AN INVESTIGATION ON REMOULD PASSANGER CAR TYRE HANDLING AND TRACTION PROPERTIES BASED ON ROAD TESTS

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Abstract

The handling and lateral stability properties of the car are dependent on the construction and technical condition of the tyres. The price dependence of these parameters has offen been not clearly defined. The comparison road tests offer a possibility to investigate these parameters of different tyres.

The objectives of the current investigation were to determine the extent of difference and the price dependance of the passenger car tyres sold in Estonia.

The handling properties of the test vehicle were evaluated taking into account the discrepancy between the maximum and the time-averaged lateral acceleration values obtained during the skidpad tests.

The traction properties of the remould tyres and new winter tyres were experimentally found to be comparable in several road and test conditions.

The results of the research show that the use of the summer tyre carcasses in remould winter tyre production potentially limits the lateral traction of the remould winter tyre. This can be related to a higher cornering stiffness provided by the summer tyre carcass.

For experimental determination of the traction and the handling properties a GPS-based analysis system was used.

Keywords: tyre, tire, remould, retreaded, traction, handling, braking, skidpad

INTRODUCTION

A passenger car is usually not driven at the limits of the its dynamical abilities by an ordinary driver. The price, durability and the driving convenience are typically the most common factors determining a consumer's preference when a tyre is chosen.

However, the most important properties of the tyre at the emergency driving situation are determined by the tyre and road contact patch and the overall handling of the vehicle. In such an extreme situation the importance of every meter of braking distance as well as every kilometre per hour of vehicle speed during cornering process becomes evident.

A remould (retreaded) tyre [1] is known to be a cost effective alternative for a new tyre. In general it has proven to be a safer choice compared to the second alternative – a used tyre, especially in winter conditions.

The purpose of this investigation was mainly targeted on the traction and handling properties of a selection of passenger car winter tyres.

The results of the study are intended for the remould tyre manufacturers in order to improve the development process of remould tyres in Estonia..

THE OBJECTIVES OF THE RESEARCH

The objectives of the current investigation were the following:

- The evaluation of the extent of the traction properties of the winter tyres studied in various road conditions;
- The comparison of the longitudinal and lateral traction coefficients of new, used and remould winter tyres;
- The development of a suitable road test methodology for determination of the influence of the tyre construction on vehicle handling properties;
- The preliminary evaluation of the handling properties of remould tyre and comparison with the properties of a new tyre.

THE EXPERIMENTS

A selection of six sets of winter tyres and six sets of summer tyres was chosen to perform the comparison road tests funded by the Estonian Road Administration. The first series of road tests was carried out by the automotive engineering departments of Tallinn College of Engineering and Tallinn University of Technology in 2003. Additionally, three sets of winter tyres were tested in 2005 in cooperation with Master Ltd - the largest remould tyre producer in Estonia. The most common passenger car tyre sizes: 195/65 R15 and 205/55 R16 were chosen for the selection of test tyres. The tyres were classified according to the price in order to investigate the price dependence of the studied properties.

The determination of the longitudinal traction properties between tyre and road by the braking test

The longitudinal traction properties are evaluated by the longitudnal coefficient of friction *φx* [3]:

$$\varphi_x = \frac{j_x}{g} = \frac{V_e - V_b}{t_j}, \qquad (3.1)$$

where: *jx* longitudinal deceleration of test vehicle;

g constant of gravity;

Ve end speed of the test vehicle during braking test;

Vb start speed of the test vehicle during braking test;

tj deceleration time.

An excample of the measured deceleration properties is illustrated on figure 3.1.

A constant deceleration phase of the braking process has only been taken into account when the data analysis was performed. The period of deceleration growth and the final stopping phase (*ts* on figure 3.1) has a dependence on the properties of the test vehicle [2] braking system. The speed of the test vehicle the deceleration phase started from *Vpid* was chosen higher (*Vpid*=85…90 km/h) than the speed (*Valg*=70 km/h) determining the starting value for the barking process taken into account (see equation 3.2).

