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THE CAD PARAMETRIC MODELING OF PARTICULAR SHAPES OF FUEL STORAGE TANKS

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Abstract: In the industrial market there are many types of fuel storage tanks available used for the short- or long-term storage, which vary in terms of their shape, complexity, usage and also the fuel which can be store within it. The most fuel storage tanks are manufactured and their construction follow a series of specific steps requested according to manufacturer's proprietary designs and beneficiary specifications. This paper explores various 3D (three-dimensional) models of fuel storage tanks using CAD parametric modeling. Considering functions of fuel storage tanks it seems reasonable investigating new 3D parametric models to adopt the standard shape according restricts imposed by available space requirements. These 3D models permit us to develop some computational algorithms and mathematical solutions for structural and thermal analyses able to design the optimized product final form.

Keywords: fuel storage tanks, engineering design, optimization methods, parametric models

1. INTRODUCTION

During the last decade, significant progress has been made by engineers and researchers in both science and industry for improvement of fuel storage tanks in terms of safety, efficiency, cost and reliability [1-5]. In the industrial market there are many types of fuel storage tanks available used for the short- or long-term storage, which vary in terms of their shape, complexity, usage and also the fuel which can be store within it [6-10].

The most fuel storage tanks are manufactured and their construction follow a series of specific steps requested according to manufacturer's proprietary designs and beneficiary specifications [11-14]. There are usually a series of various codes, standards and guidelines addressing the design, construction, safe operation, maintenance and monitoring of storage tanks to handle varying degrees of fuel pressure, often depending on the nature of the fluid contained within [15-17].

Material selection and design criteria are affected by the specific operating conditions during its lifetime, maintenance and control requirements [16, 18].

Computer-aided engineering (CAE) and fabrication of fuel storage tanks is both a complex and a computationally expensive task [19-24] and in many cases it requires the ongoing development of new ideas and methods [25, 26] which can provide accurate numerical solutions in affordable computing times [27-33].

The different physical phenomena (such as fluid-structure or structure-structure interaction with distinct sets of dependent variables), associated with the fuel storage tanks components in different operating conditions, are non-linear, and act on various spatial domains and time scales [34-36].

In order to solve these problems, the components of the system are described using appropriate assumptions and theoretical models [37-39] usually yield mathematical expressions of some conservation principle in form of partial differential equations in space and time.

From a computational perspective and algorithmic implementation, the reasonable constraints and boundary conditions under transient thermal-mechanical stress conditions are added to the structural and thermal FEM (finite element method) model thus permitting us to run a simulation as near as possible to the real state of the product, optimizing the calculation time [40, 41].

In the present study 3D models of fuel storage tanks using CAD parametric modeling are proposed.

2. DESIGN METHODOLOGY

The 3D surfaces are obtained by applying parametric modeling with SolidWorks 2017 software [42], using different mathematical equations for a family of toroidal surfaces with cross-sections described by closed geometrical figures.

– Basic elements about toroidal surface geometry

A torus is mathematically defined as a surface of revolution generated by revolving a circle in 3D space around a coplanar axis with the circle. In Cartesian coordinates for a torus azimuthally symmetric about the z-axis, the equation is expressed by the following formula [43]:

$$\left(c - \sqrt{x^2 + y^2}\right)^2 + z^2 = a^2 \tag{1}$$

where: a is the radius of the tube, and c is the radius from the center of the hole to the center of the torus tube.

Let's consider the surface generated by revolving of a closed generating curve C_G along a guiding curve C_{D1}, being tangent in the movement on a second internal curve C_{D2}, as shown in Figure 1 [12].

The curve C_G (that generates the cross-section) is located in a vertical plane, whereas the reference curves C_{D1} and C_{D2} (that determine the variation in the cross-sectional dimensions) are coplanar and situated in the horizontal plane.

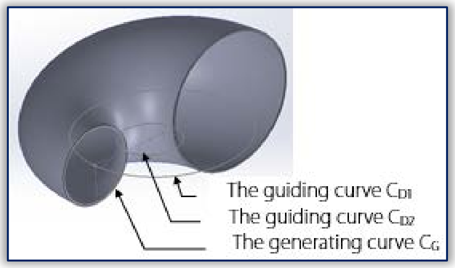

Figure 1. The axonometric representation of a general toroidal surface

– 3D modelling of particular surfaces

In this study the generating curves and the directories curves are closed geometrical figures that do not intersect on themselves. Axonometric examples of particular toroidal surfaces are shown in figures 2 to 8.

