Design of Digester Biogas Tank
Part 3: 3D Digester Biogas Tank Model

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Summary. The paper presents the 3D design process of digester biogas tank using modern engineering software.The biogas tank shell, bottom of the tank and its roof were designed. The welded and bolted connections available in the library of program were used to join the construction elements.
Key words: project, digester biogas tank, 3d model.

INTRODUCTION

The development of computer equipment and 3d design processes allow engineers to design more quickly and to optimize their work. 3d modelling programs allow for the growth of innovativeness in numerous technical disciplines [2, 9].

The market offers many CAD-like programs. One of such is the Autodesk Inventor 2014. It serves to construct different 3d models. The activity of the user focuses mostly on the creation of a 3d model, that reflects the future construction. The program allows for creation of layout drawings, working drawings, offer drawings and reference drawings. The changes introduced in the model are automatically included in the 2d drawings. This allows for innovative adapting design works and creation of prioritized models, which are reflected in the history tree of the object viewer. The method for prioritisation is FMB (Flacture – Based – Modeling). The software provides a library of materials and parts that may be used in creation of own projects. The program also allows for creation of own part libraries and to define materials that can be later used in different projects. The Autodesk Inwentor allows engineers to create intelligent components such as, e.g. constructions from sections, pipes, electric cables. The program uses four basic work modes: part, assembly, drawing and presentation [3].

Designing of every device, machine, construction is done via a separate project. Files containing parts, component drawings, libraries, etc., which serve as parts of the projects may be saved in different locations, e.g. the hard drive or a server. Information on access paths to individual files of a project are located in a text file with .ipt extension which is a project file. Creation of a project file is the beginning of work in the program [3].

When selecting the "parts" work mode it is possible to make 2d sketches, which can be created using functions similar to the ones utilized by the most popular program of the Autodesk program – Autocad. The logic of part design is different than in Autocad. When creating a sketch, the constructor tries to give it the shape of the recreated part and next provides it with a series of detailed nodes and dimensions. The 2d sketches may be edited many times and transformed into 3d models. The created parts may be subjected to stress analysis and transformed into, e.g. metal sheet construction. The next work mode is creation of assemblies, which are used to connect parts into more complex units. This mode allows the constructor to connect the individually designed parts. The "assembly" file allows for dynamic simulations, stress analysis, beam analysis, connecting of parts with cables and wiring harnesses, pipes, connecting elements via welding, screws and bolts. This mode also contains tools that facilitate creation of elements such as rollers, transmissions or bearings. The next mode is the "drawing" mode which allows for the creation of 2d drawings in a similar manner to Autocad and for projection, description and dimension of 3d elements onto a 2d surface. The program also supports a "presentation" mode that is used to present the construction of assemblies or components. The "drawing" mode also allows for the creation of animations that present operation of devices [3].

DESIGNING OF THE SHELL AND THE BOTTOM OF THE FERMENTATION CHAMBER

The individual rings of the shell (Fig. 1) of the chamber were created in the "part" mode. At the beginning, the

2d sketch of the ring was created. Next, the sketch was transformed into a 3d model using a linear extension function [4]. This way the ring achieved the required height. The tank's rings were bevelled in order to prepare place for the weld [10].

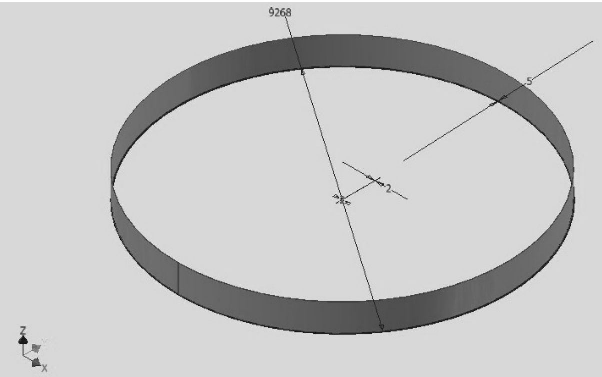

Fig. 1. The shell's ring with visible groove for the weld [own elaboration]

The bottom ring was created following the same method as the shell's rings – it was provided with an internal diameter, height and thickness (Fig. 2).

