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The optimization of the materials properties for the freight tyres in dependence on defect propagation

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Abstract. The paper deals with the optimisation of the materials properties for the freight tyres in dependence on defect propagation at the dynamic loading. The given investigation was mainly focused on cracks and defects in tyre casing, which is commonly used for passengers cars. The mentioned measurement or investigation was performed under the strictly specified conditions. The given measurement of crack propagation in car tyre casing was based on changes of speed, changes of loading as well as changes of service time interval. It is important to point out that the pressure in the tyre was predetermined to be the constant value. The experimental procedures were carried out by help of special drum testing machine with designation: IGTT 25kN – C and with the 1707mm drum diameter. The mentioned measurement was performed for the area of tyre casing shoulder and it was in the site between the first and the second buffer lining. Using the ITT- 1 program relating to non-destructive testing analyser, the CCD camera for testing procedure of tyre casing was used for the camera images which were taken from the internal side of the tyre casing. The inspection of the tyre casing was performed for the specified points or segments around the periphery of he tyre casing. The measurement was based on simple cycle. The analyser testing led to creation of the resulting protocol based on ITTView program and on the basis of this program, it was possible to display or print this protocol in the form of the phase image mode or video mode. The crack propagation was evaluated on the basis of tyre casing loading as well as kilometres which were overrun during the car service. Shearograpy is a method which can be used for specification of tyre casing cracks under the laboratory conditions and it can be also useful during the quality inspection of the new made products. The obtained knowledge relating to crack initiation and propagation in tires can be used for easier solutions referring to different areas and sites of the tyre casing and by this way, it is possible to determine which one of variants is the most suitable for utilisation in the production.

Introduction

The effort to improve the road-traffic safety leads to systematic enhancement of tyres. All producers endeavour to manufacture such tyres which would be reliable, safety, easily mountable as well as they would have long-term lifetime which is connected with wear-resistance. Moreover, the given tyres should be available from the aspect of cost and they should not have any negative influence on living environment. Enormous attention is also paid to occurrence of various material defects and failures, such as separations, air pockets, bulge and so on. Mutual adhesion between particular materials of which the tyre is made is also seriously investigated [1, 2]. Detection of defects, failures, separations in a tyre casing can be done by several methods. Destructive as well as non-destructive methods can be used for investigation and they help us to find defects occurring in new, re-treaded as well as old and worn-down tyres. Real disadvantage in relation to destructive methods is closely connected with the fact that the given tyre casings which are tested by destructive method are not able to be used again and again for testing, because destructive testing means destruction or rupture of tested object and in our case it is the tyre casing. It means that destructive methods are difficult from these aspects:

- from the economic aspect, because destructive testing means usage of high number of tested tyres,
- from the aspect of preservation of specific homogeneity for sample.

Therefore, there is the tendency to use non-destructive methods of testing in relation to tyre casings and the main contributions and advantages are:

- analysis of tyre casing without its damage or rupture,
- possibility to control the product and its following utilization for other purposes,
- the given method can be used for the process of tyre development as well as during the changes relating to manufacturing, during the control of quality of tyre casings and moreover, the mentioned method of testing can be also used for fatigue tests, speed tests and lifetime tests
- non-destructive analysis can be done again and again in relation to the same testing sample or product
- according to the type of used non-destructive method, it is possible to detect product defects in the course of a few minutes.

Structure of the tyre casing

It is necessary to have knowledge relating to structure of the tyre casing because only this is the correct way for specification of areas where the separations are initiated and moreover, it is also much easier to specify the distribution of the mentioned separations. The structure of tyre casing [3] consists of:

1. *Tread* – it is important part of tyre casing, because it is in the close or direct contact with the road surface. It is made of blend which has good adhesive properties and high wear resistance;
2. *Buffer linings* – it absorbs circumferential stresses as well as side forces and it absorbs also impacts which occur during the contact with road. It consists of individual layers of rubberized cord while the given layers are laid in a criss-cross formation;
3. *Cord carcass of casing* – it is the basic and supporting part which comprise of one or several linings from rubberized cord and they are laid around the bead plies;
4. *Filling linings* – they are the shaped rubber profiles and they are used for better and smoother mutual junction of individual construction parts relating to tyre casing;
5. *Bead bundle* – it reduces deformation in the area where there is the end of cord carcass and protection of bead;
6. *Sidewall* – it protect side part against damage and weather conditions. It is made of blend which is resistant to flex cracking and cracking in common;
7. *Inner skim rubber* – it is rubber lining which can be found on the internal side of tyre casing. It is used for protection of cord carcass and in the case of tubeless tyre casings, it avoid diffusion of air into the cord carcass of casing;
8. *Bead reinforcement* – it can be fabric as well as steel;
9. *Bead plies* – they consist of steel wires or strips which have high strength. They provide smooth and safe anchoring of cord carcass linings as well as attachment of tyre casing to wheel rim.

Fig. 1 shows the given parts mentioned hereinbefore.

Fig. 1. Structure of tyre casing: 1. tread; 2. buffer linings; 3. cord carcass; 4. Filling linings; 5. bead bundle; 6. Sidewall; 7. Inner skim rubber; 8. bead reinforcement; 9. bead plies.

Process of measurement with non-destructive analyzer

Non-destructive analyser enables us to recognize tyre structure defects quickly and easily – it is connected with closed separations (Fig. 2), the extension of which we will observe by the dynamic test. Typical arrangement of the tyre control with help of the simple cycle for tyre impurity finding is in the Fig. 3.

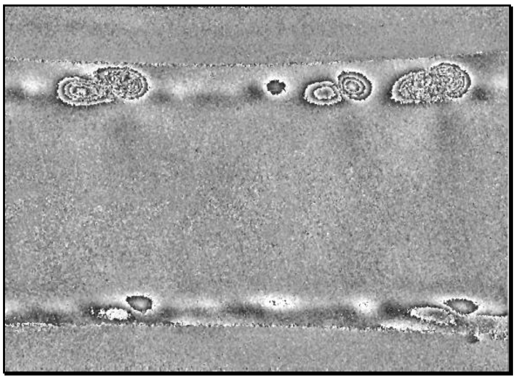

Fig. 2. Defect displayed on monitor.

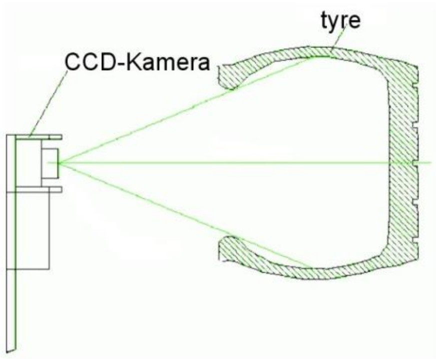

Fig. 3. Testing assembly by the simple cycle.

For observation of extension of the tyre separations, the specific tyre was selected and as it can be seen in Fig. 4, the separations in the shoulder area as well as crown area were found by the help of the ITT-1 testing analyser. After 20 hours of the dynamic test, there were only small changes in separations extension, therefore we introduce the display only after 200 hours of the dynamic test (Fig. 5) [4–6].

