David Manas[1], Ales Mizera[2], Miroslav Manas[2], Pavel Stoklasek[2], Ivan Hudec[3]

New apparatus for Chip-Chunk resistance testing

Wear is a phenomenon which can never be completely eliminated. It is present everywhere in all aspects of life. While the problem of wear in metal materials has been described in detail, the problem of wear in rubber products requires further investigation. Tire production is the largest sector in products made of rubber. Their wear is an important factor both for producers and users. Producers aim to produce tires with better resistance to wear than those of their competitors, while users look for a tire with the best resistance of wear. Wear is usually considered in terms of abrasion, which is defined as the loss of material that results from mechanical action on a rubber surface. Abrasion resistance is a complicated phenomenon and is dependent on many things, residence, stiffness, thermal stability, resistance to cutting and tearing, etc. and different applications require these properties in widely varying proportions. Aim of this article is to introduce the reader to the wear of off-road tires which are used in harsh terrain conditions such as quarries, construction sites or forests. For the study of such a type of wear referred to as Chip-Chunk effect improved equipment has been designed, built and verified in praxis.
Keywords: wear, tire, tread, testing, Chip-Chunk.

Nowa aparatura do badania odporności na zużycie typu chip-chunk*

Zużycie to zjawisko, którego nigdy nie da się całkowicie wyeliminować. Występuje ono we wszystkich aspektach życia. Chociaż problem zużywania się materiałów metalowych został szczegółowo opisany, problem zużycia wyrobów gumowych wymaga dalszego badania. Produkcja opon jest największym sektorem wyrobów z gumy. Ich zużycie jest ważnym czynnikiem zarówno dla producentów, jak i użytkowników. Producenci starają się produkować opony o większej odporności na zużycie niż ich konkurenci, natomiast użytkownicy szukają opony o najlepszej odporności na zużycie. Zużycie jest zazwyczaj rozpatrywane pod kątem ścieralności, określanej jako utrata materiału, która jest wynikiem oddziaływania mechanicznego na powierzchnię gumy. Odporność na ścieranie jest zjawiskiem skomplikowanym i zależy od wielu rzeczy, lokalizacji, sztywności, trwałości termicznej, odporności na rozcięcia i rozdarcia itp., a różne zastosowania wymagają różnego zestawu tych właściwości. Celem tego artykułu jest wprowadzenie czytelnika w zagadnienie zużycia opon terenowych, które są użytkowane w trudnych warunkach, takich jak kamieniołomy, place budowy czy lasy. W celu zbadania takiego typu zużycia, określanego jako efekt chip-chunk, zaprojektowano, zbudowano i zweryfikowano w praktyce udoskonalone urządzenie opisane w tej pracy.
Słowa kluczowe: zużycie, opona, bieżnik, badania, chip-chunk.

*Efekt chip-chunk to mechanizm zużywania się opony polegający na odcinaniu kawałków bieżnika przez ostre krawędzie kamieni, nierówności terenu itp.(przyp. tłum.).

1. Introduction

In the rubber industry the wear of rubber parts is a frequent problem. Some kinds of wear, in particular wear of tire treads or conveyor belts are in character very similar to machining. The tire tread is the part of the tire which provides contact between the vehicle and the road and is directly involved in the transmission of the driving force. Friction between the tire tread and the road surface has a direct influence on the ability to transfer the driving forces but also the ability to brake

[1]Univerzita Tomáše Bati ve Zlíně, Fakulta technologická, Ústav výrobního inženýrství T.G. Masaryka 275, 160 01 Zlín, Czech republic, e-mail: dmanas@utb.cz.
[2]Univerzita Tomáše Bati ve Zlíně, Fakulta aplikované informatiky, CEBIA Tech. Nad Stráněmi 4511, 760 05 Zlín, Czech republic, e-mail: mizera@utb.cz, manas@fai.utb.cz, pstoklasek@utb.cz
[3]Slovak University of Technology in Bratislava, Faculty of Chemical and Food Technology, Radlinskeho 9, 812 37 Bratislava, Slovakia, e-mail: ivan.hudec@stuba.sk

Aleš Mizera, Ing. Ph.D. Graduated in Tomas Bata University in Zlin, Faculty of Technology in 2011. Specialization: Technological Equipment Construction. (2011). He received his Ph.D. in Tomas Bata University in Zlin, Faculty of Technology in 2015. Specialization: Tools and processes. He is employed in Tomas Bata University in Zlin, Faculty of Applied Informatics, Research Centre CEBIA-Tech as a Junior Researcher. Topics of interest: temperature stability of polymer materials, material engineering, material testing.

the car on a required track. It depends both on the properties of the rubber compound, of which the tire tread is made as well as on the properties of the road on which it is moving. In the case of the tire of passenger cars and trucks using standard roads, the wear of the tread is characterized by its abradability. The tread of a tire is exposed to the abrasive effect of the road, on which the car is driving. In terms of design the tire is a very complicated component consisting of polymeric matrix with fillers and reinforcement. It is composed of various layers (Figure 1). In terms of wear the over layer called tread equipped with design (pattern) is the most important part.