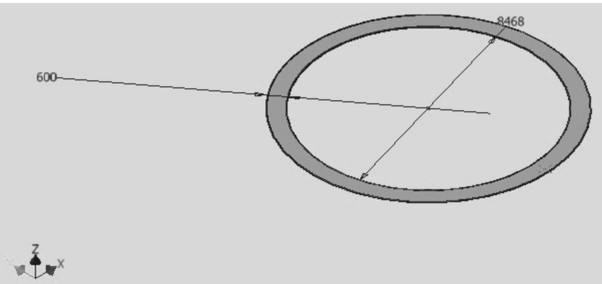

Fig. 2. Bottom ring [own elaboration]

The bottom was created by sketching a circle and using the linear extension function to provide it with the required thickness (Fig. 3).

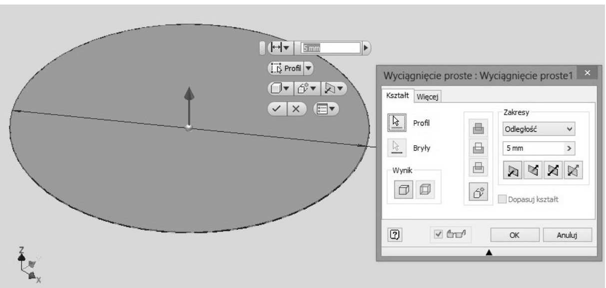

Fig. 3. Middle part of the tank's bottom [own elaboration]

The next element to design was the angle section that tops the tank, on the basis of the norm PN-B-03210. First, the sketch of the angle section was created (Fig. 4a), next it was turned by 360˚ (Fig. 4b) and then it was cut using a separate plane and the remaining edges were bevelled [7].

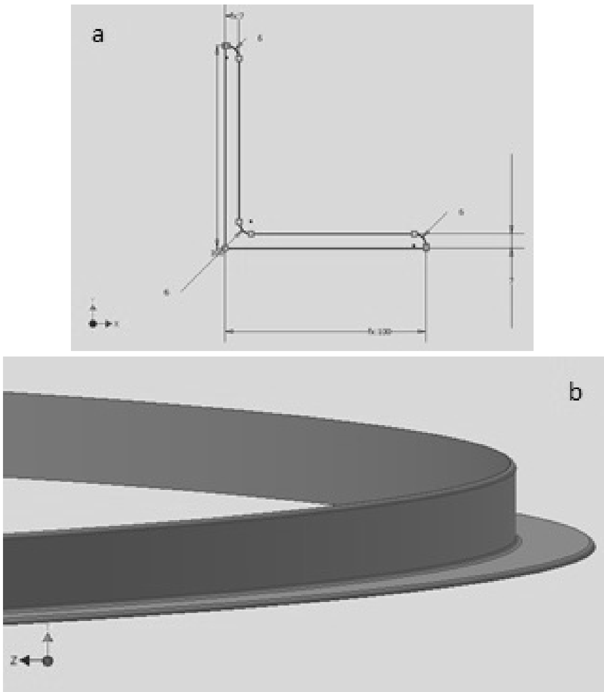

Fig. 4. Cross-section of the angle section 100x100x7; a – angle section sketch, b – rotation of the sketch by 360̊ [own elaboration]

DESIGNING OF THE DOME OF THE FERMENTATION CHAMBER

Between the applied internal and external membrane there was a seal of foamed EPDM rubber [1]. The 3d model was created in the same way as the shell elements of the tank (Fig. 5).

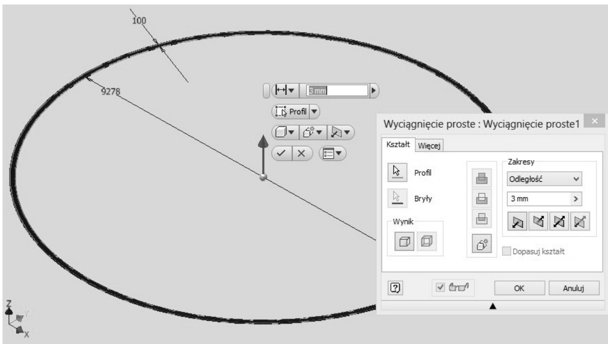

Fig. 5. 3d model of the EPDM seal [own elaboration]

Next, the internal membrane was designed (Fig. 6) and the external membrane by creating proper sketches that were transformed into 3d models by turning them [4]. This operation for the internal membrane was presented in Figure 6.

