Journal of Achievements in Materials and Manufacturing Engineering
VOLUME 37
ISSUE 2
December
2009

Wear of tyre treads

D. Manas*, M. Manas, M. Staněk, V. Pata
Department of Production Engineering, Faculty of Technology,
Tomas Bata University in Zlin, TGM 275, 762 72 Zlin, Czech Republic
* Corresponding author: E-mail address: dmanas@ft.utb.cz

Received 13.09.2009; published in revised form 01.12.2009

Methodology of research

ABSTRACT

Purpose: The description of a new method of rubber parts wear testing especially wear of tyre treads is the main aim of this paper. Understanding of wear procedure could help to improve the quality of tyres and other rubber parts working in heavy terrain conditions.
Design/methodology/approach: For that purpose testing equipment was designed and constructed. New method of testing of wear resistance based on gravimetric determination of mass loss of testing part during the test period was prepared and well – proven. Behaviour of testing samples during the test was monitored using high speed video camera.
Findings: Because of complexity of this problem it would be very useful to continue this research and to describe in details the wear procedure using the new testing methods. Monitoring of wear progress by high speed video – camera may be one of the significant methods.
Practical implications: The main benefit for praxis could be seen in new testing method which makes comparing different rubber compounds possible from the point of view of their wear (Chip - Chunk) resistance.
Originality/value: Completely new in this paper is also monitoring of wear process using high speed video - camera.
Keywords: Rubber; Rubber mixture; Wear; Chip - Chunk test

Reference to this paper should be given in the following way:
D. Manas, M. Manas, M. Staněk, V. Pata, Wear of tyre treads, Journal of Achievements in Materials and Manufacturing Engineering 37/2 (2009) 538-543.

1. Introduction

Polymer processing industry is a much branched one because of the production of a lot of products for various applications. Products from polymers and composites with a polymer matrix find a wide range of applications. Polymers are used for making common use products, products for sports and free time activities, domestic/ white goods, packaging for industrial goods and food, construction, electrical engineering and electronics, engineering and automotive industry. They also play an important role in medicine.

The production of above stated goods experiences an increasing demand. The rubber industry plays a very important part in the polymer processing since the tyre production occupies a dominant position in this branch.

Thus, tyre production is very important for in industrial development, especially regarding the raw material consumption. Together with the production of hoses their position on the market is significant. Following the development rate calls for – besides investment in technologies – investment in R&D. These institutions are of a long-term character, but ensure further development of the field and keeping up competitiveness. One of the contributions in this branch may be research works carried out at universities, reacting to practical industrial practice. The question of rubber machining and rubber wearing products including the tyres belong to these issues.

Polymer machining possesses some unique character in comparison with metal cutting. It usually requires special tools, special technology conditions, especially in terms of mechanical and thermal properties of polymers.

Rubber machining appears to bear smaller importance concerning its application in technical practice and to be less frequent, e.g. rubber rolls, although this requires only extracting a thin superficial layer as the final operation is rather grinding.

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

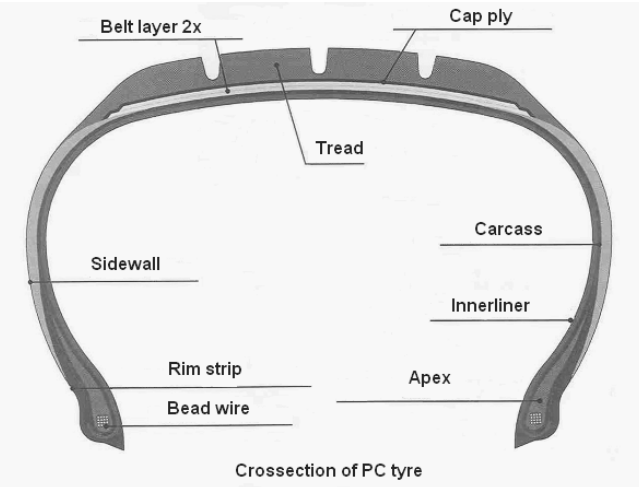

Fig. 1. Cross section of radial tread in a passenger tyre: 1 - innerliner, 2 - carcass material, 3 - bead wire (core), 4 - apex, 5 - tyre strip, 6 - rim (bead) strip, 7 - sidewall, 8 - breaker strip, 9 - PA breaker strip, 10 – tread

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

The tyre wear is usually tested under running conditions, nowadays 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 behaviour of tyre tread compounds would improve development in wear research.

2. Experiment

2.1. Used materials (compounds)

Thirteen kinds of tyre 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 183, 185, 186),
- Motorcycle tread enduro (compound 290),
- Technical vehicle treads (compound 188),
- Agricultural tyre (104, 110, 114, 116),
- Gear tyre (161),
- Tyre for high-lift (162),
- Farm-tractor tyre (165),
- MPT/R (168).

