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RESEARCH ON OBTAINING BENT TUBULAR PARTS MADE OF REINFORCED FIBER COMPOSITE MATERIALS USING MODERN METHODS OF RAPID MANUFACTURING

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***Abstract**: This paper presents research related to obtaining bent tubular parts made of reinforced composite materials using modern rapid manufacturing methods. Based on competitive prototyping, this paper presents a comparative study of two modern mould manufacturing methods. This paper is also presenting an innovative modern technology for manufacturing tubular folded and inflated parts made of fiber reinforced composite materials.*

***Key words**: tubes, composite materials, Rapid Prototyping, CAD, CAM*

1. INTRODUCTION

The development of composite materials (CM) in a sustained rate, especially last three decades, has led to research which reveal both properties and deficiencies of those materials. Composite materials entered our daily life after a peak period in the areas of world technology [1]. Is a priority obtaining composite materials using simple technologies with minimum investment. Current research of CM areas is progressing in a sustained rate incorporating advanced technologies of Rapid Prototyping or Computer-aided design (CAD) systems, Computer-aided manufacturing (CAM) manufacturing [2],[3],[4].

All these for obtaining CM parts faster, cheaper, more accessible. The migration of CM of high performance areas to daily areas is in a continuous and sustained rate [5].

The physical-mechanical properties of these materials require the use of CM more frequently. Composite materials successfully replace the traditional metallic materials. Also they are used as combination of metal and plastic materials [6], [7],[8].

The paper presents the computed design of a tubular model, using 3D CAD SolidWorks software. The 3D model is submitted to selective laser sintering machine, (SLS). A prototype from plastic material (polyamide - PA), in short time, is obtained trough this process. Using this rapid manufacturing method is chosen manufacturing a composite material mould. The steps of manufacturing the composite material mould, the advantages and disadvantages of this method are shown[9] 10].

Simultaneously, starting from marker design using the virtual model, it is presented another modern method of manufacturing moulds for composite materials. Both advantages and disadvantages of using this rapid mould manufacturing method are presented[11].

This paper continues presenting a manufacturing technology of bent tubular parts with variable section made of reinforced fiber composite materials. The new technology uses a mould and a flexible mandrel to witch an internal pressure is applied [12], [13].

The result of using rapid manufacturing technologies in reinforced composites materials is the decrease of the manufacturing time of the mould and the products. When using these modern manufacturing methods, the final result is to reduce product costs. The proposed method for obtaining bent tubular and variables section parts, offers a simple solution for obtaining models that are not requiring complex equipments or machineries [14].

2. MANUFACTURING THE MARK OF A BENT TUBULAR PART WITH VARIABLE SECTION USING THE OBTAINED PROTOTYPE FROM SLS PROCESS (SELECTIVE LASER SINTERING)

For obtaining a tubular part was necessary manufacturing a prototype. This could be made by traditional handmade processes or Rapid Prototyping due to the complex shape with variable sections of geometry.

Was preferred the faster and more accurate option – manufacturing the prototype part using the SLS machine. The virtual prototype was made using the 3D CAD SolidWorks software (Fig. 1). The designed part is a mountain bike handlebar. The final purpose of research is manufacturing the handlebar from carbon fibers composite materials in epoxy matrix. It is intended to reduce the weight and increase the mechanical characteristics of the handlebar. Considering the observations of cycle experts was design a new model of tubular part.

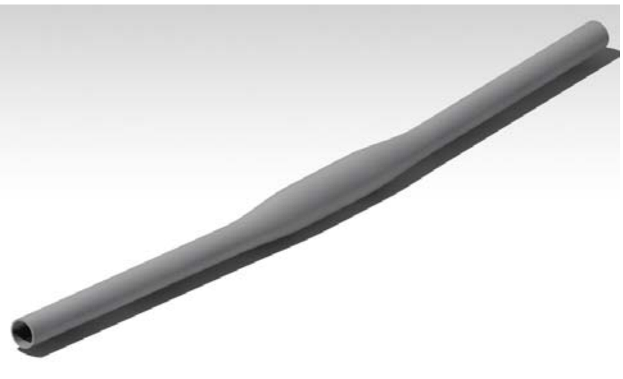

Fig. 1. The virtual model made with 3D CAD SolidWorks software.

