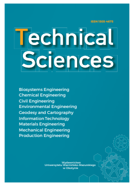
Technical Sciences, 2021, 24(1), 5–11

Quarterly peer-reviewed scientific journal
ISSN 1505-4675
e-ISSN 2083-4527
TECHNICAL SCIENCES
Homepage: www.uwm.edu.pl/techsci/



DOI: https://doi.org/10.31648/ts.5845

IMPACT OF MICROORGANISMS ON MECHANICAL PROPERTIES CHANGES OF COMPOSITE MATERIALS WITH SAWDUST AS ORGANIC FILLER

***Piotr Mazur*[1], *Jarosław Szuszkiewicz*[2]**

[1]ORCID: 0000-0002-5596-091X
[2]ORCID: 0000-0002-4490-3397
Institute of Fluid Flow Machinery
Faculty of Technical Sciences
University of Warmia and Mazury in Olsztyn

Received 10 September 2020, accepted 23 February 2021, available online 12 March 2021

Keywords: polymer, composite, organic filler, microorganisms, impact strength, polyethylene.

Abstract

The beginning of the XXIst century is characterized by rapid development of polymer materials, including polymer composite materials, which consist of a natural organic filler (wood flour, sawdust, cellulose fiber, flax fiber, sisal fiber) and reinforcement carrier (polymer). In case of that kind of the fillers under the influence of weathering (humidity, temperature) they might be subject to biodegradation due to effect of microorganisms, including funguses, which are responsible for degradation of natural organic fillers. In case of the low melting temperature polymers (e.g. PE-LD) the processing temperature does not entirely eliminate some of the fungal spores. The paper has presented the research results of twelve months. The development of the microorganisms in the natural conditions was examined in a pure filler (sawdust) as well as in a composite. Simultaneously, change of one of the fundamental strength properties, which is the impact strength, was being tested. For the investigated composite the PE-LD as the matrix and a sawdust mixture of pine, larch and oak were used. The sawdust formed the composite in 30% vol. The research results confirmed that in the natural conditions the microorganisms development depends on weathering which varies in the time of the year. The value of the *V* notch impact strength changed from 12.5 kJ/m^2 for the composite in initial phase to the value of 6.7 kJ/m^2 after twelve months operation, which is close to 54%.

Correspondence: Jarosław Szuszkiewicz, Katedra Technologii Materiałów i Maszyn, Wydział Nauk Technicznych, Uniwersytet Warmińko-Mazurski, ul. Oczapowskiego 11, 10-718 Olsztyn, phone: +48 89 523 36 64, e-mail: jerry@uwm.edu.pl

Introduction

The dynamic research development on polymers can be noticed since the second half of the XXth century (BARTON 2014). One of the directions is creation of polymer composites with natural organic fillers. The thermoplastic polymers (usually of low melting temperature) are used as matrix and plant fibers or sawdust (byproduct of wood processing) might be applied as a filler (GARBARCZYK et al. 2009).

The paper discusses a problem of mechanic properties change on an example of *V* notch impact strength of mentioned above composites connected with their destruction while exploited in outer conditions under influence of microorganisms (MIEDZIANOWSKA et al. 2018).

Materials and Methods

Low Density Polyethylene (PE-LD) was selected as the matrix because of common use and low temperature processing. Sawdust was the filler. It was composed of residue of processing of three tree species: pine, larch and oak. Sawdust share in polymer was equal to 30%. That type of composite can be applied for roofing of lightweight construction building, e.g. shed, garage, holiday cabin, deck, etc.

The composite has been produced as 4 mm plates by the extrusion method. The extruder was one screw type. The rotational speed of a screw was equal to 70 rpm. The working temperatures were as follows: feeding device – 125°C, charging barrel – 130°C, extruder head – 130°C, nozzle – 135°C. Sawdust prior to addition to the polymer was dried to the level of 0.1% (KOSZKUL 1999), which is the moisture limit value for PE-LD processing. Usually, no additional chemicals protecting against harmful effects of microorganisms during exploitation of a composite are used (POSTAWA et al. 2010).

The examined composite was kept in outer weather conditions (moisture, temperature) as the exploitation conditions are. The *V* notch strength research was done every 8 weeks for 12 months. Simultaneously, the presence and content of microorganisms in sawdust and the composite was investigated.

The maximum processing temperature (135°C) did not guarantee getting rid of all the microorganisms, primarily fungal spores, which are resistant to that level of that temperature. Regarding to the wood composition (cellulose 51%, hemicelluloses 23%, lignin 23% and other organic compounds 4%) and proper atmosphere conditions (moisture and temperature) the microorganisms can freely grow. That state may lead to the sawdust decomposition and further partial biodegradation of the composite (MAŃKA 2011).

The *V* notch impact strength research has been carried out by the Charpy impact test method according to the standard procedure. The *V* notch impact strength samples were cut mechanically to the following dimensions: 80(±2) mm × 10(±0,5) mm × 4(±0,2) mm. The angle of the *V* notch equaled 45°±1°. The fillet radius was up to 0.2 mm. Each series of research consisted of 12 measurements. Two extreme results were rejected and on the basis of ten remaining measurements the mean value was calculated.

