THE EFFECT OF MOISTURE ON THE MECHANICAL PROPERTIES OF FLAX PREPREG

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Abstract
Natural fiber reinforced laminates have gradually gained their place in the technical application of fiber-reinforced plastics. The strength of the flax fiber is high; compared to other natural fibers. The deterioration percentage during use is very small. Flax fibers have very good resistance to alkalis, acids and their solutions. The fiber is smooth-surfaced; the degree of its soiling is small. Flax fiber absorbs moisture very well and dries very well. The linen fabrics are hypoallergenic, resist mites, mold, and bacterial contamination. They are particularly suitable for people with various types of allergies, asthma, atopic eczema or psoriasis. Woven fabrics (more usually weave are plain and twill), unidirectional oriented fabric (roving, tapes, and non-crimp fabric) and chopped fibers from flax fibers serve as the reinforcement from natural fibers reinforced plastics (NFRP). Applications of linen fibers reinforced composites include for example sandwich panels (automotive), components for boats (nautisme), floor-wall panel, indoor furniture (building), component for special cars and bikes (sport and leisure), smartphone cover, tablet support (electronics), glasses, musical instrument and other (free time). The article described comparison the mechanical properties of flax fibres reinforced plastics, which was exposed to long-term action of moisture.

Key words: *Flax fibres; epoxy matrix; moisture; mechanical properties; water absorption.*

INTRODUCTION
A composite is defined as a multiphase material; dispersive phase (continuous or particulate) has a reinforcing function, continuous phase is plastic matrix. Synergic effect of phases leads to an improvement in the properties of the composite. Fibres and product of fibres are classified as continuous types of dispersion phases. The type of reinforcement is related to the production technology. The properties of the reinforcement are directly dependent on the types of fibres and production technology. Linum usitatissimum is an annual herb, grown for linen fibre and for seeds containing oil. He was one of the first domesticated plants and used to make textiles. It grows to a height of about 1.2 meters, blooms light blue, the fruit is a capsule. The bast fibre obtained from flax is one of the natural fibres of plant origin. The fibre has a textile use (yarns, threads, fabrics, ropes, medical and food industry) and technical use (flax tow, fow yarns). Flax processing procedure from the plant to the yarn is a technically demanding technological process with many steps. The processing of the stem of the plant yields a technical fibre up to 1 m long, 600 μm in diameter. Technical fibre consists of elementary fibres. The elementary fibre length is 40-60 mm, diameter 20 μm. Nodes are a typical feature of linen fibre, spaced irregularly along the length of the fibre. The microscopic sections show the elementary fibre shape as an irregular polygon with rounded corners (*Fidelis, 2013*). (*Sfiligoj Smole, Hribernik, Stana Kleinschek & Kreže, 2013*) describe detailing the composition of the stem of fibre-forming plants. All plant cells have a primary wall. The secondary cell wall is formed by successive deposition of cellulose layers, which are divided in three sub-layers, of which the middle layer is the most important for fibres mechanical properties. Each of three fibres sub-layers has a different micro fibrillary orientation, which is specific for the fibre type. Study (*Alix, Lebrun, Marais, Philippe, Bourmaud, Baley & Morvana, 2012*) was focused on chemical upgrading functional and mechanical properties of flax fibres with using commercial enzymes. Enzymes influence was monitored by optical microscopy, water sorption measurement and mechanical properties measurement.The moisture absorption and desorption in flax and hemp fibres and yarns investigate (*Mustata & Mustata, 2013*). The results of their experiment supported the conclusion, that the ratio of amorphous and semi crystalline cellulose and the microfibrillar angle defined the difference mechanical properties between other types of fibres. Flax yarns showed an increase in tensile strength in the wet state and during of water absorption in fibres in comparison with the dry state.

