EXAMINING DEPTH OF WATER JET CUT IN ICE BLOCKS THROUGH THE COMBINED EFFECTS OF OPERATIONAL PARAMETERS

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ABSTRACT

Ice accretion on surfaces during winter or in severely cold climates affects several industries, including aviation, hydropower, telecommunications, navigation, electrical distribution, and transportation. The traditional method of deicing maritime vessels is by human labour, and requires huge effort and long hours for unsatisfactory results. Current alternative deicing technologies may be too expensive or impossible to implement in a marine environment. Since water is easily accessible to maritime operations and heat energy can be diverted from the engine to heat the water, high-pressure water jet (HPWJ) is proving to be a useful deicing technology, which is the focus of our investigation. HPWJ is currently being used in high-level precision manufacturing in the automotive, aerospace, building products, electronics, food, paper and steel industries. HPWJ has relatively low efficiency under strong winds, especially when the standoff distance is long and can cause damage to equipment when operating parameters are not set appropriately.

The main objective of this study is to investigate the combined effects of operational parameters, including pressure, nozzle geometry, water jet temperature, and standoff distance, on the depth of cut (penetration) through an ice block. The significance of the main objective is to maximize the depth of cut to facilitate the delamination of ice accretion on surfaces.

Freshwater from a standard tap is routed to the pump, which pressurizes the water to the necessary pressure. For each experiment, the water temperature is adjusted via the handle of the tap and measured using a thermocouple coupled to the spray gun installed on the tripod. Before cutting begins for a set duration, the desired parameters are measured. The ice block sample in the mold is secured to a sturdy table to prevent movement. The spray gun's nozzle is preset to the desired distance. With each cut, the depth of cut is measured. The procedure is repeated for every set of the cases.

Preliminary data were acquired using a factorial design of experiments at different levels with five parameters, including the nozzle type, yielding biased results. New cases were developed and the measured responses were used to generate regression model equations for the four nozzle types. The models predicted depth of cut with a P-value less than 0.0001 and an F-value of 23.26 with 99% confidence, showing that the models are significant. Also, the predicted R² of 0.7473 is in reasonable agreement with the adjusted R² of 0.8166, i.e., the difference is less than 0.2. According to the findings, the nozzle geometry has the most significant impact on the maximum depth of cut, followed by the time of cut, pump pressure, water jet temperature, and standoff distance. Penetration depth increased with increase in temperature, pressure, distance, and time for the red nozzle with zero-degree dispersion angle. The 0° (red) nozzle also recorded the maximum penetration depth. The penetration depth of the other nozzle types increased with increasing temperature, pressure, and time. However, when the standoff distance increased, the penetration depth decreased. This phenomenon is caused by the atomization of the water jet caused by the dispersion angles. Water hammer pressure is reduced as standoff distance increases.

This study investigated the effectiveness of HPWJ deicing on maritime vessels. The optimization of operational parameters is used to develop a cuttability chart for various thicknesses of accumulated ice on the deck and different vessel surfaces. To the best of the authors’ knowledge, this is the first research on the combined effect of operating pump pressure, water jet temperature, and standoff distance of the different nozzle geometries (0°, 15°, 25°, and 40°) on the depth of cut in ice blocks.