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OPTIMIZATION OF THE CONSTRUCTION OF A PRESSURE TANK USING CAD/CAE SYSTEMS

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Key words: pressure tank, optimalization of construction, CAD/CAE.

Abstract

The paper presents a method for optimizing the construction of a vertical pressure tank with a given capacity, for specified service conditions. Such tanks are elements of process lines applied in numerous branches of the economy, including the chemical, pharmaceutical, cosmetic and food industry.

The optimization process was carried out using CAD/CAE systems. In order to find the best engineering solution, multi-criteria optimization of the pressure space of a tank was performed. This enabled to choose the optimum construction, with the emphasis on low weight, high producibility and operating comfort.

OPTYMALIZACJA KONSTRUKCJI ZBIORNIKA CIŚNIENIOWEGO Z WYKORZYSTANIEM SYSTEMÓW CAD/CAE

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Słowa kluczowe: zbiornik ciśnieniowy, optymalizacja konstrukcji, CAD/CAE.

Streszczenie

W artykule przedstawiono metodę optymalizacji pionowego zbiornika ciśnieniowego o ustalonej objętości dla określonych warunków eksploatacji. Zbiorniki tego typu są elementami linii technologicznych stosowanych w wielu gałęziach gospodarki, m.in. w przemyśle chemicznym, farmaceutycznym, kosmetycznym i spożywczym.

Optymalizację przeprowadzono z wykorzystaniem systemów CAD/CAE. W celu znalezienia najlepszego rozwiązania konstrukcyjnego wykonano optymalizację wielokryterialną przestrzeni ciśnieniowej zbiornika. Przeprowadzona analiza pozwoliła na wybór konstrukcji optymalnej, charakteryzującej się małą masą, dużą technologicznością oraz łatwością eksploatacji.

Introduction

The term “tank” describes a wide range of vessels, such as e.g. underground containers with a capacity of around 5000 m^3 used for liquid fuel storage, transportation tanks or process equipment and devices designed for various production branches. The present paper focuses on tanks which are elements of process lines, applied in numerous branches of the economy, including the chemical, pharmaceutical, cosmetic and food industry. Their capacity usually varies between several and several dozen cubic meters. Depending on the function they perform in technological processes, these can be storage tanks, buffer tanks, mixing tanks, reactors, manifolds, filters, etc. Due to the physical and chemical processes taking place inside such vessels, their construction should ensure the occurrence of internal overpressure.

The design, production and conformity assessment of pressure tanks available in the European Union are specified in the Directive of the European Parliament and the Council of the European Union 97/23/WE of May 29, 1997 on the harmonization of the national legislation of the Member States relating to pressure equipment. The objective of this Directive is to ensure the free movement and circulation of pressure equipment within the European Union as well as to lay down the essential safety requirements.

The main structural units of pressure vessels are thin-walled shells. To simplify the design process and to reduce the costs of construction, the shells take the simplest geometrical shapes: they may be flat, cylindrical, conical or spherical. The body of a pressure tank is usually a combination of these components (KONOPKO 1998). It follows that the design of pressure vessels consists primarily in determining the dimensions of the above components. The selection of the appropriate computational model and its simplification should enable to take into consideration at least the key characteristics of a real object. The rapid development of computational techniques observed today permits the generation of complex theoretical models as well as a more adequate assessment of the properties of real objects. The traditional methods employed for strength analysis are based on computations resulting from the adoption of analytical solutions and idealized theoretical models. Such computations are performed for particular components of a pressure tank, i.e. the blanket, heads and supports. The application of digital computational methods (CSD) enables to perform a strength analysis for the entire construction, without the division into components. These methods allow to examine objects characterized by complex shapes, at various boundary conditions. Due to the fact that computer-aided techniques are much less time-consuming, it is possible to analyze many constructional variants and choose the optimum one.

