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INITIAL RESEARCH OF EPOXY AND POLYESTER WARP LAMINATES TESTING ON ABRASIVE WEAR USED IN CAR SHEATHING

BADANIA WSTĘPNE ŚCIERALNOŚCI LAMINATÓW O OSNOWIE EPOKSYDOWEJ I POLIESTROWEJ DO ZASTOSOWANIA W BUDOWIE POSZYCIA WAGONU TOWAROWEGO*

The subject of the work is to present the preliminary investigations over epoxy and polyester warp laminates and its abrasion. The exploitation of various types of containers used in industry is often connected with its usage of composite materials. The composite materials are exposed to tribological wear. Basing on reality and the common tribology wear hazard testing on abrasive wear of composite materials is well-founded and significant in technical and technological point of view. The results of the experimental part of the work are only the substitute of the widely presented researches over composite materials used in the structure of the side of the freight wagons. There are presented the results of the laminates, performed in the laboratory conditions depicting the real work conditions of freight wagons. There were compared the exemplified parameters of the geometrical profile of the structure mass losses of the investigated samples, both the epoxy and polyester and other used hardeners.

Keywords: *abrasive, friction, composite materials, laminates, tribology wear.*

Praca dotyczy badań wstępnych ścieralności laminatów o osnowie epoksydowej i poliestrowej. Eksploatacja różnego rodzaju zbiorników do zastosowań przemysłowych często wiąże się z użyciem materiałów kompozytowych narażonych na zużycie tribologiczne. Zasadne jest więc podjęcie istotnych z technicznego i technologicznego punktu widzenia badań ścieralności tych materiałów. Prezentowane w pracy wyniki badań eksperymentalnych są jedynie częścią szeroko zakrojonych badań materiałów kompozytowych mających zastosowanie w budowie burt wagonów towarowych. Przedstawiono wyniki badań laminatów, przeprowadzonych na autorskim stanowisku laboratoryjnym do porównawczego badania zużycia ściernego odzwierciedlającego warunki pracy wagonu towarowego. Zestawiono przykładowe parametry struktury geometrycznej profilu oraz ubytki masowe badanych próbek zarówno w przypadku próbek epoksydowych jak i poliestrowych oraz różnych, zastosowanych utwardzaczy.

Słowa kluczowe: *ścieranie, tarcie, kompozyty, laminaty, zużycie trybologiczne.*

1. Introduction

The friction phenomenon occurs in all technical and technological processes and the fact that it is so common causes that friction is extremely vital from the engineering and scientific point of view. The simplified definition of friction determines its occurrence while different elements made from various or the same materials are in contact with each other. Testing of negative impact on the structure of materials, parts of machines and mechanisms is widely discussed. Friction phenomenon is the main reason why there are damages of machine parts, for instance in the case of abrasive wear which significantly worsens performance and very frequently makes it impossible to continue further exploitation, considerably decreasing reliability of the whole system. Taking into consideration the tribology wear is extremely important criterion on the stage of designing and selection of materials with determined resistance to abrasive action, which certainly may contribute to proper and failproof work produced technical items during designing and selecting materials with determined resistance to abrasion [1, 3, 7, 11, 23–27]. Crushing and cracking of materials and abrasive wear, fatigue and chemical consumption can be observed during such a tribology wear process. The tribologic wear appears due to the fact of friction force and states as one of the most crucial aspect of the durability and reliability of the construction. The abrasive wear is recognised to be the most common symptom of the tribologic consumption. It appears due to the mutual interaction of the materials moving towards each other. The most noticeable symptoms of such interactions are detachments of pieces of the inner layer of the material, gradual loss of the material volume and deterioration of the surface conditions. [3, 7, 8, 16, 17, 24].

