Research Article

Janis Kajaks*, Karlis Kalnins, and Juris Matvejs

Accelerated aging of WPCs Based on Polypropylene and Birch plywood Sanding Dust

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Abstract: A lot of researchers are closely related with natural, lignocellulose fibre containing bio-composites production and studies. Various of polymer matrices, mainly polyolefins, combinations with natural fibres as a reinforcement are used. Our studies are focused on polypropylene based bio-composites containing birch plywood production by-product sanding dust (PSD) accelerated weathering processes. The obtained results showed the following sight. After the aging the surface of all samples had faded, the changes of the gloss (decreasing) and of the whiteness degree (increasing) also had taken place, but microhardness of the surface of specimens significantly has decreased. The tensile strength and modulus of the samples after UV aging diminished about 30-35%. That indicates to the changes not only in the surface layers of polymer but also inside of the polymer structure. The FTIR measurements showed that during UV aging process occurs significant changes of chemical structure of the weathered surface of all samples. DSC measurements showed an increase of degree of crystallinity of the weathered polypropylene composites after the first heating due to the recrystallization process in the polypropylene matrix and a small decreasing after second heating. The melting temperatures of all composites after UV aging considerably diminish up to 30°C.

Keywords: composites, mechanical, thermal, aging, properties

1 Introduction

During the last 20-30 years, many researchers have paid attention to the studies of exploitation properties of wood plastic composites (WPCs) [1–8]. The most useful from the wide selection of polyolefins is polypropylene (PP) [2–8], but as a reinforcement of WPCs different waste materials comprising lignocellulose fibres often are used. Such materials also are different wood residues which arise for example in the plywood production industry [9–12]. A lot of researchers have cleared up the influence of the wood fibre on different exploitation properties of the WPCs such as physical- mechanical indices, water resistance and technological properties [1–12]. All these properties considerably depend on the type of the fibre, fibre length (l), l/d ratio and interaction mechanism on the surface between the wood fibre and polypropylene matrix [1–12].

Our previous studies [9–12] showed that the plywood sanding dust (PSD) are a promising reinforcement of the PP [9–11] and of high-density polyethylene (HDPE) [12] matrices. The additives of the PSD up to 40-50 wt.% increase the tensile and the flexural modulus and the microhardness but decrease the deformation ability of the PP and the HDPE matrices. The impact strength and water resistance as well as the fluidity of the composite melts also diminish. The modifying of composites with a coupling agent maleated polypropylene (MAPP) or a maleated polyethylene (MAPE) (up to 3-5 wt.%) significantly improves of all the above-mentioned properties. The tensile and flexural strength and modulus, the microhardness, the impact strength and the water resistance increase to compare with unmodified composites. The investigated WPCs practically do not swell in water and a total amount of absorbed water after 600 h of the water uptake is no more than 2.2% at the presence of coupling agents.

Nevertheless, all these excellent properties of WPCs can become worse during their exploitation in an open air under an influence of environment conditions. Therefore, many researchers in the world deal with investigations of the accelerated aging process of WPCs, including the WPCs based on the polypropylene [13–29]. Thus authors [13] have showed that the accelerated weathering

*Corresponding Author: Janis Kajaks: Institute of Polymer Materials, Faculty of Materials Science and Applied Chemistry, Riga Technical University, Riga, LV-1048, Latvia; Email: janis.kajaks@rtu.lv

Karlis Kalnins: Institute of Polymer Materials, Faculty of Materials Science and Applied Chemistry, Riga Technical University, Riga, LV-1048, Latvia; Troja LTD, Riga, LV-1004, Latvia

