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Technical and Economic Analysis of Different Types of Composite Pipes Compared to Conventional Pipes for the Same Purpose

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Abstract

In the framework of this paper, a comparison of six types of composite pipes with conventional metal pipes of prochrome was made, where it was concluded that composite pipes are more resistant to high internal pressures, while being lighter and with a much lower price.

Composite pipes are a good substitute for conventional prochrome metal pipes in terms of quality and cost and can be successfully applied in several industries for transporting fluids, chemical and fuel tanks, and tankers.

Keywords: Composite Pipes; Metal Pipes; Pressures; Price

Introduction

The production of composite pipes is of great importance because it refers to standard types of composite pipes that are in direct competition with older types, such as steel pipes. The industrial importance of the process is great because the resulting composite pipes are a good substitute for corrosive steel and metal pipes for oil, gas and water. In addition, the pipes obtained by this process are durable and durable even at high pressures. Most often, the improvements in the processes for the production of composite materials, which primarily have a technological, technical and economic effect, are seen in the more rational use of raw materials and auxiliary materials, and thus also the waste and harmful substances that, as a result of the process, are either controlled or uncontrolled thrown out or they are disposed of in the environment. If the processes for the production of composites are more compact and the stages of production are related to efficiency in the use of equipment, the time cycle per unit of the product is shorter. From this it can be concluded that in the optimized or improved/advanced processes for the production of composite materials, the cost of the consumed energy per unit of product is lower.

Most of the composite materials that have been developed in recent years have been produced precisely to improve their mechanical characteristics strength, stiffness, toughness, as well as resistance to high temperatures [1,2]. The more accurate popular definition of composites implies only non-metallic materials consisting of fibrous reinforcements, such as glass, carbon or Kevlar, encapsulated in the hardened matrix of one of several hundred polymer systems. These composite materials are characterized by their relatively high strength/weight ratios compared to traditional metal components [3].

Filament Winding Technology

Filament winding technology is a process used to produce composite structures, such as pipes for transporting fluids and gases, tanks for liquid petroleum gas, compressed natural gas, electrical insulators, lamp posts, windmills, and other products [1]. The process of filament winding technique is one of the most commonly used techniques for obtaining polymer composite materials. For the production of composite materials with this procedure, a reinforcing material is used in the form of continuous fibers (mostly glass, carbon, and aramid) which are impregnated with a polymer Thermo-reactive matrix in the form of a liquid resin (polyester, epoxy, etc.) and wound on a rotating mandrel. This technology is performed on specially designed machines, which allow precise control of the winding angles when winding the fibers. The structures can be ordinary cylinders or tubes, with different diameters and lengths. Spherical, conical and other shapes can also be wound [3,4]. This fiber winding technology is schematically represented in (Figure 1). A major limitation of winding technology is the difficulty in producing complex shapes, due to the requirement of a complex mandrel design. Production of parts with concave surfaces is not possible using this technique [6].

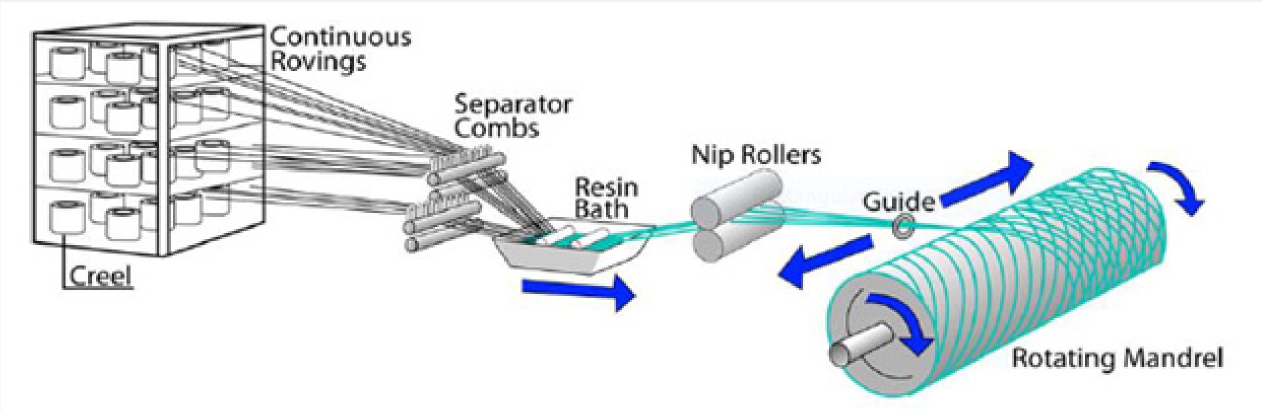

Figure 1: Fiber winding technology [5].

