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COMPUTER-AIDED DESIGN OF A CLASSICAL CYLINDER GAS TANK FOR THE AUTOMOTIVE INDUSTRY

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ABSTRACT: The objective of the present study is to employ the Finite Element Method (FEM) for the dimensional optimization of a compressed gas cylinder for cars, with classical shape, made of the 34CrMo4 material. The 34CrMo4 material as an excellent alloy has been increasingly applied in the design and manufacturing of compressed gas cylinders for cars. The predicted results using the finite element analysis are in good agreement with those obtained through experiments in terms of the normal unitary efforts and linear deformations.

KEYWORDS: engineering design, gas tank, optimization, Finite Element Method

INTRODUCTION

Over the past few decades, the global automotive industry market has become increasingly competitive [1-3]. Major efforts have been made to develop and implement computer-aided design/computer-aided manufacturing (CAD/CAM) technology for new products like the gas tanks used in the automotive industry [1-3].

The effective implementation of CAD/CAM systems offers the manufacturers from the automotive industry benefits such as: a more efficient use of materials, standardized test methods, reduced design costs, reduced cycle time, improved information flow, and a much easier mass production [4-6].

THE OPTIMIZATION METHOD

This paper presents a methodology for the optimal shape design of a compressed gas tank cylinder for the automotive industry, with classical shape, made of 34CrMo4 material, 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 to the three-dimensional complex models [7-21].

The optimization of such a gas tank will have to take into consideration a series of conditions regarding the following: working conditions, safety conditions, dimension and compactness conditions, depending on the placement of the tank, propping and anchorage conditions, aero dynamicity conditions (for external tanks anchored to the vehicle that should present low resistance to moving forward, and aerodynamic drag), specific vibration modes, economical criteria, technological conditions of manufacturing, production type (i.e. series, unique item).

Fulfilling those requirements is connected to the mathematical description of those conditions to which a series of restrictions are attached, among which there varies a series of specific parameters which intervene in the mathematical description and which are optimized by means of objective functions. By means of minimization or maximizations, objective functions determine those parameters, which obviously will finally resort to determine several dimensional sizes of the reservoir.

Practice shows that those requirements cannot be fulfilled simultaneously, but under acceptable, limited compromise conditions, for several of the criteria, there can be obtained a product with high performance operation, fulfilling the technical prescriptions in the beneficiary's specifications.

In conclusion, there results that the dimensional optimization of a cylinder which equips a motor vehicle offers real dimensions for which the real technical performances are close to the optimal ones of the objective functions defined during the planning phase.

The operating conditions of a fuel tank may generate different demands depending on the vehicle type. They may depend on: a) the temperatures connected to the climate environment in which they are operated; b) the external aggression of the environment the tank comes into contact with concerning aggression through the corrosion of the material of which the recipient is made; (generally external anticorrosive protection measures are taken), or internally, the aggressive corrosion of the metal for the internal environment connected to the fuel type it stores inside; c) mechanical stress, reactions to suspension, force due to the equipment mounted on the tank, reaction to the drag/ air resistance force when advancing (for external tanks), force corresponding to the fuel weight inside the tank, force due to the weight associated to tank mass, forces of inertia associated to the dynamics of the motor vehicle movement process (in case of deceleration or acceleration movements), centrifugal forces generated by movements carried along curvilinear trajectories, forces on front/back/lateral impact (in case of accidents), forces due to oscillatory processes damped or maintained, forces due to thermal stress as a consequence of suspension constraints which prevent the expansion of the tank structure [2, 3].

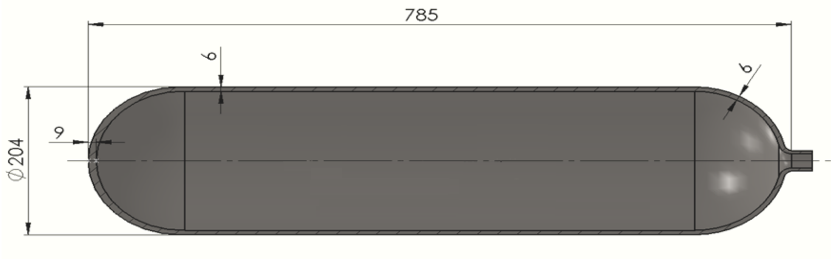


Figure 1. Constructive shape of a cylindrical gas tank

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 shape of the gas tank cover. A new analysis of the efforts and deformation states is conducted afterwards and the certainty coefficient value is calculated and compared to the admissible value.

