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Effect of Herbal Based Cutting Fluids on Machining Forces and Microbial Contagions in Turning of EN 8 Steel

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The increasing of advancements in technology achieved both in the development of new different materials and in the manufacturing technology has drastically increased the need for machining processes and accordingly the usage of cutting fluids increased. In addition, pressure from Environmental Safety and Health Agencies for all the products to be advertised more safely and without damaging the environment has also influenced the increase in the quality of the cutting fluids. The herbal based cutting fluids has been increasingly used by the engineering industry, because, moreover polluting less the environment, they cause less impairment to the operator and can deliver major progresses in the tool life, but on the other side it can be easily polluted by microorganisms, since they have a extensive variety of nutrients that enable their replica. This study assessed the machining performance of a herbal-based cutting fluid, connecting it with a mineral-based fluid when turning an EN 8 grade steel with coated cemented carbide tools. Cutting forces and the growth of fungi and microbes. The cutting speed (Vc), feed rate (f) and depth of cut (ap) were ranged and the effect of these factors in the cutting forces had been confirmed. It was clear that the herbal based fluid provided lower cutting forces during the machining. Moreover, the vegetable-based presented higher development of bacteria when used in its lowest concentration (4%), while the mineral based fluid indicated the superior microbial growth in its higher concentration (12%). In most cases, the microorganism causes respiratory and skin irritation.

Keywords: Herbal based cutting fluids, Microbes, turning, cutting forces.

Throughout the machining practices the tools grieve high wear and heat that necessitate persistent variations of their cutting edges. Additionally, there is the heating of machined parts, which can cause two effects: changes in preferred sizes and generation of internal pressures that may compromise their use. To diminish the wear of the tools and heating parts, numerous actions can be engaged, including the usage of a cutting fluid. The cutting fluids support to cool the cutting region, particularly at advanced cutting speeds, to lubricate the cutting area, especially at low speeds and great shear stresses, reducing the cutting force, improving tool life, surface finish and the dimensional precision of the work piece. Support to break the chip and therefore enabling their transportation and protect the machined surface and the machine tool against corrosion. Herbal oils are being studied as a latent source of environmentally favorable cutting fluids, due to a blend of Biodegradability, renewability and excellent cooling performance. Low erosion and thermal permanence, poor low-temperature properties and narrow range of obtainable viscosities, though, boundary their latent application as industrial coolants. Recently, abundant technical enhancements were attained in both tool resources and in machine tools. This intended that the request of cutting fluids grew significantly. High ultimatum causes affordability

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which in turn roots an intensification of product dominance. Additional feature that affects the augmented value of contemporary cutting fluids is the stress exerted by the Ecological Defense and Health Organizations, to which the products are promoted more safely and causes less harm to the environment. Cutting fluid is a type of coolant and lubricant designed specifically for metalworking processes, such as machining and stamping. There are various kinds of cutting fluids, which include oils, oil-water emulsions, pastes, gels, aerosols (mists), and air or other gases. They may be made from petroleum distillates, animal fats, plant oils, water and air, or other raw ingredients. Depending on context and on which type of cutting fluid is being considered, it may be referred to as cutting fluid, cutting oil, cutting compound, coolant, or lubricant.

The introduction of vegetable oil-based coolants in machining applications has made it possible to achieve quantum increases in overall performance. As a proven and tested technology, vegetable oils have been recognized as having superior lubricating properties since the 1960s. During this time, the process of stabilizing coolant emulsions that are based on water-miscible vegetable oils proved to be challenging, which meant that machining lubricant options were limited to mineral oil-based coolants containing various additives. Vegetable oil was used for the most part in straight oil applications. Today, a new generation of emulsifiers and stabilizing agents has made vegetable oil-based coolants practical for a variety of machining applications. Production rates for processes using these coolants have been improved significantly, with reported increases of 20 to 30 percent being typical. In addition, nominal gains of 50 percent or better in tool life also have been experienced.

