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# 3D MODELLING OF A GAS TANK WITH REVERSED END UP COVERS FOR AUTOMOTIVE INDUSTRY

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ABSTRACT: The aim of this work is to present a method that allows the optimal design of the steel gas tank with reversed end up covers for storage of the methane gas based on the application of the Finite Element Method (FEM).
KEYWORDS: engineering design, methane gas tank, optimization, Finite Element Method

## INTRODUCTION

The global automotive industry has developed over a period of more than 100 years [1-7].

Natural gas can be used as automobile fuel. Having a residue-free burn, it is a proper alternative to the use of other fuel types. The use of natural gas as fuel for automobiles leads to reduced pollution. Pollution is reduced by 80 % as opposed to gasoline use [2].

Natural gas vehicles currently offer lower fuel costs. Despite its advantages, the use of natural gas vehicles faces several limitations, including fuel storage and infrastructure available for delivery and distribution at fueling stations.

During the past decades, different methods have been applied in engineering design of gas tanks used in automotive engineering for improving manufacturing processes [1-7].

The tank for natural gas is an important part of the apparatus. Usually it can be found both out of and inside the body of the vehicle [1, 3, 4]. For non-cylindrical tanks, reinforced or not, which hold high-pressure natural gas, the ASME and SR codes (ISO 11439-2003) regulate designing and the safety factor.

Advanced control methodologies, realtime programming methods, and computer-aided engineering technologies for advanced system modeling, virtual prototyping, and testing have revolutionized engineering design in automotive engineering [1-7].

Optimization theory and methods based on the multi-objective optimization, combined with more detailed and accurate simulation methods, have demonstrated some important advantages in modern automotive engineering compared to conventional design and optimization techniques [1]. The cost of some critical stages in the engineering design process, such as aerodynamic testing, has been dramatically reduced by computer simulation [1].

Current market requirements for steel gas tanks are: cost competitiveness and availability; design flexibility; fuel capacity; mass; durability and corrosion requirements [1].

The designing of such a gas tank will have to take into account a series of factors: exploitation conditions; safety factors; dimensional compactness conditions relating to the tank's emplacement; resting and fastening conditions; aerodynamics (for tanks placed outside the body, which have to have lower drag); own vibration patterns; economical criteria; technological manufacturing conditions; manufacturing type (repetitive, discrete). Fulfilling these requirements is related to the mathematical description of the requirements.

## THE OPTIMIZATION METHOD

This paper presents a methodology for optimal shape design of a gas tank with reversed end up covers for automotive industry using the FEM and 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 [8-18].

The optimization method includes the following steps:

☐ *the shape of the gas tank is shown in Fig. 1;*
☐ *the shape is decomposed into its main components and the type of gas tank cover is identified;*
☐ *the gas tank covers are selected from the specialized database of 3D parameterized shapes;*
☐ *the material selected for the construction of the gas tank covers is chosen;*
☐ *the shape and dimensions of the gas tank covers are modeled and optimized using the FEM;*
☐ *the real dimensions of the gas tank covers are rounded to the nearest representable values;*
☐ *the 3D parameterized real model of the gas tank is modeled and assembled;*
☐ *a study of efforts and deformation states is performed using the 3D real assembly model.*

*The application of each of constrained optimization procedures is dependent on the structure's geometry, boundary conditions and the applied mathematical structure of the model.*
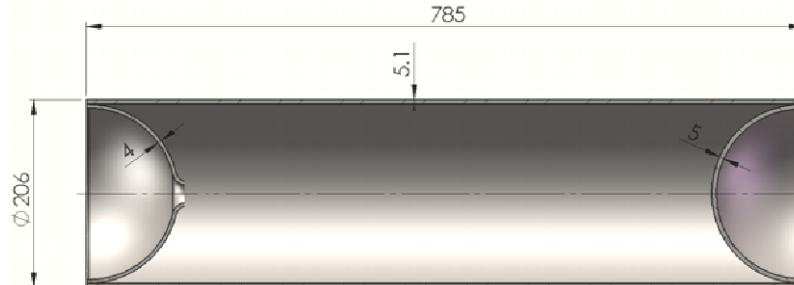


*Figure 1. Constructive shape of a gas tank with reversed end up covers*

*As a principle, a methane gas tank for automotive industry is made of three elements: a lateral one, an end up one and a bottom one (Fig. 1). Due to the wide variety of these gas tank covers, their design optimization is done separately. Elements are assembled afterwards to get the final form of the gas tank cover. A new analysis of efforts and deformation states is done afterwards and the surety coefficient value is calculated and compared with the admissible value.*

## THE FINITE ELEMENT ANALYSIS OF THE GAS TANK WITH REVERSED END UP COVERS

*The optimum design through the Finite Elements Method can significantly reduce the weight, the cost of manufacturing and increase security and even the reliability of the gas tank.*

