Approximating MIG Welds with Abaqus Spot Weld Functionality

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***Abstract**: Representing MIG welds in FEA models is often a very laborious task in preparing the FEA Models. Traditional techniques range from TIEs to shells to solid elements. Using TIEs can be subject to mesh density and parameter choices for the TIE. Shell and solid representation can require significant geometric preprocessing. Presented here is a technique that uses Abaqus spot welds to approximate MIG welds. It will be shown that this representation of welds has high accuracy with minimal pre-processing required and insensitivity to mesh density. An Abaqus/CAE plug-in has been developed to automate this process. Examples comparing stiffness, stress and strain will be shown.*

***Keywords**: Connectors, Seam Welding, Welding, Spot Welding, Fabrications, Plug-ins*

1. Introduction

Welding of structures is an important part in the analysis of fabricated structures. Welds fall into two main categories for FEA consideration: Spot Welds and Line Welds. For shorthand reference, I will refer to Line Welds as MIG welds. Even though a line weld could be modeling TIG, skip, MIG or any number of processes that create continuous welds.

FEA software packages, particularly Abaqus/CAE, have developed advanced capabilities for modeling Spot Welds. This is largely driven by the automotive industry that uses a substantial number of spot welds in auto body structures.

FEA packages have lagged in supporting MIG weld representations. This author has several specific suggestions for fully representing welds. This paper will present a very efficient first level approximation of the MIG weld using spot welds. The primary goal of this approach will be to capture stiffness of the weld joint. However, it will be shown that the stress and strain effects will be captured surprisingly well.

The design goals for this approach are to have a quick, geometry based welding technique with low influence of mesh density and welding parameters while leveraging standard Abaqus capabilities.

2. Weld Geometry considerations

Two geometries will be presented for the purposes of this paper: Tee Weld and complex three dimensional weld. The standard for comparison purposes will be a solid meshed weld using a fine FEA mesh. All results will reference back to the solid mesh results. The result being analyzed for comparison purposes will be displacement at the point of loading. For a qualitative analysis, contour plots showing cross sections will be compared. In addition, for the complex weld example the first 5 natural frequencies will be compared.

2.1 Tee Weld

The Tee Weld will consist of two 12” x 12” x 0.5” plates centrally welded on both sides of the tee joint. The weld will be 0.25” radius bead with 0.125” penetration. The weld geometry is shown in figure 1 below.

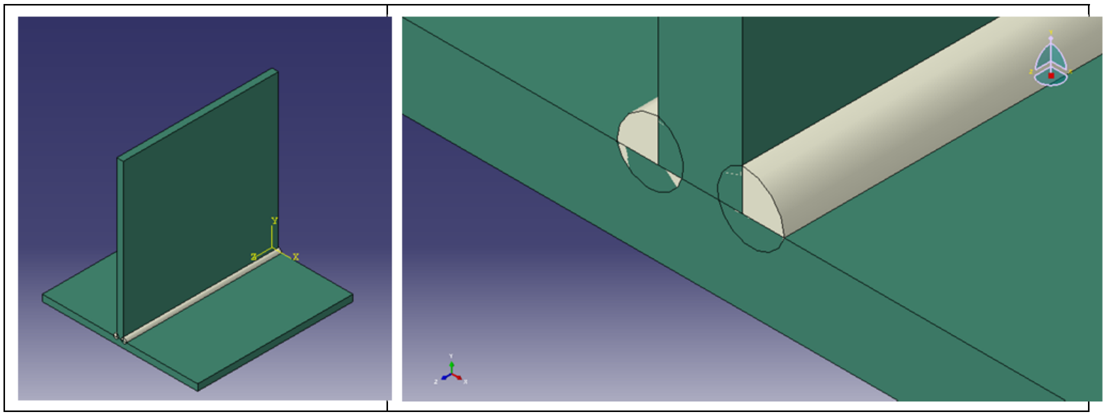


Figure 1. Tee Weld Geometry.

2.2 Complex Weld

The complex weld geometry will represent a continuous weld around tube and socket arrangement as shown in figures 2 and 3. The O.D. of the socket is 3”. The O.D of the tube is 2.5 inches with a 0.125 inch wall. The tube is 24 inches long.