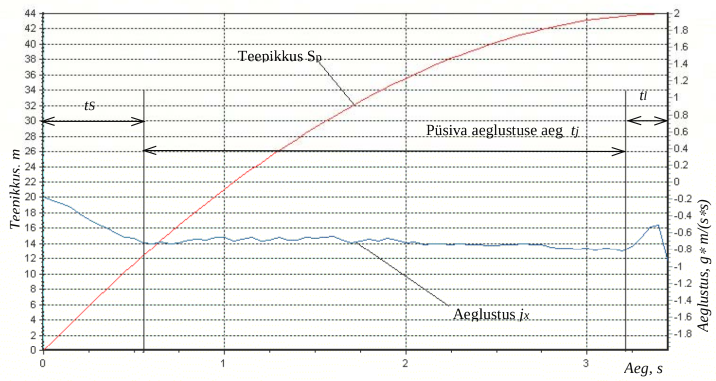

Figure. 3.1 An excample of the longitudinal deceleration j_x and braking distance S_p, duration of deceleration growing phase t_s, constant deceleration duration t_j, duration stopping phase t_l.

$$V_{pid} \geq V_{alg} + g \cdot \varphi_x \cdot t_s \qquad (3.2)$$

The determination of the lateral traction between tyre and road surface

The lateral traction properties between the tyre and road surface are described by the lateral coefficient of friction φy [3]:

$$\varphi_y = \frac{j_y}{g} = \frac{V_a^2}{R} \qquad (3.3)$$

where: jy lateral deceleration of the test vehicle moving on a curved path;

Va instantanous speed of the test vehicle;

R radius of curvature of the test vehicle path.

The coefficient of lateral friction φy was determined by the skidpad test. The test vehicle was driven on a constant radius path (see figure 3.2) at the maximum speed limited by traction. The maximum and time averaged values of the lateral acceleration were measured and used in φ_y calculation [2].

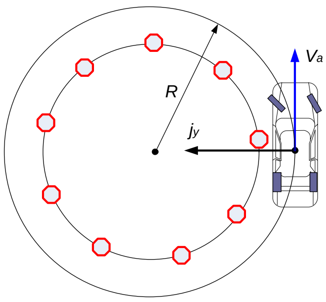

Figure. 3.2 A scheme describing the principle of the skidpad test

The experimental determination of the influence of tyre on vehicle handling properties

The influence of the tyre construction on the vehicle handling was evaluated by the discrepancy between the maximum and time averaged values of the lateral acceleration determined during the skidpad test procedure. The maximum value of the lateral acceleration j_{ymax} describes the limit of the lateral traction of the tyre on a studied road surface. The time averaged value (for example the value of the lateral acceleration averaged over 3 seconds) describes the limit of the lateral acceleration during the realistic cornering process i.e. in case of the emergency maneuvre.

The handling properties in general can be described as the reaction of vehicle to the actions of the driver. The extent of discrepancy between the maximum j_{ymax} and the time averaged values j_{y3s} of the lateral acceleration can be used to characterize the handling of the car driven at the limit of traction. In practice it is simpler to drive the vehicle at the limits of traction when this discrepancy is small. The major factor determining the car handling properties is found [4] to be the frictional forces created between the tyre tread and the road surface and the transformation of these forces by the carcass of the tyre and suspension to the vehicle body.

The lateral coefficient of friction φ_{y3s}, calculated according to the lateral acceleration value averaged over 3 seconds, offers a possibility to evaluate the critical vehicle speed during cornering if the radius of the path is known.

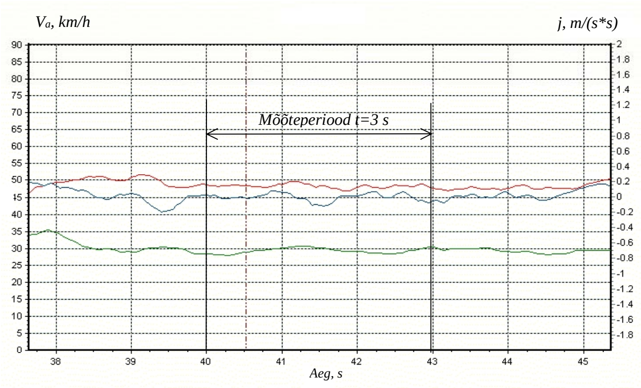

Figure. 3.3 An example of the measured skipad test data on wet road surface;

The speed of the test vehicle Va (km/h) (red line),

The longitudinal acceleration j_x/g (blue line),

The lateral acceleration j_y/g (green line)

Experimental equipment

The instantanous speed V_a, the longitudinal acceleration j_x , the lateral acceleration j_y, and the angular velocity ω_z (yaw rate) of the test vehicle were measured using a GPS-based system Racelogic VBOX Pro (figure 3.4).

