

INTEGRATED SYSTEM FOR CONSTRUCTIVE OPTIMIZATION OF RECIPIENTS MADE BY SHEET METAL

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Abstract: This paper presents an integrated method for constructive optimization and computer assisted design of recipients made by sheet metal. There were utilized the links between CAD application Solid Edge and MS Excel application. The method consists in automatization of assisted design and elaboration of technical documentation, correlated with constructive optimization regarding the materials consume.

1. INTRODUCTION

Worldwide competition has increased the pressure to optimize business processes in manufacturing enterprises.

Optimization is performed in three dimensions: costs, time-to-market, and quality. In particular, these challenges the capabilities of engineering design, which is concerned with the design of the products as well as the processes of manufacturing.

To produce innovative designs of high-quality products rapidly at low costs, methods such as concurrent and simultaneous engineering have been developed recently.

With the rapid changes in technologies and market conditions since the industrial revolution, the demand and the value of consumer goods varies drastically with time. When there is an improvement in technologies and functions of a product, the demand will increase; when a product is being substituted by another product, its demand will decrease.

2. THEORETICAL CONSIDERATIONS

The problem that must be solved is the optimization of constructive dimensions of a bunker with octagonal shape, realized from an octagonal prism and respectively an octagonal pyramid.

First must found out constructive dimensions L_1 , H_1 , H_2 , so for a certain total volume and for a certain total height to get a minimum sheet metal consumption (fig. 1).

For the optimization purpose, in the first step must be determined the relationships for geometric elements of the bunker.

The total volume of the bunker can be calculated starting by the following formula:

$$V_T = V_1 + V_2 \quad (1)$$

Where:

V_1 – volume of the prism

V_2 – volume of the pyramid trunk

Volume V_1 can be expressed by:

$$V_1 = S_{b1} \cdot H_1 \quad (2)$$

Where:

S_{b1} - represents the area of the prism

H_1 – height of the prism

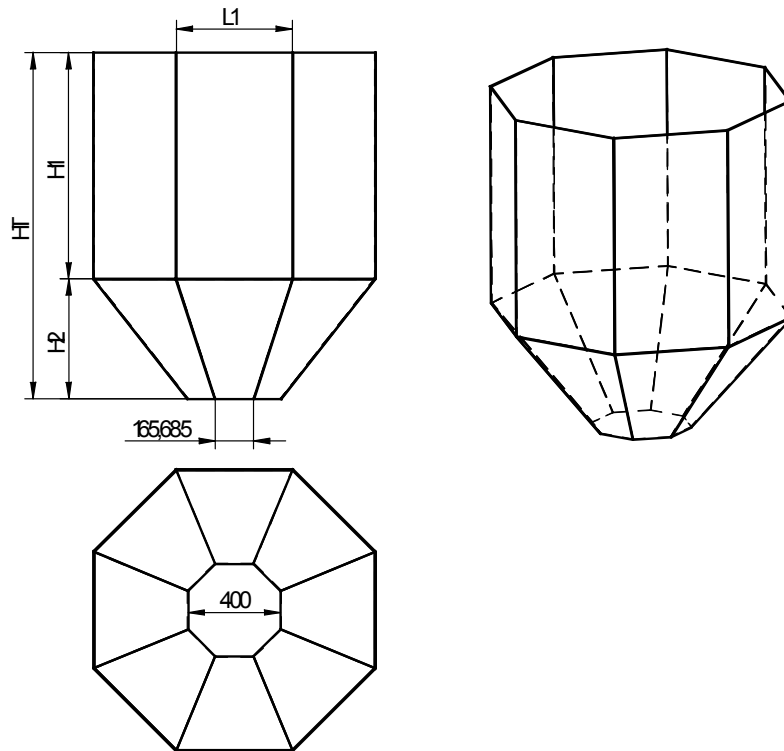


Fig. 1

Based on fig. 2, the area of the prism is given by the relationship:

$$S_{b1} = 4L_1 \cdot A_1 \quad (3)$$

L_1 – side of regular polygon that represents the base of the prism

A_1 – apotem of poligon

Knowing the angle between the side of the polygon L_1 and its apotema A_1 :

