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Researches of liquid contaminants influence on change of hardness of agricultural tyre tread

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Abstract

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Tyres represent the only element which connects a vehicle with a roadway and they are one of the most important parts of the vehicle. Investigated samples from chosen agricultural tyres were placed into a degradation medium. Degradation media were chosen on the basis of their supposed application; the second criterion of the choice was operating liquids used in machines. A primary aim was defining a change of hardness of these samples; the second-rate aim was observing changes of a tyre weight. The aim of the research is an evaluation of the hardness change in surface layers of a tread depending on specific degradation environments to which the tyre is potentially exposed. The highest influence on the hardness was proved in the case of diesel oil and engine oil. Any essential influence of NPK fertilizer solution was not proved. The effect of water and a solution of NaCl on the hardness change was minimal.

Keywords: degradation; hardness Shore A; tread

Tyres ensure a transfer of driving moments, braking torques and lateral forces, they carry a weight of the whole vehicle and they secure first spring mounting of the vehicle. The tyre is a complicated constructional composite element and it is exposed to outer and inner influences which can cause more or less marginal states leading to degradation processes (Krmela 2008).

Basic requirements on the tyre can be summarized within this research focused on the hardness change in the following points: ability to absorb impacts, to be uniformly stable, service life and low weight (Pacejka 2002).

A specification of the tyre degradation is complicated because it is the composite material. Degradation processes occur in various constructional parts or materials. Krmela (2008) states a significant marginal state of the tyre connected with a surface damage, e.g. owing to exposure to a chemical. This significantly influences an aging process of the whole tyre.

A number of chemical agents affect in a negative way the tyre whose base is created from rubber. They usually disrupt the rubber structure on the surface and so they cause a fast intense wear in a place where it has come to contact with chemical agents, fuels and oils the most often. It occurs because rubbers used for the tyre production dissolve owing to their almost non-polar character in aliphatic and aromatic hydrocarbons (e.g. petrol, benzene, toluene) and chlorinated solvents (e.g. trichloroethylene or tetrachlormethane). Vulcanizates swell in these solvents, elastomers from these

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rubbers also considerably swell in oils, too. That is why tyres from these rubbers do not have to come into contact with oils and these solvents in order they could not affect tyres and etch the rubber mixture. As long as this pollution of the tyre surface occurs, it is suitable to clean the polluted place at least by a rag (Ducháček 2006).

Water and humidity do not cause a huge change of properties, except the small swelling. The hydroscopicity is influenced by fillers, softeners and hydrophilic stuffs which the rubber contains. Also the rainwater which washes off degradation products from the surface by chemical and physical effects has a strong influence. It uncovers the surface for next degradation and thus indirectly accelerates a destruction process. Tyres which contain hydroscopic materials (textile cords) have to be protected by suitable impregnation (Sabu, Raimol 2010).

The tyre has to resist to chemical stuffs, that means to resist to the degradation caused by exerting of chemical agents e.g. halite in winter months (Ridley 2005; Krmela 2008). A situation at the agricultural machines, e.g. fertilizer sprinkler, is more difficult. These machines and equipment work with liquid contaminants distinguished for a considerable aggressiveness to polymeric materials (Müller, Valášek 2012; Müller 2013).

It is possible to pronounce a hypothesis that the tyre loses its properties owing to liquid contaminants. Also the aim of the research describing the degradation process course from the significant factors (the hardness and the weight change) point of view comes from the above stated hypothesis. The research aim is to evaluate the hardness change in surface layers of the tread depending on specific degradation environments to which the tyre is potentially exposed.

The own experimental part focused on a significant constructional part of the tyre – the tread. The tread is a load bearing part of the tyre which is produced from the wear – resistant material. The tyre pattern is created by a purposeful profiling of the tread (Krmela 2008). The pattern ensures a reliable contact of the tyre with floor (Krmela 2008; Vido et al. 2012).

MATERIAL AND METHODS

The experimental research is primarily focused on the evaluation of the hardness change in surface layers of the tyre tread owing to liquid contaminants. Three various tyre types from agricultural machines were chosen for the experiments – marked by letters A, B and C.