The 3D prototype is submitted to SLS machine (Fig. 2)
In short time, a prototype from plastic material (polyamide - PA), is obtained trough this process. The machine uses a polyamide powder type DURAFORM. On PA particle surface is applied epoxy resin.

Fig. 2. The Selective laser Sintering Machine SLS “Sinterstation 2000”

A 5 watts Lasser beam heats the powder on the prototype outline surface. The piece is formed by depositing successive layers of about 0,1 mm.

Because the prototype model is too long and didn’t fit in the work area of the SLS machine, it was split in three segments (Fig. 3).

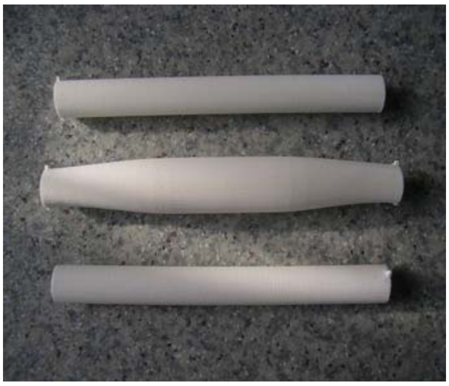

Fig. 3. Plastic material prototype

After obtaining the prototype parts, these were glued resulting the model part. Because of its high surface roughness (25 µm) obtained in SLS process, the model part surface was processed by applying a filler layer and mechanical processing with sandpaper and polish.

The surface of prototype must be as polished as possible, to offer an easy released interface. The prototype (Fig. 4) is used to manufacture a mould from composite materials. It is necessary for manufacturing the reinforced fibers composite materials tubular part. The manufacturing time for this part was 14 hours which 12 hours only on SLS machine.

Fig. 4. Assembled and processed prototype

3. MANUFACTURING THE MOULD FROM COMPOSITE MATERIAL.

For obtaining a tubular part we choose to manufacture a composite material mould. The mould is made from two semi-moulds which are closed with terminal screws.

Was noted: 1 – base plate, 2 – model part, 3 – glue (plastic polyethylene material), 4 – distance piece, 5 – separation plane, 6 – fixed mandrel, 7 – perimeter box.

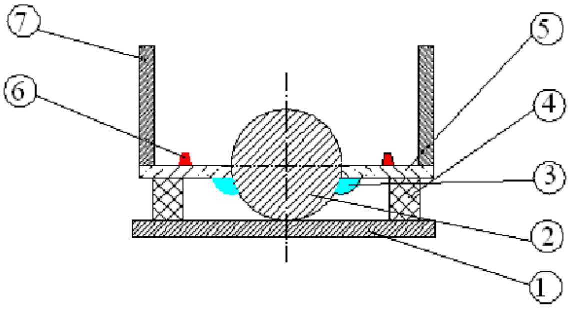

Fig. 5. Main scheme for manufacturing a composite material mould [3]

The mould is manufactured from reinforced fiberglass composite materials and impregnated with epoxy resin. We use an epoxy resin L 235 produced by Lange-Ritter Germany. It has a reduced contraction coefficient (1–2%) compared with polyester matrix (6–15%). This reduced contraction provides a good dimensional precision of obtained matrix. Also the epoxy matrix has a good behavior at high temperature after a heat treatment. The heat treatment is at a high temperature, higher then the mould's working temperature. The manufacture time was 70 hours. The weight of the mould is 5 kg and the estimated value is 350 Euros.

The advantages using a composite material mould: quick manufacturing mould, the reduced weight (easy handling of the mould), it's not necessary investments in complex equipment, relatively low costs, very good dimensional precision, the active surface is easy to work with, the edges of degraded separation planes can be easily repaired.

The disadvantages using a composite material mould: low thermal stability over 90° C, limited number of uses approximately 200, the active surface of the mould can be easily degraded.

4. MANUFACTURING A METALLIC MOULD

Proposed version requires manufacturing a metallic mould with a CNC processing center. Based on the virtual model it is used CAD CATIA system. With this software the mould is designed in 3D to the corresponding dimensions of the prototype (Fig. 6).