Experimental testing of composite materials is still necessary and it is connected with determination of many material parameters and properties. Fibre reinforced composites are used in numerous applications. In these applications abrasive wear very often initiate the damage of the whole system. Conveyor aids, vanes, gears, bushes, seals, bearings, pumps handling industrial fluids/slurries containing abrasives, sewage; chute liners used in machineries in agriculture, earth moving, mining, etc. are some of such examples [2, 5, 6, 9, 18, 21, 22]. In the paper [19] the authors present that the wear rate increased with increasing applied load, abrasive size and decreased with sliding distance. Also, abrasive size was found to be effective for the composite. The interaction of load and abrasive size was found to be effective than those of other variables. Authors of the paper [4] present the experimental results of multi-pass two-body abrasive wear of fibreglass reinforced polyester composite. The authors indicated micro-cutting, micro-cracking, micro-fatigue, micro-fracture in matrix and in the fibres ends as dominating wear mechanisms. The tests were carried out under different experimental conditions, different loads, given rotational speeds, and different grit sizes of abrasive. Over the

(*) Tekst artykułu w polskiej wersji językowej dostępny w elektronicznym wydaniu kwartalnika na stronie ***www.ein.org.pl*** last years the methodology of designing and analyzing of composite materials in aspect of multiple desirable performance criteria have been evolved. In the work [20] an attempt has been made to analyze the impact of several selected parameters and their interactions on the percussive wear of the red mud filled epoxyglass fibre composites (using statistical method of Taguchi). This method has been also successfully applied for parametric evaluation in the percussive behaviour of polymer composites [10, 12].

The main aim of the work was to investigate preliminary the abrasive wear process of the chosen composite samples, namely epoxy and polyester ones, comparing the mass loss of the probes and analysis of the geometrical profile parameters before and after the experiments. There were compared the wear parameters of chosen laminates made of fibreglass and carbon fibres, with various weave and weight, as well as using variable hardening agents.

2. Idea of the laboratory stand and the research methodology

Materials used in the construction of car sheathing should be resistant enough so that the pouring cargo does not cause the destruction of its surface that could possibly unable further exploitation. Requirements towards engineering and exploitation of rail-vehicles are determined by subjective standards applied by International Union of Railways (UIC), the Organization for Cooperation of Railways (OSJD) and National Normalizing Committees. There have been no specific regulatory guides concerning the resistance to abrasion wear found yet applied to the construction of the freight wagon containers. These materials are verified due to their strength requirements (disruptive strength, exploitation and fatigue strength and vibration strength and buffer impact strength).

The purpose of this work was to choose a proper conception and methodology of initial researches concerning abrasability and testing of selected composite samples. During the investigation the author's conception of the laboratory stand was chosen. In the author's laboratory stand the working conditions of car sheathing were considered after multiple loading and reloading. The basic idea of the proposed laboratory stand (fig. 1) is based on the rotational cylinder driven into rotary motion by means of an electric engine. The simplicity of that concept makes it possible to build a laboratory stand with low costs and to provide easy operation and maintenance of the stand. Further information concerning the control system, parameters of drive, parameters of abrasive material and degree of filling the cylinder in the laboratory work and particular parameters can be found in the article [1].

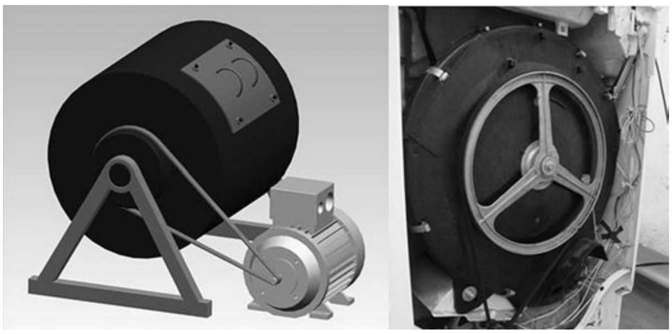

Fig. 1. The concept and implementation of laboratory stand for testing of resistance to abrasion

Dimensions of samples were limited in such a way that the sample could be situated inside the rotational cylinder. Dimensions of the tested element were determined as: length from 170 to 190 mm and width from 30 to 100 mm. Dimensions of the tested samples are also limited by the doors of cylinder where the sample is fixed. Thickness of the sample should be less than 10 mm. The choice of actual dimensions meeting the requirements depends on concrete users specifications.

