

The use of FEA in sand screen design cuts costs and accelerates development

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Expandable sand screens are a sand control system which is used to control the ingress of solids, in oil and gas reservoirs in weak and unconsolidated formations. The filtration media is typically sized to the largest 10% of the formation grain size distribution. As a consequence of this some fine solids are often produced. This has a beneficial effect in that it cleans the near wellbore of fine solids which have a tendency to plug the formations. However, in high rate gas wells there may be the possibility of erosion on the inside of the filter media part of the ESS in the transition area between expanded and non-expanded sections of the screen. To reduce the chances of this happening, the addition of thin sacrificial plates were installed over the critical area. These erosion plates would cover, and therefore blank off, the transition areas, so preventing any damaging flow through the filter. Several designs were proposed with varying number and shape of plates and the details of the welding. Ten different scenarios were modelled and subjected to analysis in FEA. The two best variations, showing the least stress at the welded corners as the ESS system changed diameter due to expansion forces, were taken forward to be physical test pieces. One of these designs was chosen for production. Using FEA for this project allowed our engineering group to discount eight of the original ten designs leaving just two to be fully manufactured and tested extensively. This helped reduce both the project time by 60% and the overall costs by 75%.

Keywords: Damage, Design Optimization, Experimental Verification, Failure , Forming, Pipeline, Tube Expansion and Visualization.

1. Introduction

The objective of this study using Finite Element Analysis (FEA) was to establish a suitable erosion plate design and configuration capable of withstanding diametrical change across the transition areas of a 7" Expandable Sand Screen (ESS[™]) joint, shown in Figures 1a and 1b. Solid metal erosion plates have previously been established as a suitable method of providing this non-flowing transition area between the expanded and unexpanded sections. A non-flowing area is required to ensure that there is no flow through the transition sections which could, potentially, lead to erosion of the filter weave in applications where very high flow rates are expected. The erosion could take place from the inside out due to the small quantities of solids entrained in the production fluids.

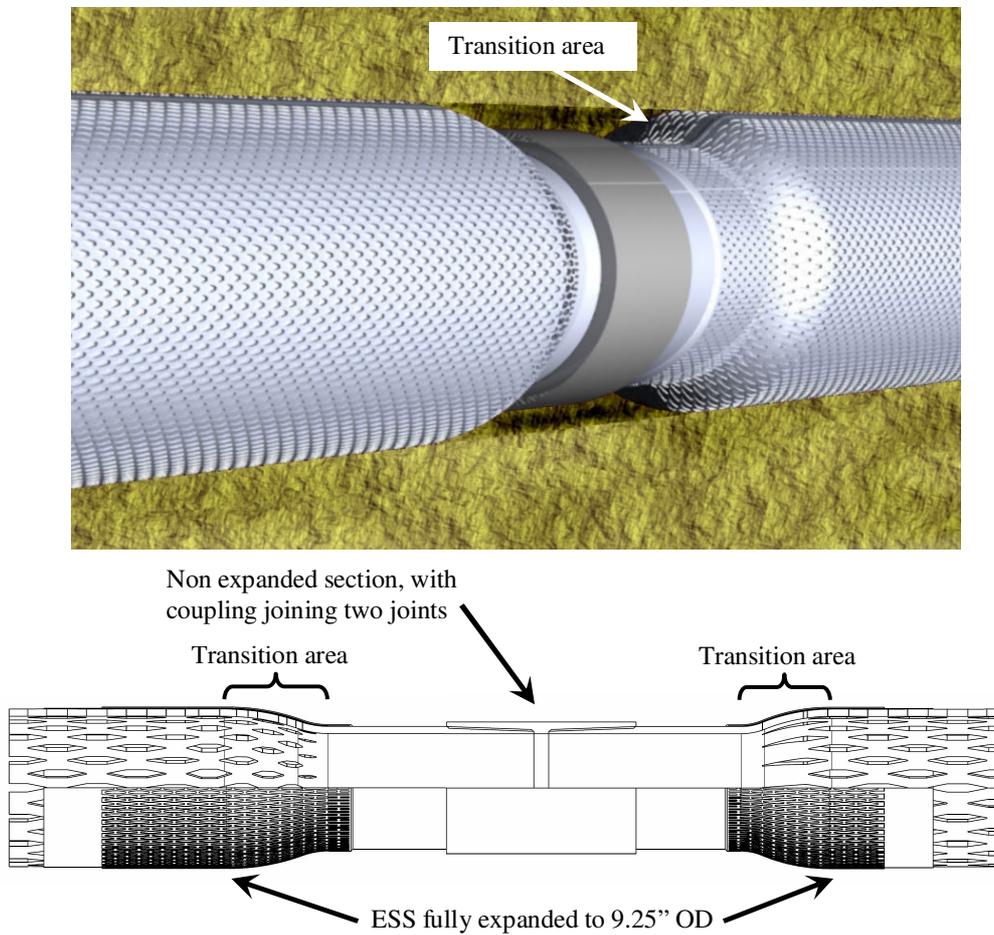
An example of ESS construction is shown in Figure 2, typically the ESS consists of three parts, **1. the slotted basepipe** or expandable slotted tubular (EST), **2. the woven filter mesh** (weave) which retains the sand and **3. the outer shroud** which protects the mesh during deployment.