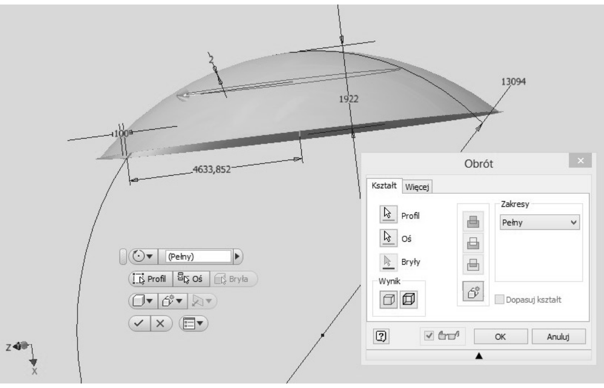

Fig. 6. Turning of a profile in order to design the internal membrane [own elaboration]

Both membranes will be held down by a ring adhering to the angle section topping the tank. The edges of the ring were rounded (Fig. 7) in order to avoid cutting of the moving membranes.

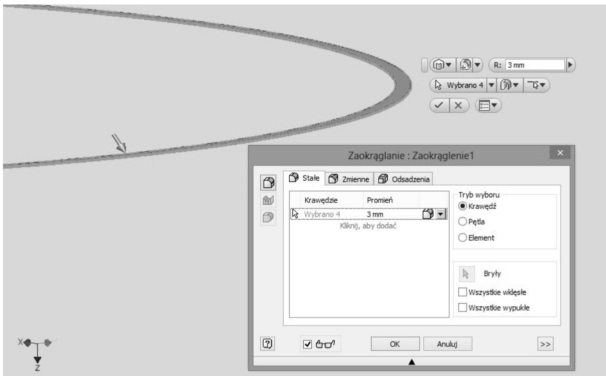

Fig. 7. The process of rounding of edges of the ring holding down the membranes [own elaboration]

DESIGNING OF THERMAL INSULATION: LAYERS OF MINERAL WOOL AND TANK'S COVER FROM TRAPEZOIDAL SHEET METAL

In order to protect the tank from weather conditions and to maintain the mesophilic temperature, the tank is insulated with mineral wool. Mineral wool model (Fig. 8) was created as a circle segment. The element was designed in such a way as to allow for placing it between sections that will be generated during the next design stage.

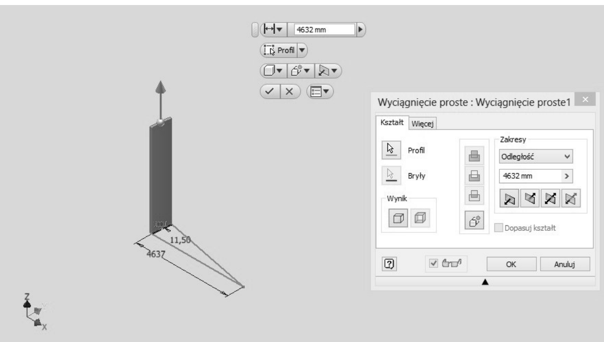

Fig. 8. Creation of the mineral wool element [own elaboration]

In order to protect against weather conditions the tank will be covered with trapezoidal sheet metal FLOLINE 40. When creating the cover element it was required to create a sketch of the sheet metal element and next multiply it and provide it with the required thickness [8]. The sketch was cut to proper length and turned 360˚, which resulted in a simplified model of trapezoidal sheet metal (Fig. 9).

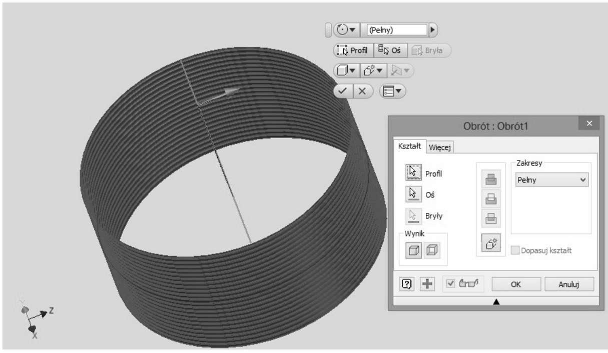

Fig. 9. Turning of the trapezoidal sheet metal model in order to create a 3d model [own elaboration]

CONNECTING INDIVIDUAL PARTS INTO THE FERMENTATION CHAMBER ASSEMBLY

Individual elements of the tank such as: shell rings, angle section topping the tank, the bottom, bottom ring, middle bottom part were connected using the concentric connection functions (Fig. 10a). The angle section topping the tank was moved up to connect it via a fillet weld to the shell ring. Next every element was marked as "fixed".

