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THE AUTOMOBILE TIRES VULCANIZATION METHOD REPAIR PROCESS EXPERIMENTAL INVESTIGATION

In the article local repair automobile tires expediency by vulcanization means in mechanical damage carcass case is shown. It has been established that analytical and experimental data on determining the required temperature of the heating element have a significant discrepancy. It was found that on the vulcanization degree among all factors temperature and pressure on the welding surfaces are the most influential. After processing the experimental data and using the static methods, mathematical dependence of the temperature on the welding surface from the heating element temperature and on the welding surfaces as a second-degree polynomial is obtained. In order to verify the research results reliability, the control welding of the automobile tires with cord lateral rupture was conducted, which gave positive results.

***Keywords:** thermal conductivity, vulcanization, automobile tires.*

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ЕКСПЕРИМЕНТАЛЬНІ ДОСЛІДЖЕННЯ ПРОЦЕСУ РЕМОНТУ АВТОМОБІЛЬНИХ ШИН СПОСОБОМ ВУЛКАНІЗАЦІЇ

Обґрунтовано доцільність проведення місцевого ремонту автомобільної шини способом вулканізації при механічних ушкодженнях каркаса. Установлено, що аналітичні та експериментальні дані з визначення необхідної температури нагрівального елемента мають значну розбіжність. З'ясовано, що на ступінь вулканізації серед усіх факторів найбільший вплив мають температура та тиск на поверхнях зварювання. За допомогою статистичних методів обробки експериментальних даних отримано математичну залежність температури на поверхні вулканізації від температури нагрівального елемента й тиску на поверхнях зварювання у вигляді полінома другого ступеня. З метою перевірки достовірності результатів досліджень виконано контрольне зварювання автомобільної шини з боковим розривом корду, яке дало позитивні результати.

***Ключові слова:** теплопровідність, вулканізація, автомобільна шина.*

Introduction. Nowadays tires repair is one of the most demanded services in the automobile service market. The statistics show that in the course of operation from 25 to 75% of tires prematurely fail due to mechanical damage to the carcass (punctures and cuts) that require local repair. In most cases, the tread does not exceed 30 – 50%, and timely and qualified repairs allow to continue using this tire. In this case local repairs are more effective than restorative. Its cost is 2 – 7% from a new product price, so even a slight increase in after-repair runs can significantly increase the economic effect from such tires use [1].

One of the most effective methods to automobile tires repairing with local injuries is vulcanization, which is the converting process general purpose caoutchouc (natural and synthetic) into rubber under pressure and at temperature of 140 – 160 ° C. Compliance with the necessary and stable temperature regime in the vulcanization zone has a decisive influence on the quality of the repaired product. The numerous studies results show, that the temperature variation in the tire vulcanization zone at 5 °C leads to a change in the vulcanization degree by more than 30% [2]. However, in a number by the industry manufactured vulcanizers, there is a significant difference in temperature across the entire heating element surface (more than 5 °C), and it is difficult or sometimes impossible to control the temperature in the vulcanization zone. It is also noticed that the temperature regime in the vulcanization zone is influenced by the pressure force between tire and the repair material and the heating element [3 – 5].

Analysis of the last research sources and publications. Analytical calculations the heating element required temperature, based on the thermal conductivity of multilayer walls theory [6], do not give objective results. There is considerable discrepancy between calculated and experimental data. Is is due to the fact that, in the analytical calculation method, it is assumed that the contact is perfect at the point of contact of the individual layers [7] and the heat transfer is carried out from the layer to the layer without considering the spaces between them. However, in a real object research, the touch of individual layers is not dense and it gives an error in the calculations. It is difficult to consider the lack of tight contact by analytical method is difficult [8]. In this connection, it was decided to conduct a physical experiment using methods of statistical data processing [9 – 11] to determine the required heating element temperature when vulcanizing the various sizes tires and with different pressures on the vulcanized surfaces. This method also gives an opportunity to obtain a mathematical investigated process model, which in the future will allow determining required temperature of heating element by the calculation method.

Objectives setting. The article purpose is to highlight the experimental studies results of the vulcanization car tires process with new improved design vulcanizer.

The mains and researches. Studies have shown that the vulcanization process with local tire repair takes place under constantly changing conditions. These changes are caused by the thermophysical vulcanizer characteristics, the uneven distribution the layer inside temperature, which is vulcanized and fluctuations in the environment temperature. Also, the clamping force is significantly influenced by the vulcanization process.

