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Effect Of The Application Of Carbon Tetrachloride Lubricant To A Cutting Operation

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Abstract:

In this research CCl_4 as a lubricant is used for machining copper specimens. It was noticed that CCl_4 has many effective effects at low machining speed, as well the effect at high speed cutting vanished which is coincided with the results obtained by the researchers worked in this field and giving the cause of their results either for lubricant penetration loss at the interface between the chip 0.005 m/sec., the cutting ratio (r) increases by more than 23% and decreases to 7% at a cutting speed of 0.08 m/sec., on other hand the friction angle decreases from about 37% to 11% as the cutting speed increases from 0.005 m/sec to 0.08 m/sec.

تأثير استخدام مزيت رابع كلوريد الكاربون على عملية القطع

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الخلاصة:

في هذا البحث تم استخدام رابع كلوريد الكاربون كمزيت لتشغيل معدن النحاس، والذي يلاحظ فيه أن رابع كلوريد الكاربون له تأثير فاعل في السرع التشغيلية البطيئة، وأيضا تم ملاحظة أن تأثير رابع كلوريد الكاربون يتضاءل في السرع العالية، وهذا يتطابق مع النتائج التي توصل إليها الباحثين الذين عملوا في هذا المجال والذين عللوا سبب ذلك أما الى فقدان النفاذية للمائع لمنطقة التلاقي بين الرايش وأداة القطع أو إلى زيادة درجة الحرارة.

أن إستخدام رابع كلوريد الكاربون أثناء عملية قطع النحاس أو تشغيليه يقلل أو يخفي الرايش المتراكم على اداة القطع الذي يتكون في حال عدم إستخدام رابع كلوريد الكاربون.

في هذا البحث النتائج توضح تأثير إستخدام المزيت برابع كلوريد الكاربون من عدمه وملاحظة التغيرات الحاصلة على القوى المؤثرة ونسبة القطع وتؤثر جليا على زاوية الإحتكاك وهذه النتائج تقل بزيادة سرعة القطع.

في هذا البحث، أظهرت النتائج، أن نسبة القطع المئوية تزداد بحدود 23 % عند سرعة قطع مقدارها 0,005 متر/ثا، وتقل هذه النسبة المئوية إلى 7 % عند سرعة قطع حوالي 0.08 متر/ثا، من جهة أخرى أظهرت النتائج أن زاوية الإحتكاك تقل من نسبة مئوية حوالي 37 % إلى 11 % عندما تزداد سرعة القطع من 0.005 متر/ثا إلى 0,08 متر/ثا.

1.The objective:

The objective of this paper is to study the effect of using the cooling fluid in a cutting process, specifically the effect of using tetrachloride as lubricant of the cutting parameters such as the active forces, the cutting ratio and as well as the friction force.

2. Introduction :

A cutting fluid is any liquid or gas that is applied directly to the machining operation to improve cutting performance. There are two general categories of cutting fluids: coolants and lubricants.

- **Coolants:**

Coolants are cutting fluid designed to reduce the effect of heat in the machining operation they carry away the heat that is generated, thereby reducing the temperature of tool and work piece. This helps to prolong the life of cutting tool. Coolants are usually water - based solution or water emulsion, since water has thermal properties that are ideally suited for these cutting fluids.

- **Lubricants:**

Lubricants are usually oil based fluids formulated to reduce friction at the tool - chip and tool - work interface. Lubricants cutting fluids operate by extreme pressure lubrication. Especial form of lubrication that involve formation of thin solid salt layers on the hot clean metal surfaces through chemical reaction with the lubricants because of Compounds of sulfur chlorine and phosphorous in the lubricants cause the formation of these surface layers, which act to separate the two metal surface [1].

The selection of cutting fluids should be carefully carried out to obtain optimum result in machining processes. Various factors are affecting the selection of cutting fluid type in machining operation such as:

- Type of workpiece materials.
- Cutting tool material.
- The method of machining processes.

