FINITE ELEMENT MODELING OF WELD-BONDED JOINTS

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ABSTRACT

The present work aimed at predicting the strength of weld-bonded joints. For comparison purposes, adhesive-bonded and spot-welded joints were also included in this study. The present work demonstrated that, the major principal stress predicted in spot welded joints is nearly five to six times, compared with those associated with weld-bonded and adhesive bonded joints, respectively. The present work also demonstrated the effective role played by the adhesive layer in strengthening weld-bonded joints.

Keywords: *Weld bonded joint, Major principal, Finite-Element modeling. Adhesive bonded Joint, Spot welded joint.*

الملخص

يهدف هذا العمل إلى التنبؤ بالاجهادات المتولدة في الوصلات الملحومة بلحام النقطة والمدعومة بالمواد اللاصقة. ويشتمل هذا العمل بالإضافة إلى ذلك تحليلا للوصلات الملصوقة والوصلات الملحومة بلحام النقطة وذلك بهدف المقارنة مع الوصلات الملحومة المدعومة بألصق. اظهر هذا العمل آن الاجهادات المتولدة في الوصلات الملحومة بلحام النقطة تصل بين خمسة إلى ستة أضعاف تلك المتولدة في الوصلات الملصوقة أو الملحومة المدعمة بالمواد اللاصقة. بالإضافة إلى ذلك فقد القي البحث الضوء علي الدور الفعال الذي تقوم به طبقة المادة اللاصقة في تدعيم متانة الوصلات الملحومة بلحام النقطة المدعم باللصق

1. INTRODUCTION

Bonded structures can be of two types based on either purely adhesive or an adhesive/ mechanical connections. The bonded/mechanical types include bonded welded, bonded-riveted and bonded- screwed connections. The combined connections (bonded-welded, bonded-riveted and bonded-screwed) ensure high fatigue strength of the structures and are extremely economical, because they do not require any fixtures for use during the cementing process.

Weld-bonded joints were first developed and used in USSR in planes of the type AN-24 [Schwartz,1979]. The weld-bonding process is essentially the spot-resistance welding of parts that subsequently have their overlapping areas adhesive-bonded. The Soviet Union initially perfected this technology, which is known there as "glue welding". The approach was a "flow-in" method, whereby parts were welded together first, then the adhesive was flowed into the joint. A low-viscosity adhesive is used which penetrated the overlap joint by capillary action and is subsequently cured. The technique used in the United States is the weld-through method, whereby the adhesive is applied to the parts to be cured, spot welded and subsequently joined. In comparison with mechanical fasteners, weld-bonding offers the following benefits [Darwish et al.,2000]:

- High static strength.
- Improved fatigue strength.
- Elimination of sealing operations.
- Improved corrosion resistance.
- Elimination of the shop noise of riveting.
- Reduced manufacturing costs and adaptability to mechanization.

The degree of acceptance of weld-bond applications has been increasing, as the process has been understood and its mechanical properties developed. Since little attention has been given in the past to the analysis of weld-bonded joints, consequently the present work aimed at predicting the strength of weld-bonded joints. The finite element technique was used in the present work as it avoids the approximations of the closed-form solutions in neglecting the strain energy of certain stresses within the joint, so enabling more accurate results to be obtained [Khalil et al,1990, Darwish et al, 1991,Al Samhan,1999].

2. FINITE ELEMENT MODELING AND BOUNDARY CONDITIONS

Fig.1 shows the configuration and dimensions (B.S.5350) of the considered joint. Three finite element models were considered; a spot welding model, an adhesive bonded model and a weld bonded model. The configurations of these models including constrain and loading conditions are shown in Fig.2. The material properties of the strips and adhesive materials are listed in table 1.

The meshes of these finite element models were generated using the ***GID*** preprocessing program [CIMNE]. The FE computation was carried out using ***Calsef*** FE program, which is an internal module inside the ***GID*** program. ***GID*** is widely used for generating data and results visualization in a number of linear and non-linear problems in structural engineering mechanics, using the finite element method. In ***Calsef*** , the principal of minimum potential energy (the force method) is used and the set of equations to be solved is:

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$$[\,k\,]\,\{b\} = \{f\}$$

Where [k] is the stiffness matrix, {b} is the vector of nodal displacement and {f} is the vector of nodal loads. The element used throughout the modeling process was three-node linear triangular element and the following assumptions and boundary conditions were considered throughout the idealization process:

- The problem is two-dimensional.
- The adhesive layer is isotropic, i.e. stresses on the micro-scale, such as those caused by flaws in the adhesive, were neglected.

