International Journal of Adhesion & Adhesives 56 (2015) 73–78

Contents lists available at ScienceDirect

International Journal of Adhesion & Adhesives

journal homepage: www.elsevier.com/locate/ijadhadh

Flexible adhesives for automotive application under impact loading

Ferhat Kadioglu [a,*], Robert D. Adams [b,c]

[a] Mechanical Engineering Department, University of Turkish Aeronautical Association, Turkkusu Campus, Etimesgut, 06790 Ankara, Turkey
[b] Department of Mechanical Engineering, University of Bristol, Queen's Building, University Walk, BS8 1TR Bristol, UK
[c] Department of Engineering Science, University of Oxford, Parks Road, Oxford, UK

ARTICLE INFO

Available online 8 August 2014

Keywords:
Adhesive joints
Impact test
Single lap joint
Structural bonding tape

ABSTRACT

In automotive construction, adhesive bonding can be used for joining metals, plastics or combinations of the two, and it offers the further advantage that, because the joints are continuous, an overall increase in body stiffness is achieved, thus enabling thinner material to be used. Because of their ability to absorb energy adhesive joints can also contribute to the impacted system. The objective of this work is to investigate the behavior of a flexible adhesive under impact loading using the single lap joint configuration. This adhesive showed a high strain to failure with good strength. These features of the adhesive under impact loading improve structural crashworthiness. Results showed that the lap joint strength increases considerably under impact loading compared with those under quasi-static loading and that there is a relationship between the joint performance and the loading speeds.

1. Introduction

In spite of the increasing use of adhesives in the aircraft and automobile industries, the crashworthiness of structures joined with adhesives is still a challenging subject. For adhesively bonded structures, consideration is made of:

- The impact performance of the joint and whether it is different from the quasi-static performance.
- The capability of any energy absorption the adhesives can contribute to the impacted system.
- Understanding of the impact loading of the joints so that they can be designed for such conditions.

Therefore, a suitable experimental set-up is necessary. A well-instrumented impact machine that can produce the required data correctly, and a suitable specimen geometry that can be representative of the joints under real working conditions, are the two parameters that must be sought. There are several impact test techniques, which are mainly based on the Izod and Charpy impact test [1], which are specified for both metals and thermoplastics. In addition, there are also the falling weight test [2–4], high speed servo hydraulic systems [5,6] and the split Hopkinson pressure bar [7,8].

Bezemer et al. [9] developed a new kind of joint specimen, the rod-ring specimen, to load the adhesive in pure shear on impact. The specimen was tested with three materials, a tough adhesive (a two-component polyurethane), a brittle adhesive (a two-component epoxy) and a sealant, at five layer thicknesses and three test speeds. They used a drop-weight tower and an air gun. They concluded that the specimen used was suitable for impact tests and for comparing impact tests with static tests, yet it did not give the desired pure shear as a consequence of lateral contraction and edge effects (stress concentrations). In most cases, increasing the load rate caused an increase in energy absorption. The brittle adhesive showed comparable behavior in both static and impact tests, but the tough adhesive behaved in a brittle fashion during the impact test. The tough adhesive showed a greater energy absorption under impact than the brittle adhesive and there was an optimum adhesive thickness at different test speeds, which the authors say was a result of the constant failure displacement. An exception occurred for relatively thinner bondlines which were affected more by the lateral contraction.

Raykhere et al. [10] investigated adhesively bonded butt joints using a torsional Split Hopkinson bar. They focused on the evaluation of the shear strength of the joints using four different commercial adhesives tested at different loading rates. Joints were prepared with two different adherend combinations, aluminum–aluminum and aluminum–glass fiber reinforced plastics. The results from this study showed that the dynamic strength was 2–4 times greater than the static strength, depending on the adhesive and adherend combination. Sato and Ikegami [11] investigated the strength of butt joints under combined tension and torsion loading using the same technique. It was found that their experimental results were comparable with the predicted results.

In structural applications, adhesives are preferably loaded in the shear mode so that the best joint performance can be

* Corresponding author. Tel.: +90 312 3428458/648; fax: +90 312 3428460.
E-mail address: fkadioglu@thk.edu.tr (F. Kadioglu).

http://dx.doi.org/10.1016/j.ijadhadh.2014.08.001
0143-7496/

achieved. Accordingly, the adhesive single lap joint has received some attention since it is the most representative configuration of joints used in the aircraft and automobile industries, and has also been tested in laboratory conditions. Harris and Adams [12] measured the strength and energy absorption of bonded single lap joints with four epoxy adhesives and three aluminum alloy adherends, using an instrumented pendulum impact test. They found that the joint was not much affected by high rates of loading for a range of structural adhesives, and that the energy absorption came mainly from the deformation of the adherends. They also claimed that by applying the correct failure criterion to the finite element results, the effects of impact loading on joint strength could be predicted and reasonable values obtained for the absolute values of joint strength both under impact and quasi-static loading. Goglio and Rossetto [13] used an instrumented Charpy pendulum to investigate the mechanical behavior of lap joints under impact loading, with a special interest in the thickness of the adhesive layer. The results from this study showed that higher joint strengths could be obtained under impact loading compared to quasi-static loading, and that joints with a relatively thin adhesive layer were stronger than those with thick layers. Sato and Ikegami [14] and Challita et al. [15] are other authors who have investigated the lap joint configuration.