Producers change the chemical composition and a vulcanization process according to the supposed usage of the tyre. So, it is possible to pronounce the hypothesis which supposes a different influence of various material compositions depending on the tyre type. Ten testing specimens of sizes 100 × 100 mm were prepared from the tested tyres.

Then individual testing specimens were placed into five different degradation media – semi-synthetic engine oil, diesel oil, rainwater, 33% aqueous solution of NaCl, and 33% aqueous solution of the NPK fertilizer.

Testing specimens were placed in the above-mentioned degradation media (liquid contaminants) for various time intervals. Testing specimens marked by number "1" were immersed in the degradation medium for 2 h and then they were left free in air outside the liquid contaminant until the next measurement. Specimens marked by number "2" were left in the contaminants for the whole time of the exposition, except the time of single measurements. The own process of measurement was carried out under laboratory conditions at a temperature of 22 ± 2°C. A cycle of measuring was 0 (comparing standard), 1, 2, 3, 4, 5, 10 and 16 weeks. The measurement procedure was following: at first, testing specimens were taken out from individual contaminants and cleaned of a rest of the medium in order the measuring devices were not polluted. The second step was weighing of a specimen which was repeated three times for eliminating possible mistake of the measurement. Then the own hardness measurement followed by the Shore A method. After carrying out the mentioned procedure at all testing specimens placed in the same medium the specimens were repeatedly placed into the liquid contaminants again. The testing specimens marked by number "1" were taken out from the contaminants after passing 2 h and they were put on a support plate until the next measurement.

The measurement of the Shore A hardness was in accordance with the Standard CSN ISO 7619-1: 2011 (Rubber, vulcanized or thermoplastic – Determination of indentation hardness – Part 1: Durometer method (Shore hardness)).

Testing specimens prepared for purposes of this research fulfilled the following requirements of the Standard CSN ISO 7619-1:2011. The testing specimen's thickness was higher than 6 mm. Other sizes

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of the specimen enabled to measure in a distance at least 12 mm from each edge. A surface of specimens was even and parallel on a sufficient area in order a supporting foot would reach the testing specimen in the area of a radius at least 6 mm from a tip of an indentor. Measurements were carried out 20 times for each specimen.

Another observed feature was the change of the weight. Investigated specimens were weighed on the scale (Ohaus CL501; Ohaus Co., Pine Brook, USA).

RESULTS AND DISCUSSION

The graphical presentation of results of Shore A hardness change of the tyre tread owing to the use of various liquid contaminants in the time interval of 0 to16 weeks is visible in Figs 1–5. The graphical presentation of results was carried out by means of ANOVA by the least square method.

The NPK fertilizer, solution of water and NaCl and rainwater had the min. influence on the change of the Shore A hardness of three various tyres tread (Figs 1, 2 and 5). Significant changes were set at the diesel oil and the engine oil. However, these changes were not the same for all the tested series (Fig. 3). The diesel oil affected tyre in a negative way; it was namely a significant hardness decrease of the tyres marked as 2C, 2A and 2B. Essential is the fact that it was the series which was exposed to the liquid contaminant for the whole time of the measurement. The considerable hardness decrease occurred at the tyre 2A.

