INVESTIGATION OF SLIDING PROPERTIES OF SELECTED PLASTICS AND GREASES APPLIED FOR ELEMENTS OF WINTER SPORT EQUIPMENT

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Abstract

The article presents the results of friction coefficient measurements of selected polymer materials applied for elements of winter sports equipment sliding against ice. After testing, one of thematerials, polyethylene, which is the most commonly used material for ski slides, was selected and tested again, this time, in the presence of various types of ski lubricants. The research was carried out on a pin-on-disc tester placed in a climatic chamber.

Obtained results revealed that the selection of the lubricant is a matter of great importance to the reduction of the frictional resistance and should be strictly conditioned by the ambient temperature and associated prevailing snow conditions.

INTRODUCTION

According to the generally accepted theory, low friction resistance on snow and ice is a result of the presence of thin water layer that is formed between the ski, or skate slide, and snow or ice. There are at least a few hypotheses that attempt to explain this phenomenon. The most popular of the theories are the theory of decrease of ice melting point temperature caused by the increased pressure on its surface [L. 3, 12, 15], the theory with additional heat generated during friction [L. 2, 6], and the theory of ice surface melting [L. 11, 13, 14, 15]. However, the analyses carried out by the researchers [L. 8, 12, 16]revealed that none of these theories explains the phenomenon of the ice film presence completely and unambiguously.

The pressure to achieve better and better results in winter sports comprises the motivation to seek new ways to reduce friction resistance. Sliding friction between ski or skate and snow or ice is the sum of three components: dry friction, fluid friction, and friction resulting from electrostatic interactions [L. 7]. Therefore, to reduce
the frictional resistance in skiing, the slides are covered with various types of greases. The temperature and snow conditions (which are closely related with it) are the factors that mainly determine the kind of grease applied \[L. 10\]. They indicate which of the friction components is dominant.

The research on reducing the frictional resistance with ski lubricants is mostly carried out by their manufacturers. They are designed to select the proper ingredients and their proportions to minimise the friction between ski and snow. However, their results are a trade secret and are not published. The results of experiments in the available publications come from university centres, and they concern only the fundamental issues related to friction on snow or ice \[L. 1, 4, 5, 9\].

The presented research aims to compare the impact of the type of applied polymeric material and commonly available ski lubricants on frictional resistance during sliding on ice and snow.

MATERIALS, METHODS AND TESTING PROCEDURE

Measurements of friction coefficients were carried out on a pin-on-disc tribological tester mounted in a climatic chamber which enables regulation of temperature and ambient humidity. In this study, the sample was a pin made of a polymeric material, and an aluminium tub filled with ice acts as the rotating disc. These measurements were carried out in two stages. The first stage was tests of non-lubricated friction couple, and the second stage was tests of lubricated ones.

The first stage concerned the examination of the friction coefficient of the sliding combination ice-polymeric material under conditions of technically dry friction (Fig. 1).

As pins, the following polymer materials were selected: polytetrafluoroethylene (PTFE), polyoxymethylene (POM), and high-density polyethylene (PE-HD). These materials are widely used for various elements of winter sports equipment \[L. 1, 12\]. Friction measurements were carried out for temperatures 0, –5, –10, –20, and –30°C at a constant sliding speed of 0.2 m/s and a pressure \(p\) of 2 MPa.

During the second stage, the values of the friction coefficient of lubricated couples were investigated. In this case, layers of different ski lubricants were distributed onto the surface of polymer pins made of polyethylene P-TEX and again subjected to sliding cooperation with an ice disk (Fig. 2). The following greases were tested: paraffin, hydrocarbon grease (CH), fluoride grease (HF), and non-fluoride grease (NF).

RESULTS, ANALYSIS AND DISCUSSION

Friction resistance of non-lubricated couples

The results of friction coefficients measurements of polymeric materials against ice in conditions of technically dry friction are presented in Table 1 and Figure 3.
Initial tests of friction of polymer materials on ice revealed that the value of the coefficient of friction, in the range from –5°C to –35°C, and thus the sliding properties of the material are strongly dependent on temperature. In general, after exceeding the temperature of –5°C (–10°C for POM), with its decrease, an upward trend was observed. It can be explained by the fact that between 0 and 5°C the thickness of the water film was the highest, and later it decreased.

The most stable material, considering the tested temperature range, turned out to be POM. The values of friction coefficients ranged from 0.05 to 0.057. PE occurred to be the least stable. On the other hand, in the temperature range from 0 to –20°C, so in the temperature range in which skiing is usually practised, it showed the lowest values of the coefficient of friction.

Friction resistance of lubricated couples

The values of friction coefficients of rubbing couples, P-TEX – ice disc, with the applied layer of grease are presented in Table 2 and diagrams in Figures 4 and 5.

