The experimental measurement of the tyre casing defects for the freight vehicles at the dynamic loading

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Abstract. The paper deals with the experimental measurement of the tyre casing defects for the freight vehicles at the dynamic loading. The given investigation was mainly focused on cracks and defects in tyre casing, which is commonly used for freight vehicles. 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 25 kN – C and with the 1707 mm 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.

Keywords: measurement, holograph, dynamic loading, non-destructive method

1 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

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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.

2 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.

The Fig. 1 shows the given parts mentioned hereinbefore.

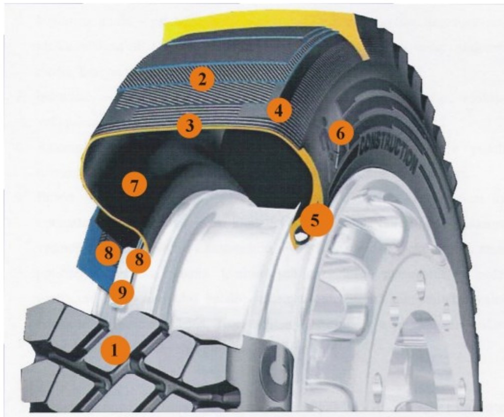

Fig. 1. Structure of tyre casing: 1) Tread; 2) Buffer linings; 3) Cord carcass; 4) Filling linings; 5) Bead bundle; 6) Sidewall; 7) Inner skim rubber; 8) Bead reinforcement; 9) Bead plies

3 Descriptions of tyre defects

The defects which have serious influence on the road-traffic safety and reliability can be classified, as follows:

- defects which occur during manufacturing (manufacturing defects)
- defects which occur during tyre operating (operating defects)

Especially, air pocket in the tyre carcass can be included into manufacturing defects because it can be source of later separation and it means that the lifetime as well as reliability of given tyre decrease. Some other manufacturing defects are closely concerned with irregular or asymmetric construction of tyre casing and these defects cause lower wear resistance. Advanced producers of tyres use the special register or list relating to defects and on the base of this register or list, the final products are classified into the specific quality grades or classes.

Operating defects involve:

a) defects which are caused during mounting on vehicle and they can occur after non-professional service or after wrong operating of service devise.
b) defects which are caused by own incorrect operating due to the overloading of vehicle, incorrect tyre pressure or even the wrong driving technique.

4 The process of measurement by help of non-destructive analyser

The distribution of separations was investigated by help of special drum testing device IGTT 25 kN – C where the diameter of drum was 1707 mm (Fig.2) and by help of non-destructive analyser see (Fig. 3).

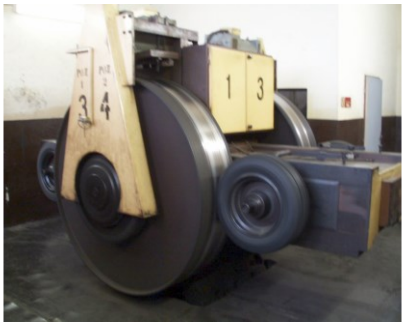

Fig. 2. Drum testing device

Fig. 3. Non-destructive analyser

Non-destructive analyser enables us to recognize tyre structure defects quickly and easily – it is connected with closed separations (Fig. 4), 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. 5.

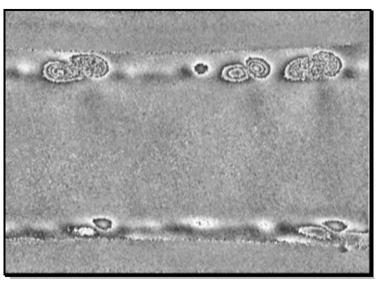

Fig. 4. Defect displayed on monitor

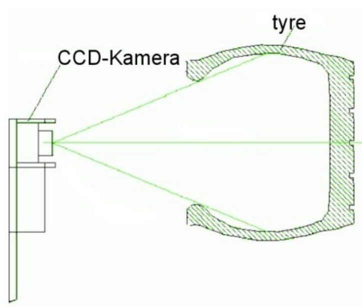

Fig. 5. Testing assembly by the simple cycle

For observation of extension of the tyre separations, the specific tyre was selected and as it can be seen in Fig. 6, 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. 7) [4–6].

