ESTABLISH THE INFLUENCE OF SOYBEAN OIL ABOVE WEAR BEHAVIOUR OF CUTTING TOOLS DURABILITY

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**Summary**

In order to formulate a new cooling oil lubricant for cutting, the paper presents the tests made on 4-balls machine on cooling fluids with different additive types and concentrations, in order to establish the proper composition. In the presence of selected cooling fluids, on Amsler machine, were determined the tribological behavior of linear couple’s carbon steel- high speed steel. The obtained friction coefficient and wear curves for tested materials couple were used to evaluate EP proprieties for proposed oil cooling fluids samples. On special devices the selected new lubricant and a classical one were tested on drilling machine. The drills durability was evaluated by simultaneous measuring the cutting torque and axial cutting force at drilling. Was measured also the wear width on drills locating surface.

**Keywords:** soybean oil, synthesized additive, drills, cutting length

**INTRODUCTION**

The proposed oil cooling fluids tested are designed for use in moderate to severe machining operations. These cutting oils are available in different EP levels and viscosity grades to cover a wide variety of machining operations and metals. The oils will be used as metalworking neat oils for industrial applications: deep hole drilling, broaching and tapping, gear cutting and shaving, grinding, honing and lapping, turning, planning, shaping, milling e.g.

Lubricants used as technologic mediums in metal cutting processes should complete some main specific demands as:
- reduce friction between working piece and cutting tool and between cutting tool and chips in order to rise tool durability and to improve machined surface;
- remove the heat and the material resulted from the cutting zone;
- assure lubrication in limit condition between cutting tool, piece and chips;
- to be stable (chemical and structural);
- to be, as possible, environmentally friendly;
- to not react with materials and even to assure a short corrosion protection till the next operation;
- resistance at microorganisms which develops in cutting medium and to assure a small toxicity;
- to be, in special cases, compatible with the other machine-tools lubricants;
- to be cheaper.

Depending of cooling and lubricating proprieties the cutting fluids could be divided in two main groups [4, 6, 7, 8]. First group are water soluble fluids characterized by small viscosity and great values for specific heat and thermal conductivity.

Second group are oil based fluids with very good lubricating, deforming and detaching chips proprieties. As surface active additives which form adsorption resistant films at high pressures, reduce friction coefficient and enter in microcracks making cutting easier are used stearic and oleic acids and organic compounds containing sulfur, chlorine or phosphor. As synthetic based oils are mostly used esters and poly-alpha-olefins [4, 6].

Because cutting oils are in contact with operator skin, the toxicological proprieties are very important. Very important are also oil thermal-oxide stability.

At cutting electro-chemical potential of machined material became more electropositive and cutting fluids should contain also anticorrosive additives. Antioxidant additives such as phenols, amines and anticorrosive additives such as zinc dithiophosphates or dithiocarbonates, esters, fat amides, amides of dodecilsuccinic acid, fatty acid derivatives etc. are mainly used [4, 6, 7, 8].

The aim of our work was to obtained extreme pressure additives based on mixture of soybean oil with metallic ester of soybean oil and a synthetic ester. To obtain extreme pressure properties the mixture must be reacted with sulphur and after sulphonated the product will be mixed with antioxidant and anticorrosion additives. This paper presents a part of tests made in order to formulate a cooling fluid for cutting and rolling.

**EXPERIMENTS**

Lubricating cooling fluids proprieties were considered as a main criterion. In this order the 15 selected esters were tested on 4 balls machine.

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In Figure 1 is shown the 4 balls machine used. The rotation speed of upper ball was 1475 r.p.m.

![Fig. 1: 4 balls machine](image)

In Table 1 are presented the ester sample types and the obtained results, [6, 7, 8].