Juris Matvejs: Latvijas Finieris JSC, Riga, LV-1004, Latvia

of the samples during 400-2000 h is equivalent at least 2-3 years aging time under natural conditions. The main influence on WPCs aging process has UV radiance, then oxygen, humidity and temperature of air [13]. Moreover, intensified weathering of WPCs materials occurs on the surface of the samples. Author [37] also have showed that during aging negative effects slowly can spread deeper into the hemp fibre/polyethylene materials up to the depth of 18-36 microns. The profound accelerated aging process of the WPCs based on the polypropylene have studied in the works [13-29]. It is well known fact that polypropylene due to their macromolecules structure is very sensitive against UV radiance and at the presence of the oxygen begins to oxidize [18, 21]. As a result, in the polypropylene structure develop a lot of oxygen containing chemical groups what promote the absorption of the UV rays [14]. Besides the wood fibres works as UV ray absorption intensifier in the PP. That the extension of the wood fibre content in the WPCs from 25 up to 50 wt.% degradation degree of the polypropylene grows up to 2 times [14]. To evaluate of the changes in the WPCs which take place during aging process, researchers study the physical-mechanical properties (strength, hardness), the surface condition changes (colour, gloss, roughness degree, cracks and voids), estimate the changes in the volume of the polymer (molecules mass, degree of crystallinity, thermal destruction processes and so on) [19]. That authors [13, 18, 20-22] have shown that during the aging of the WPCs significantly changes the colour of specimen surface. The samples lose the colour and become grey. Alterations of the surface layers are possible to see in the SEM pictures of the surface replicas [18]. Degradation of the polypropylene matrix arises molecules mass and melting temperature decreasing, but due to the recrystallization process the degree of crystallinity of the polypropylene increases [18, 21]. Furthermore, the number of additional =CO and -COOH groups have arisen. The coupling agent MAPP intensifies UV ray's absorption. After 960 h of the weathering increases the roughness, diminishes the gloss of the surface. The lignin which contain wood fibre stabilizes WPCs materials because it absorbs up to 80% of the rays and this process takes place during the first 240 h of the weathering [18]. Due to the burst of the cellulose fibre mechanical properties of the WPCs decreases. That authors [19], studying PP composites with the pine wood fibre (10-30 wt.%), noted that the photo-degradation processes significantly accelerate at the presence of water and in WPCs occur all of the previously mentioned phenomenon. The authors [15, 25] have cleared up that degrade also the layers of the surface border between the wood fibre and the polypropylene matrix. Due to these processes the wood fibres are able to pull out from the polymer matrix and

the WPCs easy fracture. The presence of water stimulates this breaking process. The loading of stabilizers in WPCs can significantly to prevent the weathering effects and to prolong the service time of materials [14, 15, 18, 22]. In the details an influence of the antioxidants on the weathering of the WPCs based on PP was investigated by authors [18]. The additives of the antioxidants (0.2-0.3%) diminish surface defects, the longer time (up to 480-720 h) and samples maintain the colour and the gloss of the surface. The recrystallization process of the PP occurs during the 240-480 h of the weathering, but during the 720-980 h period of UV exposure takes place the fracture of the wood fibre and the naked fibres appear on the surface of specimens. The presented of all the previous study results show that during the accelerated weathering processes occur essential changes in all components of the WPCs which arise the significant decreasing of the exploitation properties of WPC materials.

Our previous studies [29] of accelerated UV weathering of WPCs based on the polypropylene and plywood sanding dust (PSD) showed that the surface of all investigated samples significantly ages during artificial weathering. The degree of aging considerably depends on composition of the composites. The measurements of colorimetric analyses of the changes in a lightness and a common changes of the colour revealed that the best stability against UV aging show composites with UV stabilizers and pigments. These systems have the smallest changes of the whiteness degree, of the lightness and a common changes of the colour. After 1000 h of the UV weathering the DSC analyses results showed an increase of the degree of crystallinity of the PP in the surface layers of the samples. Due to the recrystallization processes which occur in PP matrix can improve mechanical properties of the composites. In our case the tensile strength of WPCs had no significant changes after the weathering. Seems that the serious changes during accelerated weathering occur only on the surface and in the surface layers of the samples. It was confirmed with selective increase of the tensile strength and significant increase of the tensile modulus of all composites. Looking over SEM images of the surface of the samples before and after the weathering we concluded that the surface of initial samples is not sufficiently smooth and there are no cracks and serious voids but after the 1000 h of artificial weathering the condition of the surface is worse. The surface of the samples had become rougher and a lot of different shapes and sizes of cracks and another voids in polymer matrix were observed.

