Thermal fluid-structure interaction analysis of rubber friction on ice considering phase change

Hiroyuki Minaki*

* Bridgestone corporation
3-1-1, Ogawahigashi-cho, Kodaira-shi, Tokyo 187-8531, Japan
e-mail: hiroyuki.minaki@bridgestone.com, web page: https://www.bridgestone.com

ABSTRACT

In order to develop a tire that can run safely even on a frozen road surface, it is necessary to elucidate the friction phenomenon of rubber on ice. However, it is a quite complicated phenomenon due to the melting of ice. Researches using experiments and predictions have been made, but the phenomenon remains unclear. In this study, in order to elucidate the friction characteristics of rubber on ice, thermal fluid-structure interaction analysis considering phase change using particle-based simulation is developed.

Ice and water are modelled using Lagrangian particle-based method, and a phase change model is introduced to consider ice melting. However, it is difficult to simulate solid (ice) and fluid (water) stably with a single particle-based method. Therefore, ice is modelled by peridynamics [1], which is often used for crack analysis of solid. If the deformation of the ice road can be ignored, it is modelled by rigid particles to improve the computational efficiency. Water is modelled by the moving particle simulation (MPS) method [2], which is often used for fluid analysis. Thermal fluid-structure interaction is taken into account between ice particles and water particles, and ice particles that have reached the melting point are subsequently treated as water particles.

Since the particle method is difficult to change the spatial resolution by changing the particle density, the finite element method (FEM) is used for the rubber in order to calculate efficiently. Thermal fluid-structure interaction is taken into account between FEM and particle-based method, and friction and friction heat are introduced.

The surface of the winter tire has narrow grooves called sipes to drain water between the tire and the ice road efficiently. In this research, a rubber block with sipes is pressed against the ice surface and slipped, and the prediction of the relation between the number of sipes and the coefficient of friction is carried out. The developed method predicts that the contact area between the rubber block and the ice road surface decreases due to the ice melting, and that the coefficient of friction decreases due to low drainage performance when the number of sipes is small.

REFERENCES

[1] S.A. Silling, "Stability of peridynamic correspondence material models and their particle discretizations", *Comput. Methods Appl. Mech. Engrg.*, **322**, 42-47 (2017).

[2] S. Koshizuka and Y. Oka, "Moving-Particle Semi-Implicit methods for fragmentation of incompressible fluid", *Nucl. Sci. Eng.*, **123**, 421-434 (1996).

[3] T. Hisada and H. Noguchi, *Foundations and applications of nonlinear finite element method*, Maruzen, (1995) (in Japanese).