$$A_1 = L_1 \cdot \text{tg} \alpha \quad (4)$$

So, the relationship (3) becomes:

$$S_{b1} = 2L_1^2 \cdot \text{tg} \alpha \quad (5)$$

Equation (2) will be:

$$V_1 = 2 \cdot L_1^2 \cdot H_1 \cdot \text{tg} \alpha \quad (6)$$

The lateral area of the prism is:

$$S_{l1} = 8 \cdot L_1 \cdot H_1 \quad (7)$$

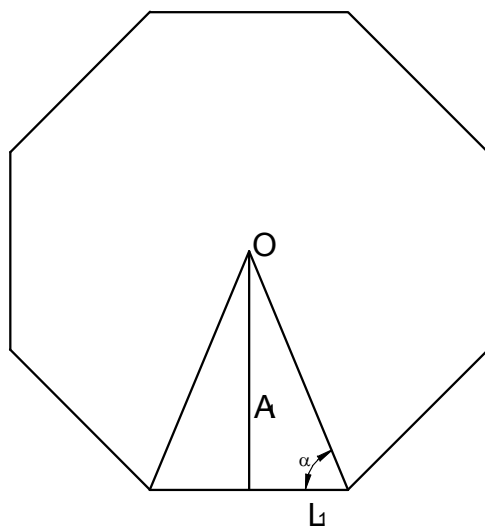


Fig. 2

The volume of the trunk of the pyramid can be expressed by:

$$V_2 = \frac{H_2}{3} (S_{b1} + S_{b2} + \sqrt{S_{b1} \cdot S_{b2}}) \quad (8)$$

where:

H_2 – height of the trunk of the pyramid

S_{b1} – area of the large base determined before (rel.5)

S_{b2} – area of the small base

Noting with L_2 and A_2 the side and respectively the apotema of the regular polygon of the small base you can write:

$$S_{b2} = 2 \cdot L_2^2 \cdot \operatorname{tg} \alpha \quad (9)$$

Taking into account constructive considerations, the value of A_2 must be 200 mm, that is requested by beneficiary. As $\alpha = 3\pi/8$ it results $S_{b2} = ct$

By substituting in (8) it results:

$$V_2 = \frac{H_2}{3} (2 \cdot L_1^2 \cdot \operatorname{tg} \alpha + S_{b2} + L_1 \sqrt{2 \cdot S_{b2} \cdot \operatorname{tg} \alpha}) \quad (10)$$

In order to determine the lateral area of the trunk of the pyramid, it is necessary to express the area of the trapezoidal part (fig.3) noted with S_3 :

$$S_3 = \frac{L_1 + L_2}{2} \cdot h \quad (11)$$

where h represents the trapezium height

From fig.4 results:

$$h = \sqrt{(A_1 - A_2)^2 + H_2^2} \quad (12)$$

Making the substitutions you obtain:

$$h = \sqrt{\left(\frac{L_1}{2} \cdot \operatorname{tg} \alpha - 200\right)^2 + H_2^2} \quad (13)$$

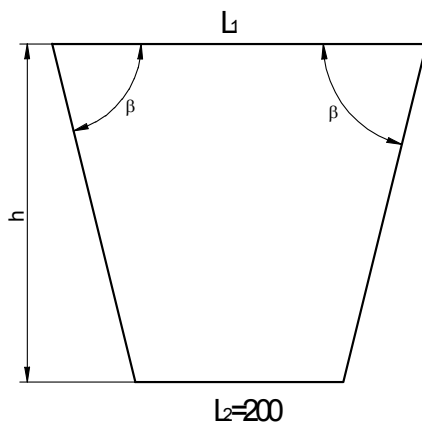


Fig. 3

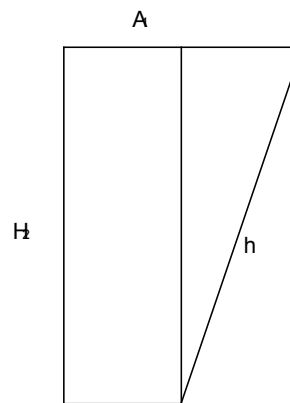


Fig. 4

By substituting in (11) you obtain:

$$S_3 = \frac{L_1 + L_2}{2} \cdot \sqrt{\left(\frac{L_1}{2} \cdot \operatorname{tg} \alpha - 200\right)^2 + H_2^2} \quad (14)$$