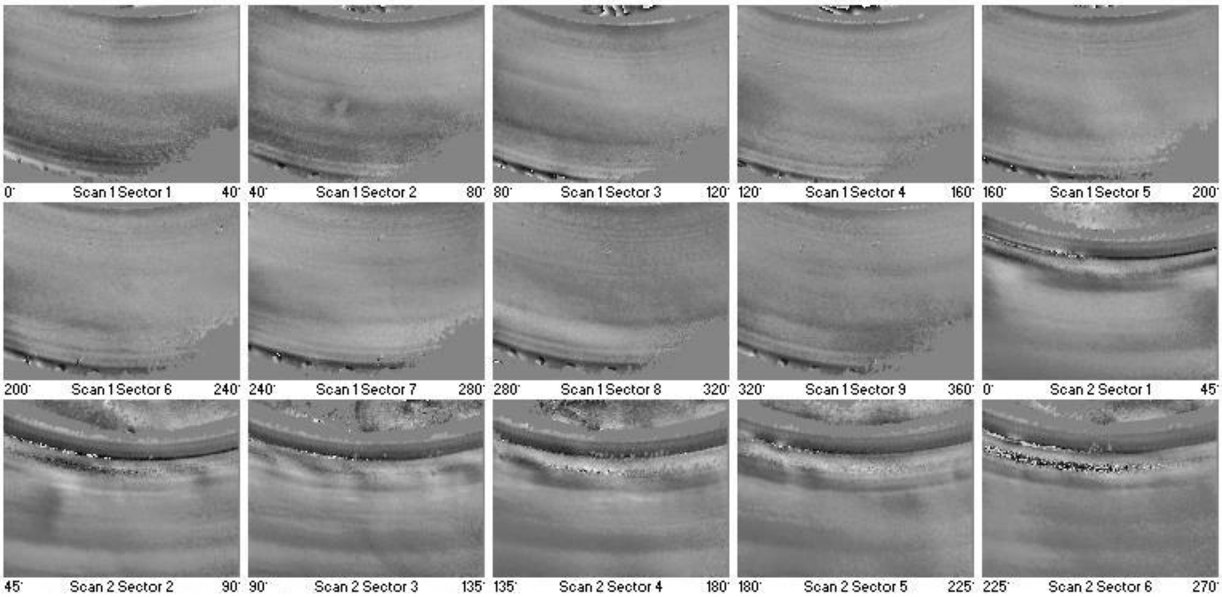

Fig. 4. First measurement before dynamic test.

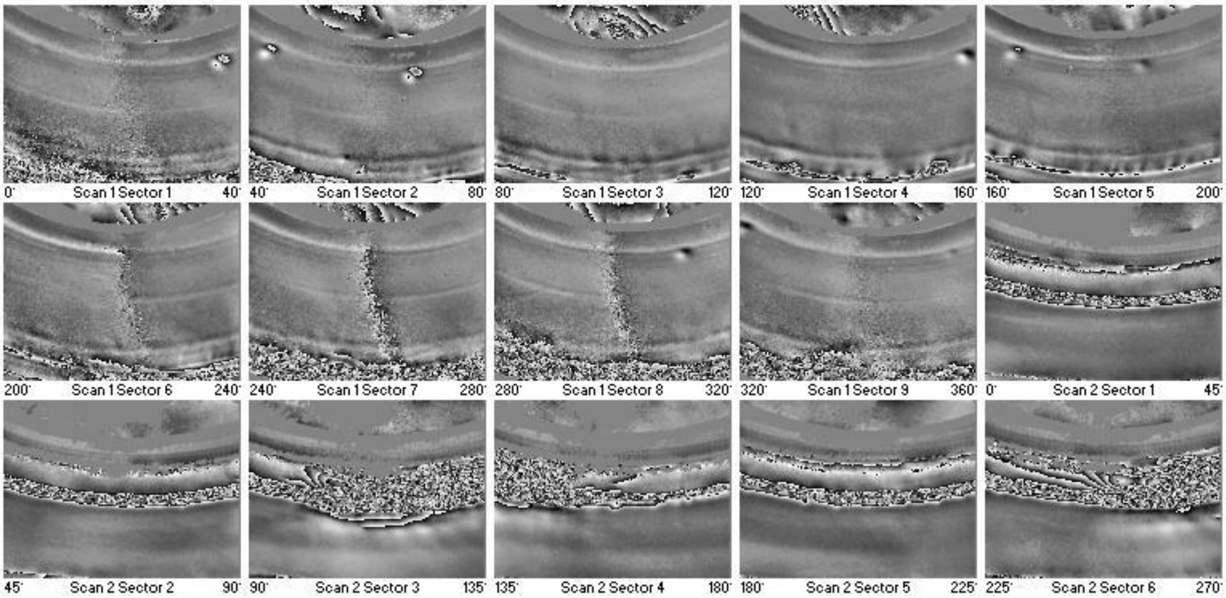

Fig. 5. 12th measurement after 200 hours of the dynamic test.