THE FINITE ELEMENT ANALYSIS OF THE CYLINDRICAL GAS 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].

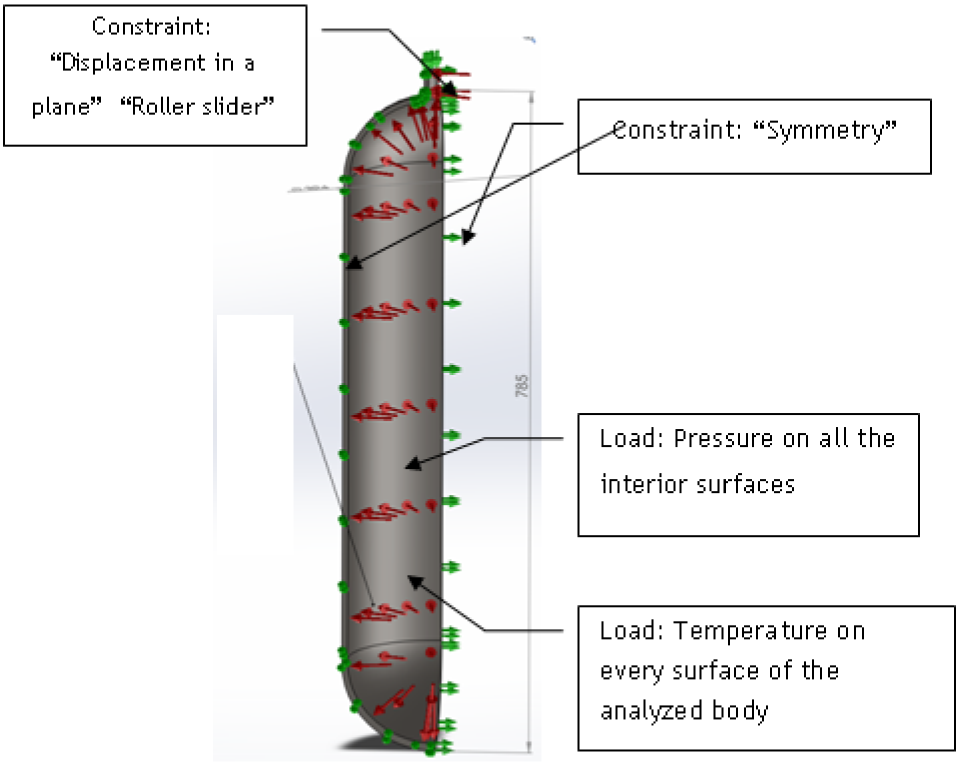


Figure 2. Loads and constraints used in the finite element analysis

The analyzed metallic cylinder has the following characteristics: capacity = 20 l; diameter = 204 mm; weight = 23.7 kg; length = 785 mm; operating pressure = 20 MPa; material - 34CrMo4.

In our analysis, the data from Table 1 have been used as reference values (values calculated for an isochoric transformation according to ISO 11439 requirements).

The constraints and loads used within the finite element analysis for the discretization of the 3D model are presented in Figure 2. For mathematical calculations, we use a normal range of working temperatures: T = -40 ^{0}C,..., +65 ^{0}C.

Table 1. Pressure variance with temperature for isochoric transformation considered as reference values

Case no.	Temperature [°C]	Pressure [N/mm^2]
1	-40	24.3
2	-20	26.4
3	0	28.4
4	15	30.0
5	40	32.6
6	65	35.2

Applying the finite element analysis to the 3D model, with the SolidWorks 2011 software [23], spatial distributions of the resulting normal unitary effort and the resulting linear deformation for the digitized values of the temperatures (Table 1) were obtained and represented in Figures 3-8.

a) Graphical representation of spatial distributions of the resulting normal unitary effort and the resulting linear deformation, for a temperature of (-40) °C and a pressure of 24.3 N/mm^2 are given in Figure 3.