When choosing the appropriate type of fibre reinforcement from flax fibres, it is necessary to take into account the method of its preparation - technological process of production. Interesting results brought (*Goutianos, Peijs, Nystrom & Skrifvar, 2006*) in the study the mechanical properties of flax fibres reinforced composites according to technological process of production linen rovings, yarns, woven fabrics and non-crimp fabrics. The results of their study have clearly confirmed that natural firer composites based on continuously produced reinforcement exhibit improved mechanical properties compared to current non-woven reinforcements. They describe a significant influence of twist of longitudinal textiles on the properties of woven and non-crimp composite reinforcements and the effect of twist on the quality of fibre impregnation by the polymer resin. In paper *(Mei-po Ho & all, 2012*) describes the processes for producing composite materials and discusses their suitability for NFRP production. Modelling of mechanical properties of composites requires good knowledge of fibre bundle behaviour during deformation. Paper (*Charlet, Eve, Jernot, Gomina, Breard, 2009*) describes the main characteristics of flax fibre behaviour in connection with their morphology. PhD. thesis (*Aslan, 2012*) deals with the problem of reliable measurement of the real strength of unidirectional composites made from flax fibres. The number of experiments were part of the research; concurrently mathematical models were created using the finite element method. The team (*Zhu, Zhu, Abhyankar & Njuguna, 2013*) investigated the effect of fibre treatment in the bio composite material from linen/tannin and the effect of adjustments on fibre surface appearance and mechanical properties of the composite, because water absorption into bio-composites limits their possibility of outdoor applications. Flax fibres absorb moisture very well and thus changes in mechanical properties. The aim of the study was to test the resistance of flax prepreg to long-term exposure to moisture and determine the size of changes of mechanical properties.

MATERIALS AND METHODS

Flax fibres reinforced composites panel was prepared for experiment. Panel is composed from two perpendicular oriented layers of flax prepreg. Using a two-layer sample for tensile strength test eliminate the need to test the composite in the 0 ° and 90 ° directions. The flax prepreg was composed from unidirectional oriented flax fibres and epoxy resin, weight ratio 50% fibres, 50% epoxy resin. Composite panel was made under conditions recommended by the manufacturer (temperature, humidity pressure). The experiment was based on long-term exposure of water to the flax reinforced polymer plate. The assumption was that when the water was absorbed to flax reinforcement, the strength of the FFRP would change significantly. Parameters of composite plates shows Table 1.

Tab. 1 Flax prepreg panels parameters

No.	Orientation	Weight before water immersion [gm^{-2}]	Weight after water immersion [gm^{-2}]
1	0°/90°	656	658
2	0°/90°	613	612
3	0°/90°	613	615

Three groups of samples were prepared for the tensile strength test. Figure 1 shows specimens preparing for tensile strength test, Figure 2 strength testing machine Tiratest T2400.