*The mathematical model used is subdivided by finite elements which are connected to each other with nodes. Reliability of the FEM predictions depends on the number of finite elements [19].*

*The 3D model was discretised into 22,230 elements (Fig. 2). The pressure is distributed on all inner surfaces of the tank (Fig. 3). Constraints (symetry and roller slider) used in the finite element analysis are represented in Fig. 4.*



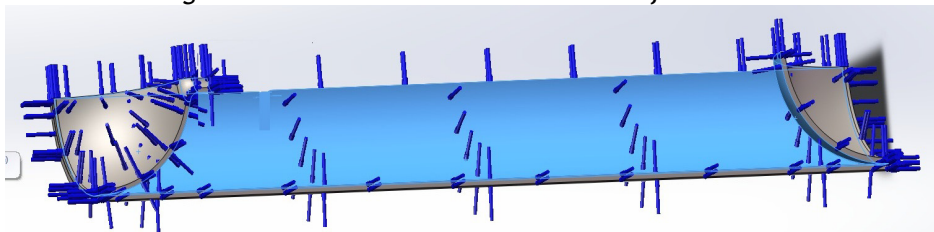*Figure 2. Finite element discretization of the model*



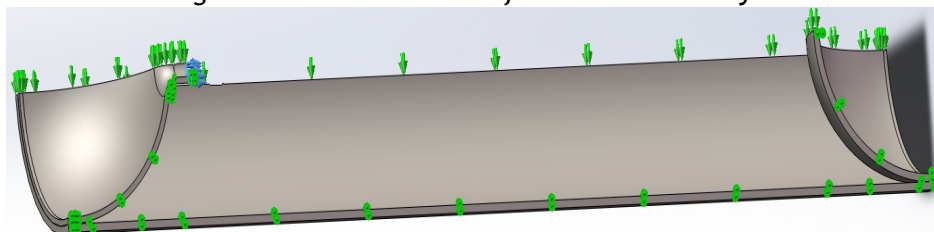*Figure 3. Loads used in the finite element analysis*



*Figure 4. Constraints (symetry and roller slider) used in the finite element analysis*

*For mathematical calculations, we use next input data: - the maximum test pressure: $p_h$ = 30 N/mm$^2$; - the normal range of working temperature: T = -40 $^0$C,..., +60 $^0$C; - the type of gas tank cover material: AISI 4340; - the value of gas tank cover diameter: $\phi$ = 206 mm.*

The material: high tensile steel AISI 4340 with the typical properties shown in Table 1. The typical chemical analysis for AISI 4340 is: Carbon 0.40 %; Silicon 0.25 %; Manganese 0.70 %; Nickel 1.85 %; Chromium 0.80 % and Molybdenum 0.25 %.

Table 1: The typical material properties of AISI 4340

| Characteristics | Symbol | Units of measurement | Value |
|---|---|---|---|
| Longitudinal modulus of elasticity | $E$ | $[N/mm^2]$ | 205000 |
| Shear Modulus | | $[N/mm^2]$ | 8000 |
| Density | $\rho$ | $[kg/m^3]$ | 7850 |
| Elongation unit load | $\sigma_t$ | $[N/mm^2]$ | 1110 |
| Admissible unit load | $\sigma_a$ | $[N/mm^2]$ | 710 |
| Coefficient of linear thermal expansion | $\alpha$ | $[^0K]$ | $1.23 \cdot 10^{-5}$ |
| Coefficient of thermal conductivity | $\lambda$ | $[W/(m \cdot K)]$ | 44.5 |
| Specific heat capacity | $c_p$ | $[J/(kg \cdot K)]$ | 475 |

Applying the finite element analysis with the SolidWorks 2011 software [20] to the 3D model, we get the results shown in Figs. 5-10.
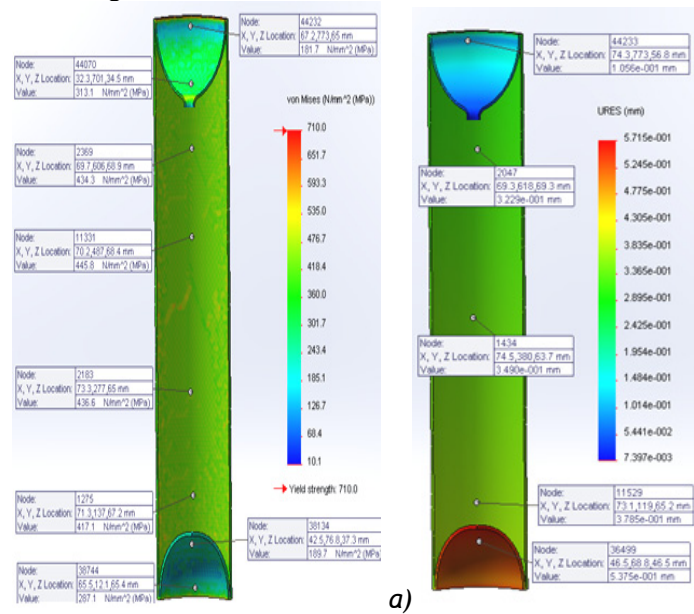