It is identified that environment can deliver a abundant broader variety for fresh resources for the production of oils that the petrochemical production. This diversity of fresh resources, joined with the novel approaches and contemporary purifying procedures, make it possible to eradicate the difficulties of ancient technology for vegetable oils, such as resinification, the viscosity increased and the development of acidity. The whole vegetable oils have several advantages, among them .They are more pleasant to human skin than mineral oils, and also have a reduced tendency to form steam, fog and smoke, besides having a higher flash point, reducing the risk for fire in the machinery. They have polar molecules that act such as magnets and align themselves to the metal surface, forming a lubricant film able to support large surface tension, improving the machining tool life. The molecules of mineral oils are not polar, and therefore its capacity is lower than that of vegetable oils. This is also an advantage when higher yield is preferred. As mineral oils, herbal oils cannot be burned, although polluting less the environment. However, the main environmental advantage of vegetable oils instead of mineral base oils is that their raw material is biodegradable, causing much less pollution to the environment. They can also be reusable, like the mineral-based. By taking a wide variety of nutrients, the cutting fluid is easily contaminated by microorganisms that use these mixtures as raw material in their physiological activities. As metabolic wastes are released in the environment the fluid becomes more active, stimulating erosion of parts in contact with the contaminated fluid. Therefore, the fluid undergoes a drastic reduction of its life, meanwhile this degradation happens quickly. Along with this fluid loss and possible damage to the parts in contact with it, microorganisms are also associated with the progress of allergic responses in workers exposed to aerosolized fluid. The fungal growth of *Penicillium* sp. occurs which did not verify the presence of bacteria called mycobacteria, which can be explained by the fact that different specimens for bacteria compete for the same substrate, inhibiting somehow, the development of other specimens. As the fungal and bacterial population grows, the fluid loses its capacity to perform the functions of lubrication and cooling, in addition to being appointed as responsible for the rise of health problems for operators, such as pulmonary hypersensitivity, which is caused by mycobacteria and their endotoxins.

This research compared the performance of a vegetable-based cutting fluid with a mineral base one used in the form of stream application, considering the machining forces and their relation to growth of fungi and bacteria during the turning of EN 8 steel, with coated carbide tools.

Approach

The machining tests were made on a

CNC lathe, manufactured by MTAB, 11kW of power, maximum speed of 3000 rpm, using eight edges tools from Sandvik. The material used for the experiments was a commercial available EN 8 grade with a diameter of 55 mm and a length of 450 mm.

The cutting fluids, manufactured by Castrol Industrial, were

a) CARECUT S100: soluble ester-based cutting fluid (vegetable), mineral oil free, bioestable with anti-corrosion and anti-foaming properties, free of boron, nitrite and phenols, suitable for grinding and conventional machining of carbon steels, alloy steels and stainless steel. This fluid has a density of 1.071 g/mL, pH approximately 9.1 at a concentration of 5%, and is not flammable because it is a water based product.

b) CLEAREDGE 6515 BF: semi-synthetic machining fluid, mineral based, boron and chlorine-free, suitable for general machining of cast irons, carbon steels, alloy and stainless steels. The Clearedge 6515 BF has density of 1.060 g/cm3, pH 9.5 at concentrations of 3 and 5%, and, being a water based product, has no flash point (not flammable).

In order to avoid contamination in the cutting fluids, the reservoir and the cooling system was washed before placing the new cutting fluid.

Cutting conditions employed in this investigation are shown in Tab. 1. The components of machining forces were measured with a dynamometer (or Piezoelectric Platform) manufactured by Kistler Instrument, with amplifier and signals conditioner, also manufactured by Kistler Instrument.

Almost fourty 10 mL samples were collected of the two cutting fluids, directly from the machine reservoir, at a depth of 10 cm and at room temperature (about 25 ° C) on alternate days, always after using the machine for the force tests. Then the samples were placed in sterile tubes and then appropriately and transported to the Laboratory. The samples were inoculated in four different culture media: Mannitol Salt Agar (for the growth of Gram-positive bacteria), Mac Conkey agar (for growth of gram negative bacteria), Triptycase Soy Agar (for quantification of microorganisms) and potato agar dextrose (for fungal growth).

RESULTS AND DISCUSSIONS

Analysis of Cutting Forces (F_c)

In general, the forces were smaller when the fluid Carecut S100 (vegetable based) was used. However, the difference between the forces obtained when using the fluid Carecut S100 and the fluid Clearedge 6515 BF was very small. In Fig.1 it can be seen one of the tests being conducted, with the cutting fluid Carecut S100 at a concentration of 3%, and the piezoelectric platform.