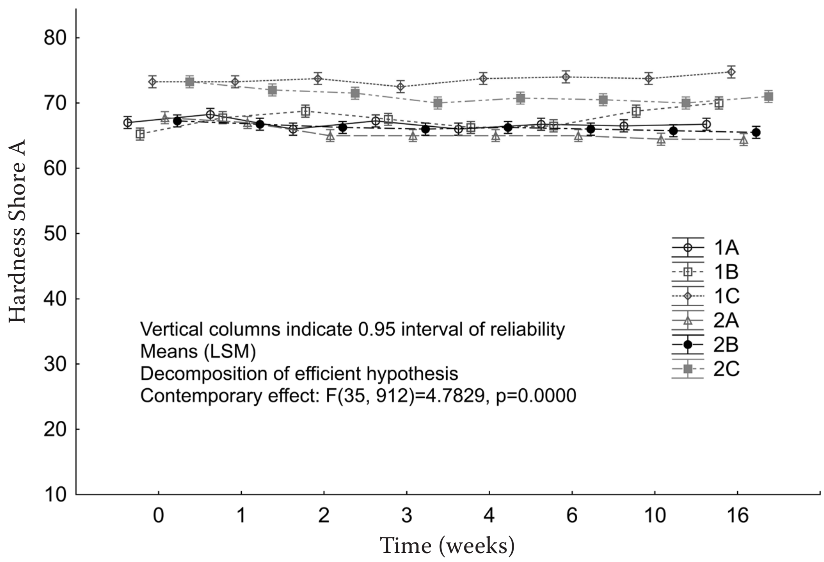

Fig. 1. Influence of liquid contaminant (NPK fertilizer) on the change of Shore A hardness

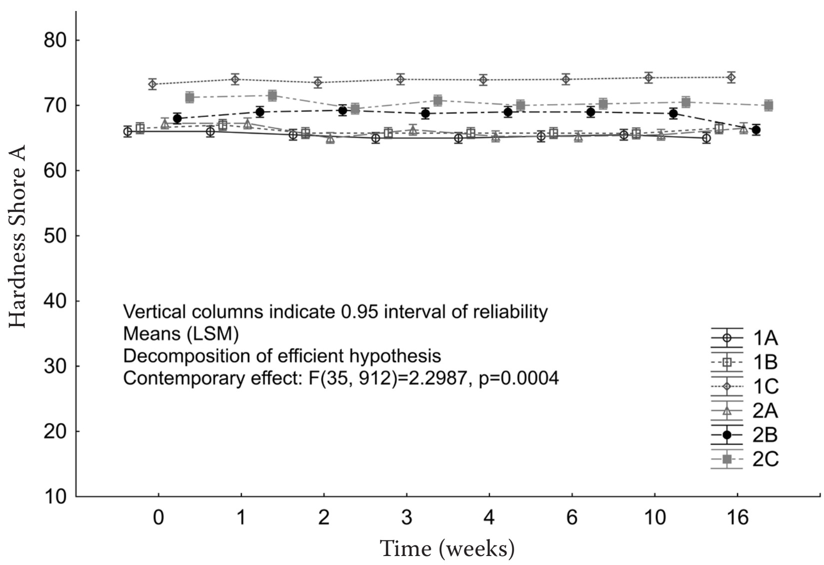

Fig. 2. Influence of liquid contaminant (solution of water and NaCl) on the change of Shore A hardness

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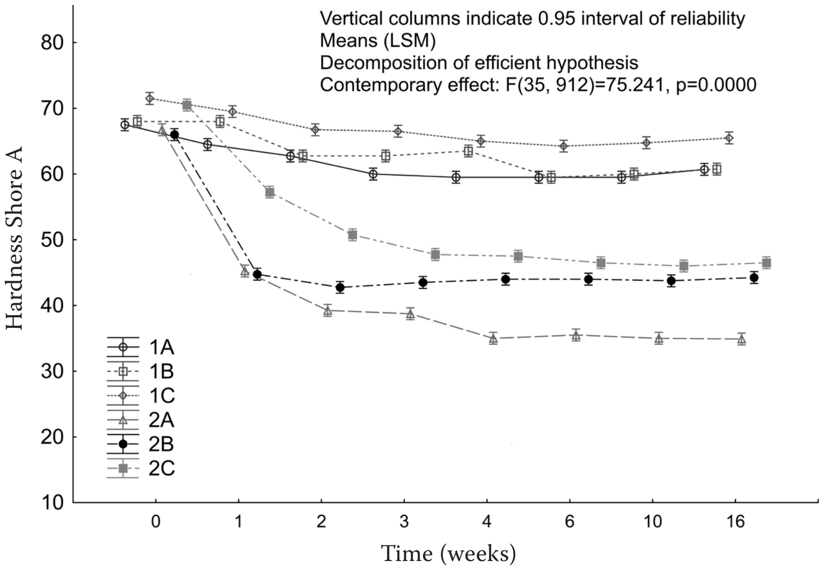