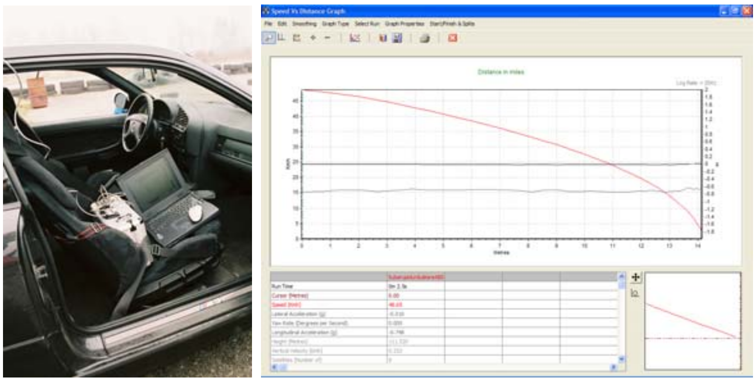

Figure 3.4 The passenger compartment of the test vehicle equipped with Racelogic VBOX system. An example of the graphical layout of the data analysis using Racelogic VBOX software

THE RESULTS AND DISCUSSION

The results from the longitudinal traction measurements

The experimental results of the longitudinal friction coefficient of the passenger car winter tyres on various road conditions are shown in figures 4.1 and 4.2.

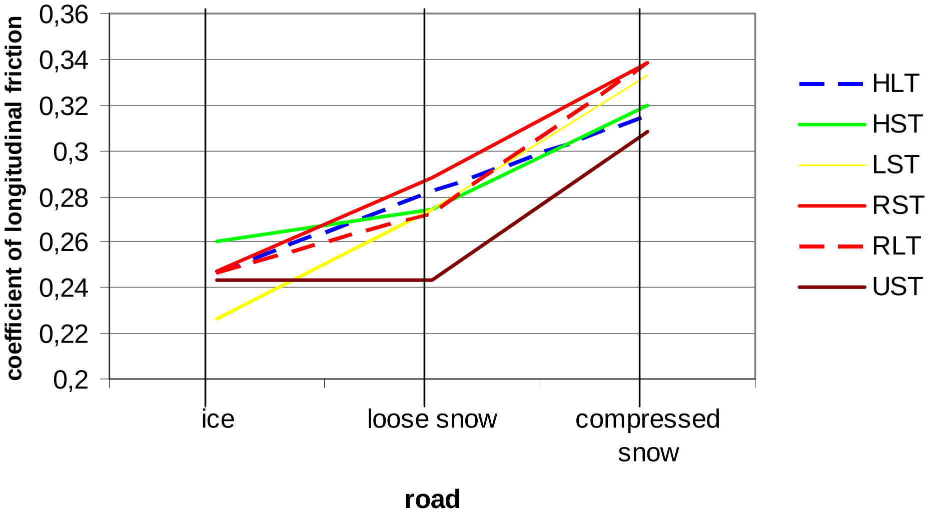

Figure 4.1 The coefficient of longitudinal friction for the selection of six sets of winter tyres studied (195/65 R15). HLT-studdless tyre, HST-studded tyre 1, LST-studded tyre 2, RST – remould studded tyre, RLT- remould studdless tyre, UST- used studded tyre

