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Use of a snow cannon to test effect of different coatings for adhesion of snow in railway applications

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Abstract. This paper describes implementation of a snow cannon for testing different coatings for adhesion of snow in railway applications. A spray of snow is targeted to a test plate and the accumulated mass of snow is measured. The test plate can be coated with *e.g.* an ice-phobic coating to test the effect of coating on adhesion of snow. Exploitation of a snow cannon for this purpose is straightforward, but certain parameters need to be measured and starts and stops of the cannon need to be precisely controlled to produce repeatable measurements. The snow cannon needs water and air supply in order to operate. These need to be measured and the flow of water and air in the cannon need to be adjusted carefully to be able to produce consistent spray of snow. The snow cannon was assembled in a cold laboratory, whose temperature could be precisely adjusted. The temperature and the humidity of the laboratory were measured. The paper describes the preliminary results of the snow cannon implemented for the described purpose.

Keywords: Snow Adhesion, Snow Cannon, Railway, Rolling Stock.

1 Introduction

Snow and ice cause great challenges for traffic and transport in the arctic areas. Not only are snow and ice problematic on traffic routes but also when accumulated to vehicles and their undercarriages [1-3]. Accumulation of snow and ice cause extensive technical problems on vehicles, traffic disturbances and significant increase in mass. Increase in mass reduces payload and increases fuel consumption and emissions and increases the risk of overloading freight carriers.

The motivation of this work lies in the snow and ice accumulation on rolling stock. The snow causes problems particularly, when built-up on rolling stock undercarriages and between the wagons [4]. The built-up snow turns gradually into ice due to the fluctuations of temperature. Hence, there can be snow and ice in the wagons potentially causing e.g. variety of technical problems extending from issues in brake and suspension systems to malfunction of railway switches caused by fallen ice and snow blocks [5, 6].

Materials and their surface characteristics affect the adhesion of snow [7]. In more specific, building up of snow is due to the adhesion between the snow and the surface and cohesion of the snow particles that further accumulate on the stack [8, 9]. The obvious fact is that the adhesion between snow and steel is sufficient for enabling strong adherence of snow to the steel, the most common material in rolling stock design. Therefore, snow accumulation could be hindered by limiting the adhesive force. For this reason, testing of different types of materials with suitable testing system appropriate for defining snow accumulation is of great interest. Building this kind of a system is in focus of this paper.

2 Materials and Methods

A simple snow cannon was made to produce snow in a cold laboratory environment. The snow cannon used in the experiments is presented in Fig. 1. The snow cannon is made from copper tubing and angled and straight fittings. The nozzle is a cap that has a hole drilled through the center of it. The snow cannon uses internal mixing principle, where the water and air are mixed inside the cannon. Water enters the top connection of the cannon and air the lower one. Water comes in at a 90° angle in relation to the air in the position where the water and air mixing occurs. The mixed water and air are then forced through the nozzle at the end of the cannon. After the mixture is forced through the nozzle, water is atomized, and small nucleuses are formed which then freeze very quickly soon after and snow is formed.

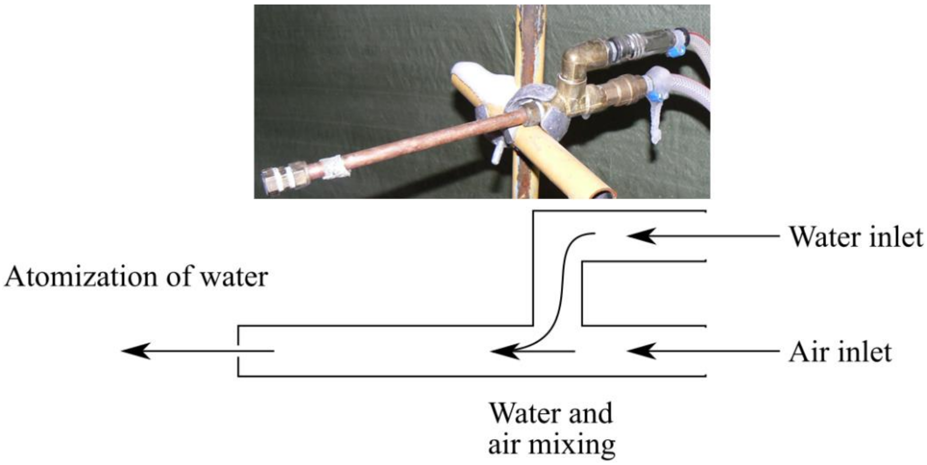

Fig. 1. The snow cannon used in the experiments and its operation principle.

2.1 Methods

Certain parameters of the system need to be precisely measured and adjusted in order to produce snow of consistent quality every time the snow cannon is operated. These include: water flow speed and pressure and air pressure. In addition to these the water temperature needs to be kept within a certain level during the process. The adjustments and measuring systems for the snow cannon and its schematic are presented in Fig. 2. These were assembled outside the cold laboratory that had a window and the test could be monitored through.

