MECHANICAL PROPERTIES OF JUTE FIBRES REINFORCED PLASTICS

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Abstract
The article describing the preparation of composites with reinforcement of jute fabrics of different basis weights in combination with an epoxy and a polyester matrix. Samples were tested for mechanical properties as tensile strength in warp and weft direction. The experiment showed that a better combination of mechanical properties achieved jute/polyester. Strength of the composite is greater in the weft (about 30%) than in the warp direction whatever the combination fiber / matrix. Research of composite materials is a broad area that provides in aerospace, automotive and other technical areas materials with excellent properties such as low weight and improved mechanical properties.

Key words: natural fibres, jute fabric, composite, tensile stress.

INTRODUCTION

Basic mechanical properties of technical materials are low weight, stiffness, strength and etc. A basic requirement in terms of internal structure is homogeneity. Most of the industrial materials are considered as homogeneous and isotropic from macroscopic view. The composite material consists of two or more components which vary in shape and composition. Each component is physically identifiable and among them an interface is located. Ingredient connection produces a synergistic effect. The composite is a multi-phase material that is composed of continuous phases and dispersion. A matrix is continuous phase of the composite that can be metal, ceramic or polymers. The dispersion is composite reinforcement that is in the form of fibres or particles. Fibre dispersion is continuous or discontinuous. Carbon, glass and aramid fibres have excellent mechanical, chemical and thermal properties and represent most commonly used fibre reinforcements. The resulting composites, which are a combination of fibres with plastic matrices, have excellent mechanical properties and they are used in the aerospace, energetic, automotive, engineering industry and many others, not only in technically oriented industries (GAY, SUONG 2007; LIU ET AL. 2004). Biopolymers are alternative of composites that are not based on fossil fuels (oil, coal and gas). They can be divided into three groups according to their origin.

Natural fibres are a large group of traditional fibres, which are further subdivided on animal and plant fibres. Plant fibres consist of fibres from seeds, stems and leaves. Fibres from stems - bast fibres consist of filaments, having a similar composition, properties and similar microscopic appearance. To this group flax, hemp, jute, kenaf, bamboo and nettle fibres belong. The fibres are obtained by the help of mechanical and physical processes from the woody stems (MILITKÝ 2005). Generally a composite production is very inefficient from an economic point of view. A production of hybrid bio composites (NFPC - Natural Fibre Polymer Composite) can replace expensive reinforcements, especially carbon fibres and represent an acceptable compromise. It may be applied when very high strength is not required. Additional benefit can be seen in the reducing of the oil and energy consumption and lower environmental footprint. Natural fibres have lower or comparable density especially in comparison with glass fibres. They are non-toxic, environmentally degradable and they do not cause a damage of machine parts during the production. Also their production requires less energy compared to glass and carbon fibre production (HOLBERY, HOUSTON 2006, LAYTH ET AL. 2015). The disadvantage of natural fibres consists in poor water resistance that causes water absorption or swelling, the possibility of damage by pests and fungi and also impairment of the mechanical properties in comparison with carbon and glass fibres. Tab. 1 shows comparison of different fibre reinforcement properties, Fig. 1 show jute fibres (FIDELIS 2013) and carbon and E-glass fibres (PETRŮ ET AL. 2015). Tensile properties of resulting composite are mostly influenced by a volume fraction of fibres (FOWLER ET AL 2006). For this is important to select an appropriate matrix. The polymeric matrixes are typically divided on thermoplastics and thermosets. Thermoplastics melt when heated and harden after cooling. Most commonly used thermoplastics are following: polyethylene, polypropylene and polyvinyl chloride. Thermosets are highly cross linked due to covalent bonds among chains. To thermoset group belongs for example polyester and epoxy resins. The used matrix has an influence on the resulting properties of the composite (LAYTH ET AL. 2015; LIU ET AL 2004). A composition of natural fibres and polymeric matrix is not chemically compatible. It leads to insufficient properties of the interface and its low capability of a stress distribution. Incompatibility of natural fibres with polymer matrix can be influenced by a fibre modification. Very suitable is the addiction of the reactive functional groups that are responsible for the reduction of moisture absorption and also improve final affinity of fibres to the matrix. Especially chemical treatment of natural fibres leads to an increase in strength and improvement of a dimensional stability of bio composites with polymeric matrix (LAYTH ET AL. 2015).