The authors mentioned so far were mostly interested in the behavior of structural adhesives which are generally in their glassy state, and so their behavior would be similar under high rates of loading. The objective of this work was to study the behavior of a viscoelastic adhesive tape (SBT 9245 from 3M) under impact loading using the single lap joint configuration. The material has already been tested by the author for the investigation of its mechanical and dynamic behavior in quasi-static and dynamic tests. Statically, SBT showed a high strain to failure with a reasonable stress and high damping. These features of the adhesive tested under impact will enlighten the contribution of such materials to the crashworthiness of structures.

2. Test specimen

Unlike Charpy and Izod tests, which are concerned with the properties of single materials, an adhesive joint usually consists of at least two materials, the adherends and the adhesive. The properties of the joint will depend upon the properties of each constituent and the geometry employed. It is thus of relevance to consider the impact properties of the whole joint, rather than the adhesive material in isolation. In order to prevent plastic deformation in the adherend, a hard steel which has a yield stress of over 1800 MPa was used. The surface portion of the adherend to be bonded was cleaned with acetone, and then grit-blasted and wiped again with acetone just before the application of the tape. After surface preparation of the adherends, the tape (SBT 9245 produced by 3M) was applied to the substrate, taking care to minimize the amount of air entrapped during the application. The tape, consisting of cured epoxy in an acrylic matrix, has a nominal thickness of 0.5 mm and a width of 25 mm. To ensure compaction, the adhesive thickness was adjusted 0.45 ± 0.01 mm by the application of heated plates which were also used for the cure process. To control the adhesive thickness, some shimsmade of steel and treated with a release agent were used in a special designed jig. The curing procedure for the tape is 45 min at 140 °C, according to the manufacturer's recommendations. The dimensions of the single lap joint specimen are shown in Fig. 1.

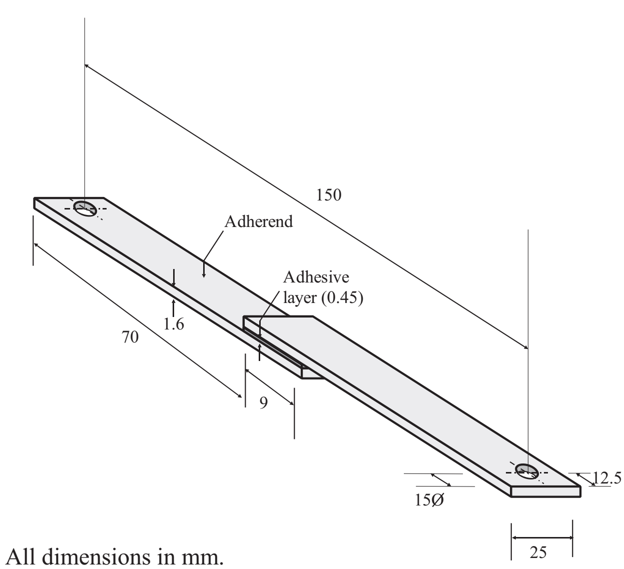

Fig. 1. Single lap joint for impact test.

3. Test design

A pendulum impact machine was used in these tests. In its design, consideration was made of the following main points:

i. the securing and positioning of the test piece,
ii. the application of the impact loading to the specimen in a smooth, controlled and repeatable fashion, and
iii. positioning of the load and displacement transducers to give the most accurate results.

The number of connections was kept to a minimum and all elements were made as stiff as possible since the impact tests are susceptible to spurious dynamic effects, caused by component vibrations and the necessity to minimize for mass (inertia) effects.

A schematic of the design is shown in Fig. 2. The specimen 5 is clamped and bolted into the rig at each end. At one end, the specimen clamp 6 was attached to a piezoelectric force transducer 7, which in turn was fixed to the base plate via the end block 8. At the other end, the specimen clamp 4 was constrained to run in a plane journal bearing, thus providing location for the loaded end of the joint, and preventing non-axial movement. The impactor attached to the pendulum was designed to strike the impact bar 3 on either side of the specimen. The load can be applied to the specimen in a relatively smooth manner by the inclusion of a layer of lead around the impact bar, providing a cushion for the impact

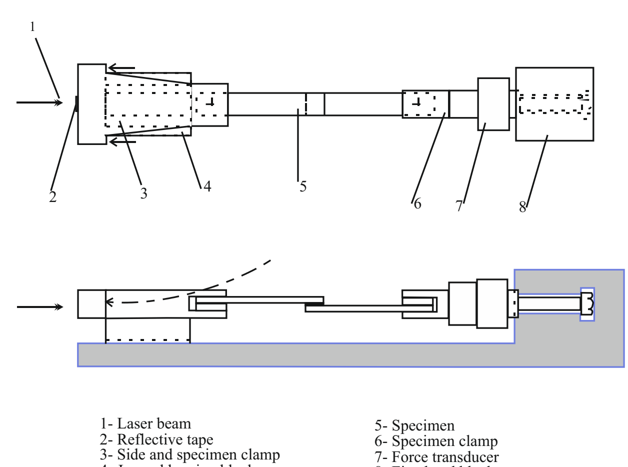

Fig. 2. Test rig for the impact testing of lap joints [12].