THE PRODUCTION COST OF CYLINDRICAL TANK SHELL DEPENDING ON THE SORT OF STEEL AND METAL PLATE DIMENSIONS

Dariusz Kowalski

Department of Metal Constructions, Technical University of Gdańsk
ul. Narutowicza 11/12, 80-952 Gdańsk, Rzeczpospolita Polska

ABSTRACT

The results of an economic analysis, comprising approximately 350 types of shells made for tanks of nominal capacity ranging from 50 - , 80-, 100.000 m^3 in view of the sort of constructional steel and overall dimensions of metal sheets used, are given. The analysis was carried out with respect to a wide variety of steel types from carbon steel St3S to low-alloy steel 18G2AV taking advantage of variable overall dimensions of width from 1.50 to 3.00 m and length of 6.0 - 12.0 m.

1. INTRODUCTION.

The progress that is taking place in automotive industry, petro-chemistry, and in the field of chemistry causes a continuous demand for products obtained from ore. The raw material it self in form of crude oil is imported by numerous countries from producers exploiting ore fields at some adopted production quantitative rates. The crude oil is transported to petro - chemical processing plants by long-distance pipelines or by oil tankers. For the purpose of ensuring some indispensable reserves of this strategic material needed in many fields of the national economy, every country undertakes some steps aimed at constructing its own resource storage bases. They are intended to secure not only the current production requirements, but also to protect the economy from temporary fluctuations in the oil cost and the suppliers.
Construction of new fuel bases and development of the old ones should not only be configured to provide on appropriate storage capacity but to take into consideration the rising stringent requirements related to the protection of the natural environment put into effect by many countries. To satisfy the rising requirements some action is undertaken to construct steel tanks with double bottom, surrounded by shielding walls. Apart from taking account of the above tendencies in tank construction, it is necessary to pay greater attention to the right choice of the construction materials, their type and dimensions.

2. ECONOMIC ASSUMPTIONS.

The estimated total cost of tank construction includes the following:

- the constructional material used in form of steel sheets,
- transport of the above material to the building site,

- the labour cost of the tank construction at the building site.

Taking a closer look at the respective constructional elements of the tank it is possible to come to a conclusion that in the case of a proper execution of work, the construction cost of the tank bottom and the floating roof is relatively invariable, and the construction itself does not make allowance for significant changes in its cost. This is due to the fact that the elements for the construction are made of steel of the lowest strength quality. The values of forces that appear in the elements make it possible to state that in the steel used for their constructional material advantage has not fully been taken of its strength capability. The most extensive application of the steel assortment selection and dimensions of steel shuts is possible to be carried out in the tank shell - the most significant part of the structure. The variations may result from different choice of the steel assortment for the respective sections of the tank, as well as the overall dimension itself of particular steel sheets.
Bearing the above in mind, a number of cases of tank shells with three exemplary nominal capacities, 50 000, 80 000, and 100 000 m^3, have been analysed. The analysis was carried out on the basis of the following assumptions:

- the static-strength calculations were made according to the Polish standard - PrPN-03210 - Concerning Cylindrical Vertical Tanks for Fuels,
- the fuel storage tank was designed for crude oil of 8.5 kN/m3 according to Polish standard PN-82/B-02003,
- corrosion allowance of 2 mm, assuming a 50 - year - long use of the tank and a mean corrosion loss of the material amounting to 0 - 0,4 mm per year,
- the tank was provided with a floating roof,
- the assembly was based on steel sheets technique.

While making the choice of the type of the oil storage, two major factors should be taken into consideration:
a) storage economics - strive for minimalization of losses during storage of products under specified operational conditions,
b) economics in building the tank, attempts should be made to build at low investment cost.

The first factor is related to the type of liquid and the storage capacity required depending on the technological destination of the tank. The construction economics of the tank depends on the engineers responsible for the designing and execution of such engineering structures.

