that the force values obtained by engineering calculations contain some errors compared to experimental measurements. Since the undeformed chip thickness and the direction of cutting speed vary at every moment. Cutting process is geometrically complex. Owing to such complexity, the cutting force even in steady state conditions is affected by many parameters and the variation of cutting force with time has a peculiar characteristic. The need for measurement of all cutting force component arises from many factors, but probably the most important is the need for correlation with the progress of tool wear. If this can be obtained, it will be possible to achieve tool wear monitoring in cutting based on force variation [8]. Another reason for the cutting forces measurement is that it is a good indicator in detecting tool wear. It is well known that during the cutting process, the cutting parameters such as cutting speed, feed rate and depth of cut often present a deviation from the calculated values. Indexable coated carbide inserts are widely used in modern manufacturing industry. These inserts have one or more thin layers of wear resistance CVD or PVD coating such as TiC, TiN, Al2O3, ZrN, CrC or Diamond, which improve machinability significantly. Today, “coated carbide grades for roughing and cermet for finishing” is a common tool in industry [9]. Unfortunately, limited work has been published regarding the performance of coated carbide inserts. There is a need for further research into the flank wear behaviour of the coated carbide inserts and the cutting force variation in high speed cutting. This paper presents an experimental study of the on-line tool condition monitoring of turning steel (C-60) with coated carbide inserts under dry cutting conditions. The tool wear propagation and cutting force variation along with it was analysed and discussed

1-3:- Tool wear:-

Tool wear influences cutting power, machining quality, tool life and machining cost. When tool wear reaches a certain value, variation in cutting force and cutting temperature will cause surface integrity deteriorated and dimension error greater than tolerance. The life of the cutting tool comes to an end. Then the cutting tool must be replaced or ground and the cutting process is interrupted [9]. The cost and time for tool replacement and adjusting machine tool increases cost and decreases the productivity. Hence tool wear relates to the economic of machining and prediction of tool wear is of the important issue, When machining steel with coated carbide tools, different tool wear mechanisms occur, such as: abrasion, adhesion, oxidation and even some diffusion, which act simultaneously and in proportions depending mainly on the temperature [10].The task of defining which of those mechanisms is the predominant one has become a very complex task.

1-4:- Surface Roughness:-

The finish turning process, which proposed as an alternative to the grinding process, must provide acceptable dimensional tolerance, form accuracy and surface integrity. Surface roughness is greatly affected by cutting conditions (feed rate, cutting speed and depth of cut), tool geometry (edge preparation, tool nose radius, tool orientation) and tool wear in finish hard turning process. Among them, feed rate and tool nose radius are believed to be the most dominant control factors. In finish hard turning, depth of cut applied is generally very small and is as the same scale as the tool nose radius or even smaller. The ploughing effect and material side-flow effect are pronounced at such cutting conditions, which pose difficulty in predicting machined surface roughness [11]

2:- Experimental Conditions and Procedure:-

Steel bars (C-60) of initial diameter 50 mm and length 500 mm was turned in a rigid lathe (TOS, 7.5 kW) using standard triple coated carbide inserts (SPUN-120408 / P-20, ISO specification) with TiCN-Al_2O_3-TiN layers . These inserts were clamped into a tool holder fixed into a three component strain gauge dynamometer to record the cutting force components using a specified speed-feed combination under dry conditions. The experimental conditions have been given in Table-1.

Table 1. Experimental conditions.

Machine tool :	(TOS, 7.5 kW)
Work material :	C-60 steel(φ50×500 mm)
Cutting inserts:	triple coated Carbide (P-20,ISO specification)

The machining was interrupted at regular intervals to study and measure the wears on main flank for all the trials. The flank wear were measured using metallurgical microscope fitted with micrometer of least count 0.01 mm. The surface roughness on the machined surface was also measured by a contact type stylus profilometer (Talysurf , Taylor Hobson).