2.2. Test of wear

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

Based on these requirements, the equipment seen in Figure 2 was designed. The Chip – Chunk wear testing machine was used for basal measurements [1]. A new machine enabling changing the tested parameters and true simulations of the process conditions was designed, see Figure 2. Arm 1 pivotal around the neck is lifted by a lifting part (pneumatic cylinder piston) 2. The arm that has a special ceramic edge tool is lifted and dropped 3 on the perimeter of a revolving wheel 4 (testing sample) driven by 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 following requirements had to be taken into consideration during designing:

- The rotations of the wheel (testing sample) must be adjustable in a wide range. To fulfil this requirement, an electro motor with adjustable revolutions using a static converter of frequency was chosen. This eliminated reduction of the revolutions by a transmitter enabling the frequency to be regulated from 0 to the maximum value. An electro motor 4AP80 – 6s and a static converter of frequency Alitivar 08 were used.
- For an adjustable arm lift, a pneumatic mechanism composed of piston with an adjustable lift was designed and machined. The cylinder is supplied directly from the control valve EVK 3120 by SMC and the process is controlled by a control unit of FESTO type FEC – FC20/10W.
- Securing constant parameters of the edge tool. First, a steel tool was designed, which however leads to a very fast wear changing conditions of the experiment. For this reason a ceramic tool was tested – a treated edge for cutting tools (type TNGN 220608, Saint Gobein). Cutting edges with 60° angle were ground (Figure 2).

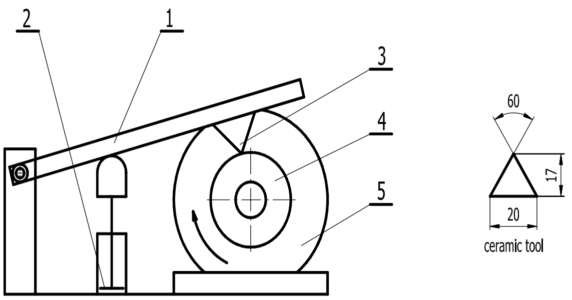

Fig. 2. Design of testing equipment: 1- arm, 2- pneumatic cylinder, 3- ceramic tool, 4- sample, 5- electric motor cross section

The ceramic edges proved a perfect resistance to wear. If the tool was well manipulated there was no difference between original and "worn" plate.

2.3. Dimensions of the testing sample

For easier preparation of testing samples, the form seen in Figure 3 was designed (the outer dimensions correspond to the testing sample of Luepke test).

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.

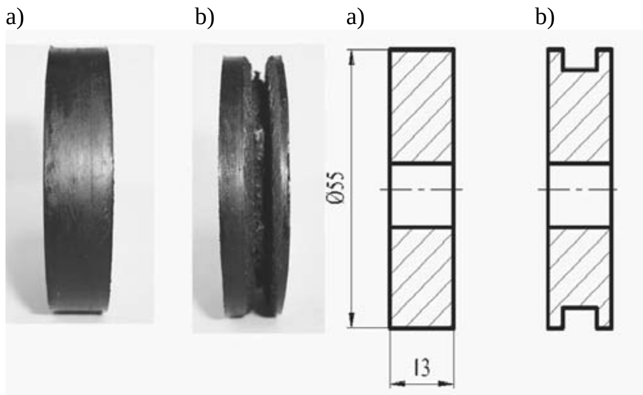

Fig. 3. Testing sample for fast wear test a) before the test, b) after the test

2.4. Wear analysis

The influence of the ceramic tool drop on the surface of the testing sample is crucial. If the sample were rigid, the evaluation of the dropping force impact 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 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 from skidding of the testing sample while running and the control system of the testing machine will secure constant conditions for testing.

2.5. Test conditions

The conditions for experimental testing of fast wear were kept:

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

The testing sample was clamped in jaws of the machine to prevent it from 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. Ten 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.

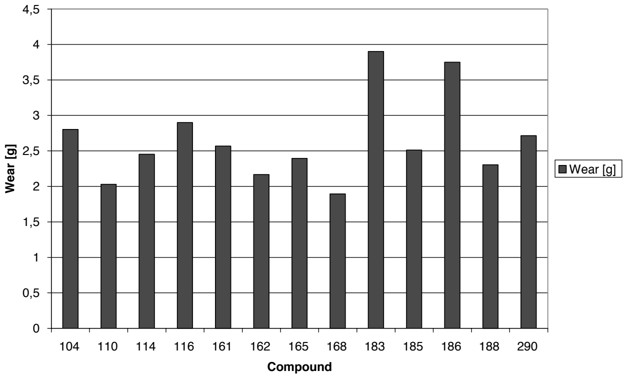

Fig. 4. Comparison of the mass loss

The greatest wear was observed with compounds 183, 186 and 116. The best properties according to the wear were reported with testing samples prepared from compounds 168, 110 a 162 (Figure 4).