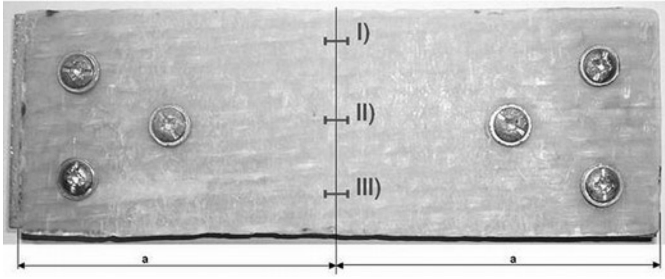

Fig. 2. The three ways of measurement by means of the profilometer

Carrying out the research relies on setting the number of cylinder rotations (there is the abrasive material in it) between consecutive measurements of the sample. It is extremely important to set the proper rate of rotation of cylinder for stable work of laboratory device. The rotary velocity is an especially important parameter in the case of described laboratory stand. It enables stable work of the device in a set of tests provided. In the considered case the rotary velocity equals 60 rpm in a steady state.

The laboratory stand gives an opportunity to close the abrasive process to real conditions. However, to carry out the research helping to evaluate if the selected composite materials are good for practical application it is necessary to define material parameters describing the degree of abrasive wear during the tests. This led to observation on what the impact of abrasion (mineral abrasive) on the tested sample was.

The first parameter which was used to check abrasive wear of the sample is the visual evaluation of the tested element. Before and after the research the surface quality of the sample was estimated visually. Determination of the impact of abrasive material on the sample became possible. Evaluation carried out in this way is, however, subjective and inaccurate and because of this it cannot be the only feature considered in comparison of tested materials.

Another parameter defining the changes following the measurement of the tested material is the mass decrement. The sample was weighed before and after the tests, which helped to define what kind of material loss is caused by abrasive material during the tests. The material loss is the comparative parameter among different laminates which were tested. The precision of weighing is approximately 0,01 g.

Additionally, the samples were tested by means of the profilometer to notify in what way abrasive material is acting on the surface of the sample. This led to define roughness (which shows the damages brought about by abrasive material) and the assessment of maximal depth of damage. The measurement was conducted using the Tylor – Hobson SURTRONIC 3+ profilometer (fig. 2).

The profilometer enables conducting the research of geometrical surface structure of material and defining parameters connected with it and also graphical representation of the results in the form of charts. For performing the research of abrasibility of composite materials the chart of roughness were generated. They allow assessing the surface quality of the tested elements. The measurements were provided on three measuring lengths in the middle of the sample (fig. 2). Each of the measuring lengths is composed of five elementary segments. The elementary segments of 0,8 mm and measuring length of 4 mm length were selected according to the ISO 4288 norm.

3. Composites grinding tests

In this paper the chosen results of experimental tests on the laboratory stand are presented. The selected laminate samples were tested determining comparative resistance to abrasive wear (table 1).

Table 1. Juxtaposition of the tested laminates

No.	Warp	Reinforcement	Liczba i ułożenie warstw	Mass of resin per one square metre G.S.M. recommended /used	Reinforce-ment part	Thickness of the sample / mass of the sample	Hardening agent
1	*Epoxy resin Epidian 6*	*Fibreglass with twill weave, 450g/m²*	*5 (0/90/0/90/0)*	*330g/300g*	*60%*	2,59mm/31,74g	Hardening agent PAC 80g per 100g of resin
2	Polyester resin Polimal 1094 AWTP-1	Roving, 400g/m²	3 (0/90/0)	350g/365g	50%	1,46mm/20,47g	Hardening agent Lu-perox K-1 con. 1,5%
3	Polyester resin Polimal 1094 AWTP-1	Fibreglass with twill weave, 450g/m²	3 (0/90/0)	350g/355g	56%	1,61mm/20,52g	Hardening agent Lu-perox K-1 con. 1,5%
4	Epoxy resin Epidian 6	Roving, 400g/m²	4 (0/90/90/0)	350g/355g	54%	2,13mm/25,14g	Hardening agent Lu-perox K-1 con. 1,5%
5	Polyester resin Polimal 1094 AWTP-1	Roving, 400g/m²	3 (0/90/0)	350g/350g	53%	1,69mm/19,12g	Hardening agent PAC 80g per 100g of resin
6	Polyester resin Polimal 1094 AWTP-1	Fibreglass with twill weave, 450g/m²	4 (0/90/90/0)	350g/385g	54%	2,55mm/28,43g	Hardening agent PAC 80g per 100g of resin
7	Epoxy resin Epidian 6	Fibreglass with twill weave, 450g/m²	3 (0/90/0)	330g/335g	57%	1,33mm/20,02g	Hardening agent Lu-perox K-1 con. 1,5%
8	Epoxy resin Epidian 6	Fibreglass coated by aluminum with twill weave, 290g/m²	7 (0/90/0/90/0/90/0)	225g/240g	55%	2,43mm/31,63g	Hardening agent PAC 80g per 100g of resin
9	Epoxy resin Epidian 6	Carbon fibre with twill weave, 280g/m²	3 (0/90/0)	330g/265g	51%	1,19mm/13,97g	Hardening agent Lu-perox K-1 con. 1,5%