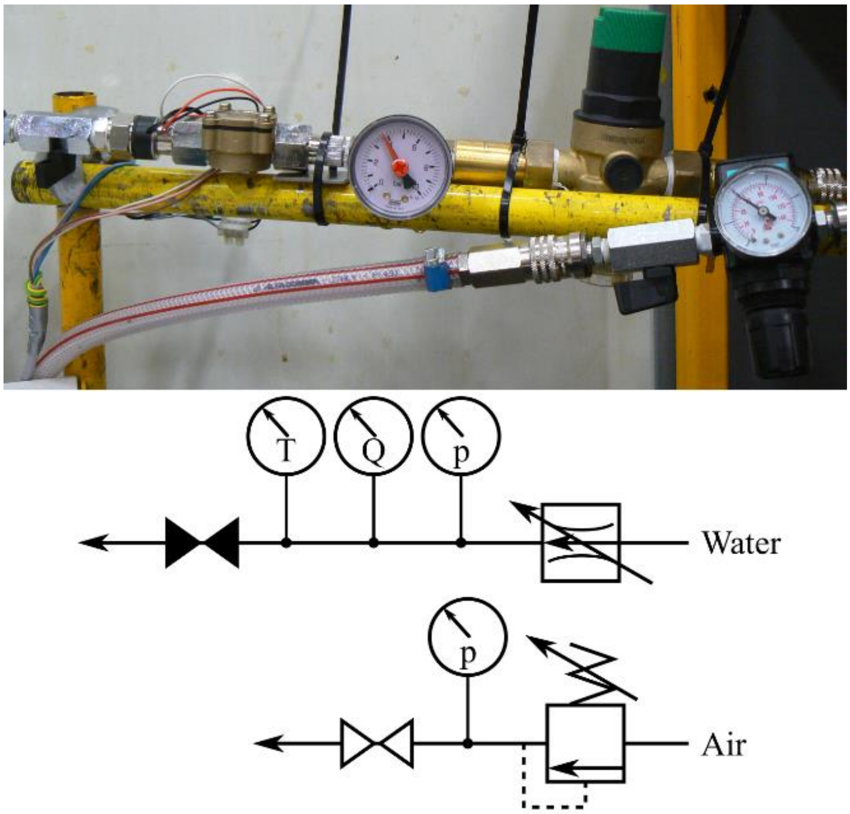

Fig. 2. The adjustments and measuring systems for the snow cannon. T is a temperature sensor, Q is a flow meter and p is a pressure gauge.

Water flow was adjusted by a flow control valve and measured by a flow meter. The temperature of the water was also measured. The air pressure was also adjusted and observed. It was noted during the tests that amount and the type of snow (moisture content) could be adjusted by changing these parameters.

The starting and shutting off process of the snow cannon are critical. It takes several seconds to start the snow cannon and have it producing the kind of snow that is desired. Usually during the starting process, the snow cannon sprays water and wetter snow or slush and this needs to be taken into account in the experiment to not add unwanted ice to the test plate. A curtain was used in the experiments that could be raised and lowered from outside of the laboratory. The snow cannon was started with the curtain down, in order to protect the test plate until the snow cannon was operating properly. The curtain was also used in the shutting off process of the snow cannon operation, so that the cannon could be cleaned of water with compressed air to avoid freezing and to prevent this water from spraying on to the test plate.

Three uncoated steel test plates exposed to a spray of snow from the snow cannon up to a point when the snow broke off are presented in Fig. 3. As can be seen from the Fig. 3 the snow in all the plates is of consistent quality. Snow's adhesion to the steel plates has been greater than its cohesion.

Fig. 3. Three uncoated test plates exposed to a spray of snow until the snow broke off.

2.2 Tested Materials and Performed Tests

Several different kinds of coatings were tested during the experiments. These could be divided into four groups: cold ceramic, nano-based, silicon and PTFE-based coatings. Samples 1-4 were cold ceramics, 5-7 were nano-based, sample 8 was a silicone and 9-12 were PTFE-based coatings. The coatings were applied on 400 mm by 400 mm square steel plates. Some coatings were described by manufacturer as hydrophobic or icephobic.

A snow break-off test was performed in order to evaluate the consistency and repeatability of the test method as well as the overall performance of the test setup. This break-off test procedure is presented in Fig. 4. As a result, also the effectiveness of the coatings was investigated. The start and end procedures for this test were discussed previously. The break-off test consists of spraying the test plates individually until the snow breaks off under its own weight, either cohesively or from the snow-steel-interface depending on the performance of the coating. An uncoated steel plate was tested as a reference baseline. The test was run two to three times for each type of coating, which included thawing the plates and allowing them to cool down in between. The accumulation and other variables were measured throughout the test.

