Fabrication process of tubes in epoxy resin

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The manufacturing process of cylindrical tubes, made by mixing epoxy resin with inorganic materials has been studied, producing samples by the method of spillage of the mixture into a mold consisting of two PVC pipes of different diameters. The use of different mold release was evaluated in order to determine what would be the best in your application as well, especially given the ease of removing the sample after curing the composite. The samples produced had a surface with a high degree of polish and your wall devoid of visible defects.

Keywords: cylindrical tube; epoxy resin; mold release

O processo de fabricação de tubos cilíndricos, feitos por resina epóxi de mistura com materiais inorgânicos tem sido estudada, produzindo amostras pelo método de derramamento da mistura para um molde que consiste em dois tubos de PVC de diferentes diâmetros. O uso de liberação de molde diferente foi avaliada a fim de determinar qual seria o melhor em sua aplicação, bem como, especialmente dada a facilidade de retirar a amostra após a cura do compósito. As amostras produzidas tinham uma superfície com um elevado grau de polonês e sua parede desprovido de defeitos visíveis.

Palavras-chave: tubo cilíndrico; resina epóxi; de libertação de molde

1. INTRODUTION

Industrially, the use of tubes has a considerable cost, reaching 25% of the cost of installation. The pipes are applied in processing industries, chemical plants, oil refineries, petrochemical, pharmaceutical and food industries can be used for distribution of drinking water vapor or processes, distribution of fuel oils, compressed air and gases [1].

Depending on the application, the type of material to be used, the length, thickness and diameter of the tube will define your manufacturing process, regulated according to rules set [2]. Beside to the geometric variables, the mechanical, electrical and optical as tensile strength and corrosion resistance, hardness, yield strength, hydrostatic pressure, resistance to temperature, thermal conductivity, should also be evaluated [3]. In addition to its construction, the cylindrical tubes can also be subjected to coating processes for various purposes [4].

The diversity of materials used in the manufacture of cylindrical tubes is large and can be divided in a very general metallic materials (ferrous and non-ferrous) and non-metallic (plastics, cement, glass, ceramics, elastomers, composites). The production of tubes with composite materials has been well developed as they could gather several properties of the materials with which they are build. The cylindrical tubes may be manufactured using two types of forms: one with and one without seam stitching. For seamless tubes stands out in its manufacture, the use of filament winding, spin casting and pultrusion. For the manufacture of welded tubes is usually laminated material and passes through a welding process for closure, and require the completion of removal of material associated with internal finishing processes [5].

Regarding the manufacture of seamless tubes, the process of filament winding occurs according to ASTM D-3299. The filament winding is used in the manufacture of PVC pipe reinforced with fibers. This process is also used in the manufacture of special pipes and rocket engines [2, 3]. Procedures performed in the manufacturing consist of steps performed on a mandrel, with the following sequence: application of film release agent, application of chemical barrier, execution of continuous filament and removal of the cylinder mold. These procedures are performed while a mandrel is rotated around its axis. In the procedure of continuous filament fibers are used for reinforcement impregnated with resin and precision guidance according to the standard adopted [6]. According to Abdalla et al [7] wraps the filament is divided into three stages: design and choice of material, shape and placement of fibers, manufacturing process control. Two disadvantages of this process is unable to manufacture parts with reverse bends and the mandrel need to use [8]. A similar process is the continuous filament fiber placement, where this can produce a slightly curved tube shapes. In the process of casting centrifugation, normally used for molding thin-walled cylinders, a permanent mold is rotated continuously about its axis at high speeds (300 to 3000 rpm), while the molten metal is poured. The molten metal is centrifugally thrown towards the inside walls of the mold, where an appropriate rate it solidifies after cooling. This process is suitable for the production of structures and large diameter pipes for oil supply, chemical industry and water facilities. Although there was no need for a core (such as with the in the lamination process) there is a need to control the speed of rotation to obtain cylinders with a wall thickness. In the pultrusion process the material is made continuously through the generalization of two steps: an impregnation of the material on the strengthening and healing in other mold. This process can form materials with sections appearing profiles, as the dispersion of the matrix with the reinforcement can produce high quality materials [9]. For the production of welded pipes it is used previously removed strips of coils containing the material to be used. The strips are rolled into tubes and shaped through a process of continuous electrical resistance welding. The tubes are cut to specific lengths and undergo finishing processes and tests to be stored after [5].

