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RADIAL FORCE VARIATION TIRE TESTING

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Abstract: *The paper is a part of study regarding the tire dynamic. In this paper the authors realize a set of lateral force tire testing. In order to evaluate the relationship between radial force variation and tire wear, we have designed several testing programs by using virtually the same type of vehicles, running on in tandem on the same selected driving course for the same distance and relative speeds.*
Keywords: *tire testing, radial force, time variation.*

1. GENERAL KNOWLEDGE

In Fig. we can see the RFV measurements on a very popular size (215/60R16). There are two curves; the blue curve is the initial RFV measurement trend (polynomial function) and the red curve is RFV after applying Machine Force Match procedure suggested by GSP9700 machine. The curvature of the trend line is not really relevant in this chart since the order of tires is random; what is important is the amplitude. For the blue line, for instance, the average RFV values are between 1.6Kg – 4.9kg while for the red line the average RFV values are between 1.2kg – 3.1kg. So the new RFV values (resulted from GSP Force Match) are significantly lower than the initial values [1].

We have used a 4th order Polynomial function to show the average trend for each RFV reading.

$$y = (c_4x^4) + (c_3x^3) + (c_2x^2) + (c_1x^1 \quad (1)$$

c_4:=INDEX(LINEST(y,$x^{\{1,2,3,4\}}$),1)
c_3:=INDEX(LINEST(y,$x^{\{1,2,3,4\}}$),1,2)
c_2:=INDEX(LINEST(y,$x^{\{1,2,3,4\}}$),1,3)
c_1:=INDEX(LINEST(y,$x^{\{1,2,3,4\}}$),1,4)
b:=INDEX(LINEST(y, $x^{\{1,2,3,4\}}$),1,5)

Please note that for the initial reading the tire was mounted with the light spot at the valve. We will call this position “P1” (see Fig. 3. Matching Points).

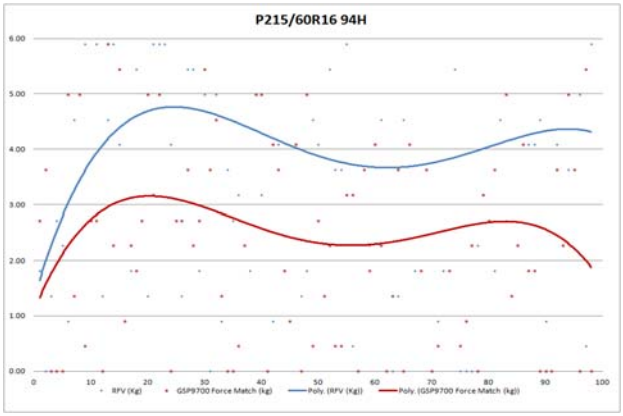


Fig. 1. P215/60R16 94H RFV before and after GSP Force Match

2. ALTERNATIVE PRACTICAL SOLUTIONS FOR REDUCING RFV

It is not always possible to have access to a special machine like GSP9700, therefore is may be useful to consider alternative practical solutions for reducing RFV on tires.