Shell optimization methods

Thin shell optimization involves searching for the optimum shape of a central surface and wall thickness (MAGNUCKI 1998). Two groups of optimization methods are applied for this purpose, i.e. variational and parametric. The variational methods are based on search for a function, and are limited to non-classic problems of variational calculus, most often isoperimetric problems. A detailed description of variational calculus applied to mechanics may be found, among others, in a monograph by H. Lippmann (LIPPMANN 1972). Parametric shaping consists in search for the dimensions of structural units of the shell, such as shell thickness, the distance between ribs, the cross-section of reinforced ribs, the distribution of supports, etc.

The problems of the optimization of shell components are still widely discussed by numerous authors (MAZURKIEWICZ, NAGÓRSKI 1986, MAGNUCKI 1993). Due to their diversity, the problems of shell optimization cannot be analyzed by one method or described in a simple way (MAGNUCKI 1998). There are many approaches to this problem and the choice of a given method depends on the complexity of a task, the nature of a feasible set and the accuracy required to determine the optimum.

The paper presents a method for optimizing the construction of a pressure tank, taking into account not only strength conditions but also other aspects affecting the production and operation of such equipment.

Methods for determining the thickness of components of pressure vessels

As already mentioned, the main components of pressure vessels are thin-walled shells. Generally speaking, a shell is defined as a body limited by two surfaces placed close to each other and an edge (MAGNUCKI 1998). Thickness h of a shell is the distance between these surfaces, and the geometric loci of the points equally distant from these surfaces are referred to as the central surface of a shell. The value that allows to differentiate between thin and thick shells is the boundary value $20 \cdot h \cong R_{\min}$, where $R_{\min}$ is the minimal radius of the central surface curvature. The shells for which the value of the product $20 \cdot h$ is less than $R_{\min}$ are considered thin, whereas those for which this value is greater than $R_{\min}$ are considered thick.

The thickness of thin shells can be determined based on various theories, including the momentless theory of rotation shells, the theory of boundary disturbances of rotation shells and the general linear theory of thin shells. These theories were formulated and developed by Gauss (1777–1855), Lame (1795–1870), Codazzi (1824–1873) and Weingarten (1836–1910). All of these theories are described in detail in literature on the subject (GALIMOV 1975, OLSZAK 1980, MAZURKIEWICZ, NAGÓRSKI 1986, MAGNUCKI, SZYC 1987, MAGNACKI 1998).

The problems of solid body mechanics may be also solved using numerical methods. The finite element method is the most popular among them. It is also applied to solve problems related to thin-walled constructions and shells. The finite element method is associated with approximate solutions of differential equations (ŁODYGOWSKI, KĄKOL 2003). It requires the selection of approximating functions which must take into account boundary conditions and the specific properties of materials, as well as to describe the geometry of the area under analysis. The mathematical basis and a description of the finite element method can be found in many papers (ZIENKIEWICZ 1980, ŁODYGOWSKI, KĄKOL 2003, RAKOWSKI, KACPRZYK 2005). Due to the popularization and development of information technology, the finite element method have become a practical and widely applied tool, used also for construction design.

As already said, the essential safety requirements to be satisfied by pressure equipment available on the EU market are specified in the Pressure Equipment Directive (PED) 97/23/WE. The Directive lays down general guidelines for the design and production of pressure equipment and assemblies. Detailed guidelines are established by regulations, provisions and standards in force in the Member States, which comply with the above Directive. An example of such norms are EN-13445, AD 2000–Merkblätt or WUDT/UC 2003. According to PED, pressure equipment can be designed using two different methods, i.e. a computational method or an experimental method (for specified service conditions). The computational method may involve design based on formulas related to the theories mentioned above, or design based on analysis performed using numerical methods. In the present paper the thickness of walls of pressure vessels was determined using one of numerical methods – the finite element method.

Optimization of the construction of a pressure tank

Various types of pressure equipment are manufactured today. They may have one or many blankets, but the key role in such constructions is always played by pressure spaces. The fittings to pressure vessels (e.g. connecting pieces, inspection openings, hatches, valves) are designed for specified service conditions. In this way series of types of the most common components, to be used within specified pressure and temperature ranges, are developed. The main task to be carried out by a designer is to design the pressure space of a pressure tank, equipped with appropriate sub-assemblies.