<table>
<thead>
<tr>
<th>Sample</th>
<th>Ester type</th>
<th>Normal force, before welding, N</th>
<th>Friction torque, before welding, Nm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Monoester of oleic acid with isodecyl alcohol C13</td>
<td>536.5</td>
<td>0.656</td>
</tr>
<tr>
<td>2</td>
<td>Monoester of oleic acid with isodecyl alcohol C10</td>
<td>536.3</td>
<td>0.225</td>
</tr>
<tr>
<td>3</td>
<td>Monoester of oleic acid with 2 etoxylated p-nonylphenol</td>
<td>536.5</td>
<td>1.379</td>
</tr>
<tr>
<td>4</td>
<td>Monoester of oleic acid with 2 o-secondary butyl phenoxynethanol</td>
<td>1223.2</td>
<td>0.164</td>
</tr>
<tr>
<td>5</td>
<td>Monoester of oleic acid with 1 o- secondary butyl phenoxynethanol</td>
<td>765.7</td>
<td>0.400</td>
</tr>
<tr>
<td>6</td>
<td>Monoester of caprylic acid with isodecyl alcohol C13</td>
<td>536.5</td>
<td>0.492</td>
</tr>
<tr>
<td>7</td>
<td>Monoester of caprylic acid with isodecyl alcohol C10</td>
<td>536.5</td>
<td>0.480</td>
</tr>
<tr>
<td>8</td>
<td>Monoester of caprylic acid with 2 etoxylated p-nonylphenol</td>
<td>765.7</td>
<td>0.656</td>
</tr>
<tr>
<td>9</td>
<td>Monoester of caprylic acid with 2 o- secondary butyl phenoxynethanol</td>
<td>2070.8</td>
<td>0.820</td>
</tr>
<tr>
<td>10</td>
<td>Monoester of caprylic acid with 1 o- secondary butyl phenoxynethanol</td>
<td>2070.8</td>
<td>0.175</td>
</tr>
<tr>
<td>11</td>
<td>Monoester of butyric acid with isodecyl alcohol C13</td>
<td>994.5</td>
<td>0.187</td>
</tr>
<tr>
<td>12</td>
<td>Monoester of butyric acid with isodecyl alcohol C10</td>
<td>994.5</td>
<td>0.673</td>
</tr>
<tr>
<td>13</td>
<td>Monoester of butyric acid with 2 etoxylated p-nonylphenol</td>
<td>2070.8</td>
<td>0.525</td>
</tr>
<tr>
<td>14</td>
<td>Monoester of butyric acid with 2 o- secondary butyl phenoxynethanol</td>
<td>2553.5</td>
<td>0.350</td>
</tr>
<tr>
<td>15</td>
<td>Monoester of butyric acid with 1 o- secondary butyl phenoxynethanol</td>
<td>994.5</td>
<td>0.656</td>
</tr>
</tbody>
</table>

The maximum normal force obtained on 4 balls machine for the 15 ester samples tested is presented in Figure 2.

![Fig. 2: Histogram of normal force](image)

The 5 ester of soybean and oleic acid type samples 4, 9, 10, 13 and 14 (with the best results so it is shown in Fig.2) were selected to produce 5 cooling oil with min. 70% biodegradability according to CEC L-33-T-82, [4, 6, 7].

The 5 oil cooling fluid samples were tested on Amsler A135 machine to establish the tribological behavior of linear couple’s carbon steel- high speed steel.

In Figure 4 are presented the friction coefficients and in Figure 5 the volumetric wear of HSS disk plate samples. Volumetric wear of cylinder samples was established with relation:

\[ V_{p} = \frac{u_{i}}{\rho} \]

where, \( V_{p} \) is volumetric wear at time \( \tau_{i} \), mm\(^3\);

\( u_{i} \)- gravimetric wear at time \( \tau_{i} \), g;

\( \rho \)- specific weight of cylinder material, g/mm\(^3\).

Disk plate samples wear was establish by microscope measuring wear width track with relation:

\[ V_{p} = L \cdot \left( \frac{\pi \cdot \alpha \cdot R^2}{360} - \frac{L}{4} \sqrt{R^2 - l^2} \right) \text{, mm}^3 \]
were, \( V_p \) is volumetric wear of disk plate, \( mm^3 \);
\( L \) – cylinder width, mm;
\( R \) – cylinder radius, mm;
\( l_i \) – wear width track at time \( \tau_i \), mm;
\( \alpha_i \) – angle which subtend span \( l_i \) at time \( \tau_i \), rad.

To calculate disk plate samples volumetric wear was used the Pascal language program:

```pascal
var gr, li, h, a, aria, R, L: real
begin
write ('li='); readln (li);
write ('R='); readln (R);
write ('L='); readln (L);
h:=sqrt(R*R-li*li/4);
a:=(2*arctan(li/(2*h)));
gr:=a*180/pi;
aria:=gr*R*R*pi/360-li*h/2;
writeln('volum=',aria*L:0:5);
readln;
end.
```

Cylinder material was carbon steel with hardness 142HBW and disk plate of high speed steel with hardness 68.5HRC. The sliding speed was 0.523 m/s at friction coefficients and wear tests. At wear tests the normal load was 1000 N.

