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Use FEM for Identifying Boundary Failure of Sheath Cylindrical Vessel

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Abstract This article deals with the shape bottom effect to different types of stress and deformation process at the junction of the cylindrical part of the shell vessel and its bottom. With the FEM using the SolidWorks were different types of stress and deformations of vessel determined. The calculation is designed as a static and during the research it was not taken any technical process into account such as the temperature impact or the materials nonlinearity, the internal stress. There were used a variety of vessel and also the different types of results were compared during the analysis.

Keywords: *FEM, membrane state, flat bottom, shell, bending moment, boundary fault*

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1. Introduction

The structure of all types of tanks and pressure vessels has been affected by the correct application of higher hardness steel theory. There are more and more solutions available now because of modern knowledge. From this reason the theory and its verification together with the practice of knowledge is getting better every day. Also the behavior of structure is much better understood at these days cause of modern information and measure technology. However, the common solution for the shell structures is still very hard to find. The form of the vessel bottom has one of the biggest influence on the stress concentration at the junction of cylindrical casing and the bottom of the vessel. There is also contravention on such places occurred very often. Boundary faults arising at the junction of cylindrical part of the vessel and its bottom are also depending on the length of the cylindrical part of the shell. The junction of cylindrical part of the vessel and its bottom subjects of boundary faults may cause to create unwanted rifts or breakage [1,2,3,4,5].

2. The Boundary Faults of Membrane State

In technical practice there is often several exercises when the common state of stress caused by internal pressure is being simplified. It is because the scrolling forces, bending moment or torque are equal to zero or to very small number so we can neglect them. From the draft perspective it is the condition when the material is being used the best. It is known as the term of membrane stress state. The clean membrane internal state is possible to achieve when the relevant deformation and static balance is created by the membrane forces. However the membrane forces are often unsuccessful and won't achieve these expected deformations by themselves.

The bending state is often bounded to boundary condition which causes unwanted membrane state faults. This is boundary fault which prevents to create the right deformation of membrane state. These faults are getting reduce by the length of boundary. It is often referred as effective length $5c$ ($e^{-5} = 0,0067$, it means 0,67% from the value for $x = 0$). If the length of the cylinder is $l \geq 5c$, then the effect from the one bottom to another one does not occur. However, the value of the length constant *c* has impact on the fault membrane length state.

The vessel which is strained by the inner overpressure at the junction of cylindrical casing and the bottom of the vessel is prevented of free deformation. From this reason the bending moment occurs on such places and creates the bending stress. Such bending faults of membrane stress create an unwanted condition of casing vessel [6].

In the bending state of rotationally symmetric shells is the length of edge fault very small and the limit is given by $1,5\sqrt{rt}$, where r is radius and t presents the vessel thickness. There is possibility to replace that short section at junction of cylindrical part on every rotational shell. The radius of spare vessel reflects the real forming curve of shell. The approximate solution is more accurate when direction of tangent to generating line will be closer to direction of rotationally axis of whole shell. The most accurate case is when the angle α between the tangent of generating line and the rotationally axis will be moved around the $\alpha = 90°$ [1,2].

2.1. The FEM Results of the Vessel Calculation with Its Bottom

With the FEM were monitored the reduced stress spikes and deformation at the sharp passages to spherical bottom if $\alpha = 90°$, $\alpha = 60°$, $\alpha = 30°$ and during the penetration to flat bottom at the same thickness of casing and shell.

In case that $\alpha = 90°$ the membrane effect prevails over the bending effect. The aim of vessel draft is to create the process when the junction of cylindrical part and sphere part is continuously. If $\alpha = 60°$ and $\alpha = 30°$ the bending effect at the junction of vessel has to be higher and the stress depends on r/t ratio.

Figure 1 and Figure 2 presents the process of reduced stress lengthwise within the cylindrical casing with the transition to hemisphere bottom where the angle α = 90. The process of the cylindrical part deformation during the transition to hemisphere bottom with angle α = 90 is shown on Figure 3 and Figure 4.