The restrained points as well as the applied load (position and value) were kept constant to enable fair comparison between the data to be made. The applied load was taken to be the relatively small value of 500 N, as the displacement and accordingly the stresses are assumed proportional to the load in ***Calsef*** program. Fig. 3, shows the deformed mesh overlaid on the undeformed mesh for the weld-bonded FE model.

3. STRENGTH PREDICTION OF SPOT WELDED, ADHESIVELY BONDED AND WELD-BONDED JOINTS

3.1. Normal Stress (Σ_x) Distribution Along The Mid Layer Of The Considered Joints

The predicted normal stresses (σ_x) through the mid-layer of the spot welded, adhesive bonded and weld-bonded joints are shown in Fig. 4. From the figure it can be observed that the normal stresses are concentrated at the far ends of the weld nugget in case of spot welded and weld-bonded joints. It is worth noting that the spot-welded joint shows a 160% higher stress concentration, when compared with the weld-bonded joint. However, the normal stresses are concentrated at the free ends of the adhesive bonded joint showing a 480% lower stress concentration, when compared with the weld-bonded joint.

3.2. Normal Stress (Σ_y) Distribution Along The Mid Layer Of The Considered Joints

The predicted normal stress (σ_y) through the mid-layer of the spot welded, adhesive bonded and weld-bonded joints are shown in Fig. 5. From the figure it can be observed that the normal stresses are concentrated at the far ends of the weld nugget in case of spot welded and weld-bonded joints. It is worth noting that the spot-welded joint shows a 280% higher stress concentration, when compared with the weld-bonded joint. However, the normal stresses are also concentrated at the free ends of the adhesive bonded joint and shows nearly the same stress concentration as the weld-bonded joint.

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3.3. Shear Stress(T_{xy}) Distribution Along The Mid Layer Of The Considered Joints

The predicted shear stress (τ_{xy}) through the mid-layer of the spot welded, adhesive bonded and weld-bonded joints are shown in Fig. 6. From the figure it can be seen that the shear stresses are concentrated at the far ends of the weld nugget, in case of the spot welded joint. It is worth noting that the spot-welded joint shows a 625% higher stress concentration, when compared with the weld-bonded joint. The shear stresses are also concentrated at the free ends of the adhesive bonded joint, however they show nearly the same stress concentration as the weld-bonded joint.

3.4. Major and Minor Principal Stress Distribution Along the Mid Layer of the Considered Joints

The predicted major and minor principal stresses through the mid-layer of the spot welded, adhesive bonded and weld-bonded joints are shown in Figs.(7 and 8).From the figures it can be observed that the stresses are highly concentrated in the spot welded joints, when compared with the weld-bonded and the adhesive bonded joints. For example, the major principal stress of the spot welded joint is nearly five to six times, when compared to weld-bonded and adhesive bonded joints, respectively.

4. CONCLUSIONS

- The stresses are concentrated at the far ends of the overlap area, in case of adhesive bonded joints. In case of spot welded joints, they are found to be concentrated at both ends of the welding nugget. However, they are concentrated at the overlap region as well as both ends of the welding nugget, in case of weld-bonded joints.
- The principal stresses are highly concentrated at the ends of the spot welded joints, compared with those developed at the far ends of adhesive bonded joints and weld-bonded joints.
- The major principal stress developed in the spot welded joint is nearly five to six times compared to the principal stresses associated with weld-bonded and adhesive bonded joints, respectively. This demonstrates the role played by the adhesive layer in strengthening weld-bonded joints.

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Table 1 Material properties for joined strips and adhesive material.

Material	Young modulus	Poisson's ratio
Steel	$2.0x10^5$ N/mm^2	0.3
Adhesive	$2.5x10^3$ N/mm^2	0.38