Characteristics of a pressure tank

The present paper deals with the optimization of the pressure space of a vertical tank, composed of the most common structural components, i.e. a cylindrical unit and two press-formed heads. The working capacity of the tank was 8 m^3 and the internal overpressure was equal to 6 bar at a temperature of 100°C. The tank was designed for fluid density of 1000 kg m^{-3}. These parameters correspond to those of pressure tanks manufactured at one of the production plants in Olsztyn. Table 1 presents the technical data for the pressure vessel analyzed in the study.

Table 1

Technical data of pressure tank

Parameter	Value	Unit
Working capacity	8	m^3
Degree of filling tank	90	%
Max. allowable pressure PS	6	bar
Max. allowable temperature TS	100	°C
Density of working medium	1 000	kg m^{-3}
Coefficient of welds	1	–
Material	1.4404	–

Construction material. The construction material used in the study was stainless, austenitic chromium-nickel steel 1.4404 (Polish Standard PN-EN 10088-1:1995). This material is commonly applied for constructing equipments for the chemical and food industry. Steel 1.4404 is weldable and has very good plastic properties. The properties of steel were adopted based on the Standard EN 10028-7:2000. Permissible stresses for the above material were determined in accordance with Annex I to the Directive 97/23/WE: "Essential Safety Requirements". In the case of austenitic steel for which ultimate elongation (at rupture) exceeds 35%, as well as in the case of the domination of steady load and temperatures beyond the range of considerable creep, reduced stress cannot exceed the value calculated from the following relationship:

$$\min\left[\frac{R_{1,0/t}}{1,2};\frac{R_m}{3}\right] \tag{4.1}$$

For steel 1.4404 used at the highest admissible temperature TS = 100°C, permissible stresses cannot exceed 143.3 MPa.

Heads of the tank. The results of supplementary studies (ŻYWICA 2005) showed that the capacity to weight ratio is much more desirable for ellipsoidal heads than for basketwork ones. Therefore it was assumed that the optimized pressure space will be limited by ellipsoidal heads at the bottom and at the top, according to the Standard DIN 28013. During the technological processes of pressing and spinning, the thickness of such heads decreases by about 10%, as compared with the thickness of semi-finished steel. That is why both technological allowance and metallurgic deviation were taken into account in the calculations (cf. PN-EN 10029:1999).

Cylindrical unit. During plastic forming the thickness of the cylindrical unit decreases by about 5%. The thickness of the blanket is also affected by metallurgic deviation, which for steel sheets is specified in the Polish Standard PN-EN 10029:1999. Te minimal thickness of the blanket was adopted for calculations, taking into consideration both these factors.

The foundation of the tank. It was assumed that the tank has three tubular legs. Such a shape has numerous advantages, including easy availability of semi-finished steel, easiness of finishing and after-machining, the smallest possible external surface exposed to external effects, and good buckling properties. The presence of three legs eliminates the occurrence of unloaded legs, which increases the stability of the tank and makes it possible to use the so called weight-leg. The tube is connected to the pressure space with a washer 10 mm thick, which enables to reduce localized stresses in the bottom head, resulting from support. While selecting the cross-section of a support we should take into account not only the loads resulting from tank weight and content, but also the possibility of occurrence of extra forces. These can be loads caused by wind blast, service platforms, etc. It was assumed that the legs of the tank were made of tubular steel profile, 219.1 mm in diameter and 3 mm in thickness. Additional studies were performed in order to correctly place the legs on the head of the tank (ŻYWICA 2005). The stresses generated in the supported head served as a criterion for choosing the optimum place for support location. It was assumed that the optimum distance (measured from the central axis of the head) between the legs is half of the outer radius of the head.

Computational model

The computational model of a pressure tank was generated using one of the popular CAD systems, equipped with the CAE module. Several such applications are available on the market today. Autodesk Inventor Professional and SolidWorks/CosmosWorks are most popular in small and medium-sized enterprises. The advantage of such programs is the possibility to perform a quick analysis of a part under design without the need to examine the details of the theory of the finite element method, which is extremely time-consuming. On the other hand, their disadvantage is that they have certain limitations when compared to the professional packages of the finite element method.

