



Debonding on command of adhesive joints for the automotive industry



M.D. Banea^{a,b,*}, L.F.M. da Silva^b, R.J.C. Carbas^b

^a IDMEC, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal

^b Departamento de Engenharia Mecânica, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal

ARTICLE INFO

Article history:

Accepted 17 January 2015

Available online 2 February 2015

Keywords:

Thermally expandable particles

Polyurethane

Epoxides

Induction heating

Lap-shear

Recycling

ABSTRACT

In this study a methodology to assure easy debonding of adhesive joints by combining the inductive heating method and the use of thermally expandable particles (TEPs) was developed. Two commercially structural adhesive systems used in the automotive industry (one polyurethane and one epoxy) were tested. First, the influence of TEPs content on the lap-shear strength of the TEPs-modified single lap joints was investigated. Further, the ability of the TEPs-modified joints to support temperature controlled debonding was evaluated. It was showed that the control of the debonding process by temperature is possible. The temperature needed for debonding is a function of TEPs content and can be lowered by increasing the TEPs content.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Adhesive bonding has found applications in various areas from high technology industries such as aeronautics, aerospace, electronics, and automotive to traditional industries such as construction, sports and packaging [1]. Adhesives can be used to join metals, polymers, ceramics, cork, rubber, and combinations of any of these materials. Moreover, nowadays, new products consist more and more of a combination of special new materials, which needs to be joined according to their specific characteristics. These materials (i.e. ceramics, carbon fibre reinforced polymers (CFRP), etc.) are usually expensive which create an increasing demand for recyclability, driven by economic as well as environmental reasons. Thus, the development of new technologies and processes for easy recycle and repair of bonded structures are becoming of great interest for the industry. If bonds can be broken without damage of the components, recycling is easier. Also for an environmental friendly disassembly of bonded structures, it is necessary to separate the joint between the bonded components so that the different materials can be reused on a qualitatively high level [2].

For the automotive industry, recent mandatory targets state that all vehicles must be 95% recyclable by the year 2015 [3,4]. Consequently, there is a growing need to develop adhesives that debond on command in order to easy disassembly the bonded structures and to separate parts for reuse or recycling. Currently, debonding of

structural adhesive joints is mainly based on mechanical destruction (thermal degradation of the adhesive, cutting of the adhesive or a combination of these methods), which can damage or even destroy the substrates. Solvents or acid immersion may also be used, but there are health and safety concerns which arise. For example, in the case of disassembly of windscreens and frames in the automotive industry, electric knives are used. This produces significant residue, wastage, and breakage and also raises serious safety issues [5]. Nevertheless, even if numerous methods for adhesive reversibility or debonding (dismantlement) have been proposed in the literature [6–12], currently, there is no generally accepted solution for the disassembly of structural bonded joints in industry, other than mechanical destruction.

One of the technologies developed for adhesive debonding involves imbedding thermally expandable particles (TEPs) in the adhesive layer [13,14]. Kim et al. [15] used TEPs with a polyurethane adhesive and found that the dismantlement of the joint was possible with microwave treatment for 4 min. More recently, McCurdy et al. [16] used TEPs with three structural adhesives for the automotive industry in order to obtain joint dismantling. They found that matching a high performance TEPs with a high performance adhesive is not sufficient to obtain an efficient joint dismantling as there are important implications for joint performance (i.e. joint durability). Nevertheless, the success of the concept of using TEPs with adhesives depends on the combination of the TEPs and the adhesive system and more research efforts in this area are necessary.

In this work a method to assure easy debonding of adhesive joints by combining the inductive heating method and the use of TEPs was developed. First, single lap joints (SLJs) were fabricated and tested to assess the influence of TEPs content on the lap-shear strength of the

* Corresponding author at: IDMEC, Faculdade de Engenharia, Universidade do Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal. Tel.: +351 225081750; fax: +351 225081445.

E-mail address: mdbanea@gmail.com (M.D. Banea).

adhesive joints. Further, the ability of the TEPs-modified joints to support temperature controlled debonding was evaluated.

2. Experimental details

2.1. Materials

2.1.1. Adhesives

A two-component structural polyurethane adhesive SikaForce[®]7888, supplied by Sika (Sika, Portugal) and a two-component epoxy adhesive Betamate[™]2098, supplied by Dow Automotive (Dow Europe, Switzerland) were selected for this study. Both adhesives are used in automotive industry being part of a new generation crash durable adhesives which combine high level of strength and elongation (see Table 1). The tensile properties of both adhesives as a function of TEPs content were obtained in a previous study by the authors [17].