Suitable cutting fluids for various material machining processes have been determined according to cutting tool materials.

3. Literature review:

The first study about cutting fluids had been determined by W.H. Northcott in 1868 with a book entitled “A treaties on lathes and turning”.

In the middle of 1890’s, F.W. Taylor emphasized that using cutting fluids would allow to use higher cutting speeds resulting in longer tool lives and higher material removal rates. It had been concluded that the application of cutting fluids in machining processes would make shaping process easier [2].

R. F. Ávila and A. M. Abrão study the performance of three types of cutting fluids (two emulsions and one synthetic fluid) were compared to dry cutting when continuous turning hardened AISI 4340 steel (49 HRC) using mixed alumina inserts. The following parameters were evaluated:

Tool life.

Surface finish.

Tool wears mechanisms.

Chips form.

The results indicated that, in general, the emulsion-based fluid (without mineral oil) and dry cutting gave the best results followed by synthetic fluid and emulsion containing mineral oil, both presenting similar results [3].

Cutting fluids are a complex blend of components that must meet a number of criteria and function under a wide range of conditions. Historical information often plays a major role in the decision of which type of fluid to use for a machining process. The foremost consideration must be compliance with health, safety, and environmental testing and regulations (National Center for Manufacturing Sciences [NCMS] 1997, Section 1). Provided these compliances are met, appropriate laboratory and machining tests are used to evaluate a fluid for compatibility with equipment and work piece materials, maintainability characteristics, and machining performance. The available bench tests in these areas can often be inadequate predictors of fluid performance in the plant environment. Plant trials are still the ultimate test of a fluid, but are time consuming, expensive, and difficult to conduct in a controlled fashion [4].

The primary objective of the work done by Herman R. Leep, Robin W. Sims was to compare the tool wear resulting when a semi-synthetic cutting fluid was used, to that from use of premium soluble oil. The secondary objective was to determine the effects of cutting speed, drill diameter, and fluid concentration, on tool wear. It was concluded that concentration had the most significant effect on land wear when the experimentally-formulated semi-synthetic cutting fluid was used. Cutting speed was the most significant factor when drilling with the commercially-available premium soluble oil. Tool wear while using the semi-synthetic fluid was slightly less than that for the premium soluble oil [5].

Significant progress has been made in dry and semi-dry machining recently, and minimal quantity lubrication (MQL) machining in particular has been accepted as a successful semi-dry application because of its environmentally friendly characteristics. A number of studies have shown that MQL machining can show satisfactory performance in practical machining operations. However, there has been little investigation of the cutting fluids to be used in MQL machining. The study done by S. Sudaa, H. Yokotaa, I. Inasakib and T. Wakabayashic, several fluids, including vegetable and synthetic esters, are compared on the basis of the physical properties that would be suitable for MQL applications. The cutting performance of fluids is also evaluated using actual MQL operations. As a result, biodegradable synthetic esters are found to be optimal cutting fluids for MQL machining [6] .

4. Lubricating mechanism:

It has been suggested that in metal cutting the conditions of the temperature and pressure existing at the chip-tool interface are such that a chemical reaction can occur between an appropriate lubricant and the freshly sheared chip. A chemical compound is thereby produced at the chip-tool interface; this compound acts as a solid boundary lubricant the shear stress in that region.

Many theories have been advanced to explain the way a lubricant can penetrate to the chip-tool interface. More recent ideas seem to indicate that a chemical fluid can reach the chip - tool interface by diffusion through the primary deformation zone. Since the diffusion process is rate-controlled, the amount of lubricant reaching the chip-tool interface will clearly diminish as the cutting speed is increased.

It has been established during machining of metals under dry un-lubricated conditions that the frictional contact between the chip and tool can be separated into two distinct regions: a region of sticking friction and a region of sliding friction. In the sticking region the normal stress is so large that the real and apparent area of contact are equal, and there is no relative motion at the chip tool interface (shearing takes place in the chip).In the sliding region the normal stress is smaller, and the real area of contact is less than the apparent .Thus relative motion at the interface can take place in the region .The frictional conditions at the chip-tool interface in each of these region are fundamentally different.