3. TECHNOLOGICAL LIMITATIONS.

Under current economical conditions particular attention should be concentrated on the capabilities of constructing such engineering objects making maximum use of the metallurgical industry potential, the means of transport, and the assembly team.

The metallurgical industry - according to [2], [3], [4]dialling with the dimensioning programme.
The Polish steel works offer the production of steel sheet of 4000 - 12000 mm in length, width 1500 to 3000, and for some sorts of steel also larger sheets - up to 3150 mm. The various qualitative assortment of steel makes it possible for an appropriate choice of the material for the tank shell.

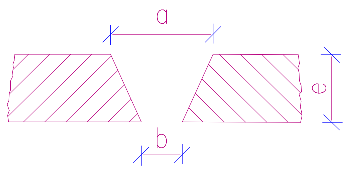
Means of transport.
Depending on the distance and location of the prospective site of the tank, one can use two kinds of transport:
- vehicular road transport limited by the road width to 2500 mm,
- railway transport restricted by width limit of railway gauge up to 3150 mm and length of elements up to 18000 mm without diminishing the railway limitation gauge given before.

However, in the case of a more extensive construction site it is necessary to take into consideration the handling of steel elements from the railway transport to road transportation to deliver the constructional materials directly to the building site. The limitation that occurs in road transport connected with the width constraint of the road can be obviated using piloted transport of the constructional elements which exceed flu accepted dimensions. Such a piloted transportation system is also applied to transport spatial constructional elements, or industrial machines.

Assembly unit.
The assembly unit should be provided with adequate welding and lifting equipment and have experience in performing this type of job.
When making a survey of the workman-ship of tanks constructed during the recent 30 years, it is possible to note a continuous advancement in the field of setting up this sort objects. The traditional hand - made welding has been replaced by welds carried out by highly professional automatic welding machines appropriate for this type of work. At present such automatic welding equipment is produced, among others, by the ESAB firm. Modern welding machines can be applied to work in tanks with a minimum curvature radius of 4000 mm. Using these machines it is possible to join elements whose height ranges from 1000 to 3000 mm. Table 1 present exemplary welding speeds depending on the steel plates used for tank construction.

TABLE 1. Typical technical parameters of an automatic welding machine compared with manual welding data.

Characteristic of the weld			Automatic welding speed	Manual welding speed	Use of filler metal
e	a	b			
mm	*mm*	*mm*	*m/h*	*m/h*	*kg/m*
10	15-20	6-8	10.0	0.78	1.35
15	15-20	6-8	5.9	0.47	2.45
20	18-22	6-8	4.9	0.34	3.05
25	20-22	6-8	4.4	0.30	3.50
30	21-23	6-8	3.6	0.22	4.40
35	22-24	6-8	3.2	0.17	4.90
40	22-24	6-8	2.6	0.15	5.85



4. ANALYSIS OF THE PROBLEM.

On the basis of same constraints caused by the capabilities of the construction, transportation, and metallurgical companies an attempt has been made to prepare a minimalization project regarding the tank construction cost. As it has already been mentioned before, attention should be concentrated on the selection of the component elements to be used for the construction of he tank shell. In course of elaborating the problem the following characteristics have been taken into consideration in the analysis of the tank shell variants:

- height of respective shell sections,
- length of individual steel sheets,
- type of constructional steel,
- weight of particular type of constructional steel,
- cost of material (steel sheets),
- length of weldments,
- volume of weldments,
- cost of carrying out the weldments.

TABLE 2. Comparison of the types of steel.

Type of steel	Strength of steel [MPa]		Comparable strength	Savings in material	Mean cost of 8-40 mm thick steel	Comparable cost	Rise in cost
	t ≤ 16	t > 16	-	%	z³/Mg	-	%
St3VC	215	205	1.00	0	1.090	1.000	0
18G2A	305	295	1.42	29.58	1.164	1.068	6.36
15G2ANb	325	315	1.51	33.77	1.181	1.083	7.66
18G2AV	370	360	1.72	41.86	1.613	1.480	32.43

TABLE 3. Characteristic result of the calculations.

