Effect of adhesive thickness on adhesively bonded T-joint

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Abstract. The aim of this work is to analyze the effect of adhesive thickness on tensile strength of adhesively bonded stainless steel T-joint. Specimens were made from SUS 304 Stainless Steel plate and SUS 304 Stainless Steel perforated plate. Four T-joint specimens with different adhesive thicknesses (0.5, 1.0, 1.5 and 2.0 mm) were made. Experiment result shows T-joint specimen with adhesive thickness of 1.0 mm yield highest maximum load. Identical T-joint specimen jointed by spot welding was also tested. Tensile test shows welded T-Joint had eight times higher tensile load than adhesively bonded T-joint. However, in low pressure application such as urea granulator chamber, high tensile strength is not mandatory. This work is useful for designer in fertilizer industry and others who are searching for alternative to spot welding.

1. Introduction

In fertilizer industry, urea granules are formed inside a granulator while floating on air cushion. Thin stainless steel perforated plate is an essential component to this process. Spot welding is mostly used to join perforated plate to its supporting frame. Welders often find difficulty in producing good quality welds on thin stainless steel plate. Due to its thinness, it sensitive to high heat input which can cause significant reduction in material strength, e.g. burn through, cracking, porosity and plate distortion.

Many researchers studied adhesive bonding that covers broad spectrum of parameters such as joint configuration, adherend material, surface preparation, temperature, corrosion and humidity. Others studied mechanical behavior such as shear, tensile and peel strength. Kant and Narayanan [1] experimented epoxy adhesive lap joint with adhesive thicknesses of 0.5, 1.3 and 2.4 mm. Costa Mattos et al. [2] studied the effect of adhesive thickness on butt joint. Both researchers concluded that thinner adhesive yield higher tensile strength. Although the conclusion is indisputable, study on adhesive thickness is limited to lap joint and butt joint.

Some researchers studied T-joint in various combinations of stiffeners and adhesive parameters. Khalili and Ghaznavi [3] examined T-joint stiffened with triangular block on each side. Various specimens with different triangular angle were subjected to tensile load. Guo and Morishima [4] constructed T-joint specimen stiffened with adhesive cleat. Silva and Adams [5] experimented T-joint with thin and thick perpendicular adherend together with various configurations of stiffeners. Hu et al.

[6] studied the effect on bond-line length of a T-joint. Tensile test were performed with varied bond-line length. Their T-joint specimen was jointed with two 90◦ angle aluminum sheet, whereas this study was focused on construction of T-joint with two plates in perpendicular to each other. Although these researchers studied T-Joint, all specimens were stiffened. Various adhesive thicknesses were also not examined.

In this study, adhesively bonded T-joint specimens were constructed with thicknesses of 0.5, 1.0, 1.5 and 2.0 mm. Adherend were SUS 304 Stainless steel plates and SUS 304 perforated plates, similar to material used in most urea granulator. Tensile tests were performed to investigate maximum tensile load and type of adhesive failure. Welded specimen was subjected to similar test for comparison.

2. The experiment

To simulate actual construction of granulator, 10 mm thick SUS 304 Stainless Steel plate and 1.25 mm thick SUS 304 perforated plate were used as adherend. In this study, two-part epoxy adhesive, Araldite 2011 were used to join both adherend to form a T-joint as shown in Fig.1. The dimension of bonded area is 10 mm width and 100 mm length. Special jig and shim plates were used to control adhesive thickness during fabrication as shown in Fig. 2.

Four specimens were fabricated with different thickness of 0.5, 1.0, 1.5 and 2.0 mm, respectively. For each thickness, testing were performed 6 times to ensure consistency, where average value were taken. Grease and dirt were cleaned by acetone before jointing. For each specimen, time taken for curing was 16 hours. T-joint specimen was bolted to a special platform before it can be mounted to Autograph universal testing machine as shown in Fig.3. To ensure consistency in result, 6 specimens were fabricated for each adhesive thickness. Tensile testing was conducted at room temperature with cross head speed of 1 mm/min. Welded specimen was also tested in similar method to analyze maximum tensile load in comparison with adhesively bonded specimens.

