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# 3D MODELLING OF A SHRINK FITTED CONCAVE ENDED CYLINDRICAL TANK FOR AUTOMOTIVE INDUSTRY

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ABSTRACT: The aim of this work is to present a method that allows the optimal design of a shrink fitted concave ended cylindrical tank for the storage of methane gas, based on the application of the Finite Element Method (FEM). This paper presents a methodology for the optimal shape design of a shrink fitted concave ended cylindrical tank for the automotive industry using the FEM and which is based on a specialized database of 3D parameterized shapes. The mechanical simulation, numerical calculations and geometrical modeling were applied for the three-dimensional complex models
KEYWORDS: engineering design, methane gas tank, optimization, Finite Element Method

## INTRODUCTION

Over the past few decades, important efforts have been made to develop and implement engineering design guidelines, construction and maintenance standards, and specifications for gas tanks used in the automotive industry, including standardized test methods [1-6].

In order to provide a better understanding of the gas tank design, optimization, reliability and manufacturing feasibility, the research efforts have been focused towards new, convergent, stable and robust CAD algorithms for obtaining the optimal solution [1-6].

## THE OPTIMIZATION METHOD

This paper presents a methodology for the optimal shape design of a shrink fitted concave ended cylindrical tank for the automotive industry using the FEM and which is based on a specialized database of 3D parameterized shapes. The mechanical simulation, numerical calculations and geometrical modeling were applied for the three-dimensional complex models [7-21].

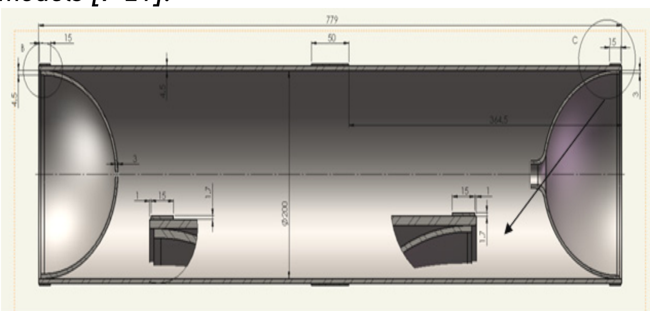

Figure 1. Constructive shape of a shrink fitted concave ended cylindrical tank

A gas tank for the automotive industry is made of three elements: a lateral one, an end up and a bottom one (Fig. 1). The elements are assembled afterwards to get the final form of the gas tank cover. A new analysis of the efforts and deformation states is done afterwards and the surety coefficient value is calculated and compared to the admissible value.

Further to consecutive optimizations, a shrink fitted cylinder with 3 rings (at the ends and around the middle of the tank) was chosen (Fig. 1). The volume of the gas tank is about 20 l.

## THE FINITE ELEMENT ANALYSIS OF A SHRINK FITTED CONCAVE ENDED CYLINDRICAL TANK

The Finite Element Analysis is a practical application of the finite element method (FEM), and can be used by engineers to mathematically model and numerically solve the complex structural problems of the gas tank [22].

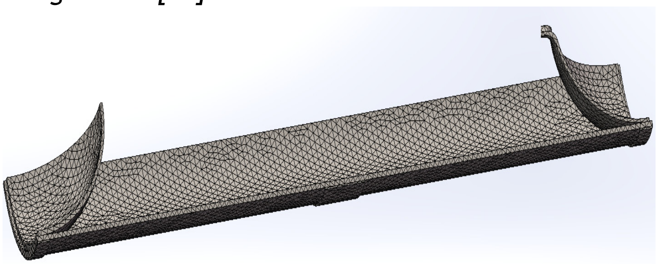

Figure 2. The finite element discretization of the model

The Finite element discretization of the 3D model is shown in Fig. 2. The pressure (distributed on all inner surfaces of the tank) and constraints (symmetry and roller slider) used in the finite element analysis are shown in Fig. 3.