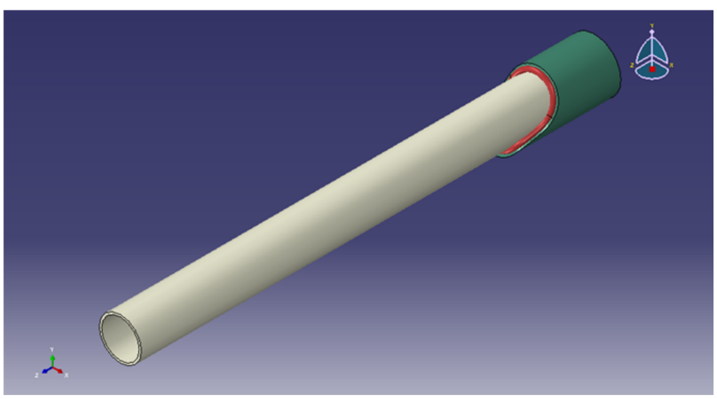


Figure 2. Complex Weld Geometry overview.

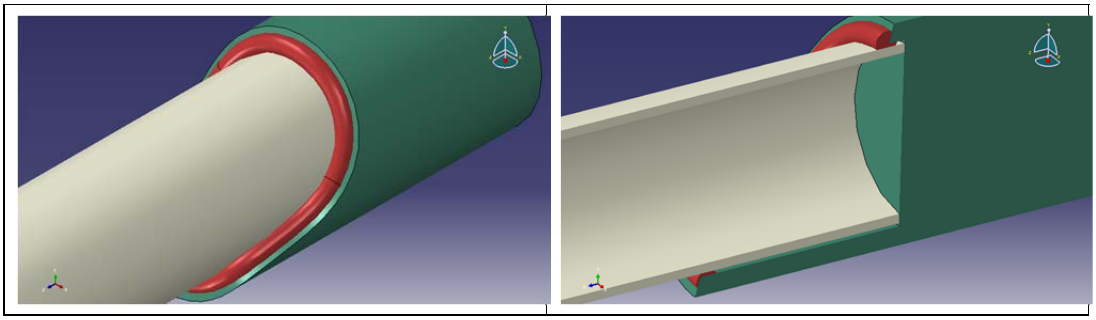


Figure 3. Complex Weld Geometry detail.

3.   Meshing

All of the geometry will be meshed with C3D10I elements. The mesh sizes will be varied from 0.1875 inches to 0.25 inches. The weld beads will be represented with C3D10I elements in the solid weld models.

For the spot weld representation of the MIG welds, the Abaqus spot weld connector element will be used. The connector elements are explained fully in Abaqus/CAE Users Guide documentation section 29.1.2. A spot weld is comprised of attachment lines and distributed couplings as the image from the Abaqus/CAE user’s manual shows (see figure 4). The distributed couplings include an influence radius parameter which approximates the radius of the spot weld.

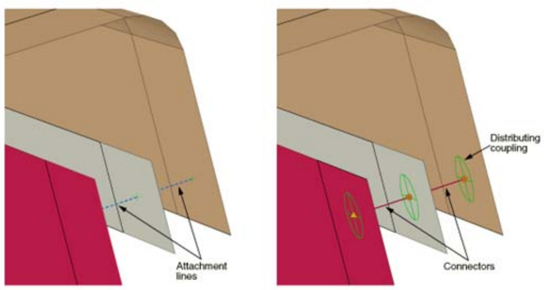


Figure 4. Abaqus/CAE Users Guide spot weld schematic.

The theory used in approximating MIG welds as spot welds is that a MIG weld can be simulated by a series of closely placed spot welds. Abaqus/CAE has tools for generating attachment points and attachment lines with user defined spacing. A plug-in has been created which automates this procedure even more. Figure 5 shows the plug-in GUI along with the selected geometry. Figures 6 and 7 show the resulting spot welds approximating a MIG weld. The only parameters for this implementation are the spacing and the search radius for the spot welds. Typically, the spacing is chosen to be two times the search radius.