3.1. Abrasive material

The choice of the abrasive material for the tests was done in the experimental random way. Relatively fast wearing of the applied charge was the biggest problem during the experiment. Granite was applied as the abrasive material, which enabled verification of grindability in critical conditions. The stones caused abrasion and devastation of the surface that also resulted in mutual abrasion and rounding of sharp edges. It required frequent (after each cycle of the test) exchange of the abrasive material.

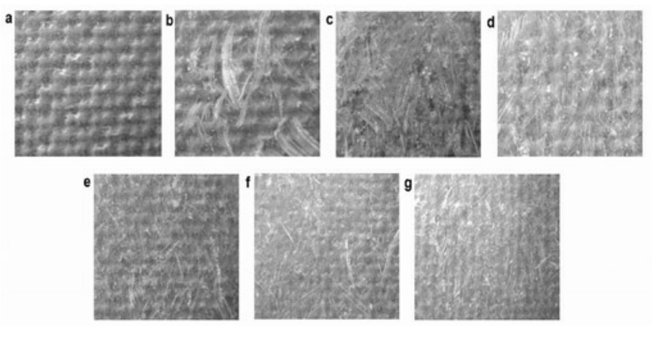

Fig. 3. Visual assessment of the surface quality of exemplary laminate made of epoxy resin and fibreglass with twill weave (the sample 1): a – before the tests; b – after 1000 rotations; c - after 2000 rotations; d- after 3000 rotations

3.2. Tested samples

The most common group of composite materials used in different industries are laminates. Laminates are produced by saturating a chosen fabric (fibreglass, carbon fibre, amide fibre) with epoxy resin or polyester resin and further they are moulded in the layer form. The surface of the material is consisted of resin which determines resistance to abrasion of material. The tests were done on the samples consisted of epoxy resin (fig. 3) and polyester together with various types of fabric, the collection of samples was presented in table 1.

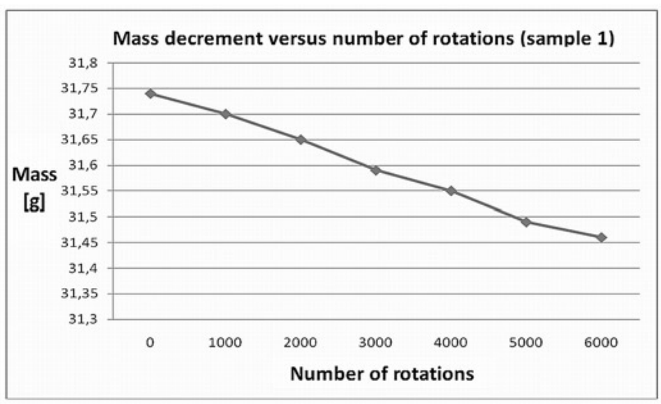

Fig. 4. Chart presenting the dependence of mass of woven fibreglass with twill weave laminate made of epoxy resin on the number of cylinder rotations (in the laboratory stand)