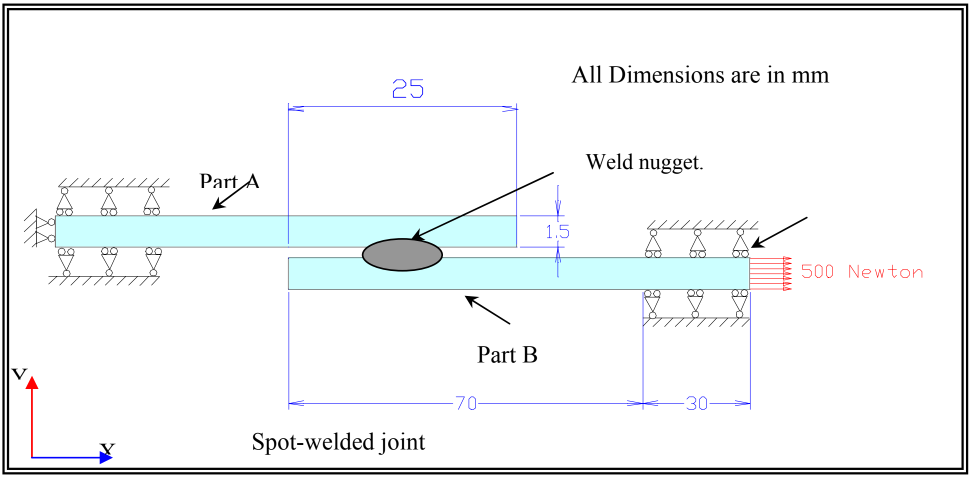

Figure 1 Overall dimensions of the spot welded joint used in FE model (BS 5350).

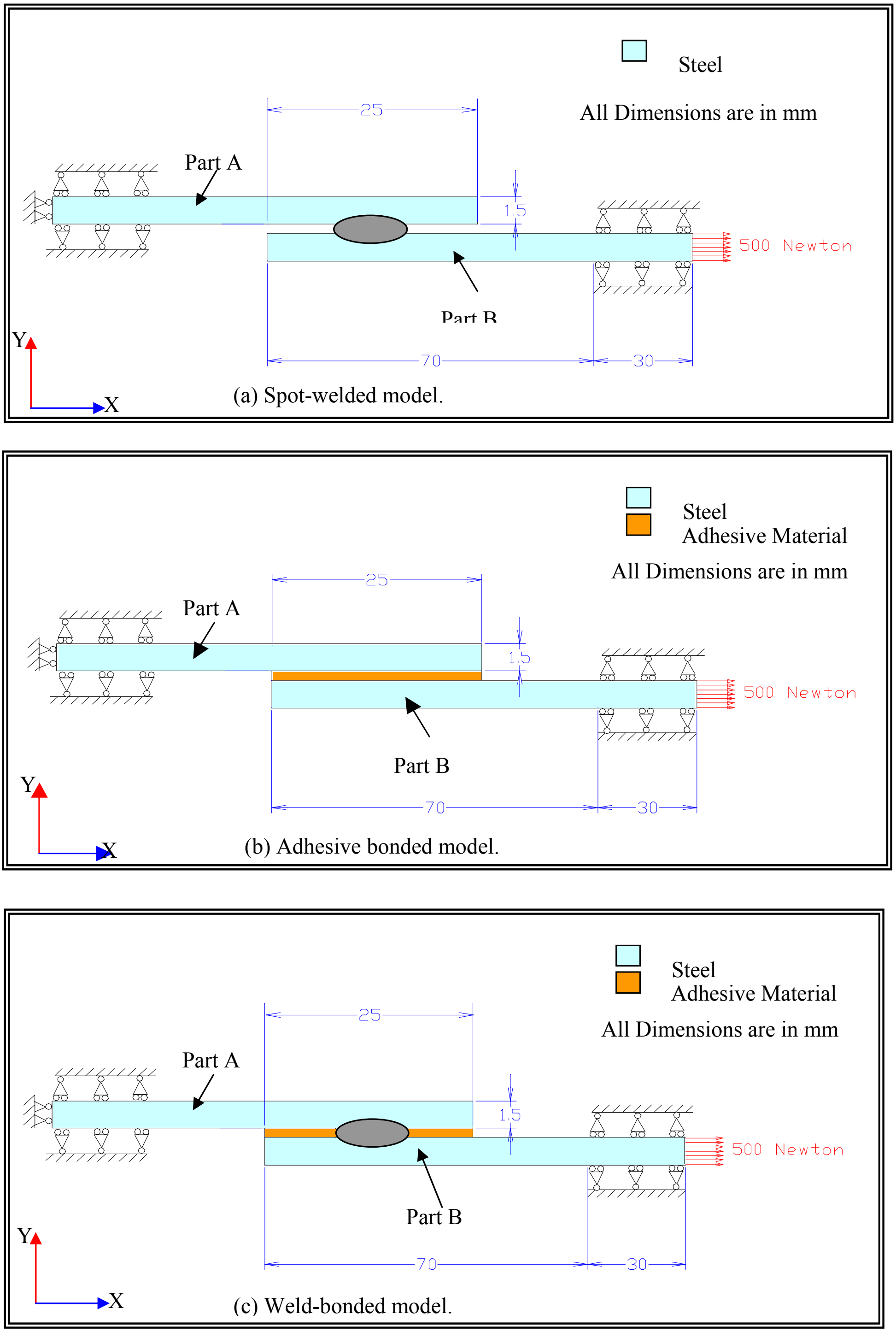

Figure 2 Spot, adhesive bonded and weld-bonded models.