The elements of the roof: the internal membrane, the external membrane, the seal and the ring holding down the membranes were also joined in a concentric manner (Fig. 10b).

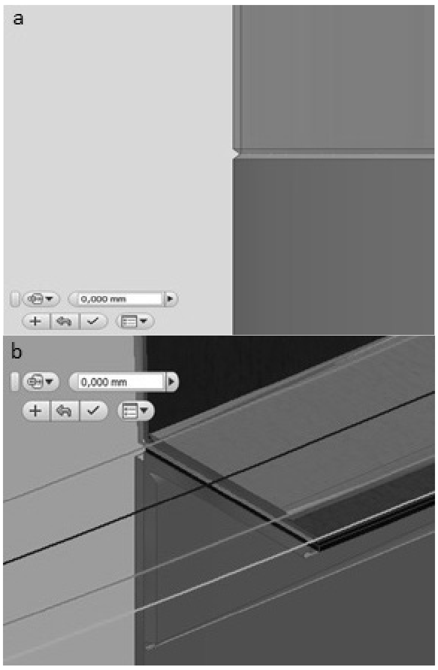

Fig. 10. Concentric connection of: a – tank's rings, b – ring pressing down on the membranes [own elaboration]

During the next stage the ring pressing down on the membranes was connected to the angle section with a screw with a hexagonal head M14x1.5x60, selected on the basis of norm ISO 8765 (two-sided with spacers 14-140 HV from norm ISO 7089) and with nuts M14x1.5 from norm ISO 8674. The connection was realized by the sketching of a point in the middle of the upper surface of the upper ring, the point that was next multiplied on a circle, which resulted in 60 points. These were used as reference points for the screws placement (Fig. 11).

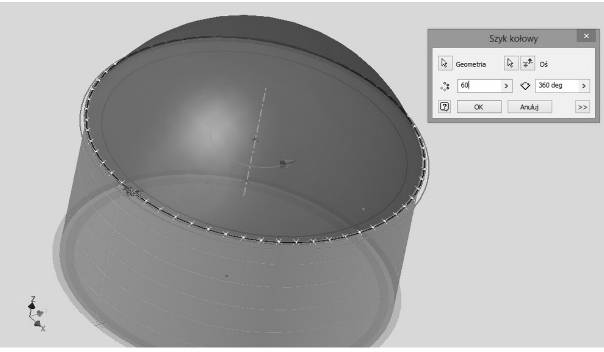

Fig. 11. Multiplication of reference points for screws using a circular array [own elaboration]

Screw joints were created in a threaded connection creator (Fig. 12). After the end of creation of the connection, the program automatically placed the screw in the indicated points (Fig. 13).

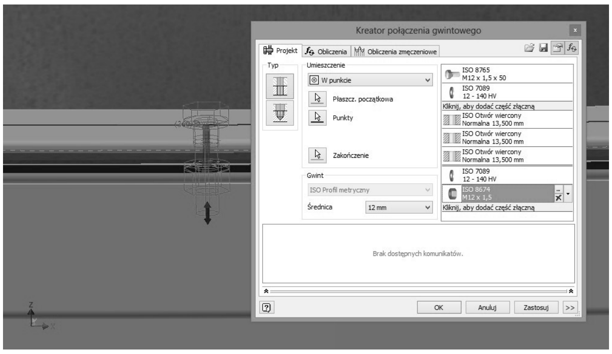

Fig. 12. Generation of screw connection of the ring holding down the membranes and the angle section at the top of the tank [own elaboration]

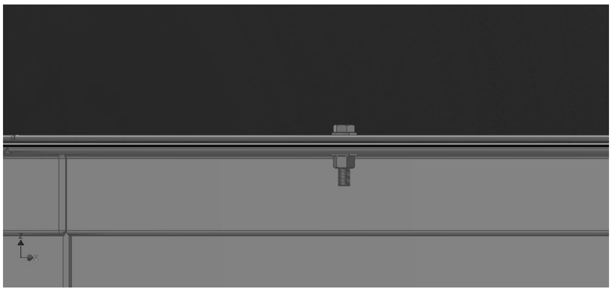

Fig. 13. Generated screw connection of the ring holding down the membranes and the angle section at the top of the tank [own elaboration]

In the next stages the issue for consideration was the strengthening of the stability of the construction and the connection between the tank and the trapezoidal metal sheet covering [6].