Employability using a polymer matrix composite-based resin and reinforced with load, in the manufacture of tubes for use in oil companies and gas, has an advantage over ordinary steel pipes. These tubes have an installation cost and lower maintenance to the steel tube and have a lower density, thus reducing the weight of the final structure, apart from the fact that the corrosion resistance of composite resin has an advantage over steel parts [10].

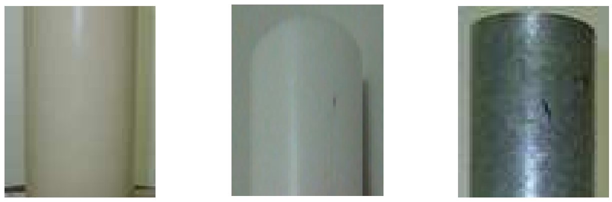
Based on this demand and observing the difficulty presented in the manufacturing processes for the production mentioned cylindrical tube, has as purpose of this study show processes for manufacturing cylindrical tubes made, other than those normally used. For the fabrication of cylindrical tubes was used as the epoxy resin matrix. The tubes produced were made not only with the use of pure resin, but with the addition of inorganic materials formed by the matrix resin. These tests are due to the fact that the inclusion of reinforcement applied with the inclusion of inorganic materials in the polymer matrix allows obtaining a significant effect on some physical properties. Stands out as improvements an increase in strength and stiffness, a reduction of problems from fatigue, greater flexibility, and increase in resistance to corrosion and wear. For the testing and manufacture of molds used geometric parameters were used with academic measures.

2. EXPERIMENTAL

For the manufacture of pipes were used resin Araldite GY 279 and hardener Aradur 2963 manufactured by Huntsman at a ratio of 3 parts of Araldite to 1 part of Aradur. The dye used as a filler pigment Saramanil was used with a percentage by weight of dye 5% to 95% resin. It was even used a agent for the reduction of bubbles with a percentage of 5% by weight.

For the preparation of the mold following materials were used (Figure 1):

- A PVC pipe with outer diameter of 75 mm and 2 mm wall;
- A PVC pipe with outer diameter of 50 mm and 2 mm wall;
- A massive in Teflon tube with a diameter of 60 mm;
- A galvanized steel tube with outer diameter of 60 mm and 2 mm wall;
- A base of acrylic.



(a) (b) (c)

Figure 1: Materials used in manufacturing the mold: (a) PVC pipe, (b) teflon tube, (c)galvanized steel pipe.

The mold used to obtain a sample had consisted of two cylindrical tubes, concentric, positioned vertically and supported on the acrylic base (Figure 2). The acrylic base has a circumferential slot with a thickness of 2 mm and 75 mm diameter PVC pipe to support the larger diameter and the other with a diameter of 6 mm and thickness to support the massive Teflon tubing and galvanized steel pipe. The PVC pipe of 50 mm was used along with the 75 mm on another base (two PVC caps of 75 mm and 50 mm concentric). The tube diameter (75 mm) PVC was used in all samples. Since the PVC pipe of smaller diameter (50 mm), massive in Teflon tube and galvanized steel pipe were used, similarly inserted into the tube of larger diameter, concentrically. The volume obtained between the inner wall of the tube and larger diameter PVC pipe outer wall of the other so that the cylindrical sample required. The wall thickness depends on the difference between the inside diameter of the largest PVC pipe and the inner diameter of the remaining tubes.

(a) (b) (c)

Figure 2: Positioning of concentric tubes (a) and the acrylic base (b) and (c) to formation of mold.