The aim of this study is to describe the preparation of composites with reinforcement of jute fabrics of different basis weights in combination with an epoxy and a polyester matrix.

Tab. 1. – Compared mechanical properties of selected fibres (LAYTH ET AL. 2015)

Fibre	Density [g/cm^3]	Elongation [%]	Tensile Strength [MPa]	Young's Modules [GPa]
Flax	1.5	2.7-3.2	345-1035	27.6
Jute	1.3	1.5-1.8	393-773	26.5
Carbon (HT)	1.4	1.4-1.8	4000	230-240
Glass-E	2.5	2.5	2000-3500	70

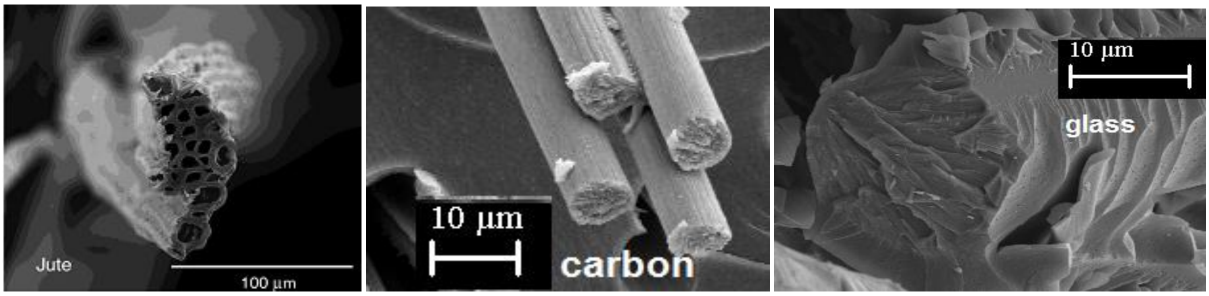

Fig. 1. – Natural fibres; jute, technical fibres: carbon and glass fibre

MATERIALS AND METHODS

Bio composites with jute reinforcement were obtained for basic knowledge about the NFPC properties. Jute fabrics having different weight were chosen because of commercial availability, and lower cost in comparison with flax fibres. For the production two matrices were applied - epoxy and polyester thermosetting resins. The composite single-layer samples were made by hand lay-up. Basic parameters of the samples are given in Tab. 2.

Tab. 2. – NFPC parameters

Samples	Reinforcement type and orientation	m_j^c [g/m^2]	Resin	M^f [%]
E1WA	jute/warp direction (J1WA)	170	EPOXY	15.53
E1WE	jute/weft direction (J1WE)			
E2WA	jute/warp direction (J2WA)	400		31.85
E2WE	jute/weft direction (J2WE)			
P1WA	jute/warp direction (J1WA)	170	POLYESTER	15.21
P1WE	jute/weft direction (J1WE)			
P2WA	jute/warp direction (J2WA)	400		29.89
P2WE	jute/weft direction (J2WE)			

Samples of jute fabric and a complete composite plate you can see in the Fig. 2. Samples for tensile stress test were prepared from fabrics and composites; test was conducted in the warp and weft direction according to EN ISO 13934-1 (textiles) and EN ISO 527-4 (composites). The tests were performed at room temperature on the unit Labortech 2.050. Jute fabric samples for testing are seen in Fig. 3 and dynamometer for tensile testing is in Fig. 4. Samples after test show in the Fig. 5.

