Development of Ecological High-Performance Tire by Modeling of Nano-Particle Network Structure in Rubber

Project Representative

Hiroyuki Kishimoto

SRI Research & Development Ltd.

Authors

Hiroyuki Kishimoto [*1], Masato Naito [*1], Hiroshi Yoshinaga [*1], Katsumi Hagita [*2], Arai Takashi [*2], Yuya Shinohara [*3], Yoshiyuki Amemiya [*3], Hiroya Suno [*4], Hitoshi Uehara [*4], Satoru Shingu [*4]

＊1 SRI Research & Development Ltd.

＊2 Department of Applied Physics, National Defense Academy

＊3 Graduate School of Frontier Science, The University of Tokyo

＊4 Japan Agency for Marine-Earth Science and Technology

Abstract

Rubber filled with nano-filler such as carbon black and silica shows the reinforcement effect. Though it is consider that the origin of reinforcement is relationship with the hierarchical structure of filler in rubber, the precise mechanism have been not well understood. In order to investigate the role of filler, we have performed the simultaneous measurements of time-resolved two-dimensional ultra-small-angle x-ray scattering (2D-USAXS) and tensile property at SPring-8, Japan. Also, in order to make the three-dimensional structure model of filler from the results of 2D-USAXS measurements, we developed the two-dimensional pattern Reverse Monte Carlo method (2Dp-RMC) with the help of powerful computational resources of the Earth Simulator Center. We succeeded in the visualization of structural changes of filler under stretch from 2D-USAXS images with 2Dp-RMC calculations. However, 2Dp-RMC cannot give the information about the behavior of rubber matrix. In order to investigate the behavior of matrix rubber in filled rubber under stretch, the large-scale nonlinear FEM code was developed at the Earth Simulator. This FEM code was made by the modification of FrontSTR code. The Aruuda-Boyce model and the viscous strain model were built in the constitutive equation of rubber. The three-dimensional structure of filler in rubber decided by 2Dp-RMC was used as the initial FEM model. The 100 million elements FEM model was divided the 128 blocks and massively parallel calculation was carried out.

Keywords: SPring-8, small angle x-ray scattering, Reverse Monte Carlo Analysis, Finite Element Method