Effect of Nugget Size on Stress Distribution in Weld-bonded Single Lap DP 600 Steel Joint

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Abstract. The effect of the nugget size from 2 mm to 8 mm in the lap zone of the adherend on the stress distribution in weld-bonded single lap DP 600 steel joint was investigated using elastic finite element method (FEM). The results from the numerical simulation show that the value of the peak stress along the bondline at the center of lap zone increases a little when the larger nugget is arranged but the width of the peak stress is increased greatly as the nugget size increased. It is suggested that a larger nugget arranged in the lap zone may be appropriate to optimize the stress distribution in the weld-bonded single lap DP 600 steel joint and its fatigue life would be longer than the joint that with a smaller one.

Introduction

The higher yield stress metal sheets including dual phase (DP) steel are increasingly manufactured with spot weld or weld-bonded joints used in the railroad passenger cars and automobile industry [1-3] to establish a low-carbon economy and energy conservation promoted globally. Hayat [2] compared the properties of adhesive bonding, resistance spot welding, and adhesive weld bonding of coated and uncoated DP 600 steel. Bartczak et al [3] presented a numerical analysis of stress distribution predictions when shearing high strength low alloy and DP sheet joints and proved that the overlap size increase results in a smaller overlap rotation in relation to the loading force. The effect of the elastic modulus of adhesives and the chamfer angle on the stress distribution of the weld-bonded single lap aluminum joint was studied in authors' work [4-5]. Liu et al [6] founded that the fatigue life of spot welds under the fixed loads increased with the nugget size, which was especially evident for the spot-welded thin plates. The goal of this work is to study the effect of the nugget size on the stress distribution in the weld-bonded single lap DP 600 steel joint made of thin plate of 2 mm thickness.

Finite Element Model and Mesh

The model and mesh were built using the ANSYS finite element software as shown in Fig.1 and Fig.2. The properties of the materials used in this study are listed in Table 1. The load applied was taken as 2 kN and the dimensions of the DP 600 steel adherend were made in accordance with the Chinese standard GB 7124 (which is equivalent to the standard ISO 4587) as shown in Fig.1. The thickness of the adhesive bondline was set as 0.2 mm and divided into 4 layers. Four nugget size sizes were taken into account as 2, 4, 6 and 8 mm respectively and the nugget was assumed in a shape of ellipsoid.

Table 1 Mechanical Properties of the Materials

Materials	Elastic Modulus (GPa)	Poisson's Ratio	Yield Strength (MPa)
DP 600 steel	207	0.3	370
Phenolic resin adhesive	2.875	0.42	90

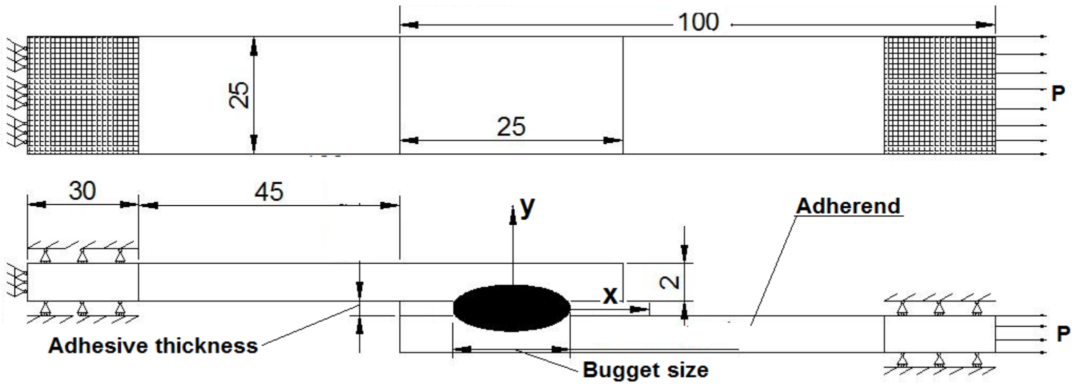

Fig.1 Finite element model (unit: mm)