Fig. 2. – On left side - jute fabric; on right side sample P1 (jute fabric 170 g.m^{-2}, polyester resin) and sample E2 (jute fabric 400 g.m^{-2}, epoxy resin)

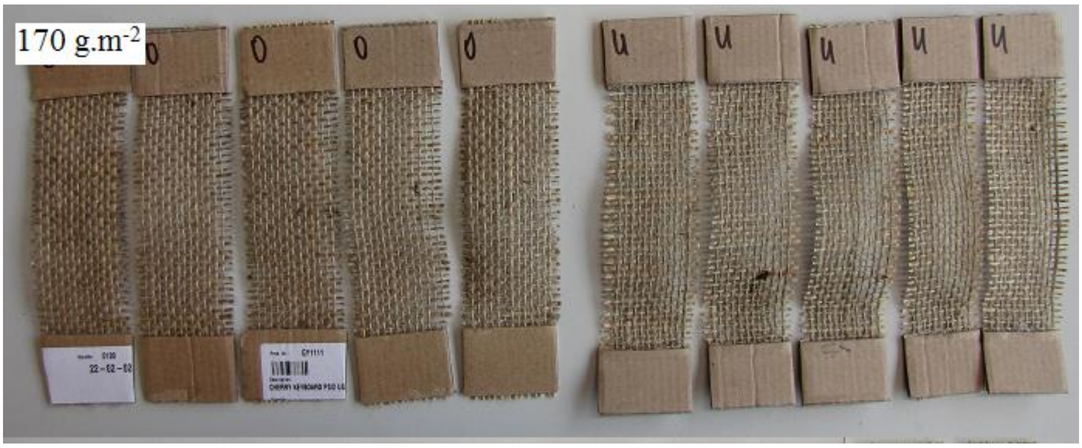

Fig. 3. – Jute fabric samples for tensile strength test (warp and weft direction)