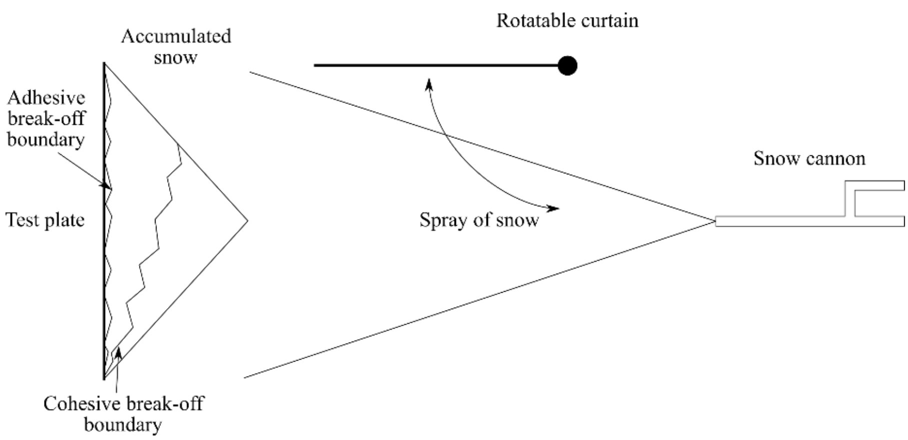

Fig. 4. Break-off test procedure. Snow cannon is used to spray until accumulated snow breaks off, either at an adhesive break-off boundary or at a cohesive break-off boundary. The mass of the accumulated snow is measured during the measurement.

3 Results

In Fig. 5 the average snow break-off masses for steel and 12 different coatings are presented. Break-off mass means the mass of snow that was required to either to drop the mass from the coated plate (adhesion break-off) or the mass of snow that was required for the breaking of the accumulated snow pile cohesively. The black dots show the individual break-off masses of the test runs. Differences between the samples can be seen from the result, that is, some of the coatings reduced the adhesion of snow to below that of steel. Some of the coatings also seemed to increase the adhesion of snow compared to steel.

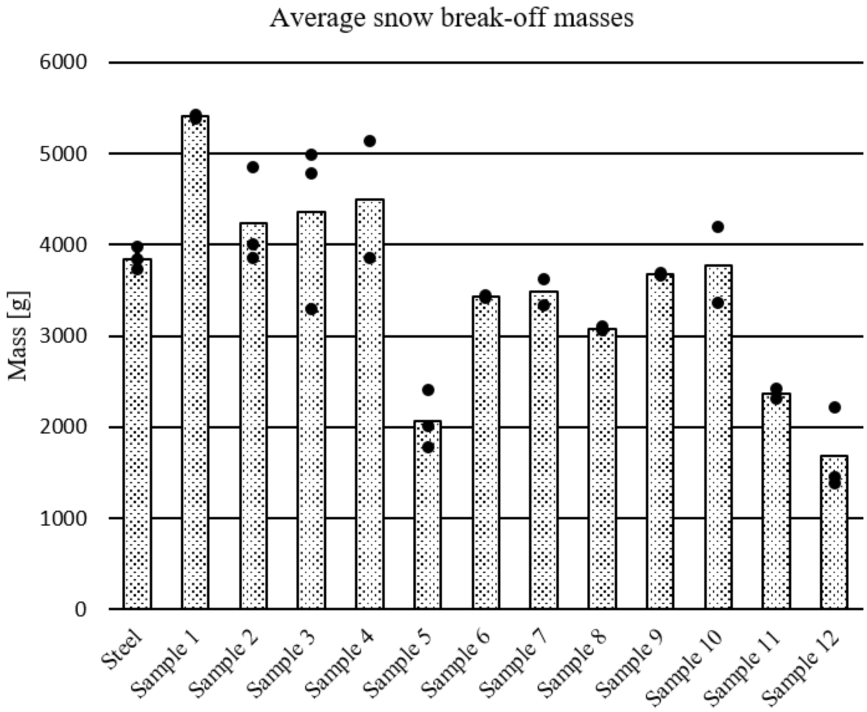

Fig. 5. Break-off masses of steel and 12 different sample coatings.

The margin of error for some of the samples was quite high. This is due to the low sample sizes. The sample sizes would need to be higher in order to accurately evaluate the repeatability of the tests and to rank all the samples in order of lowest to highest break-off mass. However, the tests performed proved for applicability of the method for straightforward evaluation of material coatings for their adhesion of snow. Based on the results rough estimations of the coatings could be done and a well-argued selection of materials could be chosen for a follow-up research.

4 Conclusion

Based on the findings, this snow cannon is a cost-effective, reasonably accurate and a repeatable way of exposing test objects to a spray of snow for estimating eg. snow adhesion. The snow produced by the cannon was consistent, and it was easy to spot the times when the snow cannon was operating differently than what was wanted. Due to the low sample sizes of the tests, the margin of error is quite high for some of the tested coatings and therefore further test are needed to confirm the actual accuracy of the test method. Nonetheless, the described testing method suited well for its purpose and could also be further developed for more sophisticated research of the matter for arctic technical applications.

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