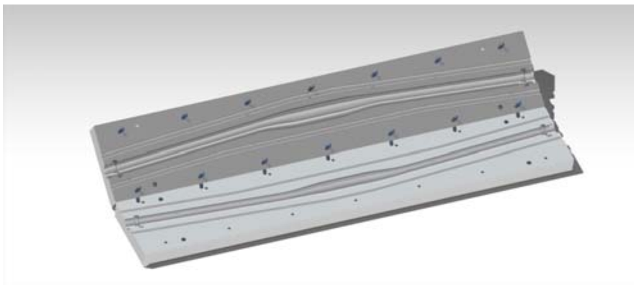

Fig. 6. The virtual model of the mould

To manufacture the mould, must run the required software to program the CNC machine in Solid CAM. The program is submitted to the process center, which execute the milling. In this case we used a CNC type Fadal VMC 4020.

The mould was manufactured from **aluminum alloy type 7075-T6**. **Aluminum alloy 7075** is an aluminum alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength. The manufacturing process of mould starts with aluminum alloy plate cutting, the external milling, processing the division planes, heavy-duty milling and shear milling. Due to three-dimensional complex shape of mould concavity and its roughness after milling, in the end the mould was hand process by grinding with sandpaper with a grain size starting from 180 to 1000 after which a polishing has been made (Fig. 7).

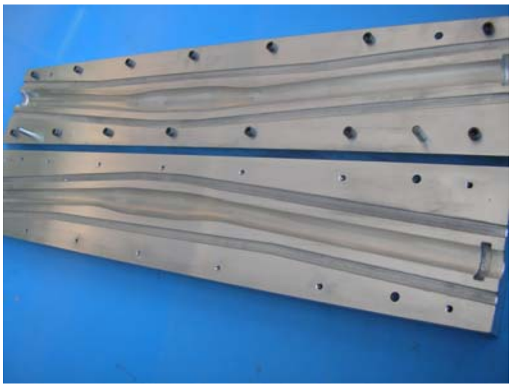

Fig. 7. The metallic mould performed by CNC

The total time for manufacturing the mould was 20 hours. The mould weight is 16 kg and its estimated value is 850 Euros.

The advantages using the metallic mould: the use of rapid manufacturing resources, low manufacturing time, high dimensional precision, high thermal stability, resistance to high manufacturing cycles over 1000 pieces.

Disadvantages: high price, highly skilled labor, modern instruments, high weight providing low handling.

5. MANUFACTURING THE BENT TUBES WITH VARIABLE SECTION FROM REINFORCED FIBER COMPOSITE MATERIALS.

The process consists in forming tubular parts of composite materials with closed matrix, the mandrel, being removed. Its place is taken by an elastic tubular element on which an internal pressure it is applied. The composite material, in non-polymerization state, is deposited on the elastic element and inserted in the mould. An internal pressure is applied on elastic element. Its volume increased. So a pressing of composite material to mould's wall is realized. The mould is heated trough its own plant or in heating room. After mould polymerization, the elastic element is removed and the composite material tube is released of the mould.

By removing the internal mandrel, we have the possibility of obtaining composite materials tubes with variable wall thickness according to reinforced composite material thickness. The process eliminates the release problems of composite tube on the mandrel after the composite material's polymerization. Trough this new technology it is allowed to obtain reinforced fiber composite materials, bent and variable sections, tubular parts of small diameters (< 20 mm), medium (20 – 200 mm) and big diameters (> 200 mm). Trough traditional processes, the mandrel, which can be used for manufacture the tube, would be impossible to remove after material polymerization. Its center section is bigger than end section.

Figure 8 presents the main scheme for facility production of bent and variable section tubes made from reinforced fiber composite materials. In the semi mould concavity 1 is placed the elastic element 3 on which is applied the composite material fabric. After closing the matrix with connection coupling 4, a pressure is applied to the elastic element this changing its volume. A compression of composite material to mould's wall is achieved. The connection coupling to pressure source 4 and the elastic element stopper is placed in channel guide 5 for not being pushed out from the mould. The semi moulds are centered with the help of centering pins 8. Setting the two semi moulds is possible using screws on setting holes 7. The mould has its own heating facility 2 or can be placed in a heating chamber for the polymerization of composite material.

