Fact Sheet

MEASURING THE ADHESION STRENGTH OF ICE

PROBLEM

Ice buildup on surfaces can adversely affect the operation of aircraft, marine vessels, surface vehicles, communication and power delivery systems, hydroelectric intakes, and other critical systems. The lack of a standardized method for testing the adhesive strength of ice has hampered efforts to develop low-adhesion materials and protective surface coatings. Ice adhesion has been measured in a variety of ways but the results are relatively scattered and difficult to compare because adhesion strength is highly sensitive to subtle differences in test conditions, e.g., ice type and structure, temperature, and test technique.

SOLUTION

CRREL has developed a laboratory facility for measuring the bond strength of ice in a relatively simple manner. We have found that attention to sample preparation and handling in conjunction with careful control of sample growth and test conditions leads to reproducible results. We recommend that coating candidates be tested in replicates of six each to achieve a minimum statistical acceptance. With this requirement, the comparative results of a 12-sample run, or two candidates, can be known in less than three days. Repetitive testing can also be conducted to provide a measure of a candidate's durability to the freeze/shear process.

Our method was adapted from the Zero Degree Cone (ZDC) test for adhesive joints. We grow ice in the annular gap between two concentric, cylindrical surfaces and then measure the force required to push the inner cylinder, or pile, out of the ice collar and outer cylinder. An O-ring, installed on the bottom of the pile, keeps the distilled, deionized, and de-aired water from leaking out while it freezes. The samples require about eight hours to freeze completely at a temperature of –10°C, and we allow another 40 hours for the internal stresses to relax before testing. We then test the samples using a materials testing machine and carefully maintain the rate of push on the inner pile.

RESULTS

We conducted baseline tests of ice adhered to stainless steel piles, having a surface finish of 5–15 μin rms, at four different strain rates ranging from 4.2 to 400 × 10^{-6} s^{-1}. We found that, through this range, the ice behavior transitioned from viscoelastic to ductile, and that the mean adhesive strength increased from 70 to 600 kPa as we increased the strain rate. We have determined that the shearing occurs cleanly at the pile/ice interface. In terms of repeatability, the standard deviation in the shear stress decreased with increasing strain rate but remained consistently below 20% of the mean values. In addition to those for stainless steel, we have adhesion test data for many other common materials and surface coatings.

Our ZDC Testing Facility is now available for comparing the relative performance of commercially available coatings for their ability to aid in ice removal. Under the terms of a Cooperative Research and Development Agreement (CRDA), we can use this technique in partnership with private industry to develop and test promising new materials in a proprietary manner.

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