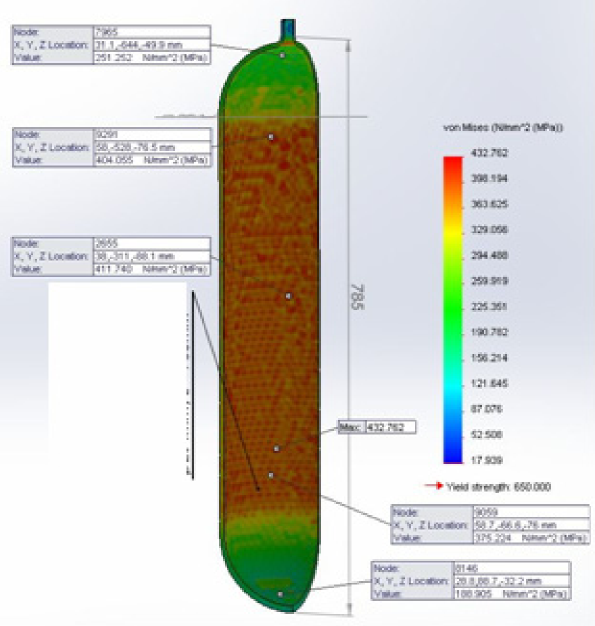


Figure 3a. Spatial distributions of the resulting normal unitary effort for a temperature of (- 40) °C and a pressure of 24.3 N/mm^2

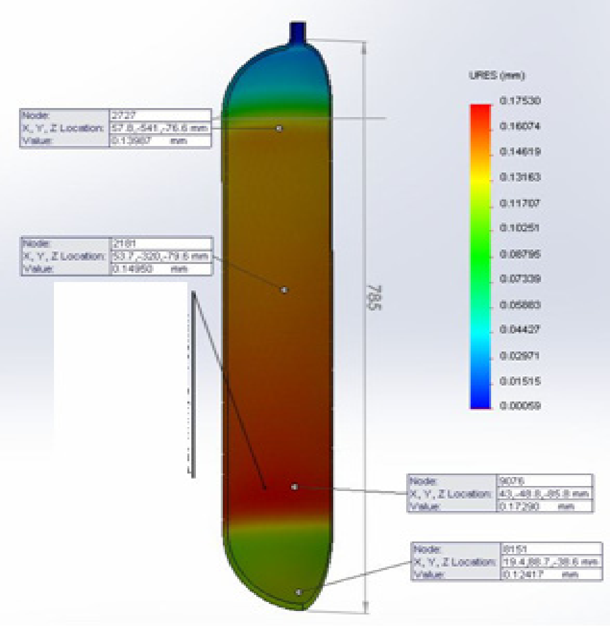


Figure 3b. Spatial distributions of the resulting linear deformation for a temperature of (- 40) °C and a pressure of 24.3 N/mm^2

b) Graphical representation of spatial distributions of the resulting normal unitary effort and the resulting linear deformation, for a temperature of (-20) °C and a pressure of 26.4 N/mm^2 are given in Figure 4.