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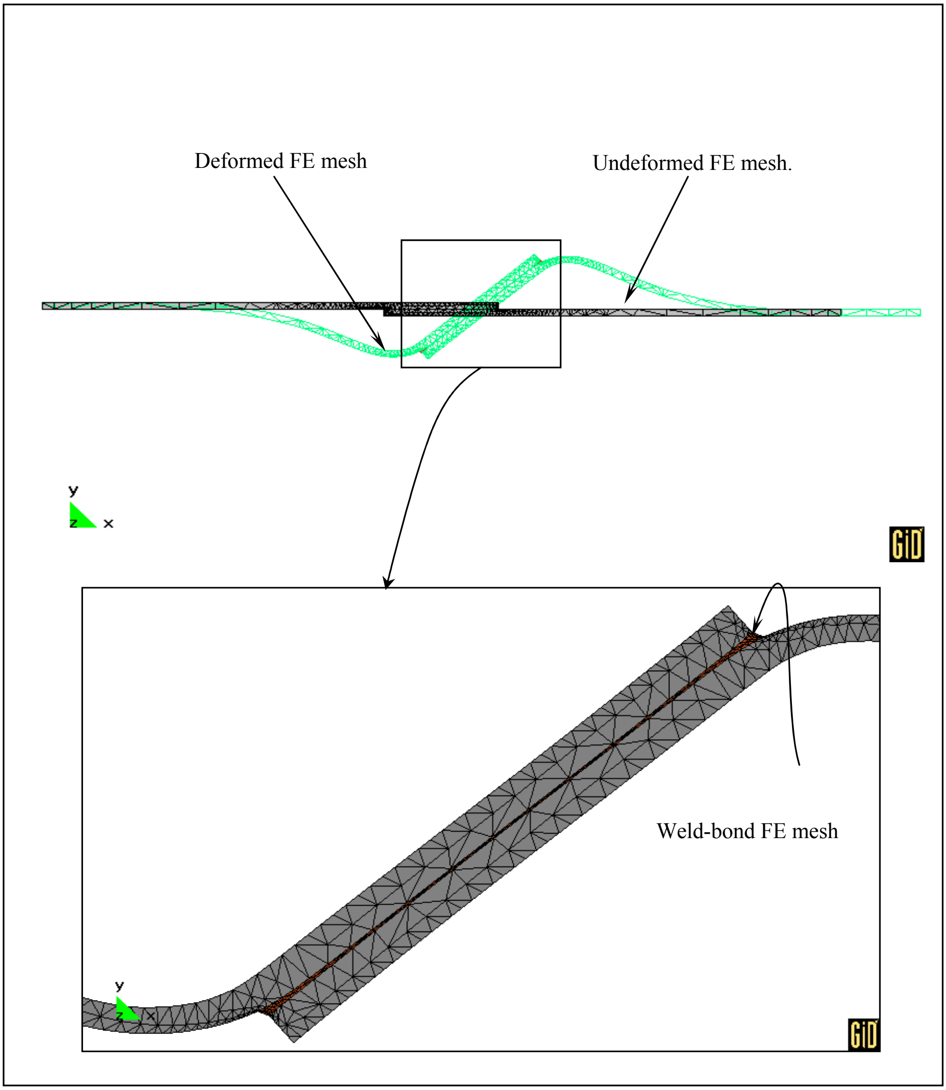

Figure 3 Post processing output of deformed and undeformed FE meshes for weld-bonded FE model.

(Note; the deformed mesh is scalled by a factor of 46 in order to illustrate the deformation)

