

VISUALISATION OF INTERSECTION CURVES RESULTING FROM THE INTERSECTION OF TWO CYLINDRICAL-CONICAL SURFACES

Abstract: *In this paper, the authors present a study regarding the capability of the Autodesk Inventor computer program to be used in the descriptive geometry process of teaching. The capacity of this software to present in real-time the way in that evolve the intersection curve between two solid bodies when the bodies dimensions vary was taken into account by the authors. They used this facility to visualize how the intersection curve between two cylinders, two cones or one cylinder, and one cone, with concurrent axes, changes its shape when the dimensions of these surfaces vary.*

Key words: Autodesk Inventor, Inscribed Spheres Method.

1. INTRODUCTION

It is a known fact that the parts may be limited on the outside by cylindrical or conical surfaces. At the same time, they may have cylindrical or conical holes. In most cases, the intersecting cylindrical-conical surfaces have concurrent axes. This is the cause why the students learn in classes of Descriptive Geometry about Inscribed Spheres Method. It is named so because, in the process of determining the intersection curve, several spheres are used and, their centres are situated at the point of intersection of the axes of the two surfaces analysed. The first helpful sphere is tangent at a surface and intersects the second one. The result of the intersection is a curve of a higher degree and, if the first helpful sphere is tangent simultaneously to both surfaces, the curve degenerates into two right segments. Students learn that to discover the shape of the intersection curve, in most cases, 3 or 4 spheres are enough [1], [2]. This knowledge is practiced on various examples in the Descriptive Geometry seminar and is then used to make technical drawings in the classes of Technical Drawing.

Although the method is easy to understand and apply when students end up drawing a mechanical part and have to solve, within it, such intersections, many of them are wrong. The reason is that they have not fully understood or have a superficial understanding of the Inscribed Spheres Method. The fact that students do not understand at all or part of the method mentioned above is due, among other things, to the fact that they have great difficulty in creating mental images of the two intersecting surfaces and the shape of the intersection curve. In other words, the spatial visual intelligence of these students is low and, the only solution, in this case, is to practice it by solving as many examples as possible. But solving an example takes time and effort on the part of the students. As the number of examples increases, fatigue sets in and, students' lack of interest in the topic under discussion increases dramatically. These shortcomings led the authors to look for a software solution to help visualize the intersection curve between two cylindrical-conical surfaces by generating images. Moreover, the looked-for solution should allow visualization of how the shape of the curve changes depending on the sizes of the analysed surfaces and the

angle between the axes of the two surfaces. The authors searched for a software application that solves the above problem but did not find it. This made them decide to build a software application that would solve this problem, starting from well-known computer programs.

2. MATERIAL AND METHOD

The authors have established the requirements that must meet by an application that must allow the visualization of the intersection curve between two cylindrical-conical surfaces, and these are:

- To be built starting from well-known and easily accessible computer-aided graphics software. This approach would make the application easy to handle by anyone who has minimal knowledge of the software from which it starts.
- To allow easy modification of the diameters of the circles at the base of the analysed cylindrical-conical surfaces.
- To permit easy change of the angle between the axes of the two surfaces.
- To allow real-time display of how the shape of the curve changes when the diameter that defines one of the surfaces is changed or when the angle between the axes of the two surfaces changes.
- To allow the visualization of the analysed surfaces from different directions.

To begin with, the authors analysed some well-known software. The first analysed software was Paint 3D. It is an integral part of the Windows 10.0 operating system and is well known to all users. It allows easily building cylinders and cones having a library of 3D bodies. Once a 3D body is inserted, it can be precisely rotated but the diameter defining them cannot be changed with an accurate value. It may be modified only by acting on the arrow located in one of the corners of the figure (Figure 1).

It can determine the intersection curve between two cylindrical-conical surfaces but does not allow their placement with precision relative to each other, Figure 2. It also does not allow viewing 3D bodies from different directions.

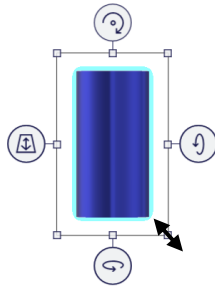


Figure 1 A cylinder represented in Paint 3D.

But the software displays instantaneously how the shape of the intersection curve evolves when the cylinder's diameter changes or when the angle between the axes of the surfaces change.

