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Ski boot soles based on a glass fiber/rubber composite with improved grip on icy surfaces

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Abstract

A study on the effect of glass fibers/rubber composites on the grip on ice has been conducted in order to develop new materials for ski boot soles with increased grip in winter environments. The study has been conducted analyzing the friction of a composite material and of a ski boot sole containing an insert made of the composite material and comparing the results with those obtained using rubber and a thermoplastic elastomer. The analysis of the morphology of the composite surface, by Scanning Electron Microscopy, shows a homogenous distribution of glass fibers of approximately 10 μm of diameter in the rubber matrix. Moreover, the measure of the contact angle shows that the composite material has a higher water repellency compared to the rubber matrix. The measure of the coefficient of friction indicates a significant effect of the glass fibers on the grip on icy surfaces. The increased grip can be ascribed to the stiffness of the glass fibers that are able to have a mechanical grip on the ice surface and to the increased contact angle and water repellency of the composite that decrease the formation of a water layer below the sole.

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Keywords: ski boot; friction; sole; rubber/glass fiber composites.

1. Introduction

Slips and falls are very common when walking with ski boots and they are often the cause of serious injuries. The sole of a ski boot is a very unique system that must have a stiff behavior in order to efficiently transmit the impulse from the ski boot to the ski, but must also have a good grip on icy and wet surfaces [1]. Several ski boot manufacturers have started to produce boots with soles [1] with parts made of materials less hard with respect to the plastic used for the main body of the boot [2], with the aim to improve the anti-slip properties of the soles. In particular, the soles of boots used for ski-touring and freeride skiing are completely or partially made of thermoplastic elastomers or rubber, in order to improve the grip when hiking and climbing [1].

A significant work has been performed in recent years in order to understand and model the friction behavior of elastomers on wet and icy surfaces. For example, Gronqvist et al [3] have tested 49 types of winter footwear on dry and wet ice, determining the most important parameters for each condition. From their evaluation, material type and hardness as well as cleat design has been defined as the most important parameters for grip on dry ice. On the other hand, on wet ice only the tread design has an influence on the friction properties. The high slipperiness of ice was also analyzed by Gao et al [4], who have measured the effect of sole abrasive wear on the coefficient of friction on dry and melting ice.

We have previously studied [5] the factors influencing the coefficient of friction (COF) of the materials used for the

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production of soles for ski boots on wet floors and icy surfaces. The results of our study [5] have pointed out that the stiffness and the roughness of the material used for the sole have a fundamental effect on grip performances. In particular, the results obtained show that softer materials provide more grip with respect to harder materials and that the surface roughness has a negative effect on friction, since the materials with the highest Sa (arithmetic mean height) and with the lowest number of contact points with the surface have the lowest COF. The measure of grip on inclined wet surfaces (according to DIN 51130-R ramp test) has also shown a relation between hardness and grip, the softer materials having the higher grip. The performance ranking of the different materials has been the same for the COF and for the slip angle ramp tests, indicating that COF can be used as a parameter for the choice of the optimal material to be used for the soles of ski boots. The comparison of different sole treads indicates that the best results in terms of anti-slip behavior are obtained with the soles that present the wider contact area with floor. However, even the most performing thermoplastic polymer or rubber tested in our previous study (complying with ISO 5355 standard for ski boots) did not possess a coefficient of friction on icy surfaces above 0.15 and therefore the soles actually present on the market do not posses an efficient grip on those surfaces.

For this reason, in the last few years, researchers and producers of boots for winter sports have started to study the application of hybrid soles containing components with improved friction on icy surfaces. Recently, Rizvi et al [6] have reported a study on polyurethane/glass fiber composites, finding a significantly increased COF on ice for the materials containing the fibers. Treksta™ has recently developed, using a proprietary patented technology named Ice-Lock™, soles for shoes for outdoor sports with parts made of a composite materials based on a rubber matrix containing aligned glass fibers that are perpendicular to the base of the sole. According to Treksta™ the purpose of the rigid glass fibers is to increase the mechanical grip on ice, while the creation of a micro-structured surface should have an effect on grip performances on wet surfaces, since it should modify the water repellency of the surface. However, no scientific data have ever been reported and no scientific study has ever investigated the mechanism of action of this type of rubber/glass fibers composite. For this reason, we have performed a study in order to assess the performances of this type of composite material and to understand the effect of the fibers in the rubber matrix. Moreover, we have prepared a ski boot sole complying with ISO 5355 norm, containing parts made of the rubber/glass fibers composite and compared its grip performances with those of a standard rubber sole.

2. Materials and Methods

The rubber/glass fiber composite (Material 1) and the rubber material used as matrix for the composite (Material 2) have been kindly provided by Treksta™.

The soles have been produced by over-injection moulding of polyurethane on the rubber and rubber/glass fiber composite and are all complaining with ISO 5355 norm. In the present study only the soles for the heel part of the ski boot have been tested since this part is more flat compared to the front part due to the constraints of ISO 5355 norm. In this way it has been possible to apply a more distributed pressure on the entire surface of the sole. A sole (Sole 3) containing two inserts of 3.7 cm^2 each of Material 1, the rubber/glass fiber composite, has been tested and compared with an identical sole without the composite inserts in Material 1 (Sole 2). A sole made of thermoplastic polyurethane (TPU) has also been used as a reference (Sole 1).

Figure 1. Soles used in the present study, indicating the zone of the rubber/fiber composite insert position in Sole 3.

The chemical composition of the Soles and Materials surfaces has been determined using Fourier Transform Infrared Analysis (FTIR) performed directly on the surface of the materials using a Perkin Elmer Spectrum One instrument equipped with