Known mathematical models and automatic control systems for the vulcanization process [8] do not consider the uncertainty factors. This leads to significant temperature deviations from the given mode, resulting in the required complex of physical and mechanical properties of the repaired product is violated. And there is also an irrational electricity use present here.

The car tyres vulcanization process was investigated on the advanced vulcanizer «Asogis EVU-3MP» [12]. In order to ensure uniform heating elements pressure and vulcanizing materials to the tyres, the cavity frame was reinforced (Fig. 1) and a bag with sand or aluminum balls was applied (Fig. 2). Experimental studies were carried out using a baking form for 215/60/R16 type tyres (Fig. 3), which was made independently. The surface temperature for baking is determined by «Laserliner» laser pyrometer (Fig. 4).

Figure 1 – The new reinforced vulcanizer frame

Figure 2 – Use the bag with sand

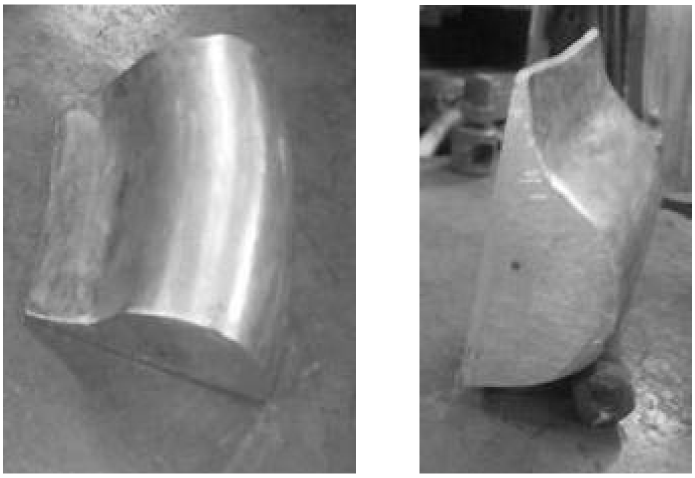

Figure 3 – A new baked form

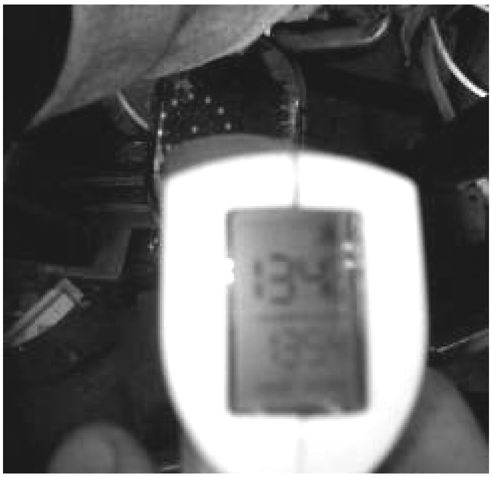

Figure 4 – The temperature definition with «Laserliner» laser pyrometer

In order to determine the optimum vulcanization and mathematical dependence regimes describing this process, the experiment planning was applied. Since the main factors influencing the vulcanization process are the heating element temperature and the pressure on the vulcanization surface, and the form of the received dependence is unknown, it is decided to accept the two-factor three-level plan of the experiment [8, 9].

During the experiment, the factors varied on three levels – the average (main), the lower and upper, the distances from the main to the same magnitude. The intervals values variables and the investigated range variables are given in Table 1.

Table 1 – The variables value intervals

Factors	Variable intervals
The heating element temperature, ° C	155 – 195
Pressure force on the welding surface, kgf/cm^2	0 – 16

The temperature welding surfaces at different heating element temperatures and the clamping force is determined by the plan are given in Table 2.

Table 2 – The three-tier experiments plan with the factors number k=2 … ($N=N_1+N_\alpha+n_0$)

Experiment number		The planning matrix, (x_i)		Variable squares, ($x^2{}_i$)		Interaction, ($x_i\,x_j$)	The surface welding temperature
		x_1	x_2	$x_1{}^2$	$x_2{}^2$	$x_1\,x_2$	y
N_1	1	+	+	+	+	+	167,3
	2	+	–	+	+	–	132,3
	3	–	+	+	+	–	158,4
	4	–	–	+	+	+	110,5
N_α	5	+	0	+	0	0	145,8
	6	–	0	+	0	0	125,5
	7	0	+	0	+	0	149,3
	8	0	–	0	+	0	122,2
n_0	9	0	0	0	0	0	141,5
	10	0	0	0	0	0	142,5
	11	0	0	0	0	0	142,1

In an investigation on vulcanization, experiments are divided into groups so that experiments at the zero point are evenly distributed among others. In particular, it is taken the following procedure for the implementation of the plan: Experiments 1, 2, 9, 3, 7, 4, 5, 10, 6, 7, 8, 11.

