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Research article

Development of natural rubber foam with water as a blowing agent *via* microwave and convection heating methods

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Abstract. This study used water as the physical blowing agent as well as microwave heating (MH) and convection heating (CH) to simultaneously foam and cure natural rubber foam (NRF). Various processing methods and parameters, such as single heating and sequential heating using a mix of CH and MH; were investigated. The correlation between these processing methods as well as different water loadings was then evaluated and compared in terms of physical appearance, density, and morphology. The NRF samples produced using sequential MH and CH (SMC) heating exhibited better shape and structure than samples produced using single heating of either CH or MH only as well as sequential CH and MH (SCM) heating at all water loadings. NRF samples with water loadings of 1.5 and 2.0 phr had a density of less than 0.1 g/cm^3. The potential heating mechanism of all the heating methods explored in this study was proposed and discussed to further understand the microwave heating process. The findings of this study proved that water could be utilized as a physical blowing agent in the production of NRF products with microwave-assisted foaming.

Keywords: *rubber microwave, water, blowing agent, rubber, natural rubber foam*

1. Introduction

Rubber foam, or cellular foam, contains voids surrounded by a continuous phase of rubber. As such, it is lightweight and possesses comparable mechanical properties. This makes it a popular choice in many fields and applicable for use as a thermal, electrical, and acoustic insulator as well as packaging, flooring, and upholstery foam [1, 2]. The manufacturing technology as well as the type of blowing agent used during rubber foam production, are important as they affect the structure and properties of the final foam [3–5]. Two-stage heat transfer, a relatively lengthy process, is typically used to manufacture rubber foam from dry rubber. However, microwave processing technology has been successfully applied in various industries, such as the chemical, rubber production, food processing, and vacuum drying industries [6, 7]. Of the many advantages of microwave heating, rapid and uniform heating provide opportunities to produce new materials [3, 6, 8, 9]. As such, the use of microwave heating for material foaming has gained popularity among researchers as a viable heating method. Furthermore, microwave-assisted foaming is an inexpensive and quick method of producing cellulose-based foams with an open-cell structure [7]. Prociak *et al*. [9] evaluated the efficacy of using microwave irradiation to heat and foam thermoplastic polyurethane (TPU) with carbon black as a filler. Their results indicated that microwave irradiation could be utilized to prepare TPU foam composites in-situ using a chemical blowing agent. However, the heating efficacy of microwave

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