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Lightweight Sheet Molding Compound Composites by Coating Glass Fiber with Cellulose Nanocrystals

Authors : Amir Asadi, Karim Habib, Robert J. Moon, Kyriaki Kalaitzidou

Abstract : There has been considerable interest in cellulose nanomaterials (CN) as polymer and polymer composites reinforcement due to their high specific modulus and strength, low density and toxicity, and accessible hydroxyl side groups that can be readily chemically modified. The focus of this study is making lightweight composites for better fuel efficiency and lower CO2 emission in auto industries with no compromise on mechanical performance using a scalable technique that can be easily integrated in sheet molding compound (SMC) manufacturing lines. Light weighting will be achieved by replacing part of the heavier components, i.e. glass fibers (GF), with a small amount of cellulose nanocrystals (CNC) in short GF/epoxy composites made using SMC. CNC will be introduced as coating of the GF rovings prior to their use in the SMC line. The employed coating method is similar to the fiber sizing technique commonly used and thus it can be easily scaled and integrated to industrial SMC lines. This will be an alternative route to the most techniques that involve dispersing CN in polymer matrix, in which the nanomaterials agglomeration limits the capability for scaling up in an industrial production. We have demonstrated that incorporating CNC as a coating on GF surface by immersing the GF in CNC aqueous suspensions, a simple and scalable technique, increases the interfacial shear strength (IFSS) by ~69% compared to the composites produced by uncoated GF, suggesting an enhancement of stress transfer across the GF/matrix interface. As a result of IFSS enhancement, incorporation of 0.17 wt% CNC in the composite results in increases of ~10% in both elastic modulus and tensile strength, and 40 % and 43 % in flexural modulus and strength respectively. We have also determined that dispersing 1.4 and 2 wt% CNC in the epoxy matrix of short GF/epoxy SMC composites by sonication allows removing 10 wt% GF with no penalty on tensile and flexural properties leading to 7.5% lighter composites. Although sonication is a scalable technique, it is not quite as simple and inexpensive as coating the GF by passing through an aqueous suspension of CNC. In this study, the above findings are integrated to 1) investigate the effect of CNC content on mechanical properties by passing the GF rovings through CNC aqueous suspension with various concentrations (0-5%) and 2) determine the optimum ratio of the added CNC to the removed GF to achieve the maximum possible weight reduction with no cost on mechanical performance of the SMC composites. The results of this study are of industrial relevance, providing a path toward producing high volume lightweight and mechanically enhanced SMC composites using cellulose nanomaterials.

Keywords : cellulose nanocrystals, light weight polymer-matrix composites, mechanical properties, sheet molding compound (SMC)
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