The lateral area of the trunk of the pyramid is determined by relationship :

$$S_{l2} = \frac{P_1 + P_2}{2} \cdot S_3 \quad (15)$$

where P_1 si P_2 represent the perimeter of the large base, respectively of the small base

$$P_1 = 8 \cdot L_1 \quad (16)$$

$$P_2 = 8 \cdot L_2 \quad (17)$$

By substituting the relationships (14), (16) and (17) in (15) you obtain:

$$S_{l2} = 4 \cdot (L_1 + L_2) \cdot \frac{L_1 + L_2}{2} \cdot \sqrt{\left(\frac{L_1}{2} \cdot \operatorname{tg} \alpha - 200\right)^2 + H_2^2} \quad (18)$$

Knowing how are expressed the volumes, surfaces and heights of the parts we can establish the values which must be optimized.

The total volume can be obtained by substituting the relationships (6) and (8) in (1):

$$V_T = 2 \cdot L_1^2 \cdot H_1 \cdot \operatorname{tg} \alpha + \frac{H_2}{3} \left(2 \cdot L_1^2 \cdot \operatorname{tg} \alpha + S_{b2} + L_1 \sqrt{2 \cdot S_{b2} \cdot \operatorname{tg} \alpha} \right) \quad (19)$$

The total surface of the sheet iron of the bunker is given by relationship:

$$S_T = S_{l1} + S_{l2} + S_{b1} \quad (20)$$

By substituting it results:

$$S_T = 8 \cdot L_1 \cdot H_1 + 4 \cdot (L_1 + L_2) \cdot \frac{L_1 + L_2}{2} \cdot \sqrt{\left(\frac{L_1}{2} \cdot \operatorname{tg} \alpha - 200\right)^2 + H_2^2} + 2L_1^2 \cdot \operatorname{tg} \alpha \quad (21)$$

The total height:

$$H_T = H_1 + H_2 \quad (22)$$

Taking into account that L_2 and α are known, by analyzing (19), (21) and (22) you can notice that these depend on three independent parameters: L_1 , H_1 , și H_2 .

The constructive optimization assumes to establish values for the named parameters to be realized simultaneously the conditions:

$$\begin{cases} V_T(L_1, H_1, H_2) = ct \\ H_T(H_1, H_2) = ct \\ S_T(L_1, H_1, H_2) = \min \end{cases} \quad (23)$$

3. DIMENSIONAL OPTIMIZATION

	A	B
1	Prisma octogonală	
2	L1	300.000
3	H1	400.000
4	A1	362.132
5	P1	2400.000
6	Sb1	434558.441
7	Sl1	960000.000
8	V1	173823376.5
9		
10	Trunchiul de piramida	
11	L2	165.6854249
12	H2	200
13	A2	200
14	P2	1325.4834
15	Sb2	132548.34
16	h	257.4622236
17	S3	59948.2025
18	Sl2	479585.62
19	V2	53807118.75
20		
21	Buncar	
22	VT	227630495.2
23	HT	600.000
24	ST	1874144.061
25		

Fig. 5

The dimensional optimization is realized by using Solver application from MS Excel.

Solver is part of a suite of commands sometimes called what-if analysis, a process of changing the values in cells to see how those changes affect the outcome of formulas on the worksheet. With Solver, you can find an optimal value for a formula in one cell—called the target cell—on a worksheet. Solver works with a group of cells that are related, either directly or indirectly, to the formula in the target cell. Solver adjusts the values in the changing cells you specify—called the adjustable cells—to produce the result you specify from the target cell formula.

You can apply constraints to adjustable cells, the target cell, or other cells that are directly or indirectly related to the target cell, to restrict the values. Solver can use the model, and the constraints can refer to other cells that affect the target cell formula.

Solver could be used to determine the maximum or minimum value of one cell by changing other cells.