This study showed that the application of carbon tetrachloride to a cutting operation where a built-up edge is usually formed under un-lubricated condition results in the disappearance of the built-up edge and an improvement in the surface finish .Application of a lubricant can produce certain other improvements in the machining characteristics, namely:

- A cooling action whereby the general of temperature in machining is lowered and the tool wear rate reduced.
- A reduction in the forces required to overcome friction on the tool face.
- A modification of the shear - flow properties of the material in the primary and secondary deformation zones.

5- Carbon tetrachloride (CCl4) as Lubricant:

Carbon tetrachloride was originally synthesized by the French chemist Henri Victor Regnault in 1839 by the reaction of chloroform with chlorine, but now it is mainly produced from methane:

$$CH_4 + 4\,Cl_2 \rightarrow CCl_4 + 4\,HCl$$

The production often utilizes by-products of other chlorination reactions, such as from the syntheses of dichloromethane and chloroform. Higher chloro-carbons are also subjected to "chlorinolysis:"

$$C2Cl6 + Cl2 \rightarrow 2\ CCl4$$

Prior to the 1950s, carbon tetrachloride was manufactured by the chlorination of carbon disulfide at 105 to 130 °C.

$$CS_2 + 3Cl_2 \rightarrow CCl_4 + S_2Cl_2$$

Prior to the Montreal Protocol, large quantities of carbon tetrachloride were used to produce the Freon refrigerants R - 11 (Trichlorofluoromethane) and R - 12 (Dichlorodifluoromethane).

However, these refrigerants are now believed to play a role in ozone depletion and have been phased out. Carbon tetrachloride is still used to manufacture less destructive refrigerants.

Carbon tetrachloride has practically no flammability at lower temperatures. Under high temperatures in air, it forms poisonous phosgene.

The production of carbon tetrachloride has steeply declined since the 1980s due to environmental concerns and the decreased demand for CFCs, which were derived from carbon tetrachloride. In 1992, production in the U.S.-Europe-Japan was estimated at 720,000 tones.

Carbon tetrachloride is also both ozone-depleting and a greenhouse gas. However, since 1992 its atmospheric concentrations have been in decline for the reasons described above. CCl4 has an atmospheric lifetime of 85 years [7] .

6. Experimental procedure:

6.1. Select of conditions:

Since the effect of a cutting lubricant generally disappears at cutting speeds greater than about 1 m/s (200 ft /min) [8], it is not necessary to exceed this value in cutting tests for both cutting with lubricant CCl_4 and for the dry cutting (without using any lubricant).

The following cutting speeds are suggested which are used for our work:

Cutting speed *v*, m/s	0.005	0.1	0.2	0.4	0.8

A suitable value for the undeformed chip thickness is 0.125 mm (0.005 in.). For each of the cutting speeds two test conditions are used, namely: 8d]][[P[POOI

- Dry Cutting.
- Cutting with carbon tetrachloride applied in the region of chip formation.

6.2. Equipments & Materials used:

A turning lathe model (NH25) is used for the work. The lathe is powered by a 5KW electric motor.

A tubular workpiece of high thermal conductivity copper.

Two - component cutting force dynamometer.

Necessary recording equipment.

High -speed steel cutting tool with a (15o rake angle).

Small quantity of Small quantity of carbon tetrachloride.