The goal of this work was to study how accelerated weathering process influences wood plastic composites based on polypropylene and birch plywood production by-

product-sanding dust structure and exploitation properties. To estimate the changes of the surface of WPC materials the measurements of colour, gloss, whiteness degree and microhardness were done. To evaluate of the structural changes into the surface layers and thermal properties of the weathered specimens FTIR and DSC investigations were made. The changes of mechanical properties were noted by tensile strength tests.

2 Materials and methods

UV accelerated aging investigations were exposed five types of the industrially prepared by extrusion process (temperature 215°C) WPCs based on polypropylene (PP) the birch plywood sanding dust (PSD). The UV accelerated weathering was realized in the UV chamber (Q-UV Spray with Solar Eye Irradiance control) corresponding with ASTM G154 (2004) standard during 814 h (68 cycles, each cycle 12 h: 8 h exposure to UV rays, temperature 60°C, 4 h in water steam, temperature 50°C, irradiation power 0.89 W/m²). As a polymer matrix serves polypropylene type TATREN HT 306 with melt flow index MFI = 3.0 g/10min. As a reinforcement the birch plywood production by-product-sanding dust (40 wt.%) with fractions by length of the fibre more than 500 microns (1.04%), between 250-500 microns (32.16%) and smaller than 250 microns (66.8%) were used. The composites also contain different additives like functional lubricant Struktol TWP, antioxidant, thermal and UV stabilizers. To colour the composites three pigment concentrates (PC) based on LDPE with carbon black (T-1, T-2, T-3), blue (T-4) and orange (T-5) were used. Precise compositions of PC are not revealed by producers. The composition of the tested composites is given in the Table 1.

Before and after the weathering (814 h) of the samples (UV light wave length 340 nm) for all specimens the whiteness degree (extent), the surface gloss, the changes of the surface colour and microhardness were noted. The colour changes were evaluated by Colour colorimeter anal-

yser (Easy Colour QA+Software CQA Easy Colour V3.0 light origin D₆₅ angle of observation 10° 1964). The whiteness degree of specimens was observed with equipment NOVO-SHADE DUO™ 45°/0 opacity/shade Meter). The gloss of the surface was measured with NOVO-GLOSS LITE™ Statistical Glossmeter at standard parameter 60°. The tensile strength experiments of the composites according to the standard ASTM 638 M (EN ISO 527-2:2012) were made. Microhardness measurements by Vickers M-41 at the load 200 g were done. The evaluation of the structural changes of material in the surface layers was made by Differential Scanning Calorimeter (DSC) measurements on Mettler Toledo DSC-1 apparatus at the heating rate 10°C/min. by 220°C. The degree of crystallinity was calculated as in [18, 29]. To evaluate the chemical changes on the surface of the composites during UV aging Fourier transform infrared spectroscopy (FTIR) was used. Type of apparatus Thermo Fisher Scientific, Nicolet 6700. FTIR spectrums were taken in the interval 650 up to 4000 1/cm with distinction ability 16 1/cm and reflection method.

3 Results and discussion

The results of tensile strength and microhardness measurements are presented in the Table 2. There we can see that the values of the tensile strength, modulus and deformation at break for initial, non-weathered specimens are similar. Some small differences of results of the surface microhardness tests are observed. May be it is related with the presence of different types of pigments in WPCs. During the UV weathering have taken place significant changes in WPCs structure, because the tensile strength and surface microhardness of the weathered* samples considerably decrease. That the tensile strength diminishes about of 30% (tensile strength measurements absolute mistake was 0.791-2.175 MPa that is approximately 10%), tensile modulus up to 1.5 times but microhardness decreases till 2 times. These results differ from our previous investigations made in [29]

Table 1: Composition of WPCs based on polypropylene + 40 wt.% birch plywood sanding dust (PSD)

Comp.	PSD, wt. %	Struktol TWP, %	1010 antiox. %	168 therm. stab. %	770 UV stab. %	Pigm. conc. %	Bondyram 1004-MAPP, %
T-1	40	3	0.33	0.33	0.50	2	3
T-2	40	3	0.33	0.33	0.33	2	3
T-3	40	3	0.33	0.33	0.75	2	3
T-4	40	3	0.33	0.33	0.50	2	3
T-5	40	3	0.33	0.33	0.50	2	3