You open a worksheet Excel and you introduce the parameters which define the geometry of the bunker and their size, expressed by the formulas defined before or by numerical values (fig.5). There are not important the numerical values for the time being, they can have any value. When you intend to define and solve a problem by using Solver, on the Tools menu, click Solver (fig. 6). If the Solver command is not available on the Tools menu, you need to install the Solver add-in program (fig.7).

On the Tools menu, click Add-Ins.

In the Add-Ins available box, select the check box next to the add-in you want to load, and then click OK.

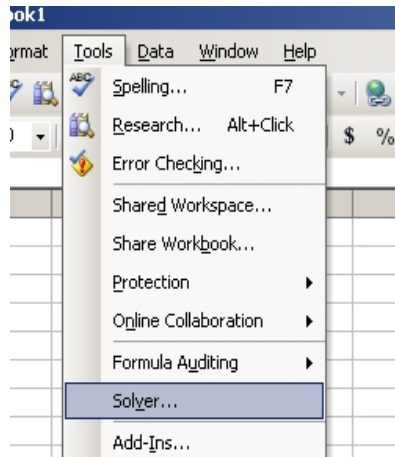


Fig. 6

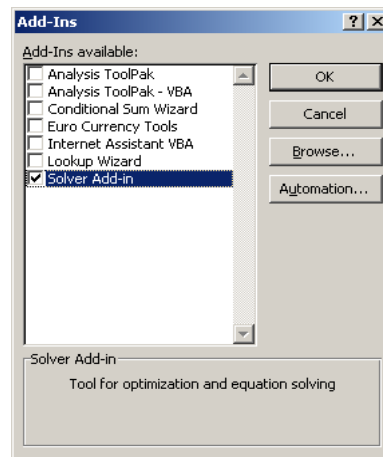


Fig.7

By relationship (23) results that the target is that the lateral surface S_T must be minimum in conditions of keeping constant the total volume V_T and height H_T .

In the dialog box that appears and in the Set Target Cell box, enter a cell reference

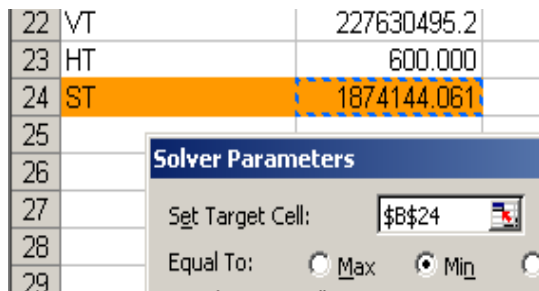


Fig. 8

or name for the target cell. The target cell must contain a formula. As we know the target cell is B24 which represents the total surface S_T . To have the value of the target cell be as small as possible, click Min (fig. 8).

From relationship (23) we can see the dimensions which can be modified in order to realize the target ($S_T = \min$), respectively L_1 , H_1 and H_2 .

In the Solver Parameters dialog, in the By Changing Cells box, enter a name or reference for each adjustable cell mentioned, separating nonadjacent references with commas (fig. 9).

The adjustable cells must be related directly or indirectly to the target cell. You can specify up to 200 adjustable cells.

If you want to have Solver automatically propose, the adjustable cells based on the target cell, click Guess.

In the following step, in the Subject to the Constraints box, we enter the constraints which we want to apply.