3:- Result and discussion:-

Figures (2-9) shows the number of trails against cutting forces (F_c, F_t and F_r) at different depth of cut (0.3,0.7,1.0,1.2mm) and feed rates of (0.05,0.11, 0.18 and 0.24) for both cutting speeds of (250 and 320 m/min). The cutting forces are increased on each trail. Figures 2, 3, 4 and 5 represent graphs at cutting speed of 250 m/min and depth of cut (0.3, 0.7, 1.0, 1.2mm) respectively against cutting force components (F_c, F_t and F_r) . At high feed rate, the cutting force required was more. When cutting speed increases, cutting, thrust and feed force components tend to decrease, Trent [12] attributes such behaviour partly to the softening effect of the workpiece material, due to temperature increase where maximum amount of heat generated in the cutting zone is carried away by chip and partial amount of heat was retained by work piece .The softening effect plasticize the chips and less cutting forces are recorded and partly to the decreasing of the chip-tool contact length. Additionally, the depth of cut apparently has an influence larger than the cutting speed, and feed rate has a moderate effect on forces. In turning steels at low cutting speed and feed rate, the contact time between tool tip and work piece was more which rub the work piece. This rubbing action generates more heat at cutting zone and carried away by the chips [13]. Tool flank wear is strongly influenced by the interactions between cutting tool and work piece in the form of contact stress and cutting temperature .The lower cutting force results in less distortion of work piece which improves surface roughness [14]. As the flank wear increased the cutting force tend to increase and reached maximum value for the maximum flank wear. The maximum cutting force of 540 N was recorded at cutting speed of 250 m/min having feed rate of 0.24 mm/rev and depth of cut of 1.2mm. This is due to excessive flank wear formation. Figure (12) shows that tool flank wear on high speed turning is higher than that at lower cutting speed. The wear for all speeds increase gradually as time goes. Temperature was claimed as the reason of tool wear in this experiment. The tool wear was affected by temperature. The higher temperature the great wear occurred. The flank wear in this experiment can be seen obviously when high speed turning applied. Through figure (12) it can be observed that tool wear is increase rapidly as feed rate and cutting speed increase obviously. When machining at high speed (320 m/min) with feed rate 0.24 mm/rev. Another fact known from the graph that the higher cutting speed the significant wear is occurred. In another word, coated carbide tools are very sensitive to cutting speed. When the cutting speed is comparatively low (250 m/min.) with feed rate 0.05 mm/min, the flank wear is very small after machining. According to figures (12 and 13), low feed rate results in better surface finish. Oppositely, wear grows rapidly at higher cutting speeds (320 m/min) and high feed rate. This is occurred because the cutting force on the tool edge increases as the federate increased at higher cutting speed. The values of different feed rates against surface roughness at different cutting speed are shown in fig. 13. It is observed that cutting speed and feed rate has impact to surface roughness. The experiments were proof that by increasing cutting speed and lowering feed rate will produce finer surface finish. It is noted that range of tool wear and surface finish investigation in high speed turning using coated carbide cutting tools roughness in high speed turning is between 1.00 to 1.7 μm. Force work in the tool was claimed as the reason wear is occurred. Tool forces usually rise as the tool is worn, the clearance angle is destroyed, and the area of contact on the clearance face is increased by flank wear. Flank wear causes scratch on the surface of workpiece and finally lead to poor surface finish. This poor surface quality can be attributed to the higher cutting forces and higher value of flank wear.

4:- *Conclusions:-*

In this study, a detailed experimental investigation is presented for the effects of cutting conditions (cutting speed, feed, depth of cut) on the surface roughness and cutting forces in the finish turning of C-60 steel. The results have indicated that the effect of cutting conditions on the surface roughness is remarkably significant. The cutting forces are influenced by these cutting conditions. From the present analysis and discussion the following conclusions can be drawn:

1. Wear occurred freshly when high speed turning applied in cutting speed. This is due to high temperature generated in high speed turning.

2. There were direct relationship between flank wear and cutting force. When the flank wear was more, more cutting forces required for cutting.

3. At a low cutting speed the life of coated tools is quite long and the surface finish of the workpiece is quite satisfactory. But an increase in cutting condition is lead to rapid wear of the tools. This is lead to excessive heat and wear. As result tool life duration of insert tools were become short.