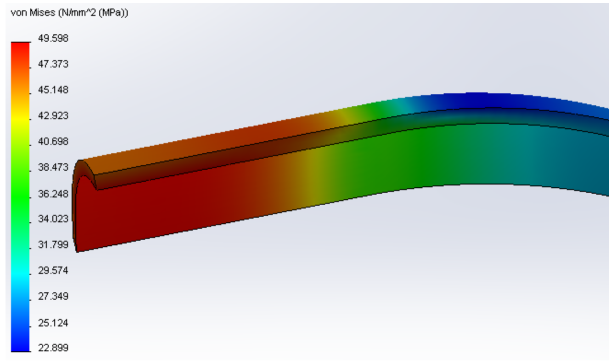

Figure 1. The field of reduced stress for α=90°

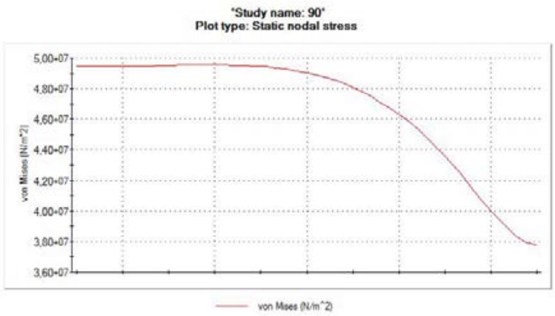

Figure 2. The process of reduced stress lengthwise the inner cylinder for α=90°

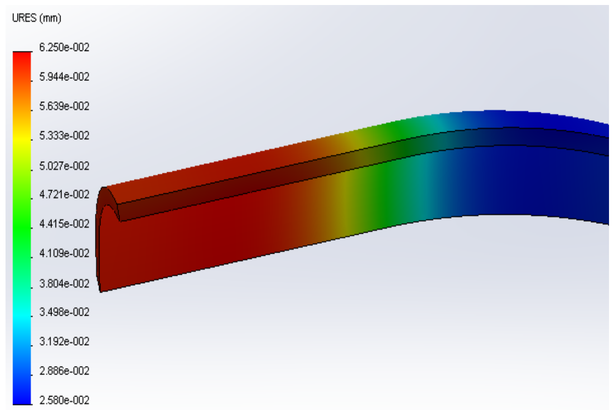

Figure 3. The field of deformations for α=90°

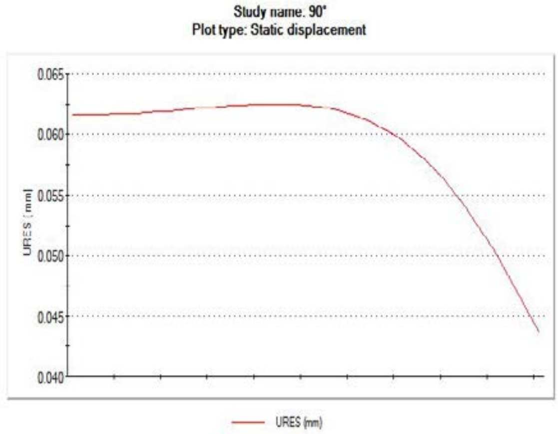

Figure 4. The process of the casing deformation for α=90°

On Figure 5 and Figure 6 is shown the process of reduced stress lengthwise within the cylindrical casing with the transition to hemisphere bottom where the angle α = 60°. Figure 7 and Figure 8 presents the process of the cylindrical part deformation during the transition to hemisphere bottom with angle α = 60°.