In Figure (2) it is shown a graph with the cutting forces (F_c) obtained during the use of two cutting fluids in three concentrations, and varying the cutting speed (v_c). It can be observed the characteristic behavior of the curves of forces in machining steels , presenting the V-profile at low speeds (between 10 and 60 m/min), advising the occurrence of the built-up edge (BUE) in all circumstances of application of the cutting fluids. In this speed range, the BUE grows to a extreme size, and then declines until it fades totally. The cutting force tracks this dimension change of the BUE, diminishing with its development, reaching a

Table 1. Summary of cutting conditions engaged

1.	Work piece material	EN 8 steel grade
2.	Dimensions	Ø55 mm x 450 mm
3.	Cutting tool	Cemented coated carbide inserts ISO
4.	Coating	CVD coating mainly composed of α-alumina
		Schematic of cutting tool and TiCN crystals; and an external layer of TiN
Cutting parameters		
5.	Cutting speed, vc (m/min)	From 20 to 400, ranging from 15 to 50 m/min
6.	Feed rate, f (mm/rev)	From 0.05 to 5.00, varying each 0.05 mm/rev
7.	Depth of cut (mm)	From 0.5 to 5.0, varying each 0.5 mm
8.	Cutting fluid types	Carecut S100 (vegetable oil), Clearedge 6515 BF (mineral oil)
9.	Flow rate (l/h)	257
10.	Cutting fluid concentration	3% , 7% and 10%

minimum point and then growing with decreasing of the BUE up to the point where it vanishes entirely. Occurrence of certain fluctuations in this area may be associated to the shortage of the value of cutting speed at which this BUE completely vanishes, and the cutting fluid may play a role in this definition. Equating all the circumstances, the cutting forces were higher when the Clearedge BF 6515 fluid was used at a concentration of 10% and were lower when using the fluid Carecut S100, also at a concentration of 10% and Clearedge BF 6515 to 7%. This position gained by the fluid, except additional influences, could be described by the cutting fluid ability of penetrating and lubricating the tool-chip interface. The cutting fluid, to be active in its lubricating action, has to be present at the interface and has to be able to interact with the workpiece material to form an effective lubricating film.

As it is shown in the Figure (3), the performance of the cutting forces (F_c) with the difference of the feed rate (*f*) is increasing and approximately linear, except for the fluid Clearedge 6515 BF 10%, where the forces were higher than the others. For the other studied fluids the values of the forces were very adjacent to each other, and Table (2) confirms those values. Under these cutting conditions, therefore, it is not probable to identify the superlative fluid and better concentration, signifying that all these fluids (except Clearedge 6515 BF 10%) had analogous lubrication and cooling powers.

Again, it is possible to verify that the practice of Clearedge 6515 BF fluid at a concentration of 10% produced the highest cutting forces. The residual fluids had very similar behaviors. In the area of depth of cut between 1 and 3 mm, the Carecut S100 fluid at a concentration of 10% showed marginally smaller forces.

Microbiological Analysis

The microbiological calculation developed from the Carecut S100 Fluid collected from the basin showed that around 60% of samples had microbial growth, particularly *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, *Bacillus* sp, coagulase-negative *Staphylococcus* and filamentous fungus, which is a causative agent of dermatitis. The growth was higher in the fluid with a lower concentration (4%), while the concentration of 10% had no growth.

In the Clearedge 6515 BF fluid a microbial growth in 53.3% of the samples collected was verified, and it was found the microorganisms: *Bacillus* sp, *Bacillus* sp anaerobic, *Staphylococcus aureus* and coagulase-negative *Staphylococcus*. At the concentration of 7%, 60% of the samples showed some growth, and at concentration of 10% this percentage was 83.3% growth. At 3% concentration no growth was detected.

It was detected that, in universal, the herbal based fluids are more prone to microbial growth and the concentration in water has a strong influence. In the vegetable-based fluid the highest concentration reduced the microbial growth, while the growth in mineral-based fluids in the lowest concentration reduced this microbial growth.

The presence of organic mixtures and minerals in the preparation of the fluid are a source of nutrients for these microorganisms to grow themselves. The temperature and pH of the

Table 2. Values of cutting forces (F_c) for the various feed rate and cooling condition tested

Depth of cut,mm	CLEAREDGE 6515 BF 3%	CARECUT S100 3%	CLEAREDGE 6515 BF 7%	CARECUT S100 7%	CLEAREDGE 6515 BF 10%	CARECUT S100 10%
0.5	540	600	520	525	650	530
1.0	900	900	790	800	980	840
2.0	1127	1110	1050	1050	1270	1120
2.5	1200	1300	1280	1290	1580	1340
3.0	1506	1497	1490	1490	1890	1450
3.5	1750	1708	1750	1750	2180	1750
4.0	1950	1909	1920	1950	2480	1950
4.5	2150	2111	2150	2140	2640	2160
5.0	2350	2360	2340	2360	2980	2380

The cutting forces (F_c) were also measured by varying the depth of cut, and the results can be seen in Figure (4).

