Finite Element Analysis of Self-Healing Composite Polymer Structures For Fracture Toughness

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Abstract-This research paper aims to develop Self-Healing Composite Polymer Structures and testing them for fracture toughness. The focus of different fields of science and engineering to develop self-sealing composite Polymer Structures. They are inspired by biological system such as the human skin which are naturally able to help themselves. Sometimes injury takes place due to excessive loading capacities which will shorten the life of material, to increase the reliability and the material life and reduce the cost of repairing material the self- healing capacity of material plays very important role. Here we used the structural polymeric material with ability to automatically heal the crack. The material consist of microencapsulated healing agent that is released upon the crack intrusion. The polymerization of the healing agent is then triggered by contact with embedded catalyst which heals the crack faces.

***Keywords* —Self-Healing, polymer, microcapsule, composite.**

I. Introduction

A self-healing material [01] is a material that has the ability to recover its strength, stiffness and fracture toughness after a crack has occurred and has been subsequently healed completely. The models are then utilized to carry out the numerical analysis of crack in self-healing composites. Efforts to develop property predictions of self-healing materials is currently the requirement in development of self-healing composites. Finally work would resulting in the development of Self-healing materials inspired by biological processes as skin wounds or muscle tears that heal by themselves.

II. Literature Review

The following research papers were referred before starting with the project.

1) Peng Li, Yuan Liu

In the using of structural materials, kinds of injury which is sometimes difficult to repair or too costly to repair may appear in the surface and interior, which will shorten the life of the materials. Self-healing technology can be used to improve material reliability and extend the service life, so composite materials with self-healing capability become an important research content of smart materials.

2) E.N. Brown, N. R. Sottos1 and S.R. White

Inspired by biological systems in which damage triggers an autonomic healing response, we have developed a polymer composite material that can heal itself when cracked. The self-healing material under investigation is an epoxy matrix composite, which incorporates a microencapsulated healing agent that is released upon crack intrusion. Once healed, the self-healing polymer recovers as much as 90% of its virgin fracture toughness.

3) Yongjing Wang, Duc Truong Pham and Chunqian Ji

Self-healing composites with a focus on capsule-based and vascular healing systems. Healing mechanisms, healing performance and fabrication techniques for producing capsules and building vascular networks have been summarized and analyzed. Capsule based self-healing materials are able to heal small cracks, while vascular systems are more suitable for healing larger damaged areas.

4) Jay A. Syrett, C. Remzi Becer and David M. Haddleton

It is a challenge for polymer and materials chemists to develop smart materials which can undergo different responses upon and external stimulation. Several

Concepts have been developed to provide the self-healing property to the material, such as microcapsule based systems, microvascular systems and Nano reservoirs. There is an increasing interest on reversible systems which can break and heal repeatedly upon external stimuli.

5) R. P. Wool and K. M. O'Connor

Recent results indicate that while crack healing is an interesting concept in itself, it provides a new insight into understanding fundamental concepts of the strength of materials. In this paper, we provide a microscopic theory for healing in polymers in which mechanical properties, e. g., stress, strain, modulus, and impact energy, are related to time, temperature, pressure, molecular weight, and constitution of the material. Examination of mechanical property restoration during healing permits one to converge on the optimal properties of the virgin state in terms of the aforementioned variables.

III. CONCEPT OF SELF-HEALING

The concept of self-healing can be understood of embedding a chemical healing agent/catalyst encapsulated in microcapsules that are dispersed throughout a material matrix. The material matrix can be a polymer, metal, or ceramics. When a macro-crack occurs leading to a fracture in the composite, the stress concentration at the crack tip of the microcapsules causes rupture releasing the healing agent, which will flow out by the capillary action filling the macro crack. The healing agent contacts the catalyst in the polymer and will eventually result in the crack closure.

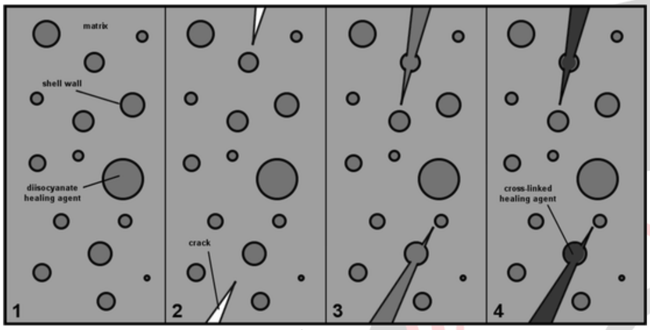


Fig.1. Basic method of the microcapsule approach

IV. PROPOSED METHODOLOGY

The very first step would be to identify the self-healing materials that can be combined into a composite.