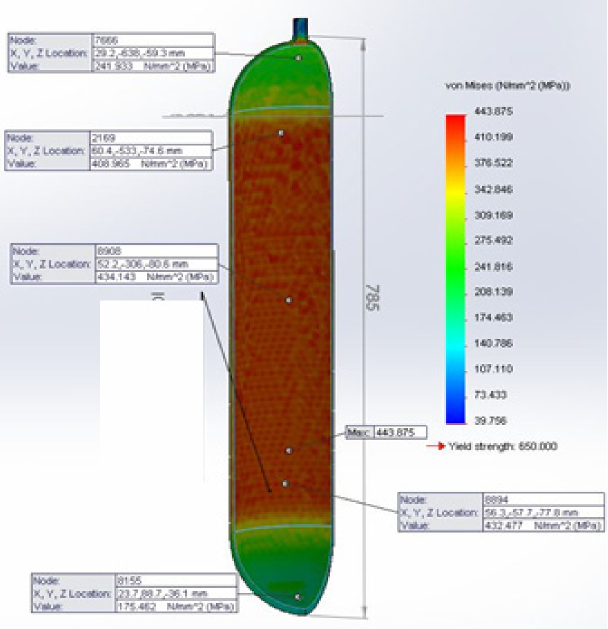


Figure 4a. Spatial distributions of the resulting normal unitary effort for a temperature of (- 20) °C and a pressure of 26.4 N/mm^2

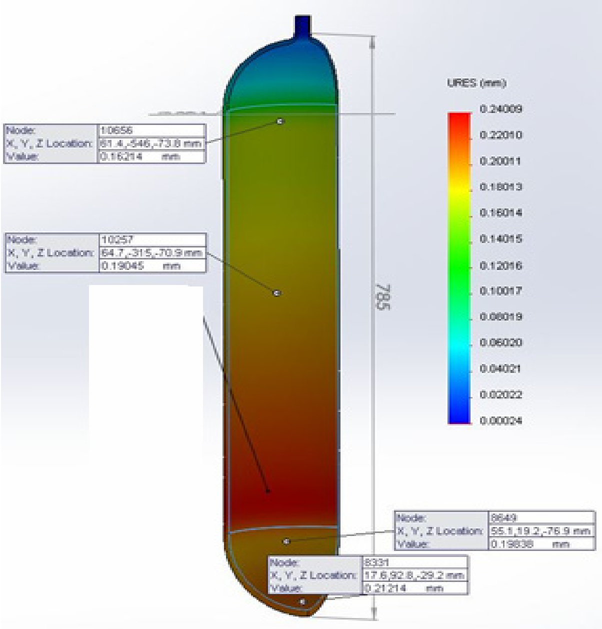


Figure 4b. Spatial distributions of the resulting linear deformation for a temperature of (- 20) °C and a pressure of 26.4 N/mm^2

c) Graphical representation of spatial distributions of the resulting normal unitary effort and the resulting linear deformation, for a temperature of 0°C and a pressure of 28.4 N/mm^2 are given in Figure 5.

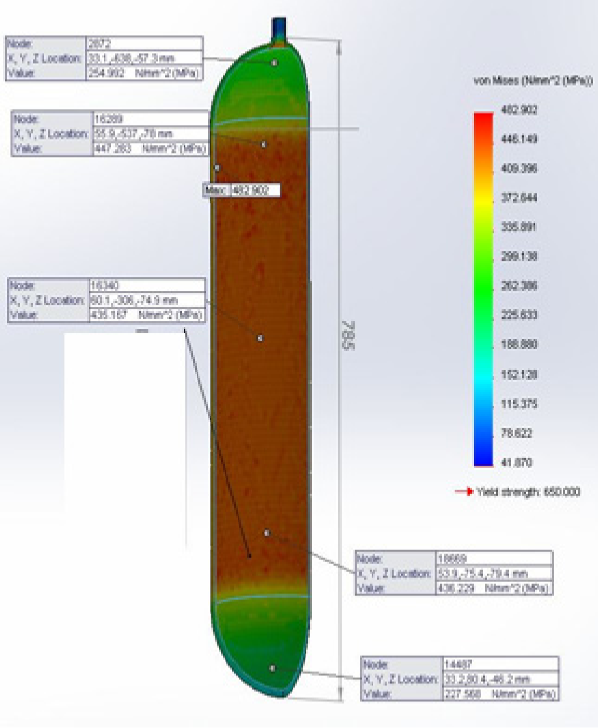


Figure 5a. Spatial distributions of the resulting normal unitary effort for a temperature of 0°C and a pressure of 28.4 N/mm^2