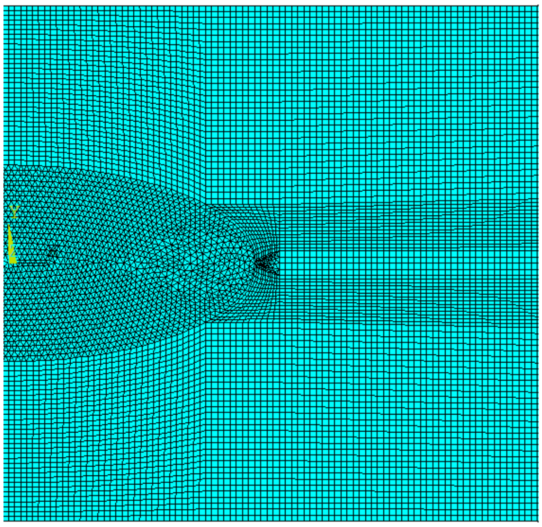

Fig.2 Finite-element meshes for right half of over lap zone.

Results and Discussion

The effect of the nugget size on the stress distribution along x axis (y = 0) is presented in Fig.3. The results from the simulation showed the peak values of the stress components *Sx* as well as *Sxy* and the von Mises equivalent stress *Seqv* are not evidently affected by the nugget size (Fig. 3) and the stress distribution along the x-axis is symmetrical to the center of the overlap zone. For the peak value of the stress *Sx*, *Sy*, *Sxy* and *Seqv* occurred at the points near both ends of the over lap zone in the joint, it is almost the same as the nugget size increased from 2 mm to 4 mm. For instance, the peak value of stress longitudinal *Sx* is increased about 0.0005 % from 10.404 MPa to about 10.409 MPa when the nugget size increased from 2 mm to 8 mm (Fig. 3b). In other words, the value of the peak stress *Sx*, *Sy*, *Sxy* and *Seqv* occurred at the points near both ends of the over lap zone is not affected by the nugget size. Compared the results obtained with that reported in Ref. [4] and [5], the effect of the nugget size for the peak stress *Sx*, *Sy*, *Sxy* and *Seqv* occurred at same points is not similar to that the peak stress was evidently decreased when the lower modulus adhesives or a chamfer angle less than 60 degree was arranged for a weld-bonded single lap aluminum joint. The reasons may be the difference in the adherends (steel to aluminum) and the length of the lap zone

(25 mm to 12.5 mm). It is clearly that the peak stress in the nugget increased as the nugget size increased and the width of the peak stress zone was increased greatly as the nugget size increased (Fig. 3a and 3d) which means a lot of load carried by the nugget. The stress distribution tendency of the peel stress *Sy* (Fig. 3b) is similar to that of shear stress *Sxy* (Fig. 3c) but the value of the valley stress *Sy* is nearly same in the middle part of the nugget. In spot weld joints, the gap between the inner surfaces of the welded plates close to the nugget increased the stress concentration in the HAZ near the gap and shortened the fatigue life [6]. But in the weld-bonded joint, part of the load is carried by the adhesive layer so that the fatigue life of the joint n could postpone according to the lower stress concentration occurred in it.

