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Effect of TETA microcapsules on self-healing ability of dual component epoxy system

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ABSTRACT

To deliver epoxy composites with enhanced self-healing ability, this study investigates healing efficiency of dual component epoxy system consisting of microcapsules containing epoxy (DGEBA) and different variants of hardener (TETA) microcapsules. Morphological investigation under FESEM confirms formation of spherical shaped intact TETA microcapsules at high agitation speed with average size of the ~65.32 µm and reduced wall thickness of ~1.823 µm. Reaction temperature is found to play significant role to tune the roughness of the microcapsule surfaces. The single edge notched bending (SENB) test was performed to evaluate the healing ability. It was found that with incorporation of microcapsules, the fracture toughness decreases but the healing efficiency increases with increase in content of microcapsules. The maximum healing efficiency observed was 65.61%. High concentration of TETA microcapsule (prepared at high agitation speed) in epoxy network gives the essence for their applicability as a potential ingredient to elevate the healing efficiency. To enhance the healing ability further of the composites as well as fibre reinforced composites with unaltered mechanical properties we believe synthesis nanocapsules and their incorporation could have significant impact. Copyright © 2016 VBRI Press.

Keywords: Smart polymers; self-healing composites; solvent evaporation technique; microcapsule; single edge notched bending test.

Introduction

Epoxy-based thermosets are used as structural composites in numerous application including aerospace, automotive, energy, etc [**1**]. These components are usually subject to fatigue loading in day-to-day use and eventually fail under stress [**2**]. Failure usually starts in the form of a micro/nano crack located deep within the structural component. However, it is practically very difficult to identify such cracks and almost impossible to fix them. Self-healing materials could be a possible solution to enhance the life-time of such materials. The motivation for synthesizing self-healing materials has been derived from biological organisms, where the damage event itself triggers the healing mechanism autonomously without any external intervention. Apparently there have been many attempts to design and develop smart materials with the ability to autonomously repair internal and external damage. [**3-9**].

Our research is primarily focused on developing self-healing materials that have a plurality of embedded microcapsules containing liquid healing agent. During the propagation of a crack, the microcapsules get ruptured and the healing agent flows into the crack plane by capillary action and then polymerizes. This mechanism ensures that the crack has been bridged completely and as a result inhibits its further propagation. At the heart of this technology are the microcapsules containing liquid healing agent and it is of paramount importance to improve their yield and quality in order to improve the self-healing efficiency of the system. Recent works carried out in both academia as well as industries highlights the healing of small crack using reinforced capsules containing single healing agent and catalyst in polymeric matrix [**9-13**]. Joseph *et al.* demonstrates encapsulation of diclyclopentadiene (DCPD) and embedding in polymeric matrix to find the healing behavior [**14**]. The processing sensitiveness to prepare uniform sized DCPD microcapsules hinders their application as self-healing agent. In other works, use of different core materials such as 5-ethylidene-2-norbornene (ENB) [**15**], dibutylphthalate-(DBP-) filled urea-formaldehyde (UF) [**16**] DCPD/ENB blend [**17**], styrene [**18**], polydimethylsiloxane [**19**], and epoxy [**20-22**] is also investigated. These capsules get ruptured as the crack intervenes and releases the healing agent into the crack plane through capillary action and polymerizes in presence of catalyst, thus heals the crack. These reports postulate efficient healing of composites provided, the capsules and the catalyst are in close proximity to each other and uniformly dispersed in the matrix. To overcome such limitations, use of dual microcapsules has been suggested by many [**21-23**]. However, there are very few literatures on dual encapsulation of amine hardener and epoxy resin [**24-26**]. In general, one part of the microcapsules contains epoxy resin and other contains curing agent. When both the microcapsules are fractured, the individual healing agents mingle and get cured according to their epoxy-hardener curing stoichiometry and thus healing occurs. The highly active nature of the amine-based hardeners limits their encapsulation in water or organic solvents. In situ emulsion polymerization [**5-13**, **28**, **29**] technique has been employed in some cases but the difficulty in controlling pH-value and