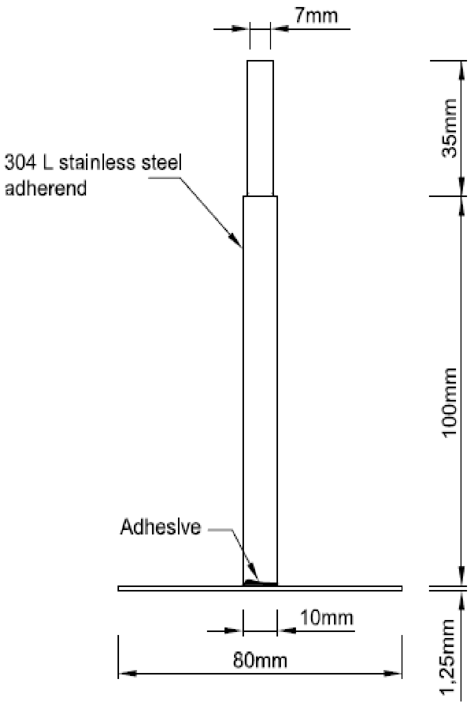

Figure 1. T-Joint specimen.

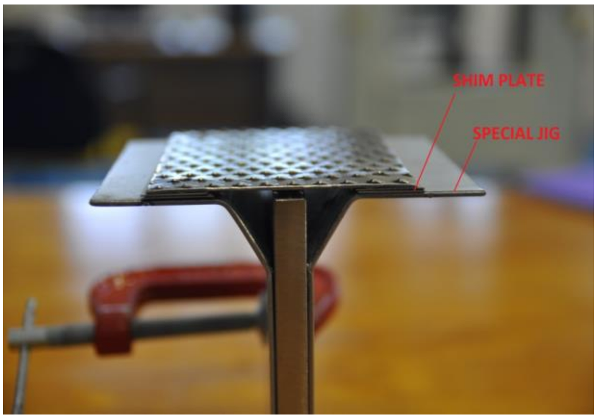

Figure 2. Special jig to control adhesive thickness by using shim plate.

Figure 3. Specimen mounted on UTM machine.

3. Results and discussion
Figure 4 shows failure load of all specimens tested. Specimen thickness of 1.0 mm yields highest tensile load among adhesively bonded specimen. In comparison, welded specimen failure load was 8 times higher than adhesive specimen. The results of this experiment show that there is an optimum thickness that yield highest tensile load. Figure 5 shows peak tensile load was observed at 1.0 mm adhesive thickness before it drops.

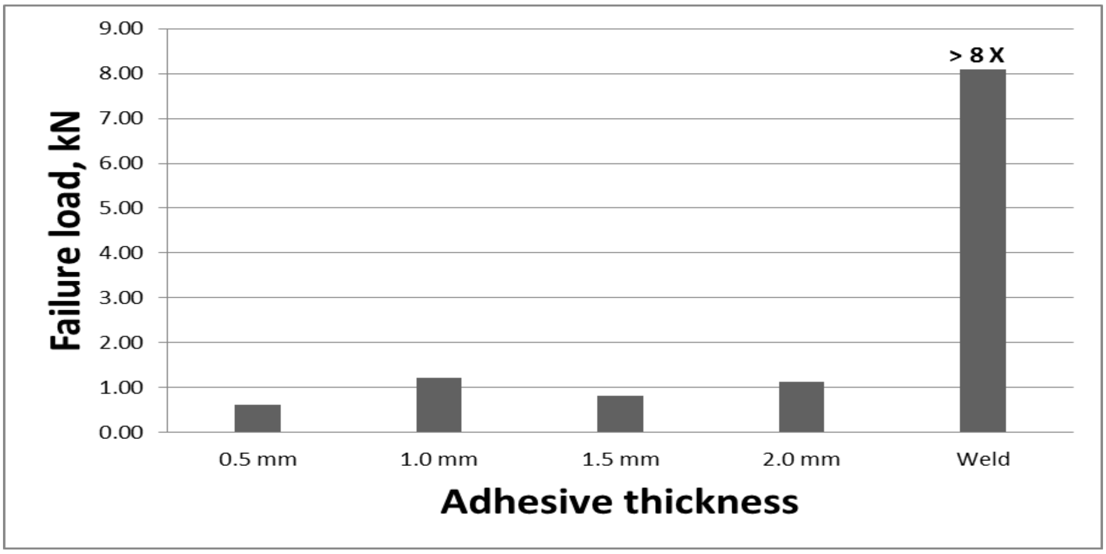

Figure 4. Failure load (kN) of 4 different adhesive thickness specimens vs. weld specimen.

