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Resole-Type Phenol–Formaldehyde Resin with Neutralized Liquid Products of Fast Pyrolysis of Birch Wood

S. A. Zabelkin[a, b, *], A. N. Grachev[a, b], G. M. Bikbulatova[a], A. E. Yakovleva[a], A. A. Makarov[a, b], and V. N. Bashkirov[a]

[a] *Kazan National Research Technological University, Kazan, 420015 Russia*
[b] *Kazan (Volga Region) Federal University, Kazan, 420008 Russia*
**e-mail: chimdrev@kstu.ru*

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Abstract—A method of preparation of a phenol–formaldehyde resin by replacing phenol with liquid products of the fast pyrolysis of wood is described. Strength tests reveal that substituting a pyrolysis liquid for 60% of phenol in the phenol–formaldehyde resin allows strength to be increased by 6% relative to the control sample.

Keywords: phenol–formaldehyde resin, pyrolysis, pyrolysis liquid, resole resin

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Phenol–formaldehyde resins (PFRs) are extensively applied in the fabrication of composites of wood, paper, cardboard, glass, and other materials. Nevertheless, the replacement of phenol with renewable raw materials has become a relevant task owing to depletion of reserves and the continuously rising cost of fossil resources [1–3]. Raw materials can take the form of liquid products obtained by fast pyrolysis of biomass, such as wood and its waste. Fast pyrolysis is thermal decomposition of organic compounds at 450–550°C in conditions of a lack of oxidant at a high heating rate and short-term (less than 2 s) finding of products in the reaction zone. The primary products of the plant biomass fast pyrolysis are pyrolysis liquid (PL) and uncondensed gases and coal. PL contains more than 350 chemical components that can be extracted various transformations [4, 5]. Other components of PL are substituted phenols and lignin oligomers, which are potential candidates for manufacturing phenol–formaldehyde resins in spite of their low functionality [6].

Resole phenol–formaldehyde resins are products of condensation of phenols or their homologues (cresols, xylenols) with formaldehyde in an alkaline medium. Resole resins are widely used in woodworking in the manufacture of waterproof board materials and plywood.

PLs can be utilized variously as a substitute for phenol in the production of phenol resins [7]. Some results on the use of total PL are reported in [8–11]. The applications of different PL fractions have been studied as well. There is also the possibility of improving pyrolysis itself in order to obtain PLs with properties more suitable for producing resins.

A synthesis of resole PFR based on fast pyrolysis liquid products seems to be attractive in both economic and ecological aspects. However, apart from phenols and furans, PLs include neutral substances, carbonic acids, and derivatives of hydrocarbons that may deteriorate the operational characteristics of final product. Carbonic acids interact with alkaline compounds with the formation of water-soluble salts. These reactions can augment the consumption of alkaline catalysts, and the formed salts are able to decrease the properties of resins. Furthermore, according to numerous studies [12–15], the functionality of replaced phenols and oligomers is inferior to that of artificial phenols.

Thereby, using PL fractions with a lower amount of these substances and inspecting the properties of resole PFR has been of great interest.

SAMPLES AND CHARACTERIZATION METHODS

Fast pyrolysis liquid products were obtained on a UBP-50 unit [16, 17] from shredded birch wood at temperatures of 450–550°C. The properties of liquid products met the requirements of ASTM D 7544 standards.

To extract a PL fraction with the highest phenol content, acidic PL compounds were neutralized