Cutting speed is increased from (0.005 - 0.08 m/s). The lathe, dynamometer and recording equipment are set up for the orthogonal end face machining of the tubular work piece, such settings are explained with the following sketches as shown in **figure.(1)** for orthogonal cutting jjfand for the end face machining as shown in **figure.(2)** below:

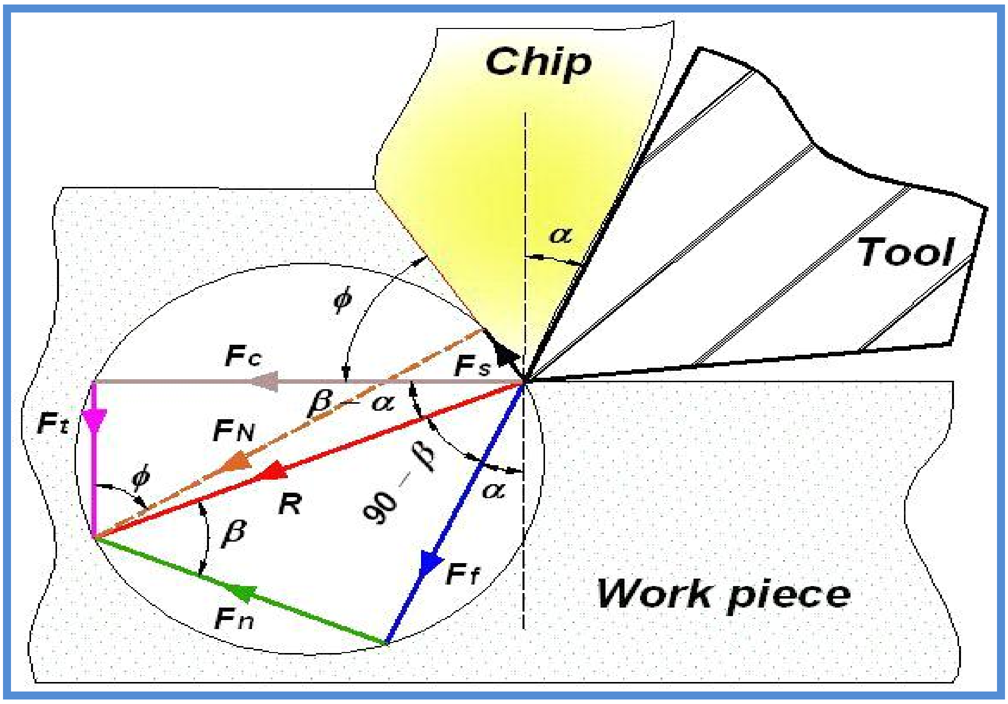

Fig. (1): Orthogonal cutting showing the forces exerted on the Tool & Chip.

Figure. (1) shows the forces acting at the tip of the tool, especially the cutting and the thrust forces (Fc & F_t) and the relation between these forces with the angle of friction (□). The angle between these forces is defined in this sketch to be equal to (□ □ □) □ □

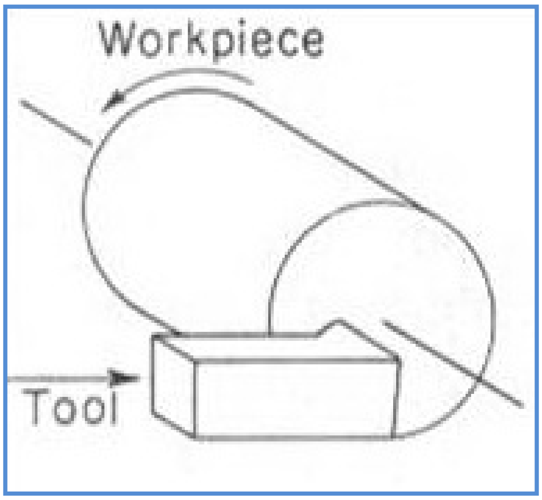

Fig. (2): End face machining

7. Results:

The tool forces (F_t ***and*** F_c) and the chip thickness are measured for each test condition, and the cutting ratio ($\mathbf{r_c}$) and the mean angle of friction on the tool face are ($\boldsymbol{\beta}$) are calculated using the following equations:

$$\mathbf{r_c} = \frac{a_c}{a_o} \qquad \textbf{......(1)}$$

<u>Where:</u>

a_c = is undeformed chip thickness.

a_o = is the chip thickness.