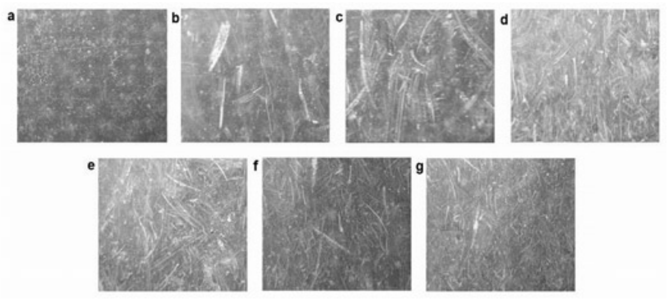

Fig. 5. Picture presenting the surface quality of the woven glass roving laminate (the sample 2 in table 1): a – before the test, b – after 1000 rotations, c – after 2000 rotations, d – after 3000 rotations, e – after 4000 rotations, f – after 5000 rotations, g – after 6000 rotations

The sample measurements were conducted evaluating influence of the dimensions of the tested element on the abrasion process. A number of tests were carried out changing the size of the analyzed material and observing the results of tests.

After the initial research, the dimensions of the samples (length, width and thickness) did not change results of the experiment. The surface of the samples was tested in the same way in each case. It was assumed that the dimensions of the tested samples were 50mm of width and 170 mm of length and various thicknesses (depending directly on the used fabrics, resins, hardening agents and fabrication technology).

3.3. Exemplary results

The epoxy resin samples tests (fig. 3) and the polyester resin sample tests (fig. 5) were carried out. Different fabrics were used by comparison. The parameters of selected samples are presented in table 1.

The measurement of mass decrement evoked by abrasion was taken before each stage of the research and mass dependence on the number of cylinder rotations is presented in figure 4. The values of mass decrement after each stage of the research are close to each other, however, the mass decrement is not exactly proportional.

In figure 5 the woven glass roving laminate made of polyester resin is presented. In the same way (fig. 3) the six stages of the research were done every one thousand rotations till six thousand ones. In figure 5 the change of surface quality of the sample is presented. During the following tests the increase in number of scratches and general worsening of the laminate surface can be observed. The observed scratches, grooves, spallings are distributed randomly on the surface of the laminate, what is a result of the non-oriented abrasion character and simultaneously it is a true representation of the real wear and tear of material used in the freight wagons construction.

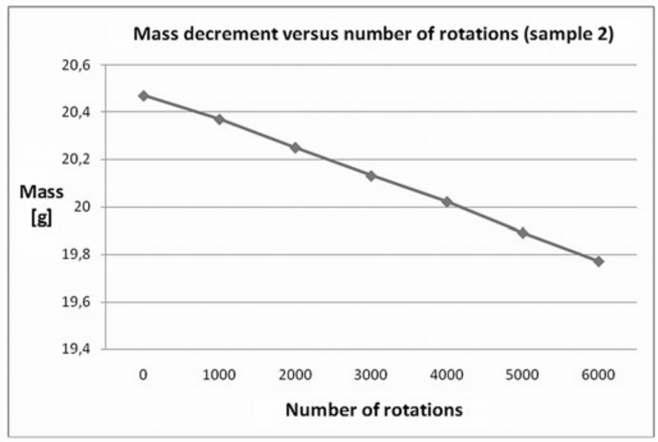

Fig. 6. Chart presenting the dependence of mass of woven glass roving laminate made of polyester resin (the sample 2 in table 1) on the number of cylinder rotations (in the laboratory stand)

Table 3. Parameters of geometrical structure of the fibreglass (g.s.m. 450g/m^2) sample surface in the polyester resin warp (sample 3) before the test

Fibreglass polyester laminate – measurement values				
	I	II	III	Avg.
R_p	1,46	1,62	1,56	1,55
R_v	1,08	1,09	1,13	1,10
R_z	2,54	2,71	2,68	2,65
R_c	1,16	1,18	1,07	1,14
R_t	3,70	3,50	3,35	3,52
R_a	0,35	0,34	0,33	0,34
R_q	0,46	0,47	0,46	0,46

The dependence of mass on the number of the cylinder rotations during the test for the sample 2 (table 1) is presented in figure 6. In this case the mass decrement preserves its linear character.

In the table 2 there are presented the parameters of the geometric structures of the investigated sample made of fibreglass in the matrix of epoxy resin (sample 1).