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Figure 3 shows an example, and an indication of the overlap of how the erosion plates were applied to the external surface of the basepipe, below the weave.

The analyses were conducted on a short section of 7" ESS base pipe with a standard slot pattern. A specialised set of constraining conditions were created, to hold the parts in place, and the slotted area of the model expanded to a full diameter of 9.25" OD.

The first simulation was carried out on the current design, Figure 4 Model #1, to determine some degree of correlation between FEA and the physical test data. During testing it could be seen that the erosion plate corner would slightly rip away from the weld. Within FEA a Stress level was picked that would reasonably equate to the damage witnessed in the testing, **Figure 5**. The value was varied, until a realistic association was established. The proposed erosion plate configurations and geometries were then simulated to determine the best comparative solution.



Figures 1a and 1b Examples of the transition area between two joints of ESS

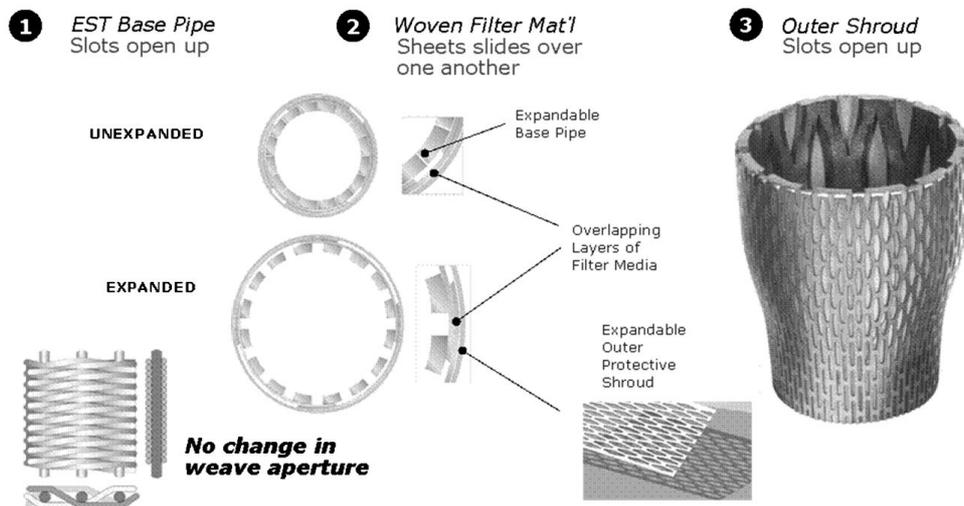


Figure 2 Details of the Construction of ESS

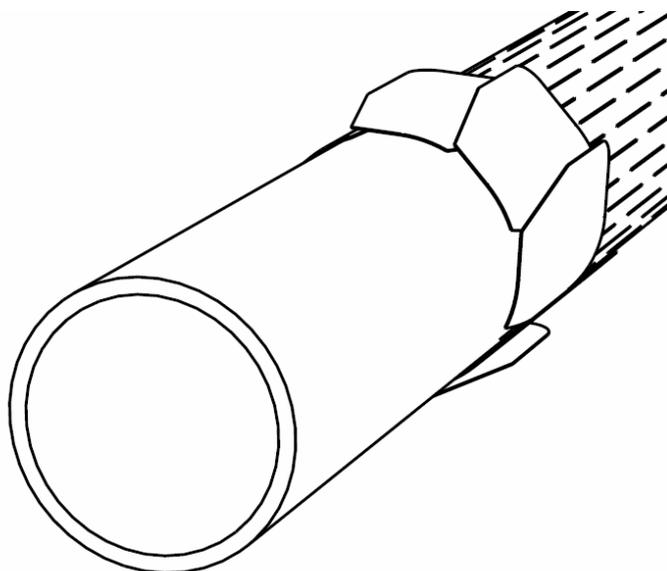


Figure 3 An example of how the erosion plates would be applied to the basepipe

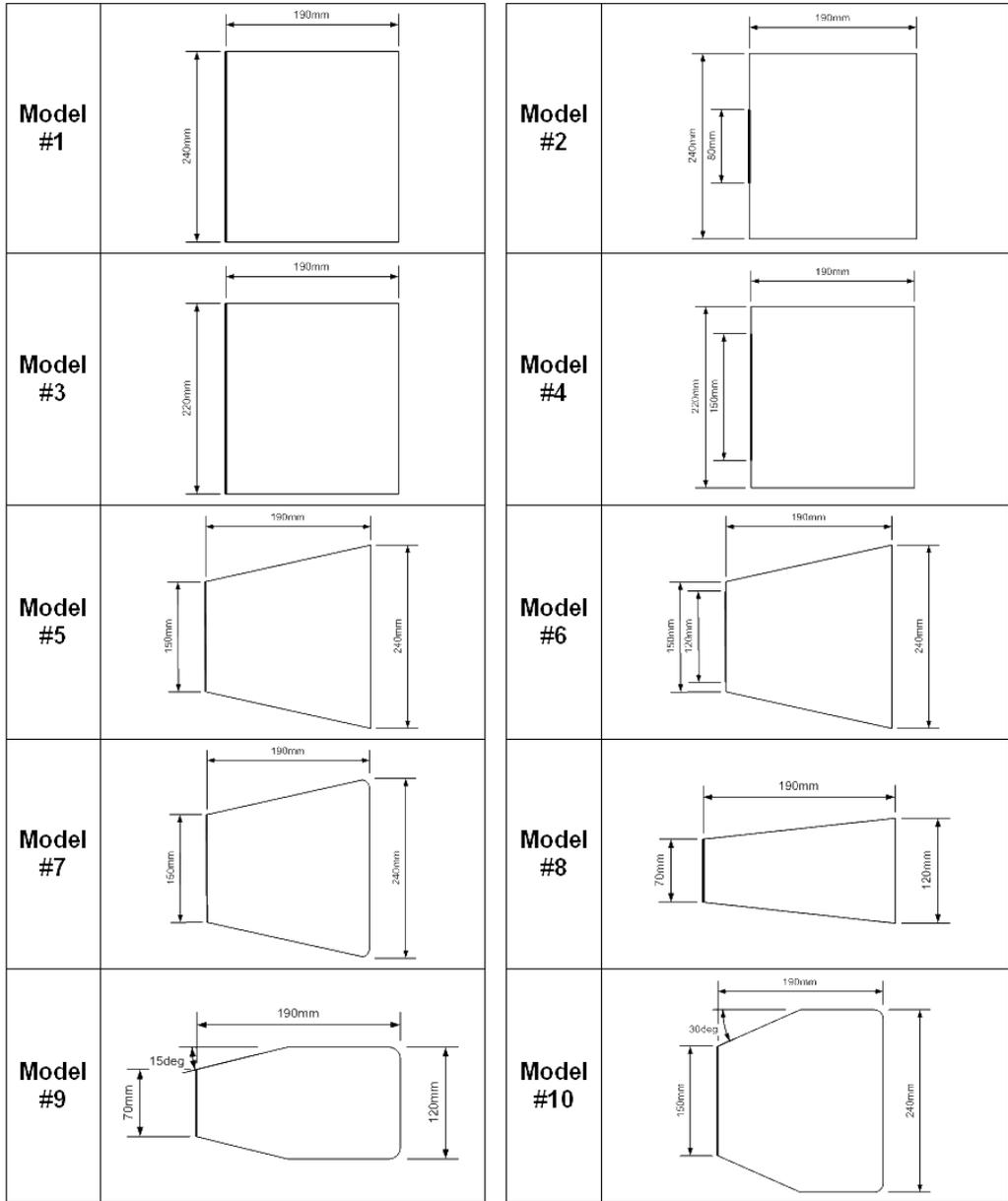


Figure 4 Details for all proposed erosion plates (Model #1 is current design)

Interpreting the data from all the FEA modelling revealed that the optimum plate designs were Models #9 and #10. Both are tapered designs, whereby the accumulated short edge lengths equal the full circumference of the base pipe, tapering to the width required to ensure full diammetrical coverage post expansion.

Model #9 utilises an eight plate configuration, equally spaced at 45deg and overlapping the plate directly next to it. Model #10 is of a similar shape, but is made up of only four plates, equally spaced at 90deg around the circumference. High stresses are still evident at the plate corners on the analysis of Model #10, however these are not so exaggerated in comparison to the current design, hence worth physical testing to fully assess, as tearing may not happen. A further consideration is the manufacturing complexity, in that Model #10 varies only slightly from the current design, but Model#9 requires additional spot welding to attach the additional plates.