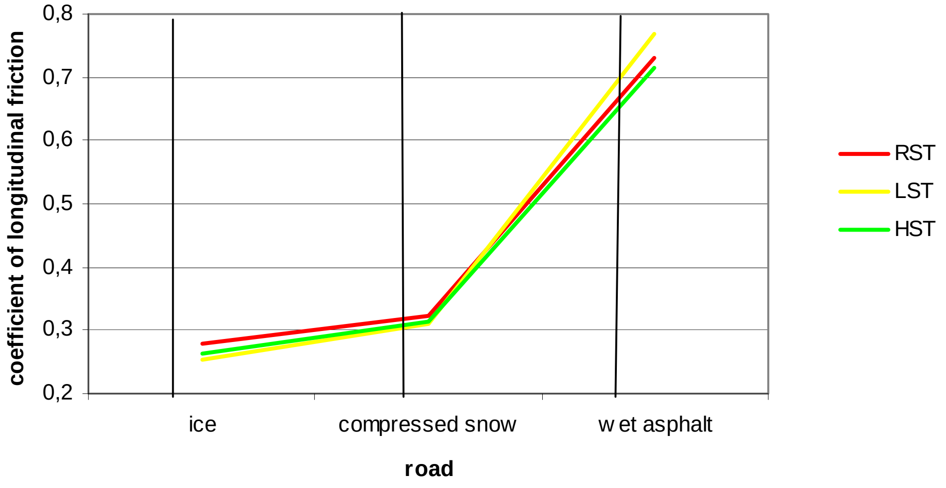

Figure 4.2 The coefficient of longitudinal friction for the selection of the three sets of winter tyres studied (205/55 R16). RST – remould studded tyre, LST- low priced studded tyre, HST- high priced studded tyre

The experimental results (see figure 4.1 and 4.2) indicate that a remould winter tyre built on a summer tyre carcass and having a modern tread design is able to provide longitudinal traction comparable to that of a high-priced new winter tyre and can outperform a low-priced new winter tyre.

The maximum extent of difference in the longitudinal traction between the tested sets of winter tires was found to be 13,2 % on ice-covered, 6,8% on snow-covered and 6,9% on wet asphalt.

The results from the lateral traction measurements

The experimental results of the lateral friction coefficient of the passenger car winter tyres on various road conditions are shown in figures 4.3 - 4.5.

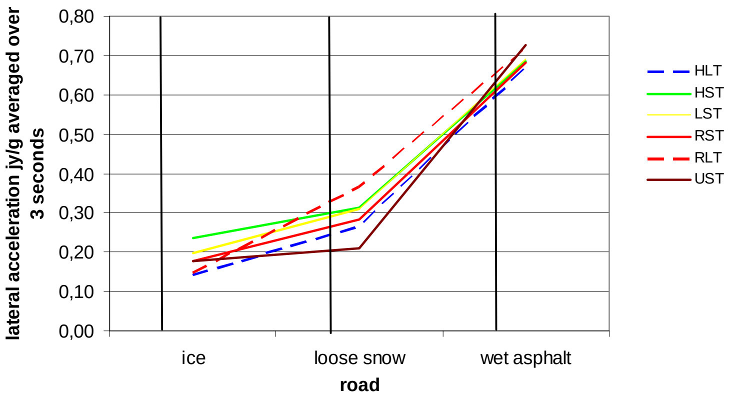

Figure. 4.3 The time averaged value over 3 seconds of the lateral acceleration of selection of six sets of winter tyres studied (195/65 R15). HLT-studdless tyre, HST-studded tyre 1, LST-studded tyre 2, RST – remould studded tyre, RLT- remould studdless tyre, UST- used studded tyre

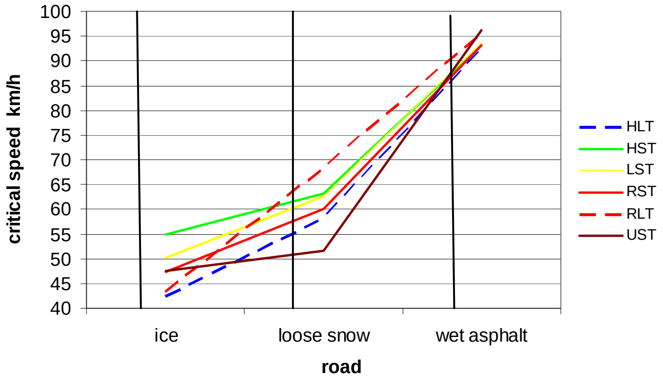

Figure 4.4 The critical speeds of six sets of winter tyres studied (195/65 R15). HLT-studdless tyre, HST-studded tyre 1, LST-studded tyre 2, RST – remould studded tyre, RLT-remould studdless tyre, UST- used studded tyre

