MECHANICAL PROPERTIES AND OPERATIONAL DAMAGE EVALUATION OF C.S.M. COMPOSITES BY DESTRUCTIVE AND NON-DESTRUCTIVE TECHNIQUES

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ABSTRACT

Among the plenitude of experimental methods of materials damage evaluation the non destructive techniques have an important role. The damage parameter D expresses the effective density of micro-cracks, cavities and any other internal defect existing in a material. In the NDT methods of ultrasounds, the ultrasonic waves' propagation is prevented by the presence of these obstacles. The change of ultrasonic waves' density is expressed by their attenuation coefficient. Based on this quantity an improved technique by which one can simply and with adequate sensitivity and accuracy determine the damage of materials has been introduced.

Also, in this study some damaging effects induced by creep loading under normal ambient conditions in CSM fibre reinforced epoxy resin composites were investigated by means of a basic type experimental approaching technique which is based on the influence of the creep-induced damaging effect on some relevant mechanical parameters such as elastic modulus and fracture stress. By the above approaches it was shown that despite the non-neglected scatter in the experimental data certain general trends may be assessed. In this context it was found that the damage "response" is markedly sensitive to the respective applied "detection" technique and therefore the damage evolution data obtained by these different techniques are only in some circumstances comparable.

Finally, an experimental and theoretical study of certain static and dynamic properties of CSM resin composites through tensile and vibrations tests was carried out in order to determine elastic modulus, fracture strength, storage and loss moduli, to investigate the influence of parameters such as filler content and to verify discrepancies between theory and experiment.

1. INTRODUCTION

As it is known, modern reinforced composites are becoming increasingly important as structural materials in a wide range of industries. In particular glass reinforced plastics (GRP) are widely used in applications such as pipe work and pressure vessels for chemical plants. These materials have many advantages over other conventional engineering materials, for example their resistance to chemical attack, sometimes-high strength/ stiffness-weight ratio, ease of fabrication and versatility in design. It is therefore necessary to be able to predict the mechanical properties of GRP under various conditions.

The two-phase nature of a fibre reinforced polymer gives rise to a multiplicity of possible failure modes. The properties and modes of failure depend not only on the fibre and matrix characteristics but also on the interface and interlaminar properties, which play a major role. Different composite systems with essentially the same constituents, that is fibres and matrix, can exhibit different tensile, compressive, flexure, fatigue and fracture behaviors due to varying properties.

In order to evaluate the structural properties of GRP construction manufactured with varying wall thicknesses, flat GRP pads are usually are made to the same nominal thickness, the panel being made up at the same time and in an identical manner to the vessel or pipe. The material is normally subjected to a uniaxial tension test and a three-or four-point bend test giving values for such quantities as the tensile strength, elastic modulus, bending stiffness extensibility etc.

On the other hand it is well known that materials subjected to stresses well below that required for macroscopic failure undergo deterioration of their structure. The deterioration of the material structure is caused by nucleation and growing-size accumulation of internal defects or discontinuities such as microcracks and voids/cavities fact, which implies related “internal” decrease in load carrying area. In this sense material damage is defined as the property whereby the material strength diminishes before failure occurs. In recent years there has been considerable effort to study the types of the so-called “material damage” and its evolution and to correlate it with adequate mechanical as well as physical properties of the material.

In this sense the first basic problem is how to define and adopt the most adequate damage variables; i.e. what kind of real physical nature these variables should have in order to represent such damage state property. The second basic complex problem, on the other hand is how the magnitude of these variables.

In this direction certain physical techniques such as sonic inspection have a very long tradition in engineering practice. The presence of macroscopic cracks influence the resonance frequencies and damping quite strongly and human ear may often be used to detect such major cracks. In contrast, micro-cracks, voids and pores, which constitute material damage may not be detected or measured by audible sonic (acoustic emission) methods. Ultrasonic techniques may be, however, be used for this scope in various ways with varying accuracy. One particular experimental ultrasonic approach is for example that proposed recently, where the material damage can be evaluated quickly and with higher accuracy than other ultrasonic techniques by measuring only changes of signal attenuation. In this context we should also mention the paper where by a similar ultrasonic technique the moisture-induced internal damage is evaluated in a good manner.

Recently, a novel non-destructive approaching technique has been proposed for the damage evaluation in certain polymer composites. This technique is based on the net effects of the internal structural changes, on the moisture diffusivity of the material. It has been shown that this thermophysical approaching technique can be used in a complementary way to study the damage and can provide a powerful tool to gain a deeper insight into the general phenomenon of damage evolution. In this sense it would be valuable to try to compare the above mentioned thermophysical (diffusive) technique with a non-physical i.e. a quasi non-destructive mechanical one such as stiffness reduction a destructive one such as fracture stress reduction and a non-destructive one such as ultrasounds.

In the present work at first tensile experiments were carried out on a CSM reinforced resin composite to determine some mechanical properties. On the other hand since damage evaluation can serve as a complementary experimental tool to study the glass fibre/polymer system in terms of its microstructural as well as internal mechanical changer, the evolution of creep-induced damage by means of stiffness reduction and fracture stress reduction was investigated. A comparison and a discussion among various techniques was made.

Finally, dynamic properties of these materials were investigated by evaluating the storage and loss moduli by means of vibration tests and theoretically by a well known formula of the literature in order to verify the discrepancies between theory and experiment and also among static, dynamic and ultrasonic tests.

Remark

Due to the fact that results are numerous and the size limit of the paper according to the conference format, experimental results will be given during the poster presentation and on the "post conference DVD".