23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

DAMAGE TO ADHESIVE SINGLE LAP JOINT MADE OF MATERIALS WITH DIFFERENT PROPERTIES UNDER STATIC LOADING CONDITIONS

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Abstract: *Adhesive joints are increasingly used in construction of machines. Calculation models for determination of strains in adhesive joints used by engineers are burdened with simplification errors. Tests of joints of homogenous materials, especially metals have already been widely discussed in literature. The goal of this study is to define actual strength of a single lap joint made of homogenous and non-homogenous materials. The tests results have confirmed that a decrease in Young modulus of bonded materials is accompanied by reduction of the joint temporary strength. It was observed that the amount of work needed for a specimen to be destroyed is similar for joints characterized by cohesion fracture through the glue layer. For specimens with adhesive or cohesive fracture running through the bonded material, the work assumes lower values.*

Keywords: Adhesive joint, Single lap joint, Stress distribution, Hybrid joints.

1. Introduction

An adhesive joint involves bonding surfaces of two elements by means of a glue layer. Strength of the joint depends on adhesion forces (ability of the glue to adhere to a material surface) and cohesion forces (internal cohesion) hardened glue and the bonded material (Godzimiski, 2002 and Skorupa et al., 2013).

There are a few different calculation models of single lap joints which allow to determine the distribution of stress in the bonded joint. The most commonly used calculation model assumes a uniform distribution of tangent stresses throughout the joint. Volkersen model (Volkersen, 1938), closer to reality, includes strain of the connected elements. Goland Reisner (Goland et al., 1940) model neglects the impact of bending moment. Benson and Kesley model (Benson, 1970) additionally includes the theory of material strength which assumes that tangent stresses cannot occur on free surfaces. Subsequently, the maximum stresses do not occur on the edges of the joint but in their proximity (Hart-Smith, 1973 and Lucas et al., 2009 and Silva et al., 2012).

Connection of elements with different stiffness makes the distribution of stresses unsymmetrical in relation to the joint center and the maximum occurs at the end of the stiffest part.

An increase in differences of the bonded elements stiffness is accompanied with a drop in the joint stability expressed by the ratio of average stresses to maximum stresses (Hart-Smith, 1973 and Silva et al., 2011)

The goal of this study is to compare temporary strength of single lap joint specimens of material with different mechanical properties. Additional aim of the study is to compare work L involved in fracture of the specimens. The scope of work included an analysis of tests results for five types of joints made from materials: steel 1.0503, aluminum D16CzATW and epoxide- glass laminate.

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2. Methods

2.1. Test specimens

The specimens were prepared according to norm PN-EN 1465:2009. Dimensions of the specimens are given in Fig. 2. The surfaces to be bonded underwent grinding with abrasive paper with grain of P240, and then were cleaned with acetone .

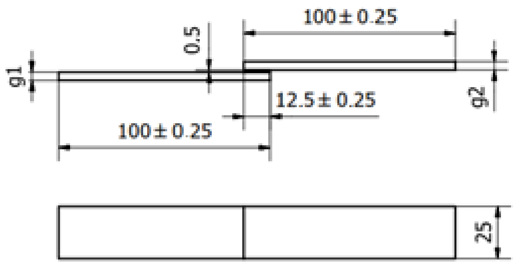

Fig. 1: Dimensions of specimens used for the tests.

Some parts of specimens were glued by methacrylic M20 in a device providing them with an axial position. Equal thickness of the joint was provided through placing in it a copper wire with diameter 0.5 mm. A clamp equal to 300n was used. The average thickness of the connected elements for given materials was respectively: steel 1.0503 – g = 3.89 mm (standard deviation 0.03 mm), aluminum D16CzATW – g = 3.87 mm (standard deviation 0.04 mm), polyester-glass laminate g = 3.61 mm (standard deviation 0.06 mm). Mechanical properties are presented in Tab. 1. Five specimens of each joint type were prepared and tested. The results are presented in Tab. 2.

Tab. 1: Properties of Construction Materials (Ligaj, 2015 and Ligaj, 2015).

Material		Steel 1.0503 (C45)	Aluminum alloy D16CzATW	Polyester-glass laminate
Tensile strength	MPa	682.0	460.0	213.4
Yield limit	MPa	458.0	336.0	-
Prolongation	%	24.3	25.2	2.4
Modulus of elasticity	GPa	215.00	68.40	11.56

Tab. 2: Types of joints

Lp.	Bonded material		Denotation
	Element 1	Element 2	
1	Steel 1.0503	Steel 1.0503	S-S
2	Steel 1.0503	Aluminum alloyD16CzATW	S-A
3	Aluminum alloyD16CzATW	Aluminum alloyD16CzATW	A-A
4	Steel 1.0503	Polyester – glass laminate	S-L
5	Polyester-glass laminate	Polyester -glass laminate	L-L

2.2. Test stand

Tests were performed on a strength testing machine Instron. During the tests the displacement parameter was controlled for which a constant value was accepted to be equal to 1 mm/min. The force was measured by means of a dynamometer with 10 kN range. Displacement was assumed to be consistent with the machine traverse. Force was applied to axes of the specimens, in the middle of the joint thickness through application of pads in the strength testing machine gripe. Thickness of the pad was the thickness of the opposite element and of the joint.