Table 2: The results of tensile tests and microhardness measurements of non-weathered and weathered* composites

Composites.	Tensile test			Microhardness
	Strength, MPa	Modulus, E, MPa	Elongation at break, %	HV, MPa
T-1	29.71	2427	4.15	149.8
	21.22*	1767*	4.33*	68.4*
T-2	30.19	2425	3.67	141.1
	21.54*	1803*	4.37*	71.0*
T-3	23.22	1975	4.30	145..4
	21.59*	1776*	4.17*	84.2*
T-4	31.67	2549	3.62	146.4
	20.98*	1798*	4.02*	124.1*
T-5	29.12	2327	4.00	154.5
	19.43*	1668*	4.71*	83.12*

where tensile properties of the samples improved after UV aging. It could be explained with different composition of WPCs. WPCs used in [29] did not contain coupling agents MAPP. In the literature [18] exist information that polar, oxygen containing groups containing additives like interfacial modifiers, maleated polypropylene waxes can promote UV irradiation process what evidently has occurred in our studies. Despite of the low initial tensile strength the smallest decreasing of the tensile properties of the weathered* samples in comparison with non-weathered is observed for system T-3 which contains the highest amount of UV stabilizer (0.75%).

The structural changes of WPCs after aging were evaluated by DSC measurements. The results of this study are presented in the Table 3. There are seen that thermal-physical properties of all initial samples after the first heating are more or less equal. The melting temperature changes only in limits 1.2 degree (165.6–166.8°C), enthalpy of the melting 66.43 J/g – 75.75 J/g but degree of crystallinity 71.29%

– 68.13% for T-1-T-3 systems, for T-4 64.72% and T-5 62.52% that changes in 10% limits. This small difference shows to distinctions of the crystallization conditions due to the presence of different types of pigments in composites. To this conclusion indice differences of crystallization temperatures up to 5.4°C instead of 1.2°C differences of melting temperatures and values of the enthalpy of crystallization up to 10 J/g. The second heating gives practically the same results and distinctions between all parameters are insignificant. In the contrary after UV aging in the surface layers of the weathered* samples considerable structural changes were observed. The melting temperatures after first heating have diminished about 13.4–14.9°C but after the second heating decreasing of the melting temperatures reached to 26.3–29.7°C in comparison with non-weathered samples. Such significant diminishing of T_m indicates to decreasing of molecular mass of polypropylene matrix what can arise degradation processes in PP during the UV aging. The degree of crystallinity of the weathered* samples after the

Table 3: The results of DSC measurements of non-weathered and weathered* composites

CompNo	W_{PP} , wt. p.	1.heating			Cooling		2.heating		
		T_m , °C	H_m J/g	X_c , %	T_{cr} , °C	H_{cr} J/g	T_m , °C	H_m J/g	X_{cr} , %
T-1	0.5084	166.0	75.75	71.29	120.2	75.90	165.9	72.39	68.13
		152.5*	87.22*	82.08*	110.3*	60.89*	138.1*	65.47*	52.20*
T-2	0.5101	166.8	71.26	66.84	119.9	71.95	168.2	77.53	72.72
		153.2*	87.55*	82.12*	110.3*	66.47*	139.1*	66.13*	62.03*
T-3	0.5059	166.4	72.04	68.13	120.0	78.26	167.3	65.68	62.12
		152.4*	86.10*	81.43*	111.4*	64.71*	139.7*	64.11*	60.91*
T-4	0.5084	166.0	68.77	64.72	125.3	70.87	165.9	59.96	56.43
		152.6*	82.43*	72.58*	113.8*	65.19*	139.6*	64.08*	60.31*
T-5	0.5084	165.6	66.43	66.52	118.0	68.69	166.9	65.53	61.67
		151.0*	66.20*	62.30*	107.3*	66.20*	137.2*	65.65*	61.76*

Table 4: The gloss of the surface and whiteness degree of the samples before and after the UV weathering.