And,

$$\tan(\beta - a) = \frac{ft}{fc} \qquad ......(2)$$

<u>**Where:**</u>

□ = the friction angle.
□ = the working normal rake angle.
F_c = the cutting component of the resultant tool force (R).
F_t = the thrust component of the resultant tool force (R).

The results are tabulated in the table (1) below. Both the mean friction angle (β) and the cutting ratio (r_c) are plotted against the cutting speed (v) for both lubricated and un-lubricated conditions as shown in **Figure(3)** and **Figure(4)** below.

Figure.(3) shows that the cutting ratio decreases as the cutting speed increases for lubricant with CCl_4, but for dry lubricant the cutting ratio almost constant at cutting speed (0.4 m/s) and beyond.

Table (1): Test result for different cutting speeds

Cutting speed *v*, m/s	Lubricant with CCl_4				Dry lubricant			
	b (degree)	r_c	F_t (N)	F_C (N)	*b* (degree)	r_c	F_t (N)	F_C (N)
0.005	32	0.64	273	909	44	0.52	460	830
0.01	34	0.62	309	897	45	0.51	475	822
0.02	36	0.61	373	888	44	0.53	460	830
0.04	37	0.59	352	880	45	0.51	475	822
0.06	38	0.57	377	876	44	0.52	460	830
0.08	40	0.55	402	862	45	0.51	475	822

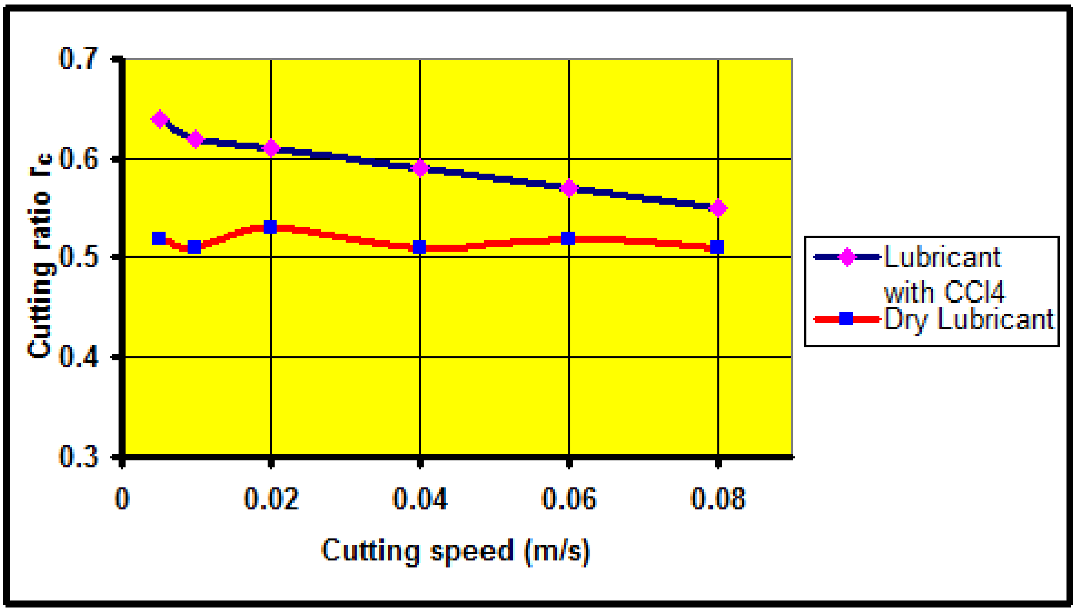

Fig. (3): The variation of Cutting ratio (r_c) with cutting speed for Dry & Lubricant with CCl_4.

Figure (4) below describes the change for the friction angle (   ) with the cutting speed. It shows the increase in the friction angle with the increase of the cutting speed with lubricant CCl_4, but on the other hand the friction angle for dry lubricant varies and fluctuates (45^o) in which it can be considered approximately constant.