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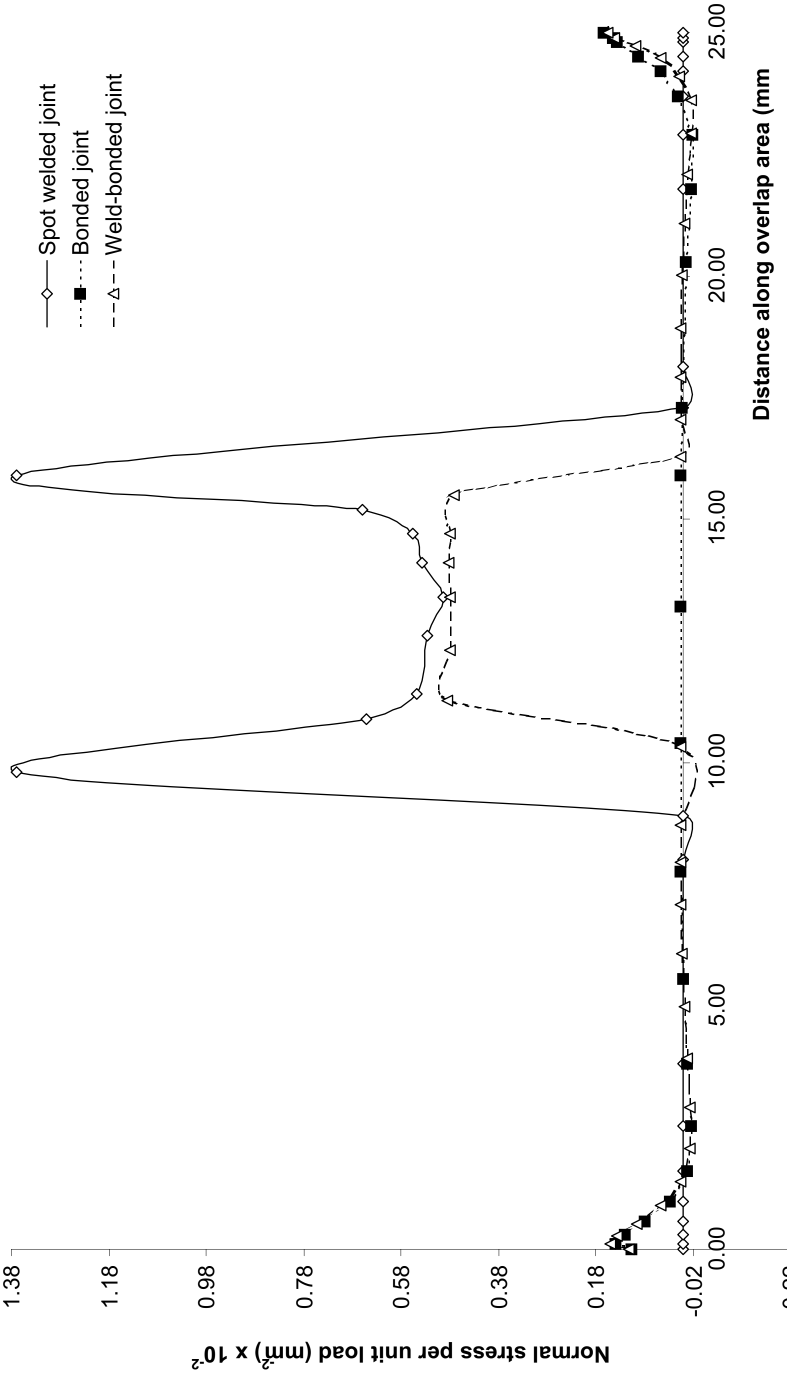

Figure 4 Normal stress σ_x distribution along the mid-layer for three models.

