Probabilistic Fracture Mechanics Applied to Compressive Ice Failure

Rocky S. Taylor
Centre for Arctic Resource Development
St. John’s, NL, Canada

Ian J. Jordaan
Centre for Arctic Resource Development, and
Faculty of Engineering and Applied Science, Memorial University
St. John’s, NL, Canada

ABSTRACT

During interactions between ice and engineered structures, ice is highly prone to brittle fracture for all but the slowest interaction rates. Under compressive loading conditions local fractures (spalls) near the interaction zone regularly propagate from either pre-existing or newly precipitated cracks that initiate from naturally occurring internal flaws in the ice. These spalling events result in the localization of contact into high-pressure zones through which the majority of the load is transmitted. During a continuous interaction, successive failure events contribute to random variations in the ice-edge geometry and contact conditions at the interaction interface. At the same time, localized microstructural modification to the ice in the highly damaged layer adjacent to the contact zone has considerable effect on the state of stress in the ice. For a given contact geometry and state of damage, the contact pressure required to trigger a fracture will depend on the size, location and orientation of flaws in the ice. Since in nature there will be random variability in the flaw structure and contact conditions, and the state of damage will depend on prior stress history, a probabilistic framework is believed to be most appropriate for modeling spalling fracture. In the present analysis a probabilistic fracture mechanics model has been used to illustrate the link between probabilistic aspects of fracture and the observed scale effect for compressive ice failure, whereby pressure is observed to decrease for increasing area. The influence of factors, such as variations in ice edge geometry associated with successive failure events, on the probability of local spalling fracture are also explored. From this work it is concluded that the mechanics of compressive ice failure are well explained through the competing yet complementary processes of brittle spalling fracture and pressure softening due to microstructural damage. Recommendations for future work are provided.

KEY WORDS: Compressive ice failure; offshore structures; local pressures; spalling fracture; high pressure zones; probabilistic fracture mechanics; scale effect.