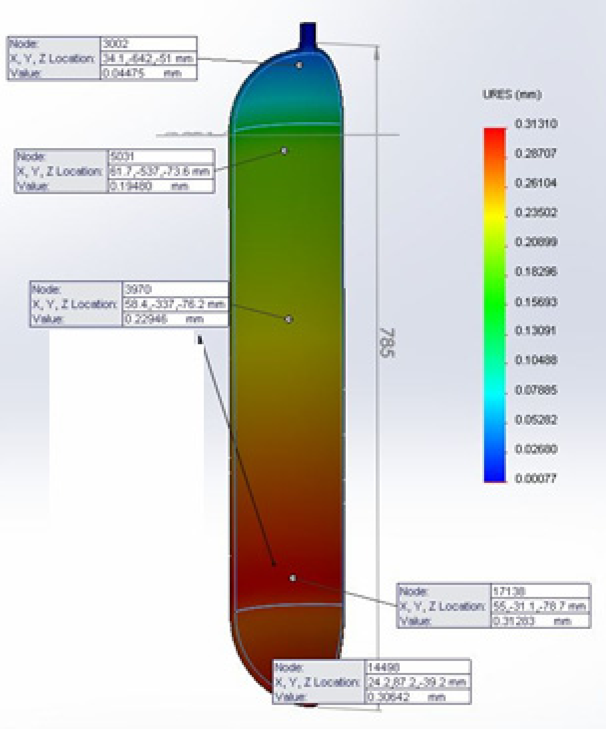


Figure 5b. Spatial distributions of the resulting linear deformation for a temperature of 0°C and a pressure of 28.4 N/mm^2

d) Graphical representation of spatial distributions of the resulting normal unitary effort and the resulting linear deformation, for a temperature of 15°C and a pressure of 30.0 N/mm^2 are given in Figure 6.

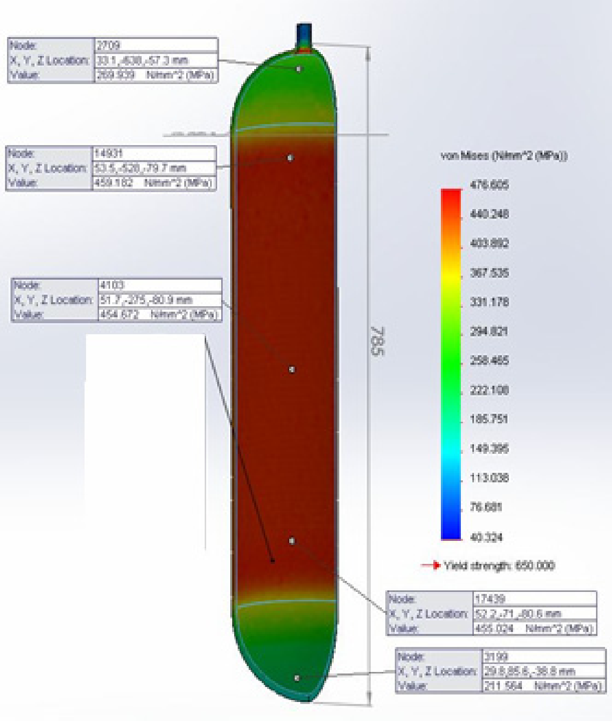


Figure 6a. Spatial distributions of the resulting normal unitary effort for a temperature of 15°C and a pressure of 30.0 N/mm^2

