

**Abstract:** Modeling of the complex geometric shapes requires the use of appropriate softwares. This study analyzes the process of modeling with two different computer softwares, AutoCAD and Rhinoceros. The aim is to demonstrate the similarities and differences between these softwares when used for modeling torus, a double curved geometric surface. The two modeling processes are compared in order to investigate the potentials of these softwares in the modeling of an architectural structure comprising a shell of the torus. After a detailed comparative analysis, the essential characteristics and shortcomings of these programs are emphasized and they were used to recommend the more appropriate one.

**Keywords:** modeling, architecture, torus, geometric surfaces, AutoCAD, Rhinoceros

## 1. INTRODUCTION

Novel advanced technologies have the potential for a dramatic improvement of design and productivity [1]. They are based on the use of the software packages, such as AutoCAD and Rhinoceros, enabling simpler modeling of architectural objects and providing support to the designers at gathering knowledge, sketch, 2D design, 3D design, prototyping and visualization stages of design process [2]. Creation of procedural 3D building models can significantly reduce the costs of modeling since it allows for generating a variety of similar shapes from one procedural description [3]. The benefits of intelligent modeling for the design process are the increased productivity, the reduced cycle time and the better work flow and life cycle applications [4]. CAD software turns out to be the key tool for architecture, interior architecture, industrial product design, graphic design, engineering and so on [5]. Today, CAD models with built-in essential product design information play a central role [6] for modeling architecture objects.

Modeling of complex double-curved surfaces is a problem in the realization of the architectural idea. Curved-line folding, the act of folding paper along a pattern of curved lines to obtain a 3D shape, is an interesting starting-point for the design of innovative pliable structures [7].

The previous studies have shown that AutoCAD and Sketchup are most similar in the modeling process of doubly ruled surfaces, the program 3ds Max is not always suitable for modeling the double-curved surfaces as shown for the paraboloid modeling while the Rhinoceros software package is proved to be adequate for this application [8].

This study analyzes the modeling of torus, a double-curved surface, using AutoCAD and Rhinoceros software programs. After modeling the designed architectural toroidal structure, the processing conditions in both programs were analyzed and the advantages/drawbacks were thoroughly discussed in order to recommend the more appropriate modeling software.

## 2. METODS AND MATERIALS

The architectural structure comprising a shell of the torus, a double-curved geometrical surface, was modeled using AutoCAD and Rhinoceros. The subject of this paper is to examine the possibilities and comparative analysis of the functioning of the software program for modeling, AutoCAD ver. 15 (Autodesk Inc) and Rhinoceros ver. 5 (Robert McNeel & Associates). The models developed by these two software packages were compared using the method of modeling combined with the deduction, abstraction and formalization methods. The developed toroidal geometric surface was cut using the deduction method. Design and visualization of the object were ignored while the resulting models were formalized.

## 3. TORUS

Torus is one of the special surfaces of revolution of the fourth order, which arises from the rotation of a circle around a permanent straight line, which is in the plane of the circle. The circle that rotates is a semi-meridian, while surfaces perpendicular to the axis intersects the torus along concentric circles, which are called parallels [9]. Depending on the position of the circle with respect to the straight line around which it rotates, there are three types of torus: ring-, horn- and spindle-shaped (Fig. 1) [10].

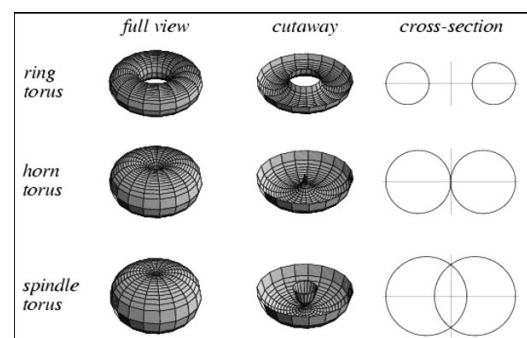


Fig. 1 Various types of torus [10].