Figure 5. The spatial distribution for T = - 40 $^0$C and $p_h$ = 24.3 N/mm$^2$:
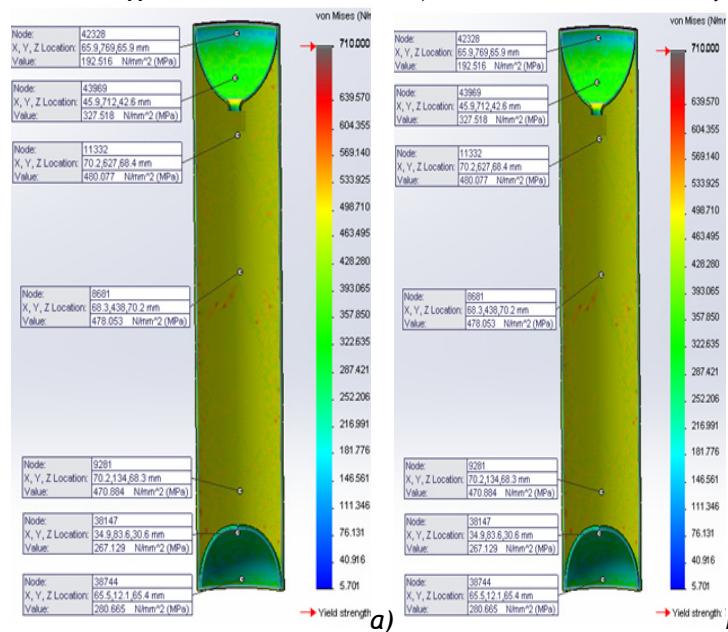a) the resultant efforts state von Mises; b) the linear resultant deformations



Figure 6. The spatial distribution for T = -20 $^0$C and $p_h$ = 26.4 N/mm$^2$:
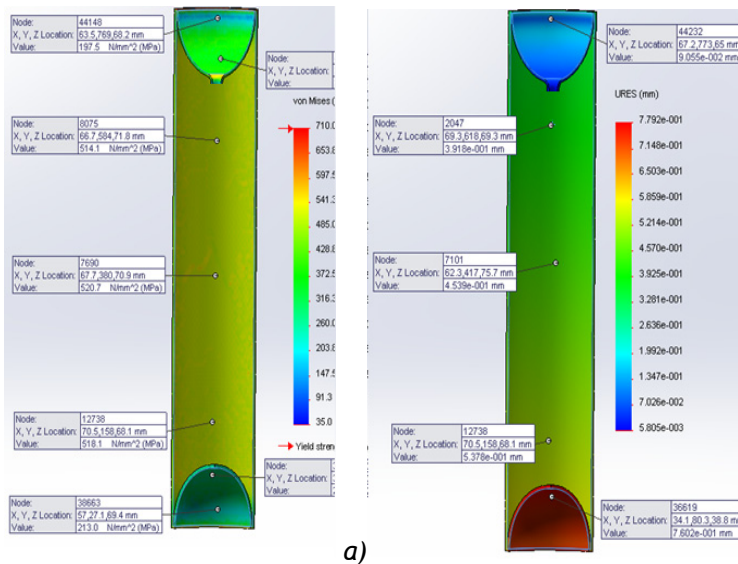a) the resultant efforts state von Mises; b) the linear resultant deformations

*a)*        *b)*

**Figure 7. The spatial distribution for T = 0 $^0$C and $p_h$ = 28.4 N/mm$^2$:**
*a) the resultant efforts state von Mises; b) the linear resultant deformations*



