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A preliminary evaluation of bio-based epoxy resin hardeners for maritime application

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Abstract

A screening of different hardeners derived from cashew nut shell liquid (CNSL) was performed; they were compared to a conventional hardener in an epoxy resin system for composite production by infusion process. All samples were submitted to different post-curing processes before tensile strength and moisture uptake were evaluated. It was observed that the use of CNSL hardeners produced cured epoxies similar in Young's Modulus (YM) to the conventional hardener with a lower moisture uptake however, the hardeners resulting in a low YM had a marked reduction in moisture uptake. Studies of the post-curing process showed that the moisture uptake of the conventional system can be improved but, depending on the temperature applied, the process can be detrimental to the CNSL hardeners, provided that moisture uptake was increased after post-curing. The results indicate that biobased content can be introduced to a conventional epoxy resin system by replacing the conventional hardener commonly used by a sustainable one derived from cashew nut shell liquid with an additional moisture uptake reduction.

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Keywords: epoxy resin; phenalkamine; phenalkamide; cashew nut shell liquid

1. Introduction

The most used and economical end-of-life methods for disposing composite materials are still incineration and landfill deposition. Still these methods can cause great impact to the environment, mainly incineration for the toxic by-products that can be generated [1]. In this context, phenalkamines and phenalkamides feature a series of benefits that make themselves interesting as sustainable hardeners applied in the epoxy resin suitable for infusion process,

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highly used in boat production. They are obtained from cardanol, shown in Fig. 1, a component present in the cashew nut shell, which is treated as a by-product in the industry [2–4]. These CNSL hardeners can bring a set of good properties to the resins where they are applied, such as chemical resistance, adhesiveness, water resistance and low temperature curing [5].

In a phenalkamine structure, there is an aromatic ring present, responsible for chemical and fire resistance, a long aliphatic chain, capable of bringing a hydrophobic character to the resin and increase the water resistance. Further, a phenolic hydroxyl, which increases the reactivity at low temperatures and consequently facilitates curing, and finally a chain with amines, which brings high mechanical properties to the resin by improving the crosslinking density [5–7].

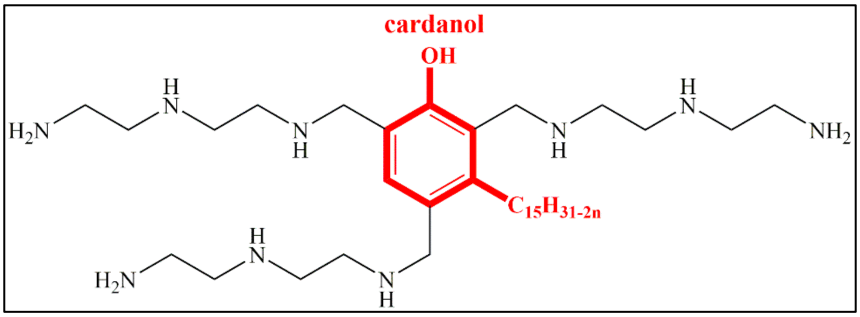

Fig. 1. Phenalkamine molecule.

Nomenclature

CNSL	Cashew Nut Shell Liquid
YM	Young's Modulus

Dai *et al*. studied the temperature sensitivity in the curing of a conventional epoxidic coating system cured by commercial phenalkamines, whose production is described by Sato *et al.* [8]. The synthesis consists on the reaction of cardanol, diethylenetriamine (DETA) and formaldehyde. It was found that the degree of curing at given temperatures was different due to their different compositions, but the pattern was the same. Further, the moisture uptake of the systems were compared to systems cured with conventional curing agents in salty water, at 25ºC and 65ºC for three weeks. The systems containing phanelkamines absorbed at least 50% less water than the system with polyamide and around 35% less than systems containing cycloaliphatic and Mannich bases curing agents [7]. Cheng *et al*. also described the synthesis procedure of another phenalkamine containing more aromatic rings, it was used 1,3-bis(aminomethyl)cyclohexane [9].

Kathalewar and Sabnis studied the synthesis of high molecular weight phenalkamine hardeners. The degree of crosslinking was determined by dynamic thermo-mechanical analysis, the phenalkamine synthesized with a higher ratio of formaldehyde and amine exhibited the highest crosslinking density. The resistance to water, acid (HCl 5%) and alkali (NaOH 5%) was tested, none of the samples showed any delamination, loss of gloss, or blistering effect [4].

Tambe *et al*. compared phenalkamines and phenalkamides with conventional curing agents with varied curing temperatures and relative humidity (RH). The curing temperature altered the properties of the cured material however RH did not. When cured at 30ºC, the phenalkamine presented the lowest moisture uptake ($\approx$5%) whereas the phenalkamide ($\approx$6,3%) performed amongst the conventional curing agents (7% $\pm$1) [10].