The most common parameter of the surface roughness is an arithmetic average of the roughness profile (R_a). The parameter enables to find precise information about the geometrical structure of the profile with ordinate layout of the profile. Therefore the measures were filled in with the following parameters of geometric structures: the maximum height of the profile (R_z), average height of profile elements (R_c), maximum height of the profile (R_t) and root mean-square-average (R_q), on which the most influential are the single highest and deepest ones. The highest value of the surface roughness is a sum of the maximum peak height (R_p) and maximum valley depth (R_v). In majority of cases very important for exploitation is also kurtosis (R_{ku}) and skewness of the profile (R_{sk}), which not only characterise the height and depth of the profile but also their shape.

In the table 3 there are presented the parameters of the geometric structure of the sample made of fibreglass of basis weights 450g/m^2 in the matrix of polyester resin (sample 3).

Table 2. Parameters of geometrical structure of the fibreglass (g.s.m. 450g/m^2) sample surface in the epoxy resin (sample 1) warp before the test

Fibreglass epoxy laminate – measurements values					
	I	II	III	Avg.	
R_p	2,21	2,29	2,24	2,25	Maximum peak height
R_v	1,17	1,22	1,15	1,18	Maximum valley depth
R_z	3,38	3,51	3,39	3,43	Average distance between the highest peak and lowest valley in each sampling length
R_c	2,07	1,71	1,70	1,83	Average height of profile elements
R_t	9,16	5,96	6,05	7,06	Maximum height of the profile
R_a	0,52	0,48	0,43	0,48	Arithmetic average of the roughness profile
R_q	0,68	0,65	0,64	0,66	Root mean-square-average

Table 4. Juxtaposition of averaged parameters of geometrical structure of the epoxy fibreglass (sample 1) sample surface and the polyester fibreglass sample (sample 3) before and after the first stage of the test

Designation of the parameter	Fibreglass epoxy laminate – measurements values				Fibreglass laminate in the polyester resin warp – measurements values				Results comparison			
	A	B	C	D	E	F	G	H	I	J	K	L
	Before the tests	After the tests	Absolute difference **|B-A|**	Difference in percentage terms **A/C**	Before the tests	After the tests	Absolute difference **|F-E|**	Difference in percentage terms **E/G**	Absolute difference **|A-E|**	Difference in percentage **(I/A)/(I/E)**	Absolute difference **|B-F|**	Difference in percentage **(K/B)/(K/F)**
R_p	1,68	4,92	3,24	193	1,67	5,37	3,7	222	0,01	1/1	0,45	9/8
R_v	0,9	8,42	7,52	836	1,16	7,55	6,39	551	0,26	29/22	0,87	10/12
R_z	2,57	13,33	10,76	419	2,83	12,92	10,09	357	0,26	10/9	0,41	3/3
R_c	1,3	6,43	5,13	395	1,25	6,8	5,55	444	0,05	4/4	0,37	6/5
R_t	4,27	20,67	16,4	384	3,71	25,96	22,25	600	0,56	13/15	5,29	26/20
R_a	0,34	1,93	1,59	468	0,42	1,99	1,57	374	0,08	24/19	0,06	3/3
R_q	0,47	2,62	2,15	457	0,54	2,61	2,07	383	0,07	15/13	0,01	0/0

In tables 2 and 3, there are parameters of geometrical structure from the selected measuring length on the surface of composite samples in the epoxy resin warp and in the polyester resin warp presented. The results juxtaposition result from three measures in every determined section on the surface of three tested samples (the same type samples). The arithmetic averages of the results are presented in table 4. The geometrical structure parameters before and after the abrasive tests are compared each other.

Before the research the samples were fabricated in the epoxy resin warp or in the polyester resin warp. The fabricated specimens had similar almost the same parameters of geometrical structure. Despite similar values of the maximum peak height (R_p) of each sample, the polyester ones had much deeper maximum valley depth. This situation is connected with the fabrication technology and characteristic of used resin. Comparing individual values of roughness parameters presented in table 4, higher roughness of polyester composite samples before and after the tests can be observed.