The ring torus or just torus is obtained when the axis of rotation doesn't touch the semi-meridian, the horn torus is obtained when the axis of rotation is tangent semi-meridians and the third type, spindle torus, is obtained if the axis of rotation intersects the semi-meridian [11].

Simulation of the architectural structure intended for modeling in AutoCAD and Rhinoceros, obtained by flat sections of the ring torus, is illustrated in Figure 2. The torus was applied as a roof cover of the object, wherein the outer edge of the toroidal shell was relied directly on the ground and the central part is supported by a central pillar. The shell of the torus was divided into 12 equal parts, after which certain parts were sectioned by planes forming a four-sided facade of the object [10].

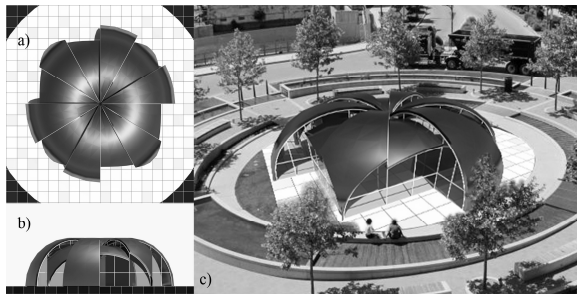


Fig. 2 A torus building: a) top view of the building; b) facade; c) 3D view [10].

#### 4. MODELING IN AUTOCAD

AutoCAD is the most used modeling software for architects. Architectural drafting and documentation is more efficient with the software's intuitive environment and tools built specifically for architects [12].

Although there are different ways for obtaining a torus, AutoCAD does not offer any direct option for its generation. It was first necessary to draw a vertical circle, called semi-meridian, followed by the vertical straight axis of rotation which was in the plane of the circle. Because of impossibility of drawing vertical 2D drawings in AutoCAD, the axis and the circle had to be rotated from horizontal to vertical position using the command "3DRotate". Next, using the command "Revolve", the circle is rotated around the straight line, producing the torus (Fig. 3). In this way, it was possible to obtain all the tree types of the torus.

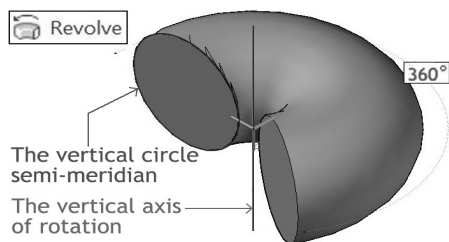


Fig. 3 Obtaining a torus in AutoCAD.

When the torus was obtained, the next step was to remove the bottom half of the torus using the command "Slice". Then, the upper half of the torus was cut into 12 equal parts using the same command "Slice" (Fig. 4). In

this case, it was necessary to draw the certain straight lines on the base and activated the command "Slice" by assigning the three spatial points, wherein the two were at the appropriate horizontal line, and the third was at the vertical axis of rotation.

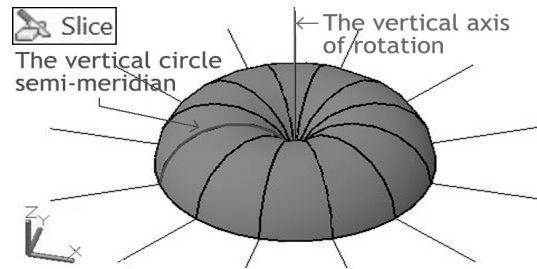


Fig. 4 Schematic presentation of cutting the upper half of the torus into 12 equal parts.

As the basis of the square-shaped object, the corresponding parts of the torus should be cut by the vertical planes coinciding with the planes raised from the squared base, also using the command "Slice". Figure 5 shows the cut off of the torus, the view is from the bottom of the object.

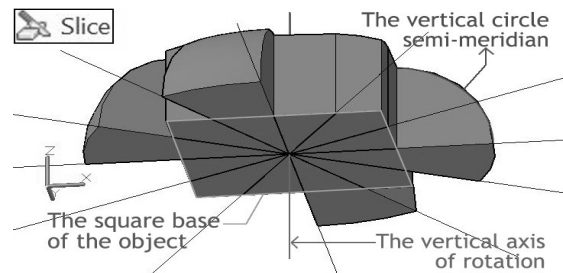


Fig. 5 The view of the object with the squared base from its bottom.