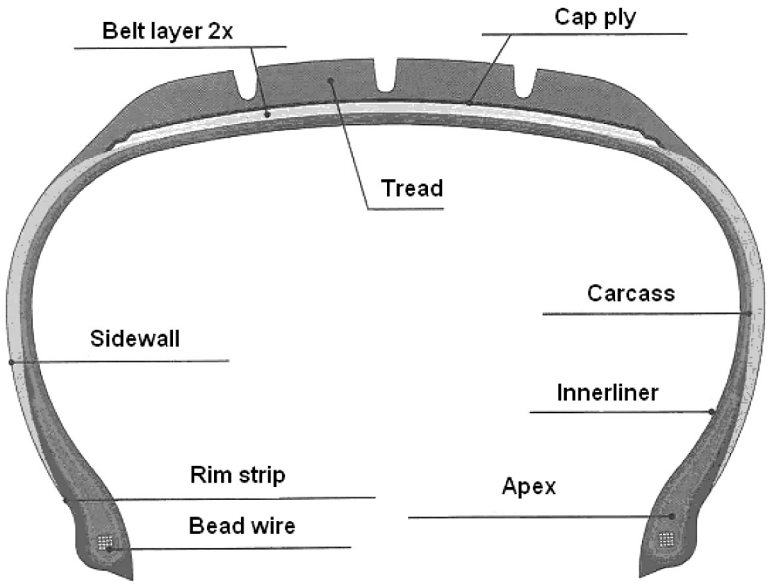

Fig. 1. Cross-section of a car tire
Rys. 1. Przekrój opony samochodowej

Resistance to wear is a very complicated property, which in laboratory testing is subject to a set testing method, though in practice is influenced by many factors and is significantly affected the composition of the compound and by the way in which the rubber product is to be used. Speaking of the composition of the compound with respect to the resistance to wear, it is important to mention the influence of elasticity and hardness. In some cases it is necessary to use rubber with great elasticity which provides resistance to the separation of particles during deformation, in other cases, the best properties can be attained by the fact that rubber provides little resistance to deformation at high deformation speeds. This phenomenon can be seen to a certain extent in the case of tire treads – harder rubber is more suitable for highways with a smooth surface and softer rubber is better for stony surfaces. Wear resistance is significantly influenced also by the type of elastomer and filler used. Good resistance to wear depends both on the composition of the tread compound and uniform dispersion of the filler used. To a lesser extent it is also influenced by which vulcanizing agent and softener is used. Seeking for good resistance to wear of rubber parts subjected to high stress, it usually involves a combination of resistance to flex cracking, dynamic stress, etc. [1].

Resistance to wear cannot be given by a positive value but by a negative one, i.e. loss during frictional stress to which rubber is subjected. The value of wear is not a given property of rubber because it depends on the means and conditions in which it is found. Wear is a very complicated phenomenon which is subject to many factors [2, 3]. There have been many studies and papers designed to establish the influence of other properties, the sum of which would give the value of wear but so far with little success. It is known for sure, e.g. that hardness, strength, tear strength, resilience, etc. have some effect on wear but this relationship is indirect and complicated [4]. Given the great variety of arrangements of these devices and different test conditions, it is not possible to compare the results from the different devices directly. Despite all these drawbacks, the laboratory tests represent a good tool for checking and the development of compounds. Due to a great number of factors which influence wear, and also due to the nature of this property itself, laboratory results do not fully correspond with the field test results, and moreover, the results are often contradictory. A number of methods and testing devices have been developed for tire wear tests. The devices can be divided into two groups. The first group contains testing devices which measure wear of standard tires used on standard roads and highways. Wear is characterized by abradability. In the other group, the devices can test off-road tires (rubber products subject to high stress). From these could be mentioned e.g. Du Pont methodology using contact friction, Bussen–Schlobach methodology, Akron–Croydon method, Dunlop–Lambourn methodology, Dry

sand – rubber wheel test (DSRW), The National Bureau of Standards (NBS) and The Pico abrader. The degree of wear and thus mileage performance of a passenger car tire depends, among other things, on the degree of slip. Slip is a relative movement between the road and the tire that occurs when force is transmitted. Slip means that the vehicle speed is greater or smaller than the wheel's circumferential speed. While slip, as such, is a necessary condition of driving, the degree of slip is greatly dependent on the motorist's driving style. The degree of wear is directly linked to the degree of slip.