Criteria for the Analysis of Justification to Produce Composite Pipes

The economics of composite pipe production are of great importance. It applies more to standard types of composite pipes that are in direct competition with older types, such as metal and steel pipes. But when it comes to special types of composite pipes such as high-volume pipes intended for transoceanic transportation of natural gas under pressure, the technical-technological category has one of the primary places in this analysis. Of course, the analysis of the economic justification is also mandatory to determine the competitive position of the existing or other alternative methods for the realization of the given project. So basically, the decision to introduce and manufacture composite pipes is never based on only one approach or analysis criterion, but it is a combination of several analysis criteria or strategies. Composite pipes that are resistant to high internal pressure, and are mainly used for transporting liquids, have more advantages compared to metal and steel pipes. Some of the main advantages are the lower weight, the absence of corrosion, a twice as long period of retesting, a higher degree of safety in the presence of fire, etc. All these advantages justify their production, but they are not always sufficient for the wider distribution of this type of composite pipes throughout the markets of the world. This is especially difficult in markets that are sensitive to the price of composite pipes. Due to the price of the material used in the metal and steel pipes, as well as the production method that has been standardized and takes place (in many cases) on old production lines that have long been depreciated, the price of metal and steel pipes is still more competitive than composite ones. But this comes to the fore if only a simple price comparison is made, without considering the advantages of composite pipes as well as the higher operating costs of steel pipes. Therefore, reducing the costs of production through a higher degree of automation, which is certainly followed by high serial production capacities, as well as the consistency of quality and its automated monitoring throughout the entire production flow, by the requirements of the standards, is one of the current directions in which is aimed at this segment of the industry to produce composite materials [6-9].

Composite pipes are lightweight and non-corrosive fiber-reinforced pipes with proven benefits. However, defects that appear during production can affect the performance of composite pipes during operation and can be singled out as disadvantages. Current production techniques need assistance spotting defects, as the pipe is regularly monitored during production. Defects are detected and action is taken, but stopping the process is costly. Potential solutions include process optimization to reduce defects and understanding the effect of parameters that cause defects to form.

The impact of manufacturing on ultimate performance is closely related to material characteristics, properties, and serviceability. For composite pipes, the fusion joining process involves heating and consolidation, with laser heating being a better heat source in terms of efficiency. Defects such as fiber misalignment, voids, and delamination are induced during manufacturing, affecting

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strength, stiffness, interlayer shear strength, toughness, and creep performance. At the same time, it is necessary to characterize the defects during the production of the composite pipes. In-situ characterization aims to produce high-quality composite pipes with reduced defects and an increased production rate in safe and environmentally friendly conditions while maintaining.

Experiment

To make a technical, technological and economic analysis of different types of composite pipes compared to conventional prochrome metal pipes intended for the transport of liquids or tanks, 6 composite pipes all differently designed and obtained from different materials were considered. Namely, the following types of composite pipes were analyzed:

i. Composite pipes based on glass fibers (type: OCV 1200tex) and epoxy resin (type: Araldite LY 564 (1135)).

ii. Composite pipes based on hybrid material: glass fiber (type: OCV 1200tex) + carbon fiber (type Toray T700 800 tex) and epoxy resin (type: Araldite LY 564 (1135)).

iii. Composite pipes based on carbon fiber (type Toray T700 800 tex) and epoxy resin (type: Araldite LY 564 (1135)).

From all three types of composite pipes, two different samples were analyzed - pipes with different winding angles of 10º and 90º i.e.. the maximum and minimum value of the winding angle (as was also taken into account in the planning matrix during the design of the experiments, (Table 1)). The diameter for all the analyzed pipes was the same, i.e., 100 mm, the length 1000 mm, while the thickness was approximately 3 mm. In parallel, data from the literature on conventional prochrome metal pipes were also included in the analysis. (Table 1) gives the markings and basic data for the analyzed samples of composite pipes.

Table 1: Basic data for the analyzed pipes.

Designation of the comp. pipe	Constituent materials	Fiber winding angle, º	Thickness of comp. pipe, mm
1-1	glass fibers epoxy resin	10	3.28
1-2	glass + carbon fiber epoxy resin	10	3.32
1-3	carbon fiber epoxy resin	10	3.37
2-1	glass fibers epoxy resin	90	3.23
2-2	glass + carbon fiber epoxy resin	90	3.13
2-3	carbon fiber epoxy resin	90	3.32

Results

In the framework of this paper, a comparison of various types of composite pipes with metal pipes of prochrome (which are most often used) for the same purpose was made. Their resistance to high internal pressure as well as their cost are compared. In (Table 2) the types of composite pipes are given with the constituents expressed in weight percentages and kilograms, as well as the price of a piece of composite pipe of each type separately. When calculating the cost of the types of composite pipes, the following prices of the materials were taken:

Cost of glass fiber = 1.75 euro/kg

Cost of carbon fiber = 18 euro/kg

Cost of epoxy resin = 5 euro/kg

Table 2: Cost per unit piece – composite pipe.