No.	Item of comparison		Nominal capacity of tanks [m^3]		
			50.000	**80.000**	**100.000**
1	Diameter	m	63.63	75.82	84.76
2	Height of shell	m	18.00	20.00	20.00
3	Storing height	m	16.90	18.90	18.90
4	Number of elements in rings (sections) [in prices]	~ 6000	34	40	45
		~ 9000	23	27	30
		~ 12000	17	20	23
5	Number of rings depending on height of rings [m]	1.50	12	14	14
		2.00	9	10	10
		2.25	8	9	9
		2.50	8	8	8
		2.75	7	8	8
		3.00	6	7	7
6	Number of component elements [pcs.]	max	408	560	630
		min	102	140	161
7	Thickness of steel sheets in the first ring depending on the type of steel [mm]	St3WD	32	40	45
		18G2A	22	29	32
		15G2ANb	21	27	30
		18G2AV	19	24	26
8	Profit from thickness of material to steel St3WD	18G2A	31%	28%	29%
		15G2ANb	34%	33%	33%
		18G2AV	41%	40%	42%
9	Weight of the structure [kg/m]	max	2708	3729	4106
		min	1727	2445	2645
10	Cost of material [z³/m]	max	2949	4137	4601
		min	2246	3033	3251
11	Maximum volume of welds [dm^3]	~ 6000	505	1012	1581
		~ 9000	465	1067	1461
		~ 12000	443	1022	1405
12	Minimum volume of welds [dm^3]	~ 6000	189	374	493
		~ 9000	171	336	441
		~ 12000	161	316	415
13	Maximum length of welds [m]	~ 6000	3011	4135	4628
		~ 9000	2813	3875	4328
		~ 12000	2705	3735	4188
14	Minimum length of welds [m]	~ 6000	1811	2467	2764
		~ 9000	1613	2207	2464
		~ 12000	1505	2067	2324

Examples results of the above analysis are presented of diagrams.

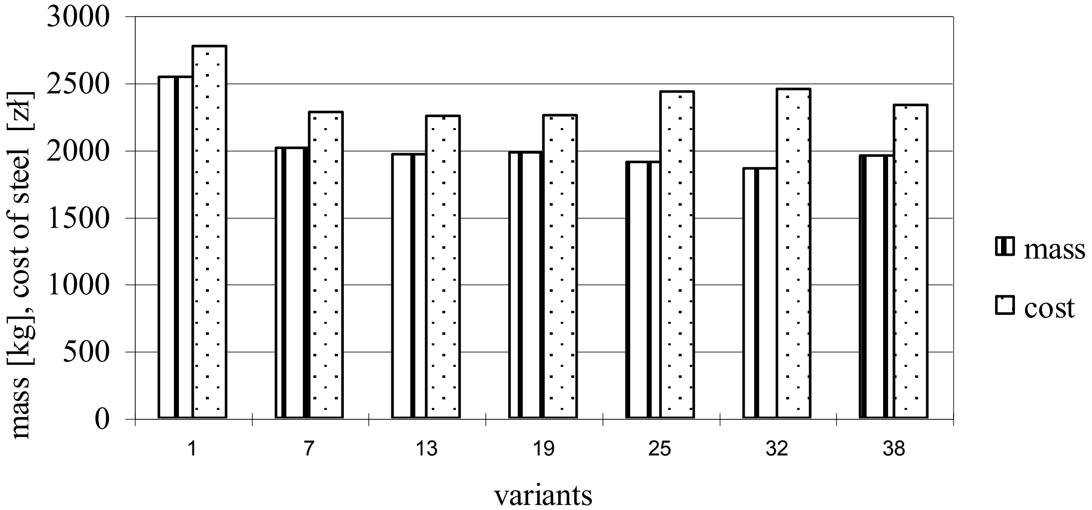


Fig. 1. Comparison of mass and cost of steel for tank V=50.000 m^3 made of rings of height 1.50 m