Out of the investigated sawdust and composites there were prepared series of 10-fold solutions by moving of 10 g of sawdust or shredded composite to a sterile bag. Subsequently, 90 cm^3 of the solution liquid was added to the bag and the content was homogenized in a stomacher (Seward, Great Britain) for one minute. Following this period the supernatant liquids were decanted to sterile Schott bottles and microbiological determinations were carried out in the sawdust and composite: raw sawdust (Fig. 1), after two weeks, after one month, after two months (Fig. 2) and composites just after production, after two weeks, after two months, after four months (Fig. 3) and after six months of storage (Fig. 4).

The Total Bacterial Count (TBC) was determined by transferring 1 cm^3 of selected solutions to the sterile Petri dishes with three replicates. The transfers were poured with the nutrient agar (Merck, Poland). They were mixed up and after solidifying they were incubated at the temperature of 30°C for 72 hours. Following the incubation all the grown colonies were counted and taking under consideration the solutions the result in cfu/g of the investigated sample was given.

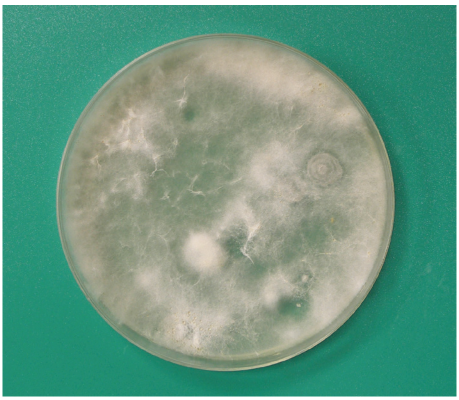


Fig. 1. Raw sawdust after pick up from sawmill

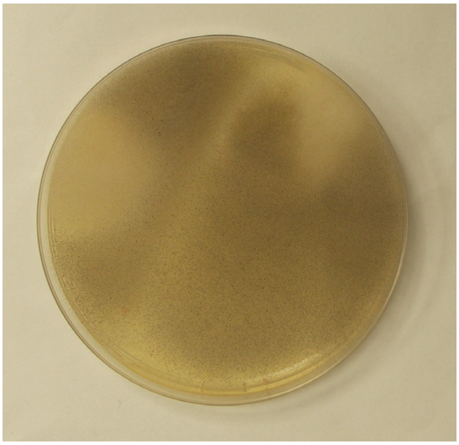


Fig. 2. Growth of fungi in sample of sawdust after two months

Fig. 3. Growth of fungi in composite after four months of storage in natural conditions

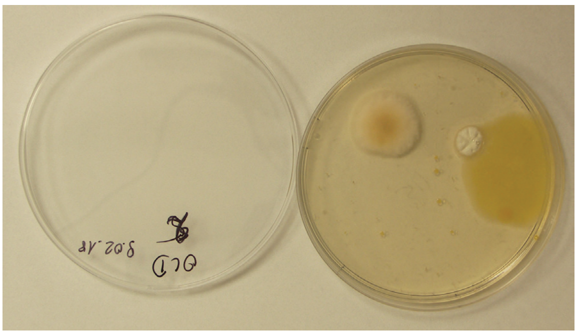


Fig. 4. Growth of fungi in composite after six months of storage in natural conditions

The number of fungi (yeasts and molds) were determined by transferring 1 cm^3 of selected solutions to the sterile Petri dishes with three replicates. The transfers were poured with YGC agar (Merck, Poland). They were mixed up and after solidifying they were incubated in the temperature of 25°C for 5 days. Following the incubation all the grown colonies of yeasts and/or molds were counted and taking under consideration solutions the result in cfu/g of the investigated sample was given (POSZYTEK 2016).

Results Analysis and Conclusions

The results of the investigation of the *V* notch impact strength value was presented in the Table 1. The course change of the *V* notch impact strength was presented in the Figure 5. The Table 2 presents the results of the microbiological analysis of the sawdust and composite materials.

Table 1

V notch impact strength results

Time [months]	*V* notch impact strength [kJ/m^2]
0	12.51
2	11.39
4	9.3
6	10.88
8	8.01
10	7.36
12	6.7

In the raw sawdust the TBC number was high of about 10^7 cfu/g and during storage it was increasing which resulted in the growth of the fungi number. Directly after the production of the composite of the polymer and sawdust the TBC as well as the number of fungi were very low (about 10^1 cfu/g). This considerably significant decrease of the number of both groups of microorganisms relates to high temperature production procedure. During four months of storage, slowly but successively, the general number of microorganisms in the composite was increasing and number of fungi lingered at about the same number from the second month of storage.