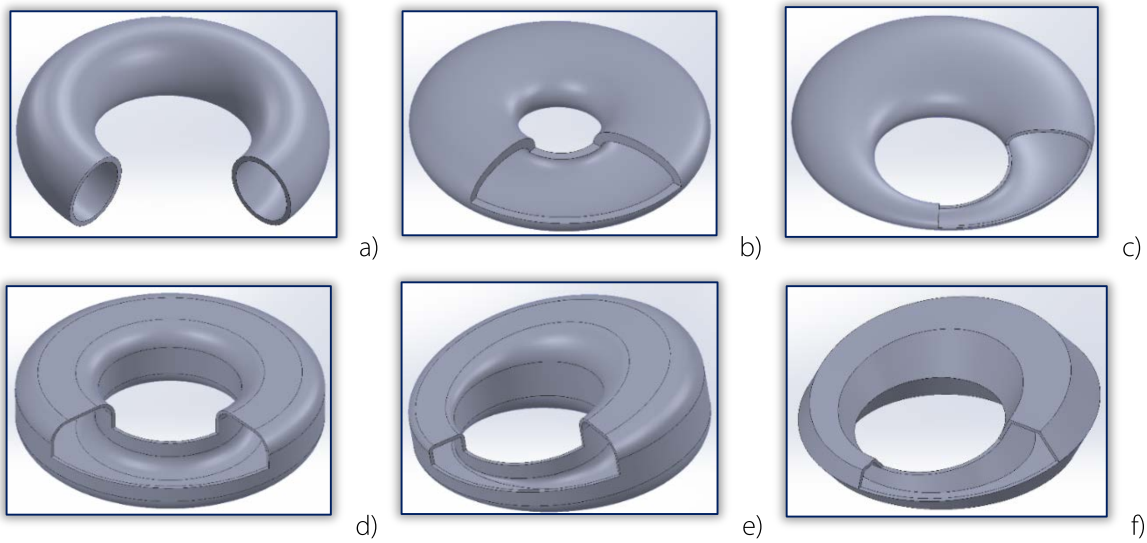

Figure 2. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D – circle; b) C_G – ellipse and C_D – circle; c) C_G – variable ellipse and C_D – circle; d) C_G – square and C_D – circle; e) C_G – variable square and C_D – circle; f) C_G – variable hexagon and C_D – circle;