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*For mathematical calculations, we use the following input data:*
- *maximum test pressure:* $p_h = 30\ N/mm^2$;
- *normal range of working temperature:* $T = -40\ ^0C,...,+60\ ^0C$;
- *type of gas tank cover material: AISI 4340;*
- *value of gas tank cover diameter:* $\phi = 200$ *mm.*

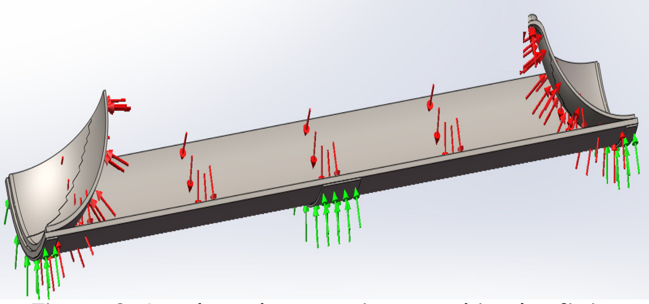


*Figure 3. Loads and constraints used in the finite element analysis*

*Applying the finite element analysis to the 3D model, with the SolidWorks 2011 software [23], the results which are shown in Figs. 4-23 were obtained.*

## *Analysis of the unpenetrated lid end tank*

*For the unpenetrated lid, the curves are symbolized by A – B and B – C. "e" index is used to define the curve on the exterior of the body, while "i" index is used to define the curve on the interior of the body.*

*Effort variation on the inner and outer surfaces of the unpenetrated lid is shown in Figs 4-5.*

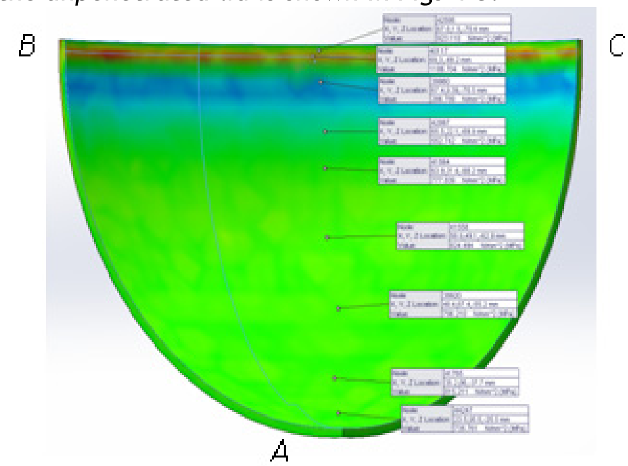



*Figure 4. Effort variation on the inner surface of the unpenetrated lid*

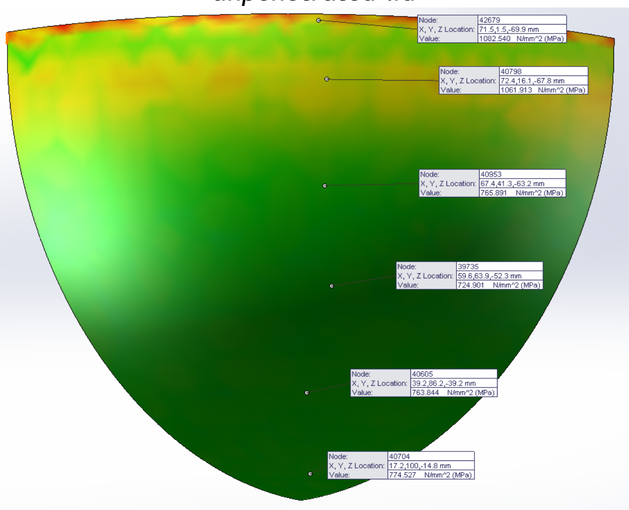


*Figure 5. Effort variation on outer surface of the unpenetrated lid*

*The distribution of the efforts along the A – B curves is given in Figs. 6-7.*

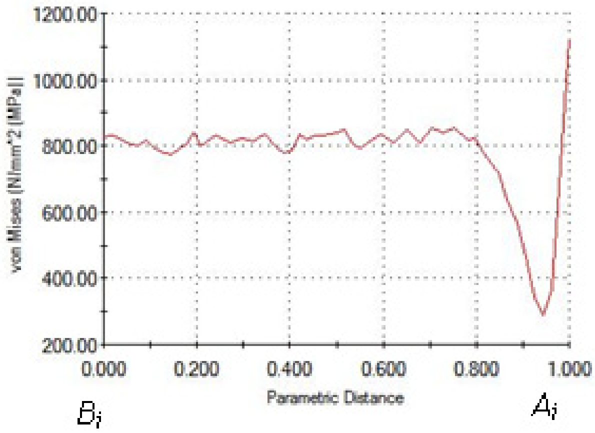



*Figure 6. Graphical representation of efforts along the* $A_i$ *–* $B_i$ *curve for the unpenetrated lid*

