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ESTIMATION OF WEIGHT DECREASE OF WOOD-POLYMER COMPOSITE CAUSED BY WOOD DESTROYING FUNGUS *SERPULA LACRYMANS* (WULFEN) J. SCHRÖT.

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ABSTRACT

This research is focused on estimation of weight decrease for wood-polymer composite made of wood fibers of *Pinus sylvestris* and polyvinylchloride. Wood-polymer composites are produced from wood and polymer particles mixed together with some additives, heated up, blended and usually injected through press matrix to a resulting shape. This newly produced material has properties highly dependent on basic substance and their mutual ratio. For this reason every kind of wood-polymer composite has different properties and of course different resistance to a wood-destroying fungi.

The purpose of this study is to find out what will be the resistance of this material to a *Serpula lacrymans* (Wulfen) J. Schröter in case of optimal growth condition of wood-destroying fungus. For better understanding to the results were made measurements also on the wood samples made of *Fagus sylvatica* L. and compared.

KEYWORDS: Wood-polymer, composite, fungus, *Serpula lacrymans*, weight decrease.

INTRODUCTION

Wood-polymer composites means material made of two major constituents – wood and a polymer. This compound is characterized by properties unlike any of the two original materials. Mutual ratio and type of the two components determine final properties (Rowell 2006). Wood can be used in shape of wood fibers or dust. Using wood fibers instead of dust significantly develop mechanical properties (Clemons 2002). Polymer part of composite can be categorized into thermosetting polymer formerly used and thermoplastic commonly used nowadays. In composite manufacturing thermoplastics are represented by polyethylene, polypropylene and polyvinylchloride (Stephan and Plarre 2008). Except the two major constituents number of additive can be used to improve its manufacturing and properties like color, resistance to biological attack, photo stabilizers, etc. (Morell et al. 2010). Production is made by extrusion, injection molding or compression molding according to product shape and way of production also has impact on the composite properties (Clemons and Ibach 2004).

Wood-polymer composites have a wide possibility of use. They can be used in a building industry, interior design, garden furniture, parts of car and trains, as street furniture and many other (Smith and Wolcott 2006). In Czech Republic is possible to buy wood-polymer composite for use as wall cladding or outdoor floor board.

As an outdoor equipment wood-polymer composite has to withstand biological attack caused by variety of wood-destroying fungi. For laboratory estimation of weight decrease is suitable to choose fungus which appears at the same place as this material is used, so in residential buildings and storage houses.

In the area of middle and north Europe is one of the most danger wood-destroying fungus *Serpula lacrymans* (Wulfen) J. Schröter (Reinprecht 2008). *Serpula lacrymans* is attacking all kinds of wood. Furthermore is attacking materials which consists of cellulose like cardboard, paper, straw, particleboard, etc. (Reinprecht 2008). This is a good reason to use *Serpula lacrymans* for laboratory testing of wood-polymer composite.

For understanding the results of weight decrease caused by wood-destroying fungus *Serpula lacrymans* on wood-polymer composite is suitable to have another package of data from "common" wood samples. Alternative measurement should be then performed on material which has the structure as similar as possible to wood-polymer composite. This condition eliminates all softwood and ring-porous species. The representation in civil building and outdoor equipment then specify *Fagus sylvatica* as a species suitable for comparing with wood-polymer composite.

MATERIAL AND METHODS

Estimation of weight decrease caused by wood-destroying fungus was done according to modified EN 113 1996. This standard is essential for testing wood and because the studied composite has particles of wood fibers it resulted in following this standard also for studied wood-polymer composite (further mentioned as composite) as well as *Fagus sylvatica*.

The chosen wood-destroying fungus is *Serpula lacrymans* (Wulfen) J. Schröter for the reason stated above.

Composite samples were made of material that is possible to buy in Czech Republic. It consists of wood fibers from *Pinus sylvestris* and Polyvinylchloride, exact ratio is not published by importer neither producer. The material was sawn to the dimensions 94x25x8 mm with a volume of 18.75 cm^3. The number of composite samples was 4x30 pcs.