Fig. 3. Influence of liquid contaminant (diesel oil) on the change of Shore A hardness

The influence of 33% solution of the NPK fertilizer was estimated higher than it really was. The Shore A hardness of the testing specimens immersed in this degradation medium for the whole time decreased of approximately 1 till 3 units which are almost negligible values in comparison with the diesel oil and the engine oil. The second set of the specimens exposed to the degradation for only 2 h showed a fluctuation of hardness both in positive and negative directions; however it did not come to high changes. The weight of all specimens placed in 33% solution of the NPK fertilizer mildly increased. The max. increase of the weight did not exceed 1.5%.

Diesel oil had the highest influence on the change of the tyres hardness. The influence of hydrocarbons contained in the oil on the tyre rubber was very significant. The Shore A hardness of all testing specimens immersed in this degradation medium for the whole time decreased of more than 20 units. On the contrary, the weight increased of more than 60% owing to the swelling. The hardness of all specimens immersed in the diesel oil for 2 h and exposed to subsequent effect of air decreased significantly less. The weight change was not as considerable as in previous cases, however, it exceeded 13% at all specimens.

The influence of the engine oil was lower than it was supposed. The hardness of the specimens placed in the contaminant for the whole time decreased of 6 till 10 units. The weight of these specimens increased of 5 %. The hardness of the specimens immersed in the engine oil for 2 h and then left free in the air decreased of 3 to 8 units of the Shore A hardness. The weight increased up to 11%. A decreasing trend of the Shore A hardness was set also at the engine oil (Fig. 4).

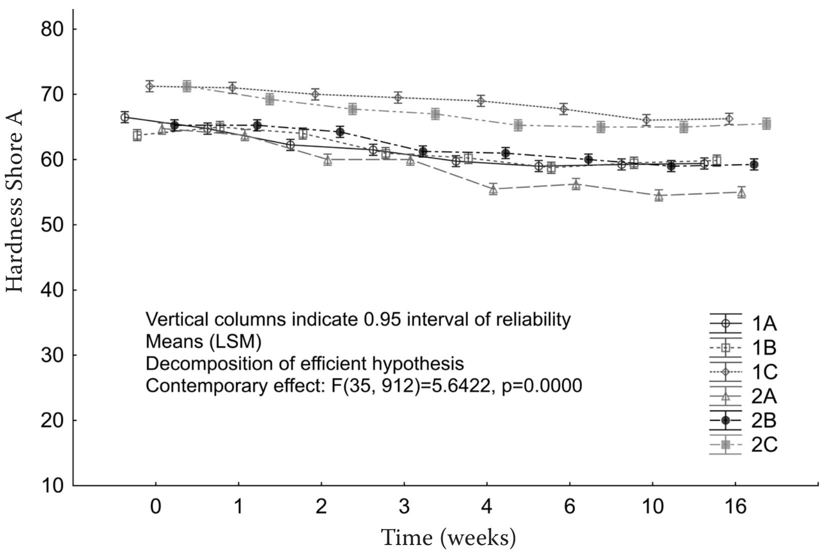

Fig. 4. Influence of liquid contaminant (engine oil) on the change of Shore A hardness