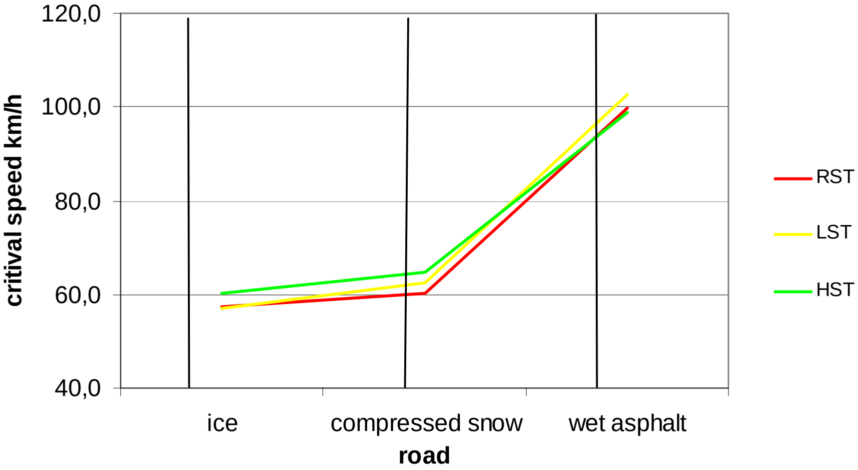

Figure 4.5 The critical speeds of the three sets of winter tyres studied (205/55 R16). RST – remould studded tyre, LST- low priced studded tyre, HST- high priced studded tyre

In figures 4.3-4.5 it seen that the lateral traction of the remould tyres is comparable to that of the low-priced new winter tyres while being outperformed by the high-priced winter tyres tested. The maximum extent of difference in the lateral traction between the tested sets of winter tires was found to be 40,4% on ice-covered, 27,0% on snow-covered and 7,4% on wet asphalt.

The extent of difference in the lateral traction is found to be remarkably larger than the value for the longitudinal traction, except in case of wet asphalt conditions.

The influence of the tyre on handling

The maximum values of the lateral acceleration of the remould winter tyres during skidpad test are comparable to new high-priced winter tyres (see figures 4.6-4.8) while the time-averaged values of this parameter remain 4-11% (on ice-covered surface), 8-16% (on snow-covered surface). This illustrates that the higher cornering stiffness of summer tyre carcass used for remould winter tyre production is not optimum for winter road conditions [3]. The results from the wet asphalt skidpad tests (see figure 4.8) show an advantage for the low-priced tyres tested as opposed to the results from the winter conditions, leading to the potentially higher cornering stiffness of those tyres.

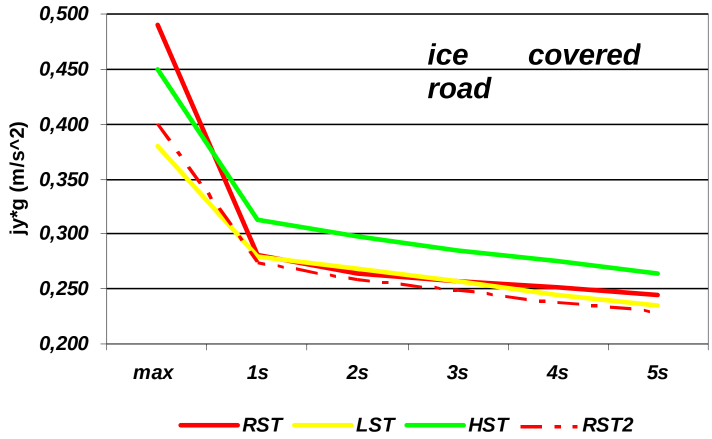

Figure. 4.6 The maximum and the time-averaged lateral accelerations of the three sets of winter tyres (205/55 R16) on ice covered surface. RST – remould studded tyre, LST- low priced studded tyre, HST- high priced studded tyre, RST2- 20% worn remould studded tyre.