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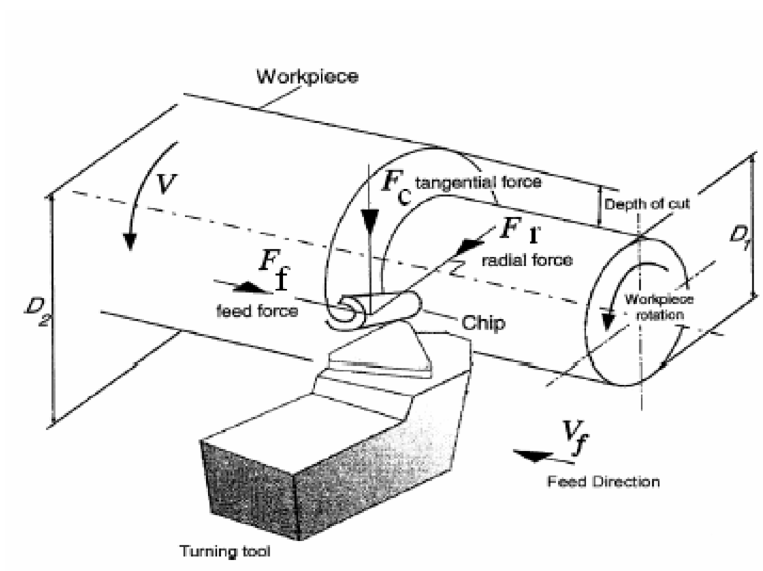