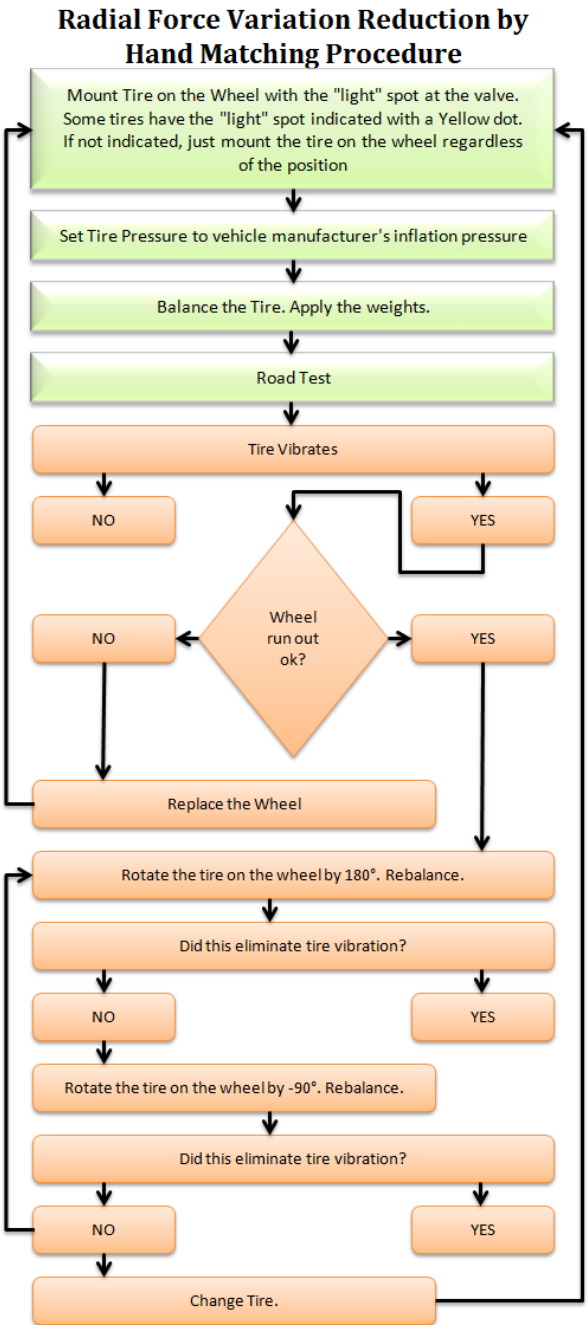


Fig. 2. Hand Matching Procedure

Since most of the tire shops have a balancing machine but not all the tire shops have a RFV machine, we're suggesting a very simple procedure of Radial Force Variation Reduction by Hand Matching the tire on the wheel (Fig.). There are three main steps:

- Check TWA run out and balancing condition. Record the data.
- Apply good lubrication and install tire with light spot at the valve. If the light spot is not indicated on the tire, we can use the last installing position when the tire was brought for vibration complains (P1) (see Fig.).
- If a vibration still exists, turn 180° clockwise from the previous position (to P2).

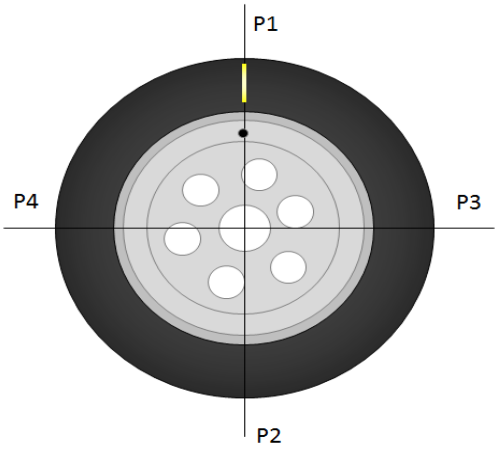


Fig. 3. Matching Points

For minimizing vibration even more, we can do try P3 and P4. We can make note of the progress and eventually install the tire on the position with the minimal vibration.
After following thoroughly this procedure we still have a vibration, we will need to change the tire.

We do understand that this procedure may become time consuming and most of the time vibration complains are brought to the tire dealers during the "rush season". Therefore we underline the importance of properly carrying out of steps 1 and 2.

We have determined by experimental ways that the vibration is considerably reduced after the first 180° rotation (P2) on the wheel.

In order to verify if this procedure can give reliable results, we're using the information from measuring several tires for RFV (**Error! Reference source not found.**).

By using unique wheels on each size, we're keeping constant wheel factor among all the tires. Therefore we can consider that the measurements are reflecting tire values only.

Most of the tires were at 0% wear and a large number of tires were within 8% - 12% wear (Fig.). Maximum tire wear was 16%.

So we can consider that the overall tire condition was close to brand new.

Table 1. Tested Tires

Tire Size	Units
P215/60R16 94H	98
P205/65R15 92H	74
P215/60R16 94V	49
P205/60R16 91V	33
P215/60R15 93H	33
P205/60R16 91H	31
P195/65R15 89H	28
215/60R16 94V	27
225/60R16 98H	22
225/50R17 94W	22
P195/60R15 87H	22
205/55R16 91W	15
P185/65R15 86H	13
255/40R17 94W	8
P205/55R15 87V	7
Others	98
Grand Total	**580**