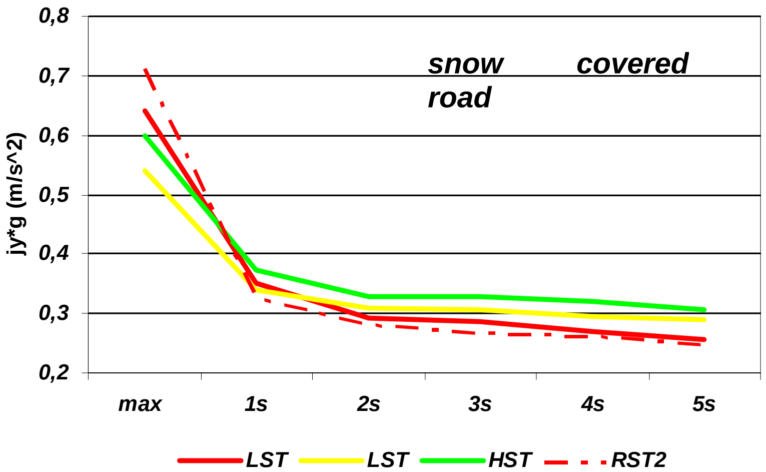

Figure. 4.7 The maximum and the time-averaged lateral accelerations of the three sets of winter tyres (205/55 R16) on snow covered surface. RST – remould studded tyre, LST- low priced studded tyre, HST- high priced studded tyre, RST2- 20% worn remould studded tyre.

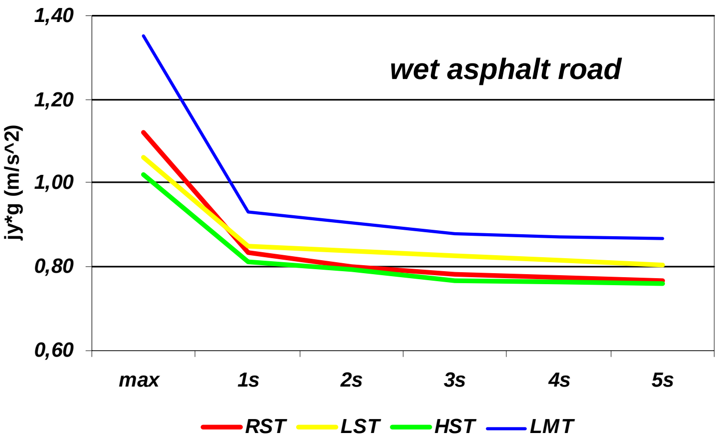

Figure. 4.8 The maximum and the time-averaged lateral accelerations of the three sets of winter tyres (205/55 R16) on wet asphalt. RST – remould studded tyre, LST- low priced studded tyre, HST- high priced studded tyre, RST2- 20% worn remould studded tyre.

SUMMARY

The purpose of the research was to investigate and compare the traction and handling properties of retread and new winter tyres.

The longitudinal coefficient of friction was determined experimentally in braking tests. In order to measure the lateral coefficient of friction the skidpad tests were performed in different road conditions.

A GPS-based system (Racelogic VBOX) was used to carry out the measurements and to perform the data analysis.

The handling properties of the test vehicle were evaluated taking into account the discrepancy between the maximum and the time-averaged lateral acceleration values obtained during the skidpad tests.

The experimental results indicate that a modern retread winter tyre has the longitudinal traction comparable to that of a new wintertyre.

It was found that the use of the summer tyre carcasses in remould winter tyre production potentially limits the lateral traction of the remould winter tyre. This can be related to a higher cornering stiffness provided by the summer tyre carcass.

However, the lateral traction properties of the tested remould tyres showed to be comparable with the low-priced new winter tyres studied.

A possible objectives for the future studies could be related to the following subjects:

- The evaluation of the influence of tyre carcass properties on the handling characteristics of passenger car
- The determination of the optimum cornering stiffness characteristics for the remould tyre production

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