Figure (1) Cutting force components in turning

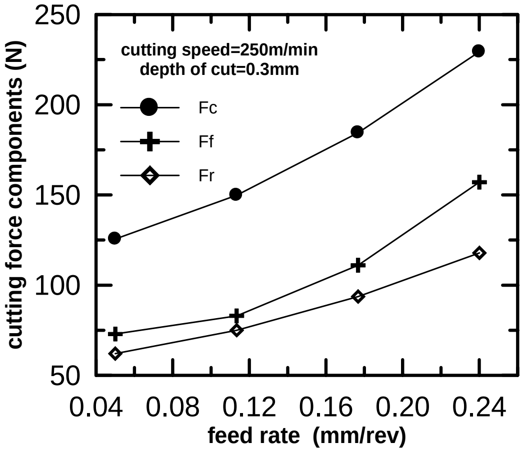

Fig (2) cutting force components versus feed rate

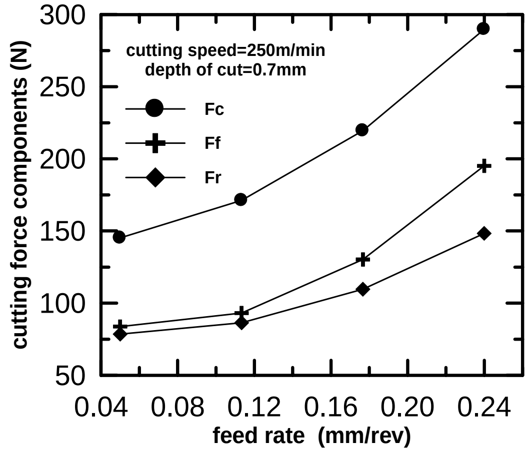

Fig (3) cutting force components versus feed rate

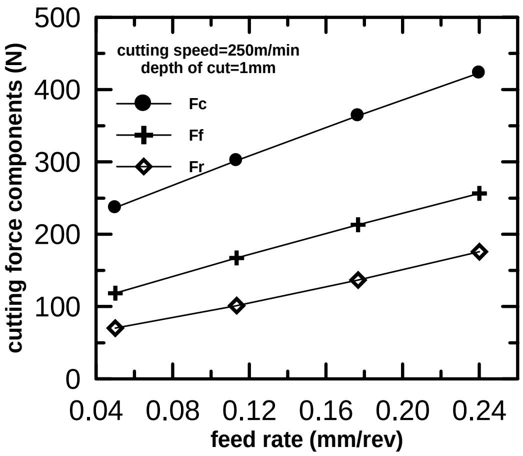

Fig (4) cutting force components versus feed rate

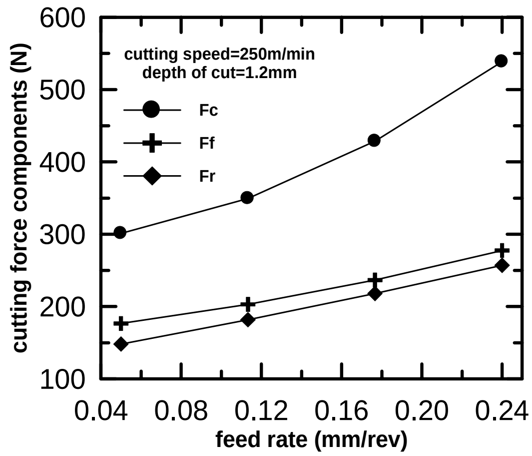

Fig (5) cutting force components versus feed rate

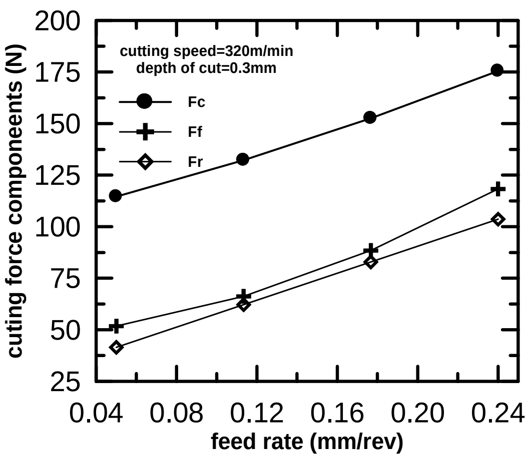

Fig (6) cutting force components versus feed rate

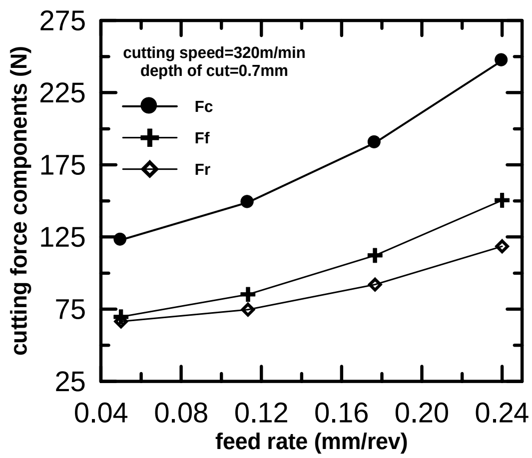

Fig (7) cutting force components versus feed rate