Composites	Gloss parameters, GU		Whiteness degree	
	UV weathering time, h		UV weathering time, h	
	0	814	0	814
T-1	65.9	10.6	7.1	23.3
T-2	65.1	9.6	7.4	23.5
T-3	69.7	11.1	7.0	22.2
T-4	45.2	12.4	3.6	16.4
T-5	68.4	7.3	23.2	64.2

first heating has increased up to 10% what can explain with additional recrystallization process which takes place in PP like in [18]. After the second heating opposite phenomenon is observed. In this case occurs small decreasing of Xcr whether values of Xcr. do not change. Tcr of the weathered WPCs decreases after UV aging in limits 9.9–11.5°C what also indicates to the changes of structure of WPCs.

In addition of DSC measurements extended colour colorimetry and FTIR studies were done. The results of the gloss and whiteness degree investigations are given in the Table 4 but the data of the colorimetry studies in the Table 5. From Table 4 we can see that the gloss of the surface decreases. It was determined by the surface reflectivity of a substance. The gloss also is highly related to the smoothness of the surface of samples if it becomes rougher. Before the weathering all systems show high values of the gloss. After the UV aging the significant influence of weathering on the gloss and whiteness degree of the surface is observed. For all systems are fixed the significant decrease of the numerical values of the gloss and the surface of the samples becomes matted. The similar results were observed by authors [18] during the study of accelerated weathering of the

WPCs based on polypropylene. Necessary to note that the highest (up to 9 times) diminishing of the gloss observes for the composite T-5. It could be explained with different composition of T-5 system what contain another type of pigment (orange), to compare with systems T-1, T-2, T-3 which contain pigment carbon black what can serves also as UV stabilizer of materials. During the weathering the whiteness degree of the surface of the samples has increased approximately 3-4 times. In general necessary also to note that these results very well correlate with our measurements of the changes of the lightness (ΔL^*) and the common colour changes (ΔE_{ab}) (see Table 5). If the whiteness degree increase it means that surfaces of all samples have faded. Seems that the best stability against UV light influence shows system T-3. After 814 h of the weathering time the values of the whiteness degree have changed from 7.0 up to 22.4. For this system also has the smallest changes in a lightness and in a common colour changes (see Table 5). Researches of the whiteness degree, the changes of the lightness and colour also confirm that the presence of the pigment concentrate based on carbon black in the composites and additional amount of UV stabilizer (0.75%) in system T-3 retard UV weather-

Table 5: Colour parameters of WPCs samples before and after* UV weathering

Composites	UV weathering time, h										
	The colorimetry measurements (medium values from 10 parallel measurements)										
	L*	a*	b*	ΔL^*	Δa^*	Δb^*	C_{ab}^*	ΔC_{ab}^*	h_{ab}^*	ΔH_{ab}^*	ΔE_{ab}^*
T-1	43.67	2.38	-4.56	14.84	0.74	2.17	5.16	-1.23	-1.09	1.94	15.01
	58.47*	3.12*	-2.39*				3.94*		-0.66*		
T-2	43.19	3.41	-4.24	15.34	-0.43	2.05	5.47	-1.77	-0.90	1.13	15.48
	58.53*	2.97*	-2.19*				3.70*		-0.64*		
T-3	43.19	3.61	-4.51	14.11	-0.67	2.02	5.78	-1.92	-0.90	0.91	14.27
	57.31*	2.93*	-2.49*				3.86*		-0.71*		
T-4	37.67	-1.26	-24.59	18.13	-12.65	-7.41	24.63	10.27	1.52	-10.47	23.32
	55.80*	-13.91	-32.01*				34.91*		1.16*		
T-5	53.01	34.19	23.08	30.56	-26.34	-11.23	41.25	-27.03	0.59	9.44	41.88
	83.57*	7.85*	11.86*				14.22*		0.99*		

ing process. The smaller losses of the surface colour and whiteness degree of WPCs with additional presence of the pigments also was explained by authors of [33]. Some UV aging characteristics of the composites also are able to determine by colorimetry measurements (see Table 5). For instances a^* , b^* – color vector of co-ordinates in plane; L^* – lightness; ΔL^* – distinctions of color lightness; C_{ab}^* – saturation; ΔC_{ab}^* – distinction of color saturation; h_{ab}^* – tone of color; H_{ab}^* – distinction of color tone; ΔE_{ab}^* – common (summary) distinctions of color.

