Petroleum-based Safe Process Oils: From Solubility Aspects to Practical Use in Carbon Black-Reinforced Rubber Compounds

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Abstract

Safe rubber process oils containing low Polycyclic Aromatic Hydrocarbons (PAHs) are in need for replacement of toxic distillate aromatic extract (DAE). Potential and commercially available petroleum-based safe process oils are: Treated Distillate Aromatic Extract (TDAE), Mildly Extracted Solvate (MES) and Naphthenics (NAP). This work investigates the petroleum-based TDAE and MES safe process oils for replacement of DAE. The characteristics of DAE-, TDAE- and MES oils, and solubility in unfilled NR, SBR and 50/50 NR/SBR blends are analyzed. The solubility parameters (δ) are calculated based on the group contribution method, and the difference of δ values between oils and rubbers are correlated with the mass swelling of lightly crosslinked NR and SBR at different temperatures. At high temperature in the range of mixing temperature, MES oil shows less compatibility compared to TDAE and DAE, respectively. The replacement of DAE with TDAE and MES oils in unfilled NR, SBR and 50/50 NR/SBR had only minor effects on Mooney viscosity and mechanical properties of all the compound types. When considering the overall changes in properties, NR is most sensitive to a change of oil types. For carbon black filled NR and NR/SBR blend compounds, typically applied in tires, the properties are strongly affected by oil contents, but less by the oil types. The compounds with DAE oil have a lower Mooney viscosity but higher complex viscosity as well as higher Payne effect when compared to the mixes with TDAE- and MES-oils. The replacement of DAE- with TDAE- and MES-oils in NR compounds has only small effects on the vulcanization characteristics and mechanical properties, but clearly influences the properties which are related to changes of the glass transition temperature (T_g) and viscoelastic behavior. The lowest T_g of MES leads to the best elastic response in the NR vulcanizates, but TDAE gives the best overall elastic response for the NR/SBR blend vulcanizates.

Keywords: natural rubber; styrene-butadiene rubber; process oils; TDAE; MES