2. Background

The purpose of the analysis was to establish a suitable erosion plate configuration capable of withstanding diametrical change across the transition area of a 7" ESS joint. Solid metal erosion plates have been established as a suitable method of providing this non-flowing transition area between the expanded and unexpanded section. This non-flowing area is required to ensure that there is no flow through the transition sections which could lead to erosion of the weave in applications where very high flow rates are expected.

The FEA was conducted using Abaqus/Explicit and Pro-Engineer Wildfire for 3D model creation. A section of 7" ESS base pipe was prepared with a standard slot pattern. To minimise computational time, the base pipe model complexity was reduced to half symmetry and a shortened length selected, yet still accommodating the erosion plate plus some additional length. For each individual model, a small section was designed to represent the weld, sized to match the cross sectional area of plate that would be welded. One erosion plate was analysed, effectively a one quarter symmetry of four plate set-up, Figure 5a. This plate was formed uniformly around the base pipe. No filter media or outer shroud was included in the assembly, therefore a small, extra, pressure was applied to the outer surface of the erosion plate to mimic the restraining forces applied by the weave and the shroud. This pressure was sufficient to hold the plate snugly in place against the basepipe outer surface.

The parts were all given 316L stainless steel properties, including plasticity information as the problem was highly non-linear.

The basepipe was partitioned such that the non-slotted region could be fully encastred. To fully expand the ESS to 9.25" OD, an internal pressure was applied. Using this method helps reduce analysis times. Using a representation of the field tool to provide the required expansion (by swaging out) would have increased computational time dramatically. Previous analysis runs have demonstrated that the finished properties of an ESS sample expanded by pressure has very similar properties to an ESS that has been expanded by an expansion tool.