Reference samples were made of sapwood *Pinus sylvestris* L. with dimensions of 20x20x40 mm.

Wood samples were made of natural beech *Fagus sylvatica* L. Karst with dimensions of 20x20x40mm and volume of each sample was approximately 16 cm^3. The number of wood samples was also 4x30pcs.

Samples were marked and inserted into drying machine to dry them up to 0 % of moisture content under the temperature of 103±2°C. Dry samples were weighted with accuracy of 0.01g for estimation of initial weight (m_0).

Culture bottles were prepared by adding 3-4 mm thick layer of cultivation medium at their bottoms. Cultivation medium was Malt extract agar base M137 compounded according to EN 113 1996. Culture bottles were then sterilized in an autoclave under the temperature of 120°C by saturated steam for 20 minutes. After sterilizing and cooling culture bottles at the temperature 21°C were cultivation mediums inoculated by a culture of Serpula lacrymans. Culture bottles were then inserted into incubator for 14 days under the temperature of 21°C for having mycelium all over the cultivation medium surface. Afterwards the sterilized glass pads were laid on the mycelium to prevent contact between mycelium and samples. On this glass pads were placed sterilized samples. Culture bottles were then placed back into incubator for the time 4, 8, 12, and 16 weeks.

In 4, 8, 12 and 16 week period were one wood and one composite sets of samples removed from culture bottles for data evaluation. Samples were cleaned and weighed with an accuracy of 0.01g (m_2). Furthermore the weighed samples were dried up to 0 % of moisture content under the temperature of 103±2°C and weighed again with an accuracy of 0.01 g (m_3). At the end of the data evaluation the moisture content was estimated (m_2-m_3) in percentage to the final weight of absolutely dry samples (m_3). For each tested sample was estimated weight decrease (m_0-m_3) as percentage to the weight of absolutely dry sample (m_0).

RESULTS

Estimated data were statistically processed in program Statistica. The results are summarized in Tab. 1. for composite samples and Tab. 2. for samples of *Fagus sylvatica*.

For better understanding the results were made box graphs. Fig. 1 indicates weight decrease of composite samples during exposition to wood destroying fungus *Serpula lacrymans*. Fig. 2 indicates then weight decrease of wood samples *Fagus sylvatica*.

We can say that the results of composite samples are more or less variable with coefficient of variation up to 20 %. For samples of *Fagus sylvatica* was variation coefficient 46 % for the first set of samples (4 weeks of degradation), 80 % for the second set of samples (8 weeks of degradation), 47 % for the third set of samples (12 weeks of degradation) and 30 % in the last set of samples (16 weeks of degradation). Variability of results for *Fagus sylvatica* is much higher for the second measurement with decreasing trend for further testing.

Tab. 1: Descriptive statistics of weight decrease for wood-polymer composite samples.

	N samples	Average	Median	Minimum	Maximum	Quantile	Quantile	Standard deviation	Coeff. of variation
4 weeks (%)	30	0.077	0.077	0.053	0.135	0.059	0.088	0.015	19.860
8 weeks (%)	30	0.143	0.145	0.096	0.263	0.105	0.161	0.030	21.294
12 weeks (%)	30	0.352	0.361	0.254	0.606	0.274	0.378	0.063	17.824
16 weeks (%)	30	0.822	0.837	0.574	1.101	0.618	0.956	0.129	15.708

Tab. 2: Descriptive statistics of weight decrease for wood samples of Fagus sylvatica L. Karst.