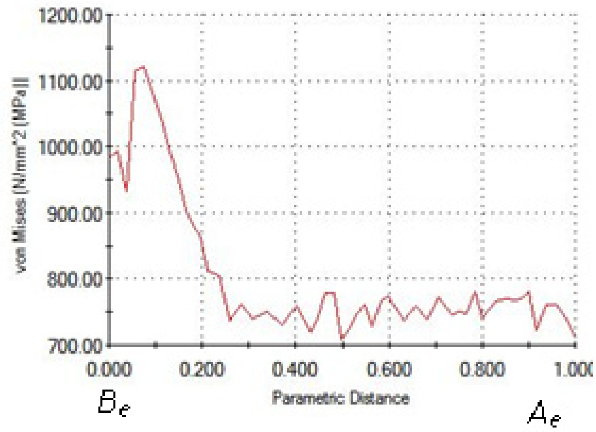



*Figure 7. Graphical representation of efforts along the* $A_e$ *–* $B_e$ *curve for the unpenetrated lid*

*Based on the distribution of efforts on the external side (Fig. 7), a maximum value of effort is obtained at about 3.5 mm distance from the unpenetrated lid. Let us note this curve with D – E, keeping the same indexes "e" and "i" (Fig. 8) and let us trace the graphical variation of efforts (Figs. 9-10).*

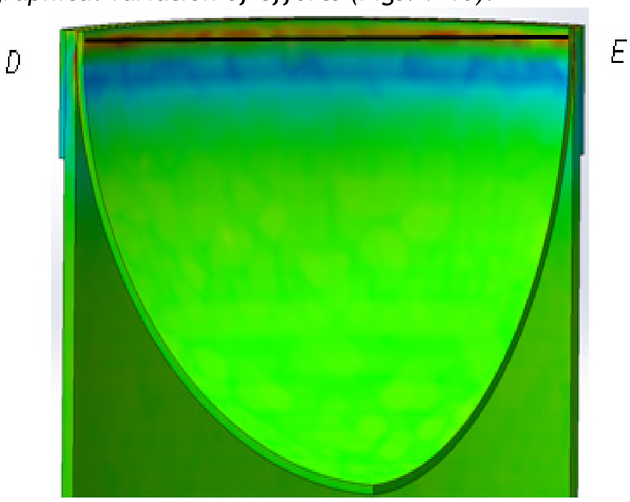



*Figure 8. D - E curve, used to analyze the effort variation for the unpenetrated lid*

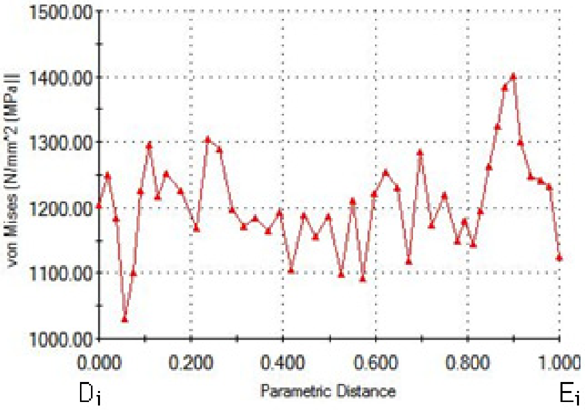



Figure 9. Graphical representation of the efforts along the $D_i$ - $E_i$ curve for the unpenetrated lid

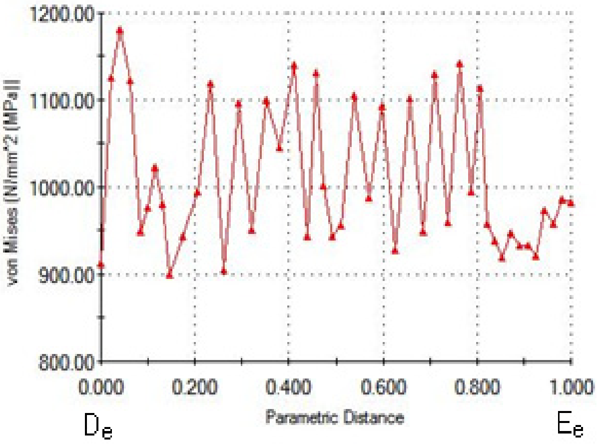



Figure 10. Graphical representation of the efforts along the $D_e$ - $E_e$ curve for the unpenetrated lid

## Analysis of the penetrated lid end tank

For the penetrated lid, the curves are symbolized with A – B and B – C. "e" index is used to define a curve on the exterior of the body, while "i" index is used to define a curve on the interior of the body. Effort variation on the inner and outer surfaces of the penetrated lid is shown in Figs. 11-12.