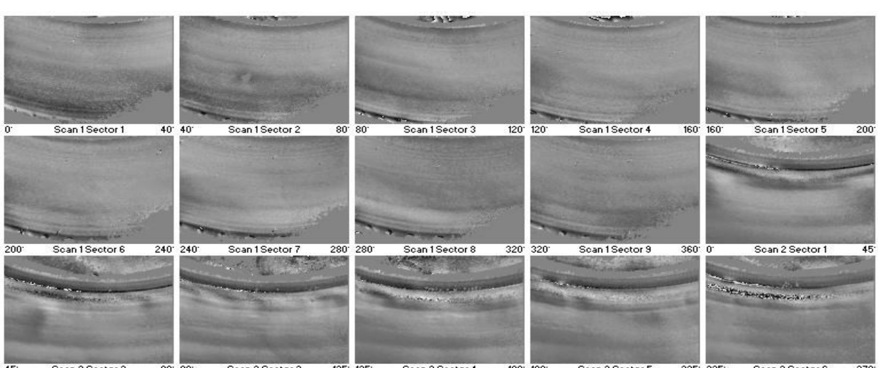

Fig. 6. First measurement before dynamic test

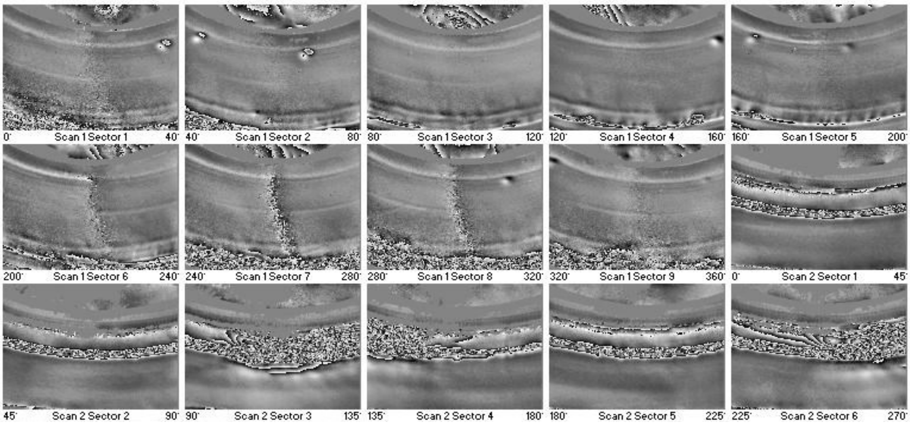

Fig. 7. 12th measurement after 200 hours of the dynamic test

5 The results of measurement for separations in the tyre casing which were obtained with the help of laser interferometry

The Figs. 8 - 21 reveal that there is the occurrence of given separations and cracks in various places in tyre. It can be seen that distribution of the cracks or separations is random or stochastic and it is influenced by many specific factors therefore the best way for evaluation is with help of statistic methods of probability for analysis of variance.

5.1 The basic types of separations in the site of shoulder and crown area of tyre casing

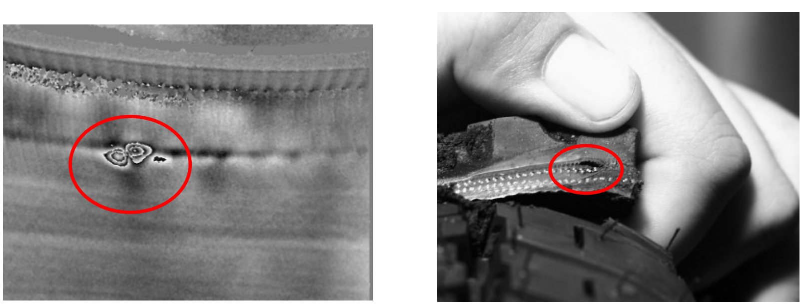

Fig. 8. The local separation in the site where the second buffer lining ends

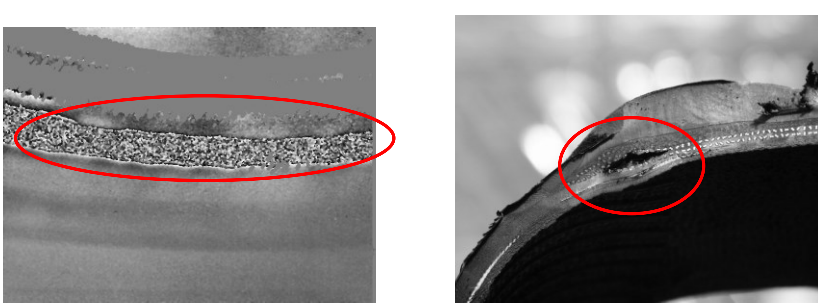

Fig. 9. The longitudinal continuous separation in the shoulder between the first and second buffer lining

