

Comparisons of processing and strength properties of two adhesive systems for composite joints

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Abstract

In the present study rheological, static and impact tests are carried out on two adhesive resins usually employed in marine applications; then single lap joint tests are conducted on composites joints evidencing the effect of the curing time of both resins on the mechanical properties of the joint.

The applicability and workability conditions of the adhesive resins are determined evaluating the curing evolution by a preliminary rheological analysis; then the relation of curing properties with the mechanical performances of the resins themselves and with ones of the composite joints is estimated. Static flexural and Izod impact tests are performed on the resins at increasing time after the specimen production (curing time); also the resistance properties of adhesives joints are studied as well the stabilisation of the mechanical properties after long times. Moreover a relationship between the different failure mechanisms, observed for both resins joints, and the curing reaction is observed.

A numerical model of the single lap joint test is developed: a simple and versatile numerical analysis (FEA with software ANSYS) is carried out in elastic regime. Such model should be suitable for designing and/or verifying the mechanical performances of composites joints, evaluating the shear, axial and peel stress trends on the joint overlap length.

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1. Introduction

Ships structures are reinforced by internal transversal panels, such structural solution is optimal to resist to axial deformations, shear loads and unsymmetrical static or dynamic loads that can occur locally under working conditions. The panels require to be connected to the hull determining high local stresses along the junctions. Adhesive structural resins permit to avoid typical discontinuities due to mechanical bolts, to realise complex joint geometries and to uniformly distribute stresses on the

whole joined surface, to dampen vibrations and to obtain lighter structures because of the absence of bolts or rivets. The above reported advantages consent to attain lower production costs and/or better properties joints, when adhesives are used in complementary way with traditional connection methods [1].

The performances of adhesive joints are strongly influenced from the adhesive resin characteristics, from the interaction adherent/adhesive, from the variability of these characteristics during the time and from the changing in environmental conditions.

The mechanical properties are greatly time dependant as a consequence of the curing phenomena (gelation and vitrification) and aging at long times; this induces uncertainties in the characteristics of the whole joint and its constituents [2]. It is generally accepted that bond strength variation of the adhesive joint is affected by

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the overlap length, the laminate stacking sequence, the laminate thickness and strongly by the chemical/molecular features and the mechanical properties of composite adhesive [1]. It is not still clearly defined how the working conditions can affect the mechanical properties and how much these ones influence the behaviour of each joint component (adhesive, substrate or interface). After the adhesive deposition, in fact, the cure of the resin occurs, the viscosity increases exponentially until the system becomes solid; at this point a relevant increment of mechanical properties of the adhesive can be noticed; for longer times these characteristics are quite stable.

Usually the studies on the joints failure modes are conducted by empirical analysis of the damaged surface, as a consequence of the structural failure of the joint. Moreover, these studies evidenced that the failure mechanisms are heavily influenced by curing times [2].

To formulate forecasts about the damaging mechanisms of the joint is difficult due to the lack of experimental data necessary to identify the critical area of the joint [3]. So the industrial application of such adhesive junctions is difficult to implement in the production process. Until now the choice of an adequate joining method for composite structure and the correct time when the boat can be tested by sea is based on empirical data or on the technical experience; being a limit for application of structural adhesives in marine field. Until now a standardised design procedure, able to predict the degradation of the adhesive joint and applicable in industrial filed, do not exist.

Several works in the literature are referred to composites joints characterisation with the adhesive resin yet fully cured, analysing several phenomena like damaging [4], ageing [5], modelling [6] and so on, but few works focuses their attention on the effect of the adhesive resin curing time on the joint mechanical properties.

The aim of the present work is to evaluate the pot life (i.e. the length of time, after the adhesive resin is mixed, until it remains useable) and the minimum time until the mechanical properties are stabilised. Moreover the evaluation of the relationship between the mechanical properties of the composites joint and the curing times of the adhesives is investigated to identify the minimum times necessary to reach also the joint performances stabilisation. Therefore a preliminary rheological characterisation of two different types of structural adhesive resins, usually employed in industrial marine field for the joining of yacht-hull components, is performed with the purpose to evaluate the effect of viscosity and cure conditions on the workability of the resins.

Then, static and dynamic mechanical tests are realised to find the relationship between mechanical properties and curing time of the resins. With this purpose several samples are prepared in the same conditions expected during the real application of the adhesives in the industrial practise. The comparison of rheological and mechanical properties of the resins is then focused to suggest the better solution for specific applications.

Single lap joint tests are carried out on samples realised with the two different structural adhesives at different curing times.

To better understand the phenomena that occur at the adhesive/adherent interface during the phase transitions taking place in the curing process of the resins, the adhesive/adherent system is characterized also on the basis of the occurred failure modes.

Finally a simplified Finite Element Model of the single lap joint test is developed evaluating the shear, axial and peel stress trends on the joint overlap length; the proposed model is verified by comparing experimental and numerical data.

2. Experimental procedure

2.1. Materials

Two adhesive resins employed in marine application are taken into account, in the following called resins A and B, their characteristics are reported in Table 1. Resin A is a short-fibre reinforced resin while Resin B is an unsaturated acrylic urethane resin.

For the joints an E-glass fibre reinforced polyester matrix laminated composite is used as substrate. These one is realized with the manual lay-up technique obtaining a combined mat/woven structure, with the woven fabric on the joining surface; the laminate is characterized in elastic field by means of tensile tests, reported in Table 2.

Table 2
Finite element modelling parameters

	Axial Young modulus (Mpa)	Poisson coefficient
Composite laminate	2110.7	0.35
Resin A	410	0.35
Resin B	207.7	0.35

Table 1
The adhesive resins employed

Resin	Product	Producter	Description	Catalyst
A	Eurobond PT 15V	Euroresins	Glass fibres reinforced plaster	BPO 2% on weight
B	Crestomer 1186PA	Scott Bader	Unsaturated acrylic urethane resin	Butanox M50 2% on weight

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