For the purpose of this study we created a parametric model of a pressure vessel. The model was developed in the assembly context, which means that its parts have external references and require time-related operations. While creating parts in the assembly context, the geometry of one component may be used to define another component. Models are then fully matched and any changes introduced into the reference component are followed by the update of dependent components. Various configurations of components were applied to rebuild the model.

Due to the fact that the tank had three supports composed of three identical segments, the computational model was simplified and only one third of this part of the tank was analyzed, under appropriate symmetry conditions. The use of symmetry for model building contributes to lower costs and higher accuracy of calculations (ZAGRAJEK et al. 2005). The transformation into the simplified model of a pressure tank is illustrated in Figure 1.

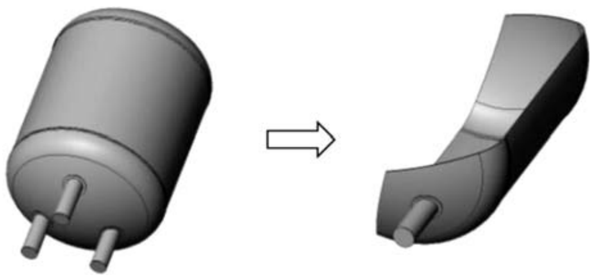

Fig. 1. Simplification of the computational model

The number of finite elements in the MES model was increased until it was found that its further increase did not considerably improve the results anymore. This operation was aimed at minimizing the risk of the discretization error (RAKOWSKI 1996), and enabled to obtain a network composed of elements whose number ensured conformity of results and numerical efficiency. In consequence, the model made up of about 80 000 elements was adopted for further analysis. The application discussed permits the division of a given geometric shape into tetrahedral elements only, so such elements were used in the study. Figure 2 presents ten-node tetrahedral elements of the Solid187 type. Each node of the Solid187 element has three translational

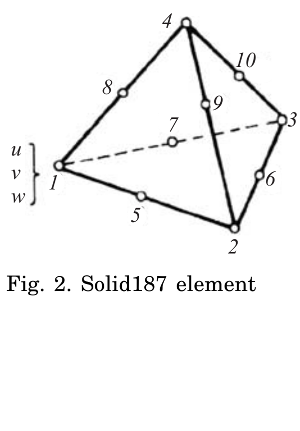

Fig. 2. Solid187 element

degrees of freedom. The displacement area between nodes is approximated with a quadratic function of shape.

The main advantage of the above elements is the possibility to discretize any three-dimensional geometry. That is why they are universally applied in programs based on the finite element method, designed for automatic structure division (RAKOWSKI, KACPRZYK 2005).

Boundary conditions. The following boundary conditions were applied: in the nodes of lower planes of the supports displacements were blocked in all directions, whereas in the nodes of division planes displacements were blocked in the directions perpendicular to the division planes (Figure 3).

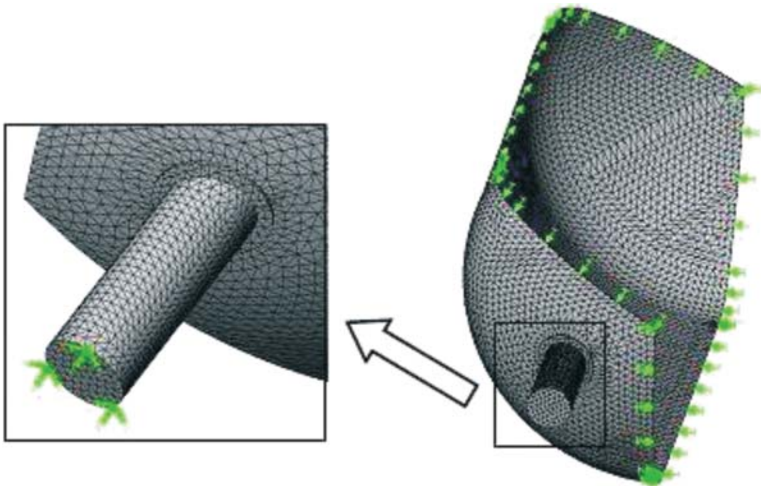

Fig. 3. Boundary conditions

The model of a pressure vessel was exposed to internal surface load whose value was determined as the sum of THE highest permissible pressure and the maximal hydrostatic pressure that could affect a given part of the pressure space. It follows that the value of the pressure applied was different for the bottom head, top head and blanket of the tank. The gravity force was also taken into account in the calculations.