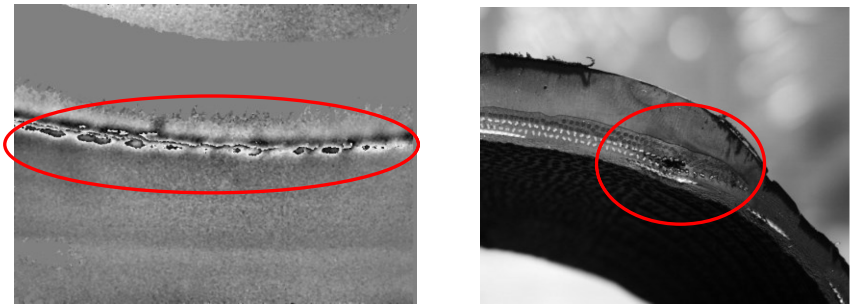

Fig. 10. The longitudinal chain separation in the shoulder between the first and second buffer lining

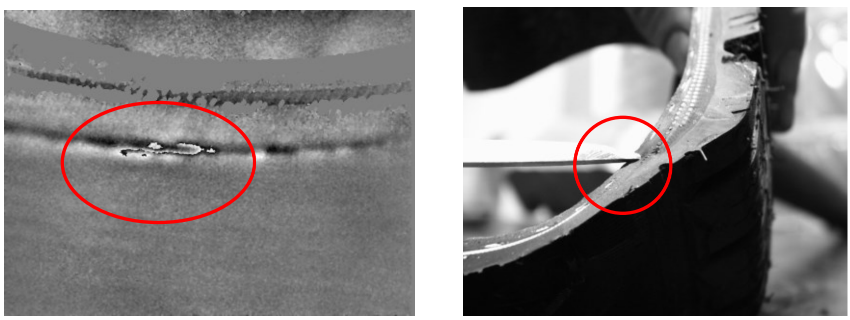

Fig. 11. The local separation in the shoulder where the first buffer lining ends

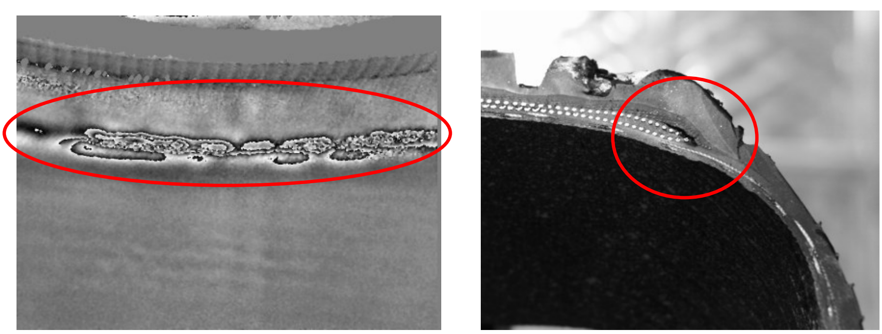

Fig. 12. The longitudinal separation in the shoulder where the first and second buffer linings ends and its expanding to the crown

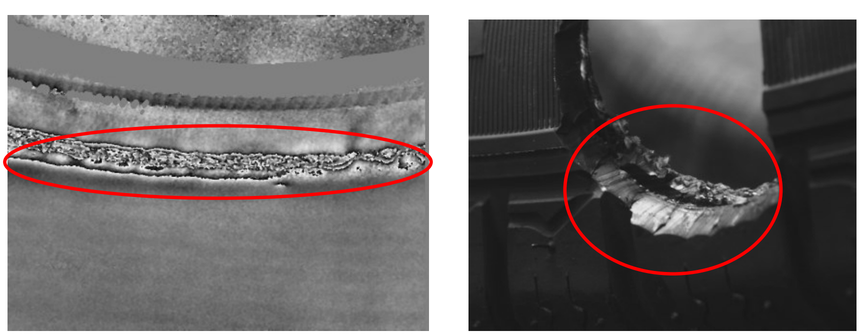

Fig. 13. The longitudinal separation in the shoulder and its expansion to the side directions

