



Research Article

# Woven Reinforced Composites for Improving the Design of the Hyperextension Brace

Barburski M<sup>1\*</sup>, Weigert L<sup>2</sup>, Fernández I<sup>2</sup>, Pouplier S<sup>2</sup>, Roth S<sup>2</sup> and Huurnink G<sup>2</sup>

## Abstract

Hyperextension braces are the orthopaedic instruments mainly used to treat spinal compression fractures and for spine surgery recovery. The brace used for the research has a three-point leverage system which attaches to the sternum and pubic body regions and a back-embracing component that attaches to the lumbar region. This category of braces has proven to be effective in the treatment of vertebral problems, however research confirms that the use of this equipment is not comfortable. The brace has two main uncomfortable areas, the first one is located in the armpits and side-chest zone and the second one on the hips or pubic region, as a result, the aim of this research is to use textile reinforcement composites to improve the design of the hyperextension braces and to find a way to make it more comfortable for the user.

## Keywords

Woven; Design; Textiles; Reinforced composite

## Introduction

The back brace, Hyperextension Brace Jewett (Figure 1), produced by mdh has the function of stabilizing the back of the patients. However, it is not comfortable to wear the brace. The current type xbrace and the areas where it causes irritation are shown in Figures 1 and 2.



Figure 1: Back brace Jewetta HX-3.

\*Corresponding author: Marcin Barburski, Lodz University of Technology, Institute of Architecture of Textile, Stefana Żeromskiego 116, 90-924 Łódź, Poland, Tel: +426313333; Fax: 426313343; E-mail: marcin.barburski@p.lodz.pl

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The assignment given at the beginning of the project is to find and create a new application for 3D woven textiles in composites. This assignment and the problem that has been discovered results in a final goal for the project: "Can the Hyperextension Brace Jewett be produce composites in such a way that it will improve the ergonomics and is more comfortable to wear for the user?"

## Materials and Methods

The used materials for this project were glass fiber fabric 80 g/m<sup>2</sup> AEROGLOSS, a Carbon-Aramid blend fabric HP-P 167 AC and Tubus Honeycomb PP 8.0-80T30F75. More details about these materials are given below.

### Glass fiber 80 g/m<sup>2</sup> Aeroglass

This material has a weight per unit area from 80 g/m<sup>2</sup> +/- 2 g and the weave is a plain. The weft- and warp density are 12 +/- 1 y./cm. Furthermore, has this material a tensile strength ≥ 600 N/50\*200 mm [1].

### Carbon-aramid (blend fabric HP-P 167 AC)

The used carbon-aramid fabric has a weight per unit area from 165 g/m<sup>2</sup> +/- 5% and the weave is plain. The warp yarn consists of 200 Tex 3K Carbon with a warp density from 4 y./cm +/- 2%. The weft yarn consists of 158 Tex Aramid with a weft density from 5 y./cm +/- 2%. The thickness of the yarns is 0.35 mm [2,3].

### Tubus waben

We have also used one kind of honeycomb structure - it is Tubus Waben. It was a brand-new material, which was already used in vehicle-, aircraft- and shipbuilding. This material was produced from polypropylene and has pipes instead of hexagonal shape as structure.

Polypropylene is the lightest plastic and has already a high degree of hardness, stiffness and heat resistance. The pipes were welded together with an offset. Tubus Waben offers different types of their product. The used material for this project is the Tubus Honeycomb PP 8.0-80T30F75 (Figure 3). This material is laminated with a polypropylene film and a polyester fleece on the top and the bottom [4].

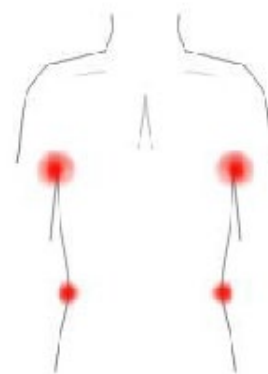
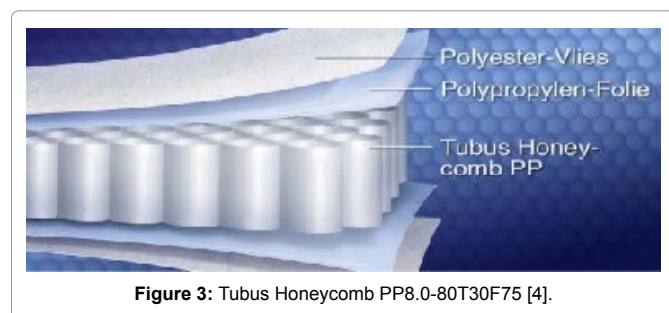


Figure 2: Pressure points.