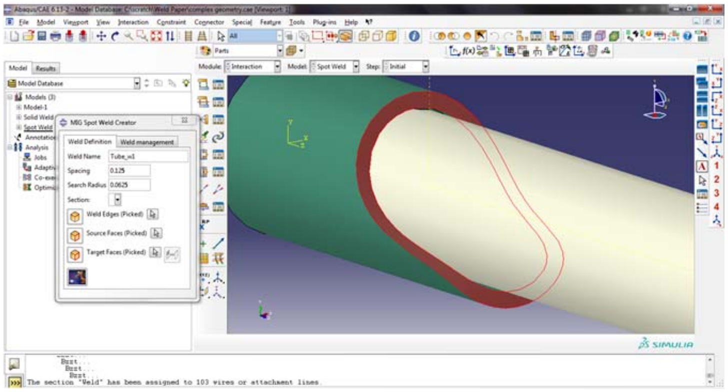


Figure 5. MIG Spot Weld GUI.

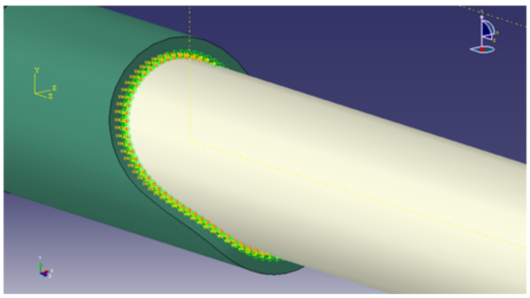


Figure 6. MIG Weld approximated by Spot Welds.

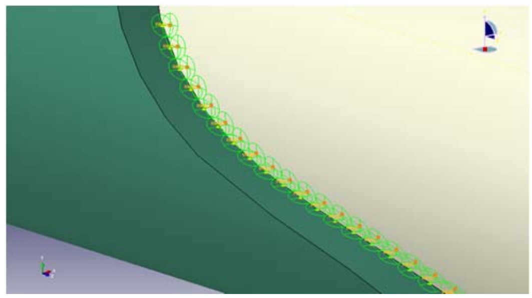


Figure 7. Close up of MIG Spot Weld.

4. Results

The following parameter study was performed on the solid weld and the MIG spot weld FEA models. The mesh size on the solid weld model was varied to understand the sensitivity to mesh size on the baseline model. The global mesh sizes used were 0.125, 0.1875 and 0.25 inches.

For the spot weld models, the search radius parameter was studied in addition to the mesh size. The spot weld spacing was fixed at two times the search radius. This resulted in the following design of experiments (figure 8):

		Search Radius			
		0.0625	0.125	0.1875	0.25
Mesh Size	0.125	x	x	x	x
	0.1875	x	x	x	x
	0.25	x	x	x	x

Figure 8. MIG Spot DOE.

For the static run, the results being compared are the displacement at the point of loading. This will be expressed in terms of absolute value percentage error. The reference measurement will be the corresponding displacement in the solid weld model.

For the normal modes analysis of the complex weld configuration, the first five modes natural frequency will be compared to the corresponding natural frequencies in the solid weld model.

Stress contour plots will be compared. No exact error calculations will be performed for the stress analysis. This will be purely a qualitative analysis.

4.1 TEE Weld Results

The TEE weld static model was loaded in bending with a 100lbf force as shown in figure 9.

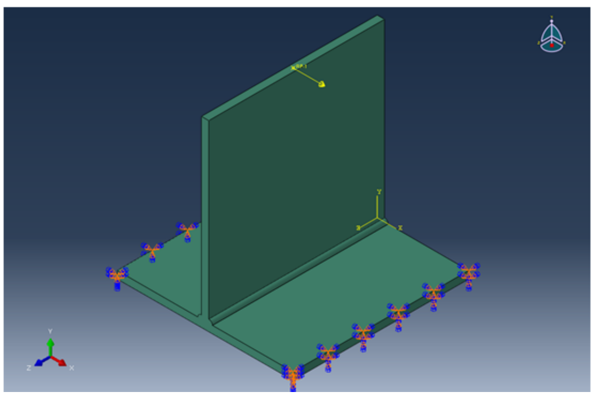


Figure 9. Loading for the Tee Weld model.

Solid Weld deflection variation due mesh size is shown in figure 10. The amount of error introduced by mesh variation is 0.3%. Figures 11 and 12 show that the variation in stiffness due to the spot weld approximation ranges from 0.99% to 5.36%. The stress contour plot (figure 13) shows a reasonable approximation of stresses in the vicinity of the weld compared to the solid representation of the weld.