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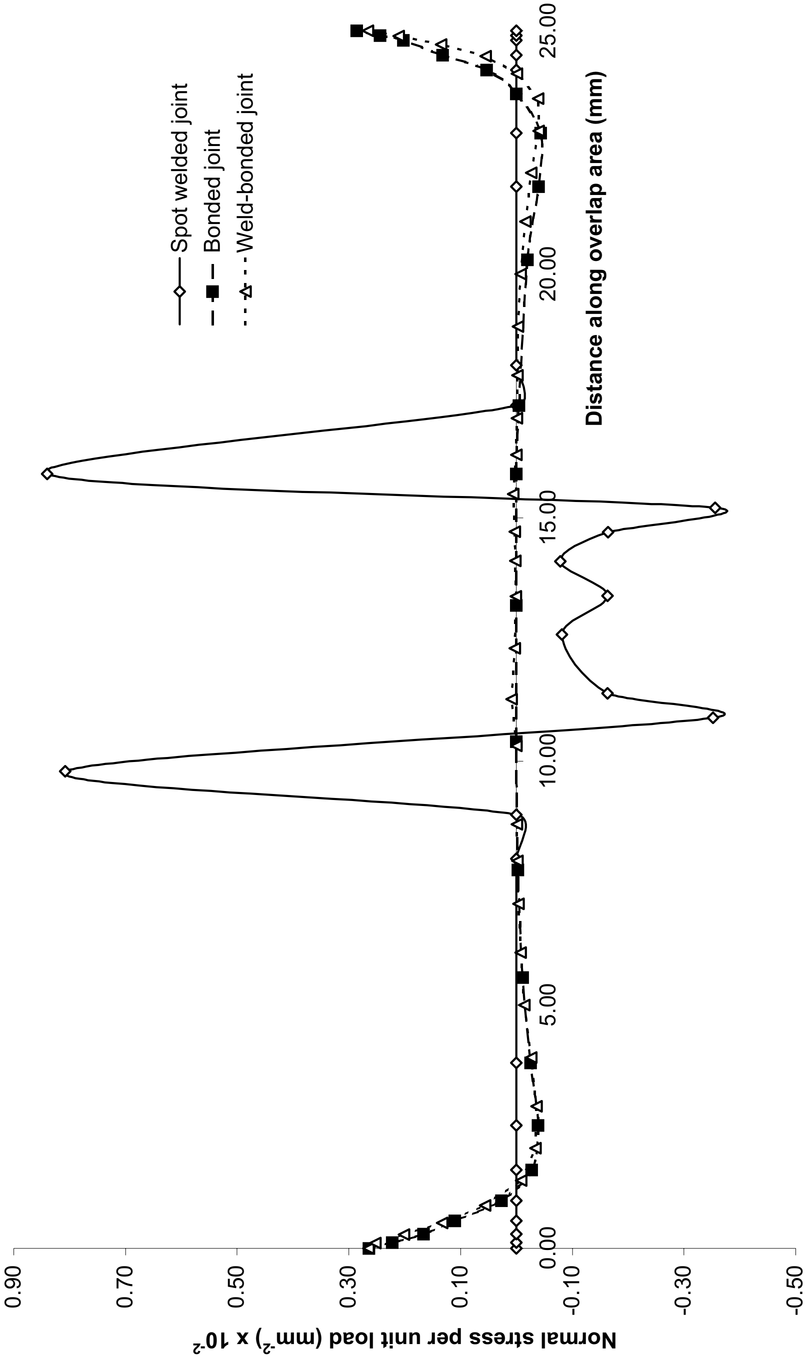

Figure 5 Normal stress σ_y distribution along the mid-layer for three models.

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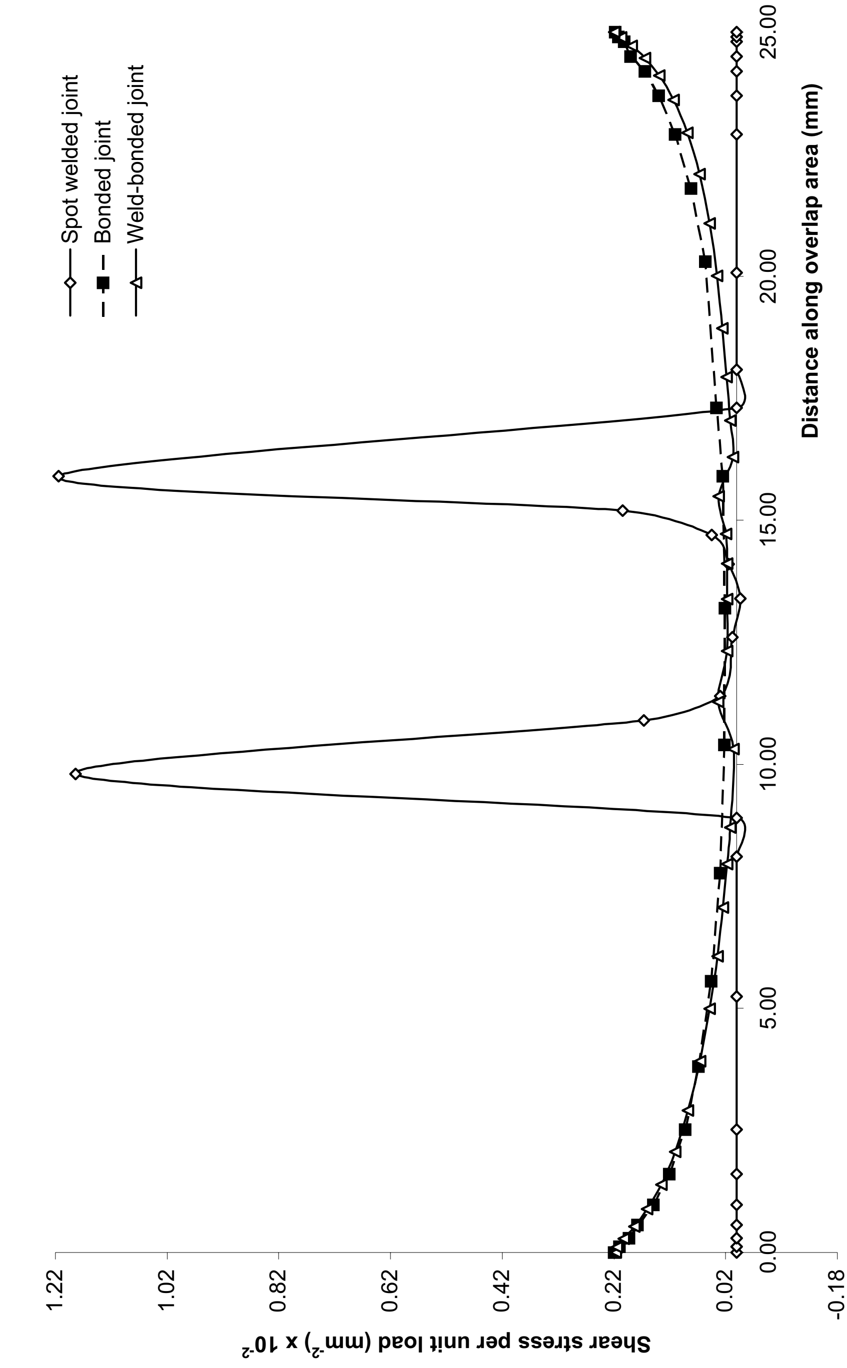