The obtained results indicated that *Bacillus* sort dominated among the bacteria. These bacteria are capable of surviving in high temperatures applied during the composite production process. They owe this to the sporulation ability. Some of those bacteria, like *B. pumilus* and *B. circulans*, have cellulolytic

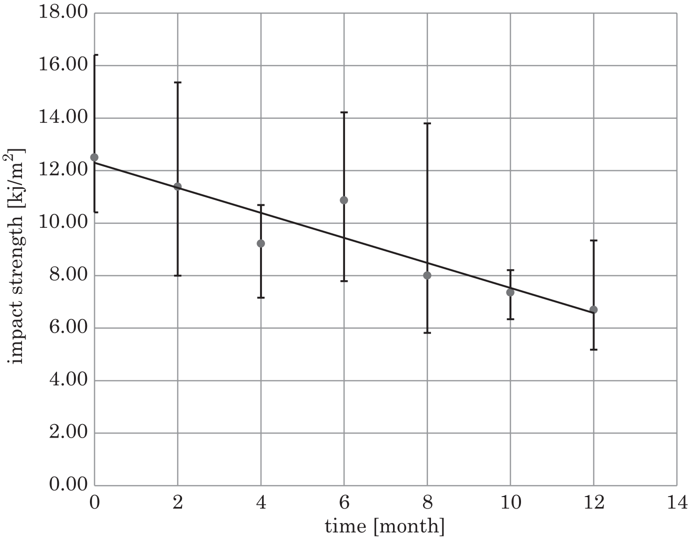


Fig. 5. Changes in the *V* notch impact strength for the composite

Table 2

Microbiological analysis of samples

Sample	Number [cfu/g]	
	Total Bacterial Count (TBC)	Microscopic fungi
Sawdust (Raw)	$4.6 \cdot 10^7$	$4.2 \cdot 10^5$
Sawdust (2 weeks)	$7.25 \cdot 10^7$	$1.4 \cdot 10^7$
Sawdust (1 month)	$5.0 \cdot 10^5$ (Molds $7.1 \cdot 10^6$)	$1.1 \cdot 10^7$
Sawdust (2 months)	$3.5 \cdot 10^5$ (Molds $1.5 \cdot 10^6$)	$2.2 \cdot 10^6$
Composite material	$7.5 \cdot 10^1$ (spore-forming bacteria, e.g. *Bacillus*, that survive sterilization temperature even for several minutes) + white downy molds	$3.0 \cdot 10^1$ (white downy molds fouling all the plate)
Composite material after 2 months	$1.2 \cdot 10^3$ (mainly *Bacillus* bacteria type; single mold colonies)	$5.5 \cdot 10^1$ (flat colonies, low; grey or black colonies; other colonies are yellow, hyphae quite high, loose; *Zygomycetes* class – sporangium)
Composite materials after 4 months	$9.1 \cdot 10^3$ (including molds)	$4.8 \cdot 10^2$
Composite materials after 6 months	$1.08 \cdot 10^4$ (molds $4.0 \cdot 10^2$; mainly *Penicillium*)	$1.3 \cdot 10^2$
Composites after 8 months	$4.1 \cdot 10^2$	$2.1 \cdot 10^2$

properties thus they contribute to decomposition of the cellulose contained in sawdust. Yet, the microscopic fungi, especially *Trichoderma*, *Penicillium*, *Aspergillus*, *Fusarium*, etc., have greater cellulolytic capability (POSZYTEK 2016). So, their metabolic activity may become a reason of loss of lignocellulosic components contained in sawdust, and thus they weaken the composite structure.

The *V* notch impact strength changed from 12.5 kJ/m^2 in the initial phase to 6.7 kJ/m^2 after twelve months of exploitation, so by almost 54%. The rate of changes of *V* notch impact strength values depends on the rate of multiplication of microorganisms connected with weather conditions (according to the season of a year). Therefore, it is deliberate to apply additional means to avoid microbial growth in that sort of the composite materials.

References

BARTON J. 2014. *Polymer composites, biocomposites and nanocomposites. Obtaining, composition, properties and fields of application*. Chemik, 68(4): 280-287.

GARBARCZYK J., PAUKSZTA D., BORYSIAK S. 2009. *Thermoplastic polymer composites with lignocellulosic materials*. Mechanics, 106(1-M): 93-97.

KOSZKUL J. 1999. *Polymer Materials*. Wydawnictwo Politechniki Częstochowskiej, Częstochowa.

MAŃKA M. 2011. *Forest Trees Diseases*. Powszechne Wydawnictwo Rolnicze i Leśne, Warszawa.

MIEDZIANOWSKA J., MASŁOWSKI M., STRZELEC K. 2018. *The natural fiber reinforced polymer composites - factors affecting the mechanical performance*. Technologia i Jakość Wyrobów, 63: 45-54.

POSTAWA P., STACHOWIAK T., SZAREK A. 2010. *Research of properties of wood-polymer composite using DMTA method*. Kompozyty, 10(3): 266-269.

POSZYTEK K. 2016. *Microbial cellulose utilization*. Postępy Mikrobiologii, 55(2): 132-146.