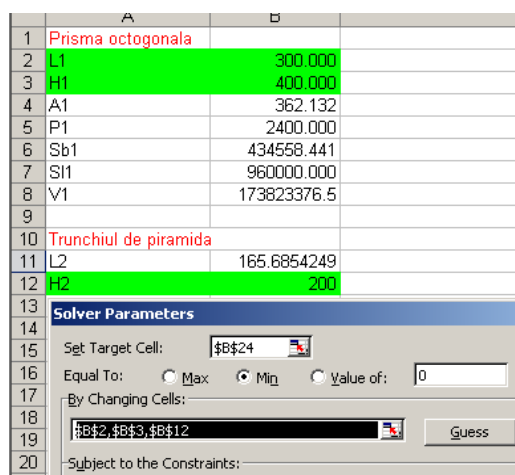


Fig. 9

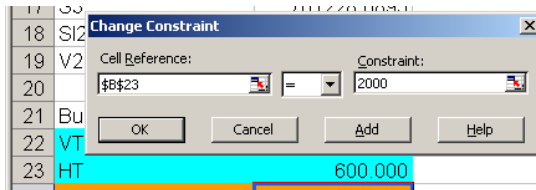


Fig. 10

	A	B
1	Prisma octogonala	
2	L1	506.369
3	H1	1263.162
4	A1	611.242
5	P1	4050.954
6	Sb1	1238056.321
7	Sl1	5117010.737
8	V1	1563865441.574
9		
10	Trunchiul de piramida	
11	L2	165.685
12	H2	736.8382078
13	A2	200
14	P2	1325.483
15	Sb2	132548.340
16	h	843.831
17	S3	283550.224
18	Sl2	2268401.795
19	V2	436134558.426
20		
21	Buncar	
22	VT	2000000000
23	HT	2000.000
24	ST	8623468.852
25	Solver Results	
26	Solver found a solution. All constraints and optimality conditions are satisfied.	
27	<input checked="" type="radio"/> Keep Solver Solution <input type="radio"/> Restore Original Values	
28	<input type="button" value="OK"/> <input type="button" value="Cancel"/> <input type="button" value="Save Scenario..."/>	
29	<input type="button" value="Reports"/> <input type="button" value="Answer Sensitivity Limits"/>	
30		
31		
32		

Fig. 11

As we though mentioned, these are the maxim volume of the recipient 2 m^3 , and the maxim height $H_T = 2000 \text{ mm}$. In order to do this, in the Solver Parameters dialog box, under Subject to the Constraints, click Add.

In the Add a constraint box, in the Cell Reference box, enter the cell reference or name of the cell range B22 and B23 for which we want to constrain the value (fig. 10).

Click the relationship = between the referenced cell and the constraint. In the Constraint box, type the numbers mentioned above. You also may type a cell reference or name, or a formula.

To accept the constraint and add another, click Add, and then to accept the constraint and return to the Solver Parameters dialog box, click OK.

To instruct Solver to find the solutions click Solve. If the solution values are right, on the worksheet, click Keep Solver Solution in the Solver Results dialog box.

To restore the original data, click Restore Original Values. If Solver finds a solution, you can click a report type in the Reports box, and then click OK. The report is created on a new worksheet in your workbook.

The obtained results are presented in fig. 11.

4. CAD INTEGRATION

The spreadsheet created in Microsoft Excel can be used to drive the dimensions in a Solid Edge model. We can link the spreadsheet to a variable in the Solid Edge document.

Before we can link a variable to a spreadsheet, we must first create the variables you want in the Solid Edge document. In Excel application, the document that contains the spreadsheet we want to link to must be opened. The spreadsheet should contain the appropriate names and values for dimensional relationships. Open or create the Solid Edge document that must link to and, on the Tools menu, point to Variables, and then click Variables. We arrange the windows of the spreadsheet document and the Variable Table in the Solid Edge document so that we can see the appropriate cells in both documents. Before this, we must set the Allow Inter-Part Links Using: Paste Link to Variable Table option on the Options dialog box. This option is on the Inter-Part tab. When making changes to a managed document that has links to a spreadsheet, such as Excel, we should open the Solid Edge document first.

They are designed one by one the iron sheet components of the bunker, without paying attention to dimensions, being important just to exist as parts in the design project.

It is opened Solid Edge in the module Sheet metal, because we have to project iron sheet pieces. In the sketcher window draw a rectangle and dimension its sides.

After the dimensions are applied on the project it is opened the menu Tool→Variables→Variables (fig. 12).