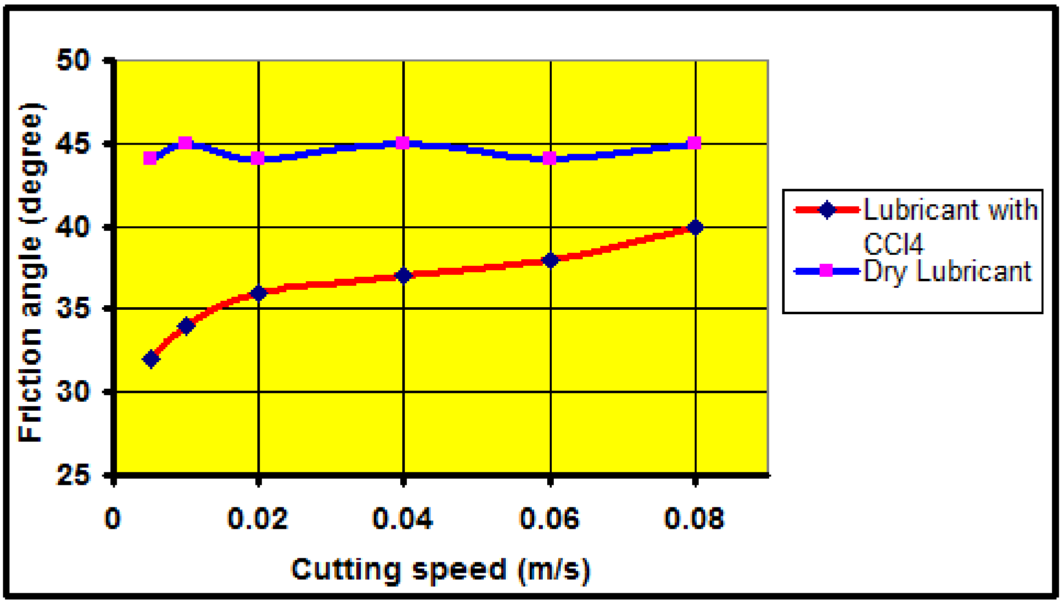

Fig. (4): The variation of Friction angle (□) with cutting speed for Dry & Lubricant with CCl_4.