To make the modeled object most similar to the simulation one, it was necessary to change the height of the parts of the toroidal roof shell by the command "Move" (Fig. 6). After that it was necessary to add a box below the squared base and then used the command "Subtract" to reject the parts of the torus moved below the floor level because of moving the shells.

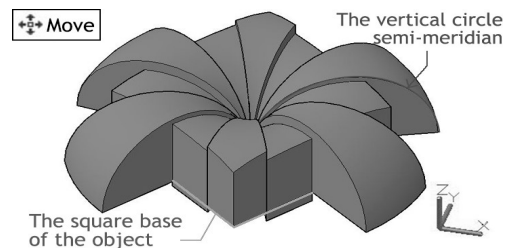


Fig. 6 Vertical movement of toroidal roof shells.

So far modeled object was a solid which should be disassembled into the surfaces by the command "Explode", to give the façade surfaces that were separated from the roof shells. Removing the internal surfaces coming out of the object is not simple. The intrinsic problem of the AutoCAD comes out from the

fact that it works only with solids, making difficult the cutting of surfaces. In this case, using the command "Explode", it was necessary to disassemble the façade plane to the contour lines, followed by the command of "Loft" to link the appropriate lines. In AutoCAD there is no command that gives thickness to surfaces, i.e. that makes solids. Therefore, the process of modeling is more complicated because another torus should be made with the shells distant from the existing original ones for a particularly desired thickness.

AutoCAD is the most frequently used software for drawing and modeling. It is older than Rhinoceros. Modeling in AutoCAD can be very difficult or even impossible in the case of complex models. Therefore, it is necessary to complete the model obtained by AutoCAD in another software modeling program.

### 5. MODELING IN RHINOCEROS

Rhinoceros 3D is a relatively new software for 3D modeling with many advanced features in the modeling process [8]. This program has a direct command for modeling the torus as a ready-to-use surface. The command is located in the "Solid" drop down menu named 'Torus'. Unlike AutoCAD, where only one projection of working plane is shown, Rhinoceros shows four projections at once. This facilitates overviewing the modeled objects but one should be careful to use right commands in proper views. The possibility of switching from one to another view without interrupting the command greatly simplifies the modeling process. After modeling a torus, it was cut by a horizontal plane using the "Cutting Plane" and "Trim". Then, as in the above analysis (Fig. 4), the torus was cut into 12 equal parts. In this case, unlike the AutoCAD, the commands were used for setting the cutting planes by the command "Cutting plane", followed by the command "Split" which cut the torus. After cutting the torus, it was desirable to temporarily hide the cutting planes by the command "Hide".

Next step for modeling the object is drawing a square using a command "Rectangle" with the center set in the center of the torus. Then, using the command "Extrude Curve/Straight", the third dimension of the rectangle, which is higher than the height of the torus, was defined (Fig. 7 left). After using the command "Explode", the vertical flat surfaces and the unhidden cutting planes became visible (Fig. 7 right). Using the commands "Trim" and "Split", the modeling was almost completed (Fig. 8).

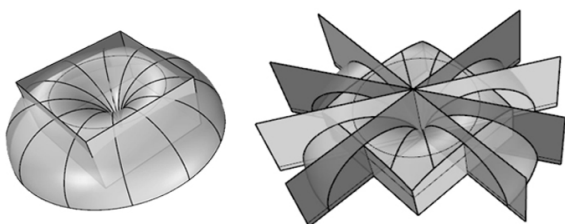


Fig. 7 The perspective view of cutting the torus.

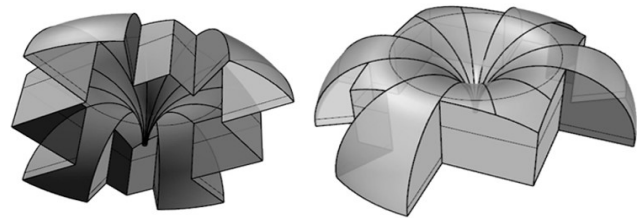


Fig. 8 The perspective view of empty interior object – left and the exterior of obtaining object – right.

