Constructive CAD Variants of Toroidal LPG Fuel Tanks Used in Automotive Industry

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Abstract—This study addresses to CAD modeling of toroidal LPG fuel tanks used in automotive industry, whom section is described by imposed algebraic plane curves. The CAD modeling of toroidal LPG fuel tanks can help to better understand the dynamic movement of fuel within the tank during vehicle maneuvering.

Keywords—automotive industry; industrial engineering design; optimization methods; toroidal LPG fuel tank

I. INTRODUCTION

In last few decades, significant progress has been made by engineers and researchers in both science and industry for improvement of vehicle design for achieving better performance and increasing passenger comfort to meet the customer needs [1-7].

The first CAD systems began to appear in automotive industry in the 1980s. Product assemblies within CAD-platforms include structure-related information including the automatic generation and extraction of multiple relational matrices, and provide lots of data for production and manufacturing engineering [1].

Computer-aided design (CAD) is a powerful and flexible tool that involves creating complex computer models defined by geometrical parameters [8-11] within a virtual environment for integrated product development [12-17].

Modern 3D CAD software packages using complex algorithms and automated programmable interfaces have demonstrated to be vital to build safer, cheaper and better performing vehicles [1].

3D-CAD models support visualization of value-related information in the early stages of design providing geometry information, but also additional constraint information, that can serve as a basis for configuration of modules and systems, as well as for different simulation and verification processes [1].

CAD of the storage fuel tanks used in automotive industry generates a component design structure matrix (that include hierarchical relations and dependency strengths between geometrical elements) considering the supershapes design variables [18-20], specific structural parameters [10-14, 21], geometrical conditions [14], design constraints [2-7], computer tools [22-27], numerical computational algorithms and methods [28-31], visualization techniques [32-38], and measurement methods [39, 40].
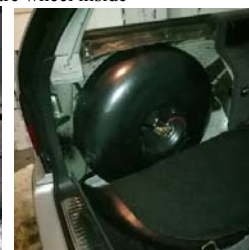
There are different options for the placement of the toroidal LPG fuel tank that depend of amount of space available (as shown in figure 1), but the majority of vehicles have the tank installed in place of the spare tyre [41].

a) LPG installed instead of spare wheel inside

b) LPG installed outside

c) LPG installed in left side

FIGURE I. EXAMPLE OF TOROIDAL LPG FUEL TANK INSTALLATION

The manufacturing process of toroidal LPG fuel tanks has received lesser attention, due to the geometric complexity and 3D shape design. For a toroidal LPG fuel tank the wall thickness is considered small in comparison with its other dimensions and can be compared as a shell in the form of the surface of revolution [13].

The first stage for designing of toroidal LPG fuel tank is the calculation of wall thickness that depends on several factors such as capacity of the tank, material selection, yield strength of material, test pressure, weld joint factor etc. [13, 21].

In this study, constructive CAD variants of standard toroidal LPG fuel tanks (figure 2) used in automotive industry are proposed.

FIGURE II. STANDARD SHAPE OF TOROIDAL LPG FUEL TANK
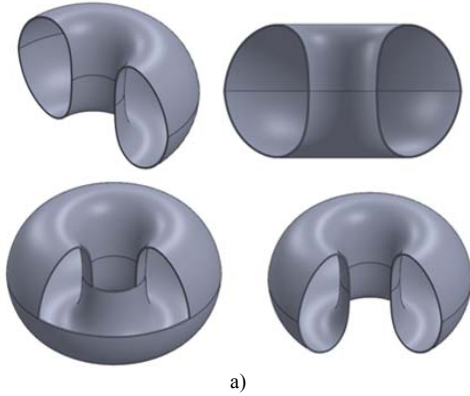
II. DESIGN METHODOLOGY

The parametric 3D modeling of the toroidal surfaces for different mathematical equations is shown in figure 3.