	N samples	Average	Median	Minimum	Maximum	Quantile	Quantile	Standard deviation	Coeff. of variation
4 weeks (%)	30	0.176	0.176	0.054	0.441	0.072	0.270	0.081	46.193
8 weeks (%)	30	1.717	1.408	0.075	6.210	0.491	3.365	1.367	79.594
12 weeks (%)	30	7.555	6.552	2.256	15.666	3.354	12.198	3.533	46.762
16 weeks (%)	30	20.726	20.350	6.975	40.100	13.365	26.505	6.274	30.270

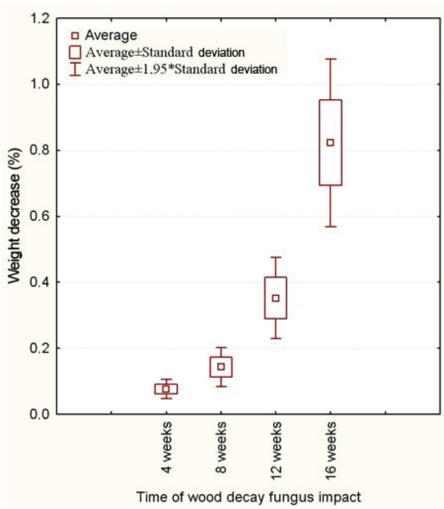

Fig. 1: Weight decrease of wood-polymer composite samples caused by wood destroying fungus Serpula lacrymans.

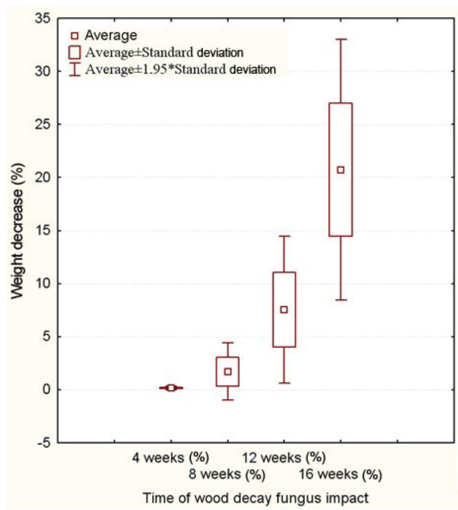

Fig. 2: Weight decrease of wood samples made of Fagus sylvatica L. Karst caused by wood destroying fungus Serpula lacrymans.

Tab. 3: Moisture content of wood-polymer composite samples after 4, 8, 12 and 16 weeks of wood destroying fungus Serpula lacrymans impact.

	N samples	Average	Median	Minimum	Maximum	Quantile	Quantile	Standard deviation	Coeff. of variation
4 weeks (%)	30	2.350	2.400	1.970	2.644	2.079	2.516	0.166	7.061
8 weeks (%)	30	5.112	5.216	4.291	5.753	4.530	5.468	0.358	7.005
12 weeks (%)	30	7.842	8.012	6.584	8.829	6.955	8.394	0.548	6.990
16 weeks (%)	30	9.209	9.403	7.728	10.362	8.163	9.849	0.645	7.006

Moisture content of composite samples were also processed by Statistica software and summarized to Tab. 3. In box Fig. 3. is possible to see moisture content for samples exposed 4, 8, 12 and 16 weeks to wood destroying fungus *Serpula lacrymans*.

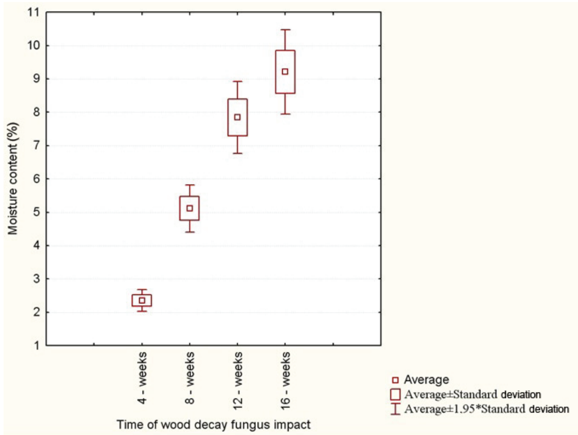

Fig. 3: Moisture content of wood-polymer composite samples in time of wood destroying fungus activity.

Tab. 4: Descriptive statistics of weight decrease for reference samples of sapwood Pinus sylvestris L.

