Tire Wear of Technical Vehicles

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Abstract: The issue of wear represents a very important role in the functionality of most products. The description of the wear process for very heavily stressed rubber parts, for example off-road tire treads, conveyor belts for stone transport etc., is very important. Sharp edges of stones and terrain roughness gradually cut (chip) off rubber parts. This wear considerably damages separate parts of the product and destroy it. In technical terminology, we call this type of wear CHIP – CHUNK effect. High-speed video camera provides records which helped us to evaluate behaviour of ceramic tool dropped on the surface of rotating test rubber sample. Also evaluation of weight loss during this test describes resistance of tested rubber compounds.

Key-Words: Wear of tire, CHIP – CHUNK effect, rubber compound testing, tire, tire wear testing machine, evaluation of heavily stressed rubber parts

1 Introduction

In rubber practice we often meet the problem of wear of the rubber parts. Some types of wear, especially the wear of tire treads, are very similar to machining. The tire tread (Fig. 1.) is a part of tire which is in direct contact with the road and thus is responsible for the driving force transfer. The wear of the tire tread of passenger and trucks cars travelling on common roads is characterised by its abrasion. The tread of a tire of a car is disposed to the abrasive effect of the road.

However, the mechanism of wear of tires working in very hard terrain conditions is absolutely different. Sharp stone edges and terrain irregularities gradually cut (tear off) parts of the rubber tread surface, which can be understood as a way of working – e.g. milling, although under very specific conditions. The mechanism of tire tread wear working in hard terrain conditions is technically called Chip-Chunk effect and it can be considered as "workability" of rubber surface. [1,2,3]

The tire wear is usually tested under running conditions, these times demanding tests are very expensive. It would be very useful in practice to find a quick test of wear which could be carried out on small samples. Creating a model predicting the behaviour of tire tread compounds would improve the development in wear research.

Fig. 1. Cross section of radial tread of a passenger tire [Source Barum Continental]

1 – Inner-Liner, 2 - Carcass material, 3 – Bead wire (Core), 4 – Apex, 5 – Tire strip, 6 – Rim (Bead) strip, 7 – Sidewall, 8 – Breaker strip, 9 – PA Breaker strip,
10 - Tread

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2 Experimental Part

13 kinds of tire tread compounds used for motorcycle treads subjected to high stress, treads for technical, agricultural and multipurpose vehicles were experimented. All compounds represent real products and are produced and machined:

- Motorcycle tread cross (compounds number I, J, K);
- Motorcycle tread enduro (compound M)
- Technical vehicle treads (compound L)
- Agricultural tire (A, B, C, D)
- Gear tire (E)
- Tire for high-lift (F)
- Farm-tractor tire (G)
- MPT/R (H)

2.1 Measured properties

Based on the analysis of the properties, which might influence the final behaviour of rubber products, the following series of measurements were carried out:

- Tensile strength (tensile test machine T 2000, Alpha Technologies)
- Elongation (tensile test machine T 2000, Alpha Technologies)
- Resilience Luepke (Testing equipment Luepke)
- Shore Hardness (Hardness tester HPE – D Bereiss)
- Dynamic behaviour (DMA) (DMA DX – 04T, RMI)
- Fast test of wear (Chip – Chunk tester, Manas 2005)

The testing samples for all tests were prepared by compression moulding process on laboratory press. The shape and dimensions of the testing samples are according to the norms .[2,3]

2.2 Test of wear

The tests of tire (tread) wear are time and money consuming. They are carried out using real tires in testing rooms or directly in the terrain during driving tests. That is one of the reasons for searching a method that would in a very short time (in minutes) and on small samples test the wear for a comparison of the different kinds of compounds.

Based on these requirements an equipment seen on Fig. 2 was designed. The Chip – Chunk wear testing machine (J. R. Beatty and B. J. Miksch in RCHT, vol. 55, p. 1531.) was used for basal measurements [1]. A new machine enabling changing the tested parameters and true simulations of the process conditions was designed, see Fig. 2.

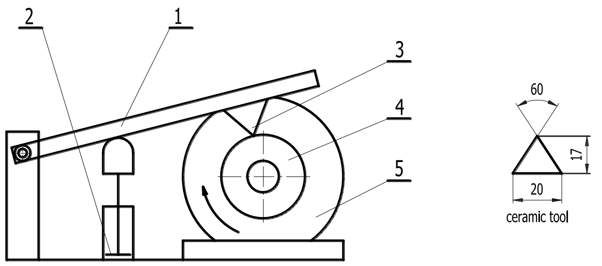

Fig. 2. Design of testing equipment
1 – Arm, 2 – Pneumatic cylinder, 3 – Ceramic tool, 4 – Sample,
5 – Electric motor

Arm 1 pivotable around the neck is lifted by lifting part (piston of the pneumatic cylinder) 2. The arm that has a special ceramic edge tool is lifted and dropped 3 on the perimeter of the revolving wheel 4 (testing sample) driven by the electric motor 5. When it drops on the revolving wheel, the ceramic tool gradually chips the material and creates a groove on the wheel. The size of the groove chipped by the ceramic tool in a given time is the scale of wear. The ceramic edges proved a perfect resistance to wear. If the tool was well manipulated there was no difference between original and “worn” plate. [7,8]

2.3 Dimensions of the testing sample

For easier preparation of testing samples the form seen on Fig. 3 was designed (The outer dimensions are corresponding to the testing sample of test Luepke).A groove was made (chipped) by the ceramic tool into the testing sample during the experiment. It was expected from experience with tooling other materials, esp. metals, wood or plastic, that the groove would be regular. Due to the properties of machined rubber – which demonstrated its elasticity – the moment the rotating ceramic tool dropped on the rotating wheel, pieces of material were torn off. For this reason, the initial intension of wear evaluation by measuring the groove diameter was changed to gravimetric evaluation.