For tires which are used in harsh terrain conditions (motocross, agricultural, construction and forest vehicles, Figure 2) the mechanism of wear is totally different. Sharp edges of stones and terrain irregularities cause cuts in the tread, which can be compared to the mechanism of machining. There is a certain similarity, e.g. with milling, although very specific conditions are necessary. The mechanism of wear of tire treads operating in harsh terrain conditions is referred to as Chip--Chunk effect and it can be compared to "machining" of a rubber surface. Cutting takes place when the tire strike a sharp object with enough force that the surface is penetrated or cut. Chipping can follow cutting by the effect of reactive, braking, or other forces on rough or sharp surfaces, causing tearing of the rubber compound.

This upgraded laboratory apparatus provides test conditions which can be thank to use user friendly control units widely changed [7, 8]. It enables to measure different characteristics of chip and chunk processes [9].

2.1. Material and method

Nine various types of tire tread compounds (marked I, II… to IX) designed for off-road tires production (tires for motocross, mine, building and agriculture vehicles) have been chosen for the experiments.

The tests were carried out on cylindrical samples of the Lüpke test with diameter 55 mm and thickness 13 mm (Figure 3). The rotating vulcanized cylindrical samples (6) were abraded by a sharp ceramic edge tool (5), mounted on beam (1), rotating around the turning pin (2) lifted and dropped on the rubber sample perimeter by the piston (3) of a pneumatic cylinder (4). The control of the impact frequency of the tool and of the revolutions of the electric motor (8) is provided by the control unit (Figure 4). The samples were weighed before and after the test. The evaluation of the wear progress during the testing period was tested as well.

The influence of drop of the ceramic tool on the surface of the testing sample is crucial. If the sample

Fig. 2. Wear of tires – Chip-Chunk effect
Rys. 2. Zużycie opon – efekt chip-chunk

2. Experiment

The cutting and chipping test of rubber compounds which correlates with service behavior and provides test results at a reasonable speed and with accuracy was described by J. R. Beatty and B. J. Miksch [5, 6]. In accordance with their description we constructed a rather modified apparatus [7].

were rigid, the evaluation of the impact of dropping force would be quite easy. The elastic properties of the testing sample however cause a series of other effects of smaller intensity („jumping" on the surface) apart from the main effect (the first drop of the ceramic tool on the testing sample). The main effects of the ceramic tool have only partial influence on the total wear. It turned out that evaluating total work needed for wear

(i.e. creating a groove on the testing sample) only by the energy of the drop would be biased. After the first testing of the testing equipment, it was clear that the results in a given series of measurements would be comparable if the experiments ran under the same conditions. The construction of the main body with a key fitting the groove on the shaft and clamping basement with teeth prevent skidding of the testing sample while running and the control system of the testing machine will secure constant conditions for testing.

3. Discussion

There is clear from the results of the Chip-Chunk resistance test (Figure 5) that the used equipment and way of testing are suitable for comparison of various types of rubber compounds from the point of view of Chip-Chunk resistance. The method is very sensitive to changes in examined properties of rubber compounds.

