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REVIEW OF SELF- HEALING MATERIAL

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INTRODUCTION

Composites have been widely used in tremendous engineering fields because of their advantages including light weight, process transformation and chemical stability in any atmospheric conditions. Due to long durability and reliability of polymeric material it still problematic when they serve for structural application. Comparatively, micro cracking is one of the fatal deteriorations generated in service, which bring about catastrophic failure of the material and hence significantly shorten lifetimes of the structures. Since the damage is deep inside material which is difficult to be perceived and to repair in particular, the materials had better to have self-healing ability. While the development of self-healing materials is progressing at a rapid rate, most successful examples of self-healings are heavily reliant on polymers from petroleum precursors. Hence, in this work, we undertake the first concerted effort to develop self- healing polymers and composites. Lightweight, high strength, high stiffness fiber reinforced polymer composites are leading contenders as component materials to improve the efficiency and sustainability of many forms of transport [2].

1.1 NEED OF SELF REPAIRING MATERIALS:

1. Built in capability to substantially recover their load transferring ability after damage.
2. Contribute greatly to the safety and durability of polymeric components.
3. Capable of continuously sensing and responding to damage over the lifetime.
4. Restoring the material performance.
5. Recovery of properties such as fracture toughness and tensile strength.

1.2 SELF-HEALING/REPAIRING COMPOSITES:

Key to the development of self-healing composite materials is identifying a healing monomer/catalyst combination with the requisite feature to be compatible with the healing mechanism, designing an adequate encapsulation technique to contain the liquid monomer. For example, the liquid monomer must have a long life. It must have a low enough viscosity to flow out of broken microcapsules onto the crack surface, but must not exit the crack volume, for example, volatilization and/or diffusion into the composite matrix and the particles of liquid monomer contacts the catalyst particles and instantly form an adhesive polymer with good adhesion. We begin by describing the three primary self-healing conceptual approaches (capsule based, vascular, and intrinsic), its demonstration in a variety of polymer systems as well as critical issues and challenges associated with each work. Review the literature on the basis of self-healing of actual testing limitations, including resistance to fracture (quasi-static, fatigue, impact) recovery of barrier properties and corrosion protection [2].

LITERATURE REVIEW

2.1 HISTORY

Healing /Repairing material only emerged as a widely recognized field of study in 21st century. The first international conference on self-healing materials is related to bio-mimetic materials (material inspired by living nature) as well as to other materials such as the self-lubricating and self–cleaning materials. The similar applications have been known for centuries, such as self-repair of cracks in concrete studied microscopically since the 19th century.

2.2 REVIEW:

R S Trask et al. [2009] showed the self-healing technologies currently being developed for fibre reinforced polymeric composite materials and most of which are inspired by observation of nature. The most recent self-healing work has attempted to mimic natural healing using more detailed study of natural processes.

Self-healing reinforcement extend the concept of self-healing beyond the repair of matrix dominated failure modes [4].

B.J. Blaiszik et al. [2010] studied three approaches: capsule-based healing systems, vascular healing systems and intrinsic healing polymers. Self-healing can be without human intervention or may require some external energy or pressure. Thus, they concluded that current self-healing polymer composites offer a new route toward safer, longer-lasting, fault-tolerant products and components across industries [1].

Y. Yuan1 [2008] objective was to increase the life of composite materials by healing which often get shorten due to micro cracking. Studied intrinsic self-healing ones that are able to heal cracks by the polymers themselves, and extrinsic in which healing agent has to be pre-embedded and summarized early sensing, diagnosis and repair of micro cracks become necessary for removing the latent perils in case of micro-cracking of materials [5].

Kessler1 [2009] observed bio renewable composites with self-healing functionality and showed development of self-healing composites identifying a healing monomer/catalyst combination with the requisite features to be compatible with the healing mechanism, also designing an adequate encapsulation technique to contain the liquid monomer catalyst [7].

Swapan Kumar [2008] found that many common terms such as self-repairing and autonomic-healing are used to define a property in materials. Thus they concluded that self-healing can be representing by two processes autonomic (without any intervention); non autonomic (needs human intervention/external triggering [2].