a) **b)**

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Fig. 3. Testing sample for fast wear test
a) Before the test, b) after the test

2.4 Wear analysis
The influence of drop of the ceramic tool on the surface of the testing sample is crucial. If the sample 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 experiment 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. [5,6]

2.5 Test conditions
The conditions for experimental testing of fast wear were kept:

- Sample revolution 500 rpm, 750 rpm, 910 rpm
- Impact frequency 1 Hz
- Ceramic tool stroke 60 mm
- Temperature 21 °C
- Test period 270s

The testing sample was clamped in the jaws of the machine to prevent is skidding and was rotated. The lifting mechanism for lifting the arm with ceramic tool was started. The time was measured from the first contact of the ceramic tool with the testing sample. The samples from each compound were used for the measurements. The mass loss was investigated by weighing on analytical balances after the experiment. Measured values were statistically evaluated.

The greatest wear was observed with compounds I, K. The best properties according to the wear were reported with testing samples prepared from compounds H, B (Fig. 4.).

2.6 Dependence on running conditions
The vehicles move in a different speed in the terrain in running conditions which can be characterised by the circumferencial speed of the tire tread. For this reason, other experiments were carried out to characterise the wear during different conditions. The wear test was done during the frequencies of testing samples of n_1= 910 revolutions/min, n_2= 500 revolutions/min, n_3= 250 revolutions/min. The other conditions of the experiment remained unchanged. Figure 4 shows the expected increasing tendency of the wear.

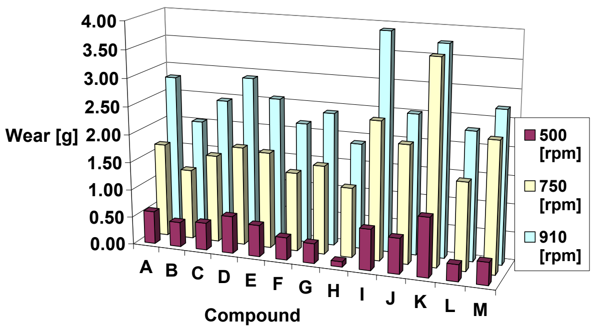

Fig. 4. Comparison of mass loss at different frequencies

2.7 Wear procedure
The aim of the experiment was also to observe the mass difference of the testing sample (wear) during the test.

The mass of the samples was measured in regular intervals (30s) during the wholetime of the experiment (270s). Attention was paid to the interval 0 – 60s due to the different behaviour of the tested compounds and the mass of the tested sample in this interval was measured every 10s.

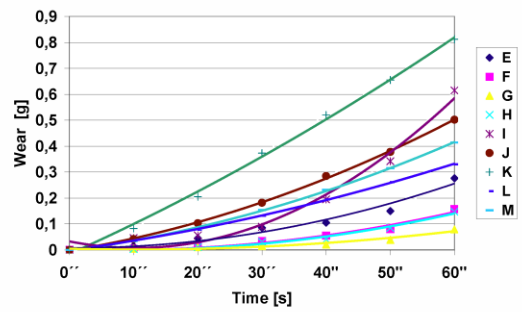

Fig. 5. Gradual mass loss in all compounds in time (0 – 60)s

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

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happen, the surface wear is negligible. The compounds with low resistance to wear (e.g. compound I) increase already from the beginning of the test. The comparison of the chosen compounds is seen on Fig. 5.

Figures 6 and 7 show the mass loss (wear) during the whole experiment (0 – 270)s.
Gradual tendency to faster wear with proceeding time is observed in most cases. This means that before the creation of first rips on the surface of 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. Figure 8 shows a remarkable similarity between the real tire tread wear and the wear of the testing sample.

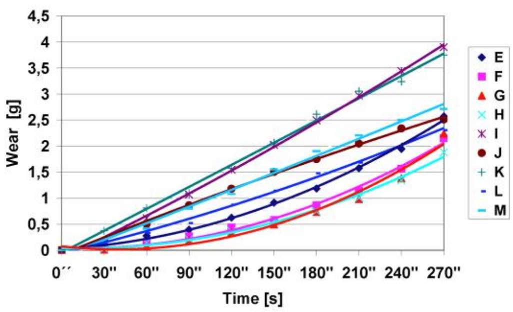
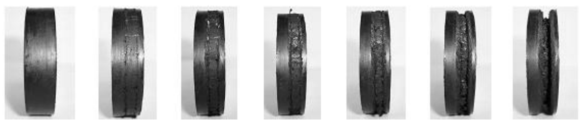


Fig. 6. Gradual mass loss in all compounds in time (0 – 270)s



0" 20" 40" 60" 80" 180" 270"

Fig. 7. Wear of tested samples in time (0 – 270)s

3 Conclusion

This experiment deals with the wear of heavily stressed rubber parts, especially the tire treads. An instrument for fast test of wear was designed and machined. Standard set of measurements was carried out, specifically the tensile tests (tensile strength, tear strength) tests of hardness, resilience and dynamic properties (DMA test).

The experiment included a project and realisation of experimental machine for a fast test of wear. This machine enabled measurements on the testing samples prepared from thirteen different types of tire treads used for the production of tires undergoing high stress such as motorcycle tires and tires for technical and agricultural vehicles. The results of the measurements are compared.

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