In order to connect the trapezoidal sheet metal different sections or wooden battens can be used. Their spacing is based on calculations concerning the circumference of the tank. The Autodesk Inventor has an option for automatic placement of sections. When using this function, two points must be indicated between which the section is to be placed. On the surface of the ring holding down the membranes a point was drawn that was then projected on the bottom ring. Next, from the level of the bottom ring a plane was created that was moved away from the top surface of the ring. This way the two points were created required for the placement of sections. From the available sections a CH channel section 100x10 was chosen (Fig. 14). The section will provide space to place mineral wool between the tank's shell and the sheet metal that will be connected to it.

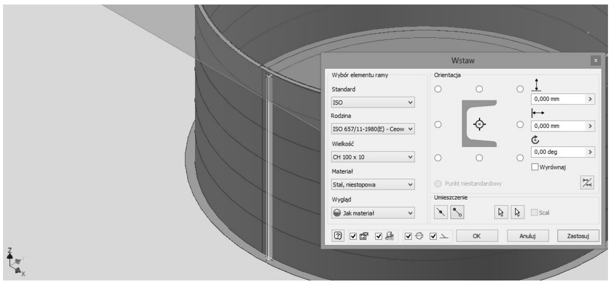

Fig. 14. Placement of the CH channel section 100x10 using section placement generator [own elaboration]

The section is then turned in such a way that it touches the tank's ring with its side surface (Fig. 15).

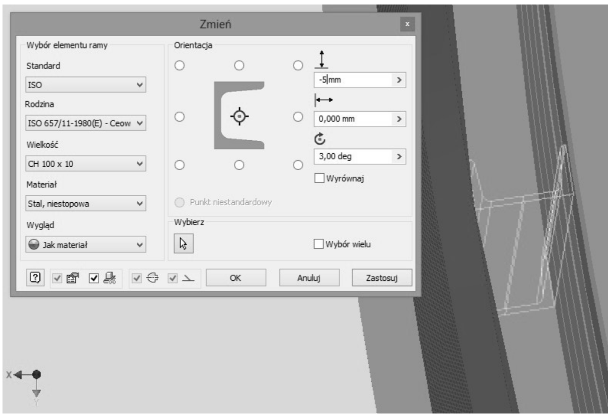

Fig. 15. Tangential orientation of the section to the edge of the tank [own elaboration]

Next it was required to attach the trapezoidal sheet metal to the generated channel section. From the level of trapezoidal sheet metal there was created a plane as an element tangential to the element (sheet metal) and parallel to the plane passing through the centre of the element [8]. Onto that plane there were projected the edges of the previously placed section and the edges of the sheet metal in order to determine the connection point. In that point a circle was sketched, which was pulled to the next plane using the “cut” function. In this way a hole was created – a place for a screw.

Using the library of the program – „ConcentCenter ” from norm ISO 1479, there was chosen a sheet metal screw C ST 9.5x32-C (Fig. 16). In the next step the screw was multiplied in a “linear array” along the surface of the section.

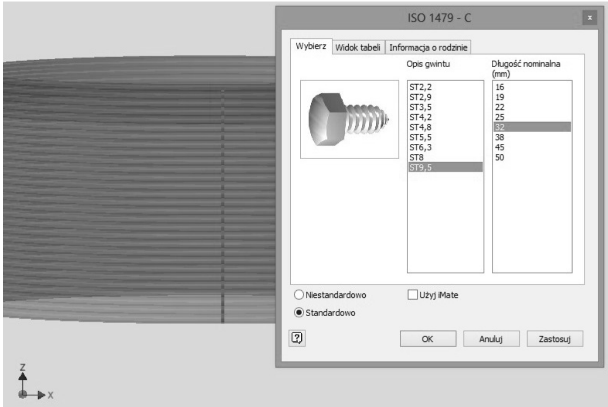

Fig. 16. Selection of a screw from the program’s library [own elaboration]

Using automatic connection and selecting the “rigid connection” option the screws were placed in their intended locations.

