EXPLOITATION INDICATORS OF RETREADED TIRES DEPENDING ON THE NUMBER OF RETREADINGS

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Abstract: *The usage of retreaded tires is becoming more common due to the effects that are achieved by this method. In practice, the distance travelled by a retreaded tire is a key parameter that shows the effects of retreading itself. This parameter is not independent of the number of previous retreading, and, as a rule, it is a random variable. This paper presents a set of output results obtained by the statistical analysis of the database of travelled distance depending on the number of previous retreading but also on the previous exploitation history of the tire. In practice, these analyses may be of importance in making decisions about further exploitation – retreading of tires.*

Keywords*: retreaded tires, number of retreading, number of retreading of tires, statistical analysis.*

1. INTRODUCTION

Tires belong to the category of wearing products/parts which appear during the exploitation of a vehicle. Once the working life of a tire has expired, it is usually classified into a category of waste, which means that it gets its index number (19 12 04) determined according to the Waste Catalogue (Belgrade, 2010). When it is disposed on the ground as waste, that is, at a landfill, its decomposition lasts for more than 150 years and as such it represents a threat to the environment (Hammond at al. (2009)). One of the treatment modes of these parts of the vehicle, allowing to use them again – restoring their function after their tread has been worn out, is called retreading – a procedure consisting of application of a new tread on a prepared/treated tire (Hammond at al. (2009) and Dabić-Ostojić (2014)).

The use of retreaded tires for commercial road vehicles has been growing, both worldwide and in our country. The reason lies in a number of positive effects reached by this procedure. Retreaded tires are cheaper than the new ones with equivalent standard and almost identical quality; retreading of tires leads to important savings in money ranging to about 45% (cost of a retreaded tire compared to the cost of a new one). This procedure has also a positive effect on the environment – about 5 l of fuel is used for the process of tire retreading instead of 35 l for the manufacture of a new one (Dabić-Ostojić (2014) and Dabić at al. (2013)).

A special group of problems concerns the exploitation of retreaded tires. Regarding this aspect, one of the most important parameters are the number of retreadings (NRT) and the distance travelled by a tire (TD) (of a new tire and after each retreading). It can be deduced that there are

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few papers dealing exclusively with the decision making during the exploitation of retreaded tires. This is the reason why the authors of this paper have decided to devote themselves to these issues. In practice, the question is often if retreading is useful and how many times it can be done and what decision shall be made? It is especially important to bear in mind that the costs of tires are among the highest exploitation costs related to commercial vehicles (Gavrić at al. (2009) and Boustani at al. (2010)).

In order to decide whether a tire shall be retreaded or not and if yes how many times, it is necessary to carry out appropriate statistical analyses and obtain appropriate results related to its exploitation (Dabić-Ostojić at al. (2013)). The aim of this paper is to identify certain causal connections concerning the relationship between TD and NRT on the basis of a sample of tires belonging to a subset of the vehicle park of the largest company for public city and suburban passenger transport in Belgrade.

Having this in mind, the paper includes different parts. After the introduction, the second part of the paper presents statistically processed data, mathematical expectations (μ) and standard deviations (σ) for the subset of the above mentioned sample of tires with the highest participation of tires according to the number of retreadings (up to 3) and TD classes (from 20 to 40.000 km, from 40 to 60.000 km and 60 to 80.000 km). There has been observed the mutual dependence between NRT and TD and there has been discovered that there are some deviations regarding this relationship which require more detailed statistical analyses. They have been carried out within this part of the paper divided into two units. Within the first unit, we have observed the change of parameters μ and σ after the I, II and III retreading for the above mentioned TD classes. The second unit of this part of the paper includes only the analysis of the parameter μ according to the different TD classes after the I and then after the II and III retreading individually. The fourth part of the paper includes a conclusion based on the realized analysis which has also indicated potential directions of the future research.