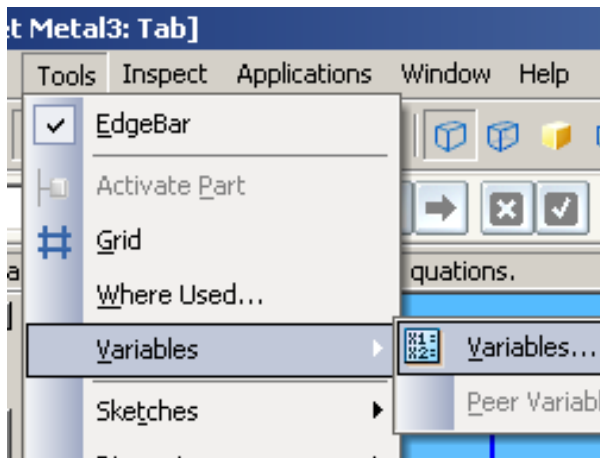


Fig. 12

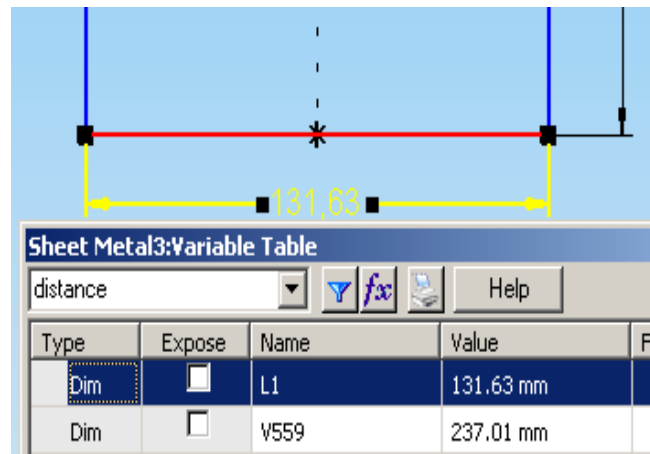


Fig. 13

By using Select Tool there are one by one selected the dimensions of the rectangle. In Variable Table the dimensions will be highlighted. In the Name box it is written L_1 (fig. 13).

Then it pass to the worksheet in Excel, where were fill in the dimensional optimizations. In the spreadsheet, select the cell that contains the dimensional value you want to link to. For example, select the cell that contains the value of dimension L_1 .

Copy the selected cell (fig. 14).

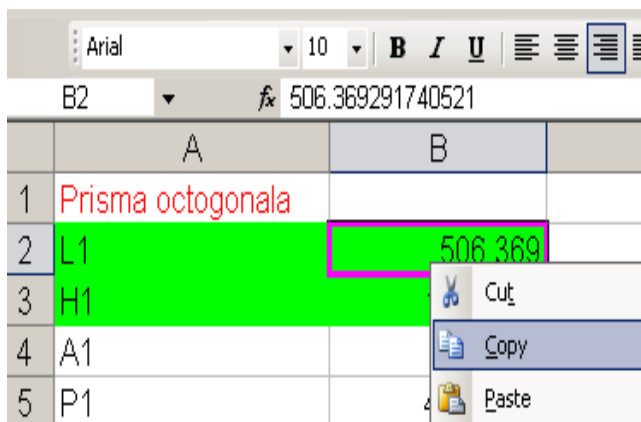


Fig.14

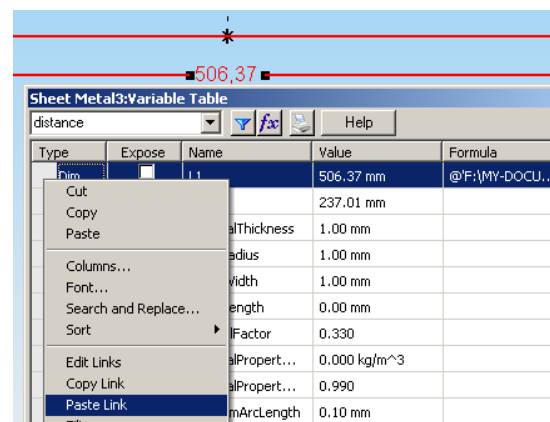


Fig. 15

In the Variable Table, click the row that contains the variable that you want to link the spreadsheet value to, in our example dimension L_1 and on the shortcut menu, click Paste Link.

You have to proceed similarly for the other rectangle side. Then the Variable Table is closed and you come back in Sheet metal, where is specified the thickness of the sheet metal. For the trapezoidal side the procedure is similar.

The pieces realized in Solid Edge and Excel workbook are saved and then is realized the assembly for the bunker, using the known relationships from Solid Edge.