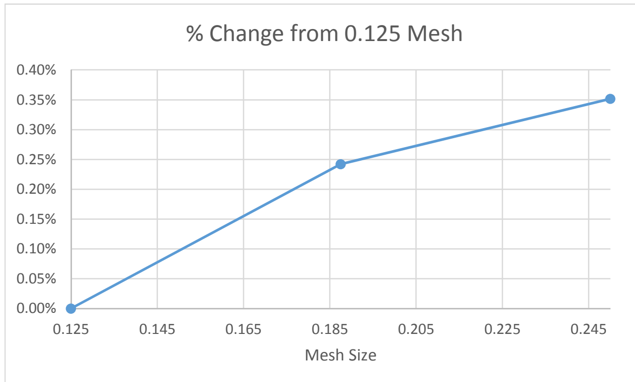


Figure 10. Solid Weld deflection variation due to mesh size.

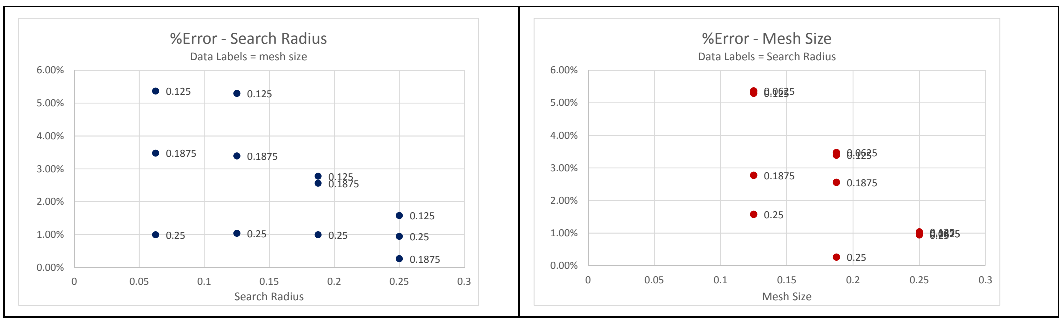


Figure 11. Error charts for static defection

%Error		Search Radius			
		0.0625	**0.125**	**0.1875**	**0.25**
Mesh Size	0.125	5.36%	5.29%	2.77%	1.58%
	0.1875	3.47%	3.39%	2.56%	0.26%
	0.25	0.99%	1.04%	0.99%	0.95%

Figure 12. Error table for static defection

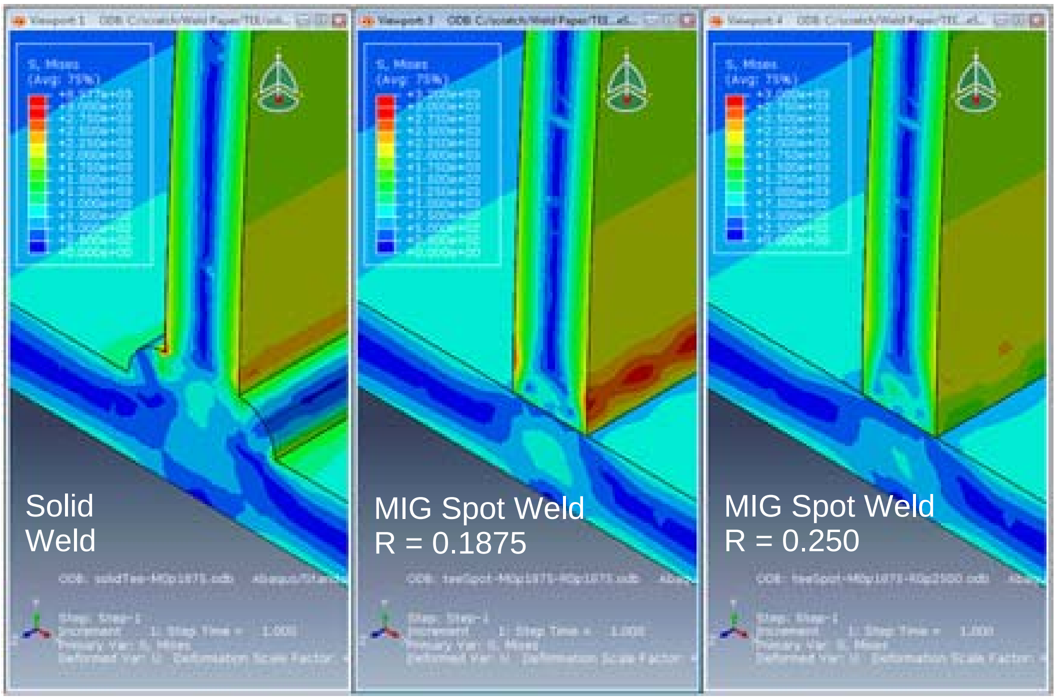


Figure 13. Stress Contour Comparison (Solid, R0.1875, R0.250).