**Figure 3:** Tubus Honeycomb PP8.0-80T30F75 [4].

**Table 1:** Mechanical properties of Tubus Honeycomb PP 8.0-80T30F75 [4].

| Feature                          | Value Tubus Honeycomb PP 8.0-80T30F75 |
|----------------------------------|---------------------------------------|
| Tube Diameter                    | 8.0 mm                                |
| Density                          | 80 kg/m <sup>3</sup>                  |
| Compressive strength             | 1.8 MPa (N/mm <sup>2</sup> )          |
| Compressive modulus              | 85 MPa (N/mm <sup>2</sup> )           |
| Shear strength                   | 0.52 MPa (N/mm <sup>2</sup> )         |
| Shear modulus                    | 13 MPa (N/mm <sup>2</sup> )           |
| Temperature range of application | -30°C up to +80°C                     |
| Core height range                | 6.0 mm up to 65.0 mm                  |
| Core height tolerance            | +/- 0.15 mm                           |

This kind of material offers a lot of different benefits. It is an ultra-light material, so the weight can be reduced between 60 – 120 kg/m<sup>3</sup>. Furthermore, the material offers a high bending-, tensile- and compressive strength. Polypropylene is also corrosion resistant, moisture proof as well as recyclable and can reduce vibrations and sounds properly. A processing benefit is its thermal deformability. A precise cut enjoys high size accuracy. With all these properties, the Tubus Honeycomb is ultra-versatile.

The mechanical properties of the used Tubus Honeycomb are shown in Table 1. Due to the mentioned type of polyester fleece offers the opportunity to connect different kinds of materials, like 2D woven fabric as well as wood or metal. There is also a possibility to put screw threads in the pipes before the connection process starts, thus the surface of the textile will not be destroyed.

### Thermoset resin

Epoxy resin is one of the thermosetting polymers. This thermoset consists of two parts, the resin and the hardener. The resin, depends on the manufacturer and is viscous with a liquid as hardener. These components must be mixed to start the chemical reaction. The epoxy resin will cure due to polyaddition to a moulding material and ensures the connection between the filling material and the 2D woven fabric. Each epoxy resin has his one mixing ratio between resin and hardener. In most cases the mixing ratio between these parts is 10% of hardener related to the weight of resin [5]. To perform the bending test, it was necessary to create some samples. The samples consisted of two layers glass fibre fabric on the body side, one layer of carbon-aramid fabric on the visible surface, Tubus Honeycomb PP 8.0-80T30F75 as filling material and a thermoset resin to connect the materials. The chosen production process was the vacuum bagging process.

### Methods

The bending test was performed due to the expected forces while wearing the brace. The test itself was performed according to standard BS EN ISO 14125:1998.

**Table 2:** Average results of bending test.

| Sample | Name                                              | Fmax [N] | Rg [MPa]  | dl przy Fmax [mm] |
|--------|---------------------------------------------------|----------|-----------|-------------------|
| A      | Tubus Honeycomb PP 8.0-80T30F75 Carbon horizontal | 35.70664 | 11.413894 | 4.9101294         |
| B      | Tubus Honeycomb PP 8.0-80T30F75 Carbon vertical   | 27.19346 | 6.147073  | 2.9071264         |

The results (Table 2) will be focused on the samples with carbon-aramid fabric, because the prototype was made with these materials. Furthermore are these results the arithmetic average of three tests. The difference between the results is the direction of the carbon rovings. In sample 1 hese rovings were in horizontal direction and in sample 2 they were in vertical. The results of this test showed, that the carbon fibers absorb more forces than the aramid fibers. Therefore, it was obvious that the carbon fibers have to be in the horizontal direction for the prototype [6,7].

The flexural stress Rg is given by the following equation [8]:

where:

Fmax is the load in newtons (N);

Rg is the flexural stress, in megapascals (MPa); dl przy Fmax is the span in millimetres (mm);

b is the width of the specimen, in millimetres (mm);

h is the thickness of the specimen, in millimetres (mm).