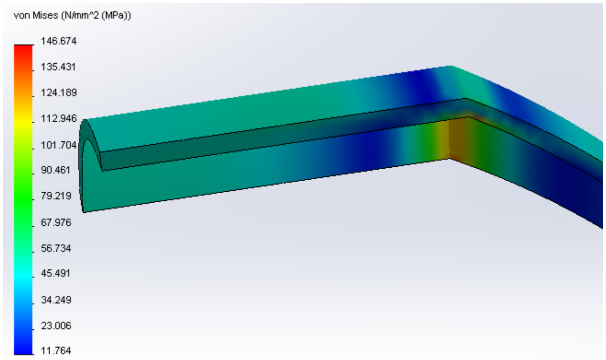

Figure 5. The reduced stress field for α=60°

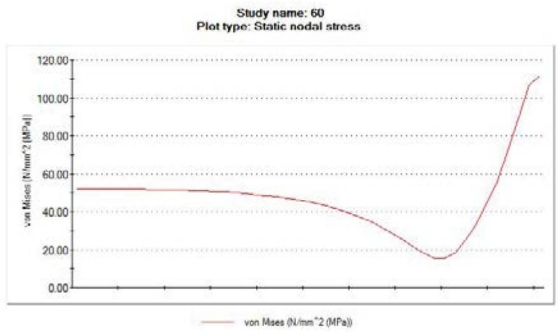

Figure 6. The process of reduced stress lengthwise the inner cylinder for α=60°

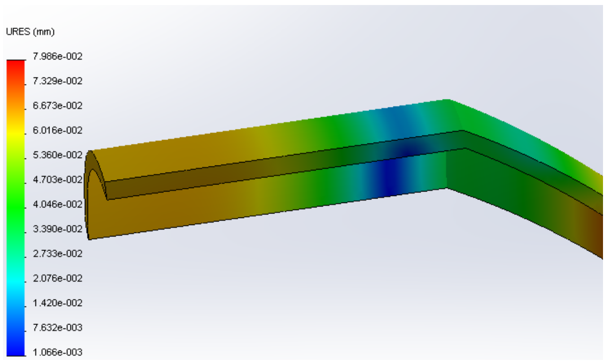

Figure 7. The field of deformations α=60°

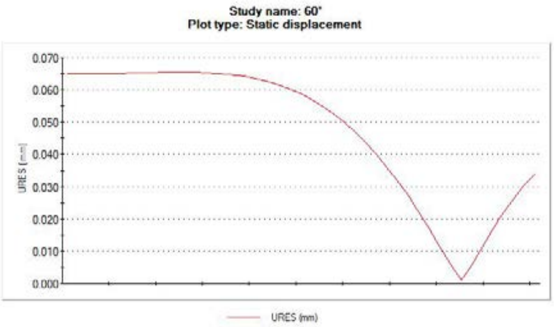

Figure 8. The process of the casing deformation for α=60°

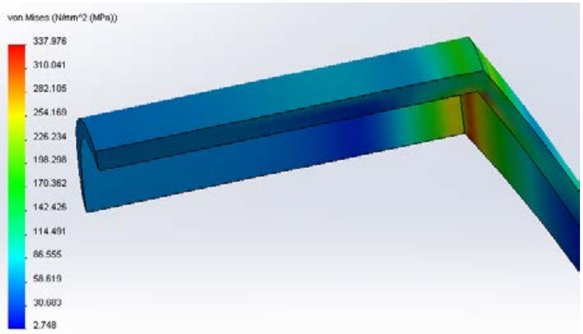

Figure 9. The field of reduced stress for α=30°

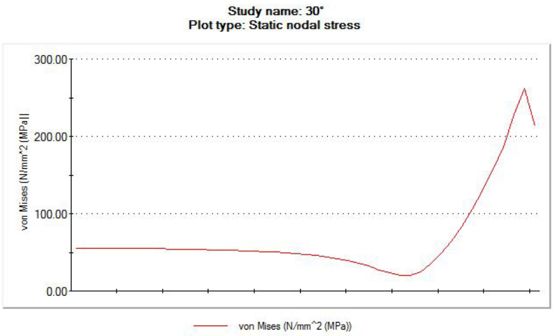

Figure 10. The process of reduced stress lengthwise the inner cylinder for α=30°

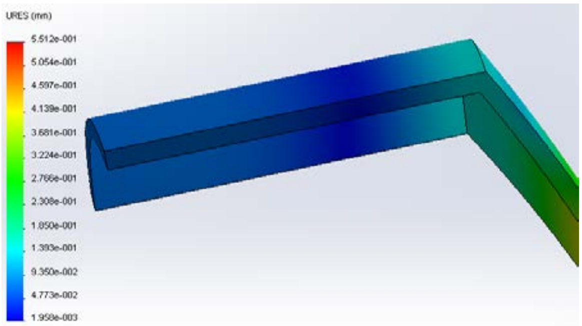

Figure 11. The field of deformations for α=30°

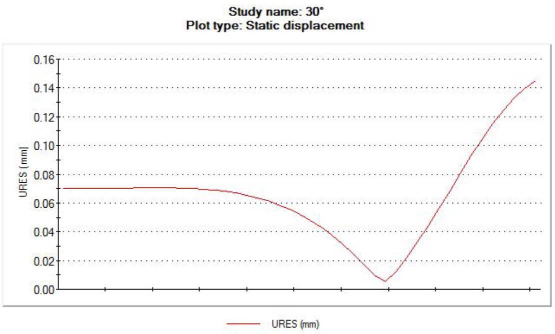

Figure 12. The process of the casing deformation for α=30°