4.2 Complex Weld Results

The complex weld static model was loaded in bending with a 100lbf force as shown in figure 14.

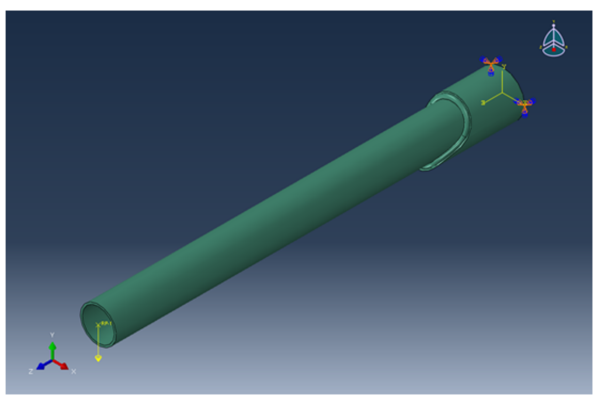


Figure 14. Loading for the Complex Weld model.

Solid Weld deflection variation due mesh size is shown in figure 15. The amount of error introduced by mesh variation is 0.3%. Figures 16 and 17 show that the variation in stiffness due to the spot weld approximation ranges from 0.15% to 1.95%. The stress contour plot (figure 18 and figure 19) shows a reasonable approximation of stresses in the vicinity of the weld compared to the solid representation of the weld. Figure 20 shows a table of the variation in natural frequencies due to mesh size in the solid weld model. The variation due to mesh size in the solid weld model is no more than 0.23%. Figure 21 shows the variation in natural frequency in the spot weld models. The range of variation due to spot weld search radius and mesh variation is 0.01% to 1.28%.

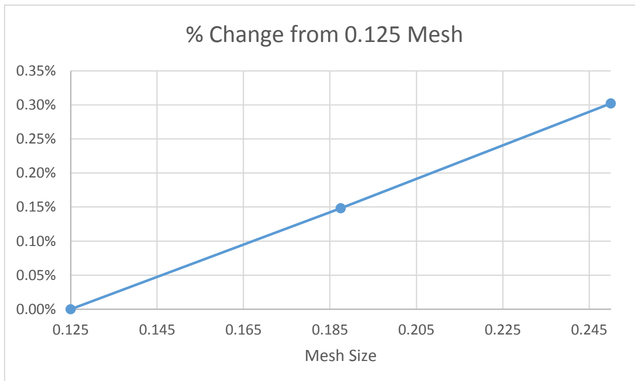


Figure 15. Solid Weld deflection variation due to mesh size.

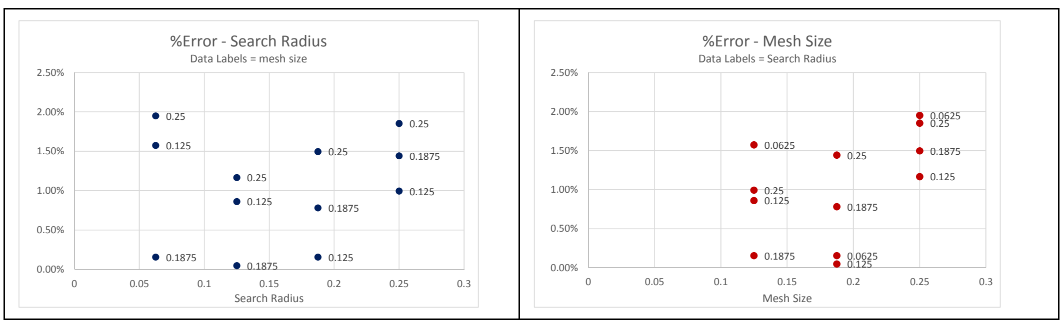


Figure 16. Error charts for static defection

	%Error	Search Radius			
		0.0625	**0.125**	**0.1875**	**0.25**
Mesh Size	0.125	1.57%	0.86%	0.15%	0.99%
	0.1875	0.15%	0.05%	0.78%	1.44%
	0.25	1.95%	1.17%	1.50%	1.85%