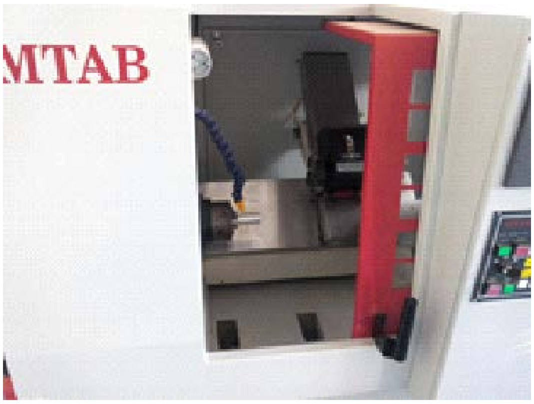

Fig. 1. Application of cutting fluid during an experiment

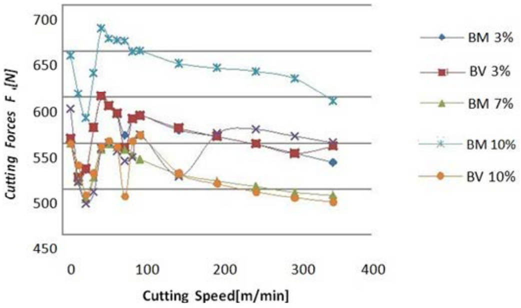

Fig. 2. Cutting force (F_c) variation with the cutting speed, for a feed rate of 0.2 mm/rev and depth of cut of 1 mm – BM (Mineral Based Fluid) – Clearedge; BV (Herbal Based Fluid) – Carecut.

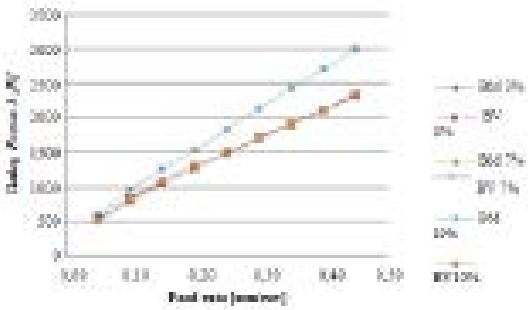

Fig. 3. Variation of cutting forces (F_c) with the feed rate, for the cutting speed of 150 m/min and depth of cut of 1 mm

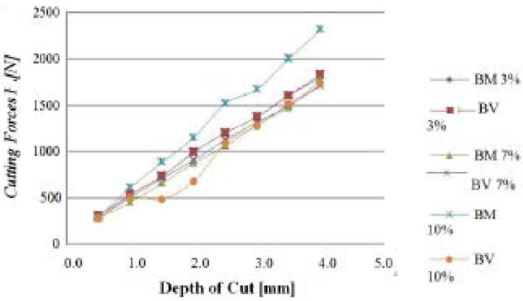

Fig. 4. Variation of cutting forces (F_c) with the depth of cut, for the cutting speed of 150 m/min and feed rate of 0.2 mm/rev

fluid systems are similar essential aspects to be considered for the growth of microorganisms, since room temperatures and pH around 9 encourage microbial growth.

In this study in the basin of the machine were found microorganisms such as *Bacillus* sp., *Staphylococcus aureus*, *Pseudomonas aeruginosa* and filamentous fungi, which are previously labeled in literature as common organisms existing in cutting fluids and they should be avoided since of the amount of problems that may be caused by the lack of control and care. It is understood that the primary cause for the presence of these microbes is the air, which is in continuous exchange with the fluid. And, as these machines are situated at a location that habitually comprises manymachining materials, several people employed and several experiments being performed, there is a high chance of having bacteria in the air such as *Staphylococcus aureus*.

CONCLUSIONS

The biodegradability of vegetable oils is the strongest point in the case for their industrial use. In the light of more concerns about the environmental impact of the use of industrial fuels and lubricants, they offer in theory the most plausible solution to the issue of obtaining renewable and ecofriendly lubricants and fuels. With established biodegradabilities in the range of 70 – 100%, their eco friendliness is not in doubt. The challenge is the improvement of their performance in industrial uses; specifically with reference to their oxidative stabilities and pour points which in general leave much to be desired.

Improvements are inevitable and are already being recorded with increasing research directed in these areas. In the research, the state of lubrication and cooling which provided the lowest forces was the use of Carecut S100 fluid at a concentration of 10%, and with the Clearedge BF 6515 fluid at a concentration of 10% the highest cutting forces was observed. In the detection of microorganisms in the fluid allocated in the machine reservoir the following microorganisms were found: Bacillus sp., Staphylococcus aureus, Pseudomonas aeruginosa and filamentous fungi, and in general, vegetable-based fluids showed higher growth of these microorganisms, and curiously, a higher growth of microorganisms was observed in the fluid Clearedge BF 6515, at a concentration of 10%.

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