Mathematical optimization model

Parameters. The following parameters (variables with specified values) describing the model were adopted:
– the highest permissible pressure – PS = 6 BAR,
– the highest permissible temperature – TS = 100°C,
– total capacity of the tank – V_c = 8.9 m^3,
– permissible stresses for steel 1.4404 f = 143.3 MPa,

– shape of ellipsoidal heads according to the Standard DIN 28013 $R = 0.8D_z$ and $r = 0.154D_z$,
– distance form the top of the bottom head to the ground 0.5 m,
– three legs made of tube Ø219.1x3.

The other parameters were: design of the tank, values of the material properties of steel 1.4404, load and fastening of the pressure tank.

Decision variables. The following decision variables were adopted:
– outer diameter of the heads D_z ,
– height of the cylindrical part of the tank H_C,
– thickness of particular components of the pressure space g_{DD}, g_P, g_{DG}.

The vector of the above decision variables has the form:

$$x = (D_Z, H_C, g_{DD}, g_P, g_{DG}) \in R^5$$

All decision variables may only take discrete values.

Feasible set. The feasible set includes all solutions fulfilling the conditions below:
– strength condition $\sigma_{HM} \leq f$,
– geometric condition $1400 \leq D_z \leq 2800$,
– volume condition $V \geq V_c$.

According to the Huber-Mises hypothesis, reduced stresses σ_{HM} depend on thickness g_{DD}, g_P, g_{DG}. Their values can be determined by the finite element method. The geometric condition ($1400 \leq D_z \leq 2800$) limits the mean values of the heads, and in this way also the tank diameter. The minimum value (1400 mm) is assumed to limit the height of the blanket, provide the possibility of mounting various fittings and accessories on the heads and ensure the stability of the entire construction. The maximum value (2800 mm) permits rail or road transportation of the ready-made pressure vessel (ZIÓŁKO 1995). The volume condition specifies the minimal height of the blanket, which cannot be less than V_C, including the heads.

The feasible set can take the form:

$$\phi = \phi(x) = \phi(D_Z, H_C, g_{DD}, g_P, g_{DG}) \subset R^5 \tag{4.3}$$

Optimization criteria. In order to choose the best solution from the set of feasible solutions, the following optimization criteria were established:

a) Weight criterion:

Lightweight constructions contribute to reducing the production costs, which is of primary importance in the case of expensive materials, such as stainless steel. Lightweight machines are easier to manufacture, assemble and transport. That is why the mass of the pressure space of a tank was taken into consideration.

b) Producibility criterion:

Producibility consists in adjusting the construction to the technical requirements (OSIŃSKI, WRÓBEL 1995). A machine should be easy to manufacture, and the production costs should be low (DIETRICH 1999). The production capacity of a given production plant is also very important, especially in the case of series production, where certain facilitations applied in many devices bring good economic results. The most labor-consuming part of the production of pressure vessels is connecting components of their working spaces. The length of welds and the thickness of steel sheets is of great significance during the production of pressure equipment. Lower thickness of steel sheets facilitates their plastic forming. Lower length of welds increases their safety and reliability. In order to obtain the numerical value of the objective function, during the optimization process the producibility criterion was expressed as the cross-section of the minimal number of welds necessary to join components of the pressure space.

c) Operating comfort criterion:

If a machine is to perform functions for which it was designed, it must be easy to operate. This concerns everyday operation, maintenance and repairs. Therefore, the machine must be adjusted to the needs and possibilities of the man operating it. Because in tanks used for technological purposes many fittings and accessories are placed on the top head (e.g. stirrers, inspection opening, safety valves, hatches, etc.), their height should be as low as possible. Taking this into account as well as considering the fact that this criterion is difficult to describe using numbers, it was assumed that the height of the pressure space of a tank is a measure of maintainability.