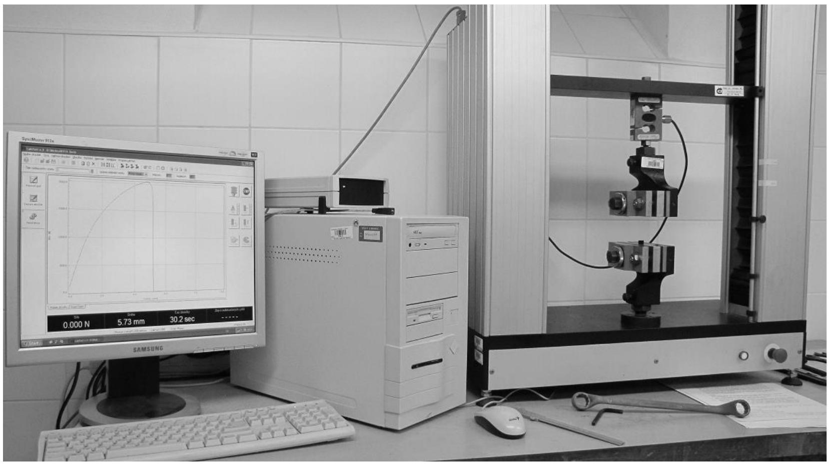

Fig. 4. – Dynamometer Labortech for tensile testing

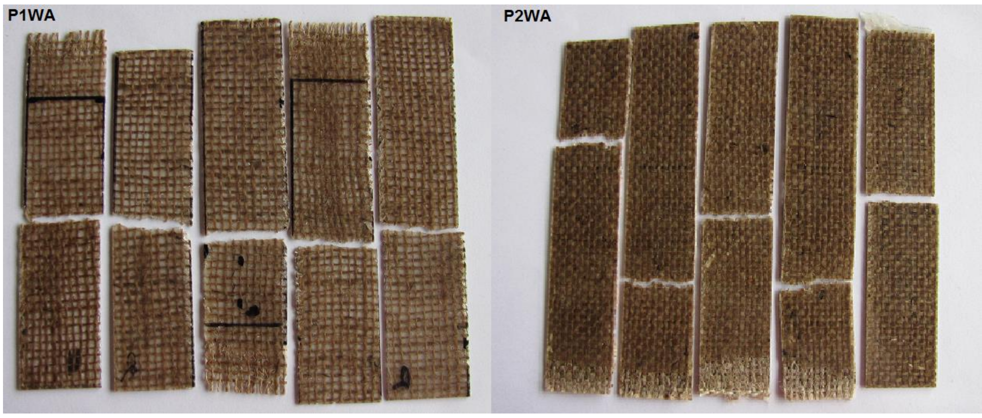

Fig. 5. – The samples after tensile strength test (P1WA - jute fabric 176 g.m^{-2}/ polyester resin, warp direction; P2WA - jute fabric 400 g.m^{-2}/ polyester resin, warp direction)

RESULTS AND DISCUSSION

From results it is seen that composite properties are significantly different depending on applied matrix even though they have similar mechanical properties. These differences could be obtained with different viscosity of the matrix during the application. Epoxy resin is more viscous and its ability to penetrate into the yarn structure is significantly lower. The viscosity of the resin can be decreased by a warming, but it also accelerates a cross linking process of the matrix. It leads to a shortening of application time that is relatively long in the case of hand lay-up process. Results of initial modulus calculated for the jute fabric 400 gm^{-2} reinforced with epoxy and polyester matrix in weft direction are shown in Tab. 3. The results show increased initial modulus of composites compared with raw jute fabric. Module has grown to ten times. Comparison the strength of jute fabric and jute composite with polyester matrix shows the graph in Fig. 6. Comparison the strength of warp and weft direction for all samples you can see in Fig. 7. Strength in weft direction is about 30% higher than strength in warp direction. Difference of strength between P2 samples (in warp and weft direction) is up to 50%. Strength of jute/polyester composite was measured about 100% higher than strength of jute/epoxy composite. The results obtained during the experiment were compared with the results of other authors. Tab. 4 presents own measured results, and this results were comparison of the results from Ajith et al 2014. Parameters of composites were similar for type of fibers, matrix and fibers nominal content. The resulting values are in agreement. Differences are for examples in a different type of reinforcement (fiber – woven fabric) and on the use of chemical addition.

Comparison the modules of single layer composite and ten layers composites from jute fabric (SABEEL AHMED, VIJAYARANGAN, 2008) show the possibility of significant growth of module. Similar composite input parameters are required. The comparative results are shown in Tab. 5. Table shows the resulting modulus measured in the warp direction and weft direction.

Tab. 3. – NFPC parameters

	Jute fabric (J2WE)	Epoxy resin (E2WE)	Polyester resin (P2WE)
Initial modulus [MPa]	18.77	1336.93	1848.86