Figure 17. Error table for static defection

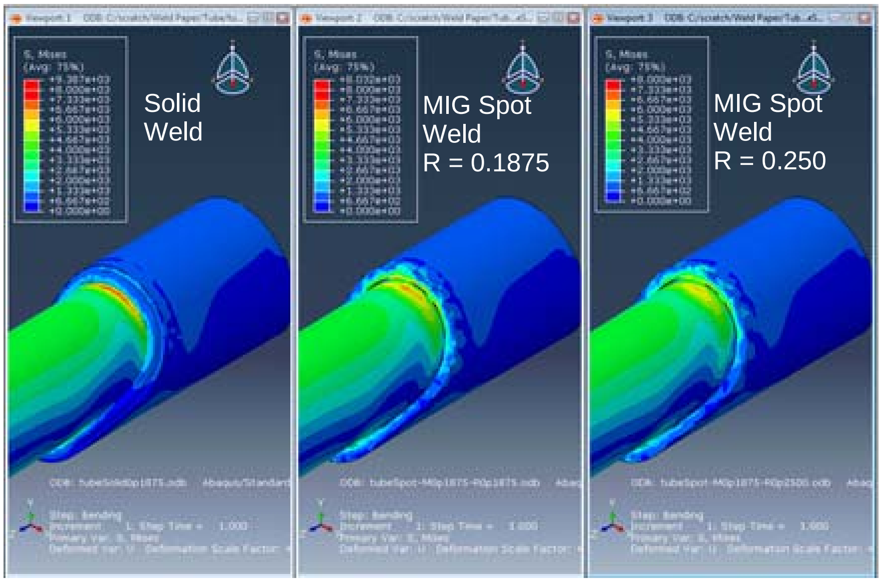


Figure 18. Stress Contour Comparison (Solid, R0.1875, R0.250)

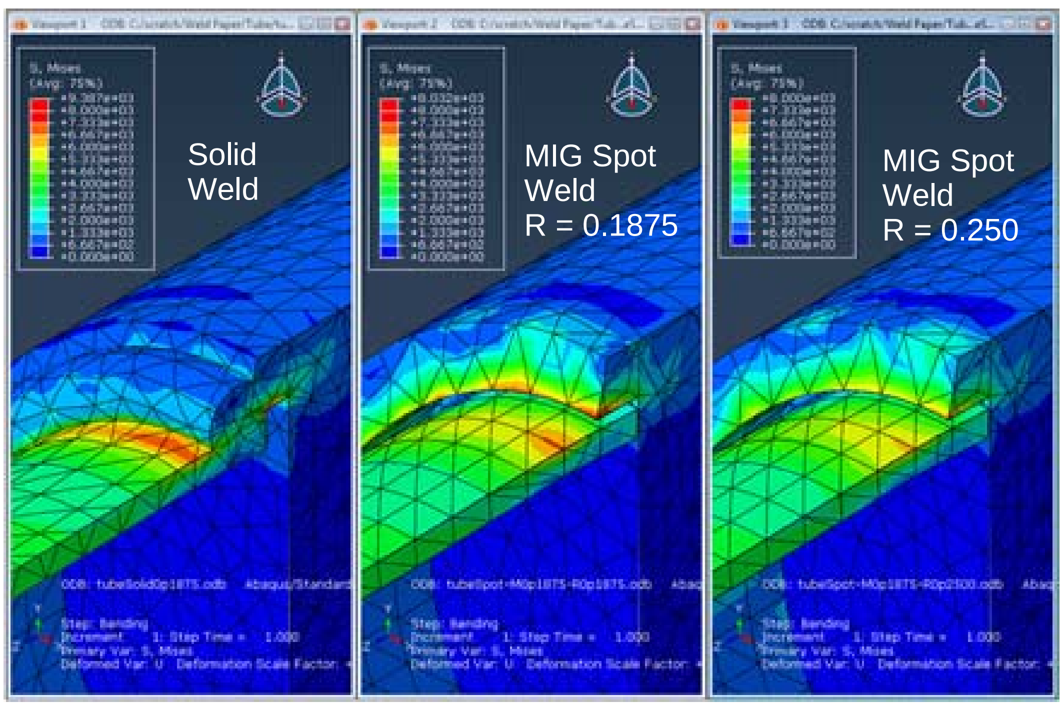


Figure 19. Stress Contour Comparison (Solid, R0.1875, R0.250)