a) Bean curve

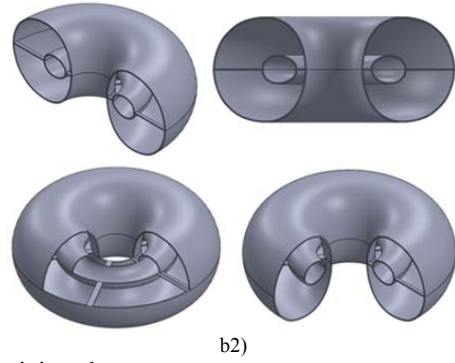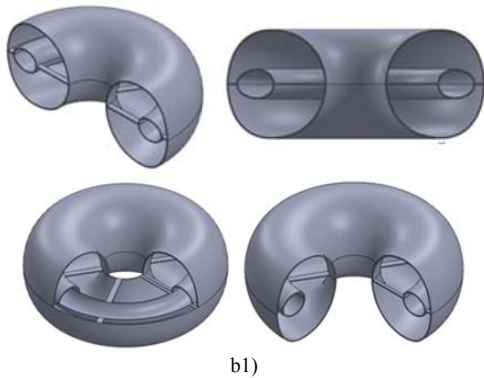The quartic curve (figure 3a) is given by the implicit equation [42]:

$$x^4 + x^2 y^2 + y^4 = x\left(x^2 + y^2\right). \tag{1}$$

a)

b) Cartesian ovals

The "Cartesian ovals," are the quartic curve (figure 3b) consisting of two ovals that is given by the implicit equation [42]:
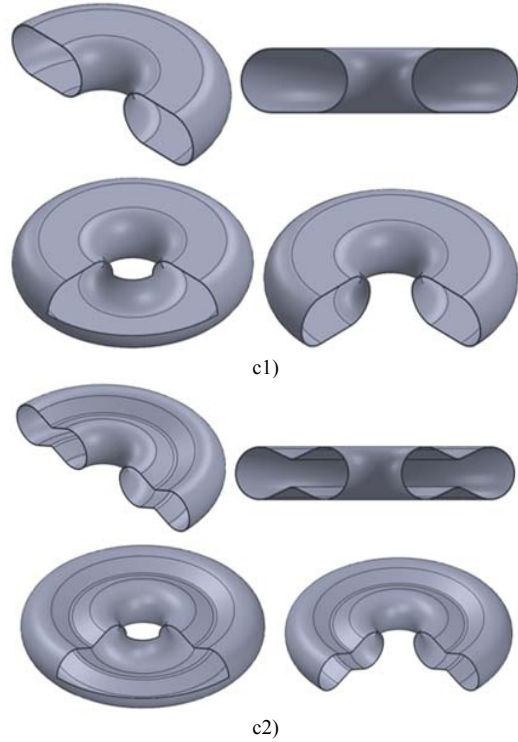
$$m \sqrt{(x - a)^2 + y^2} + n \sqrt{(x + a)^2 + y^2} = k. \tag{2}$$

b1)

b2)

c) Cassini ovals

The Cassini ovals are a family of quartic curves described by a point such that the product of its distances from two fixed points a distance (2a) apart is a constant b^2 (figure 3c). The Cassini ovals have the Cartesian equation [42]:
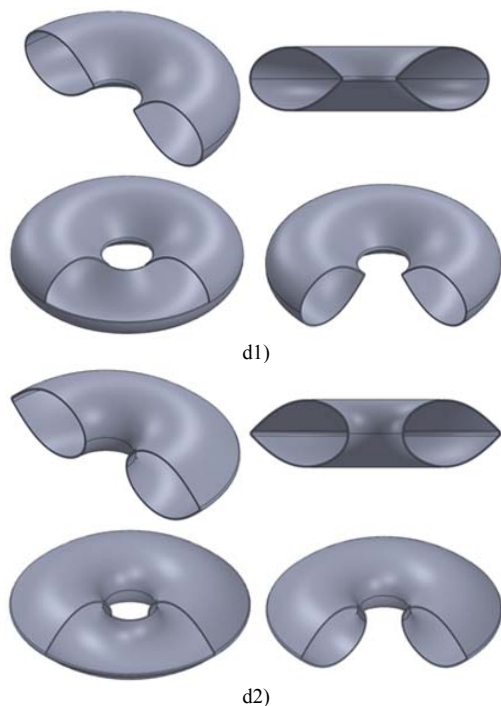
$$\left[(x - a)^2 + y^2\right]\left[(x + a)^2 + y^2\right] = b^4 \tag{3}$$