2. STATISTICAL PROCESSING RELATED TO A SUBSET OF TIRES

When the tread of a tire is obsolete or damaged, the decision related to its next retreading or dismiss should be made. Beukering and Janssen (2001) assume that TDs of retreaded tires are the same as the new ones. Ferrer (1996) presumes that the TD of a retreated tire is reduced after every retreading process and that total NRT also depends considerably on the manufacturer – it is not unlimited. In that case, there are two important issues, the first one related to the NRT by that moment and the second one concerning the TD during the exploitation. It can be assumed that these two parameters are random values, since they depend on a number of factors (manufacturer, driving conditions, road quality, type/load of vehicle, mode of driving…). It is clear that these parameters have been observed for homogenous groups of tires and conditions of their exploitation. As illustration, the Table 1 presents the results of statistical processing of TD of a tire depending on the NRT for the analysed sample.

Table 1. Average TD of a tire as a new one and depending on the NRT

NRT	*average TD (km) depending on NRT*
0 (as a new one)	70256
1	35237
2	32830
3	36971
4	30738

The Table 1 generally shows that the increase of NRT causes the decrease of TD of a tire. This correlation can be described by the exponential trend with the correlation coefficient, R^2=0.7586.

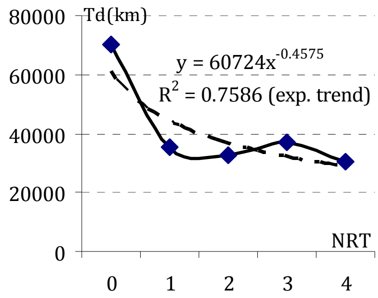

Figure 1. Dependence of (TD) by tire on NRT – exponential trend

The diagram of the Fig. 1. shows that TD decreases by the second retreading, then increases slightly after the third one and then decreases again. These oscillations have initiated a more detailed analysis of the above mentioned dependence in order to obtain a basis for a better decision making regarding retreading and it will be carried out further down in this paper.

3. DATA ANALYSIS FOR THE SUBSET OF A RETREADED TIRE SAMPLE

In order to search for the specificities of the relationship between TD and NRT, in this part of the paper we have carried out some additional analyses regarding the change of TD after a characteristic NRT. The first analysis included the application of statistical parameters of the number of tires (μ and σ) especially after the I, II and III retreading, according to TD classes. The second analysis included a change of the parameter related to the number of tires (μ) but only for characteristic TD classes.

3.1 Analysis of statistical indicator after each retreading

Within this unit of the paper, the analysis has shown the frequencies of the number of tires according to the TD classes depending on NRT. As input values, there have been used the frequencies of the number of tires (obtained from the data base), given in Table 2 (Dabić-Ostojić (2014)).

Table 2. Frequency of the number of tires depending on the TD after the I, II and III retreading

	TD after I retreading (000 km)		
TD of new tire (000 km)	*20-40*	*40-60*	*60-80*
20-40	**25**	**36**	**10**
40-60	**43**	**55**	**13**
60-80	**14**	**10**	**1**
	TD after II retreading (000 km)		
TD after I retreading (000 km)	*20-40*	*40-60*	*60-80*
20-40	**22**	**17**	**2**
40-60	**22**	**20**	**3**
60-80	**7**	**4**	**0**
	TD after III retreading (000 km)		
TD after II retreading (000 km)	*20-40*	*40-60*	*60-80*
20-40	**9**	**6**	**2**
40-60	**4**	**6**	**0**
60-80	**0**	**2**	**0**

Statistical processing of data from Table 2 has provided the parameters (μ and σ of the number of tires) given in tables 3, 4, 5 for the different TD classes after the I, II and III retreading. These values are presented by a diagram on the Fig. 2.

Table 3. Parameters related to I retreading

TD after I retreading (000 km)	**μ** (tires)	**σ** (tires)
from 20 to 40	**34.69**	**37.32**
from 40 to 60	**36.96**	**39.74**
from 60 to 80	**38.46**	**41.77**

Table 4. Parameters related to II retreading

TD after II retreading (000 km)	**μ** (tires)	**σ** (tires)
from 20 to 40	**31.77**	**35.39**
from 40 to 60	**32.03**	**35.45**
from 60 to 80	**27.86**	**29.62**

Table 5. Parameters related to III retreading

TD after III retreading (000 km)	**μ** (tires)	**σ** (tires)
from 20 to 40	**20.60**	**25.47**
from 40 to 60	**20.98**	**26.60**
from 60 to 80	**18.53**	**21.44**