The Second step would be to develop the global-local FEM technique using the available standard analysis software ANSYS.

Third step the fracture toughness as well as the strength (tensile or compressive) before and after healing of micro-capsule based self-healing composites must be computed for the comparison of healing efficiency.

Finally the Engineered materials such as metals, concrete and polymer composites with self-healing properties promise to minimize the possibility of catastrophic failure in devices such as airplanes and spacecraft, or in hard-to-repair areas such as electronic circuit boards or human medical implants.

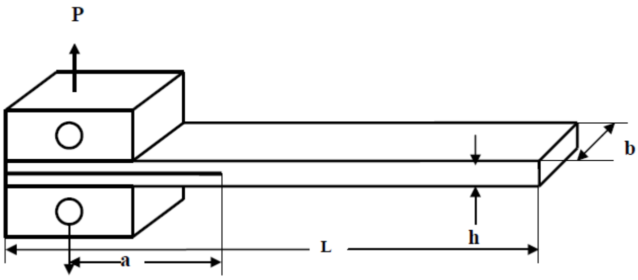
V. FRACTURE TOUGHNESS

Fracture mechanics is the field of mechanics concerned with the study of the propagation of cracks in materials. It uses methods of analytical solid mechanics to calculate the driving force on a crack and those of experimental solid mechanics to characterize the material's resistance to fracture.

There are three ways of applying a force to enable a crack to propagate:

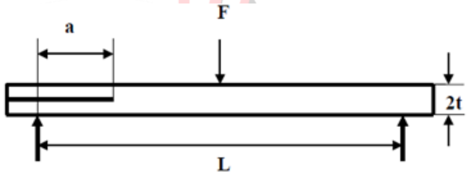
Mode I fracture – Opening mode (a tensile stress normal to the plane of the crack)

A non-adhesive Teflon film was inserted in the mid-plane of the laminate during fabrication which acted as delamination initiator. The loading blocks were mounted on the top and bottom surfaces of the end of DCB specimen arms. The delaminated end of the DCB specimen was opened by quasi-static loading at a displacement control mode with a constant crosshead speed of 1-5mm/min. Delamination lengths are determined visually during the test.



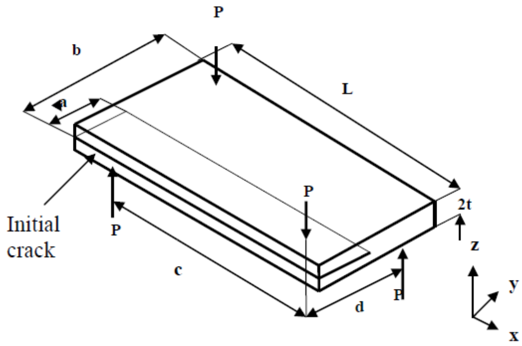
Mode II fracture – Sliding mode (a shear stress acting parallel to the plane of the crack and perpendicular to the crack front)

The End-notched flexure test is one of the methods designed to measure the interlaminar fracture toughness under in-plane shear deformation mode, commonly known as Mode II. Mode II interlaminar fracture toughness is calculated from the initial crack length and the load-deflection curve using the highest load and deflection level.



Mode III fracture – Tearing mode (a shear stress acting parallel to the plane of the crack and parallel to the crack front)

Recent studies have focused on the edge crack torsion (ECT) test, which the ASTM is working to standardize. The ECT specimen shown in Figure below consisted of three support pins and an upper loading pin, which generate torsion moments responsible for the Mode III shear sliding.



VI. 3D MODEL OF SPECIMEN

Our project model consist of Double Cantilever beam(DCB) which consists of a rectangular uniform thickness unidirectional laminated composite specimen of 0° orientation of fibre reinforcement with and without microcapsules. We designed specimen by 3D modelling software CATIA V5.