Table 2. Rim Run Out Specifications

Wheel	RRO (mm)	LRO (mm)
6.5x15	0.203	0.127
6.5x16	0.254	0.203
7.5x17	0.305	0.229

Table 3. Test Program Card

Tires used	580 tires of different sizes, different brands. See **Error! Reference source not found.**.
Air pressure	Recommended by the manufacturer for each specific size; most often 200kpa
Ambient Temperature	Room temperature
Speed	Slow speed uniformity testing
Machine	Hunter GSP9700
Wheel centering check	Done on every single tire / wheel
Initial mounting	Yellow dot at the valve (P1).
Rims	3 master (alloy) rims, one for each tire diameter. Rims have very low radial and lateral run out (see Table)
Tire wear	Most of the tires were brand new tires or under 12% worn-out. See Fig. .
Tire run out check	Done on about 30% of the tires. Run out was within specifications (less than 1mm). We can reasonable assume that all the tires were within specifications.
Balancing	Static & Dynamic
RFV measurement	P1. Yellow dot at the valve, P3. 180° clockwise from the valve (from P1) P2. 90° clockwise from the valve (from P1)

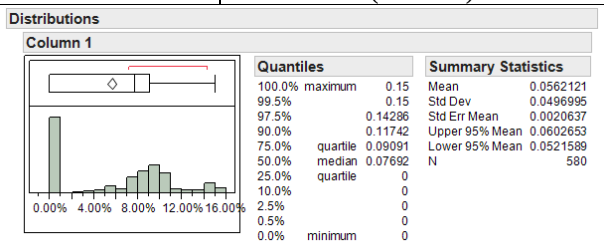


Fig. 4. Tire Wear

Tire uniformity from balancing point of view was relatively good Fig. . Most of the tires required between 0 –0.75oz (0 – 21g) on one side.

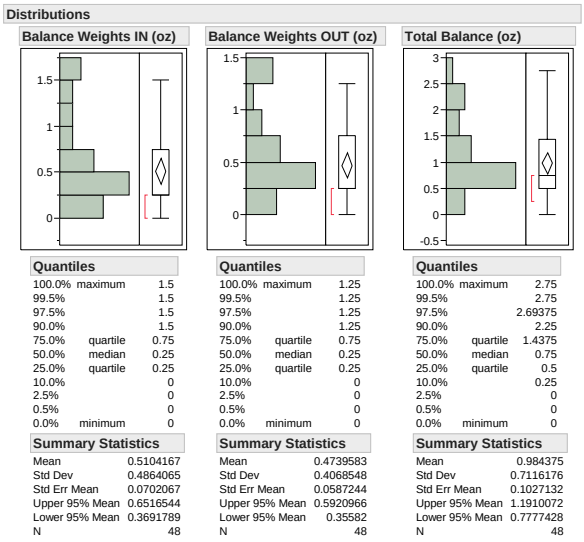


Fig. 5. Balancing weights for all tires

Most of the tires required total balancing weight between 0.5 – 1oz (14 – 28g). And the total balancing required weight was less than 3 oz (85g), which is the maximum acceptable level for Passenger Car tires by TMC.

We applied Hand Matching Procedure to all the tires. So we turned the tires that had RVF over 5kg from P1 at P2 then we turned the tires that had RVF over 5kg from P2 at P3. Then we compared the results with the RFV results when following the matching points suggested by the machine.

All tires to P1

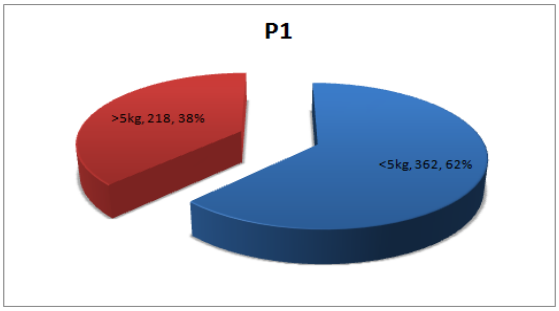


Fig. 6. RFV on all tires at P1

After proper lubrication and installing of all of tire to P1 we found 62% of tires to be less than 5Kg of RFV. We considered those tires as "Good" and we focused on the remaining 38%.

Remaining tires to P2

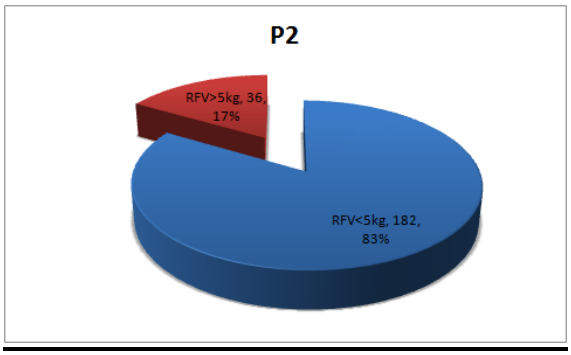


Fig. 7. RFV at P2 of remaining tire (RFV_{P1}>5kg)

At P2 we found 83% of tires to be "Good" (RFV_{P2} < 5kg). So we continued the procedure with the remaining 17%.