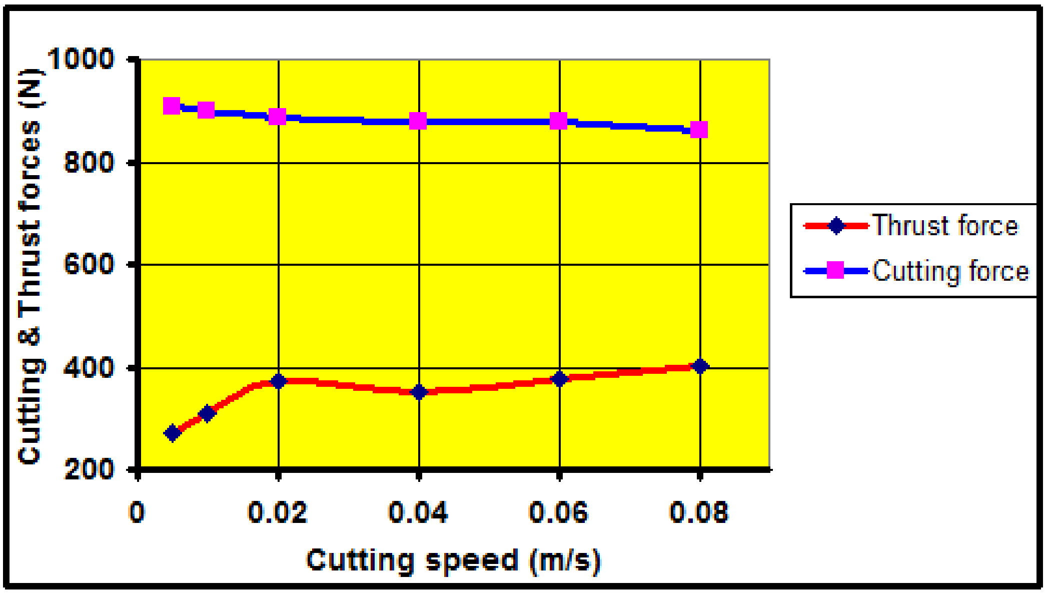

Fig. (5): The variation of Cutting & Thrust forces with cutting speed for Lubricant with CCl_4.

Figure .(5) above shows the variation of the cutting and thrust forces with increase of the cutting speed for lubricant with CCl_4, it is notified that the cutting force decreases and the thrust force increases as the cutting speed increases.

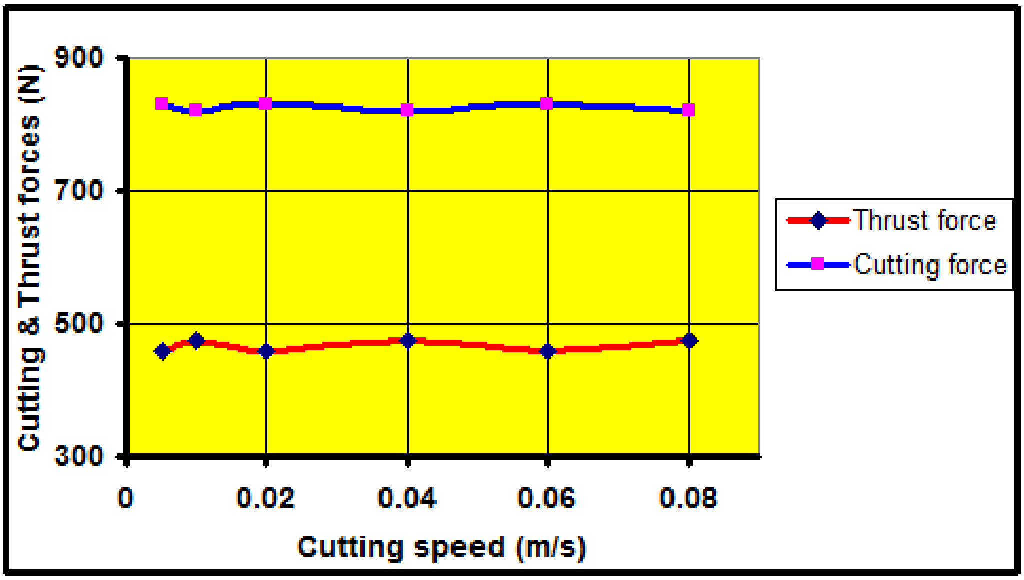

Fig. (6): The variation of Cutting & Thrust forces with cutting speed for Dry Lubricant.

Figure. (6) above shows the variation of the cutting and thrust forces with increase of the cutting speed for dry lubricant, it is notified that the cutting force and the thrust force varies slightly as the cutting speed increases.