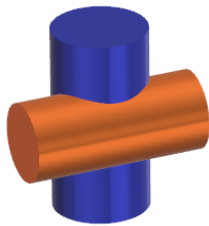


Figure 2 Intersection between two cylinders in Paint 3D.

The authors decided that due to the accuracy of the input data, it is not appropriate to start from this software.

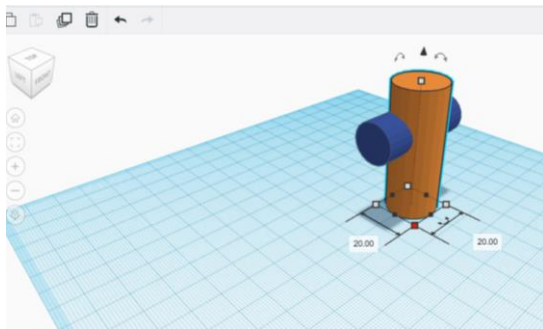


Figure 3 Intersection between two cylinders in Tinkercad.

Another software analysed was Tinkercad, a product that may be used for free that allows the use of 3D bodies such as cone, cylinder, torus, sphere, etc.

The dimensions of the 3D bodies can be introduced with precise values but these dimensions are only on the OX, OY, and OZ axes direction. Thus, to change the diameter of a circle located in the XOY plane, the dimensions that define the circle at the base of the cylinder, along the axes OX and OY must have equal sizes, 20 mm in the example shown in Figure 3. If these values are different the circle will be replaced with an oval. Simultaneous modification of the dimensions is not possible, which is a shortcoming. Actually, the software draws a curve inscribed in a rectangle. The user controls

the dimensions of this rectangle. If the quadrilateral becomes a square, the curve becomes a circle. Thus, another main drawback results, namely, when the size of one side changes, the calculation is made starting from the other side and not from the centre of the rectangle. Therefore, once two cylinders with intersecting axes have been built, when the circle's diameter at the cylinder's base changes, the position of the axis of the respective cylinder changes in space, which makes the cylinders no longer have intersecting axes. Thus, after each change of the circle's diameter at the base of the cylinder, it is necessary to reposition it.

The software allows viewing how the shape of the intersection curve changes when there are changes in the analysed surfaces' dimensions or related to the angle that the axes make between them. It also allows viewing of 3D bodies from any direction, but the shortcomings of the input data have led, as well, the authors to abandon this software.

The results presented above determined the authors to turn their attention to a much more powerful and sophisticated software than those analysed above. It is about Autodesk Inventor. It meets the conditions imposed by the authors [3].

- Autodesk Inventor software is well-known among engineers. It's easy to use because it has contextual menus, which means that are displayed only the commands that can be used at some point. In addition, it allows building dialog boxes with a very intuitive look.
- The drawings made with this software are parametric. So, if it is needed, the parts' dimensions can be easily changed. This means that changing the size of the circles' diameters at the base of the cylinders and/or cones can be done very easily.
- For the same reasons set out in the previous point, the angle between the axes of the two surfaces can be easily changed.
- If two 3D bodies or two surfaces intersect, the program provides the resulting intersection curve and changes it simultaneously with the changes operated related to the dimensions of the 3D bodies or surfaces.
- The Autodesk Inventor program allows viewing analysed bodies from any direction.

Based on the above arguments, the authors decided to precisely learn how the Autodesk Inventor software can be used for the above stated purpose.

The first step was to identify the cases that should be taken into consideration and these are:

- The intersection of two cylinders, as outer surfaces, when both surfaces remain.
- The intersection of two cylinders, as outer surfaces, when only one surface remains (one of the surfaces has a cylindrical hole).
- The intersection of two cylinders, as interior surfaces.
- The intersection of two cones, as outer surfaces, when both surfaces remain.
- The intersection of two cones, as outer surfaces, when only one surface remains (one of the surfaces has a conical hole).
- The intersection of two cones, as interior surfaces.

- Cylinder-cone intersection, as outer surfaces, when both surfaces remain.
- Cylinder-cone intersection, as outer surfaces, when only the conical surface remains (the cone has a cylindrical hole).
- Cylinder-cone intersection, as outer surfaces, when only the cylindrical surface remains (the cylinder has a conical hole).
- Cylinder-cone intersection, as interior surfaces.