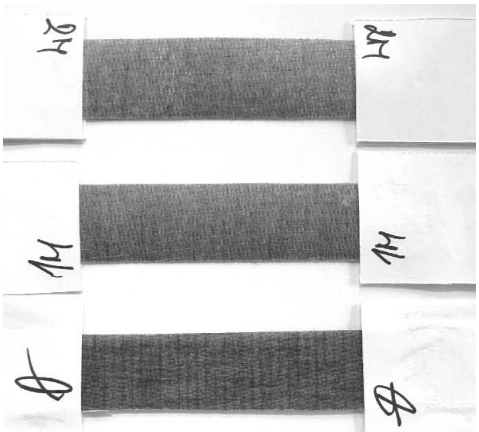

Fig. 1 Specimens for tensile strength test

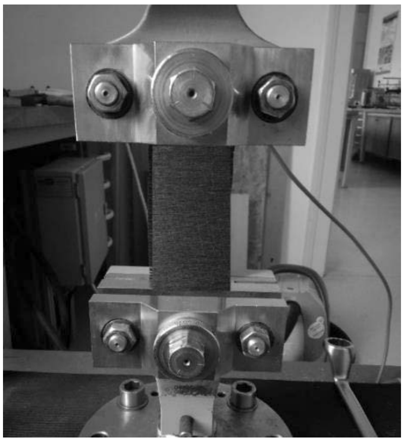

Fig. 2 Strength testing machine

The first group of samples was exposed to water at room temperature and normal humidity to 500 hours, the second group of samples was exposed to water at room temperature and normal humidity of 1450 hours. The last group of samples was used for comparison; the samples were stored at room temperature and normal ambient humidity. Conditioning the samples (after water action) was performed at room temperature and normal humidity for 24 hours.
The specimens for uniaxial stress test was prepared according Standard ČSN EN ISO 527-4. Thickness of specimens was measured using thickness gauge SDL M 034/1. Tensile strength test was realized on strength testing machine Tiratest T2400, speed of test was 2mm/min. Specimens size (length, width and thickness) was entered individually for each specimen. Tensile curves, values of maximum breaking force (F_{max}), maximal strength (R_{max}) and tensile strength modulus (E) were results of test.

RESULTS AND DISCUSSION

Tensile strength test was realized for prepared flax pepreg specimens after long-term water exposure. Water absorption is typical property of flax fibres and flax products. The study (*Mustata, 2013*) describe differences between the breaking force and the strength of dry and wet flax yarns with different fineness and different finishing of rovings. Article (*Alix, 2012*) describe using of different methods for detection of changes of flax fibres properties using enzymatically upgrading. It was used tensile strength test for comparison mechanical properties befor and after enzymes action. Internal structure of flax stem was inspected using optical microscopy.
The study (*Zhu, 2013*) describe influence of fibre treatment to tensile properties and water absorption of flax/tannin composite material. The effect of different chemical reagents on surface of flax fibres was analysed using the SEM micrograph, pure flax fibres and modified fibres was compared. The treatment of fibres was performed to increase adhesion between the flax fibre and the tannin matrix. The tensile strength test was exploited to confirm the assumption of an increase in the mechanical properties of the composite using the adhesion improvement of resin to surface of flax fibres.
Table 2 presents the specimens parameters and statistically processed results of measurement. Tensile curves, values of maximum breaking force (F_{max}), maximal strength (R_{max}) and tensile strength modulus (E) were results of test. Graph of F_{max} values shows Figure 3 and Figure 4 shows specimens after test.

Tab. 2 Results of measurements

FRP	Thickness [mm]	F_{max} [N]	R_{max} [N/mm^2]
0 (1)	0,75	1780,8	79,146
500h (2)	0,60	1785,0	99,170
1450h (3)	0,61	1775,6	92,056

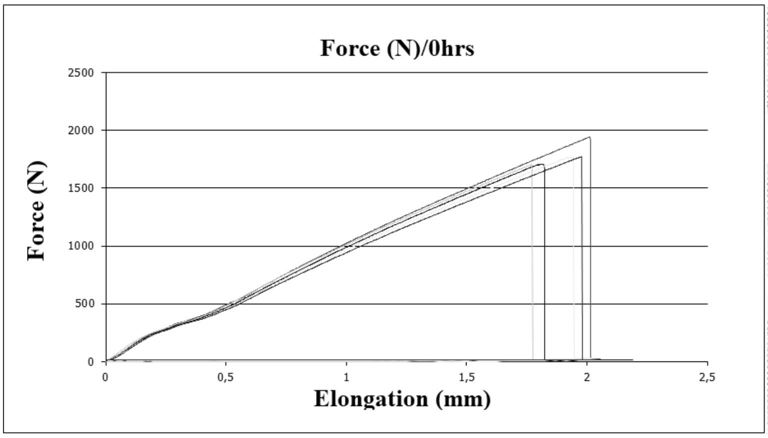

Fig. 3 Graph of maximal force

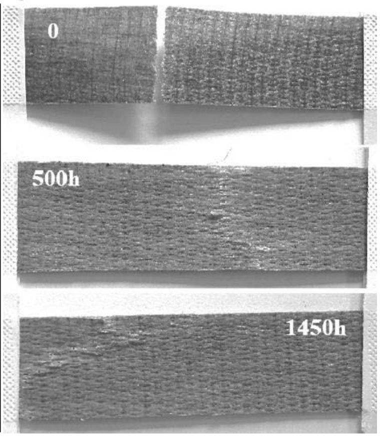

Fig. 4 Specimens after test

Studies that deals with the relationship between mechanical properties of flax and moisture clearly shows that water absorption increases the strength of flax fiber. The experiment did not produce clear results in this direction. The experiment showed only that the specimens of flax fibers reinforced plastic (flax prepreg) absorbed only very little or no moisture.