The section was multiplied in a circular array around the tank’s shell (Fig. 17).

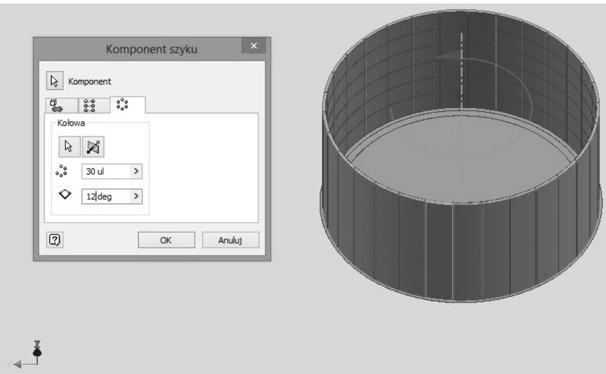

Fig. 17. Multiplication of the channel section around the rings of the tank [own elaboration]

In the next stage the screws were multiplied using the same principle as the sections. This way there was created a connection between the trapezoidal sheet metal with every channel section placed around the tank’s shell (Fig. 18). The top-view of the connection is given in Figure 19.

At the next stage of creation of the model of the fermentation chamber there were created the welds between the elements of the tank’s shell. The lowest ring was welded to the peripheral ring of the bottom using a fillet weld from both the inside of the tank and the outside [Ziółko 1995]. The top angle section was welded to the top ring with fillet weld from the outside of the tank. The channel sections on the circumference of the shell were welded to the shell using fillet welds (Fig. 20).

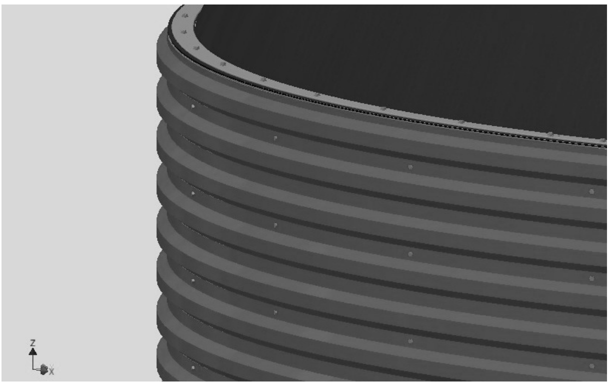

Fig. 18. Finished connection of trapezoidal sheet metal and sections [own elaboration]

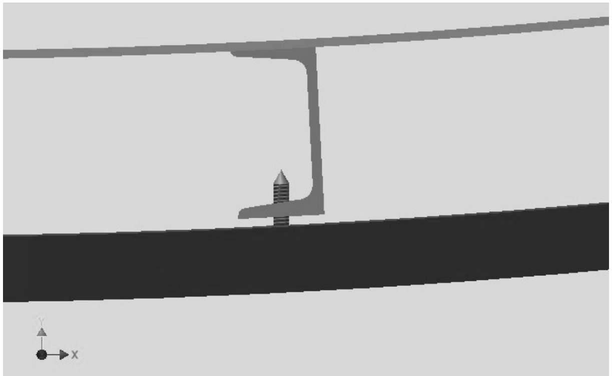

Fig. 19. Connection of trapezoidal sheet metal and section – top-view [own elaboration]

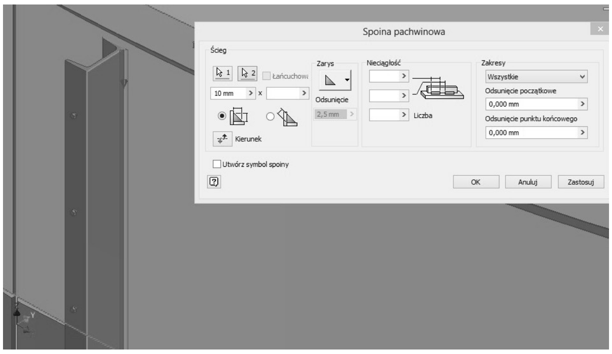

Fig. 20. Creation of continuous fillet weld connecting the tank’s shell with the channel section [own elaboration]

Next, between the sections the mineral wool element was placed, using the “concentric placement tool”. The element was multiplied with “circular array” (Fig. 21).