*a)*        *b)*

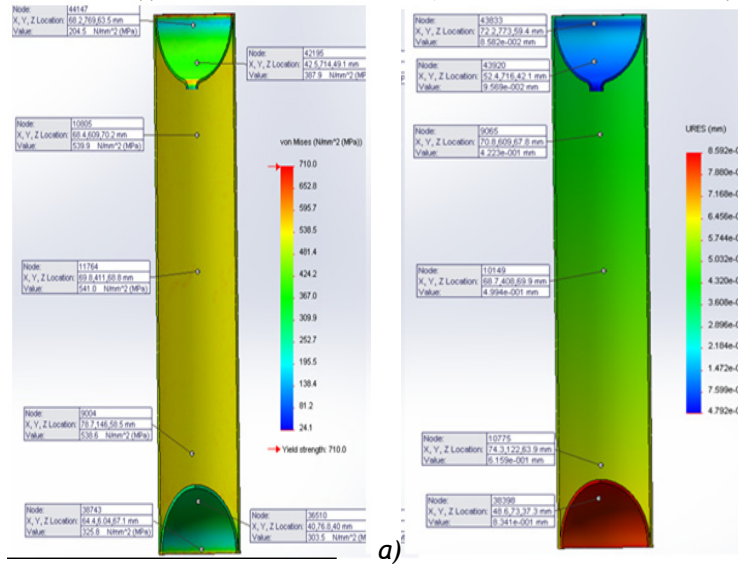**Figure 8. The spatial distribution for T = 15 $^0$C and $p_h$ = 30 N/mm$^2$:**
*a) the resultant efforts state von Mises; b) the linear resultant deformations*



*a)*        *b)*

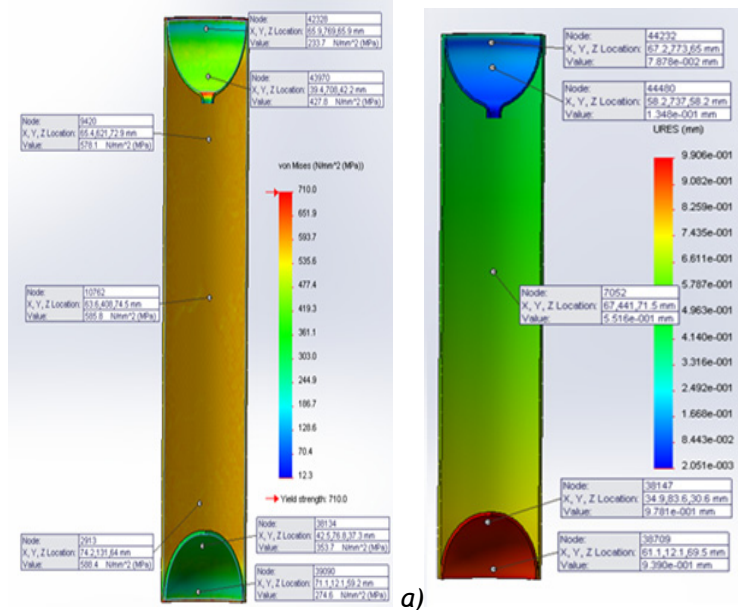**Figure 9. The spatial distribution for T = 40 $^0$C and $p_h$ = 32.6 N/mm$^2$:**
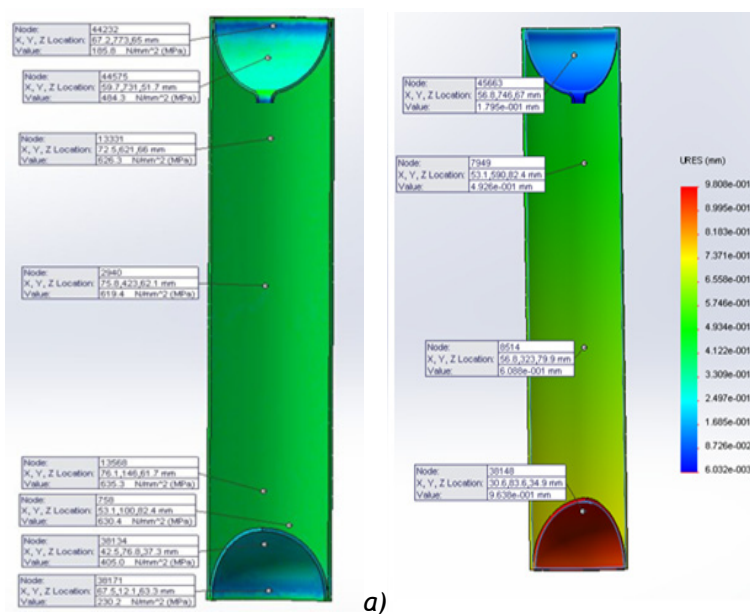*a) the resultant efforts state von Mises; b) the linear resultant deformations*

Figure 10. 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

The resultant efforts state von Mises and the linear resultant deformations agree well with those derived from the experimental measurements.

## CONCLUSIONS

A modern method for designing of a gas tank with reversed end up covers for automotive industry is presented in the paper. Based on these results, it can be seen that the proposed method for dimensional optimization applied to the 3D parameterized components is correct and efficient.

Results from technical analyses and simulations indicate, that depending on the requirements and considering manufacturing costs and operational conditions, the proper variant of the gas tank can be chosen.

The following acceptance tests were performed prior to delivery for methane gas tank: a) preliminary examination; b) pre-proof volumetric capacity; c) ambient proof pressure; d) post-proof volumetric capacity; e) external leakage; f) final examination; g) cleanliness measurement.

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