The above criteria are not the only ones, but were found to be the most important in our study. The objective function (F_c) can take the following form:

$$F_c(x) = (f_1(x) + f_2(x) + f_3(x)) \tag{4.4}$$

where stand for the criteria of weight, producibility and operating comfort respectively.

Methods

The aim of the first stage of the study was to find the height of the cylindrical unit of the tank, belonging to the set of feasible solutions. This height was determined using the spreadsheet Microsoft Excel and the mathematical dependences included in the Standard DIN 28013 concerning ellipsoidal heads. The height of the cylindrical unit was dependent on the thickness and diameter of heads, whose values were selected based on the Standard DIN 28013. The values of the diameters had to remain in the range specified by the geometric condition $1400 \leqslant D_z \leqslant 2800$. The total capacity of the pressure space had to fulfill the volume condition. Figure 4 shows a comparison of three variants of a tank of identical capacity.

The aim of the next, main stage of the study was to find the minimal thickness of components of the pressure space. The strength analysis was

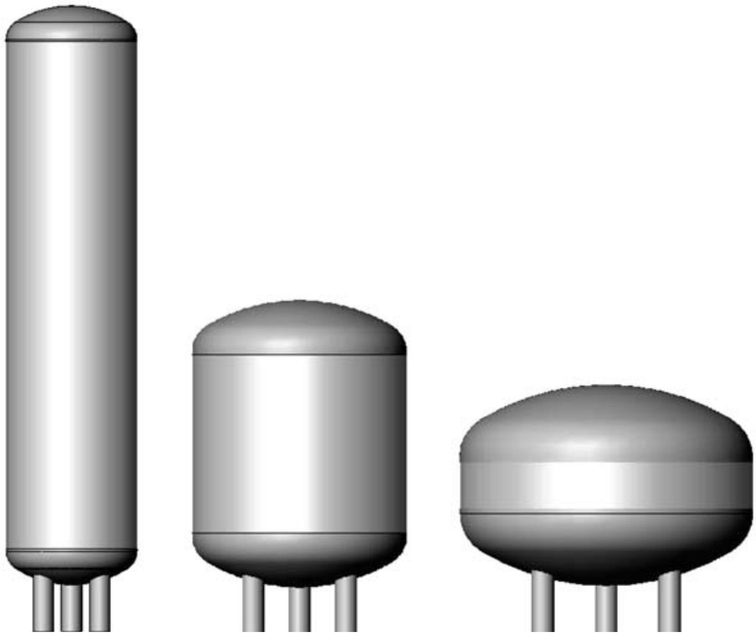

Fig. 4. Comparison of different variants of a pressure tank

carried out using the finite element method. Subsequent variants of the tank were generated in the CAD system, using a table of configurations. This enabled prompt restructuring of the computational model. For each variant the wall thickness was selected so as to meet the strength condition $\sigma_{HM} \leqslant f$. Then the minimal section of welds was calculated, and the mass and height of the pressure space were checked.

The last stage of optimization included the estimation of the values of the objective function for all variants belonging to the set of feasible solutions. Knowing the value of the objective function it was possible to choose the best engineering solution.

Results

This part of the paper presents the results of calculations. Table 2 shows the heights of cylindrical units of tanks as dependent on the diameter of their heads. All these variants represent the set of feasible solutions.

Figure 5 illustrates the reduced stresses obtained as a result of computations by the finite element method. Since the strength condition is fulfilled, i.e. the maximal reduced stresses do not exceed the permissible values, the variant present below belongs to the set of feasible solutions. The thickness

Table 2

Value of diameter and height cylindrical part of pressure tank

External diameter of tanks (mm)	Height of cylindrical part (mm)	External diameter of tanks (mm)	Height of cylindrical part (mm)
1400	5410	2200	1600
1500	4610	2300	1360
1600	3960	2400	1140
1700	3400	2500	950
1800	2930	2600	780
1900	2530	2700	620
2000	2170	2800	460
2100	1870		