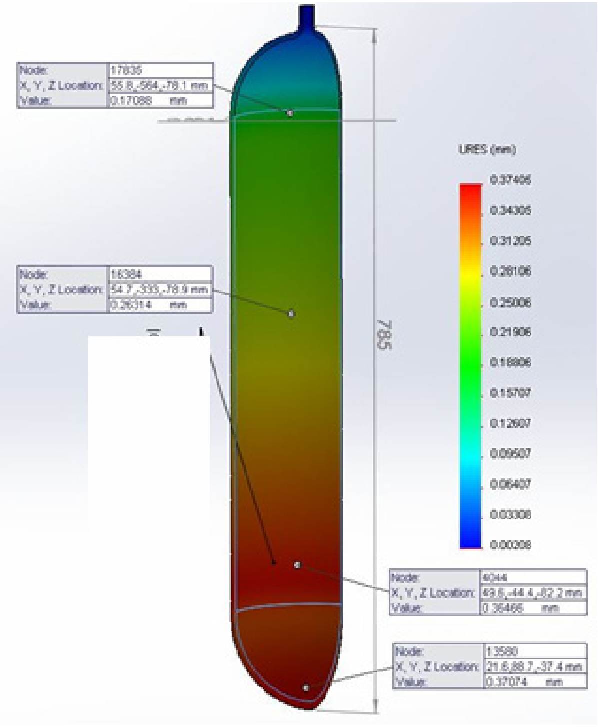


Figure 6b. Spatial distributions of the resulting linear deformation for a temperature of 15°C and a pressure of 30.0 N/mm^2

e) Graphical representation of spatial distributions of the resulting normal unitary effort and the resulting linear deformation, for a temperature of 40 °C and a pressure of 32.6 N/mm^2 are given in Figure 7.

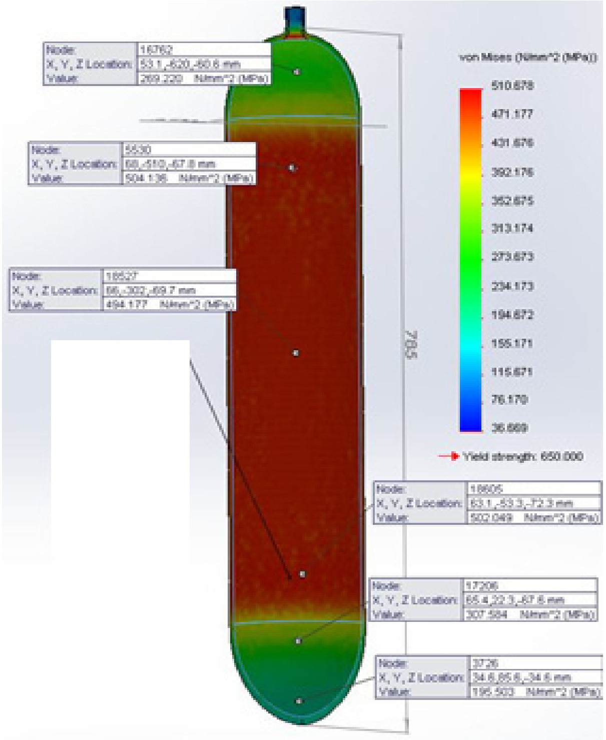


Figure 7a. Spatial distributions of the resulting normal unitary effort for a temperature of 40°C and a pressure of 32.6 N/mm^2