<table>
<thead>
<tr>
<th>Material</th>
<th>Temp</th>
<th>Friction coefficient</th>
<th>Measured friction coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>average deviation</td>
<td>trust</td>
</tr>
<tr>
<td>PTFE</td>
<td>0</td>
<td>0.02 ± 0.006</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>-5</td>
<td>0.02 ± 0.001</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>0.03 ± 0.007</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>0.06 ± 0.006</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>-30</td>
<td>0.07 ± 0.000</td>
<td></td>
</tr>
<tr>
<td>PE-HD</td>
<td>0</td>
<td>0.01 ± 0.004</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>0.02 ± 0.004</td>
<td>0.003</td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>0.04 ± 0.006</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>-30</td>
<td>0.08 ± 0.005</td>
<td>0.004</td>
</tr>
<tr>
<td>POM</td>
<td>0</td>
<td>0.05 ± 0.018</td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td>-10</td>
<td>0.04 ± 0.011</td>
<td>0.010</td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>0.05 ± 0.007</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>-30</td>
<td>0.06 ± 0.004</td>
<td>0.003</td>
</tr>
</tbody>
</table>

Fig. 3. Comparison of the friction coefficients values of the tested polymer materials on ice

Rys. 3. Porównanie wartości współczynników tarcia badanych materiałów polimerowych po lodzie

Measurements of friction coefficients at a temperature 0°C were possible to perform only for PTFE. In the case of PE-HD and POM, it was not possible to keep the ice in the solid state, and the samples penetrated the semi-fluid water-ice disk. Probably, due to friction, more heat was generated, which contributed to the melting of ice.

Table 2. The results of measurements of friction coefficients of lubricated couples: P-TEX covered with ski grease – ice disc

Tabela 2. Wyniki pomiarów współczynników tarcia węzłów smarowanych: P-TEX pokryty warstwą smaru narciarskiego – tarcza lodowa
The lowest values of the friction coefficient, at temperatures –3, –10, and –15°C, were observed for friction couples in which hydrocarbon lubricant was applied. Values of the friction coefficient, of the non-lubricated sample, at –3°C, were also noted to be relatively low. However, at the lowest temperature tested, –20°C, the smallest value of the coefficient of friction was observed for a sliding pair with a layer of fluorine-free lubricant.

The highest value of the coefficient of friction was recorded for couples with paraffin grease for all measuring temperatures. Slightly lower values of friction coefficient were obtained for high-fluoride grease. According to the manufacturer’s recommendations, the high-fluoride grease should be the most preferable at –3°C. It is designed for use in the temperature range from 0 to –4°C. However, when comparing the values of friction coefficients for all tested sliding nodes, friction couple with paraffin and fluorine grease occurred to present the highest ones. Nevertheless, it should be noted that this specific grease is dedicated to snow conditions in which the crystals have ovoid shapes and do not reveal a high tendency to penetrate the grease layers. Testing conditions differed from those that can be observed while skiing. In the tests, the friction co-partner was ice formed as a result of water freezing. The formed ice crystals thus have sharp edges and easily penetrate into the soft grease. High-fluoride lubricants, designed to a temperature of about –5°C, similar to paraffin greases, are classified as soft greases with a low internal friction but also high penetration sensibility. Therefore, the values of the friction coefficients of these two soft greases turned out to be higher than the others. However, the lowest coefficients of friction, considering the entire range of measurement temperatures, revealed sliding pairs with hard greases, i.e. CH and NF. Non-fluorine grease, as the hardest of the tested lubricants, had the highest resistance to penetration, which was confirmed by the fact that the couples in which it was applied had the lowest friction coefficient at –20°C. The sample without an applied layer of the ski lubricant is characterised by intermediate values of the friction coefficient. It can be understood as follows: the lack of a soft lubricant layer made it more resistant to the penetration of ice crystals, but not as much as in the case of hard grease.
CONCLUSIONS

On the basis of the conducted tests, it can be concluded that the value of the friction coefficient during sliding of polymeric materials on ice strongly depends on the temperature of the ice, regardless of friction ambience, i.e. the presence of ski grease or in the conditions of dry friction. After exceeding –5°C, as the temperature dropped, an increase in the value of the friction coefficient was observed regardless of the polymeric material and the type of grease applied. In the temperature range from 0 to about –5°C, the lowest values of the coefficient of friction were recorded, which is most probably related to the presence of a water film with a thickness ensuring minimum resistance during sliding.

Application of a ski lubricant layer to the friction pairs sliding surfaces had an ambiguous effect on sliding resistance. The use of hard lubricants (CH and NF) resulted in a decrease in the value of the friction coefficient at the lowest temperatures, i.e. at –10, –15, and –20°C. However, in the case of the use of soft greases, an increase in the coefficient of friction was observed in the entire range of temperatures tested.

It should be noted that the experimentally determined friction coefficient values of selected ski lubricants were relatively small. It is because the measurements were carried out at a linear speed of around 9 km/h, which was caused by the measurement station limitations. Meanwhile, an intermediate skier moves along the ski slope with speed in the range of 30 to 50 km/h. The second reason for the low values of friction coefficients was neglecting the friction resistance, which is related to the penetration of the ski in the snow during the turning phase. Nevertheless, providing the same measurement conditions for each of the samples allowed comparing the results and drawing conclusions.

It should be emphasised that the research carried out relates to the combination of polymeric materials with ice. Therefore, the obtained results can be referred to the conditions that occur when skiing on the glaciated slope. However, in the case of the most frequent occurrence, i.e. the appearance of snow on the slope, the sliding conditions change. The friction then occurs between the polymeric material and the snow and the measurement results described in this article can no longer be a reference. The direction of further research will, therefore, be to carry out measurements in which the counterspecimen of friction will be covered with snow.

REFERENCES


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