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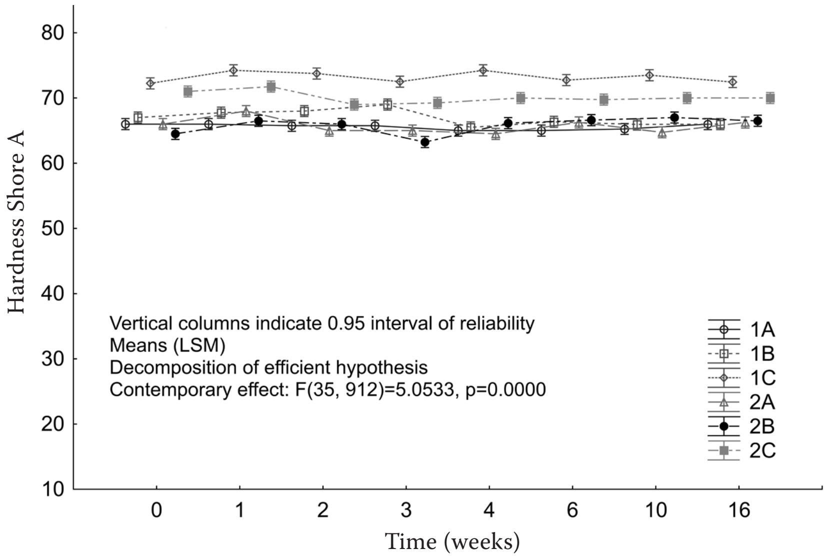

Fig. 5. Influence of liquid contaminant (rainwater) on the change of Shore A hardness

A supposed measure of the influence of 33% solution of NaCl and water itself was confirmed. In all cases of exposing tyre to this medium the Shore A hardness did not change of more than 2 units. At specimens immersed in the water for the whole time, a mild increase of the weight can be observed; however, the max. was 1.6%, which might be explained by absorption of textile cords. Other specimens did not show the weight changes or they were wholly negligible.

The results graphical presentation of the hardness depending on the environment was carried out by means of ANOVA by the least square method (Fig. 6). The Tukey's HSD test was used for the statistical comparison of the mean values. Table 1 shows individual means in statistically homogenous groups.

When comparing the mean values of hardness data sets, the clear difference is visible among individual tested series, which means the tyre type, the environment and the way of testing (2 h in the degradation medium/the whole time in the degradation medium).

From the comparison of the Shore A hardness values for various environments and type of tyres that was carried out (the value of Tukey's HSD test – mean of all values of the Shore A hardness in defined length of the degradation), it is clear that homogeneous groups are as follows: for "diesel oil" tyres marked as A and B in test 1, for "engine oil" tyres A and B in test 1, for "solution of NaCl" tyres A and B in test 1, for "NPK fertilizer" tyres A and B both in test 1 and 2, for "water" tyres marked as A and B in test 1.

However, from the statistical testing point of view, it cannot be considered as the statistically ho-

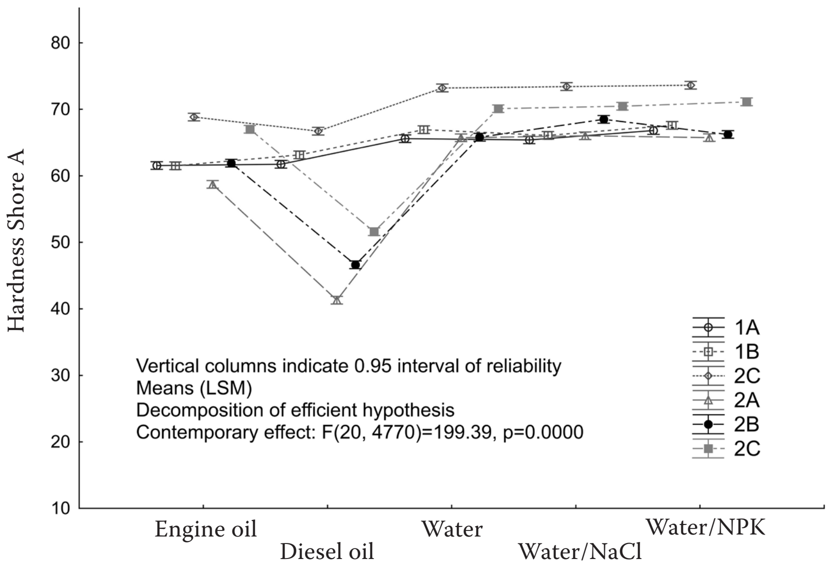

Fig. 6. Hardness depending on environment

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Table 1. Statistical comparison of mean values – Tukey's HSD test