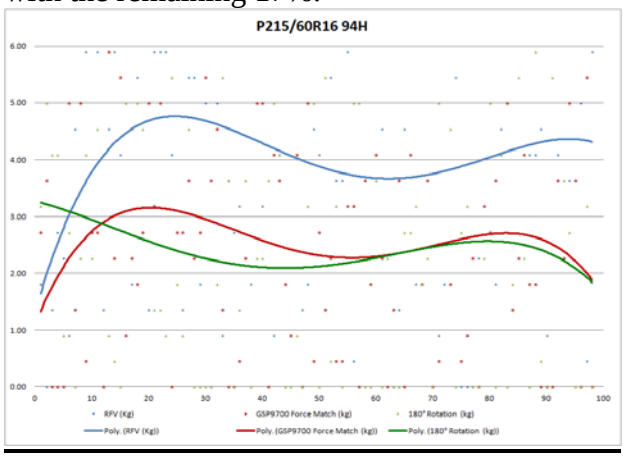


Fig. 8. P215/60R16 94H with 180° turn (P2)

As an example, here above (Fig.) is the data at P2 from the same popular size that we've used in Fig. . We see that the new RFV values (green line) are much lower than the values at P1 (blue line) and there is a relatively close approximation of the RFV from GSP Force Match (red line).

Remaining tires to P3

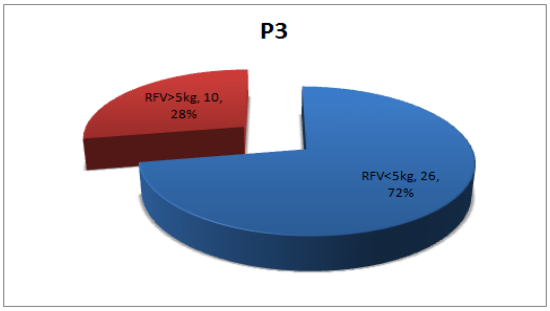


Fig. 9. RFV at P3 of remaining tire (RFV_{P2}>5kg)

At P3 we have 72% "Good" tires. The remaining 28% can be considered for further investigation or accepted as scrap.

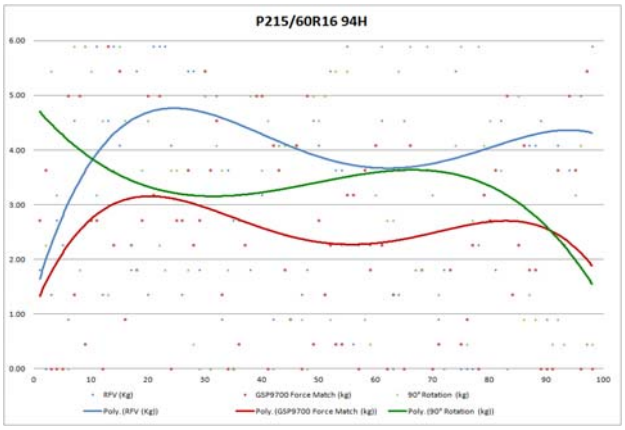


Fig. 10. P215/60R16 94H with 90° turn (P3)

If we're using again the example of P215/60R16 94H size, by turning the tire at P3 (Fig.) the RFV_{P3} is slightly higher than RFV_{P2}. However, we can see that RFV_{P3} is overall slightly lower than RFV_{P1} and can still give a pertinent comparison with GSP Force Match.

If we consider all the tires together we see that the results from 215/60R16 are reflected very comparatively Fig. .

If we're doing a Distribution analysis for all the tires we can see a substantial improvement from P1 to P2. And that P3 is projecting very acceptable values as well.

A complete graph with all the tires data at P1, GSP FM, P2 and P3 is presented in Fig. . We see that the RFV are projected between 0kg – 8.6kg. As we saw it previously, at 8.6kg RFV there should be a strongly noticeable vibration on the vehicle. However, the polynomial average line at P1 (blue line) is running between 3.5kg – 4.5kg. After the first match (GSP FM), the average is dropping between 2.2kg – 3.6kg. At P2 however, the variation is

between 2.1kg – 3kg. And at P3 RVF is between 3.3kg – 3.9kg.

