Abstract

The tire industry's adoption of silica fillers, driven by the quest for fuel-saving tires with low rolling resistance, contrasts with carbon black-filled compounds. Silica mixing, which consumes more energy, involves reactive processes influenced by internal mixer parameters. The need for fuel-efficient green tires is crucial in this generation as we are moving towards a green environment. This thesis investigates the impact of mixing parameters on energy consumption and silanization efficiency. Employing the Taguchi method, we identify critical factors such as silanization temperature, time, fill factor, and chamber-rotor temperature using a contribution plot. Further, the significantly affecting mixing parameters were optimized to have better silanization with optimum energy consumption using design of experiment (DOE) like Taguchi and response surface methodology. The optimized compounds exhibit superior properties compared to the control, with improved filler dispersion confirmed via scanning electron microscopy. To enhance silanization, we explored the incorporation of hydrolyzed silane molecules via the addition of demineralized water (DMW) to silane and sprayed it on the silica surfaces as a carrier before mixing, incorporating it into passenger car radial tire tread compounds. Increased DMW content lowers heat generation during mixing, reduces dump temperature, and enhances wet grip properties and rolling resistance properties while retaining abrasion resistance due to the improved filler dispersion. The reaction kinetics related to water addition and the pH of water using HPLC analysis were also discussed. Further, the possible silanization catalysts like ionic liquid and amines were also explored and reported. Thus, this thesis takes one step closer to paving a new path towards development in the field of silica-silane technology in tire application by enhancing the performance of tire compounds, rolling resistance, and cutting down energy consumption, which also contributes to the green environment.

Keywords: Silanization, Silica, Tire, Design of the experiment, Catalyzed silanization, Energy efficiency, Ionic liquid, Processing, Optimization.