Marking testing specimens	Medium	Arithmetical mean Shore A*	Agreement													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
2A	diesel oil	41.30	*													
2B	diesel oil	46.63		*												
2C	diesel oil	51.59			*											
2A	engine oil	58.72				*										
1B	engine oil	61.52					*									
1A	engine oil	61.55					*									
1A	diesel oil	61.74					*	*								
2B	engine oil	61.91					*	*								
1B	diesel oil	63.16						*								
1A	water/NaCl	65.41							*							
1A	water	65.59							*	*						
2A	water	65.72							*	*						
2A	water/NPK	65.75							*	*						
2B	water	65.81							*	*						
2A	water/NaCl	66.03							*	*						
1B	water/NaCl	66.09							*	*	*					
2B	water/NPK	66.22							*	*	*					
1C	diesel oil	66.72							*	*	*					
1A	water/NPK	66.81							*	*	*					
1B	water	66.94							*	*	*					
2C	engine oil	67.00								*	*	*				
1B	water/NPK	67.59									*	*	*			
2B	water/NaCl	68.50										*	*			
1C	engine oil	68.85											*	*		
2C	water	70.09												*	*	
2C	water/NaCl	70.47													*	
2C	water/NPK	71.13													*	
1C	water	73.21														*
1C	water/NaCl	73.43														*
1C	water/NPK	73.63														*

*arithmetical mean of data found out in interval 0, 1, 2, 3, 4, 6, 10 and 16 weeks

mogeneous groups at the tests of groups 1 and 2 and type of tyres A, B and C.

A negative aspect is increasing tyre hardness which has the influence on safety and noise, which are important factors in a tyre service. Ho et al. (2013) found out that the influence of the tyre mechanical wear on the noise is smaller, while the chemical effect of the tyre rubber aging can increase the noise of 6–7 dB. During the tyre service life cycle the hardness increase of min. 10 units of Shore A occurs due to the chemical aging. Ho et al. (2013) further reported that the noise level is increased of 0.08–0.48 dB for each unit of the Shore A hardness. The noise increase also depends on the roadway surface (Ho et al. 2013). The tyre hardness increases with its age that means during common using (Sitirat et al. 2007).

The research results show that the degradation processes affected by the atmospheric oxygen are more significant factors than the wear process itself. An essential conclusion is also the fact that the environment significantly affects the tyre tread from its wear point of view (Cadle, Williams 1980).

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Another significant agent, from the long-term point of view, is the contamination by oil materials, compared with other tested contaminants.

CONCLUSION

The tread belongs among significant active parts of the tyre construction. One of the essential properties is the hardness which later shows itself in riding qualities and in the wear intensity. From results of the research focused on the evaluation of the hardness change in the surface layers of the tread depending on the specific degradation environment to which the tyre is potentially exposed, the following conclusions can be set:

– Diesel oil had a marked influence on the tyre hardness change; very significant was then the influence of hydrocarbons contained in the oil on the tyre rubber. The engine oil was the second significant contaminant whereas the effect of NPK fertilizer solution was expected in a lesser extent. The effect of water and the solution NaCl on the hardness change was supposed as minimum.
– A significant change of the Shore A hardness occurred at the diesel oil, at the series marked 1 it was of 8% on average, at the series 2 it was of 37% on average.
– A significant change of the weight occurred at the diesel oil, the average value in all tested cycles was 19.5 ± 6.9%. A gradual increase of the weight occurred with the time of exposition of the testing specimens in the diesel oil. Other media showed average change of the weight in all tested cycles from 0.4 to 2.6%. A more significant increase of the weight was observed at the series where the testing specimens were placed in the liquid contaminant for the whole time of the testing. The only exception was the medium engine oil.
– The results show different Shore A hardness of the original tread part depending on the tyre type as obvious; the presumption of different influence of various tyre types was confirmed.
– The results confirmed the negative influence of the long-term contamination (the exposition to the degradation environment). The difference between series 1 and 2 was considerable.

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