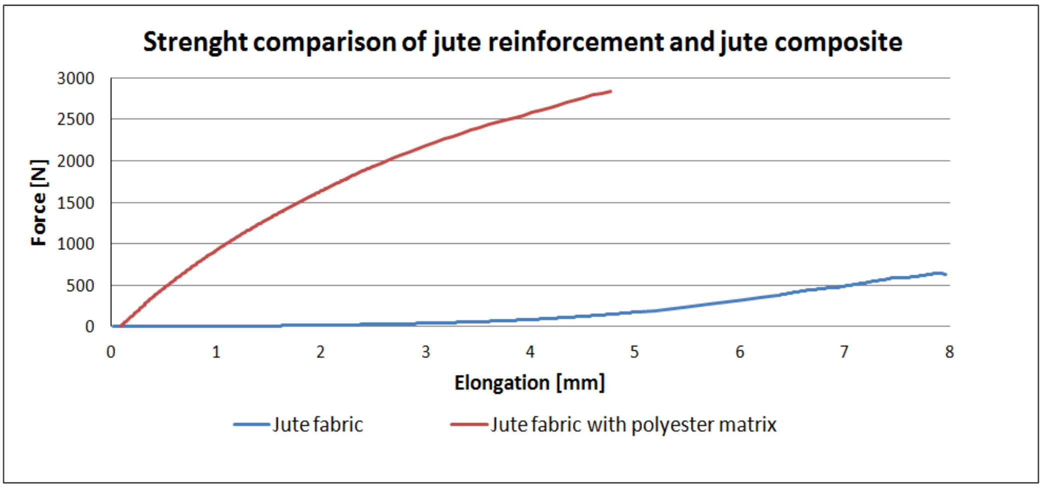

Fig. 6. – Graphs of tensile strength a) J2WE sample (jute fabric, m_j^c 400 g.m^{-2}, weft direction), b) P2WE sample (jute/polyester composite, m_j^c 400 g.m^{-2}, weft direction)

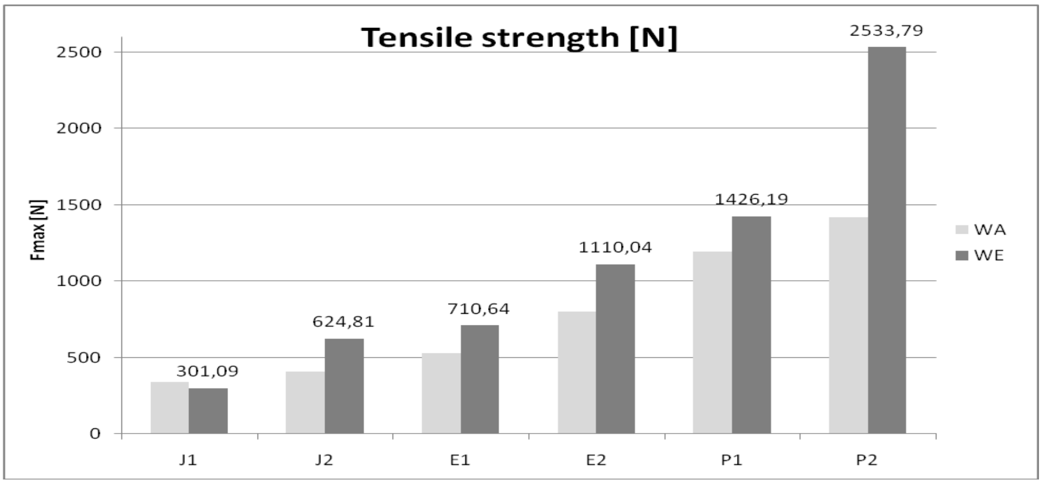

Fig. 7. – Graph of result; average tensile strength from jute fabrics and jute reinforced composites

Tab. 4. – Results comparison

composite parameters		results of measurement	*references result*
jute/epoxy	nominal fibres content	15.53 [%]	*18 [%]*
	force	512 [N]	*748 [N]*
	tensile modulus	1.14 [GPa]	*1.06 [GPa]*
jute/polyester	nominal fibres content	15.21 [%]	*18 [%]*
	force	1283 [N]	*554 [N]*
	tensile modulus	0.93 [GPa]	*0.81 [GPa]*

Tab. 5. – Results comparison

composite parameters		results of measurement	*references result*
jute/polyester	nominal fibres content	30 [%]	*43 [%]*
	tensile modulus	1.3 (wa); 1.8 (we) [GPa]	*9.5 [GPa]*

CONCLUSIONS

From the results it is evident that bio composite production is easy and has good mechanical properties. The low price of the reinforcing material compared to glass or carbon fibres to be noted. Also the environmental footprint is very low compared with technical man-made fibres not only from point of view of easy recycling.

ACKNOWLEDGEMENTS

The results of this project No. LO1201 were obtained through the financial support of the Ministry of Education, Youth and Sports in the framework of the targeted support of the “National Programme for Sustainability I”.

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