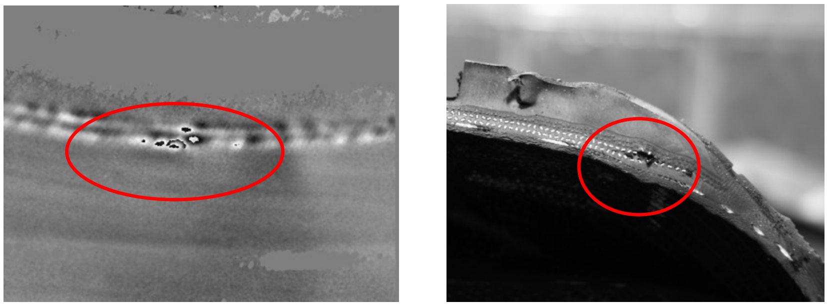

Fig. 14. The local separations in the shoulder in the site where the second buffer lining ends

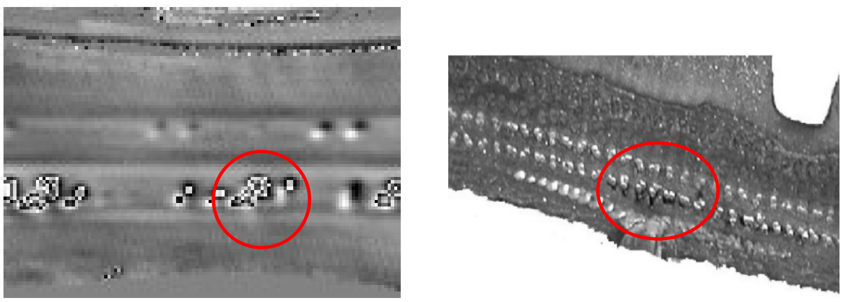

Fig. 15 The local separations in the crown between the first buffer lining and the cord carcass

5.2 The basic types of separations in the sidewall area and bead area of tyre casing

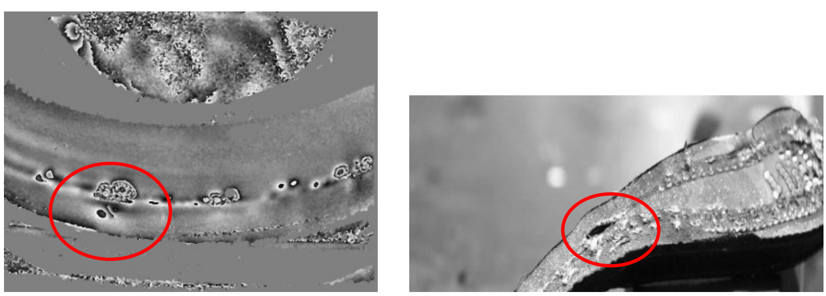

Fig. 16. The local separation in the sidewall between the end of carcass lining and bead bundle

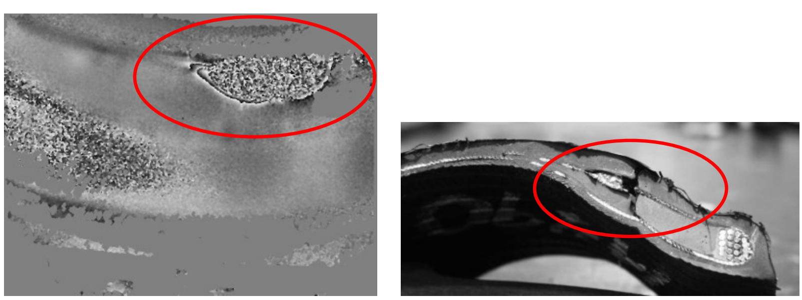

Fig. 17. The local separation in the sidewall - burst bead rubber and bead bundle, separation is between the end of carcass lining and bead bundle

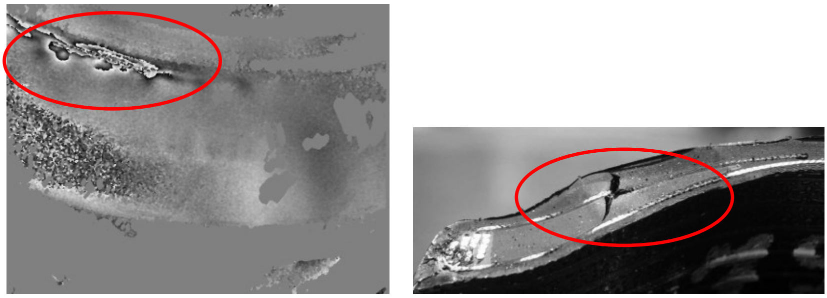

Fig. 18. The local separation of the tyre casing - burst bead rubber and bead bundle