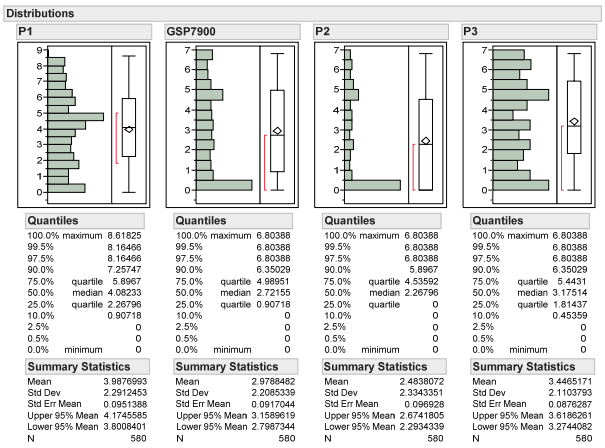


Fig. 11. RFV of all tires at P1, machine FM, P2 and P3

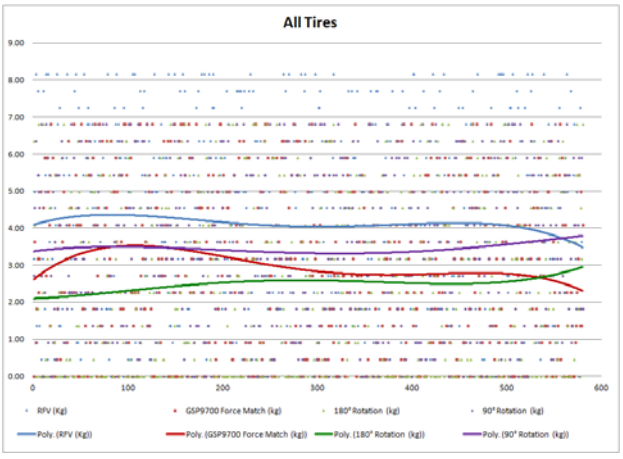


Fig. 12. All Tires with machine FM, 180° turn (P2) and 90° turn (P3)

For better accuracy we compare all the tires together by rim diameter. As we saw above, we have 15", 16" and 17".

We can make a very complex analysis based on the above charts. But our main objective here is to understand the reliability of our suggest Hand Matching procedure. We see that Hand Matching procedure gives a substantial improvement consistently for all of the 3 categories (rim diameter) at P2. The result at P3 is better for 16" tires while at 17" we have the highest RFV values. 17" is generally a heavier tire and it is very possible that tire weight itself can induce higher RFV levels.