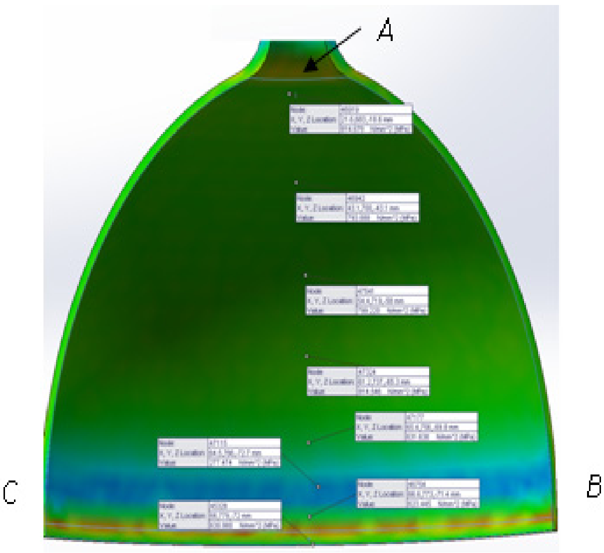



Figure 11. Effort variation on the inner surface of the penetrated lid

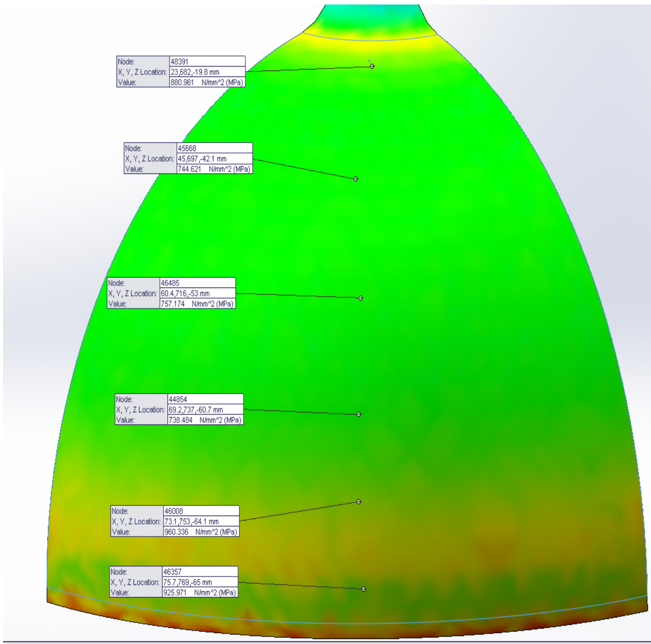


Figure 12. Effort variation on the outer surface of the penetrated lid

The effort distribution along the A – B curves is shown in Figs. 13-14.

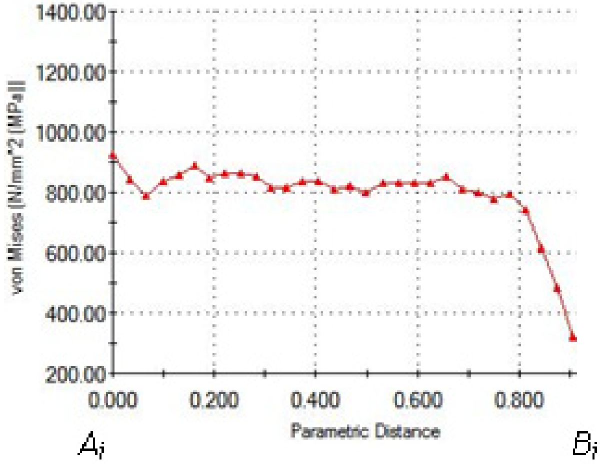



Figure 13. Graphical representation of efforts along the $A_i$ - $B_i$ curve for the penetrated lid