The inner surface of the component representing the weld was also fully encastred. The two surfaces of the weld and erosion plate facing each other had a tied constraint to hold them together. All surfaces had frictional interaction properties applied. All components had 4 layers of C3D8R mesh elements. For the weld and erosion plate the four layers gave a very fine mesh, ideal for visualisation purposes.

3. Analysis

With the parts and constraints mentioned previously, typical run times for each analysis were approximately four hours, which was acceptable for these complex analyses which were run in rapid succession.

The material has a maximum plastic limit of 930 MPa. The spectrum legend, in the results viewer, was set at around 85% (800MPa) which was a realistic portion of the failure stress of the material. Therefore, when viewing all the results in Abaqus, anything coloured grey was beyond the acceptable limit and was predicted to fail, or rip. The setting remained constant across all results, which allowed for an easy comparison over the wide range of analyses.

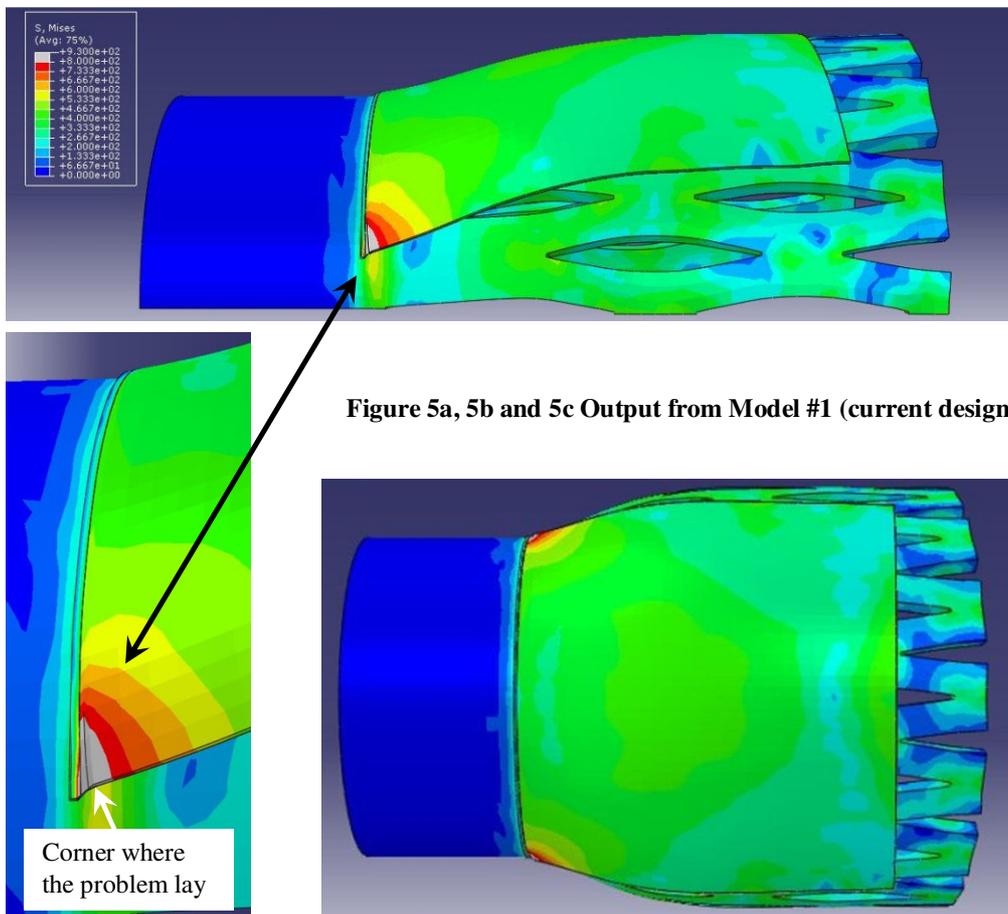


Figure 5a, 5b and 5c Output from Model #1 (current design)

The following images, Figure 6 to Figure 12, show each simulation for Model #2 to Model #8.

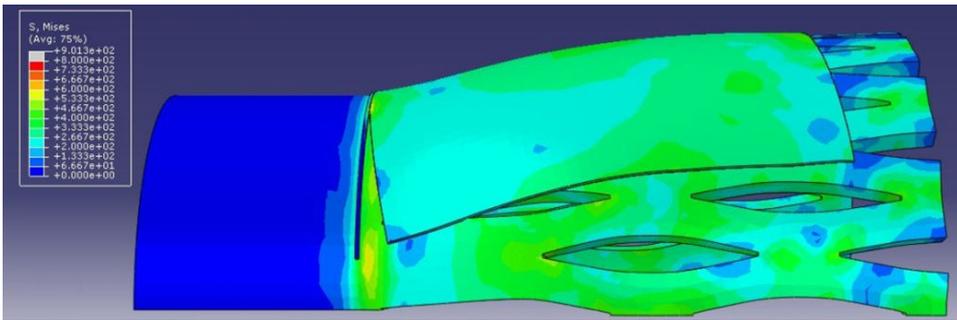


Figure 6 Output from Model#2 (low stress throughout)