Several changes were made to achieve the following objectives:

- A sample with a smaller amount of bubbles in the inner and outer surfaces of the tube: this was used for the agent;
- A lower adhesion between the sample and the mold produced in order to facilitate the removal of the sample without damaging the mold;
- A sample with an internal surface with greater softness and shine;
- A reduction in cure time;
- Possibility of further experiments using samples with standard sizes of 6 m in length.

To reduce the adhesion between the walls of the tube produced and the mold, was tested, in the following release, agents: vaseline paste and vaseline liquid, paraffin, PVA release agent and carnauba wax.

Yet been conducted, aimed at modification of the ripening period, a sample heating by conduction within the mold. In this procedure we used the galvanized steel pipe applying internally at this water temperature of 100^{o}C. For heat conduction the heat pipe wall made of steel heating the sample contained between the outer wall of the steel tube and the inside of the PVC pipe.

In the resin was standardized procedures mixture through the following sequence of steps:

1. Mixture of Araldite and Aradur in the ratio of 1:3 using a magnetic stirrer for 5 minutes at room temperature. For the tests with the use of modifying agent was added 5% of the agent to the mixture Araldite / Aradur before the agitation;

2. In samples with the use of the dye, after accomplishing the mixing Araldite / Aradur / agent, was added 5% by weight of dye and the mixture again held under the same conditions.

The first tests were conducted producing samples with the use of pure resin (mixed epoxy / hardener). Later, to have a reduction in the amount of bubbles was used a agent added into the mix resin / hardener. In subsequent experiments was also added to the mix resin / hardener / modifying agent and the dye load. Table 1 describes the relationship between the mold, the mixture adopted and other materials.

Table 1: Description of the processes and materials used.

Test #	**MOLD**	**DEMOULDING AGENT**	**MATERIAL**	**OBSERVATION**
1	- PVC pipe 75 mm - Teflon tube	Solid vaseline applied only to the inner wall of the PVC pipe	Pure resin	- Building on acrylic base
2	- PVC pipe 75 mm - Teflon tube	Solid vaseline applied only to the inner wall of the PVC pipe	Resin + Modifier	- Building on acrylic base
3	- PVC pipe 75 mm - Teflon tube	Solid vaseline applied only to the inner wall of the PVC pipe	Resin + modifier + dye	- Building on acrylic base
4	- PVC pipe 75 mm - Galvanized steel tube	Liquid vaseline	Resin + modifier + dye	- Building on acrylic base
5	- PVC pipe 75 mm - Galvanized steel tube	Liquid vaseline	Resin + modifier + dye	- Building on acrylic base - Heating
6	- PVC pipe 75 mm - PVC pipe 50 mm	Liquid vaseline	Resin + modifier + dye	- Supported by covers of the same diameter
7	- PVC pipe 75 mm - PVC pipe 50 mm	Paraffin	Resin + modifier + dye	- Supported by covers of the same diameter
8	- PVC pipe 75 mm - PVC pipe 50 mm	Carnauba wax and PVA	Resin + Modifier	- Supported by covers of the same diameter

3. RESULTS AND DISCUSSION

The samples obtained in carrying out the procedures from 1 to 8, shown in Table 1 are shown in Figures 3, 4, 5 and 6. Figure 3 shows the sample obtained with the use of PVC tubing and Teflon tube (procedure 3). Solid vaseline was applied only to the outer wall of the PVC pipe, since the Teflon showed no adhesion with resin. In the figure 3a the sample has already withdrawn with a piece of PVC pipe and figure 3b the sample is only attached to the Teflon tube. In the figure 3c the sample was removed from the Teflon tube. It can be seen in this picture that the sample had a lot of slots, possibly due to excessive use of solid vaseline.

(a) (b) (c)

Figure 3: Sample obtained with use of teflon andsolid vaseline applied to theinner wall ofthe PVC pipe.