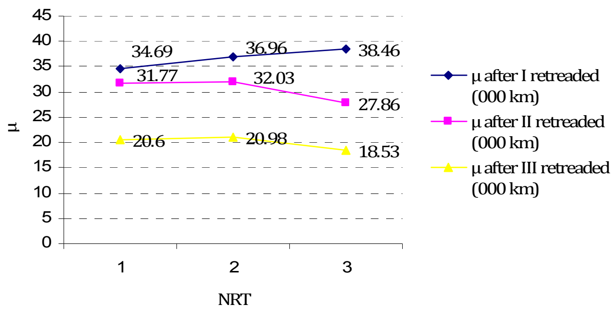

Figure 2. μ of NRT depending on TD

In order to obtain additional basis for decision making regarding retreading, it has been necessary to analyse the statistical indicator μ, that is, its values, but for the above mentioned TD classes. This has been done in the following unit of this part of the paper.

3.2 Analysis of the parameter μ after each retreading for the characteristic TD classes

Based on the analysis carried out after each retreading, but separately for each of the TD classes, the table 6 presents the change of the parameter μ. It can be concluded that μ of the number of retreaded tires decreases with the increase of the NRT, namely within each of the TD classes, which is shown by the diagrams of the figures 3, 4 and 5.

Table 6. μ of tires (for TD classes) for I, II and III retreading

TD (000 km)	**μ** (tires) after **I** retreading	**μ** (tires) after **II** retreading	**μ** (tires) after **III** retreading
from 20 to 40	**34.69**	**31.77**	**20.60**
from 40 to 60	**36.96**	**32.03**	**20.98**
from 60 to 80	**38.46**	**27.86**	**18.53**

In order to test the change of the parameter μ there has been done a dependence analysis describing this relationship. There has been observed that for TD in the class from 20 to 40.000 km (Fig. 3.) this correlation (with $R^2=1$) is best described by the polynomial trend of the 2nd degree. The same trend describes the correlation of μ and NRT when TD is in the class ranging from 40 to 60.000 km (Fig 4.), as well as when TD is in the class from 60 to 80.000 km (Fig. 5.).

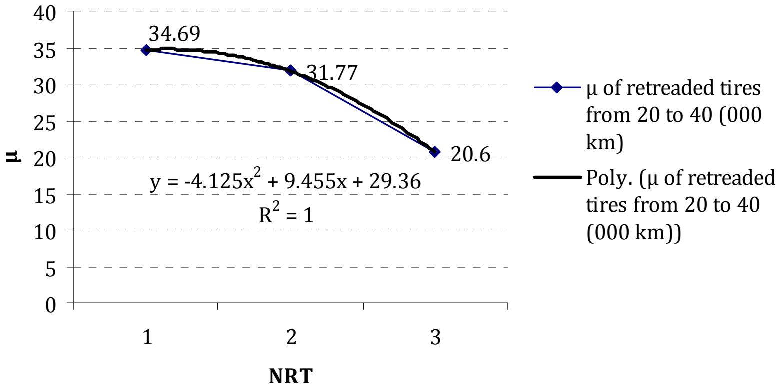

Figure 3. μ of retreated tires (TD from 20 - 40.000 km)

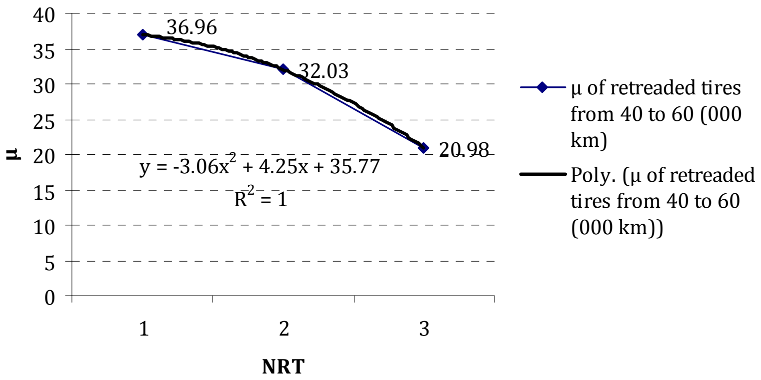

Figure 4. μ of retreaded tires (TD from 40 - 60.000 km)