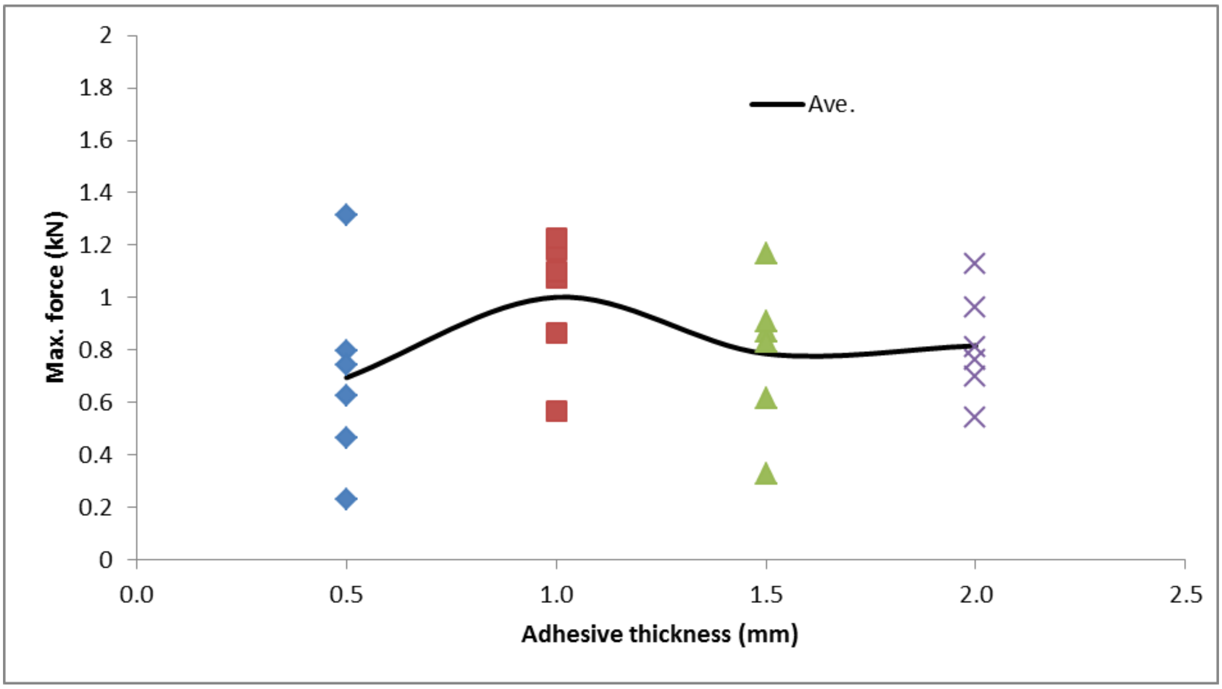

Figure 5. Tensile load peak at 1.0 mm adhesive thickness.

The experimental result indicates that failure load increases as adhesive thickness increases, until it reaches the optimum thickness. Once optimum thickness is reached, failure load will decrease slightly and consequently plateau. Kinloch [7] studied Goland and Reissner, Volkersen theory as well as finite-element analysis on thickness effect in adhesively bonded single lap joint. All theories in Kinloch's study indicate that thicker adhesive layer will result in increased failure load. In contrast, experimental result shows that fracture load does not increase in tandem with increasing adhesive thickness but rather fall slightly. The experimental result of this current work shows similar pattern as Kinloch's report.

4. Conclusion

In this paper, tensile tests were conducted on stainless steel T-joint specimen. The effect of adhesive thickness was analyzed. Optimum adhesive thickness was found at 1.0 mm where the failure load was the highest. Experimental result shows that failure load increases as adhesive thickness increase until it reaches 1.0 mm adhesive. Once it reaches 'optimum' thickness, failure load will reduce slightly and plateau.

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5. References

[1] Ravi K and Narayanan R G *J. Testing and Evaluation* **40**
[2] Mattos H S C, Sampaio E M and Monteiro A H 2010 *Int. J. Adhes. Adhes.* **30** 774
[3] Khalili S M R and Ghaznavi A 2011 *Int. J. Adhes. Adhes*. **31** 347
[4] Guo S and Morishima R 2011 *Composite Structures* **94** 229
[5] Lucas F M S and Adams R D 2002 *Int. J. Adhes. Adhes.* **22** 311
[6] Ping H, Qi S, Weidong L and Xiao H 2012 *Int. J. Adhes. Adhes.* **38** 17
[7] Kinloch A J 1987 *Adhesion and Adhesives* (Chapman and Hall) 227