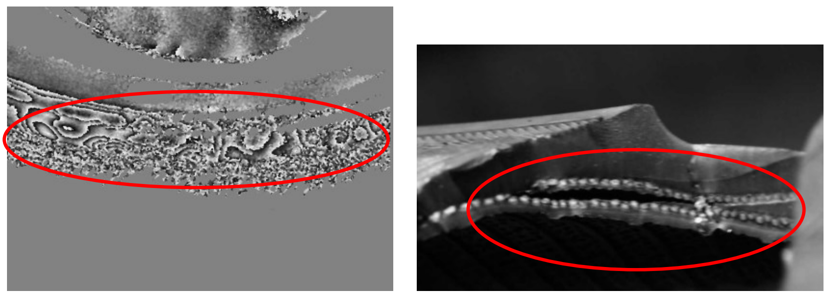

Fig. 19. The longitudinal separation in the sidewall of the tyre casing – it is in the site where the carcass lining is bent

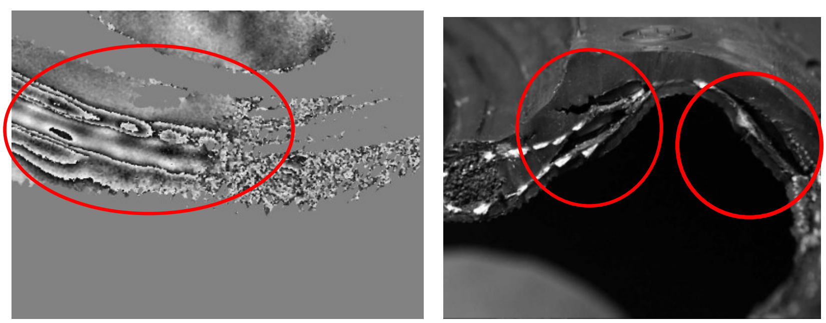

Fig. 20. The longitudinal separation in the shoulder and sidewall of the tyre casing between the bent carcass lining and filling linings of bead

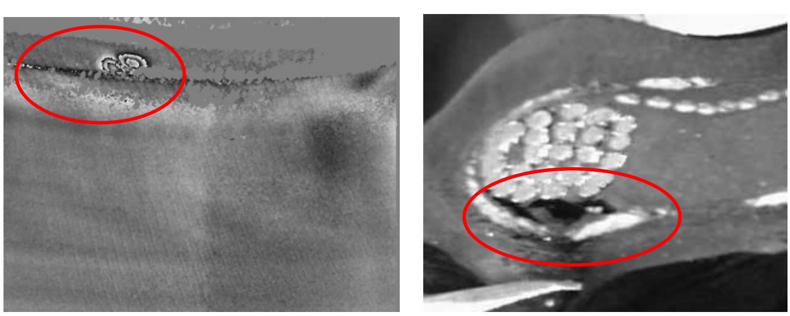

Fig. 21. The local separation in the bead area between bead plies and bent - burst bead rubber and bead bundle carcass lining

Conclusion

The individual scans of Figs. 6 and 7 reveal that there is the distribution of separations and their following mutual connection. On the base of scans in Fig. 7, we could conclude that there is the occurrence of separations around the whole periphery. The detailed and much closer observation of scan 1 (Fig.7) gives us information that separations in the shoulder can be even seen in outer or external part of tyre. The separations in the crown of tyre casing were not changed after 16000 km of dynamic testing. After this non-destructive testing of separations with help of ITT-1, the given tested tyre casing was tested in a destructive way. It was cut up, and it was inspected to confirm the occurrence of separations which were seen in the scans relating to non-destructive testing. There was the real confirmation of occurrence of separations. The distribution of separations and their mutual connection is shown in individual figures hereinafter (see Figs. from 8 to 21). The Figs. from 8 to 15 show the basic types of separations in the site of shoulder and crown area of tyre casing. The Figs. from 16 to 21 reflect the basic types of separations in the sidewall area and the bead area of tyre casing. For comparison, the images which are on the left side in the individual figures were obtained by non-destructive analysis and the images which are on the right side were obtained after slitting of the tire casing in the given site of separation.

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