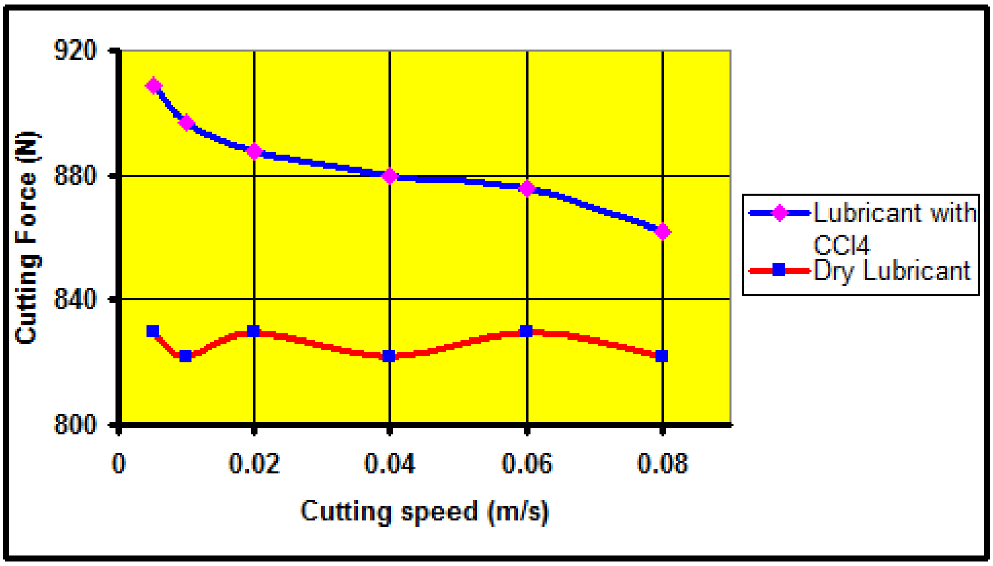

Fig. (7): The variation of Cutting forces with cutting speed for Dry & Lubricant with CCl_4.

Figure. (7) above shows the variation of the cutting force with increase of the cutting speed for both lubricant with CCl_4 and dry lubricant, it is notified that the cutting force for lubricant with CCl_4 decreases as the cutting speed increases, but the cutting force fluctuate slightly around (830 N) as the cutting speed increases.

8- Discussion:

The result will show that the lubricating action of carbon tetrachloride (CCl_4) measured by its effect on the cutting ratio and the mean angle of friction on the tool face decreases as the cutting speed is increased. The lubricating action of (CCl_4) is mainly of chemical nature as shown in [figure.(4)] that at low cutting speeds the friction is reduced considerably by the application of the fluid.

Carbon tetrachloride (CCl_4) has been found to be efficient lubricant when machining at low speed (0.005 – 0.4 m / sec) during cutting copper,

At a cutting speed of about 0.4 m/s (80 ft/min) the effect of the lubricant disappears because the motion of the chip at these speeds prevents the cutting fluid from reaching the tool-chip interface, and no benefits (except perhaps those of cooling the cutting tool and thereby increasing its life) are obtained.

In addition, high cutting temperatures at these speeds cause the oil to vaporize before it can lubricate the interface region. For this reason the fluids apply in high-speed machining operations, such as turning, and drilling, are chosen for their cooling action. Lubricants are only beneficial in the low-speed operations, such as broaching, screw cutting, gear hobbling, etc., as expressed with the following equation [8]:

$$\square_f = \frac{P_f}{\rho \,.c \;.a_c \,.a_w} \quad \ldots\ldots(3)$$

Where:

$\square_f$ = the average temperature rise of the chip resulting from secondary deformation.

P_f = the rate of heat generation by friction between the chip and tool.

$\square$ = the density of the workpiece.

c = the specific heat capacity of the workpiece.

a_c = unreformed chip thickness.

a_w = width of cut chip.

It is clear that the reduction in tool – chip friction when machining with (CCl_4) lubricant would imply a reduction in the size of the built – up edge and this would give an improvement surface finish.

Also it is observed that the cutting force can vary considerably for a copper material and is affected by the changes in cutting speed as shown in **figure. (7).**

9. Conclusion and recommendation:

The results show that the lubricating action of chemical component measured by its effect on the cutting ratio, the mean angle of friction and on the forces. It decreases as the cutting speed is increased.

It is found that as the cutting speed increases from 0.005 m/sec to 0.08 m/sec, the increment percentage of cutting ratio decreases from about 23% to 7%, and the increment percentage in friction angle decreases from about 37% to 11%.

For this reason the cooling fluid is applied in a high speed machining operation, such as turning, milling and drilling are chosen for their cooling action. Lubricants are only beneficial in low-speed operations such as broaching, screw cutting etc.

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