Changes in appearance of the surface of the specimens were monitored by SEM analysis. The images show that the surface of the specimens remained unchanged overall. Images on specimens affected by water was taken at the point where small white spots/clusters appeared on the surface (Fig 5). The clusters did not affect the mechanical properties of the specimens.

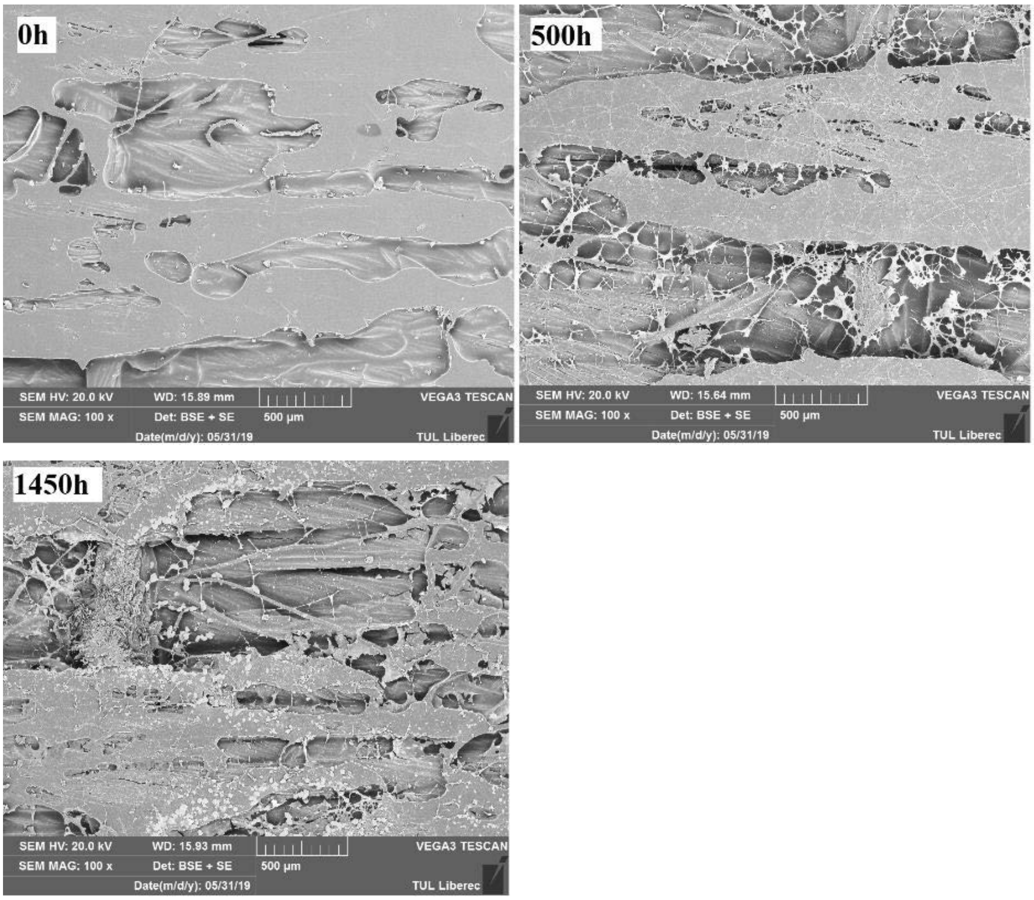

Fig. 5 Surface of composite specimens

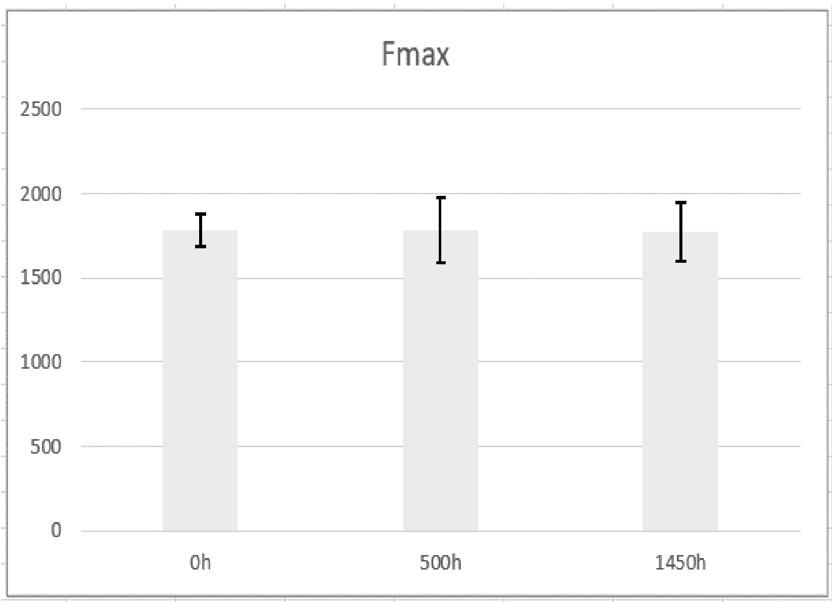

Fig. 6 Comparison of maximal force results

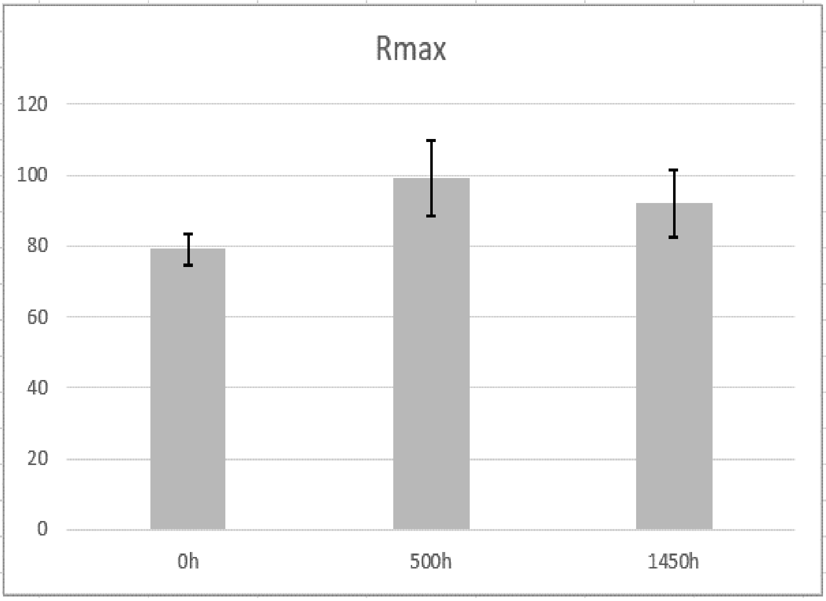

Fig. 7 Comparison of maximal strength results

Comparing the breaking force F_{max} of individual specimens groups is not showing no significant differences. The average values are moving in rang 12N, is not possible to exclude that it is measurement error. The differences for maximal strength R_{max} is more pronounced, but is not possible to exclude that it is measurement error also.

CONCLUSIONS

The influence of moisture on mechanical properties of flax fiber reinforced polymer in this work was studied. Samples made from linseed prepreg were exposed to the long-term effect of water. Results of measurement were obtained during the uniaxial stress test. Statistically processed values were compared. The results cannot be considered conclusive. Differences in values of individual variables are not significantly different.

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