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The effect of the adherend width on the strength of adhesively bonded single-lap joint: Experimental and numerical analysis

Kürşat Gültekin [a], Salih Akpinar [b,*], Adnan Özel [a]

[a] Dept. of Mechanical Eng., Atatürk Üniversity, 25240 Erzurum, Turkey
[b] Dept. of Mechanical Eng., Erzurum Technical University, 25050 Erzurum, Turkey

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ABSTRACT

In the present study, mechanical properties of different Single Lap Joint (SLJ) configurations with different adherent width values subjected to tensile loading were investigated experimentally and numerically. Using AA2024-T3 aluminum alloy as adherend and DP460 as paste adhesive, eight different types of single-lap joint samples (width of the adherent was 5, 10, 15, 20 or 25 m; overlap length was 5 ,10, 15, 20 or 25 mm) were produced for experimental studies. Stress analyses in the SLJ were performed non-linear finite element method by considering the geometrical non-linearity and the material non-linearities of the adhesive (DP460) and adherend (AA2024-T3). As a result, in SLJ geometries, increasing the adherent width raises the load-carrying capacity of the joints higher when compared to increasing overlap length. The failure load value of the joint increases as the area of bonding varies from rectangle to square. In addition, it was found that the data obtained from finite element analysis were coherent with experimental results.

1. Introduction

Adhesively bonded joints are increasingly being used in aerospace and automotive industries [1,2]. The use of adhesive bonding rather than traditional mechanical fasteners such as bolt, rivet, weld, and solder offers the potential for reduced weight and cost. However, there are still a number of issues that need to be solved before this technique is fully trusted by the industry. The stress distribution in the adhesively bonded joints are concentrated at the ends of the overlap giving rise to premature failures. Different methods, e.g., tapering the adherend, forming an adhesive fillet, changing the lap joint geometry, exist to reduce these stresses and many studies were conducted on this subject [3–9].

There are different types of adhesively bonded joints mentioned in the literature such as single-lap joint, double-lap joint, butt joint, T joint, bevel and scarf joint, etc. One of these joint types is single-lap joint (SLJ) which was examined extensively due to its simple geometry. These analyses showed that peel stresses and high stress concentrations form at the free edges of the adhesively bonded SLJs. In adhesively bonded joints, there are many techniques to increase the strength of the joint by reducing the values of these peel stresses.

One of these methods is spew fillet technique. The studies demonstrated that peel stress values reduced with this method and it was observed that strength values of the joints increased at the same time [9–17]. Crocombe and Adams [10] included the effect of additional parameters such as material and geometric properties. They found that triangular spews reduce the stress levels from those predicted for square-ended joints without spews. The effect of the change in the geometry of the adherend corners on the stress distribution in SLJs and, therefore, on the joint strength has been studied numerically and experimentally by Zhao et al. [15,16].

Another method to increase the strength of the adhesively bonded joints is increasing the overlap length [18–20]. In a study conducted by Ozel et al. [18], the effect of overlap length on durability of a film type adhesive was investigated. Within the scope of this study, failure load of the joints was increased by increasing the overlap length. However, it was also found that this increase occurred up to a certain overlap length value, above which it had no significant effect on failure load [19].

Meanwhile, it was observed that the use of a bi-adhesive in the overlap length region of the adhesively bonded joints also increased the failure load of the joints [21–25]. In a study performed by da Silva and Lopes [25], the behavior of SLJ geometry, which was obtained by using mixed-adhesive technique in the overlap area, under tensile loading was investigated. It was seen that the load-carrying capacity for mixed adhesive joints increased higher than that for adhesive joints obtained by using either brittle or ductile adhesives.

In a study conducted by Temiz et al. [26], mechanical behaviors of the two different single lap joint geometries, i.e., SLJ with flat

* Corresponding author. Tel.: +90 532 363 1099.
E-mail address: salih.akpinar@erzurum.edu.tr (S. Akpinar).