### Results

The bending test on different samples provided insight into the exact properties of the composite. The directions of the carbon and the aramid fibers of the HP-P167AC Carbon-aramid fabric are different. In one test, the carbon rovings were horizontal and the aramid vertical, in the other vice versa. The test as well as the research about these materials showed that the carbon fibers have more tensile strength than the aramid fibers. So, the HP-P167AC Carbon-aramid fabric should be placed on the top of the prototype in such a way that the carbon rovings are horizontal oriented. The highest stiffness is needed in vertical direction to prevent the spine of bending. For the prototype one layer of carbon-aramid fabric was used with the carbon rovings in horizontal direction on the base of the bending test, as well as two layers of glass fiber fabric. One layer of carbon-aramid and two glass fiber layers give enough strength. Based on the expensive purchase price, it is better to use as little as possible.

### Production of Prototype

To attach the side, top and bottom pads to the brace, inserts in the Tubus Honeycomb are placed. This will prevent the Tubus Honeycomb from breaking when the screws are inserted. To avoid damage of the structure this reinforcement - in our case small aluminium cylinders - should be done before the production process started. These cylinders transfer the forces from the screw equally to the cross.

At the beginning of the production process of the new brace, the measurements from Solid works served as a scale. These are sketched on the Tubus Honeycomb. Because of the stiffness from the Tubus Honeycomb and the carbon-aramid fabric, the prototype should be as narrow as possible to minimize the weight. A special attention should

be given to the inner corners in the central part of the cross because of their function as connectors with the pads. To avoid or decrease mechanical stresses it is necessary to cut a radius instead of a sharp edge. Since the sketch on the Tubus Honeycomb was well prepared, the tailoring could start.

Shaping the Tubus Honeycomb is quite easy. With a customary heat gun, the Tubus Honeycomb can be heated to its softening temperature which is between 66°C and 150°C. The dimensional stability of Tubus Honeycomb was given up to 78°C, so the honeycomb should be heated a bit over this temperature.

After the shaping process, the production process of the composite could start. The selected process to create the composite was the vacuum bagging process.

Firstly, all materials (including the vacuum bag) should be tailored and prepared. After this step the thermoset resin can be mixed and the first impregnation step can be done. Upon completion of the lamination steps (surface impregnation with resin and the placed layer), the composite can be placed on the bag film and it can be closed with a sealant tape. Now the vacuum pump can be connected with a rubber valve. When the connection is secured the pump can be started. After a few hours the resin is hardened and the composite could be removed from the bag.

The last step in the construction process was assembling the pads to the composite cross (Figure 4). The cross was removed from the bag and the material on the side was removed. This was quite difficult to do, since the composite is a tough material. But later when the brace is produced with a more advanced production process there is less rest material to remove, this should therefore be no problem.

The added pads are the original ones from the previous brace, Jewetta HX-3. The top and bottom pad are identical. The side pads, where also the belt is attached to, needed some modification. The end of the pads has been cut from the rest of brace. The holes in the aluminium are used to attach the pads to the cross in the correct position. The two screws go thru the holes in the brace with the aluminium inserts.

The core benefits of this new brace are the light weight, a high wearing comfort as well as the stiffness of the composite.



**Figure 4:** New composite hyperextension brace.

As comparison: just the belt from the old brace weights 197 gram, whereas the complete frame produced in composites just weights 110 gram.

## Conclusion

The main question of this project was: Can the Hyperextension Brace Jewett be produced in composites in such a way that it will improve the ergonomics and is more comfortable for the user to wear? And the answer is yes- as the prototype and this report prove. The prototype is functional, and fulfils the complete list of demands. The shape has been re-designed to improve comfort and ergonomics of the brace. The new brace design is quite simple, so, after doing some more research about the materials and the shape, it will not be difficult to produce the brace with composites. The new brace has a lot of strong points related to ergonomics: comfortable, lightweight compared to the previous brace and easy to put on and put off. To conclude, these advantages based on research, well-thought design and the convenient properties of the composite.

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## Author Affiliations

Top

<sup>1</sup>Lodz University of Technology, Institute of Architecture of Textile, Stefana Żeromskiego, Poland

<sup>2</sup>Lodz University of Technology, International Faculty of Engineering, Stefana Żeromskiego Łódź, Poland