Composite pipes: ID = 100 mm, L = 1000 mm, d = 3 mm								
Type comp. pipe	Glass fiber, % wt.	Carbon fiber, % wt.	Epoxy resin, % wt.	M Composite pipe, kg	m glass. fiber, kg	m carbon fiber, kg	m epoxy resin kg	Unit price / comp. pipe, euro
1-1	72.8	0	27.2	2,173	1.581944	0	0.591056	5.72
1-2	34,375	34,375	31.25	1,898	0.652438	0.652438	0.593125	15.85
1-3	0	64.7	35.3	1.63	0	1.05461	0.57539	21.86
2-1	72.8	0	27.2	2,145	1.56156	0	0.58344	5.65
2-2	34,375	34,375	31.25	1,797	0.617719	0.617719	0.561563	15.01
2-3	0	64.7	35.3	1,605	0	1.038435	0.566565	21.52

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The following figure 2 graphically presents the unit price of the six types of composite pipes. As can be seen from the diagram, the types of composite pipes 1-3 and 2-3, which have the best mechanical characteristics, i.e., the highest internal pressure, have approximately the same and highest price. However, those composite pipes based on carbon fiber have the lowest weight compared to the rest. But if you compare the composite pipes type 1-1 and 2-1 it can also be noted that the price is about the same, but there is a difference in their resistance to internal pressure. Composite pipe type 2-1 showed twice the internal pressure compared to type 1-1. One of the biggest advantages of composite pipes is that they can reduce the weight, and therefore the cost, and again ensure resistance to high internal pressures.

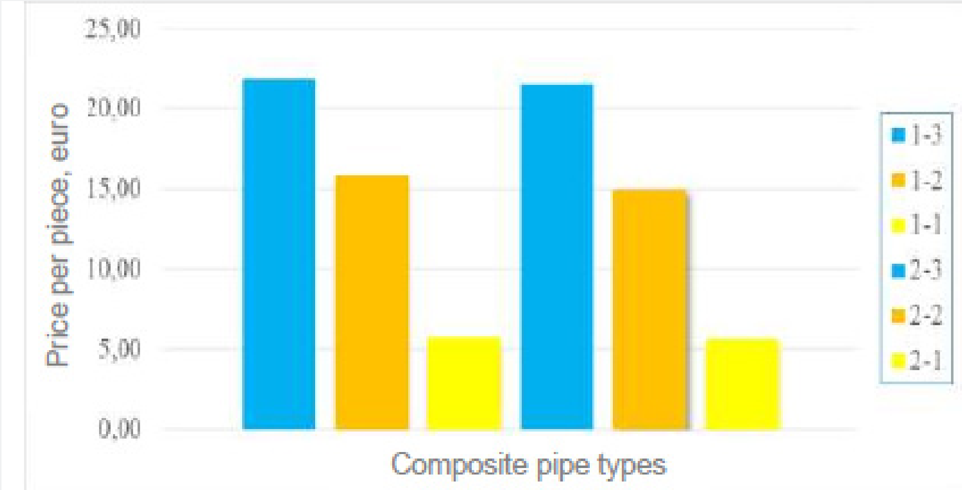

Figure 2: Price of one piece of composite pipe.

(100x1000x3mm) for all types of composite pipes

Table 3 gives the resistance to internal pressure for various types of metal pipes with the same dimensions as the types of composite pipes: length L = 1000 mm and thickness d = 4 mm. The data on the internal pressure resistance of metal pipes are taken from the literature [10]. The considered metal pipes have a mass of 10.719 Kg, while their price per unit piece of metal pipe is 42.87 Euro. When calculating the cost of the different metal pipes made of prochrome, the average price of metal prochrome = 4 euro/kg was taken. Figure 3 shows the internal pressure resistance of various types of metal and composite pipes.