Evaluating the results of the colorimetry studies have seen that after 814 h of aging all colour parameters significantly have changed. The smallest changes of the colour characteristics have T-3 system. This material has the smallest common colour changes $\Delta E_{ab}^* = 15.01$, distinctions of color lightness $\Delta L^* = 14.11$ and the sample has become more saturation (see ΔC_{ab}^* – distinction of color saturation value is -1.92). In general it is possible to say that all three composites (T-1, T-2 and T-3) which contain pigment concentrate based on carbon black have the best after aging results. A little higher endurance of T-3 composite against UV weathering can explain by higher content (0.75%) of

the UV (770) stabilizer comparing with T-1 (0.50%) and T-2 (0.33%) composites. Necessary to note that pigment carbon black can serve also as UV stabilizer. Composites T-4 and T-5 are weathered more because the values of ΔL^* (18.13 and 30.56) and ΔE_{ab}^* (23.32 and 41.88) are the greatest. Obviously in this case the main role plays type of pigment concentrate (T-4 blue and T-5 orange) because another components of T-4 and T-5 are the same like as of the system T-1.

To evaluate the changes of structure what have taken place on the surface and in the surface layers of the samples after weathering the FTIR spectrums before and after aging were taken. As an examples two composites T-1 and T-3 were chosen which show the more promising results of UV weathering from prior made DSC and colorimetry measurements. In the Figure 1 (T-1) and in the Figure 2 (T-3) are presented FTIR spectrums of un-weathered and weathered samples. To interpret and explain the FTIR spectrums the standard spectrum of polypropylene also is done (see Figure 1, violet curve and Figure 2 green curve).

To facilitate of interpretation of FTIR spectrums in the Tables 6, 7, 8 are given the peaks of identification of differ-

Figure 1: FTIR spectrums of the surface of unweathered and UV-weathered WP composite (sample T-1): green of unweathered, red curve of weathered and violet of standard spectrum of polypropylene

Figure 2: FTIR spectrums of the surface of unweathered and UVweathered WP composite (sample T-3): red of unweathered, blue of weathered and green of standard spectrum of polypropylene

ent groups of all the main WPC components: polypropylene, cellulose and lignin respectively

FTIR absorption bands and identifications for polypropylene reference are given in the Table 6.

FTIR absorption bands and identifications for cellulose reference are given in the Table 7.

FTIR absorption bands and identifications for lignin reference are given in the Table 8.

Table 6: FTIR absorption bands and identifications for polypropylene reference [31]

IR Frequency (cm ⁻¹)	Functional group
2950, 2918, 2836	CH Stretch
1456	CH ₂ Deformation
1378, 1376	Symmetric CH ₃ Deformation
1166	Isotactic PP band
998	Isotactic PP band
974	Isotactic PP band
842	Isotactic PP band

Antioxidant 1010 has intensive absorption band at 1738 1/cm but thermal stabilizer 168 can identify with bands at 1083 1/cm and 771 1/cm. As it is seen the FTIR spectrums have a lot of bands due to very complicated composition of the WP composites. Therefore we had not managed to work out details of changes what occur in the surface layers during UV aging but some essential changes by FTIR measurements were fixed.

Comparing of un-weathered and weathered spectrums can conclude that in spectrums occur essential changes in all parts of WPCs which characterize cellulose, lignin and polypropylene.

The most essential changes of intensity of absorption bands are observed in the region 1500-1000 1/cm. In this part of spectrums due to UV aging significant increase of intensity of absorption bands of weathered samples are occurred. Some increase of absorption intensity takes place also in the region 3500-3000 1/cm at which show -O-H groups and hydrogen bonds. In the contrary in the region 3000-2500 1/cm occur only very small deviations. Necessary to note that after weathering in spectrums of the samples appear new absorption bands in the region 1710-1850

Table 7: FTIR absorption bands and identifications for cellulose reference [32]

Band position, cm^{-1}	Absorbance	Assignment
3348	0.78	OH stretch (hydrogen bonded)
2902	0.27	C-H stretching
1640	0.21	Absorbed O-H conjugated C-O
1430	0.37	C-H deformation (asymetric)
1372	0.43	C-H deformation (symmetric)
1336	0.39	O-H in plane deformation
1318	0.41	CH_2 wagging
1201	0.35	O-H deformation
1163	0.67	C-O-C asymmetric
1112	0.80	Glucose ring stretch (asymmetric)
1059	1.00	C-O stretch
1033	0.90	C-O stretch
897	0.12	Glucose ring stretch, C-H deformation