After carrying out the first stage of the research, deterioration of the surface quality both in the case of the sample in epoxy resin warp and the sample in polyester resin warp can be seen. Large deterioration of the surface quality of the epoxy sample can be observed. This conclusion is confirmed by over 400 percentage increase in the values of roughness parameters (R_a, R_q, R_z, R_c, R_t). Similar damages can be observed in the case of composite samples in the polyester resin warp, but the maximum valley depth (R_v) and maximum height of the profile (R_t) distinguish from the common pattern. One can pay attention to much deeper maximum valley depth (R_v) in the case of the epoxy sample than in the case of polyester one. This situation can be also connected with numerous scratches and chippings on the surface of the composite sample. Furthermore in the polyester sample the increase in maximum peak height (R_p) was a bit higher the in the case of the epoxy sample.

Despite the fact that the average values (arithmetic R_a and the root mean-square-average R_q) became much worse in the case of the composite sample in the epoxy resin warp, the maximum height of the profile R_t in the percentage terms increased more in the case of the polyester sample than in the case of the epoxy one. Moreover, in the case of the registered value of the parameter (R_v) of the epoxy sample much higher increase in depth of valley can be seen.

Table 5. Mass of the samples weiged after following stages of the test

Stage of the test /number of cylinder's rotations	Number of the sample								
	1	2	3	4	5	6	7	8	9
	Mass of the sample [g]								
0	31,74	20,47	20,52	25,14	19,12	28,43	20,02	31,63	13,97
1/2000	31,65	20,25	20,28	25,06	19	28,21	19,94	31,43	13,79
2/4000	31,55	20,02	20,02	24,97	18,87	27,99	19,82	31,19	13,59
3/6000	31,46	19,77	19,78	24,87	18,76	27,76	19,71	30,97	13,39
4/8000	31,37	19,55	19,58	24,79	18,66	27,56	19,62	30,78	13,21
5/10000	31,27	19,31	19,34	24,69	18,54	27,35	19,52	30,58	13,02
6/12000	31,19	19,11	19,14	24,61	18,44	27,15	19,44	30,39	12,85
Mass decrements in percentage terms [%]	1,73%	6,64%	6,73%	2,11%	3,56%	4,50%	2,90%	3,92%	8,02%

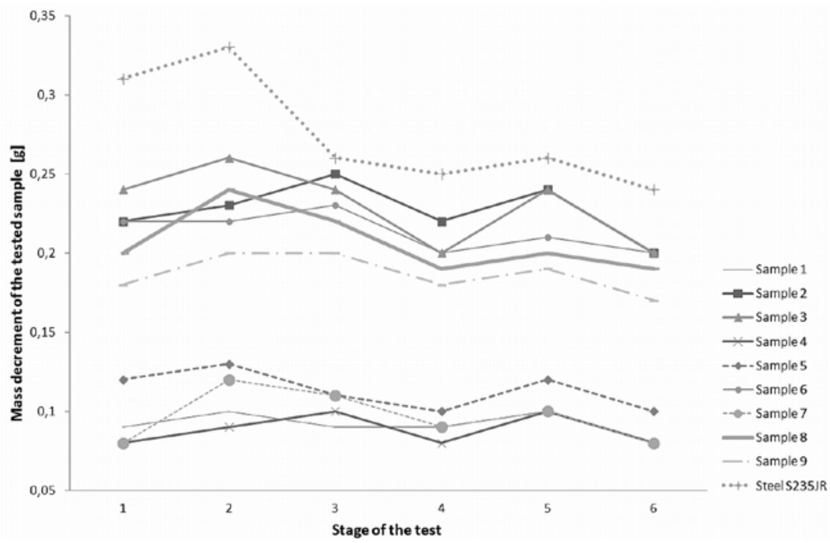

Fig. 7. Juxtaposition of mass decrements of the tested samples

In the table 5 there are shown the mass values of chosen samples, provided after six following stages of the experiment. Each and single time of the experiment the rotational cylinder on the laboratory stand was rotated 2000 times.

Figure 7 presents the graphs illustrating the mass losses of the chosen samples after six following stages of the experiment. Due to the specific wearing character suggested in the laboratory tests, the mass losses are not identical but show high similarities. Due to the fact it is easy to compare the individual values of the parameters and forecast the probable wear of the material in the conditions close to real.