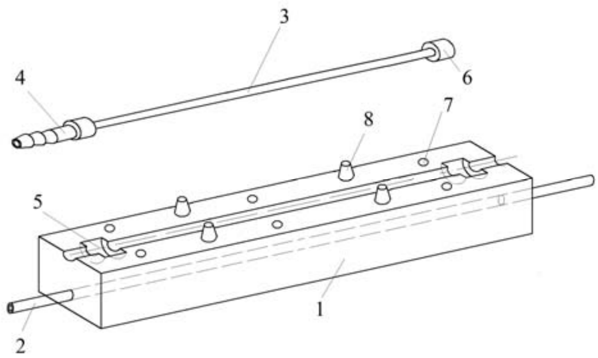

Fig. 8. Main scheme of tubes facility production

The result of proposed innovative technology is shown in figure 9, which represents a tube made from carbon fiber in epoxy matrix.

Easy machining is required in the separation plan area. This removes the excess of the material from the surface.

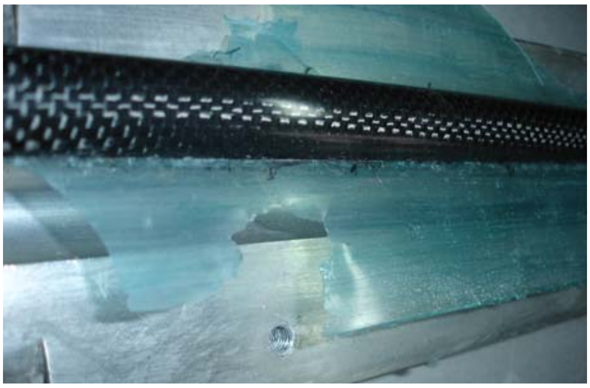

Fig. 9. The released composite material tube

Advantages of this process.

Trough the innovative solutions adopted, this technology allows us to produce tubular parts calibrated on the outside of mould used. The reinforced material can be preferentially oriented on request direction, keeping its architecture after polymerization. It is obtained a well compressed composite material with a uniform structure, with a high reinforcement degree, which has high mechanical characteristics.

Disadvantages.

The main disadvantage of this process is the necessity of using a mould, which conditions the tube sizes. Using this process, for production of tubes with larger diameters (> 1000 mm) it is necessary that mould to be consolidated. Due to internal pressure applied to elastic tap holder, the resulting forces on mould have significant value. The consolidation of the matrix leads to increasing its weight.

6. CONCLUSIONS

The paper presents the implementation of modern rapid manufacturing technologies in reinforced fiber composite materials fields. We start from rapid manufacturing of SLS prototype, next making the mould using CAD and CAM system and in the end the use of new technology for manufacturing complex composite materials parts.

Manufacturing the prototype using SLS system conducts to reduce manufacturing time. Also the dimensional precision is superior to hand processed prototype or combined manufacturing technologies.

A comparative study between two modern manufacturing methods is made for manufacture moulds. Both methods offer advantages and disadvantages. It must be analyzed lots of factors that influence a decision, factors like: the dimensional precision, the life time, the work temperatures of the moulds, the weight, the cost price, the manufacturing time, human resources or instruments used.

This paper also presents a new manufacturing technology of bent tubular parts with variable section made of reinforced fiber composite materials. The resulting parts have superior mechanical characteristics than common materials having a 7 times low density comparing to steel. As applications of these parts we mention: orthopedic prostheses, manufacturing of performing bicycles, robotic arms, motor-sport etc.

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CERCETĂRI PRIVIND OBȚINEREA PIESELOR TUBULARE ÎNDOITE DIN MATERIALE COMPOZITE ARMATE CU FIBRE PRIN METODE MODERNE DE FABRICAȚIE RAPIDĂ

Rezumat *Această lucrare prezintă cercetări legate de obținerea pieselor tubulare din materiale compozite armate utilizând metode moderne de fabricație rapidă. Plecând de la proiectarea competitivă a prototipurilor lucrarea prezintă un studiu comparativ între două metode moderne de fabricație a matrițelor. De asemenea lucrarea mai prezintă o tehnologie modernă inovativă de fabricație a pieselor tubulare îndoite şi gonflate din materiale compozite armate cu fibre.*

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