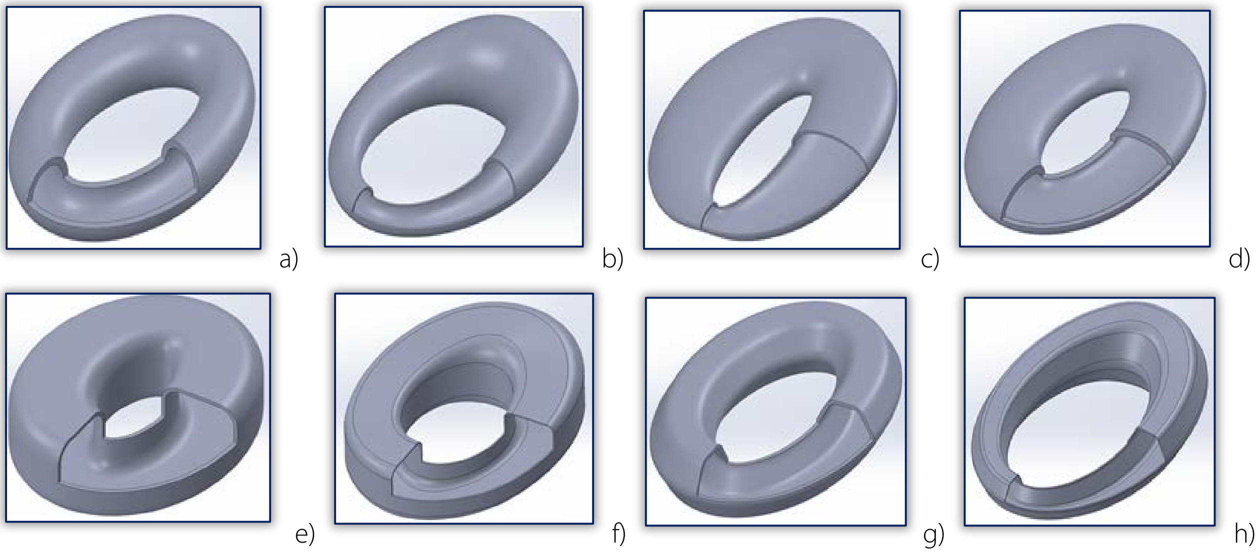

Figure 3. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D – ellipse; b) C_G – variable circle and C_D – ellipse; c) C_G – variable ellipse and C_D – ellipse; d) C_G – ellipse and C_D – ellipse; e) C_G – square and C_D – ellipse; f) C_G – variable square and C_D – ellipse; g) C_G – hexagon and C_D – ellipse; h) C_G – variable hexagon and C_D – ellipse


a) b) c)

Figure 4. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D - equilateral triangle; b) C_G – ellipse and C_D - equilateral triangle; c) C_G – square and C_D - equilateral triangle


a) b) c)

Figure 5. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D - square; b) C_G – ellipse and C_D - square; c) C_G – septagon and C_D – square

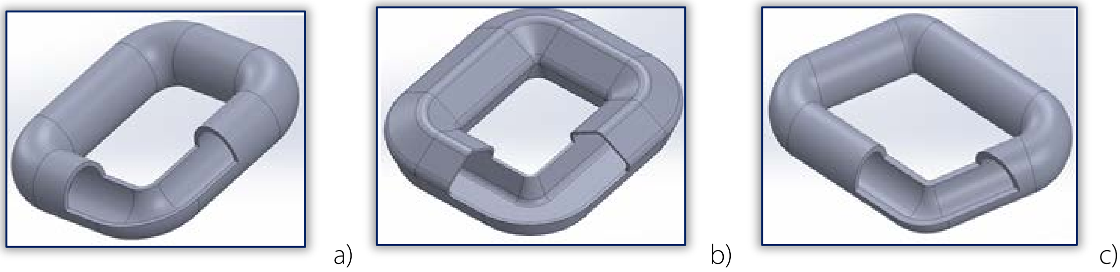
a) b) c)

Figure 6. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D - rectangle; b) C_G – pentagon and C_D - rectangle; c) C_G – ellipse and C_D – rectangle


a) b) c)

Figure 7. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D - hexagon; b) C_G – square and C_D - hexagon; c) C_G – hexagon and C_D – hexagon

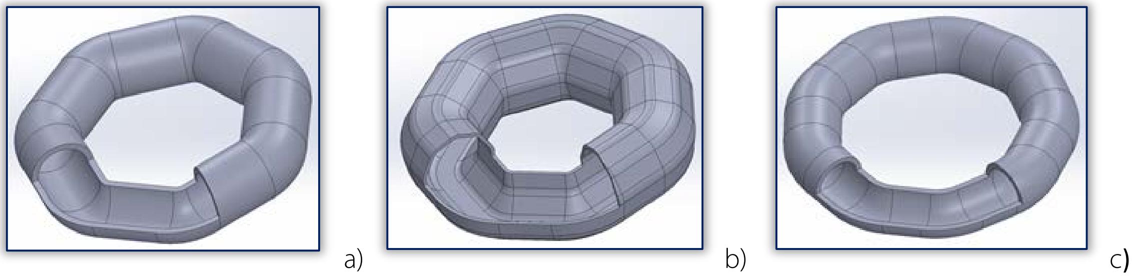
a) b) c)

Figure 8. The axonometric representation of a sectioned toroidal surface generated by: a) C_G – circle and C_D - septagon; b) C_G – nonagon and C_D – septagon; c) C_G – circle and C_D – nonagon

3. CONCLUSIONS

In this study the 3-D solid modeling were applied to find various 3D geometric models of fuel storage tanks according to the restrictions imposed by available space requirements.

The mechanical, thermal, hydraulic and aerodynamic simulations can be applied alongside model testing to improve the product performances in terms of efficiency and safety or real world validation sessions.

Acknoledgements

- Financial disclosure: Neither author has a financial or proprietary interest in any material or method mentioned.
- Competing interests: The authors declare that they have no significant competing financial, professional or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665

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