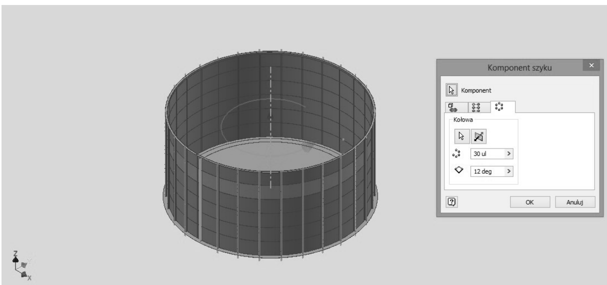

Fig. 21. Multiplication of the mineral wool element around the tank [own elaboration]

At the end, the pipes were designed used for the feeding and removing of the substrate [5]. The pipe was created by making a sketch of a circle of the required diameter and next by extending the sketch which resulted in the required thickness of the element. Next, the resultant sketch was extended to the required height.

The pipes placed in proper positions were connected with fillet welds from both sides of the rings (Fig. 22).

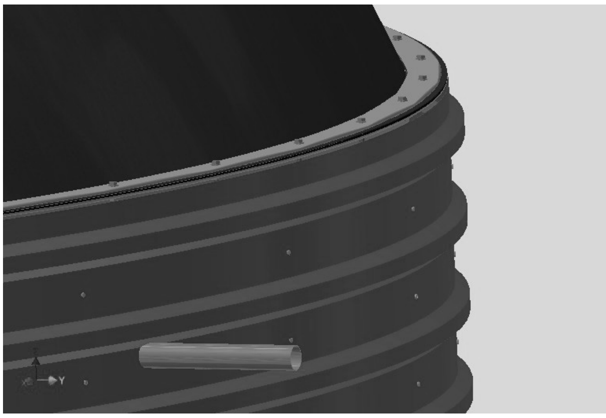

Fig. 22. The substrate feeder pipe [own elaboration]

The finished fermentation chamber was presented in Figure 23.

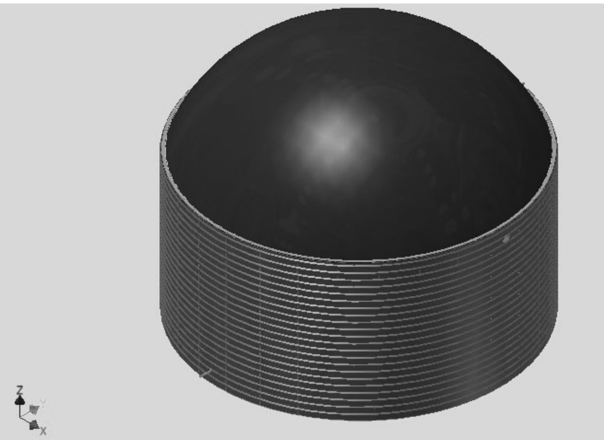

Fig. 23. Visualization of the designed fermentation chamber [own elaboration]

CONCLUSIONS

Modern engineering software makes it much easier for constructors to create a complete technical documentation – starting from the concept and ending with detailed engineering analyses. This process was presented using a digester biogas tank as a design example. Some characteristics of the modern software include: checking correctness of the model in 3d option, automatic creation of detail projections and ability to realize exhaustive stress analyses, and ease of use.

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PROJEKTOWANIE ZBIORNIKA KOMORY BIOGAZOWEJ CZ. 3.: MODEL 3D KOMORY FERMENTACYJNEJ

Streszczenie. Opisano proces projektowania 3D komory biogazowej przy wykorzystaniu nowoczesnego oprogramowania inżynierskiego. Zaprojektowano płaszcz zbiornika biogazu, jego dno oraz kopułę dachu komory. Do połączenia elementów wykorzystano połączenia spawane oraz śrubowe dostępne w bibliotece programu.

Słowa kluczowe: projekt, zbiornik komory biogazowej, model 3d.