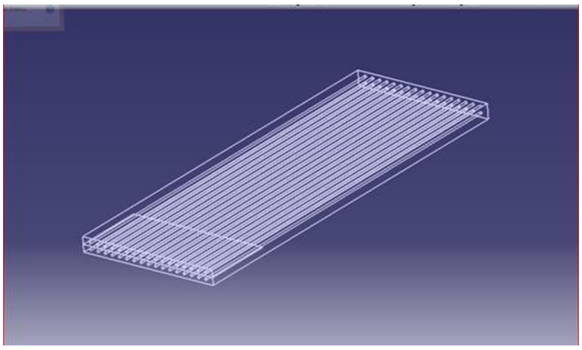


Fig.2. 0º oriented fibre reinforcement model

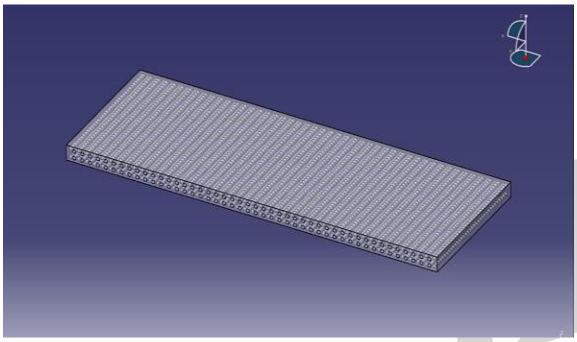


Fig.3. Microencapsulated 0º oriented fibre reinforcement model

VIII. RESULT

The results are obtained from ANSYS WORKBENCH 17.1 It consist of stress intensity factors for 0º fiber reinforcement epoxy matrix.

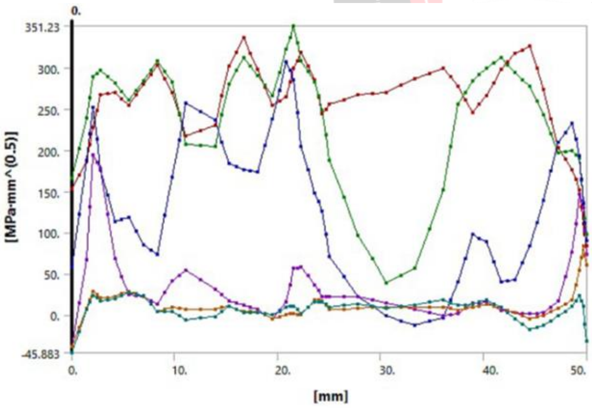


Fig.4. stress intensity factor of Mode-I(K1)

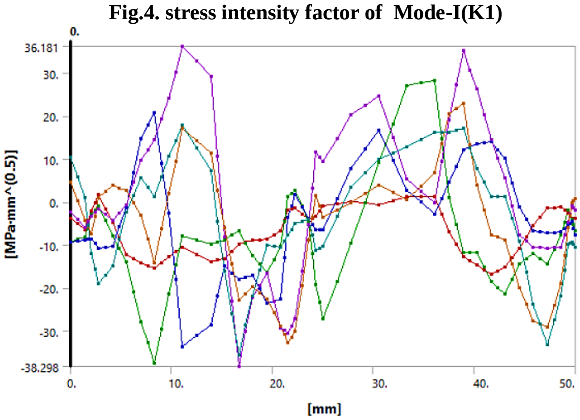


Fig.5. stress intensity factor of Mode-II (K2)

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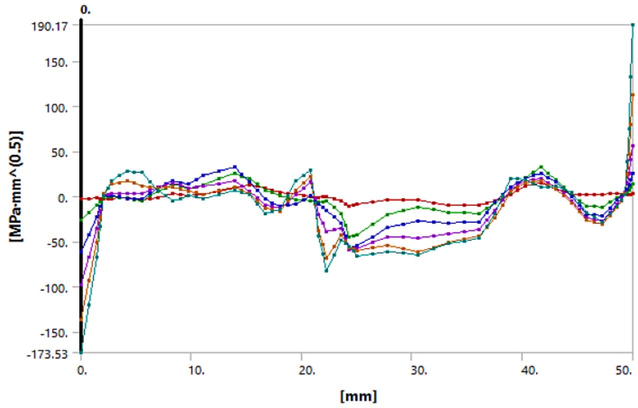

Fig.6. stress intensity factor of Mode-III (K3)

	K1 (Mpa-mm^0.5)	**K2 (Mpa-mm^0.5)**	**K3 (Mpa-mm^0.5)**
Minimum	-45.883	-35.658	-173.53
Maximum	27.622	17.955	190.17

IX. CONCLUSION

Encapsulation is the most effective method. The challenge now is to improve healing efficiency and reduce time required for healing. For that fracture toughness parameter can be checked for different fibre direction i.e. 0˚,45˚ and 90˚ for better efficiency.

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