c1)

c2)

d) Folium curve

The folium curve is the curve (figure 3d) with Cartesian equation [42]:

$$\left(x^2 + y^2\right)\left[x\left(x + b\right) + y^2\right] = 4\,a\,x\,y^2. \tag{4}$$

d1)

d2)

d) Hippopede

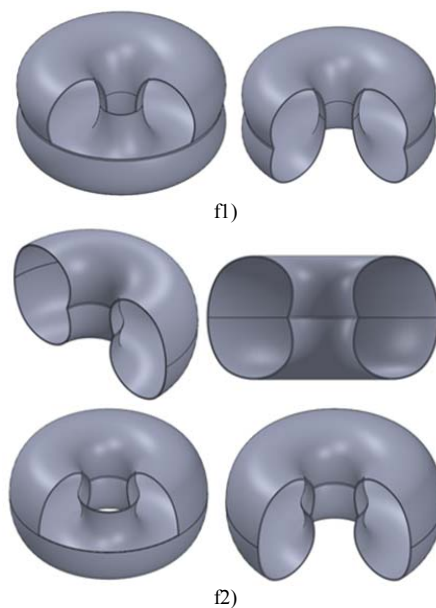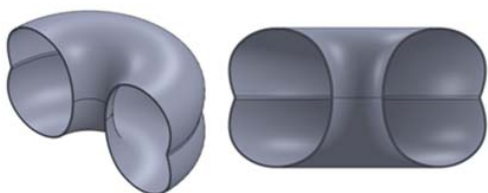The hippopede (figure 3e) is a curve given by the polar equation [42]:

$$r^2 = 4\,b\left(a - b\sin^2\theta\right).\qquad(5)$$

e)
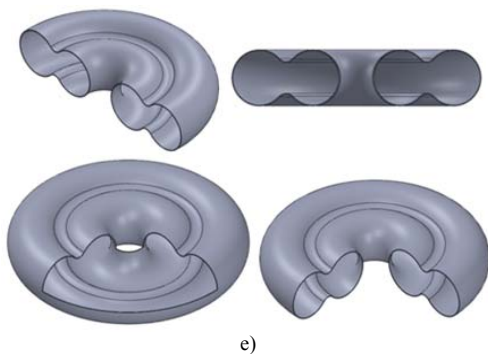
e) Limaçon

The limaçon is a polar curve (figure 3f) of the form [42]:

$$r = b + a\cos\theta\qquad(6)$$

f1)

f2)

f) Pear-Shaped curve

The pear-shaped curve (figure 3g) is given by the Cartesian equation [42]:

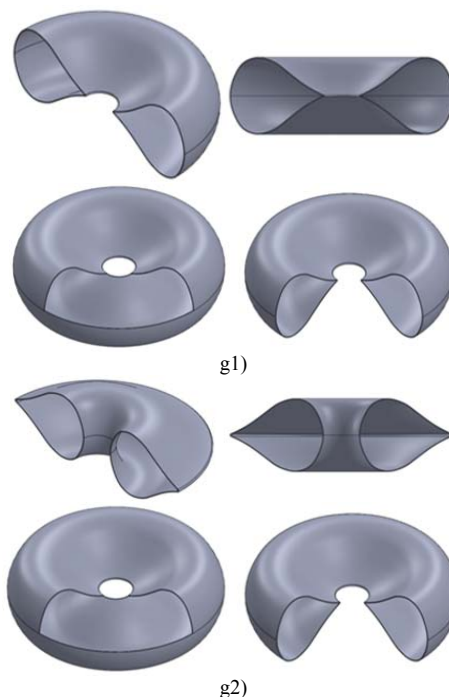$$r = b + a\cos\theta\qquad(7)$$

g1)

g2)

FIGURE III. EXAMPLE OF PARAMETRIC 3D MODELING OF THE TOROIDAL SURFACES

III. CONCLUSIONS

In this study different constructive CAD models of toroidal LPG fuel tanks used in automotive industry were proposed.

These 3D models of toroidal LPG fuel tank can help engineers and researchers in optimal engineering design process.

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