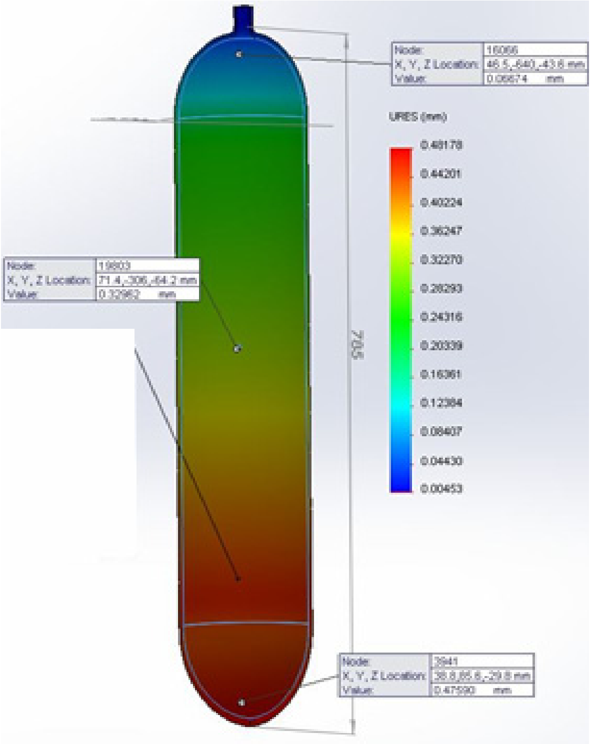
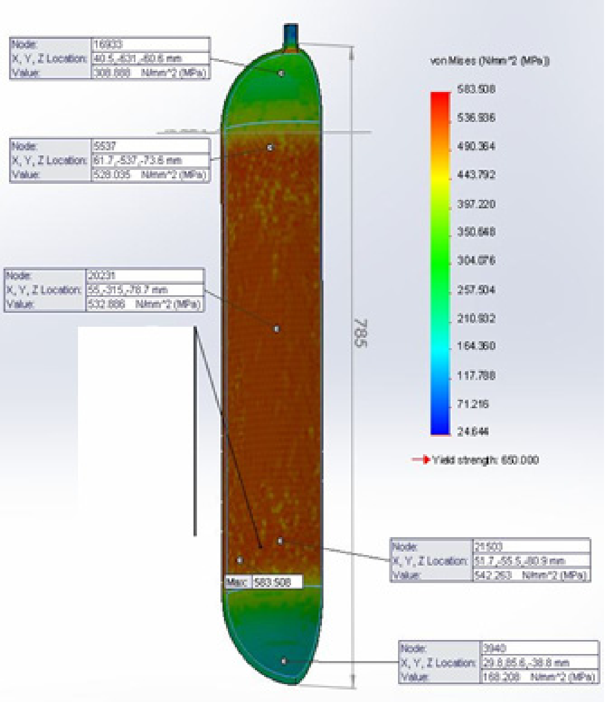


Figure 7b. Spatial distributions of the resulting linear deformation for a temperature of 40°C and a pressure of 32.6 N/mm^2

f) Graphical representation of spatial distributions of the resulting normal unitary effort and the resulting linear deformation, for a temperature of 65 °C and a pressure of 35.2 N/mm^2 are given in Figure 8.



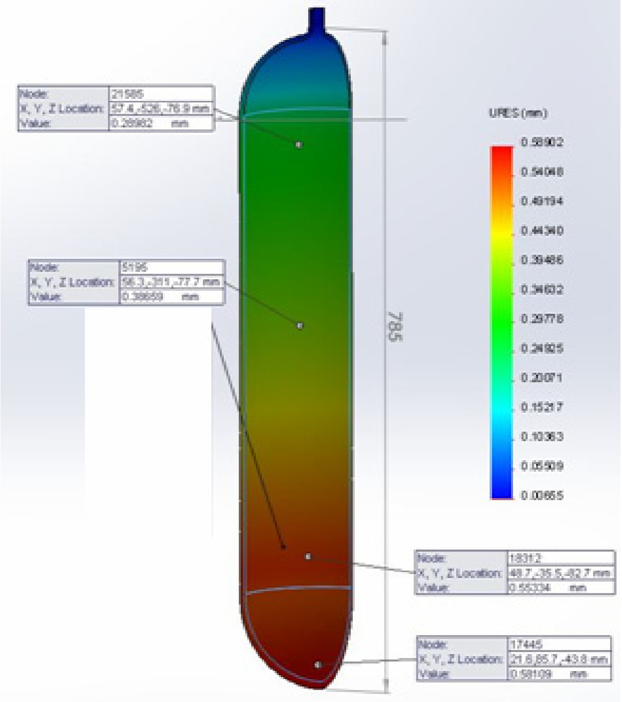


Figure 8a. Spatial distributions of the resulting normal unitary effort for a temperature of 65°C and a pressure of 35.2 N/mm^2

Figure 8b. Spatial distributions of the resulting linear deformation for a temperature of 65°C and a pressure of 35.2 N/mm^2

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

CONCLUSIONS

Results from the technical analyses and simulations indicate that the predicted results using finite element analysis are in good agreement with those by experiments in terms of the normal unitary efforts and linear deformations.

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