On Figure 9 to Figure 12 are shown the processes of reduced stress and also the process of deformation on the cylindrical part of shell with the angle α = 30° during the transition to hemisphere bottom.

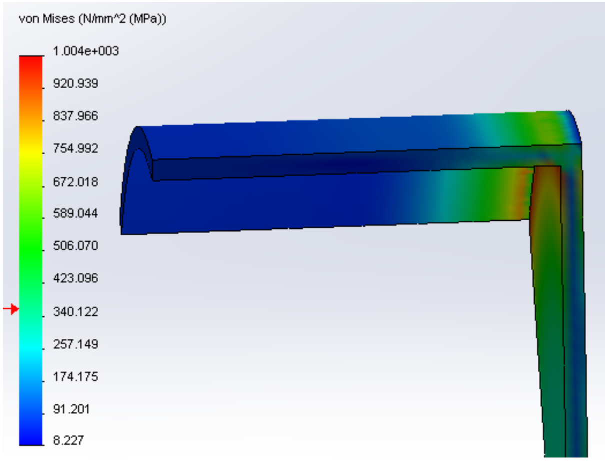

Figure 13. The field of reduced stress for the flat bottom

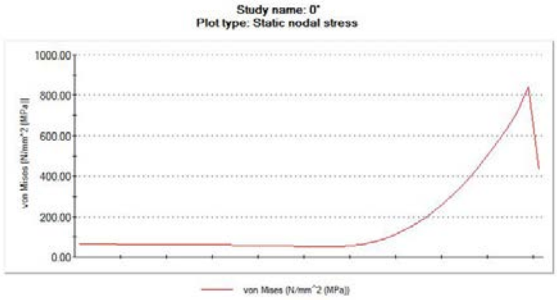

Figure 14. The process of reduced stress lengthwise the inner cylinder for the flat bottom

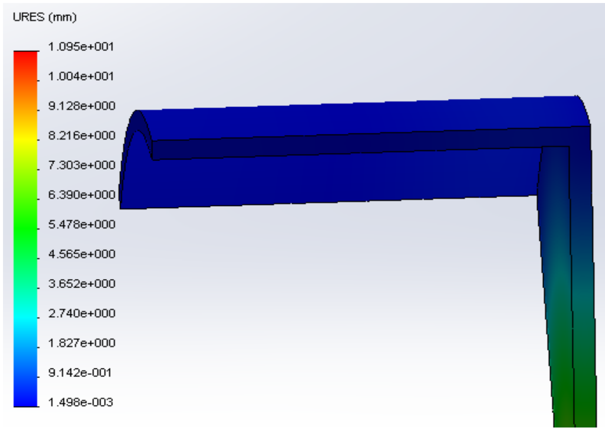

Figure 15. The field of deformations for the flat bottom

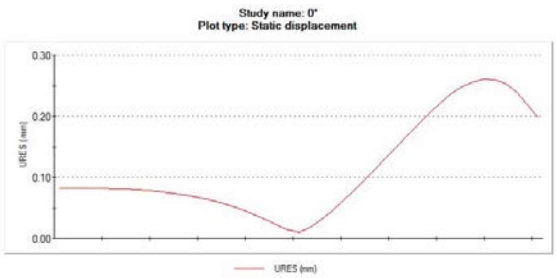

Figure 16. The process of the casing deformation for the flat bottom

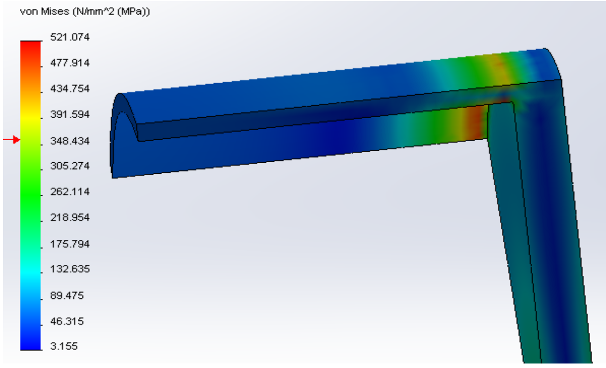

Figure 17. The field of reduced stress for the flat bottom with the change of thickness of the bottom