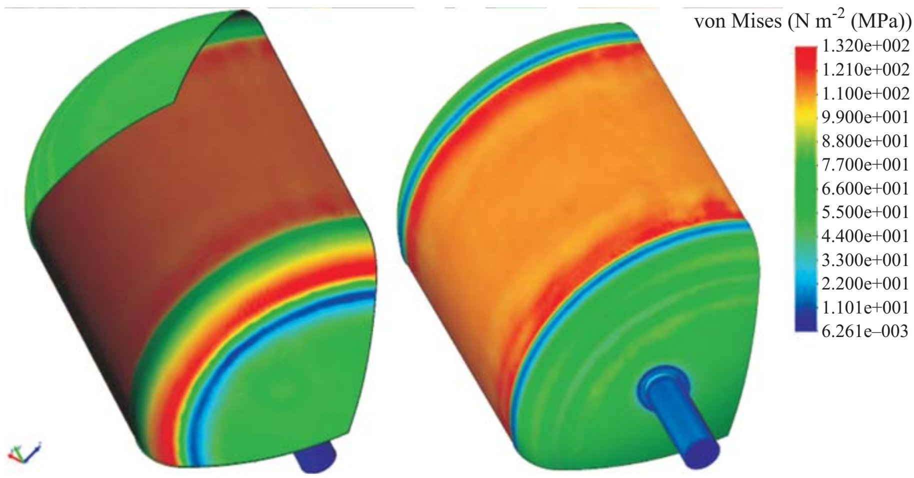

Fig. 5. Reduced stress on the internal and external surfaces of a pressure tank

of walls of the other tanks with known diameters was determined in a similar way (Table 2).

Table 3 summarizes the nominal thicknesses of components of the pressure space of tanks, belonging to the set of feasible solutions.

Table 3

Nominal thickness of pressure space elements

External diameter of tanks (mm)	Nominal thickness of lower bottoms (mm)	Nominal thickness of upper bottoms (mm)	Nominal thickness of cylindrical parts (mm)
1400	8	8	4
1500	8	8	5
1600	10	10	5
1700	10	10	5
1800	10	10	5
1900	10	10	6
2000	12	12	6
2100	12	12	6
2200	12	12	6
2300	12	12	6
2400	14	14	6
2500	14	14	8
2600	14	14	8
2700	14	14	8
2800	16	16	8

Selection of the optimum construction

Table 4 contains the values of particular criteria. Since we deal with the problem of multi-criteria optimization, it is necessary to apply one of the polyoptimization methods. The method of multipliers, also referred to as the method of scalarizing function or the method of pseudopolyoptimization, was employed. The significance of particular criteria was determined using weight coefficients – their values are given in Table 5.

All criteria were standardized so as to make them remain in the range [0,1]. Table 6 presents the standardized values of particular criteria.

The objective function, taking into account all optimization criteria, has the form:

$$F_c = \sum_{i=1}^{3} \rho_i q_i^* \tag{4.5}$$

and considering the values of weight coefficients:

$$F_c = 0{,}3 \cdot q_1^* + 0{,}3 \cdot q_2^* + 0{,}4 \cdot q_3^* \tag{4.6}$$

According to each of the criteria, various models of a pressure tank are the optimum constructions. According to the weight, producibility and operating comfort criteria, the best models are those of a diameter of 1500 mm, 1400 mm and 2800 mm respectively. Table 7 and Figure 6 present the values

Table 4

Data value for particular criterion of optimization

External diameter of tanks (mm)	Weight of pressure space (kg)	Cross-section of welds (mm^2)	Height of pressure space (mm)
1400	1060.8	91610	6178
1500	1024.2	116795	5428
1600	1081.2	94727	4841
1700	1071.0	103799	4332
1800	1068.9	111072	3912
1900	1189.8	137577	3563
2000	1322.4	147879	3276
2100	1343.1	115220	3026
2200	1368.0	119950	2807
2300	1398.6	124620	2618
2400	1621.5	134744	2460
2500	1791.0	172880	2321
2600	1839.3	178787	2202
2700	1890.3	184661	2093
2800	2193.6	197363	2005

Table 5

Value of scale coefficient for particular criterion of optimization

Mass criterion	Producibility criterion	Simplicity of exploitation criterion
0.3	0.3	0.4