2.6. Dependence on running conditions

The vehicles move at different speed in terrain in running conditions which can be characterised by the circumferential speed of the tyre tread. For this reason, other experiments were carried out to characterise the wear in 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 the same. Figure 5 shows the expected increasing tendency of the wear.

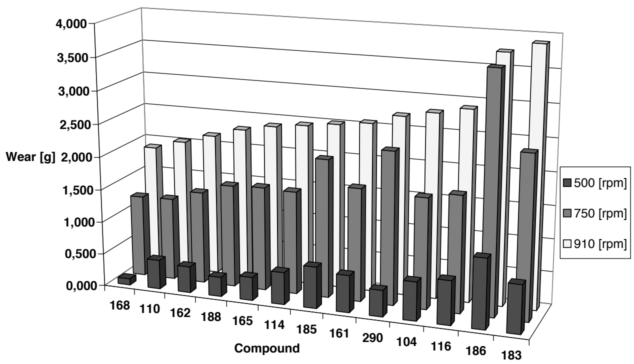

Fig. 5. Comparison of mass loss at different frequencies

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

Study of wear procedure using high speed camera.

To be able to learn and understand much more about wear procedure, the study using high speed video camera Olympus of i type – speed was carried out. Observation of wear mechanism showed that the wear mechanism itself occurs in the area between the "splinter" and testing sample, which is found between already deformed and not yet deformed material (Figure 6 and Figure 7). This is usually determined by the proportion between the layer thickness of the chipped rubber material and the thickness of the deformed "splinter". Considerable part of exerted energy (kinetic energy of the ceramic tool during drop) is - while wearing - concentrated to the place where the rubber material touches the ceramic tool and where parts of rubber material are detached.

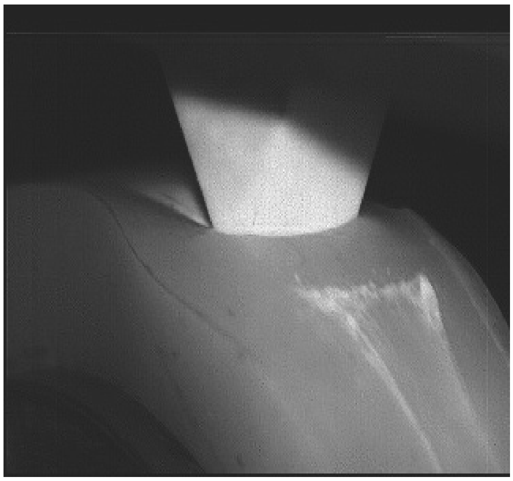

Fig. 6. Jumping on the surface

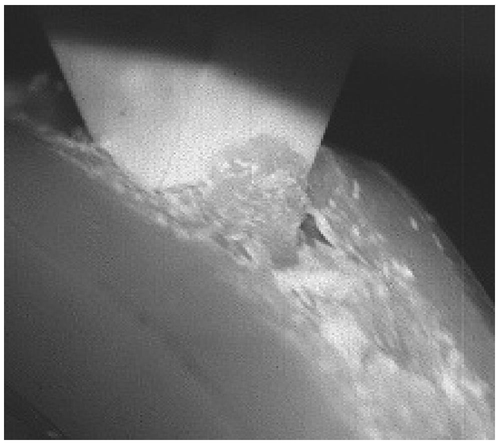

Fig. 7. The "avalanche effect" starts

The amount of the deforming force is closely related to angle front (rake) of the ceramic tool (terrain roughness and sharp stone edges). In practice, this means that the angle front (rake) and the speed of motion on terrain roughness and sharp stone edges dramatically influence the conditions of created distortional deformation. The area between the splinter and rubber sample represents the crucial moment of the wear process during which material is taken away and splinter created. However, this is also a moment where shear stress and shear force, having a substantial importance on the process appearing on the ceramic tool area, are generated. Friction also plays a very important role, as the rubber material is during the ceramic tool drop exposed to high pressures. The rubber splinter is moving due to the deformation process on the front area of the ceramic tool and affects the temperature slightly by its activity and movement. There is a wide range of rubber mixtures with different properties. For that reason, it is necessary to pay attention to their behaviour and bear in mind that the force ratio distribution during the wear is different at each mixture. This process was confirmed using high-speed video camera (Figures 6, 7).

3. Discussion

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 186) show wear increase just from the beginning of the test. The comparison of the chosen compounds is seen in Figure 8.