	N samples	Average	Median	Minimum	Maximum	Quantile	Quantile	Standard deviation	Coeff. of variation
4 weeks (%)	6	5.301	5.235	4.263	6.890	4.680	5.503	0.908	17.122
8 weeks (%)	6	11.413	11.161	10.858	12.256	10.907	12.133	0.622	5.453
12 weeks (%)	6	16.313	16.493	15.242	17.380	15.296	16.978	0.875	5.366
16 weeks (%)	6	22.203	22.144	21.882	22.501	22.075	22.472	0.240	1.081

DISCUSSION

The results of laboratory testing durability of wood according to weight decrease can be classified into five groups. In the first group is wood with very high resistance to wood destroying fungus. Weight decrease is none or minimal (by EN 113 1996 have to be the ratio between tested wooden material and beech $\leq$ 0.15, so decrease of weight for wood-polymer have to be in this experiment less then 3 % /3 : 20.726 $\leq$ 0.15/). From average value 0.822 % of weight decrease of wood-polymer composite after 4 months of wood destroying fungus impact on samples we can classify this material among first class wood, very resistant to wood destroying fungus.

One of the main reasons for higher resistance to wood-destroying fungus can be seen in structure of the composite. Wood is decomposed to wood fibers mixed with polymer and processed by profile extrusion. All these steps have an impact on the wood fiber length making them smaller (Rowell 2006). Also during profile extrusion wood fibers are dispersed in polymer.

This prevents *Serpula lacrymans* to grow from surface deeper into composite as well as it prevents increasing moisture content of composite.

Moisture content is the second major condition for growing wood-destroying fungus *Serpula lacrymans*. The optimal moisture content for decomposition of wood caused by *Serpula lacrymans* is 30-40 % with having significantly lower growing speed and stopping of its growth if moisture content was under 18-20 % (Reinprecht 2008). The average measured moisture content of composite samples was only 2.35 % after 4 weeks of exposure to *Serpula lacrymans*. Not even *Serpula lacrymans* was able to increase moisture content of tested samples to its optimal value as it is doing with other material. Reason can be deduced from the structure of composite and the ratio between wood fibers and polymer and also in way of composite production (Clemons 2002). Production of composite is at temperature high above the water boiling point. Moisture is highly decreased and wood fibers are then enclosed by polymer so they cannot absorb moisture from surroundings. Initial conditions for wood destroying fungus expansion are less favorable in the composite then in "simple" wood where fibers are mutually connected and using certain forces balances moisture content between surface and inner parts. *Serpula lacrymans* is able to make water from cellulose decomposition (Unger et al. 2001) and use it for its own growing. However the final average moisture content of composite samples was 9.2 % at the end of tests, so after 16 weeks. This value is still too low to provide optimal mycelium growing.

In the Tab. 2, which describes *Fagus sylvatica* samples, is possible to see that after 16 weeks of wood destroying fungus *Serpula lacrymans* activity is average weight decrease 20.7 %. Although graphical expression of the weight decrease in time looks to have approximately same course for both materials – beech wood and wood-polymer composite, absolute values are very different. In four weeks of samples decomposition by *Serpula lacrymans* had wood samples 2.2 times higher weight decrease then composite samples. In eight weeks it was 11.9 and in twelve weeks already 21.5 times higher weight decrease for wood samples. At the end of testing wood was decomposed 25.2 times more then composite. These values clearly show the difference between mycelium growing between structure where fibers are connected together through whole material and structure where fibers are enclosed by material which doesn't succumb to decomposition by *Serpula lacrymans*.

CONCLUSIONS

Serpula lacrymans participates almost by 50 % on the damages caused by wood-destroying fungi in buildings over the Europe. In spite of the ability to decompose wood and material consists of cellulose wood polymer composite wasn't very affected. Average value of weight decrease was 0.82 % after 16 weeks of its activity. Average moisture content of the tested samples was 9.2 % at the end of testing period.

So low value of moisture content after 4-month lasting activity of *Serpula lacrymans* is explained by a structure of wood-polymer composite and manufacturing technology during which wood particles are mixed together with polymer at high temperatures (Clemons 2002).

We can state that the studied wood-polymer composite is highly resistant to activity of *Serpula lacrymans*.

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