Summary

On the basis of individual tyre figures it can be concluded that defects and separations on the tyre periphery are propagated and they join after dynamic loading. In Fig. 5, separations created almost around the whole periphery can be observed. Separations in the crown of the tyre casing were not detected after 10 000 km of running. After this detection by means of the ITT-1 machine, we cut the tyre and studied it for specification of separations which were seen in the individual scans. The occurrence of separations was confirmed, while small separations were detected for both shoulders in the end area in relation to the buffer lining and these separations were propagated around the whole tyre periphery – see Fig. 6 and 7.

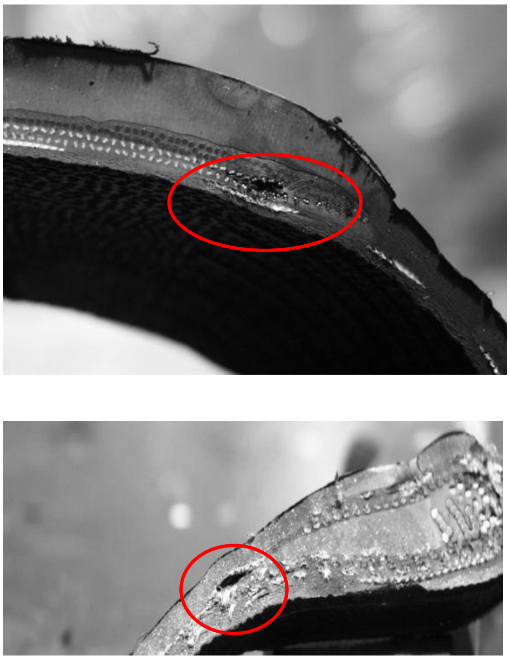

Fig. 6. Tyre section after 100 hours of dynamic testing

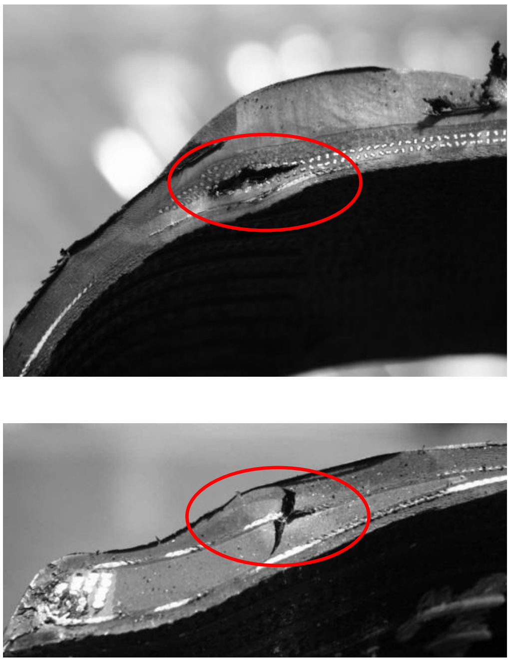

Fig. 7. Tyre section after 200 hours of dynamic testing.

Taking individual variants of tyres into account, the mutual comparison of tyres, which were made of different rubber blends, was carried out, while the dependence on the defect area (measured in mm^2) represented the crucial factor in relation to comparison. The given comparison can be seen in Fig. 8.