While comparing the mass losses of the samples it was suddenly revealed that the composite in the matrix of epoxy resin shows less mass loss than the composite made in a matrix of polyester resin. The very same results were presented in the previous work [13], where the same materials samples were undergone the experiments. No matter what methods were used to provide the tests, considering the various loads, rotator velocity and the distance from the abrasive roll the results came out the same. On the other hand the composites made of the fibres with bigger weight shows relatively bigger mass loss in the proposed test than the composites of fibres with smaller weight. Such phenomenon appeared in both the examined materials with polyester and epoxy matrixes. Moreover, the hardener does not play any role in the experiment. The results of composites wear were presented in the work as well as in the others [4, 13–15]. Undoubtedly the lowest resistance was presented by the sample made of the carbon fibres with the smallest basis weight of all the chosen sample materials (sample 9). Additionally noticeable is the role of a hardener in the wear process. For the epoxy composites the better hardener is PAC from Organika Sarzyna, which shows better wear resistance. On the other hand, the hardener Luperox K1 produced by Arkema Inc suits better for the polyester composites, what actually does not influence positively the wear process.

Among the investigated samples the fibreglass composite 450 g.s.m. in the matrix of the epoxy resin shows the highest quality and resistance for wear, what is visible as the lowest mass loss and its value.

4. Final remarks

In the work the abrasive features of tested laminates were initially determined. The assessment of abrasive wear of composites materials and the determination of potential technical applications are possible thanks to the carried out research. In the research the method of periodical verification of the surface condition and mass decrement was used. Verifications follow after performing the specified number of rotations of the cylinder in the laboratory stand. The similar values resulting from tests were achieved on different stages of research, mass decrement of laminates oscillated around the close value preserving its linear character.

In this paper the most endurable laminate was determined. The research pointed out that the laminates made with the usage of epoxy resin have the greatest resistance to abrasive wear, much greater than the polyester ones. As the result of abrasion the surface of laminates consisting of epoxy resin had shallower scratches and the whole sample had lower mass decrement. Further measurements indicated that the resistance to abrasion of the considered composites was dependent on basis weight of fabric used to produce laminate. The research pointed out that the laminates made with the usage of epoxy resin have the greatest resistance to abrasive wear, much greater than the polyester ones. As the result of abrasion the surface of laminates consisting of epoxy resin had shallower scratches and the whole sample had lower mass decrement. Materials consisted of fabric with greater basis weight were characterized by smaller value of mass decrement of samples and also shallower scratches.

Damages of samples were observed thanks to the analysis of surface profile of the tested composites. The surface profile analysis of the investigated composites after applying loose abrasive material let us observe the damages coming out of the crushes on the laminates surfaces and better quality parameters of the profiles made of epoxy laminates.

In the first part of this measure process, when the material is smooth, there are scratches arising, which during the ongoing process of abrasion become wider, but after further damages of the surface their depth is becoming smaller. Testing of the steel sample made it possible to define the intensity of laminate surface abrasion. It turned out that such materials distinguish themselves with quite high resistance to abrasion. The steel sample had much deeper scratches and much bigger mass decrement [1].

If one analyses measurements results it can be stated that considered laminates are good for application in the construction of freight wagon taking into consideration the parameters of resistance to abrasion (mass decrements). When deciding which component to use to produce laminates one has to keep in mind that fabrics with high basis weight are the best for this purpose. Also, the epoxy resin is better than the others. The suitable selection of such elements will allow obtaining laminate which will be resistant to abrasion. There are the parameters that could exclude this group of materials from application for construction of freight wagon. That was crucial the technology of the composites to be chosen due to its general availability and economic point of view. Handmade laminates production technology caused occurrence of air bubbles inside the resin which attenuated the structure of the material. The proposed method of the experiment provides only the predictable and comparable results of the tested samples in the considered application. Percussive acting of abrasive material caused crushing of the laminate material in the places where the bubbles appeared. As a result if one would like to define the possible applications of the laminate materials in construction of freight wagon, the impact resistance tests should be carried out. Additionally it is worth considering the proper scale and energy of the device. To determine the usage of the investigated composites in structure of the sheathing coal cars it is absolutely necessary to provide numerous and complex experiments.

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