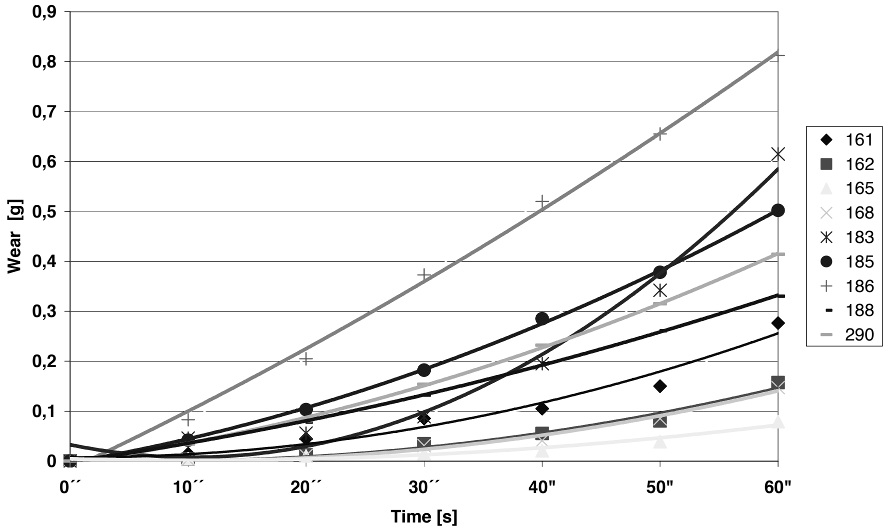

Fig. 8. Gradual mass loss in all compounds in time (0 – 60)s

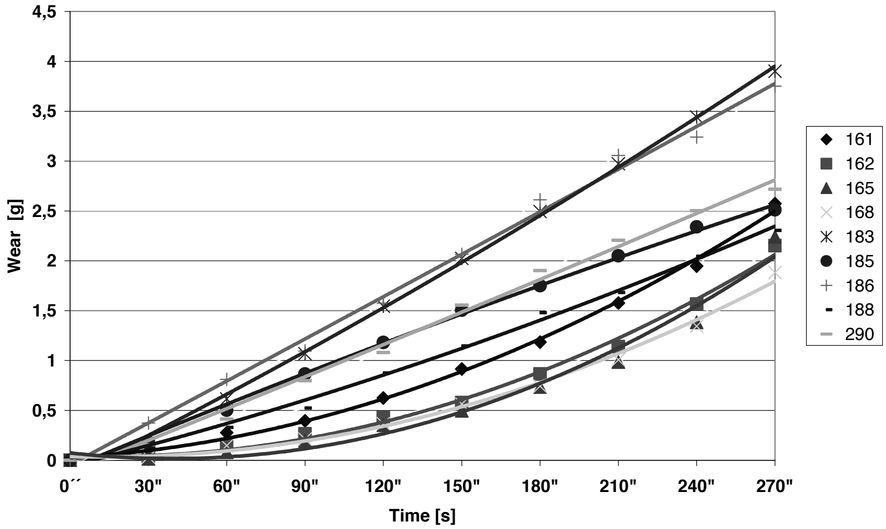

Fig. 9. Gradual mass loss in all compounds in time (0 – 270) s

Figures 9 and 10 show the mass loss (wear) during the whole experiment (0 – 270) s.

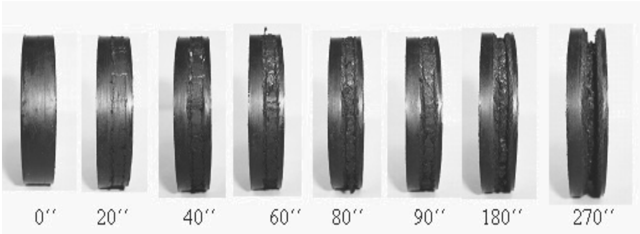

Fig. 10. Wear of tested samples in time (0 – 270) s

Fig. 11. Comparison of the real wear using the tested sample

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 tyre tread while driving on harsh terrain conditions (sharp stone edges etc.) the wear is quite small. The first damage to the tyre tread however starts the "avalanche effect" of other damages and the wear increases faster (Figure 7). Figure 11 shows a remarkable similarity between the real tyre tread wear and the wear of the testing sample. A new aspect about a problem of wear of rubber compounds brought the investigation using high – speed video camera. The first results show that wear of rubber part is a very complicated problem and it is necessary to study it in details.

4. Conclusions

Rubber parts wear is a very complicated problem. Learning and understanding it could help to improve the quality of rubber products.

The new testing equipment where the testing conditions can be widely changed was designed and constructed.

The used method allows to compare different rubber compounds from the point of view of their wear resistance. The test is very rapid and of low cost.

New testing technique using high speed video – camera makes it possible to describe the wear procedure much deeper in details.

Acknowledgements

This article is financially supported by the Czech Ministry of Education, Youth and Sports in the R&D project under the title of 'Modelling and Control of Processing Procedures of Natural and Synthetic Polymers', No. MSM 7088352102.

Additional information

The paper was published also in the Archives of Materials Science.

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