The last step of modeling was the vertical movement of the toroidal roof shells by the command "Move". Then, it was necessary to re-cut the vertical cross-sectional planes and close all openings resulting from the movement of the parts of the roof (Fig. 9 left). Then, in Rhinoceros, it was possible to give the thickness to the surfaces by the command "Offset" located in the "Solid" drop down menu (Fig. 9 - right).

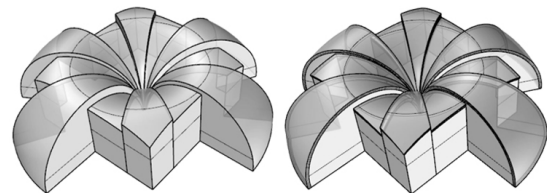


Fig. 9 The perspective view of the finished formalized object.

The final part of the formalized modeling, without detailing, can be carried out to the end in Rhinoceros without any difficulty.

### 6. DISCUSSION

Both used software packages, AutoCAD and Rhinoceros, have advantages and disadvantages. AutoCAD has already been used in the practice, and despite its upgrading, it has not reached a satisfactory level. It demands a large memory for storing complex models, often bugs and crashes with the subsequent loss of the unsaved files. Work in this program requires a lot of patience and tolerance because it takes much more time to model of certain objects than other programs such as, for example, Rhinoceros.

The Rhinoceros software has many similarities with the AutoCAD software. It is a newer program that has already been well-demonstrated in the previous research. It requires less memory and modeling in it is simpler. Rhinoceros has several different options for modeling and is equally good for work with lines, surfaces and solids, while AutoCAD is mainly designed for 2D drawings and simple 3D modeling using solids. Rhinoceros has only direct command for modeling a ring torus, while the other two types, horn and spindle-shaped torus, have to be modeled like in AutoCAD, using a circle and an axis of rotation.

### 7. RESULTS

In the case study of modeling a torus in different modeling software advantages and disadvantages of softwares AutoCAD and Rhinoceros are showed.

Table 1

Characteristic of AutoCAD and Rhinoceros		
Characteristic	AutoCAD	Rhinoceros
2D drawing, works by lines	✓	✓
Works by surfaces, cutting planes, gives thickness to surfaces to make a solid	X	✓
Works by solids	✓	✓
Cutting off solid by surfaces	X	✓
2D drawing into vertical planes without moving horizontal coordinate system	X	✓
2D drawing into any planes assigning a new position of a coordinate system	X	✓
3D modeling of the existing 2D drawings	✓	✓
The excellent precision of modeling	✓	✓
The ability to view the model from different angles	✓	✓
The number of view projections	1	4
Moving through inside of the modeled object	X	✓
Transparent display of the object, where there can see its inner space	X	✓
Existence of Layers and their temporary deactivation	✓	✓
Temporarily hiding a part of an object without turning off the Layer.	X	✓
Requires a large computer memory	✓	X
It bugs and cracking during work	✓	X
Compatibility with the other softwares	✓	✓
Work with parametric design	X	✓
There is a command of drawing a ring torus	X	✓
There is a command of drawing the horn and spindle torus	X	X
Moving the contour points of the modeled object, its edges or its surfaces	X	✓
Working with complex geometric surfaces	X	✓
Automatic making four 2D facade views from the 3D modeled object	X	✓

## 8. CONCLUSION

Modeling in appropriate software packages accelerates the design process. Time saving is of great significance to each architect, which strives to choose the best possible modeling program.

Today, there are many different software packages for modeling, out of which AutoCAD is used most. The program Rhinoceros has proven to be good at modeling of complex geometric surfaces, such as double-curved, including a torus, as well. This study has also confirmed that the software Rhinoceros is more suitable and convenient to operate, when compared to the software AutoCAD. With Rhinoceros, the process of modeling is faster and easier and it is possible to model all geometric shapes, contrary to AutoCAD, which is not possible to do the final part of modeling.

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