COMPOSITE MATERIAL SELECTION FOR A PATIENT TRANSFER ASSIST DEVICE

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Introduction

Laminates - layered composites containing at least two elements (matrix and reinforcement) widely used in industry have also found their usage in medicine. Their main feature is the ability to modify the material in order to obtain the required properties. Depending on the needs, we can modify reinforcement, type of resin or the method of bonding substrates. Commonly used fibers are: carbon fiber, glass and aramid fibers; resins are epoxy, vinyl and polyester. The following commercial forms of fibers are distinguished: roving, mat and fabric (multidirectional and unidirectional - UDC) with several styles of bandwidth connections: differing in number of layers and the way they are combined (at various angles or in different ways of sewing/ plaiting) [1, 2] (TABLE 1).

TABLE 1. Comparison of mechanical properties of carbon, glass and aramid fibers [1,2].

Fiber	Density ρ [g/cm³]	Tensil strength Rm [MPa]	Young's Modulus E [GPa]
Glass	2,5-2,6	1350-4900	60-90
Carbon	1,6-2,0	2800-5490	230-588
Aramid	1,44-1,47	2900-3450	59-179

The main goal of this project is to select a proper composite material for a medical device – lightweight, durable and ergonomic patient lift which efficiently transfers patients between two plains. The material selection contains the choice of matrix, reinforcement, form of fibres, style of bandwidth, the thickness and the fibre mass for the individual layers of laminates, as well as the strength calculation.

Materials and Methods

Based on a comparison of composite material properties, an epoxy-carbon laminate was selected. High stiffness and low weight have outweighed the lower durability for dynamic loads that are not present in the design. The proposed laminate structure is made of three layers arranged alternately. The outer layers will be a multidirectional fabric in the Biaxial (BXC) version, in which the carbon fibers are laid at an angle of +/- 45°, while the inner layer will be the UDC roving fabric with carbon fibers arranged in one-directional manner. A literature review allowed to construct the following assumptions: BXC type outer layers should have an equal thickness and the ratio of the thickness of the inner layer to the outside should be approximately 2:1.
In order to carry out strength calculations, the shape and size of device was designed using AutoCAD.
The strength calculations assumed lifting capacity of 150 kg and were performed in the following order: determination of elementary stresses, determination of the most dangerous cross-section, calculation of tensile strength, calculation of Young's modulus, selection of channel dimensions, determination of material parameters (thickness, fibre mass), determination of substitute stresses. The calculations regarding the properties of laminates have been made in accordance with the European standard EN ISO 12215-5: 2008 [3].

Results and Discussion

Lamination technology was one of the criteria that determined the shape of the profile. A contact method is proposed for applying laminate layers to a specially prepared internal form. A profile in a C-shape and dimension of 138x90x14 mm has been designed. Patient lift includes an arm of 1,6m height and 1m length of the horizontal beam (FIG. 1).

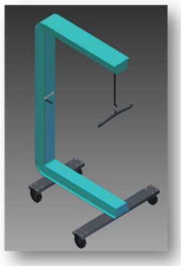

FIG. 1. 3D Model of the proposed patient transfer assist device.

The vertical bar is simultaneously bent and compressed, while the horizontal bar is bent and sheared. Using the mathematical formulas contained in the EN ISO 12215-5: 2008 standard, the results of the main strength calculations have been presented in TABLE 2.

TABLE 2. The main calculations of a C-shaped patient lift designed with carbon-fibres [3].

TENSIL STRENGTH Rm [Pa]	YOUNG' S MODULUS E [Pa]	ALLOWABLE STRESSES k [Pa]	STRESS σ_z [Pa]		DEFLECTION f_c [m]	
			Vertical	Horizontal	Vertical	Horizontal
491526000	49740000000	163842000	7958879	1742431	0,007504	0,003312

The profile meets the strength conditions ($\sigma_z \leq k$) and the deflection (f) is acceptable. Selection of the C-profile dimensions allowed also to determine the thickness and the fibre mass for the individual layers of laminates (TABLE 3).

TABLE 3. The mass of carbon fibres of individual layers depending on the mass content of fibres in the laminate and the thickness of the given layer [3].

LAYERS	THE MASS OF CARBON FIBRES w $\left[\frac{kg}{m^2}\right]$	MASS CONTENT OF FIBRES IN THE LAMINATE []	THICKNESS t [mm]
BXC	0,0033	0,594	3,712963
UDC	0,0056	0,5742	6,571694
BXC	0,0033	0,594	3,712963
Sum	0,0122	0,584911	13,99762

Conclusions

To design a lightweight, durable and ergonomic patient lift with lifting capacity of 150 kg an epoxy-carbon laminate composed of three layers should be used. External BXC layers, each with a thickness of 3.71 mm containing 0.0033 [kg/m^2] of fibre mass and an internal layer of UDC with a thickness of 6.57 mm and a fibre mass equal to 0.0056 [kg/m^2].

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