Table 8: FTIR absorption bands and identifications for lignin reference [32]

Soft wood (birch)		
Band position, cm^{-1}	Absorbance	Assignment
3414	0.92	O-H stretching (hydrogene bonds)
2935	0.58	C-H stretching
2842	0.45	C-H stretching
1714	0.35	C-H stretch (unconjugated)
1606	0.76	Aromatic skeleta vibration C-O stretching
1502	0.99	Aromatic skeleta vibration
1462	0.93	C-H deformation (methyl and methylene)
1425	0.75	C-H in plane deformation with aromatic ring stretching
1268	1.00	C-O of gualacyl ring
1214	0.97	C-O of gualacyl ring
1140	0.75	Gualacyl C-H and synogyl C-H
1086	0.79	C-O secondary alcohols
1050	0.55	C-O of primary alcohol gualacyl C-H
866	0.565	C-H out of plane

$1/\text{cm}$ which could be related with absorption of carbonil groups. The intensity of absorption considerably has increased. It indicates to growing up of concentration of $\text{C}=\text{O}$ groups during weathering. Authors [18] investigating UV aging process of WPCs also recorded similar occurrences. They increasing of absorption band of weathered samples at $3650\text{--}3200\text{ }1/\text{cm}$ explained with the increase of concentration of O-H groups due to the destruction and oxidation processes of PP and migration of cellulose fibres on the surface of the samples. Significant changes of absorption bands at $1500\text{--}1000\text{ }1/\text{cm}$ are related with degradation of lignin during UV aging and partially with oxidation of cellulose chains too [18].

Obviously in all our samples mainly the intensities of absorption bands of O-H and $\text{C}=\text{O}$ groups have increased (see Figure 1 and Figure 2). Evidently during UV aging thermal destruction and photo oxidation processes have occurred and form additional O-H and $\text{C}=\text{O}$ and $\text{C}=\text{C}$ absorption bands.

The main absorption bands of destruction products of polyolefins in FTIR spectrum see below [30]:

hydroxyl (O-H at $3650\text{--}3200\text{ cm}^{-1}$ – a broad absorption band),
 carbonyl ($\text{C}=\text{O}$ at $1850\text{--}1630\text{ cm}^{-1}$),
 methylene ($\text{C}=\text{C}$ at $1680\text{--}1620\text{ cm}^{-1}$ – weak absorption band)

and vinyl ($-\text{CH}=\text{CH}-$ at 908 cm^{-1})

4 Conclusions

The accelerated UV weathering studies of the WPCs based on virgin polypropylene and birch plywood production sanding dust (PSD) showed that the surface of all investigated samples significantly ages during artificial weathering. The degree of aging considerably depends on composition of the composites. The measurements of the colorimetric analyses show the changes in lightness, whiteness degree and a common changes of the colour. These studies revealed that the best of UV stability have the composites with UV stabilizers and pigments based on carbon black (T-1 and T-3). These systems have the smallest changes of the whiteness degree, of the lightness and a common changes of the colour.

DSC analyses results showed the increase of the degree of crystallinity (after first heating) of the PP in the surface layers of the samples due to the recrystallization processes which can occur in PP matrix. The melting temperatures of all composites significantly diminished what point to the decrease of molecular mass of polypropylene. The tensile properties (strength and modulus) and microhardness also decreased after the UV weathering.

Looking over the FTIR spectrums of the surface of the samples before and after the weathering can conclude that after artificial UV weathering the essential changes of chemical structure of all components of WPCs take place. The significant increase of intensity of absorption bands in the regions $3650\text{--}3200\text{ 1/cm}$ and $1500\text{--}1000\text{ 1/cm}$ which can be attributed to the changes of cellulose and lignin is observed. Appear also a new absorption bands at $1710\text{--}1850\text{ 1/cm}$ what could be related to weathering of polypropylene matrix in which due to aging process concentration of carbonyl groups considerably has grown up.

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