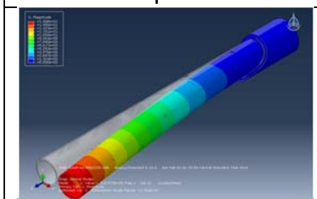
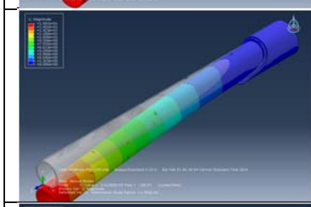
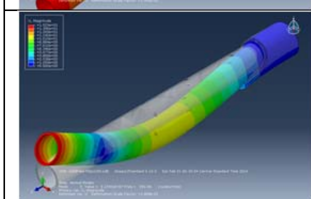
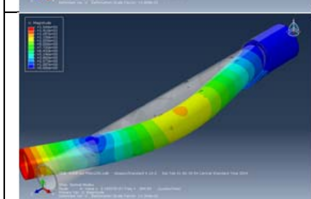
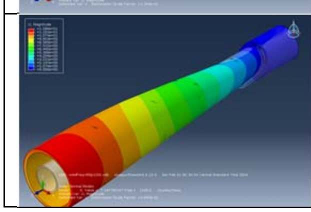
Mesh size influence on natural frequencies	Solid Mesh	0.125	0.1875	0.25
	Mode 1	0.00%	0.06%	0.13%
	Mode 2	0.00%	0.09%	0.19%
	Mode 3	0.00%	0.03%	0.23%
	Mode 4	0.00%	0.03%	0.22%
	Mode 5	0.00%	0.01%	0.04%

Figure 20. Error table for natural frequencies.

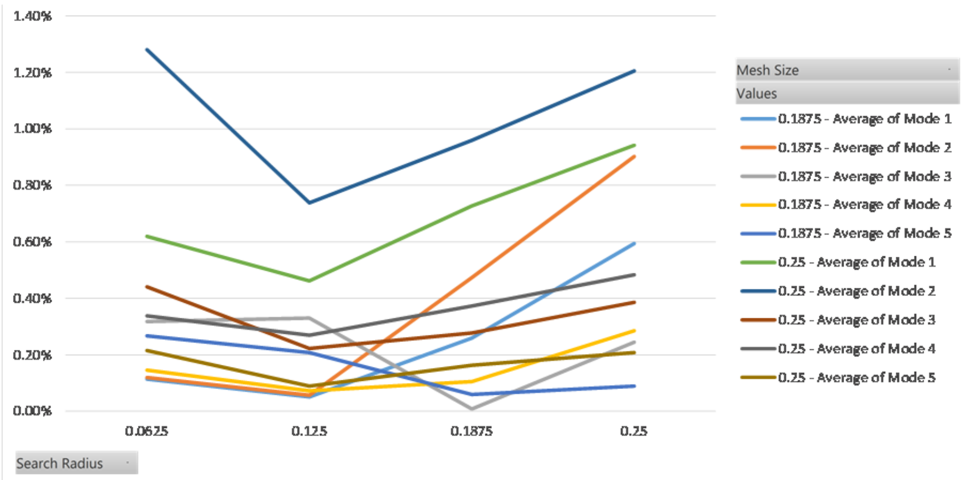


Figure 21. Error plot for spot weld natural frequencies.

5. Conclusions

In conclusion, it has been shown that spot welds can approximate a MIG weld with very good accuracy in stiffness and stress. This approach is recommended for first level analysis of fabricated structures. For a more detailed investigation of weld joint, it is recommended that traditional shell or solid weld meshing approach be applied. However, for about 2% of the effort to get 90% of the accuracy, the spot weld approximation of MIG welds is a very efficient and accurate approach to modeling fabricated structures.

6. References

1. Abaqus Users Manual, Version 6.13-2, Dassault Systèmes Simulia Corp., Providence, RI.