2.1.2. Thermally expandable particles

Expancel 031 DU 40 particles supplied by Expancel Nobel Industries (Sweden) were selected. The diameter of these particles ranges mainly from 10 to 16 μm . The dimensions of the particles before and after expansion were verified through a scanning electron microscopy (SEM) analysis (see Fig. 1). Data provided by the manufacturer is given in Table 2 [18].

2.2. Specimens manufacture

Hard steel substrates characterized by a high tensile strength with a thickness of 2 mm and 25 mm width were used. The joint surfaces were grit blasted and degreased with acetone prior to the application of the adhesive. The substrates were bonded and then the specimens were cured at room temperature (RT) for 7 days. A mould with spacers for correct alignment of the substrates was used [20]. The bondline thickness was controlled using packing shims. The bondline thickness was 0.2 mm and the length of the overlap was 25 mm. The geometry of the lap-shear joint specimens used is shown in Fig. 2.

Table 1
Mechanical properties of the adhesives.

	Young's modulus [GPa]	Tensile strength [MPa]	Elongation [%]	T _g ^a [°C]
SikaForce [®] 7888	2.50	30	46	40
Betamate [™] 2098	0.93	18	56	60

^a Data provided by the manufactures.

The TEPs-modified adhesive was mixed with a Speed Mixer (DAC 150.1 FVZ Speedmixer, Hauschild, Germany) for 60 s at 2500 rev/min. This allows an efficient and homogeneous dispersion, creating visibly bubble-free mixing. The TEPs-modified adhesive cured matrix structure was examined through a SEM analysis, in a previous study, and a uniform dispersion of particles within the adhesive matrix was observed [19]. Single lap joints with different TEPs concentrations by percentage weight (0, 5, 10, 15, 20 and 25 wt% TEPs) were produced.

2.3. Test method

2.3.1. Single lap joint tests

Testing was conducted at RT at a constant displacement rate of 1 mm/min using a MTS 312.31 servo-hydraulic machine. At least three joints were tested to failure for each wt% TEPs. For each joint tested, a load–displacement curve was produced.

2.3.2. Evaluation of debonding

The evaluation of debonding was performed by exposing the SLJs' adhesive layer to an electromagnetic field (the SLJs specimens were locally heated by an electromagnetic induction method). The induction heating process relies on induced electrical currents within the material to produce heat [21]. The main advantage of the induction heating technique is that heat can be focused at or near the adhesive bondline. When properly set up, the process becomes very repeatable and controllable. The test setup designed for temperature controlled debonding is presented in Fig. 3. A power supply sends an alternating current through an induction coil which was specially designed for this end. For a specific application, the design of a suitable induction coil is very important. Experience acquired from previous research formed the basis for the design of the induction coil [22,23]. The SLJs specimens were placed in the fixture inside the induction coil and then a 100 N mass was applied in tension. The alternating magnetic field induces eddy currents in the SLJs overlap region and heats it. The heating profile was measured using a thermographic camera (Fluke FLK-Ti25, Eindhoven, Netherlands). This setup directly allows determining the temperatures that the TEPs-modified adhesives are subjected to. When the power supply is switched on, the timer is started in order to measure the time to failure for each joint tested.

Table 2
Characteristic data of used Expancel 031 DU 40 [18].

Particle size [μm]	10–16
T _{start} [°C]	80–95
T _{max} [°C]	120–135

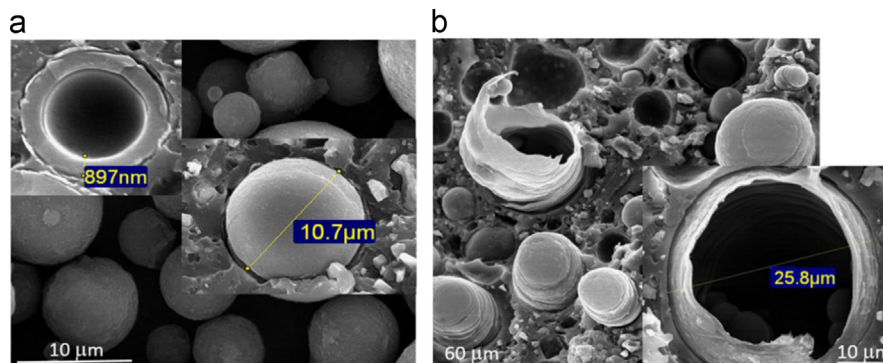


Fig. 1. SEM image of TEPs before (a) and after expansion (b) [19].

Download English Version:

<https://daneshyari.com/en/article/779890>

Download Persian Version:

<https://daneshyari.com/article/779890>

[Daneshyari.com](https://daneshyari.com)