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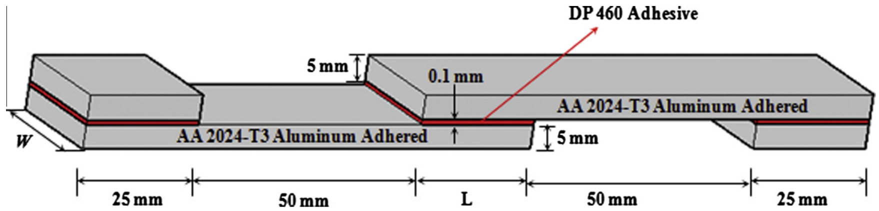
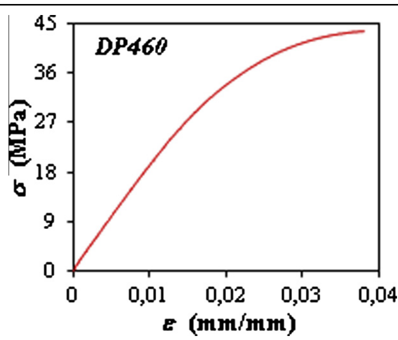
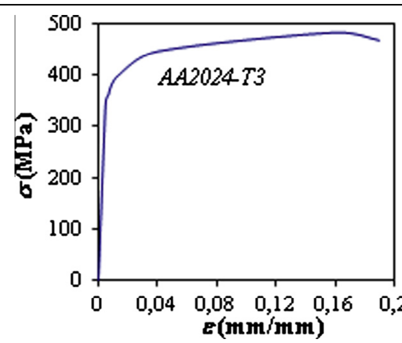


Fig. 1. Geometric parameters of SLJs:

Table 1
Tensile stress–strain curves and the material properties of the adhesive and adherend [17].





Properties	Materials	
	AA2024-T3	DP460
E (MPa)	72400	2077
v	0.33	0.38

v: Poisson's ratio, E: Young's Modulus

Table 2
Experimental parameters for SLJs.

Joint type	W–L (width–overlap length)	Adhesive area (mm^2)
Tvpe I a	25–25	625
Type I b	20–25	500
Tvpe I c	15–25	375
Type I d	10–25	250
Type I e	5–25	125
Tvpe II a	25–25	625
Type lib	25–20	500
Tvpe II c	25–15	375
Type II d	25–10	250
Type II e	25–5	125
Type III a	25–20	500
Type IIIb	20–20	400
Tvpe III c	15–20	300
Type III d	10–20	200
Tvpe III e	5–20	100
Type IV a	20–25	500
Type IV b	20–20	400
Type IV c	20–15	300
Type IV d	20–10	200
Type IV e	20–5	100
Tvpe V a	25–15	375
Type Vb	20–15	300
Tvpe V c	15–15	225
Tvpe V d	10–15	150
Type V e	5–15	75
Tvpe VI a	15–25	375
Type VIb	15–20	300
Type VI c	15–15	225
Type VI d	15–10	150
Type VI e	15–5	75
Type VII a	25–10	250
Type VII b	20–10	200
Tvpe VII c	15–10	150
Type VII d	10–10	100
Tvpe VII e	5–10	50
Type VIII a	10–25	250
Type VIII b	10–20	200
Tvpe VIII c	10–15	150
Type VIII d	10–10	100
Type VIII e	10–5	50

edges of the adherent and SLJ with curved overlap length of the adherent, subjected to tensile loading, were examined experimentally. In curvature SLJ, pressure was applied to the curved overlap area throughout the curing process until they were flattened. After curing, the elastic adherends' tendency to restore their shape back to their original curved form created a compressive stress perpendicular to the overlap area, which was particularly high at the overlap termini. These resulting compressive stresses decreased the effect of the peel stresses normally present at the overlap termini and increased the load-carrying capacity and displacement capacity of the adhesive joint [27].

In the literature, there is a limited study on investigation of the effect of adherent width on mechanical performance of adhesively bonded joints. In a study conducted by Adin et al. [28], the effect of the adherend width on the tensile strength and the failure load of Z joints was analyzed both experimentally and numerically using two adhesives with different properties. However, in that study, the area of the bonded region was not constant but increased with increasing width. The results showed that the joint strength