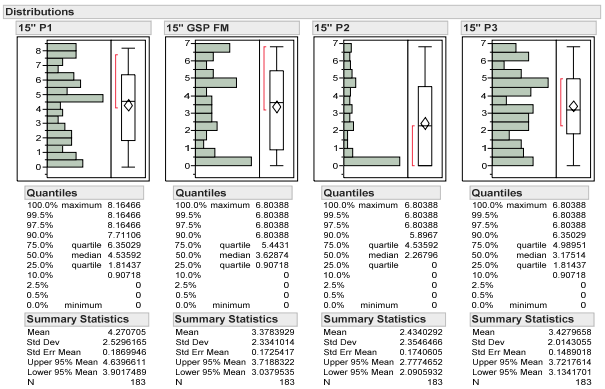


Fig. 13. RFV of all 15" tires at P1, GSP FM, P2 and P3

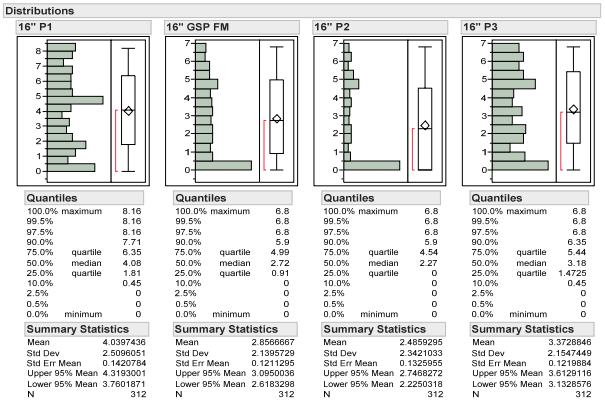


Fig. 14. RFV of all 16" tires at P1, GSP FM, P2 and P3

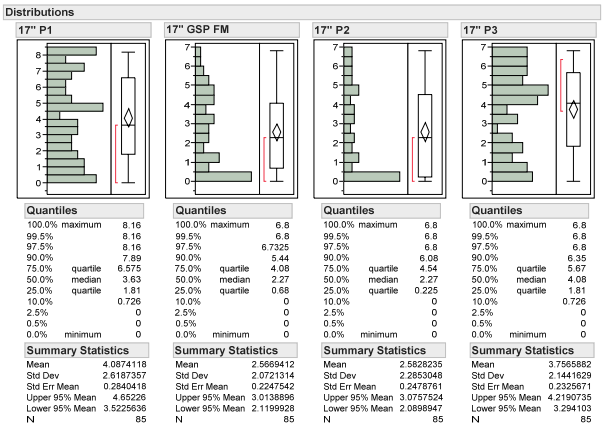


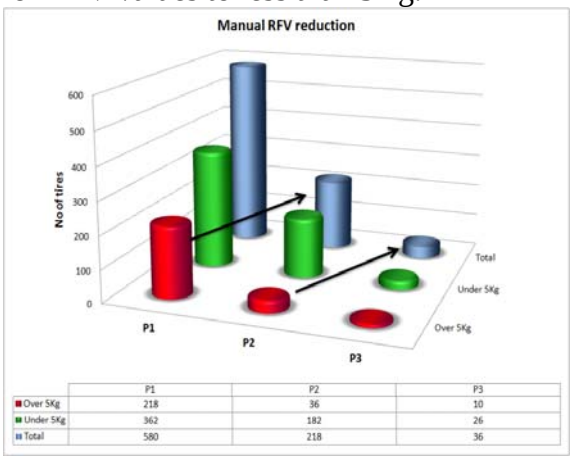
Fig. 15. RFV of all 17" tires at P1, GSP FM, P2 and P3

3. GENERAL OBSERVATIONS ON RFV REDUCTION

- Over 62% of tires have showed a RFV value under 5kg when properly installed (good lubrication and mounting procedure) on a good quality wheel at P1 (light spot of the tire at the valve).
- When applying Tire / Wheel Hand Matching procedure suggested here – tire at P2 (180°

from initial point) on tires with over 5kg RFV_{P1}, 83% of tires have showed a reduction of RFV values to under 5Kg.

- When we turned the rest of the tires to P3, 72.2% of the tires have showed a reduction of RFV values to less than 5Kg.



	P1	P2	P3
Over 5Kg	218	36	10
Under 5Kg	362	182	26
Total	580	218	36

Fig. 16. Manual RFV reduction procedure results

4. COCLUSIONS

There is a certain chance that the initial vibration was actually caused by an accumulating factor of maximum rim run out with the tire stiffness. In other words, a "good" tire with a "good" wheel can give a "bad" matching form Radial Force Variation point of view (and the vice versa).

We can measure and reduce the RFV by using specialized machines that offer this option. However, we don't always have access to such a machine; therefore we considered it may be interesting to evaluate alternative hands-on options for reducing RFV.

Using data from measuring almost 600 tires, we can suggest a simple procedure for Radial Force Variation Reduction by Hand Matching the tire on the wheel. The main advantages of this procedure are that: It's very simple; There is no need for a highly trained technician to solve a tire vibration problem; It can be explained by the phone; It doesn't require a special machine with RFV measurement function.

The results of this test may suggest that a lot of tires that are refused by tire dealers for "unbalance" condition may be still good to use. By simply applying a proper mounting procedure, paying particular attention at tire lubrication and good tire bead seating, a lot of tires initially claimed for warranty adjustment can still be used. On the tires that are still showing a higher level of RFV, we can apply further tire – rim matching with a large probability for succeeding in reducing tire vibration. Please note that for best results we still recommend using a machine with RFV measurement function, when possible.

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Variația forței radiale în testarea pneului

Rezumat: *Această lucrare este parte component a studiului dinamicii pneului. In această lucrare autorii realizează un set de experimente "in situ" pentru testarea forței radiale a pneului. In scopul de a evalua relația dintre variația forței laterale şi suprafața acoperitoare a pneului, autorii au priectat şi realizat câteva programe de testare a unor tipuri de vehicule, care rulează în tandem în aceleaşi condiții de conducere, pe aceeaşi diatnță u aceeaşi viteză.*

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