When is necessary to project other bunker of the same shape, but with a modified total volume $V_T=11.5 \text{ m}^3$ and total height $H_T=1500 \text{ mm}$, you modify only these constrains (fig.10) in Solver. The comparative results are presented in fig. 16.

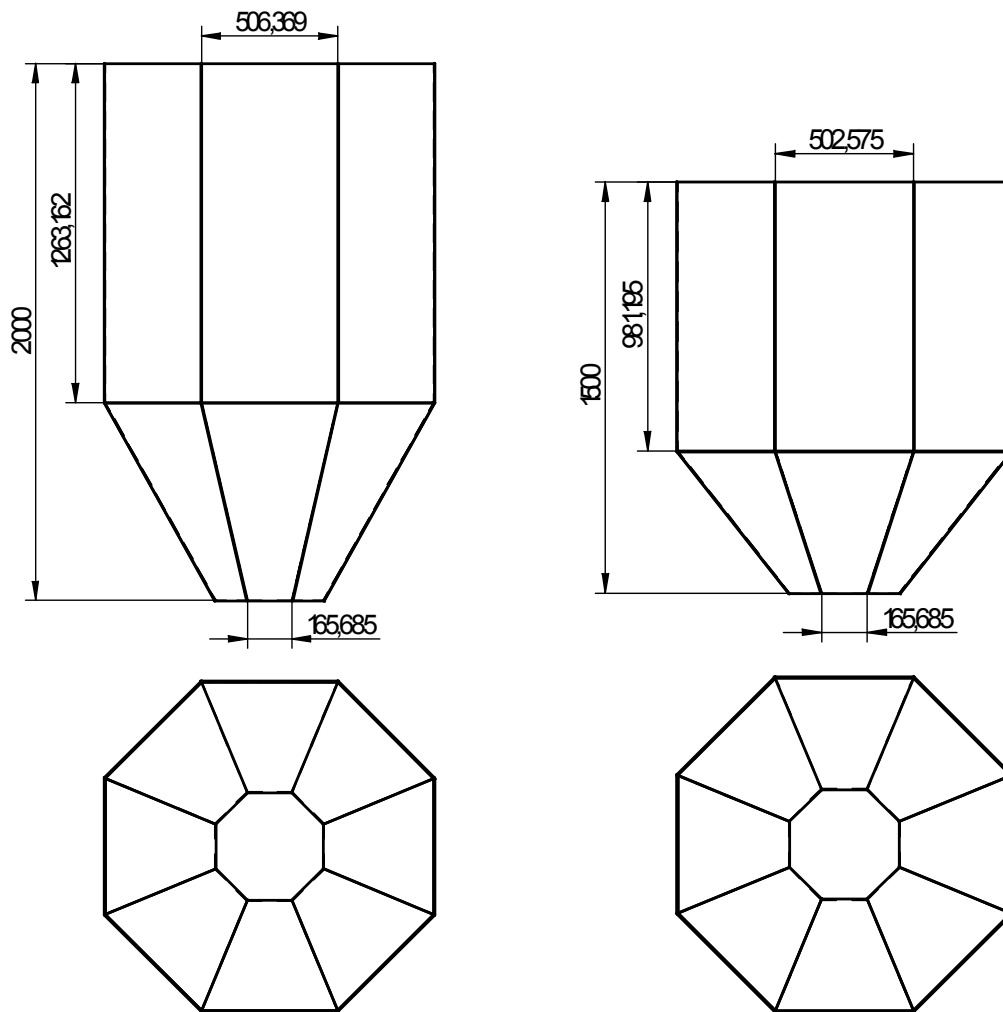


Fig. 16

5. CONCLUSIONS

Due to the permanent links between SE and Excel each any new actualization of the parts and assemblage can be done rapidly and also the technological documentation. In this way the time needed to project a new product is reduced to several minutes. When you edit the value in the spreadsheet, the variable in the Variable Table updates as well. The Solid Edge document automatically updates.

The proposed method is generalized, so it can be extended to project other shapes of parts as recipient type.

By applying this method they are obtained economies of material, which are as important as the manufacture production is bigger.

6. REFERENCES:

- [1]. <http://www.frontsys.com>
- [2]. Microsoft Excel Help
- [3]. Solid Edge Help