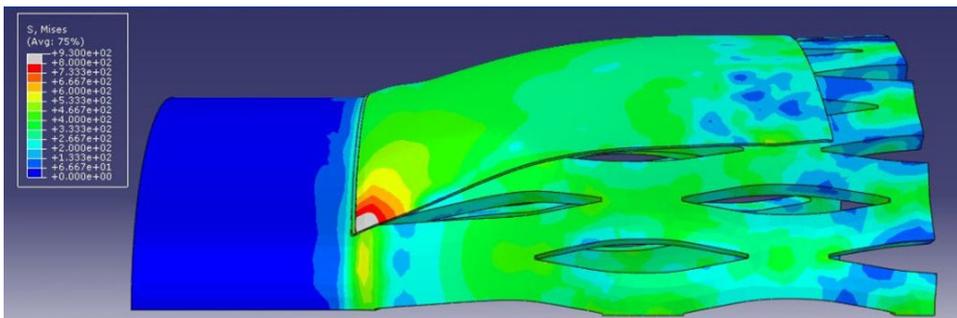


Figure 7 Output from Model#3 (high stress at corner)

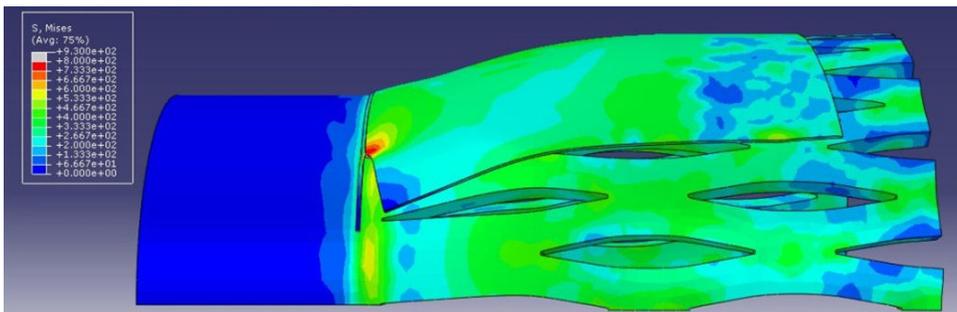


Figure 8 Output from Model#4 (high stress at weld/plate interface)

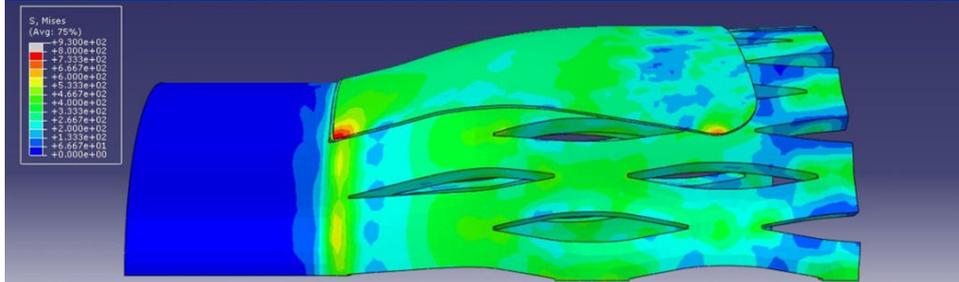


Figure 9 Output from Model#5 (high stress at corner)

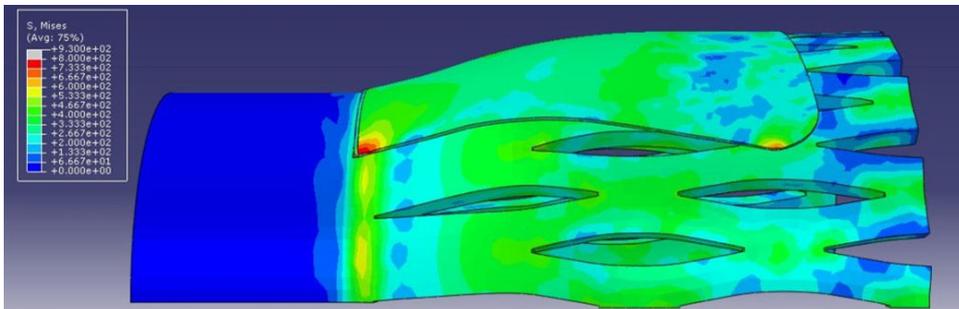


Figure 10 Output from Model#6 (high stress at corner)

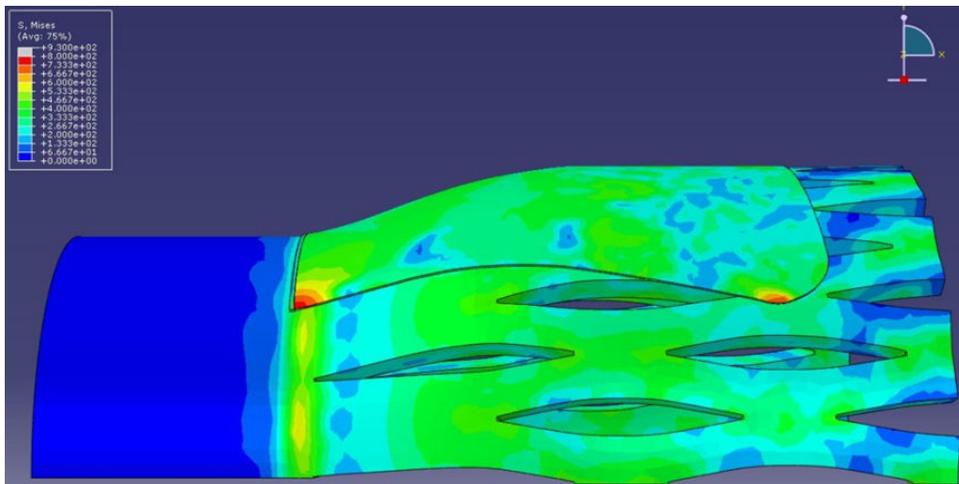


Figure 11 Output from Model#7 (high stress at corner)