The second step was the in-depth analysis of Autodesk Inventor features, and the authors decided to use the related software facility in this software known as iParts. The lines of code written in iParts allow creating *Rules* that, among other things, permit changing values of some parameters, and in this way, the part's behaviour, when its dimensions are changed, may be controlled. The iParts offers the possibility of building so-called *Forms*. They are used to customize the way data is entered and, if desired, can also be used to launch some previously created *Rules*. The tools provided for building the *Forms* allow the creation of very friendly dialog boxes for entering or modifying data [3]. At this point, the authors considered the use of the sliders. These allow the introduction of new values continuously with a step chosen by those who build that dialog box.

A substantial advantage of this programming facility consists in that all lines of code are automatically included in the file in which the body (s).

Therefore, for each case to be analysed, a file can be created containing two intersecting cylindrical-conical surfaces then dialog box can be built for the customized input of data on the dimensions of the two analysed surfaces. Also, can be created *Rules* to impose the range in which input data can vary [3].

A great advantage is that the working file is a standard one, .ipt type, and all the viewing possibilities offered by this software, are available. Moreover, the possibility of viewing the studied parts in a half section view or a three-quarters section view is also available.

3. RESULTS AND DISCUSSION

The first case solved was related to the intersection of two cylinders. The authors understood that if the two outer cylinders have a hole each, the cases when cylinders are treated both as outer and inner surfaces can be addressed in a single file, Figure 4.

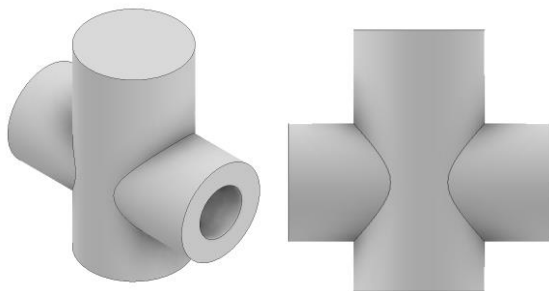


Figure 4 Cylinders seen from different directions.

When the file opens, the axes of the cylinders are perpendicular. A dialog box called *Variables*, Figure 5, has been built to easily change the sizes of the outer and inner cylinders' diameters and the value of the angle between the cylinders' axes.

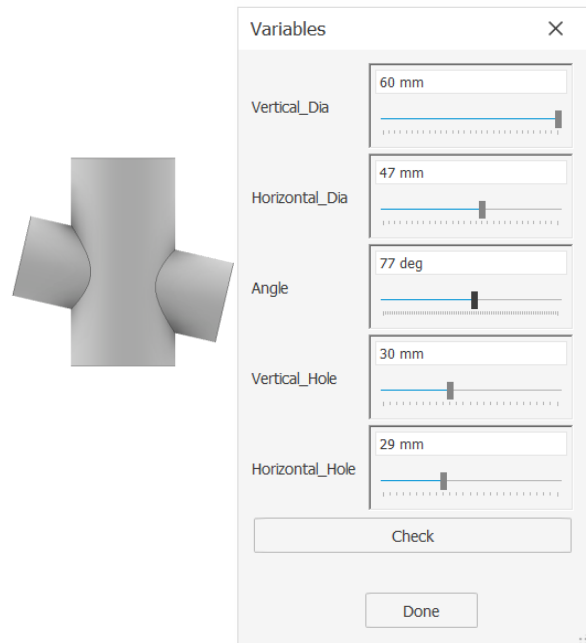


Figure 5 The dialog box named *Variables*.

The size of each diameter can be changed with a *Slider*, the step being one unit. When the value of one diameter or the angle between the axes changes, the intersection curves change simultaneously.

The analysed cylinders can also be viewed in three-quarter sections view so that both the outer and the inner intersection curve can be seen, or they can be viewed in half sections view and only the curves resulting from the intersection of the holes can be seen, Figure 6.

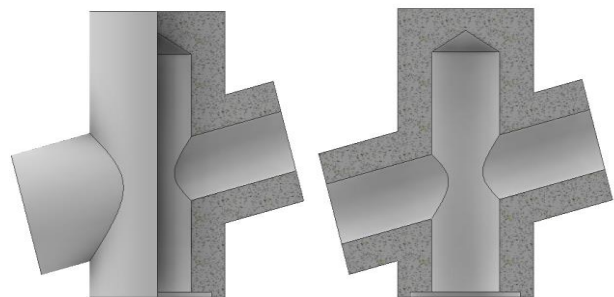


Figure 6 Three quarter section view and half section view.