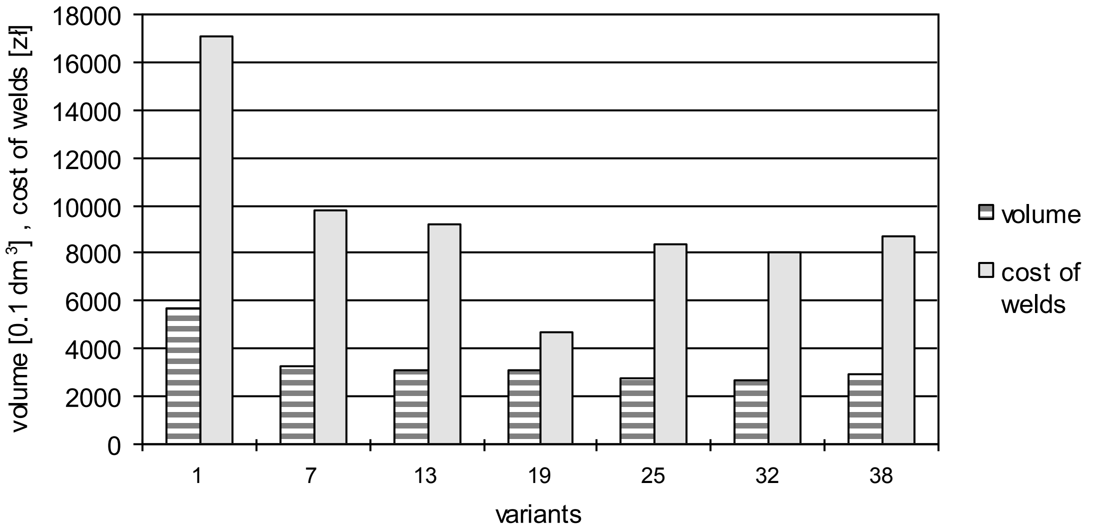


Fig. 2. Comparison of volume and cost of welds with constant length - 3011 m.

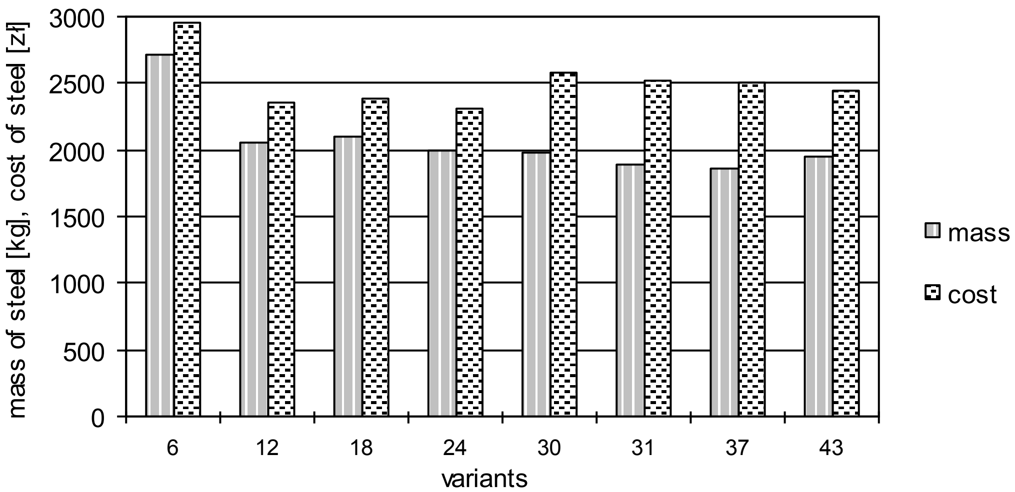


Fig. 3. Comparison of mass and cost of steel for tank V=50.000 m^3 made of rings of height 3.0 m

