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Modeling of truck tire curing process by an experimental and numerical method

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Abstract Due to the complexity of tire curing process and deficiency of the thermocouple method itself, an effective method which would combine thermocouple method with finite element method to determine the state-of-cure of the truck tire was proposed for the optimization of tire vulcanization. For this purpose, a finite element model was developed based on a new characterizing model for state-of-cure named "departure of torque", and the user subroutine UVARM was used to calculate the curing degree in tire curing process. To accurately simulate the actual temperature in curing process, a composite heat transfer model of belts in tire curing process was developed. Then, the temperature in the internal points of tire was measured to verify the accuracy of the method. The results indicated that there was very good agreement between the model predictions and actual data. The improved method was more accurate and effective than the finite element analysis method, where in the former the temperature deviation basically was not greater than 3 °C.

Keywords Rubber · Tire · Departure of torque · State of curing · Finite element modeling

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Introduction

Vulcanization is the final step in tire manufacturing whereby a green tire, constructed from layers of rubber compounds, by help of a press would produce fiber/rubber composites to the desired shape. Figure 1 shows the schematic diagram of tire curing process. In this process, heat is transferred to the green tire from the mold and bladder, which are kept at higher temperatures by hot water circulation. Then, tire part is removed from the mold, and cooled at room temperature. A typical example of curing condition is shown in Table 1 [1]. The curing process requires high energy consumption and its optimization not only helps to produce high-quality tires but also improves the processing cost. To optimize the vulcanization process for different compounds there is a requirement for the proper evaluation of the time-dependent temperature distribution of various compounds in the tires. The conventional method to determine the curing conditions is by thermocouple method [2], which directly measures the temperature–time profiles using thermocouples inserted into various parts of a green tire and then converts the measured profiles to the state-of-cure (SOC). However, this method is costly and very time-consuming. Consequently, tire industries are seeking alternative ways based on finite element modeling of the process to predict the temperature and SOC distributions.

Several studies on the finite element simulation of curing process have been carried out. Ambelang and Prentice [3] calculated the SOC in tire curing process by a finite difference technique, in which, thermal diffusivity and rate of heat generation were assumed to be constant. Then, the model was somewhat extended by Prentice and Williams [4] by considering the thermal conductivity and chemical-generated heat production as a function of temperature and the SOC.