Regina Frei [2013] studied various **technologies of** self-repairing, including work in software engineering, materials, mechanics, electronics, MEMS, self-reconfigurable robotics, and others. It suggests a terminology and taxonomy for self-healing as well as self-repairs, and discusses the various related types of other self-properties [8].

PROCESS AND DESIGN STRATEGIES OF COMPOSITE MATERIALS

The different types of materials such as plastics/polymers, paints/coatings, metals/ alloys, concrete and composites have their own self-healing mechanisms.

The different strategies of designing self-healing materials are as follows:

1. Release of healing agent
2. Reversible cross-links
3. Miscellaneous technologies

- Shape memory effect
- Nanoparticle migration

3.1. RELEASE OF HEALING AGENTS

In case of a crack, these reservoirs are ruptured and reactive agents are poured into the cracks by capillary force where it solidifies in the presence of pre dispersed catalysts and used to heal the crack. The propagation of cracks is the major driving force of this process. On the other hand, it requires the stress from the crack to be relieved, which is a major drawback of this process. The following sections give an overview of different possibilities to explore this concept of designing self-healing materials [2].

3.1.1 MICROCAPSULE EMBEDMENT

Microencapsulation a process of inserting a small micron particles of solids, liquids, as well as gases in an inert shell, which in turn isolates and protects them from the external environments. The end product of the microencapsulation process is termed as *microcapsules*. The self-healing strategy used by them is shown in Figure 3.1.

3.1.2 HOLLOW FIBER EMBEDMENT:

Microcapsule-based self-healing has the limitation of non-similar to get complete or no. of healing as it has limited amount of healing agent and it is not known when the healing agent will be consumed entirely.

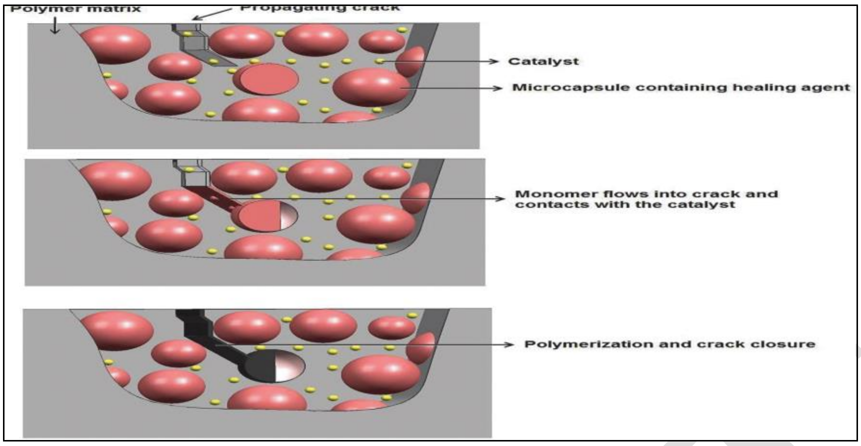

Fig 3.1: embedded microcapsules.

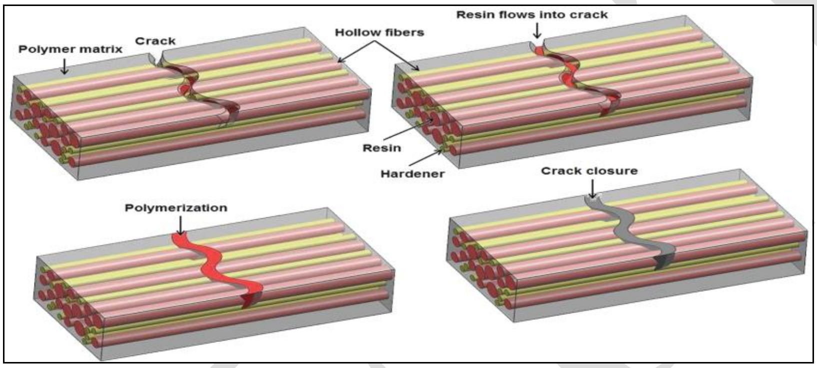

Fig 3.2: hollow fiber

3.2 REVERSIBLE CROSS-LINKS-REVERSIBLE CROSS-LINKED

System does not show self-repairing ability by its own. Thus, these systems show non autonomic healing phenomenon.