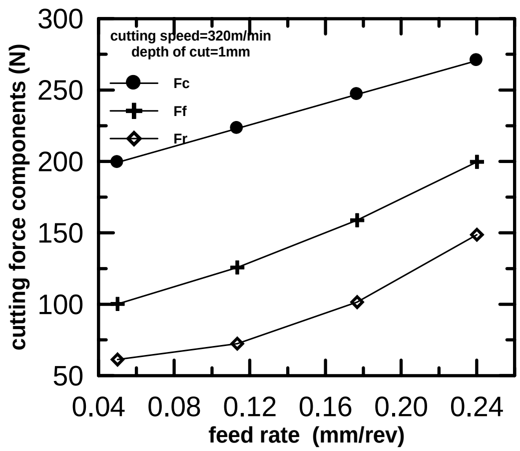

Fig (8) cutting force components versus feed rate

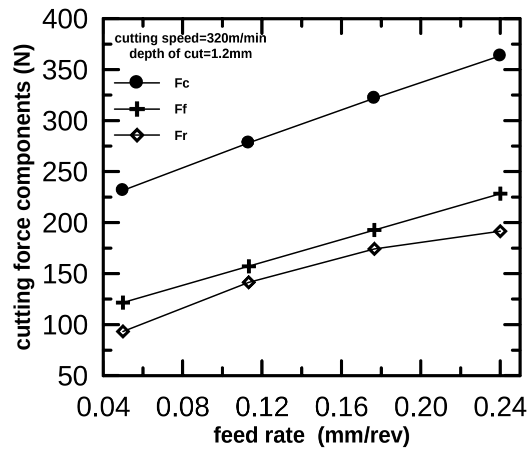

Fig (9) cutting force components versus feed rate

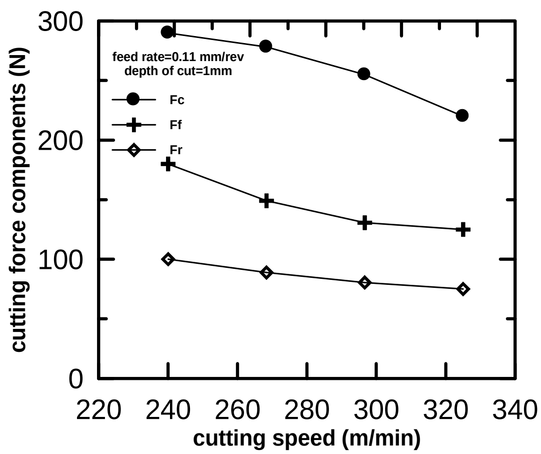

Fig (10) cutting force components versus cutting speed

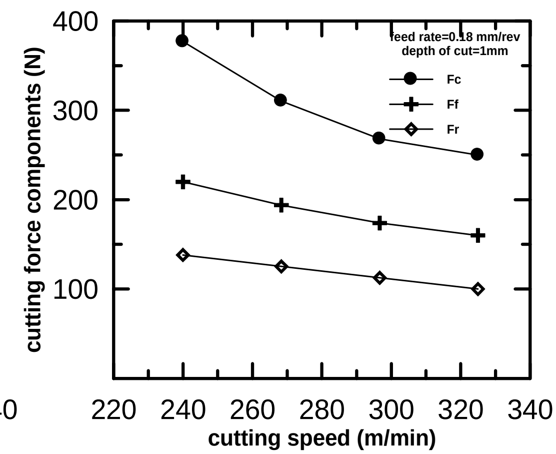

Fig (11) cutting force components versus cutting speed

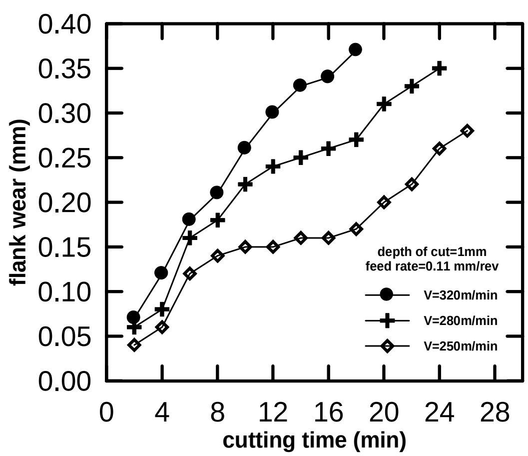

Fig (12) flank wear versus cutting time

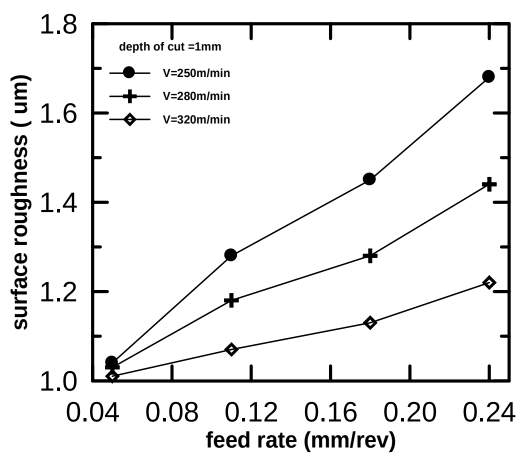

Fig (13) cutting force components versus feed rate