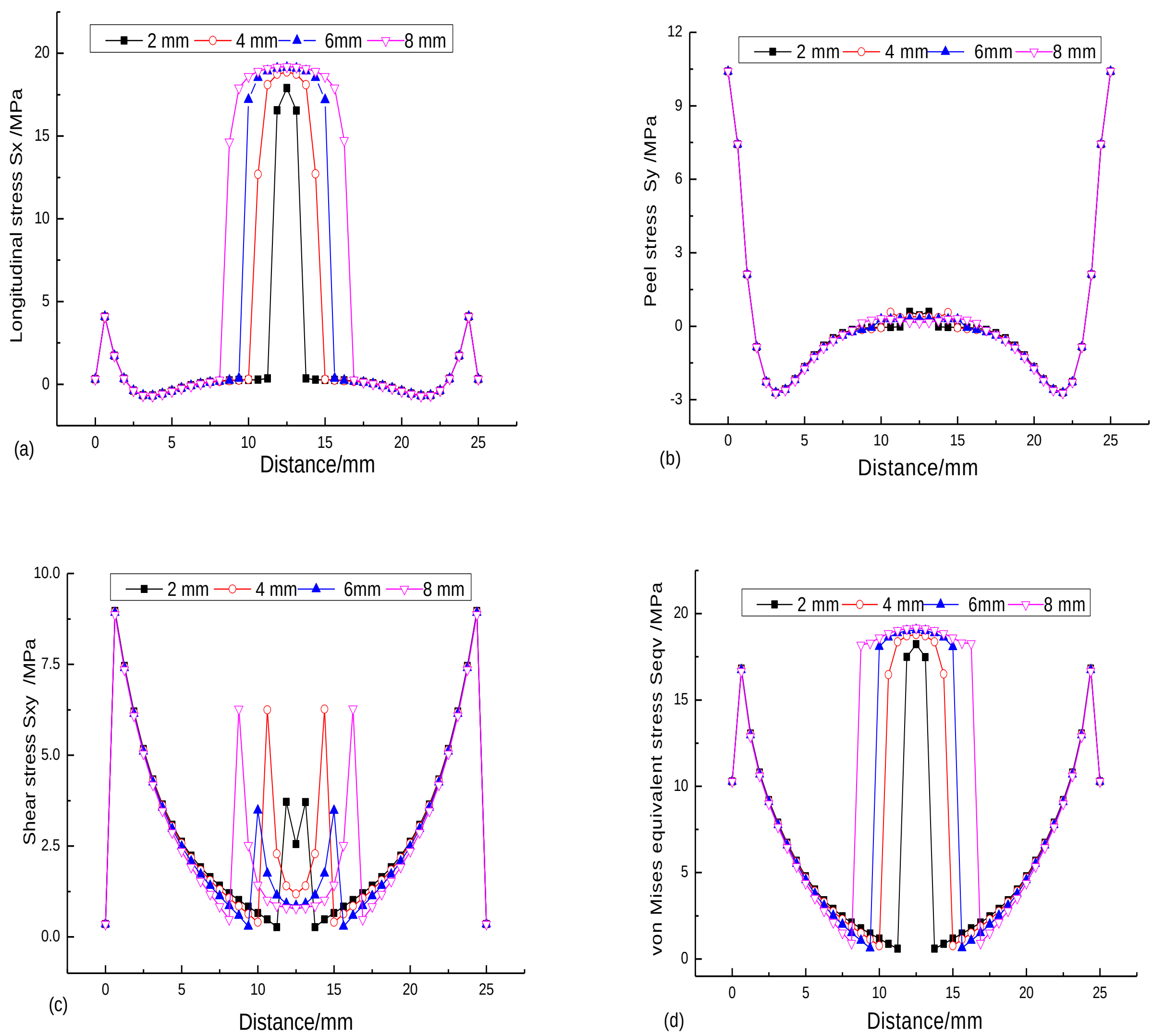

Fig.3 Effect of the nugget size on the stress distribution along the mid-bondline: (a) longitudinal stress Sx;

(b) peel stress Sy; (c) shear stress Sxy and (d) von Mises equivalent stress Seqv

When the conditions was kept as the same, the effect of the nugget size on the stress distributed in the adherend near the interface (y = - 0.15 mm) is shown in Fig.4. The results from the finite element analysis also showed that the values of the stress *Sx*, *Sy* and *Seqv* are not varied evidently as the nugget size increased. For shear stress *Sxy*, the peak values at points corresponding to both edges of the nugget is increased first as the nugget size increased from 2 mm to 6 mm and then kept as the same at right edge of nugget as its size increased to 8 mm (Fig. 4c).