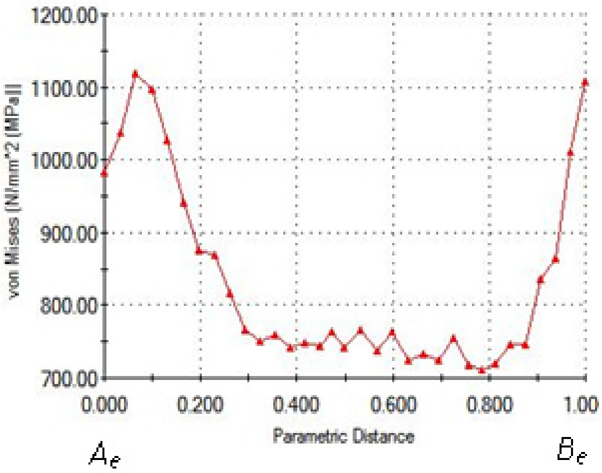



Figure 14. Graphical representation of efforts along the $A_e$ - $B_e$ curve for the penetrated lid

The effort distribution along the B – C curves is shown in Figs. 15-16.

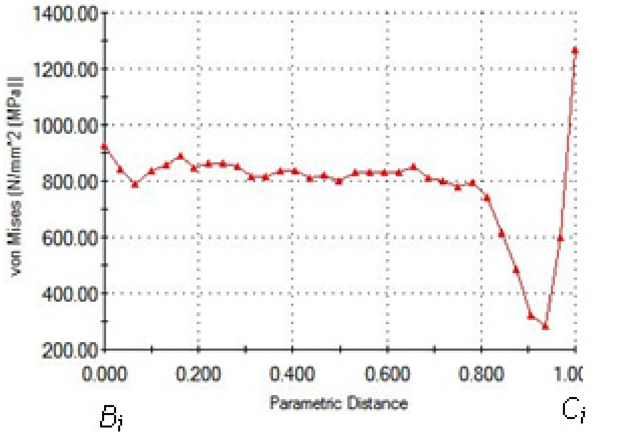



Figure 15. Graphical representation of efforts along the $B_i$ - $C_i$ curve for the penetrated lid

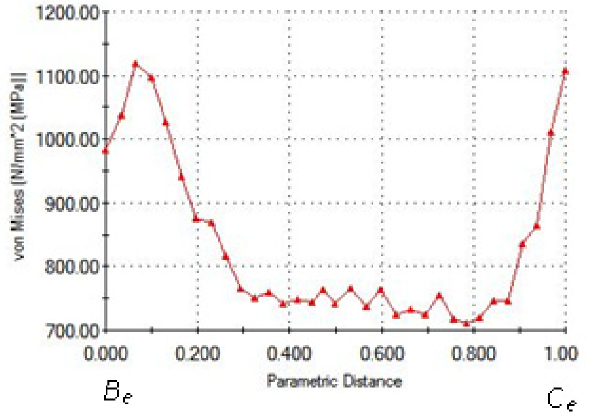



Figure 16. Graphical representation of efforts along the $B_e$ - $C_e$ curve for the penetrated lid

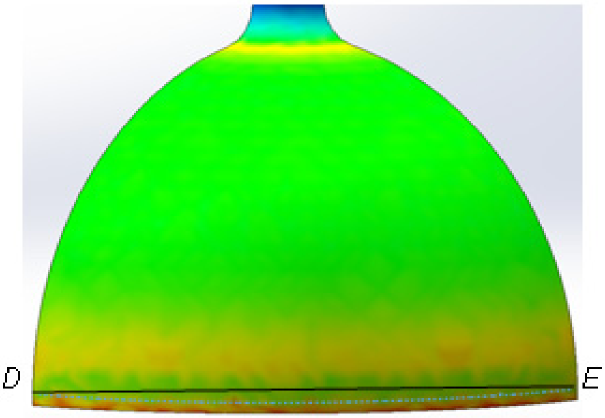



Figure 17. D - E curve, used to analyze the effort variation for the penetrated lid