Figure 6 Shear stress τ_{xy} distribution along the mid-layer for three models.

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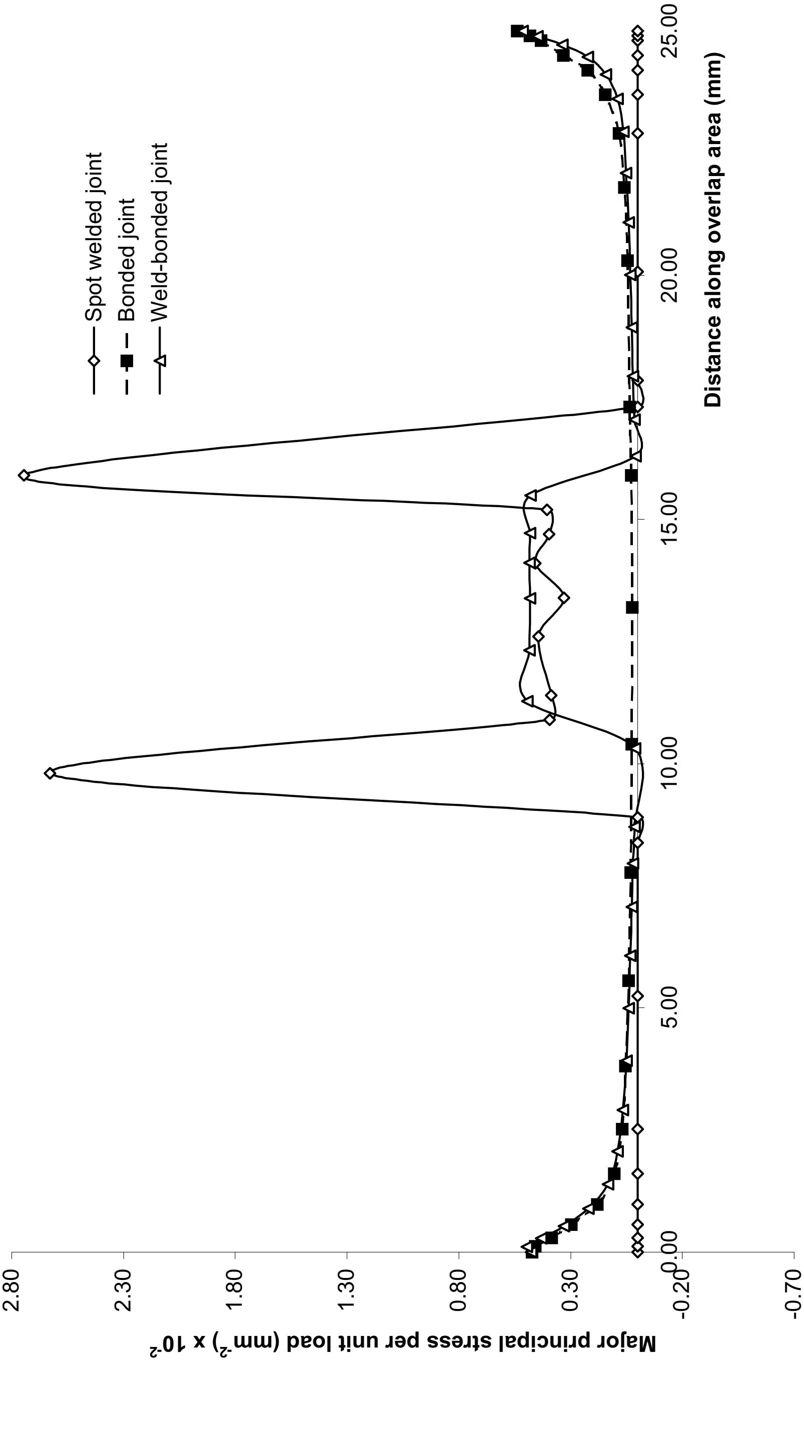

Figure 7 Major principal stress σ_1 distribution along the mid-layer for three models.