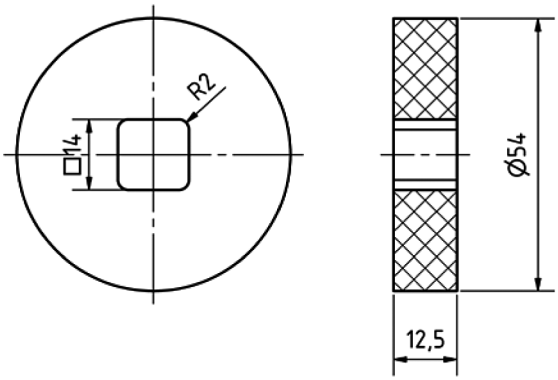

Fig. 3. Dimension of testing sample
Rys. 3. Wymiary badanej próbki

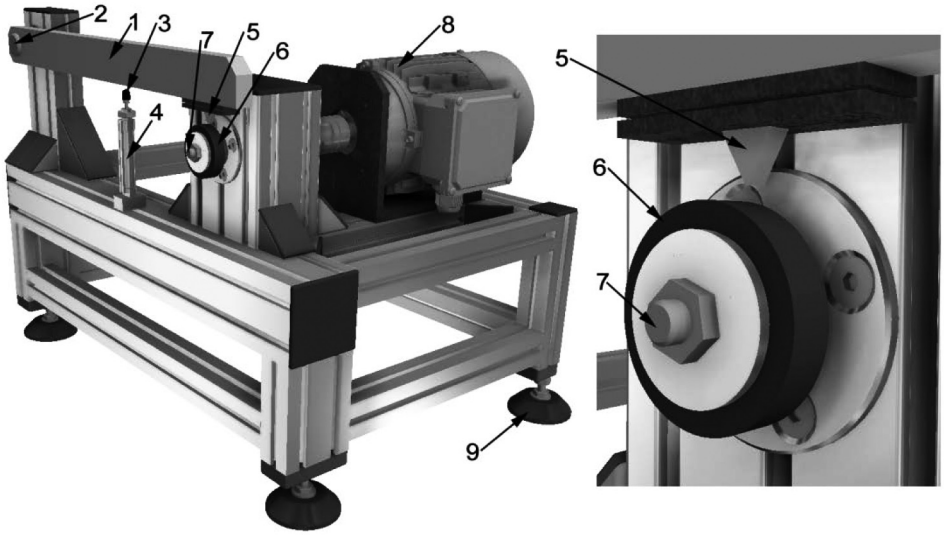

Fig. 4. Testing apparatus
Rys. 4. Urządzenie badawcze

2.2. Test conditions

- Sample revolution 15 s^{-1}
- Impact frequency 1 Hz
- Ceramic tool stroke 60 mm
- Temperature room temperature 21°C
- Test period 270 s

A part of these experiments has been also the study of wear development during the test. The mass of the samples was measured in regular intervals (30 s) during the whole time of the experiment (270 s). Most of the samples showed a gradual increase in wear in the first interval of the experiment. A marked increase of the wear starts after the creation of the first rip, which means that before the first rips happen, the

surface wear is negligible. The compounds with low resistance to wear (e.g. compound VII) show wear increase already from the beginning of the test. The comparison of the tested compounds is seen on Figure 6.

Figure 7 presents the view on the progress of wear on the real testing sample. Gradual tendency to faster wear in time is observed in most cases. This means that before the creation of first rips on the surface the tire tread while driving on harsh terrain conditions (sharp stone edges etc.) the wear is quite small. The first damage to the tire tread however starts the "avalanche effect" of other damages and the wear increases faster. The vehicles move at a different speed in the terrain in running conditions which can be characterized by the circumferential speed of the tire tread. Also the load of the tire depends on the current load of the car. From this reason the testing equipment is equipped in such a way to be able to change the speed of testing samples, the incident energy and frequency of the cutting tool. This gives the possibility to change the testing condition in wide range.

Upgraded equipment allows also using the possibility of the scanning of the wear process using high speed camera and in such a way a study of the mechanism of wear in detail (Figure 8).

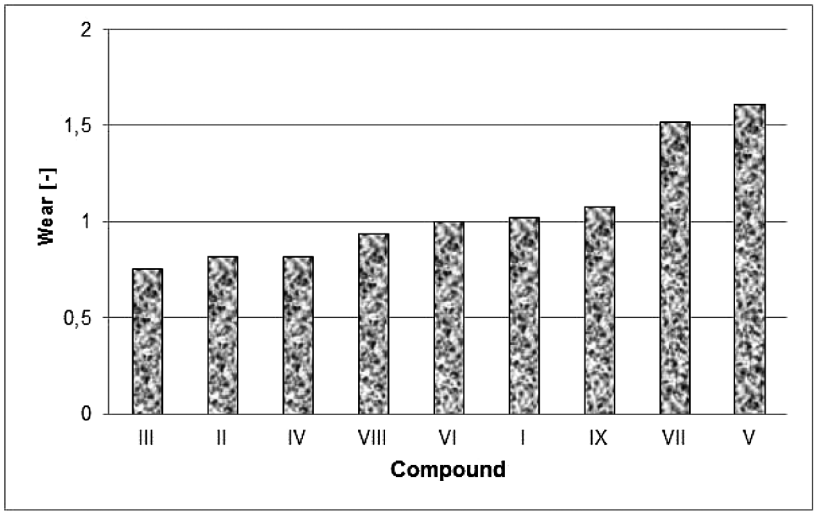

Fig. 5. Wear – comparison of tested compounds
Rys. 5. Zużycie – porównanie badanych mieszanek