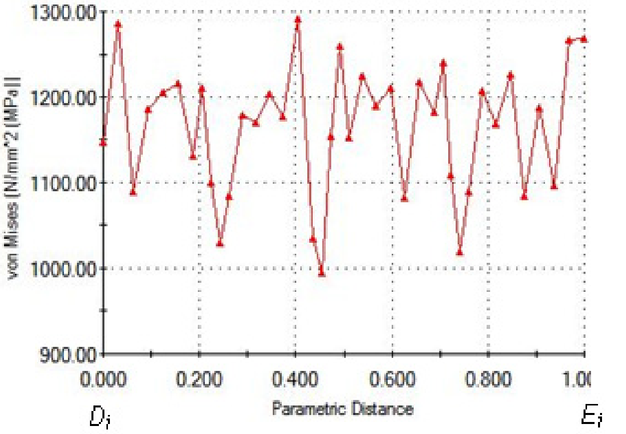



Figure 18. Graphical representation of efforts along the $D_i$ - $E_i$ curve for the penetrated lid

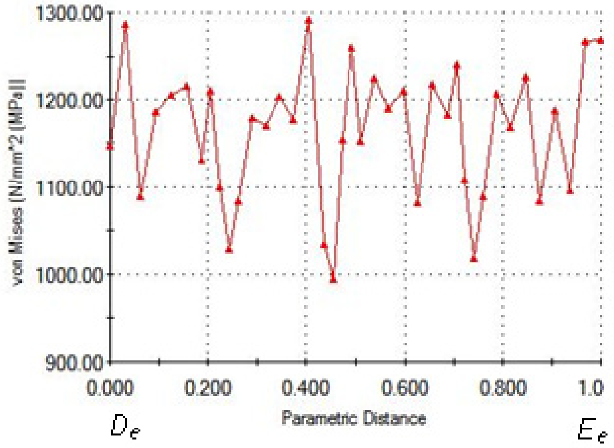



Figure 19. Graphical representation of the efforts along the $D_e$ - $E_e$ curve for the penetrated lid

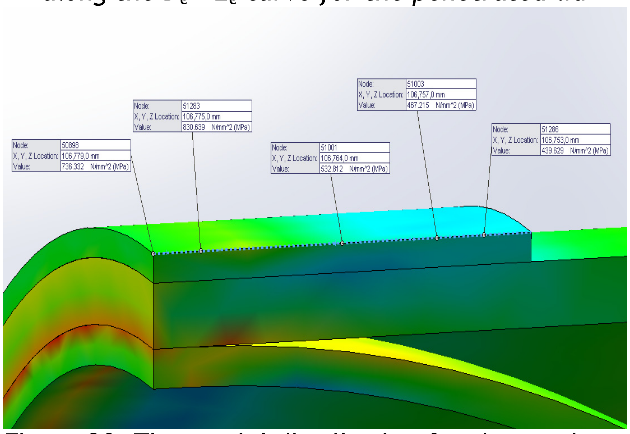


Figure 20. The spatial distribution for the resultant efforts on the shrink end ring