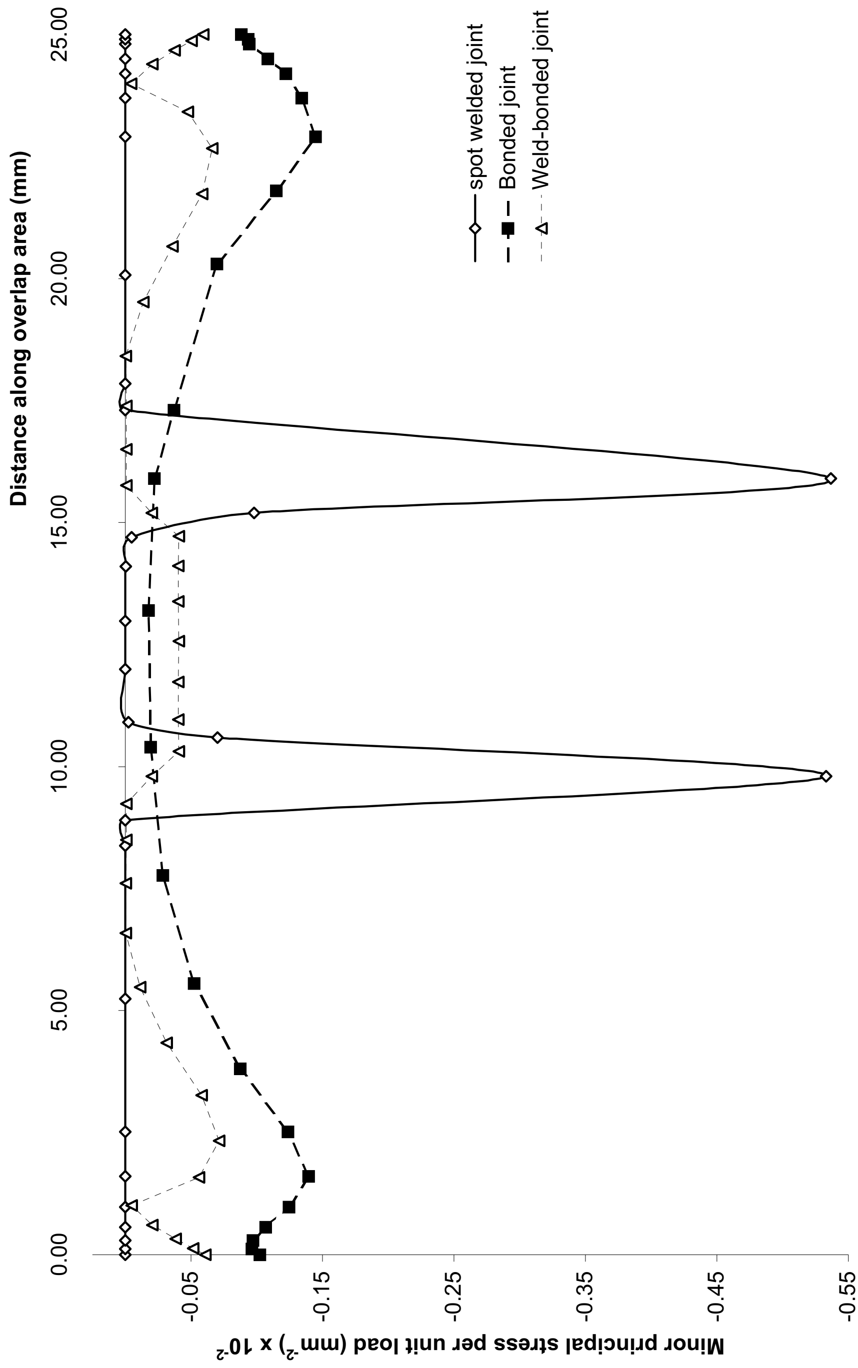

Figure 8 Minor principal stress σ_2 distribution along mid-layer for three models.

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