From figure 4 could be observed that the additive effect begin at different loads for the 5 oil cooling fluids samples presented. For oil samples 5 and 4 were obtained the smallest values of friction coefficient. This means that formulas with monoester of butyric acid with 2 ortho secondary butyl phenoxyethanol and formulas based on monoester of butyric acid with 2 etoxylated para nonylphenol are better than the rest.

The volumetric wear of carbon steel cylinder samples is presented in Figure 6.

In the presence of oil sample 5 the HSS disk plate present the minimum volumetric wear (fig.5), and the carbon steel cylinder the maximum volumetric wear (fig.6).

With oil sample 5 which presents the best behavior was formulated experimental soybean lubricating oil. With this cooling oil and with classic UP4 oil were made tests to establish the 10 mm HSS drills durability, drills having the same hardness as HSS disk plate used on Amsler machine.

With a special device, were simultaneous measured the cutting torque, axial cutting force at drilling and wear width on drills locating surface vs. cutting length. To measure cutting axial force and torque was designed and realized a device presented in Figure 7.
The torque and cutting axial force were simultaneously measured using a resistive strain transducer with two strain gauges [2, 3, 5]. On downside part of device was fixed the strain gauge for axial force and on upper part the strain gauge for torque (fig. 7).

Were tested 10 mm HSS drills and drilling conditions were: speed of rotation \( n = 630 \text{ r.p.m.} \), axial feed \( s = 0.13 \text{ mm/rot.} \), workpiece of carbon steel plate, bore deep 55 mm in the presence of experimental cooling oil and in the presence of cooling oil UP4.

Flank wear was determined by metallographic microscope examination as is shown in Figure 8.

For each drilling conditions were tested more drills. In Figure 9 is shown the torque variation versus cutting length for different drilling conditions.

Was measured also the wear width on drills locating surface vs. cutting length. The tests were stopped when wear width was grater then 0.4 mm [1]. All tests were made with new drills.

The variation of cutting axial force is presented in Figure 10.

From figure 9 and 10 it is obvious that cutting torque is more sensible than cutting axial force at lubricant type.

In the presence of experimental cooling oil, at drilling tests the cutting torque (fig.9) and cutting axial force (fig.10) are smaller. In Figure 11 is presented the drill flank wear. The 0.4 mm value of flank wear, when drills must be sharp is reached in the presence of experimental cooling oil at double cutting length instead in the presence of classical cooling oil UP4, (fig.11).

CONCLUSIONS

The cutting oils contain unique synergistic extreme pressure additive systems that readily react at chip-tool interface to form extremely effective lubricating films which reduce frictional heat and prevent meta-metal contact between the tool and workpiece and chip. The cooling fluid samples were made with various percent from soybean oil, low esters of soybean oil, oleic acid esters, sulphonated soybean oil and additives. The tests presented in this paper were made to select the proper oil cooling fluids sample and composition in order to obtain good EP proprieties which are important for the metalworking process.
The proposed oil cooling fluids are designed for use in moderate to severe machining operations. These cutting oils are available in different EP levels and viscosity grades to cover a wide variety of machining operations and metals. The oils will be used as metalworking neat oils for industrial applications: deep hole drilling, broaching and tapping, gear cutting and shaving, grinding, honing and lapping, turning, planning, shaping, milling e.g.

Tests on 4 balls machine for the initial 15 ester samples let us to conclude that monoester of butyric acid with 2 ortho secondary butyl phenoxyethanol is the best. In figure 4 could be was observed that the additive effect begin at different loads for the 5 oil cooling fluids samples presented. For oil samples 5 and 4 were obtained the smallest values of friction coefficient. This means that formulas with monoester of butyric acid with 2 ortho secondary butyl phenoxyethanol and formulas based on monoester of butyric acid with 2 etoxylated para nonylphenol are better than the rest. From figure 5 of HSS wear it could be observed that oil sample 5 assure the smallest volumetric wear values. In the mean time for the workpiece, similar with carbon steel cylinder the wear should be maximum values. In figure 6 it is shown that oil sample 5 assure the greatest wear values.

These results obtained for oil cooling fluid samples on universal machines testing machines shows that formula for oil sample 5 is better than the rest of oil samples. With this oil sample and with a classical cooling fluid UP4 were made tests on drills machine with special device in order to establish axial cutting force, cutting torque and cutting tools wear. Tests made on drills tools in the presence of new formulated cooling fluid show that the drills durability was 90% greater than with UP4 oil at drills in carbon steel.

ACKNOWLEDGMENT

We are grateful for the resources provided by Romanian Ministry Education and Research by Programme “Matnantech-P 80”.

REFERENCES