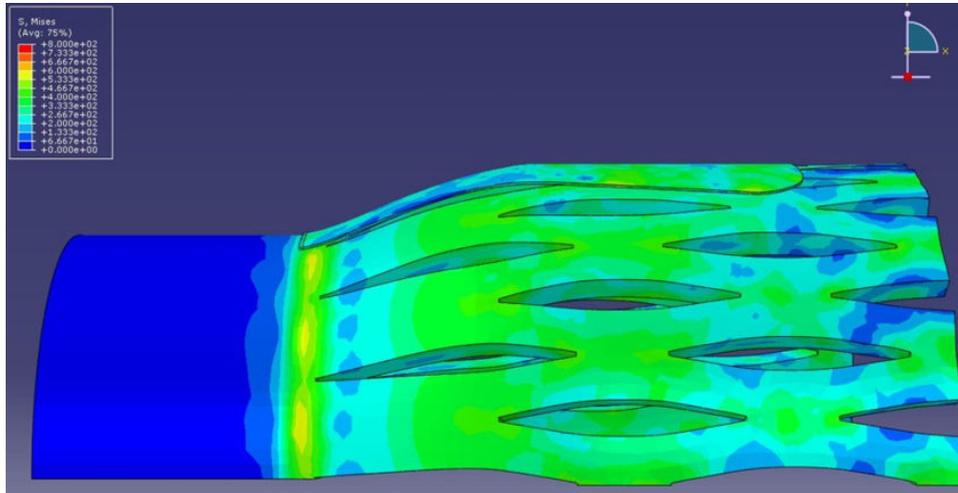


Figure 12 Output from Model#8 (low stress throughout)

The differences between each Model are as follows.

Model #2; same plate shape and size as current design (Model #1) but the weld length is reduced. Low stress throughout but edge lifting to create a flow path.

Model #3; same plate shape, but narrowed to minimum width that allows for overlap. High stress at corner, as per current design.

Model #4; same plate shape and size as Model #3 but weld length is reduced. High stress at corner and potential for edge lifting up.

Model #5; geometry now has a full length taper. High stress at corner and potential for overlap edges to lift apart.

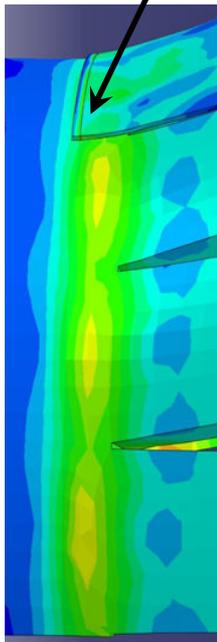
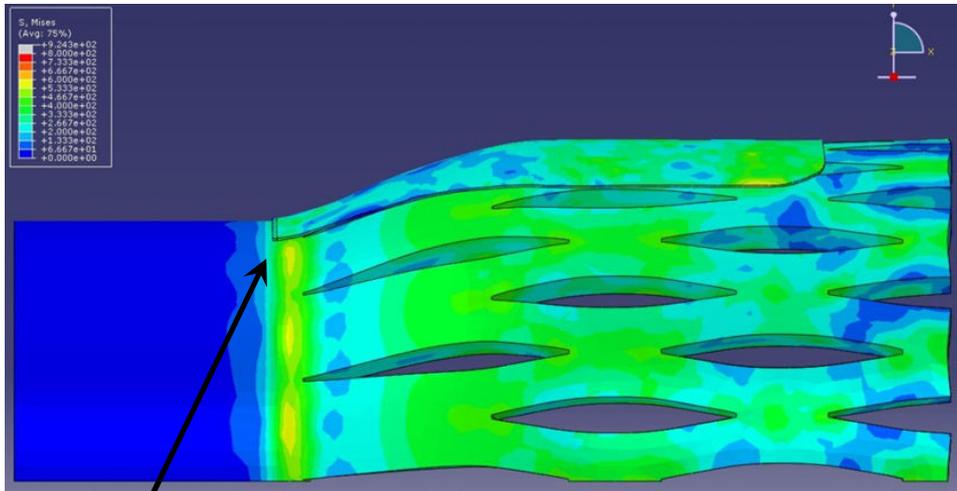
Model #6; same tapered geometry as Model #5 but with reduced weld length. High stress at corner and potential for overlap edges to lift apart.

Model #7; same tapered geometry but with a 50% thicker plate. High stress at corner and potential for overlap edges to lift apart.