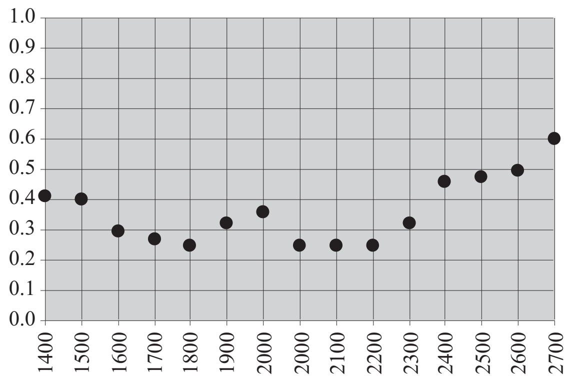

Fig. 6. Values of the objective function (axis of abscissae – tank diameter, axis of ordinates – values of the objective function)

Table 6

Normalized data value for particular criterion of optimization

External diameter of tanks (mm)	Weight of pressure space	Cross-section of welds	Height of pressure space
1400	0.031	**0.000**	1.000
1500	**0.000**	0.238	0.820
1600	0.049	0.029	0.680
1700	0.040	0.115	0.558
1800	0.038	0.184	0.457
1900	0.142	0.435	0.373
2000	0.255	0.532	0.305
2100	0.273	0.223	0.245
2200	0.294	0.268	0.192
2300	0.320	0.312	0.147
2400	0.511	0.408	0.109
2500	0.656	0.768	0.076
2600	0.697	0.824	0.047
2700	0.741	0.880	0.021
2800	1.000	1.000	**0.000**

Table 7

Value and sequence of aims function

External diameter of tanks	Values of aims function $-F_c$	Sequence values of aims function
1400	0.409	11
1500	0.400	10
1600	0.295	6
1700	0.270	5
1800	0.249	4
1900	0.322	8
2000	0.358	9
2100	0.247	2
2200	**0.245**	1
2300	0.248	3
2400	0.319	7
2500	0.458	12
2600	0.475	13
2700	0.495	14
2800	0.600	15

and courses of the objective function for a substitute criterion. Since our task was to minimize the objective function, the best design solution is a tank of a diameter 2200 mm (Figure 7). However, there are also some other solutions belonging to the feasible set, for which the values of the objective function are only slightly higher. These are tanks with a diameter of 1800, 2100 and 2300 mm. Taking into account the adopted criteria, the least desirable model is that of a tank whose diameter is equal to 2800 mm. This tank guarantees operating comfort, but is the heaviest and least producible.

Fig. 7. Optimum construction of a pressure tank at a capacity of 8 m^3

Summary and conclusions

In the age of the uniform market it is not enough for a product to simply perform the functions it was designed for. It should be also characterized by a broadly understood quality. The quality of machines and technical equipments is shaped already at the design stage, which has a profound impact on their final form. Numerous factors must be taken into account during the design process, the most important being safety, reliability, producibility and low weight as well as ergonomics, ecology and economics. All of these factors affect the competitiveness of the ready-made product, and their significance is decided about during the optimization process. The design of modern and competitive constructions requires the use of appropriate computer techniques, enabling to conduct detailed analysis.

The paper presents a method for optimizing the construction of a vertical pressure tank, for specified parameters, according to the adopted optimization criteria. The optimization process was carried out using CAD/CAE systems, which allowed to do calculations for many variants of a tank within a relatively short period of time. The optimum construction, i.e. a tank 2200 mm in diameter, was selected based on strength and geometric analysis. This construction, chosen from among other feasible and technologically justified solutions, is characterized by low weight, high producibility and high operating comfort. It should be also noted that if the method of multipliers is applied during the optimization process, the choice of the best construction is strongly affected by the values of weight coefficients. Even a slight change in their values may make the designer choose a given solution.

It should be also stressed that our aim was to present an example of an algorithm of multi-criteria optimization of the construction under analysis, using the applications available to small and medium-sized enterprises. The method used for strength analysis as well as the theoretical model proposed in the study may be modified depending on software and the required accuracy of computations. Other optimization criteria may be also adopted, if they are considered of greater significance under certain conditions.

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