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The Effect of Ice Type on Ice Adhesion

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Ice formation is unavoidable at low temperatures. Ice and frost cause not only inconvenience but also danger in the daily life of human beings, especially in cold regions. For example, ice accumulation on roads or on aircraft wings causes accidents and ice accumulation on wind turbines or overhead power lines can affect the distribution of electricity, power losses and mechanical and electrical failures. To avoid such situations, icing mitigation methods using both anti-icing and deicing systems have been developed over the last decades, with differing efficacy depending on their application field.

There are three main pathways to achieve anti-icing surfaces, or icephobic surfaces. These three pathways are the removal of water before freezing, the delay of ice nucleation and the reduction of ice adhesion strength. The ideal icephobic surfaces have an ice adhesion so low that the ice formed on them would shed merely due to its own weight or a natural wind action. To achieve such a low ice adhesion, the fundamental mechanisms of ice adhesion need to be fully, or at least better, understood.

This investigation is the first study on the impact of different types of ice on the ice adhesion strength for the same substrate and the same temperature of formation. Ice is likely to behave in different manners depending on the conditions during freezing, and the type of ice is therefore an important factor of ice adhesion strength. The different ice types were formed and tested at the same temperature of -10 oC. The three ice types studied were impact ice generated in a wind tunnel, hard rime ice created in a cold room with water droplets raining from above, and glaze ice frozen directly on to the bars with silicon molds. The ice was frozen on similar aluminum 6061-T6 bars, and ice adhesion strength was measured with the centrifuge adhesion test at the AMIL facilities.

A total of 126 tests were performed. The mean ice adhesion strength was measured to 0.78 ± 0.10 MPa for hard rime ice, 0.53 ± 0.12 MPa for impact ice and 0.28 ± 0.08 MPa for glaze ice. The ice adhesion strength for glaze ice is therefore more than 60% lower than for hard rime ice. A significant correlation was found between apparent density of the ice and ice adhesion strength, indicating that the ice adhesion strength decreases when the density of the bulk ice increases. The interface porosity of ice seems also to influence the ice adhesion strength.

The results indicate that ice adhesion models need to include a density factor of the ice in additions to the temperature to differentiate between different ice types. If correct, these observations may inspire a new strategy in icephobic surfaces.

Significance statement

For the first time, it was shown that ice adhesion strength differs for different ice types generated at the same temperatures. The density of the ice showed significant correlation with ice adhesion strength. These observations may inspire a new strategy in icephobic surfaces to combat hazardous icing in cold climates.

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