Value ranges in which diameters may vary have been established for all cylinders used. The same goes for the angle that the cylinder axes make. However, there may be situations where the values entered by the user do not have a physical meaning. Thus, Figure 7 shows the case where one of the cylinders is missing (when a hole appears). If the diameter of the hole is chosen to be larger than the diameter of the upright cylinder, the program

gives the result in Figure 8 that does not make sense to be analysed.

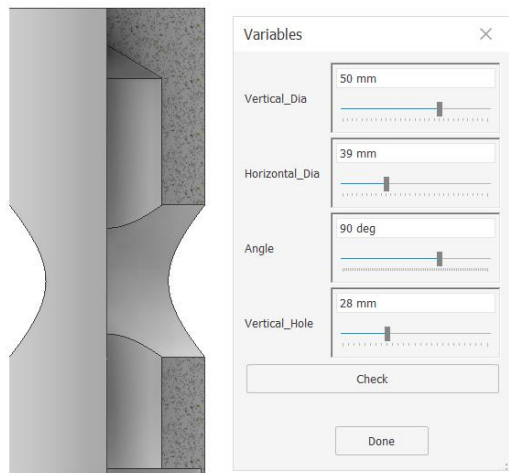


Figure 7 The case of a hole in a cylindrical surface.

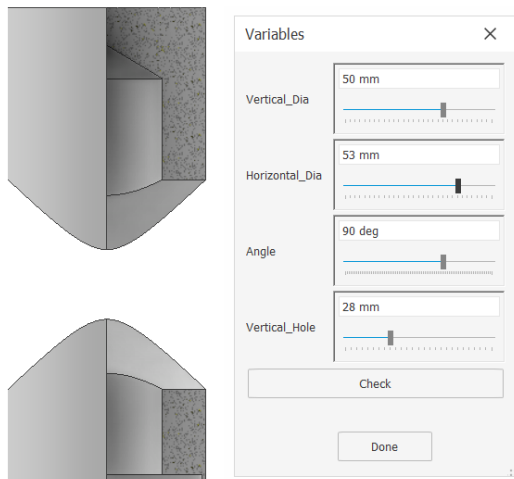


Figure 8 This case needs to be corrected.

Pressing the Check button at the bottom of the dialog box has the effect of launching particular *Rules* built by the authors that bring the previously modified size to an acceptable value.

Following the above ideas, the authors elaborated solutions for the following cases: the intersection between a cylinder and a cone when the cylinder is visible, Figure 9, and when the cylinder is not visible (the cone has a hole), Figure 10.

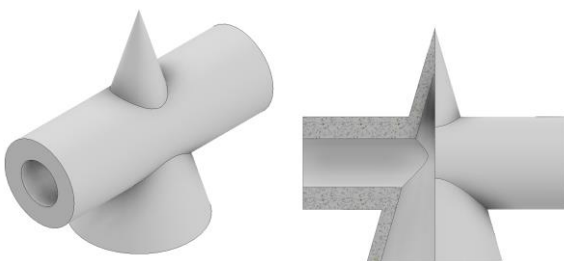


Figure 9 Both the cylinder and the cone are visible.

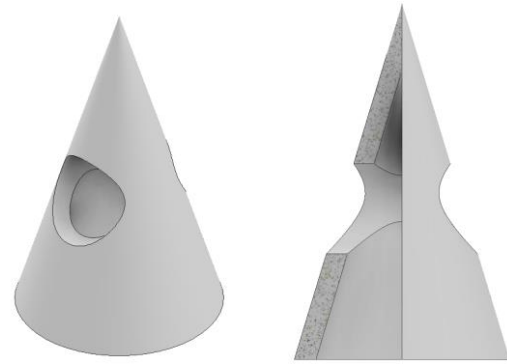


Figure 10 Only the cone is visible (the cone has a hole).

4. CONCLUSIONS

- Autodesk Inventor software, with its iParts feature that allows writing lines of code, makes it usable even in the teaching of engineering graphics. Thus, the ability to easily change the dimensions of a 3D body as well as its ability to change, simultaneously, the appearance of that body makes it usable in explaining the aspect of intersection curves between two cylindrical-conical surfaces.
- Because any application is stored within a single standard .ipt file, all Autodesk Inventor viewing features are available.
- Friendly dialog boxes, automatic fixes, and intuitive software interface make such applications usable even by people with minimal knowledge of using Autodesk Inventor.

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