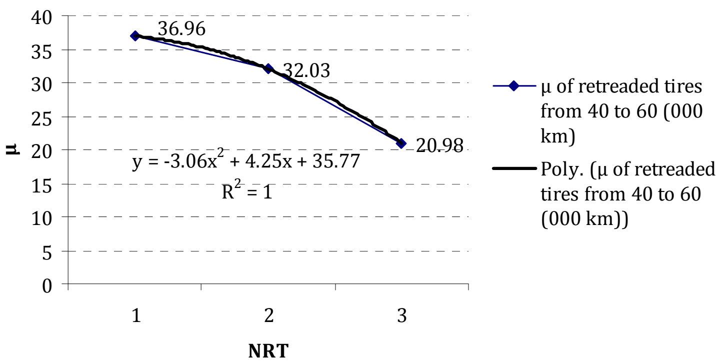

Figure 5. μ of retreaded tires (TD from 60 - 80.000 km)

4. CONCLUSION

Decision making of a transport company deciding whether to by new tires or retread the used ones is especially important for the use of retreaded tires that have reached the wear limit of the tread. Therefore, it is necessary to know the exploitation parameters of tires, while the accent shall be on the specificity of the change and relationship between NRT and TD. The results obtained in this paper have indicated important stochastic character of these parameters, but also a high level of correlation between these values although the concerned sample of tires has homogenous exploitation conditions.

According to the realized analyses, there has been observed that there are certain correlations related to the decrease of the TD of tires depending on the NRT, which puts in question the hypothesis of Beukering and Janssen (2001) saying that these values are independent from each other (Dabić Ostojić (2014)), as well as the hypothesis of Ferer (1996) that the NRT is unlimited.

Based on the results obtained by sample processing, it is concluded that in real working conditions of a transport company it is necessary to carry out continuous and detailed statistical analyses in this field. Such a data base and its processing would indicate the behaviour of the relevant parameters.

For other combinations of the above mentioned exploitation conditions (non-homogenous vehicle park, characteristics of a road…) the necessary analyses could be done in an appropriate manner. This would ensure an appropriate base for decision making on retreading for each tire separately which is of extreme importance for rational business of a transport company.

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REFERENCES

[1] Beukering, P.J.H. and Janssen, M., (2001), Trade and recycling of used tyres in Western and Eastern Europe. Resource Conservation and Recycling, 33 (3), 235–265.

[2] Dabić-Ostojić, S. (2014), Logistički aspekti menadžmenta protektiranja pneumatika, Doktorska disertacija, Saobraćajni fakultet Univerziteta u Beogradu, Beograd

[3] Dabić, S., Miljuš, M., Bojović, N. Vidanović, N, (2013), Decision Support for The Choice of Tire Manufacturer, FME Transactions, 41 (1), Faculty of Mechanical Engineering, Belgrade, Serbia, 72-76.

[4] Dabić-Ostojić, S., Miljuš, M., Bojović, N. Glišović, N., Milenković, M, (2014) Applying a mathematical approach to improve the tire retreading process, Resources, Conservation and Recycling, 86 (1),107-117.

[5] Ferrer G., (1997), The economics of tire remanufacturing. Resource Conservation and Recycling; 19 (4), 221–55.

[6] Gavrić, P., Danon, G., Momčilović, V. i Bunčić, S. (2009), Eksploatacija i održavanje pneumatika komercijalnih vozila, Istraživanja i projektovanja za privredu, Beograd, 25,1-10

[7] Katalog otpada - Uputstvo za određivanje indeksnog broja, Republika Srbija, Ministarstvo životne sredine i prostornog planiranja, Agencija za zaštitu životne sredine, Beograd, 2010

[8] Hammond, P., Lindquist, K., Wendt, M., (2009), Retreaded Tire Use and Safety, *Synthesis, Washington State Department of Transport, USA*