2.3. Tests results

Exemplary dependencies of force in the function of displacement F = f(s) for each type of the joint are presented in Fig. 2a. Mean values of forces destroying a given type of joint are presented in Fig. 2b.

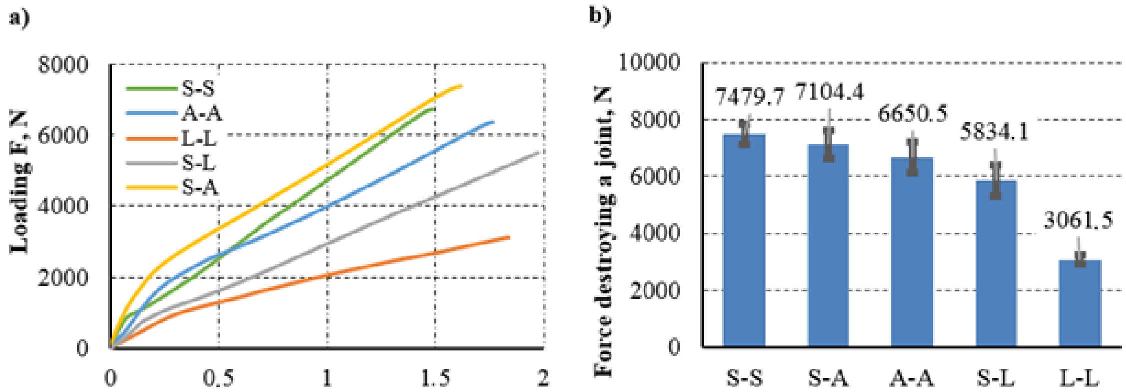

Fig. 2: a) Dependence of force in the function of displacement F = f(s) for tested adhesive joints; b) Presentation of maximum destruction forces F.

3. Conclusions

It was observed that the lower the stiffness of bonded elements the lower the temporary strength of adhesive joints. Damage to an adhesive joint involving bonding materials with different Young modulus occurred at a force whose value was a medium value of forces which destroy homogenous joints of these materials. This means that an increase in a joint strength is more affected by total stiffness of bonded elements. Results of tests were not consistent with the analysis of stress distribution according to Volkersen method. This analysis reveals higher maximum stresses for tested joints S-L or S-A than for homogenous joints with lower added stiffness, respectively L-L and A-A, which is inconsistent with experimental tests. Joints with higher total stiffness of bonded elements can be more resistant to bending moment. It is included in Golan-Reissner analysis, however it does not find application in joints made of non-homogenous elements. Stress at break that occurs in result of bending can have a significant influence on strength of the glue layer. Acceptance of linear properties of glue can also be the cause of error in majority of calculation models.

Analysis of diagrams F = f(s) (Fig. 2a) enabled calculation of the value of amount of work needed for each speencim to be destroyed. The method for determination of this work is presented in Fig. 3a. The determined values were averaged for a given type of joint and standard deviation was calculated. The results are presented in Fig. 3b.

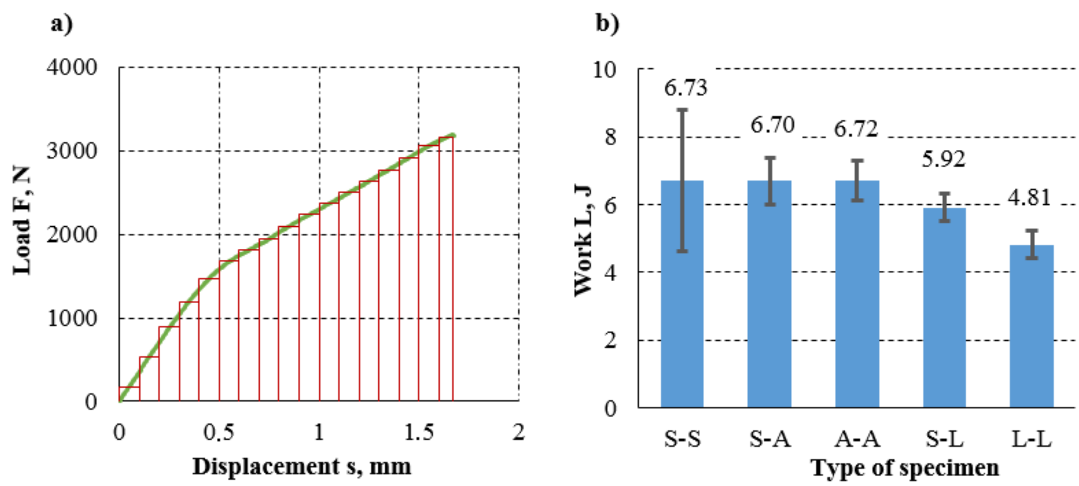

Fig. 3: a) Method for determination of work needed for a given specimen to be destroyed; b) Mean values of work performed until destruction of the specimens of a given joint with standard deviation.

The calculation results of the amount of work needed for joints of the type S-S, S-A, A-A to be destroyed, revealed similar values. The character of damage to specimens of these joints was found to be of adhesive. Joints, whose one part was made of laminate showed local separation of the laminate in the closest to the joint layer (Fig. 4a). Full one sided separation of laminate was found for specimens in Fig. 4b.

Fig. 4: Fractures of bonded joints: a) laminate – steel 1.0503; b) laminate – laminate.

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