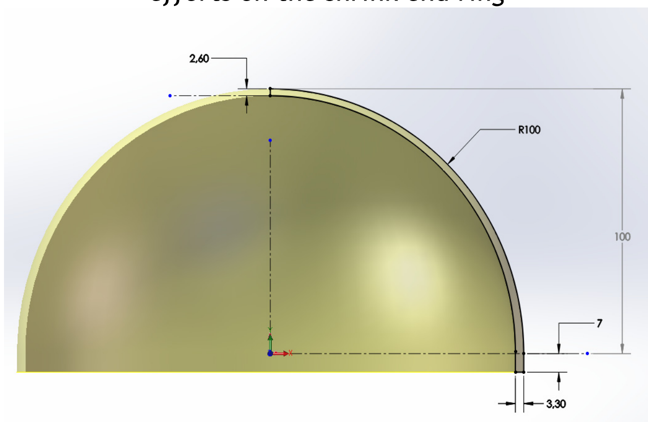



Figure 21. Constructive shape for the unpenetrated lid

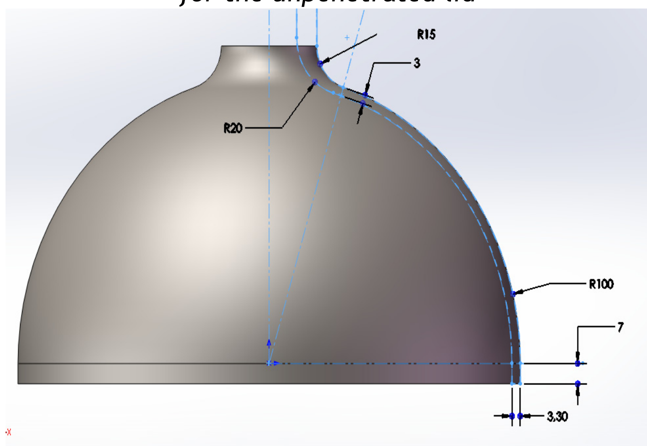
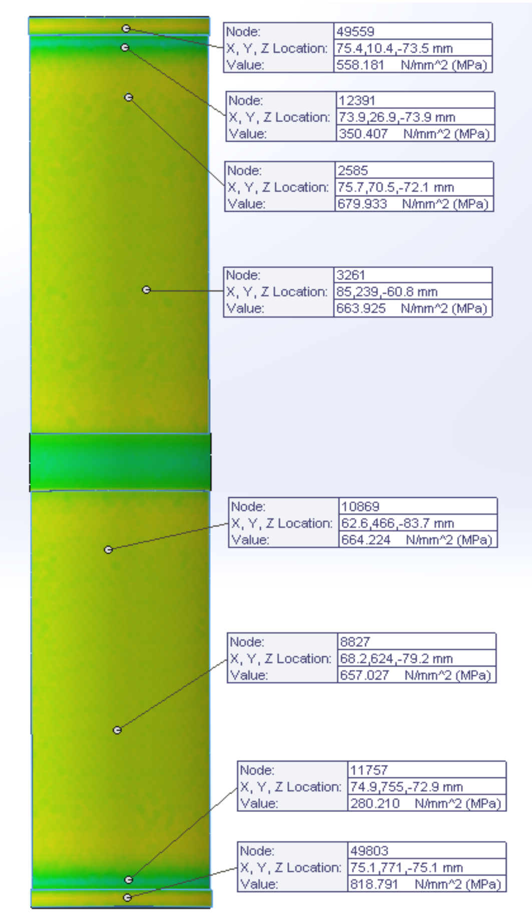
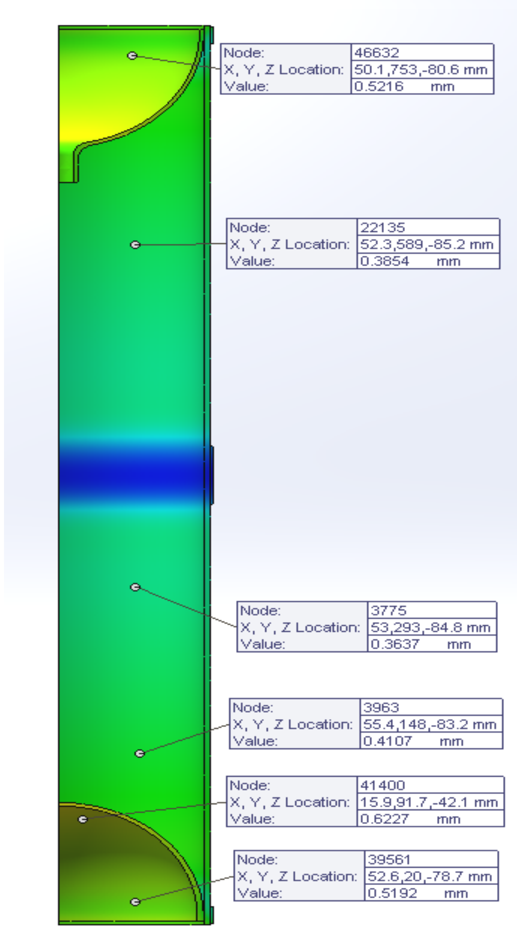



Figure 22. Constructive shape for the penetrated lid




a)




b)

*Figure 23. The spatial distribution for T = 65 $^0$C and $p_h$ = 35.2 N/mm$^2$: a) the resultant efforts state von Mises; b) the linear resultant deformations*

## CONCLUSIONS

*The resultant efforts state von Mises and the linear resultant deformations agree well with those derived from the experimental measurements. To validate the theoretical results, a reduced scale gas tank was built and tested with full pressure on a special test stand.*

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