Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 8 (2018) 561–565

Structural Integrity Procedia

www.elsevier.com/locate/procedia

AIAS 2017 International Conference on Stress Analysis, AIAS 2017, 6–9 September 2017, Pisa, Italy

Fracture toughness of structural adhesives for the automotive industry

Marco Alfano[a,*], Chiara Morano[a], Fabrizio Moroni[b], Francesco Musiari[b], Giuseppe Danilo Spennacchio[c], Donato Di Lonardo[c]

[a]*Department of Mechanical, Energy and Management Engineering, University of Calabria, P. Bucci 44C, 87036 Rende (CS), Italy*
[b]*Department of Engineering and Architecture, University of Parma, Parco Area delle Scienze 181/A, 43124 Parma, Italy*
[c]*CRF/WCM R&I - Campus Manufacturing, Zona Industriale San Nicola Di Melfi, 85025 Melfi (PZ), Italy*

Abstract

Adhesive bonding is currently employed by automotive manufacturers to complement (or replace) welding in joining dissimilar materials. In order to reduce the impact on the existing manufacturing infrastructures, structural adhesives are deployed in the body shop but hardening is accomplished in the paint cure oven. Various adhesive formulations have been specifically developed for the implementation in the automotive manufacturing chain. However, it is very important to assess the mechanical behaviour of the joints which results from the peculiar curing strategy. In the present work, automotive grade single component epoxy and two component epoxy modified acrylic adhesives were evaluated. T-joints were fabricated using a cold rolled galvanized steel (FeP04) employed in the production of car body parts. The fracture toughness of the joints was determined using the test protocol proposed by the European Structural Integrity Society (ESIS). Optical microscopy was employed to ascertain the mechanisms of failure. The results indicated that both adhesives were able to provide a fairly good mechanical response with minimum preparation of the mating substrates. Moreover, the obtained values of fracture toughness were shown to be essentially independent of the adhesive layer thickness.

Peer-review under responsibility of the Scientific Committee of AIAS 2017 International Conference on Stress Analysis

Keywords: automotive, adhesives, fracture toughness, T-joint

1. Introduction

Cars are responsible for around 12% of total EU emissions of carbon dioxide (CO_2). To improve the fuel economy of cars sold on the European market the EU legislation established mandatory emission reduction targets, such as those recently disclosed in the Climate Action EU no. 333 (2014). In order to meet these requirements, automotive manufacturers are currently increasing the share of lightweight materials and high strength steels in car body manu-

* Corresponding author. Tel.: +39 0984 494156; fax: +39 0984 494673.
E-mail address: marco.alfano@unical.it

Peer-review under responsibility of the Scientific Committee of AIAS 2017 International Conference on Stress Analysis
10.1016/j.prostr.2017.12.055

facturing, see D'Aiuto (2016). The strategy pursued is to place the right materials with the right properties at the right place. This approach led to the compelling need of joining materials with dissimilar properties. From this standpoint, adhesive bonding emerges as a suitable technique able to replace -or complement- fusion or spot welding (Chiodo et al. (2015); Rotella et al. (2015)). However, at present time it is highly desirable that the introduction of structural adhesives in car body manufacturing is made with minimum impact on the manufacturing infrastructures. For this reason, adhesives are commonly applied in the body-in-white stage (*i.e*. assembly of frame and panels) while final curing is performed in the paint shop. Tailored structural adhesives have been developed to accommodate the implementation in the manufacturing chain. The scope of the present work is to assess the fracture properties of two types of automotive grade structural adhesives deployed in modern car body manufacturing. T-joints were fabricated following the curing cycle employed in the paint shop according to the classical process chain of automobile production. Adhesive joints featuring cold rolled galvanized steel substrates (FeP04) were bonded with either a single component epoxy (DOW Betamate 1060S) or a two component epoxy modified acrylic adhesive (LORD Versilok 265/254). The results of mechanical tests were post-processed using the ESIS Test Protocol (2010) proposed by the European Structural Integrity Society. The fracture surfaces were finally analyzed by means of optical microscopy to ascertain the mechanisms of failure.

2. Materials and methods

2.1. Materials

The steel employed herein for the fabrication of T-joints is a cold rolled galvanized steel (FeP04) deployed in the production of body components in the automotive industry. Two selected substrate thickness have been considered in mechanical tests, *i.e*., 1.2 mm and 1.5 mm. The chemical composition of the FeP04 steel is reported in Tab. 1 while the corresponding stress-strain curve obtained through tensile tests is reported in Fig. 1(a).

Table 1: Chemical composition of the FeP04 cold rolled galvanized steel

Material	C	Fe	Mn	P	S
FeP04	≤ 0,08%	≥ 98%	≤ 0,4%	≤ 0,03%	≤ 0,03%

Two selected structural adhesives have been used to fabricate the joints, namely the Betamate 1060S (DOW Chemical Company, USA) and the Versilok 265/254 (LORD Corporation, USA). The Betamate 1060S is a one component, heat curing, epoxy based adhesive. It is especially tailored for the body shop because it features excellent adhesion to automotive steels (including coated steels and pre-treated aluminium). Moreover, it is compatible with the e-coat process and it is wash off resistant. Typical applications include bonding of the vehicle body structures. No details are disclosed concerning the curing conditions, *e.g*., curing temperature and duration. On the other hand, the adhesive Versilok 265/254 is a two component epoxy-modified acrylic adhesive used to bond a variety of automotive sheet metals. Glass beads are included in the adhesive system to prevent shifting of mating substrates panels. The manufacturer claims that the adhesive bonds well through various stamping lubricants and eliminate the need for advanced cleaning or surface preparation. The data sheet suggests low temperature cure conditions for getting high strength joints, while induction heating is recommended at 110^{o}C. Here we use the curing conditions employed in the paint shop for both adhesive types and which consists in thermal heating at 180^{o}C for 30' followed by slow curing down to room temperature (*i.e*., 25^{o}C).

2.2. Sample fabrication and determination of fracture toughness

T-joints were fabricated and tested according to the procedures and recommendations reported in the standard ISO 11339 (2010) and ASTM 1876-08 (2015). Joints geometry and boundary conditions are reported in schematic of Fig. 1(b). FeP04 plates were cut down to 25×200 mm^2 strips from larger sheet metals. Surface degreasing was carried out as standalone surface pre-treatment in order to remove dust and contaminations due to substrate cutting and handling.