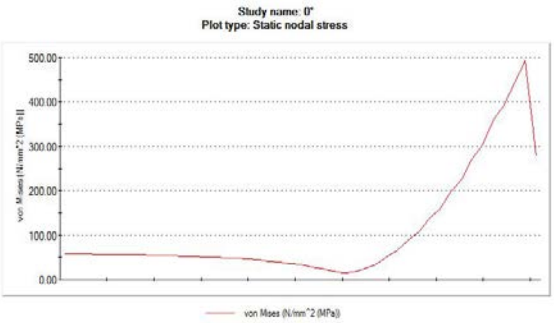

Figure 18. The process of reduced stress lengthwise the inner cylinder for the flat bottom with the change of thickness of the bottom

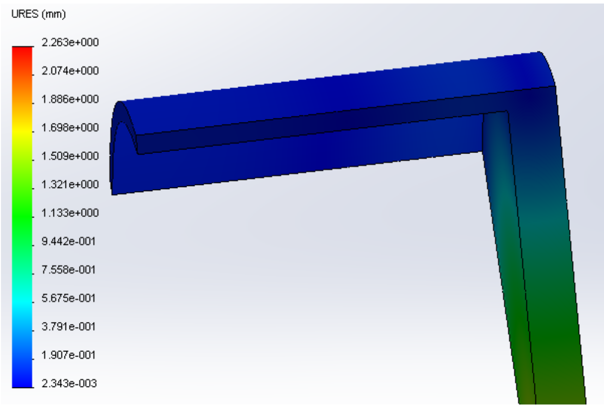

Figure 19. The field of deformations with the change of thickness of the flat bottom

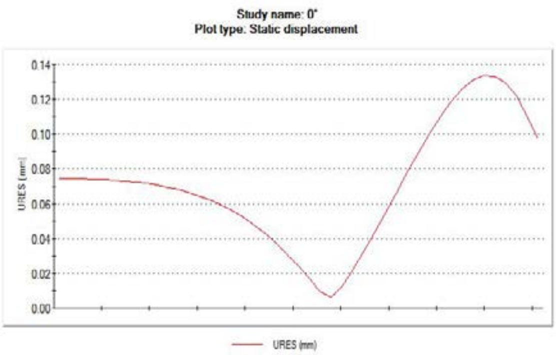

Figure 20. The process of the casing deformation with the change of thickness of the flat bottom

The case when the reduced stress process and the deformation process of the cylindrical part of shell during the transition to flat bottom are plotted on Figure 13 to Figure 16. The most stressed point is the junction of cylindrical casing and its bottom. There is possibility to reduce the stress and deformations by the expansion of the thickness of the shell bottom. The process of stress and deformation during the changes of thickness of the flat bottom are shown on Figure 17 to Figure 20.

From the results it can be concluded that the most boundary faults created by the bending fault at the junction of cylindrical part of vessel and its bottom are caused at the flat bottom. The case when the smallest spikes of stress and deformations are occurred is caused by the transition to hemisphere bottom with the angle $\alpha = 90°$.

3. Conclusion

The FEM, the dimensional model has been used to determine the reduced stress and possible displacement. The stress and deformations of casing shell were examined during the research. There were used a variety of vessel and also the different types of results were compared. It was found out that the reduced value of stress and also deformation of casing the shell occurs at the junction of the cylindrical part of the vessel and its flat bottom. The stress and deformation were gradually stabilized over the length of the cylinder. The worst bottom case is flat bottom because there are a lot of boundary faults. However the best case is when the hemispherical bottom of vessel is used.

Acknowledgement

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