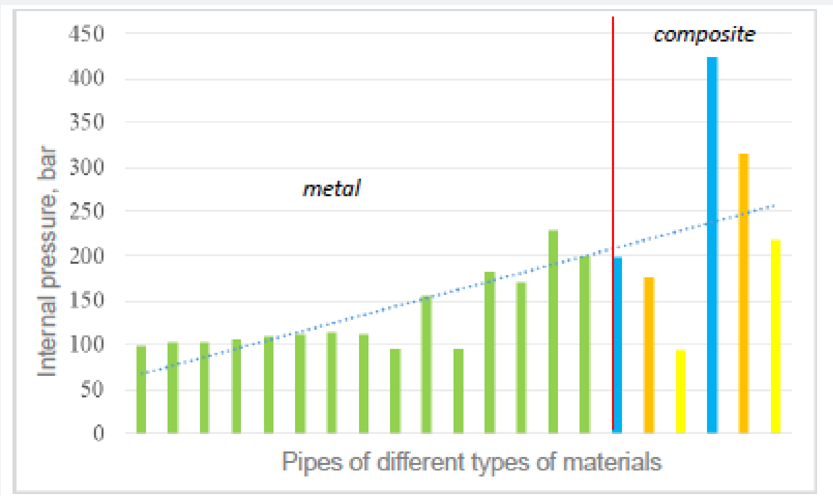

Figure 3: Internal pressure resistance of various types of metal and composite pipes.

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Table 3: Internal pressure of metal pipes.

Type of metal pipes prochromic (stainless steel)	Internal pressure, bar
EN 1.4306	98
EN 1.4435	103
EN 1.4404	103
EN 1.4541	107
EN 1.4550	109
EN 1.4571	112
EN 1.4539	114
EN 1.4563	112
EN 1.4335	96
EN 1.4466	155
EN 1.4547	96
EN 1.4558	183
EN 1.4462	171
EN 1.4410	229
EN 1.4424	200

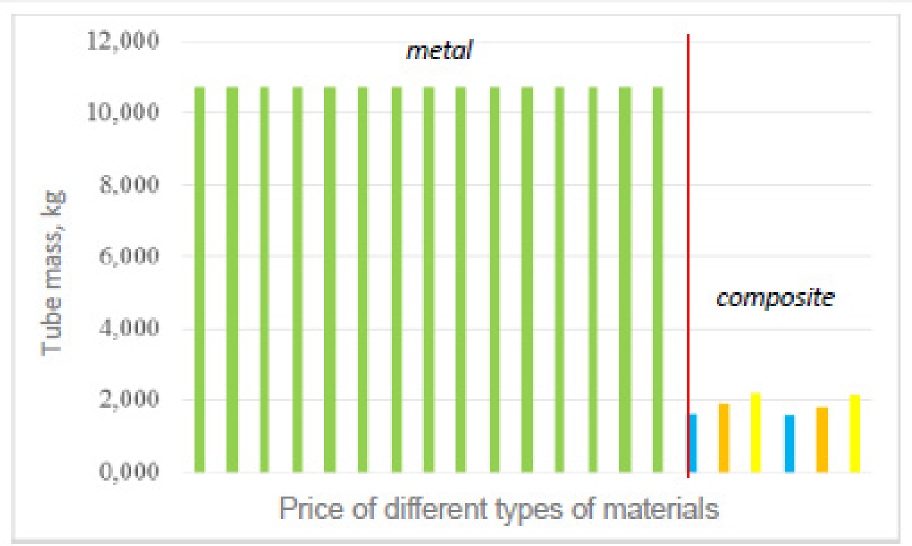

Figure 4: Mass of various types of metal and composite pipes.

It can be noted that the internal pressure resistance of various types of metal pipes is from 100 to 200 bar while composite pipes are resistant to much higher internal pressures up to about 450 bar. The internal pressure resistance of the metal pipes is comparable to that of the composite pipes obtained based on glass fibers with a winding angle of 10º. Composite pipes based on hybrid material, and especially those based on carbon fibers wound at an angle of 90º, have more than twice the internal pressure resistance compared to metal pipes. On the other hand, composite pipes have much less mass compared to the same metal pipes. This comparison can be seen in (Figure 4). This means that a metal pipe that can withstand an internal pressure of about 200 bar has a mass of 10, 719 kg while a composite pipe that can withstand the same pressure has a mass of 2.145 kg. This is a composite tube that has the largest mass and is based on glass fibers. Composite tubes based on hybrid fibers (glass + carbon) as well as tubes based on carbon fibers have an even lower mass of 1,797 Kg and 1,605 Kg respectively and are durable

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at the same internal pressures of about 200 bar. This leads to the conclusion that composite pipes represent a good substitute for conventional metal pipes for transporting fluids. Composite tubes based on hybrid fibers (glass + carbon) as well as tubes based on carbon fibers have an even lower mass of 1,797 Kg and 1,605 Kg respectively and are durable at the same internal pressures of about 200 bar. This leads to the conclusion that composite pipes represent a good substitute for conventional metal pipes for transporting fluids. Composite tubes based on hybrid fibers (glass + carbon) as well as tubes based on carbon fibers have an even lower mass of 1,797 Kg and 1,605 Kg respectively and are durable at the same internal pressures of about 200 bar. This leads to the conclusion that composite pipes represent a good substitute for conventional metal pipes for transporting fluids.