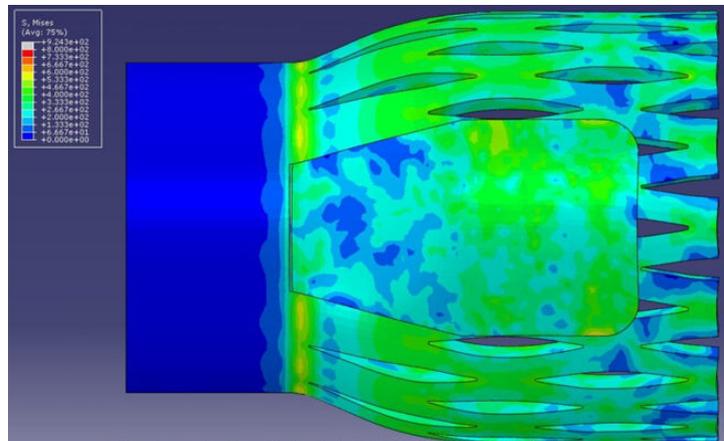
Model #8; fully tapered geometry, but with half the width for double the number of plates. Low stress throughout but potential for overlap edges to lift apart.

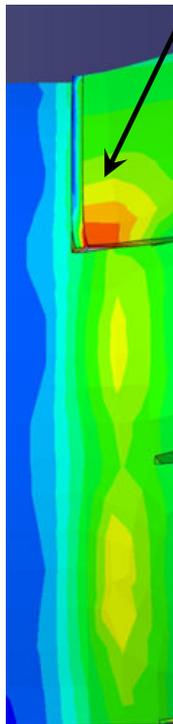
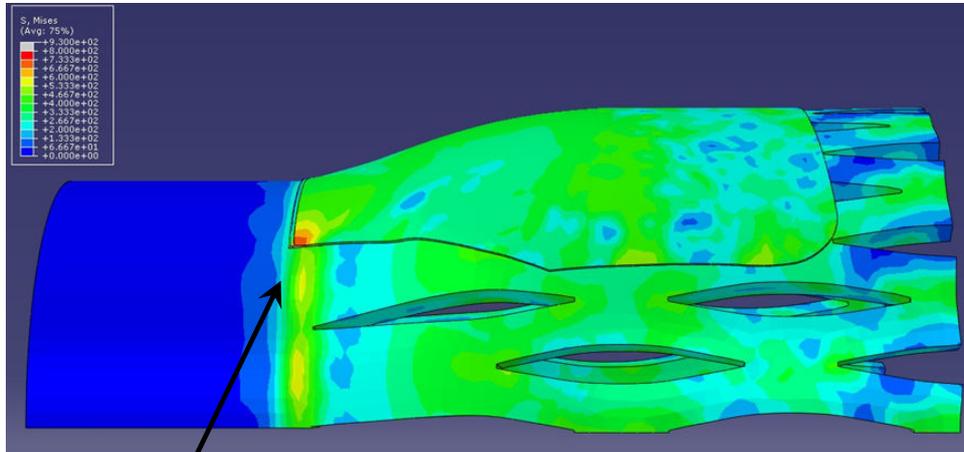
Model #9; repeat of Model #8 but with taper change to ensure no loss of overlap during expansion. Low stress throughout and with overlap edges remaining in contact.

Model#10; repeat of Model #5 but with taper change to ensure no loss of overlap during expansion. Low stress throughout and with overlap edges remaining in contact.

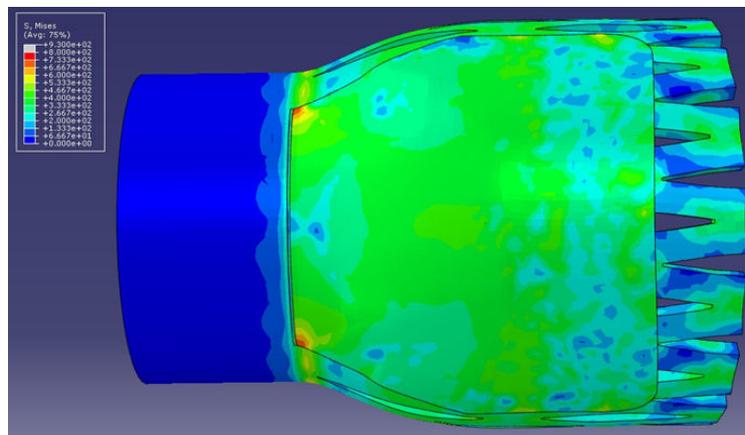


Figures 13a, 13b and 13c Output results from Model #9





Figures 14a, 14b and 14c Output results from Model #10



4. Conclusions

Examination of the FEA modeling revealed that a shorter weld length reduces the stress levels in the erosion plate, however the full plate width would have to be fixed to prevent any movement in the non-fixed area, which would otherwise distort to create a flow path.

The most successful design is one of optimum width to allow welding over the entire fixed area, with all fixed end plate widths accumulated to equal the full circumference of the pipe and this ensures complete protection against a flow path. Furthermore, the plates are tapered out to the width required to ensure that on expansion to full diameter, there is adequate overlapping with the adjacent erosion plate along their entire length.