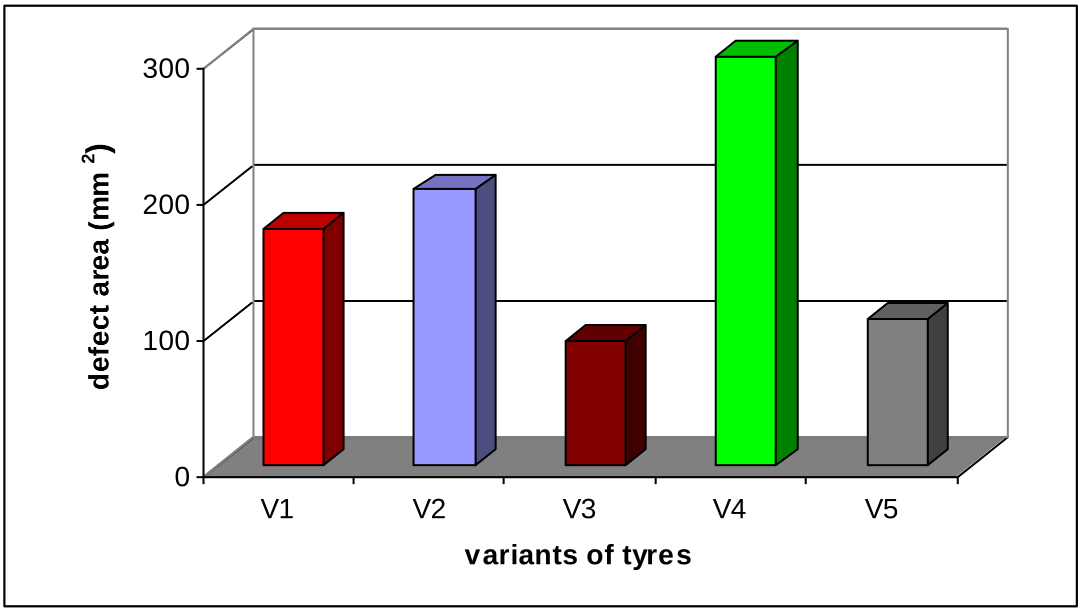

Fig. 8. Mutual comparison of tyres made of different rubber blends.

The given comparison of defect propagations in tire casing in dependence on increasing speed during the fatigue test can be seen in Fig. 9.

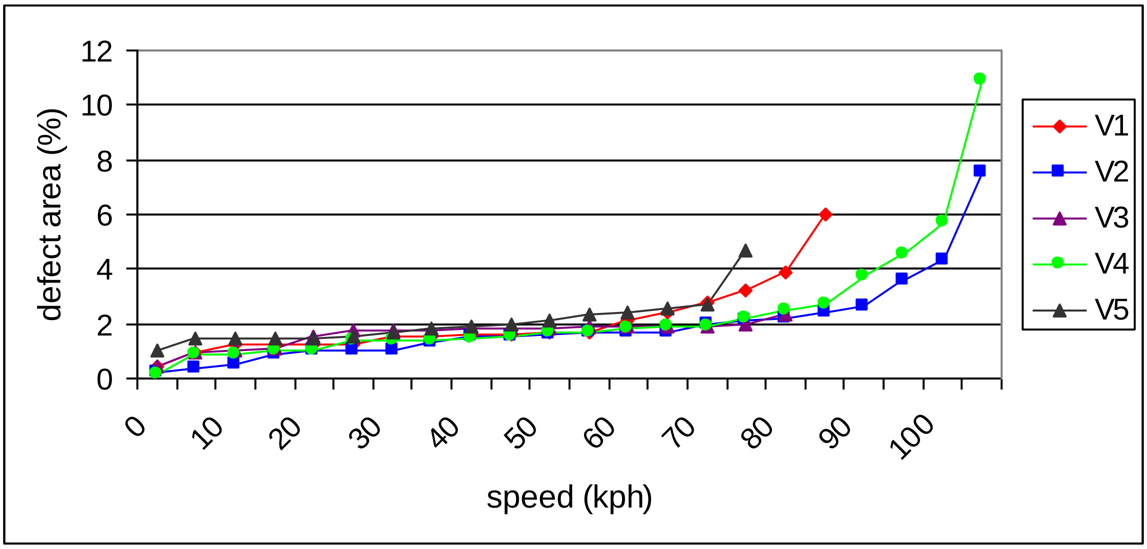

Fig. 9. The mutual comparison of defect propagations in tire casing in dependence on increasing speed during the fatigue test

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