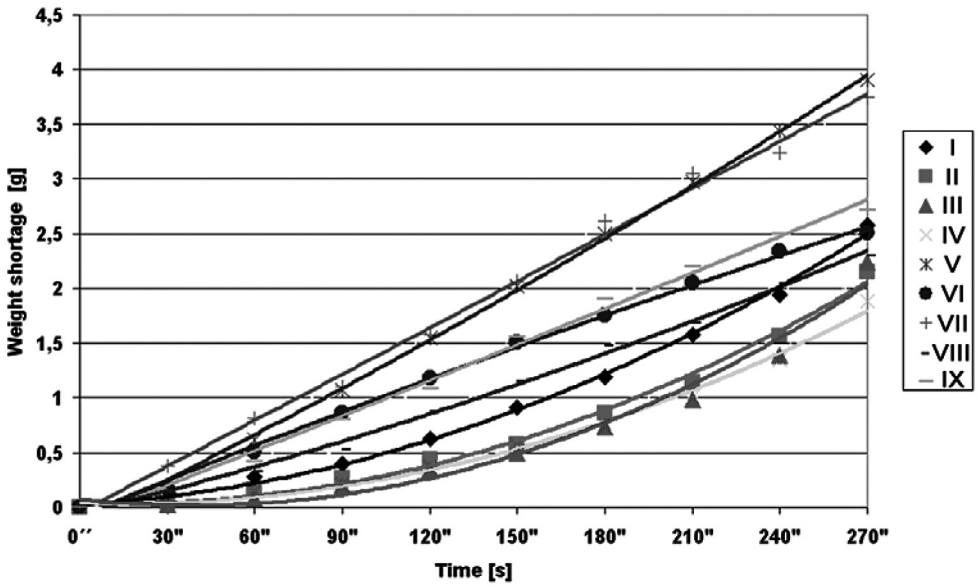

Fig. 6. Wear development
Rys. 6. Przebieg zużycia

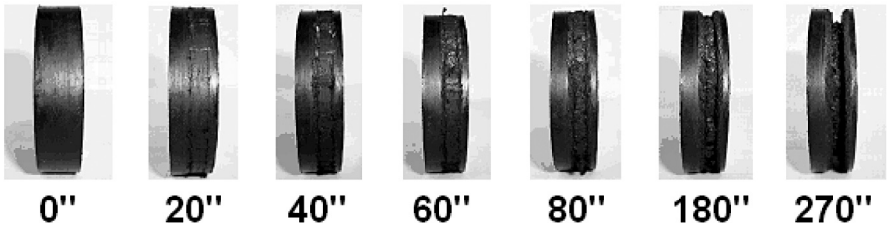

Fig. 7. Progress of wear – real samples
Rys. 7. Postępujące zużycie – próbki rzeczywiste

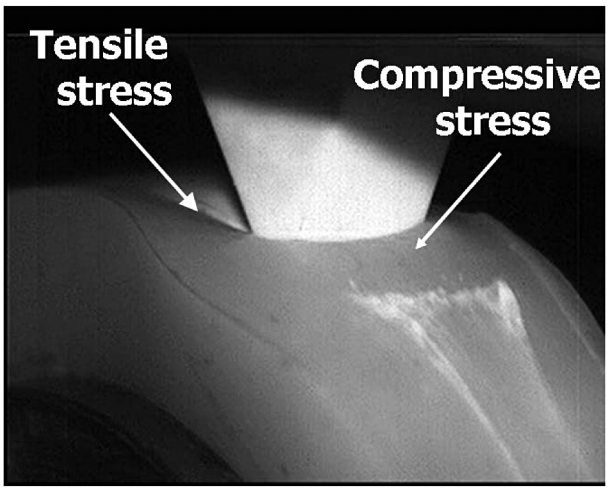

Fig. 8. View on the wear process – scan of the high speed camera
Rys. 8. Widok procesu zużycia – obraz z kamery do zdjęć przyspieszonych

4. Conclusion

The new apparatus for Chip-Chunk resistance testing has been designed and verified in praxis. Because of expensiveness of traffic test of tires, especially test of off-road tires, the laboratory tests are very useful. The designed apparatus and method for the realization of the tests is very simple, takes only short time and requires only small amount of rubber mixture for testing sample preparation. This apparatus give many other possibilities to study wear of tire treads and other rubber products.

Acknowledgement

This paper is supported by the Ministry of Education, Youth and Sports of the Czech Republic within the National Sustainability Programme project No. LO1303 (MSMT-7778/2014) and also by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

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