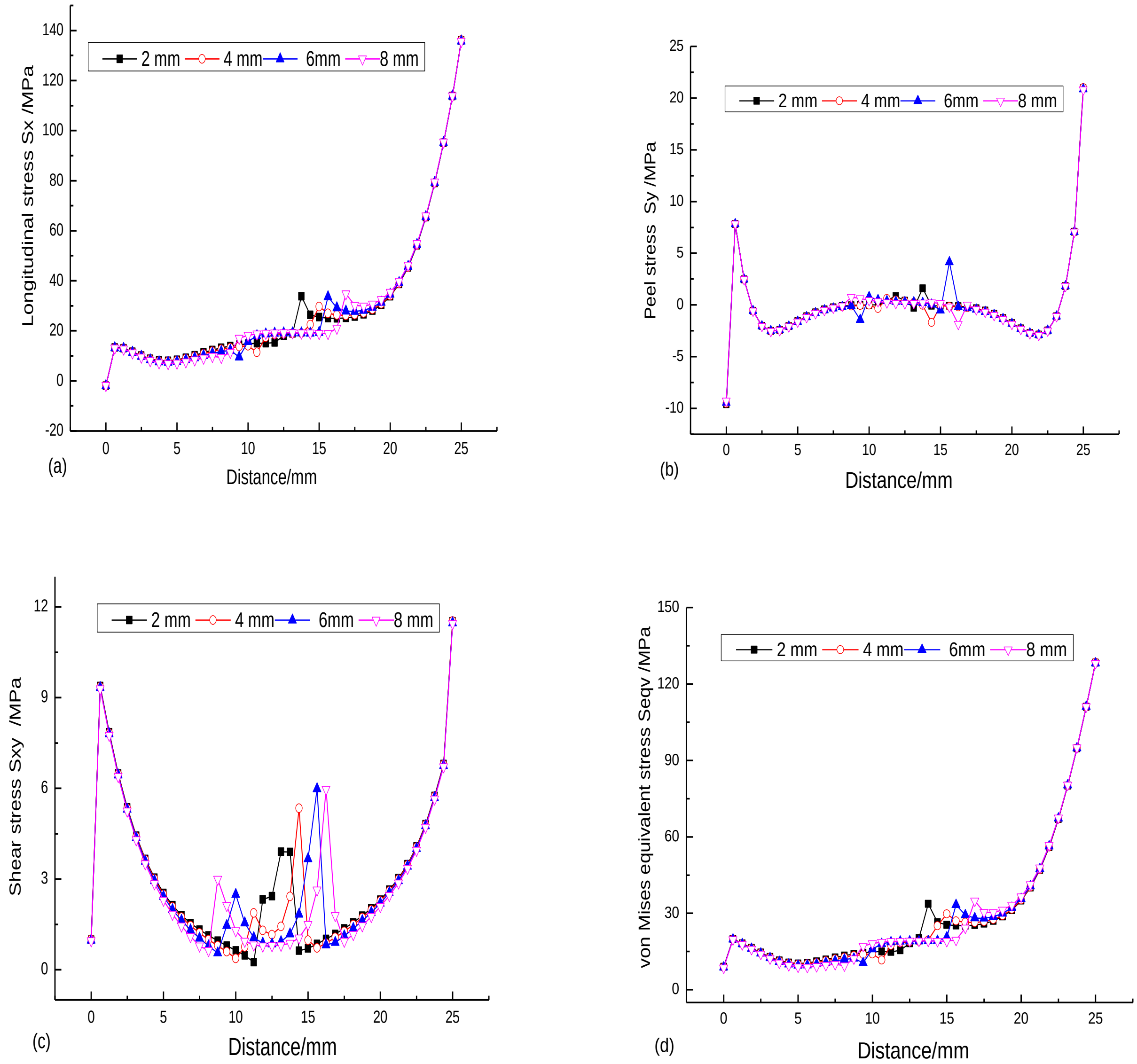

Fig.4 Effect of the nugget size on the stress distribution in adherend near the interface: (a) longitudinal stress Sx; (b) peel stress Sy; (c) shear stress Sxy and (d) von Mises equivalent stress Seqv.

Summary

The results obtained show that peak stress along the x-axis in the nugget increased as the nugget size increased meanwhile the width of the peak stress zone was increased greatly which means that much more load is carried by the nugget. It is suggested that a larger nugget be arranged in the lap zone to optimize the stress distribution in the joint and its fatigue life would be longer than of the joint with a smaller nugget. The value of the peak stress occurred at the points near both ends of the over lap zone is not affected by the nugget size. It is also recommended that weld-bonded DP 600 steel joint be used to replace the spot-weld joint in which part of load is carried by the adhesive layer so that the lower stress concentration could postpone the fatigue life of the joint.

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