Development of Bio-based Phenol Formaldehyde Novolac Resins Using Mountain Pine Beetle Infested Lodgepole Pine Barks

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Abstract

Phenol formaldehyde (PF) resins have increasing market demands and commercial market values with a projected global volume market value of 16 million tons in 2016. The novolac PF resins, formulated with formaldehyde to phenol ratio of less than one, have been extensively used as molding compounds, wood adhesives, frictional materials, and thermal insulation materials due to their outstanding mechanical properties, bonding performance, water and heat resistance and durability. With the rising concerns associated with the use of petroleum-based phenol in the commercial PF resin production due to the fossil fuel depletion and regarding environmental impacts, there is a strong interest in searching environmental friendly, sustainable and renewable resources as alternative feedstock to replace the petroleum-based phenol. Bark, with rich reactive phenolic compounds, becomes the potential substitute to partially replace the petroleum-based phenol in the phenolic resin production.
In this study, mountain pine beetle (MPB; *Dendroctonus ponderosae*) infested lodgepole pine (*Pinus contorta*) barks were converted to phenol substitutes under the acid-catalyzed bark phenol liquefaction using sulfuric acid and hydrochloric acid. Two types of bio-based phenol formaldehyde novolac resins, namely sulfuric acid-catalyzed liquefied bark novolac PF resin and hydrochloric acid-catalyzed liquefied bark novolac PF resin, were synthesized and characterized. The applications of these synthesized bio-based novolac PF resins in preparing thermal molding composites were also investigated.

It was found that both sulfuric acid and hydrochloric acid catalysts were effective in the bark-phenol liquefaction for obtaining the adequate phenol substitutes from mountain pine beetle (MPB) infested lodgepole pine bark with maximum yield of 88.1% and 69.8% respectively. The synthesized bio-based novolac PF resins have higher molecular weight, more complex resin structures and comparable resin characteristics, curing performance and thermal stability to the reference lab-made control novolac PF resins, which do not contain liquefied bark components. The HCl acid-catalyzed liquefied bark novolac PF resins were successfully molded into composites with comparable mechanical properties, thermal stability, bonding performance, and enhanced water resistance in comparison to the lab-made control novolac PF resin.

This thesis study revealed the great potential of the bio-based phenol formaldehyde (PF) novolac resins containing acid-catalyzed liquefied bark components as an environmentally friendly, renewable and sustainable alternative to the commercial petroleum-based PF resins. This research also proposed an innovating application of incorporating largely available MPB infested lodgepole pine bark waste into the novolac PF resins formulation and explored the possibility of using this novel bio-based novolac resin as molding materials in the industrial application of thermal molding composites.