Figure 4 shows a sample obtained using the procedure number 6. It is observed from this figure that the sample showed a smoother surface with fewer stretch marks compared with the sample in Figure 3. The improvement was made due to the use of an adequate amount of vaseline, obtained by applying a bath and subsequent gravity drainage.

(a) *(b)*

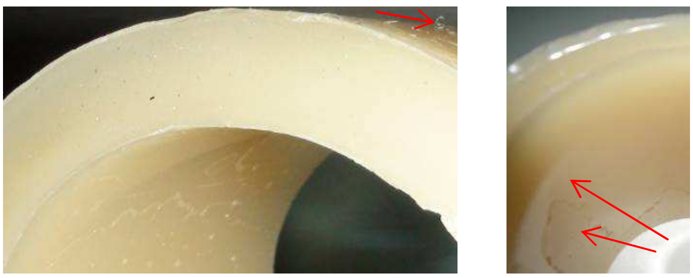
Figure 4: Sample achieved using two PVC pipes and vaseline liquid demoulding agent applied to the inner and outer walls of the inner tube and the inner wall of the outer tube.

Figure 5 shows the samples obtained with the use of demolding wax applied to the walls of PVC tubes (procedure number 7). We can observe the interfaces formed by paraffin, PVC pipes and pipe resin (Figure 5a). In Figure 5b there is a wall made of paraffin, after a little effort during removal of the sample. Figure 5c shows that the outer wall of the sample has a very smooth surface without grooves. To perform these procedures the PVC pipes were bathed in liquid paraffin by dip-coating process. For the removal of the sample were performed two procedures. One of them has done a little manual effort, initiated as shown in Figure 5b, which was applied a little pressure to remove the sample. In a second procedure, the mold with the sample was placed in a bath of hot water at 100 ° C for a short time, enough to melt the paraffin, thus the sample out freely without match any effort. The only problem presented was the need for cleaning the sample with warm water to remove all the wax impregnated on the walls of the sample.

(a) *(b)* *(c)*

Figure 5: Sample achieved using two tubes of PVC and paraffin wax as a demoulding agent applied to the inner and outer walls of the inner tube and the inner wall of the outer tube.

The last sample was obtained with the procedure number 8, as shown in Table 1 (Figure 6). This procedure was used two tubes of PVC, resin and dye and without the modifier was applied as demolding carnauba wax and PVA. Initially, the wax was applied on the walls of the tubes to make the surface smoother and subsequently applied PVA on the polished surface. This demolding leaves a plastic film that makes it easier to remove the sample has the sample with a polished and bright wall as seen in Figure 6. It is observed in the upper right of figure 6a a leftover plastic film. It is also observed on the inner wall of the Figure 6b a polished surface and an unpolished. The polished surface has the same brightness of the top section did not come into contact with the PVC, i.e., the resin cured freely. The polished appearance presented was due to polishing and application of PVA performed efficiently in this area or did not occur on the surface that is presented without much brightness. Despite this sample showed this to be much more smooth than that obtained with the procedure number 7.



(a) (b)

Figure 6:. Sample obtained using two PVC pipes, Carnaud wax and PVA liquid as a release agent applied to the inner and outer walls of the inner tube and the inner wall of the outer tube.

4. CONCLUSION

The results showed that the application of demoulding agent is essential, first to facilitate the removal of the sample and the second to make the surface more polished. Among the samples that showed a lower resistance in the removal of the mold that was used as a demoulding agent the paraffin, either by removing the cold as hot with the withdrawal. But this process has the disadvantage of removing the hot, where there was the need to make several hot baths in the sample after its removal from the mold, to carry out the paraffin impregnated cleaning the walls of the sample. The sample that was used with wax polish and application of the PVA film with the gloss looks polished and presented in some areas, with the same brightness obtained in cross-section that was not in contact with the mold, was more employability as they possibly will not present adhesion and resistance to passage of fluid. The improvement of the wall, making it the brightness and uniform polishing is required. Improved application of PVA, with an additional drying time, possibly making the walls of the sample with polishing uniform, enabling the manufacture of molds of dimensions found commercially.

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