If a price comparison is made, it is also concluded that the use of composite pipes is more profitable compared to conventional metal pipes. The comparative price of various types of metal and composite pipes is given in (Figure 5).

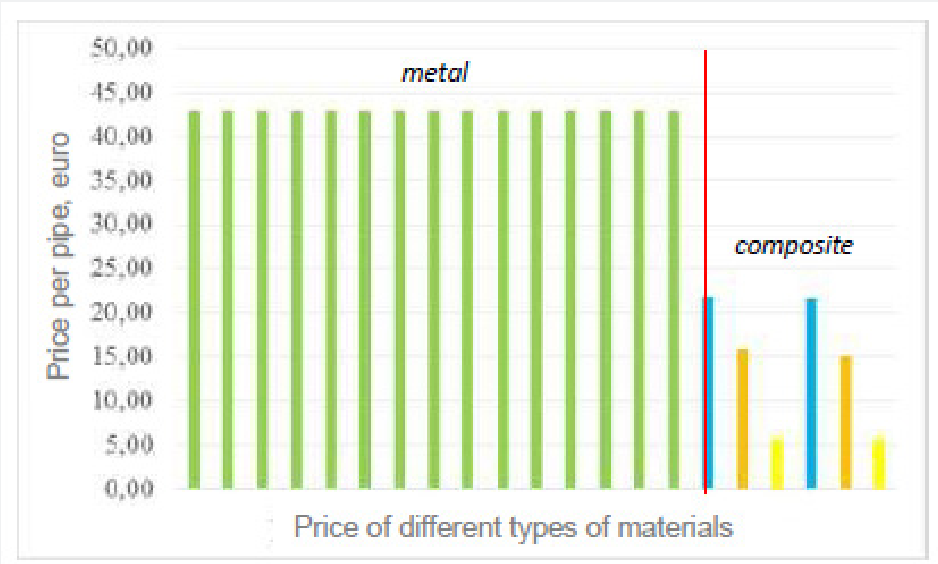

Figure 5: Price of various types of metal and composite pipes.

Conclusion

During the comparison of the composite pipes with the conventional metal pipes made of prochrome, it was concluded that the composite pipes are more resistant to high internal pressures, and at the same time lighter and with a much lower price. Composite pipes obtained by the fiber winding process are a good substitute for corrosive steel and metal pipes for oil, gas and water. In addition, the pipes obtained by this process are durable and resistant to much higher pressures. Composite pipes that are resistant to high internal pressure, and are mainly used for transporting liquids, have more advantages compared to metal and steel pipes. Some of the main advantages are the lower weight, the absence of corrosion, a twice as long period of retesting, a higher degree of safety in the presence of fire, etc. All these advantages justify their production.

References

1. Sobrinhoa LL, Caladob VM, Bastian FL (2011) Development and Characterization of Composite Materials for Production of Composite Risers by Filament Winding. Materials Research 14(3): 287-298.
2. Akkus N, Genc G, Girgin C (2008) Control of the presentation in Filament winding process. Acta mechanica et automatica 2 (3).
3. Cohen D (1997) Influence of filament winding parameters on composite vessel quality and strength. Composites Part A: Applied Science and Manufacturing 28(12): 1035-1037.
4. Daniel Gay, Suong Hoa V, Stephen Tsai W (2003) Composite Materials - Design and Application. CRC Press, USA.
5. https://www.thecompositeshub-india.com/filament-winding--a-cost-effective-composites-process
6. Deborah Chung DL (2010) Composite Materials London: Springer-Verlag London Limited.
7. Miracle DB, Donaldson SL (2001) ASM Handbook – Composites. In: Miracle DB & Donaldson SL(eds.), ASM International, Detroit, Michigan, United States, pp. 1201.
8. Suong Hoa V (2009) Principles of the Manufacturing of Composite Materials.2nd DEstech Publications, North Duke Street, Lancaster, USA.
9. Koussios S (2004) Filament Winding: a Unified Approach. Delft University Press, Netherland, pp. 404.
10. European standard for Industrial piping -EN 13480-3.

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