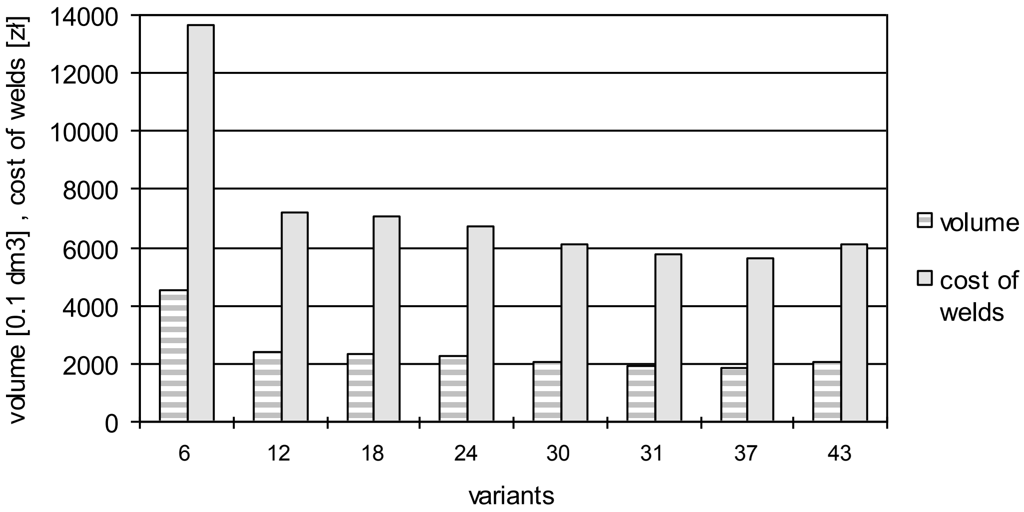


Fig. 4. Comparison of volume and cost of welds with constant length - 1811 m.

In the under cases investigation the sheet dimensions were chosen in the following way:

- heights: 1500, 2000, 2250, 2500, 2750, 3000 mm
- lengths: ~6000, ~9000, ~12000 mm.

The types of constructional steel listed in Table 2 have been used for comparative analysis. The Table includes also a brief comparison of steel strengths and its estimated cost.

As a result of the calculations the following characteristic data been obtained.

5. SUMMARY.

By an engineer's appropriate approach to the execution of the investment task, it is possible to affect significantly the method of carrying out the construction object and its building cost even at the stage of designing the structure.

The exploitation of the metallurgical industry production potential, and the transportation capability constrains the time of completing the building structure.

When deciding about the choice of a particular variant of shell it is necessary to take account of the following,

- lower weight of the constructional steel. This can have an influence on reducing the transport cost of the component elements,

- smaller length and volume of the weldments which can affect significantly the welding time. The reduction in the welding expenses by 50 % causes a substantial lowering of the construction time. The reduced quantity of welds can contribute much to save the time and cost of the defectoscopic welding tests, and to reduce the use of the electrical energy needed for the assembly,

- to use larger segments for the construction of a tank, which results in lowering the total quantity of the construction elements applied and thereby to reduce the handling and transport operations employed.

All the above listed factors are related to a reduction of the investor's labour costs which take the second place in the total cost calculation. Limitation of the assembly work at the building site affects the speed of completing the capital construction. Which is important for the investor, and thereby also a sooner repayment of the capital invested in the structure.

6. REFERENCES.

[1] PrPN-03210 - Steel Structures. Cylindrical vertical tanks for fluids. Design and execution. Polish Normalisation Committee.
[2] PN-80/H-92200 - Thick hot rolled steel sheets. Dimensions. Polish Normalisation Committee.
[3] EN 10029 - Warmgewalztes Stalblech von 3 mm Dicke an, GrenzabmaBe, Formtoleranzen, zulassige Gewichtsabweichungen.
[4] Pricelist for thick rolled metalurgical products of the Częstochowa Steelworks (in Polish).
[5] Technical materials for ESAB automatic welding machines.
[6] Tęczyńska B., 1971, Selection of optimum rolled tank dimensiones in view of the minimum cost., Inżynieria i Budownictwo