CASE STUDY ON SELF-HEALING COMPOSITES: SOLVENT-EPOXY FILLED HOLLOW GLASS FIBER

4.1 INTRODUCTION

Functional repair components placed in internal hollow glass fibers are assumed for self-healing systems for advanced composite structures. This study describes the strength of compression of composite laminates combined with epoxy resin-filled HGFs, which provided self-healing. The healing efficiency was found to be 74-89% after 11 days. This work has provided evidence, the HGFs lay-up investigated, a significant fraction of lost strength is regenerated due to self-healing and suggesting that self-repair is possible advanced composite structures.

4.2 METHODOLOGY:

4.2.1 REAGENT GRADE ORGANIC SOLVENTS:

Not all solvents are suitable as healing agents. Solvents with dielectric constants, ranging from 5-60 are universal. Improving self-repair results with the use of aprotic polar solvent-filled microcapsules embedded in thermo-set composites [3].

4.2.2 EPOXY/HARDENER SYSTEM:

Epoxy is widely used as polymer composites diverse industry/engineering purposes. Fiber-reinforced epoxy thermo sets use two-part components that create a glassy polymer network with a high material strength and stiffness when cured. The function of the matrix is to secure the reinforcement and to facilitate load-transfer to the fibers [3].

4.2.3 CAPSULE-EMBEDDED SPECIMENS:
These components are the result of ongoing work at CERL-ERDC composite lab to evaluate the self-healing recovery performance of used work pieces combined with microcapsules. Capsules were sprinkled on each of the E-glass fiber sheets (11 and 16 wt %) before adding the composite laminates [3].

4.2.4FILLING HGFS WITH HEALING AGENTS:
The HGF diameter, wall thickness and fiber hollowness are important tool in the healing process [3].

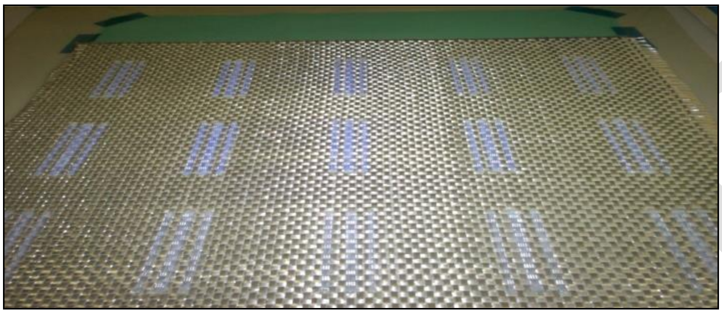

Fig 4.1: Solvent-epoxy filled (with a fluorescent dye) HGFs glued on E-glass fiber sheets before infusion of the resin and hardener mixture.

4.3 CONCLUSION
It observed that HGFs containing solvent-epoxy mixtures as self-repair agents added into composite laminates, a significant fraction of lost strength is regenerated due to self-healing.

ADVANTAGES
1. Excellent strength to weight and stiffness-to-weight ratios can be achieved by composite materials.
2. Laminate patterns and ply buildup in a part can be tailored to give the required mechanical properties.
3. Easier to achieve smooth aerodynamic profiles for drag reduction.
4. Part count is reduced.
5. Composites offer excellent resistance to corrosion, chemical attack, and outdoor weathering.

DISADVANTAGES
1. Composites are more brittle than wrought metals and thus are more easily damaged.
2. Repair introduces new problems, for the following reasons: Materials transport and storage have limited shelf lives.

APPLICATIONS
1. Self-healing aircraft.
2. Self-healing paint can also be used for bearing surface coatings.
3. Self-repairing technology are car tires invented around 1934.
4. Self-healing clear coat for car surfaces.
5. Biocompatible self-healing composite.

CONCLUSIONS
[1] Core damage successfully restored to the undamaged strength using vascular self-healing system which releases liquid healing agent into the damage zone created by an impact event.
[2] Hollow-fiber and micro-encapsulation have greater potential to provide healing abilities over extended time frames.
[3] A biomimetic approach has been used to develop an effective way to recover mechanical strength and highlight concealed damage after impact damage.

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