By this criteria, Models #9 (Figure 15) and #10 (Figure 16) presented the optimum design solutions and, therefore, were proposed for evaluation through physical testing. Consideration was also given to manufacturing complexity. While Model #10 varied from the current design only in geometry, Model #9 required additional spot welding to attach the additional plates. The full circumferential weld did not change, as this was still required as per current design. Figure 17 shows an expanded version of Model #10. The weave and shroud are removed to view the overlap between the adjacent plates. There are no rips or lifting within the areas of concern. Figure 18 also shows an expanded sample (again with weave and shroud removed) but this variation has failed due to the plate overlap edges lifting and creating a potential flow path. Figure 19 shows an example of where there has been ripping at the corner of the erosion plate

Ultimately, Model #9 was chosen for manufacture. Although Model #10 was initially promising due to being similar to the current design and having reduced stress levels at the corners, it was felt that the arrangement and geometry of Model #9, even with the addition of extra welds, would have the least chance of ripping at the erosion plate corner and the best chance of staying in contact along the overlap edges, therefore satisfying the requirement of stopping flow in the transition area of the 7" ESS Joint.

Originally there were ten plate designs, but only two new designs were taken forward for manufacture and physical testing as a result of our using Abaqus/Explicit FEA as the driver for which particular variations were to be made. This helped reduce both the project time by 60% and the overall costs by 75%.

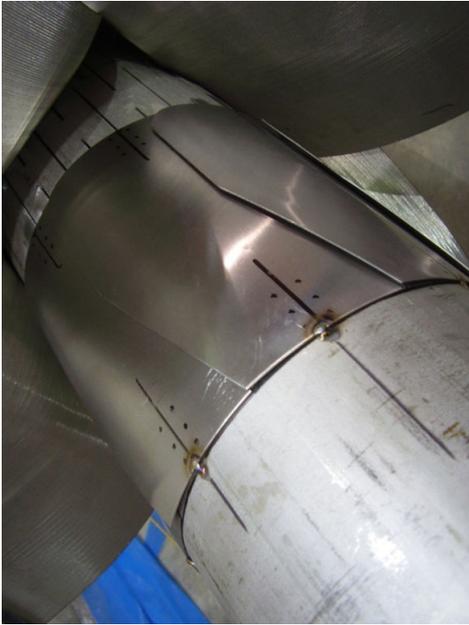


Figure 15 Model #9 before circumferential weld Figure 16 Model #10 with circumferential weld



Figure 17 an expanded example (filter and shroud stripped off)

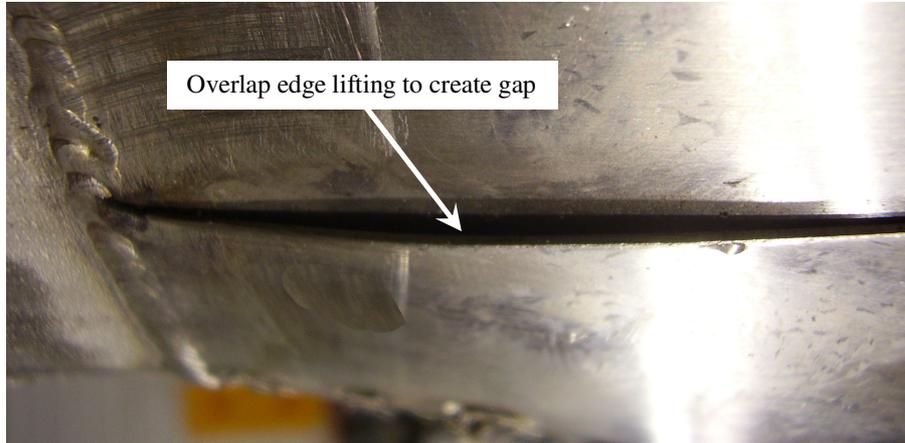


Figure 18 an expanded example showing the overlap edges lifting away

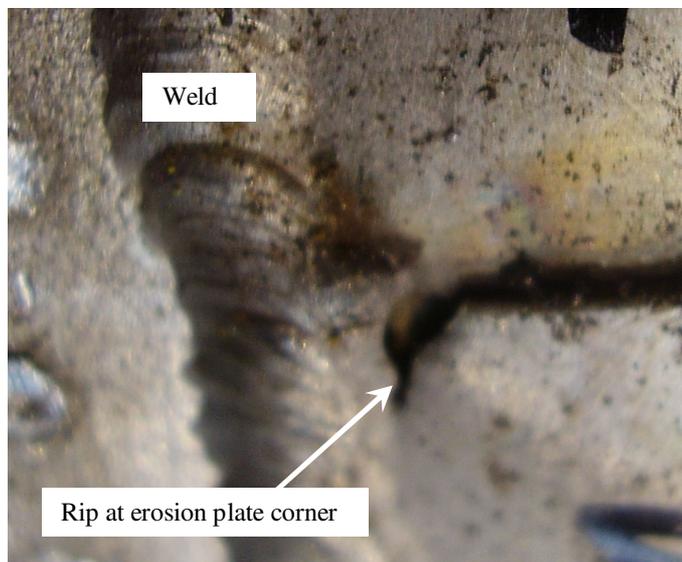


Figure 19 an expanded example showing a rip at the erosion plate corner