The experimental results are processed using from the mathematical statistics [8, 9]. As an implementation result of this experimental plan, it is obtained an algebraic equation in the form

$$\bar{y}_i = b_0 + b_1x_1 + b_2x_2 + b_{11}x_1^2 + b_{22}x_2^2 + b_{12}x_1x_2 \ , \qquad (1)$$

where $\bar{y}_i$ – the investigated surface welding temperature ;

x_1, x_2 – outgoing factors;

b_0 , b_1 , b_2 , b_{11} , b_{22} , b_{12} – equation coefficients.

Having determined by the method [6, 7] the coefficients and substituting them in to (1) it is obtained the regression equation in code form

$$\bar{y}_i = 139{,}4 + 8{,}5x_1 + 18{,}34x_2 + 0{,}26x_1^2 + 0{,}36x_2^2 - 3{,}23x_1x_2 \ , \qquad (2)$$

Further equation (2) refine by checking the difference coefficients b_i zero by Student's test. Check the equations for the Fisher criterion confirms its suitability to describe the process under study.

For the convenience of further calculations, the equation (2) is reduced to the natural form (3)

$$t_л = 0{,}0041 \cdot P^2 + 0{,}0009 \cdot t_{н.е.}^2 + 4{,}52 \cdot P + 0{,}76 \cdot t_{н.е.} - 0{,}02 \cdot P \cdot t_{н.е.} - 30{,}02. \quad (3)$$

Using equation (3) building graphical dependencies from surface temperature welding depend on the heating element temperature and values pressure (fig. 5).

Based on the graphic depending determine the necessary heating element temperature and values pressure which provide temperature at bottom 150 ° C, which is the best value.

According to experimental studies, control of car tyre vulcanization with the side gap rupture of the rubber-coated layer was carried out (Fig. 6). The quality of the repaired tyre is tested pumped to pressure that exceeds the operating in twice. The repair defects is not found.

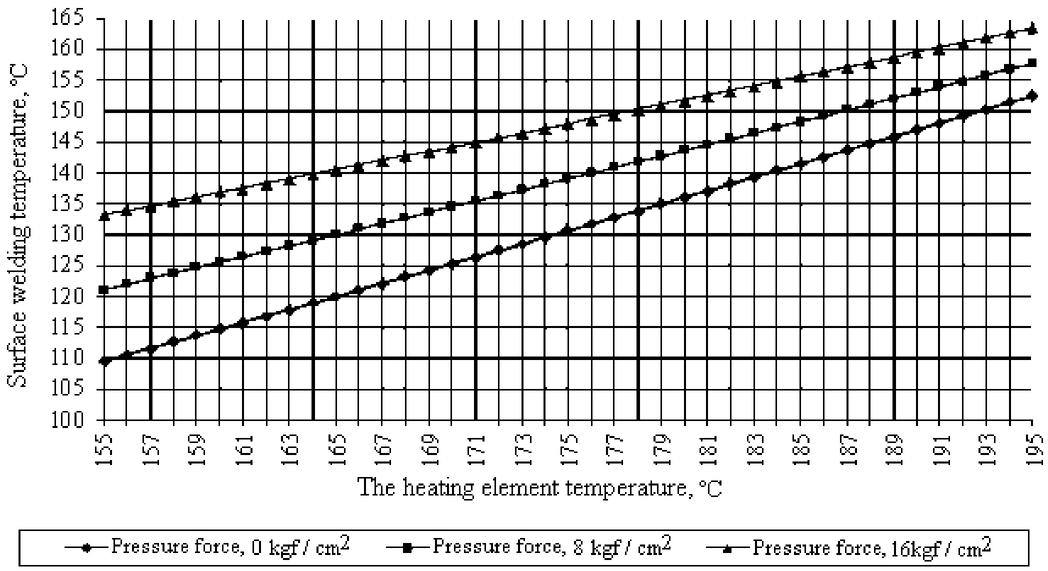

Figure 5 – The graphical dependencies from surface temperature welding depending on the heating element temperature and values pressure

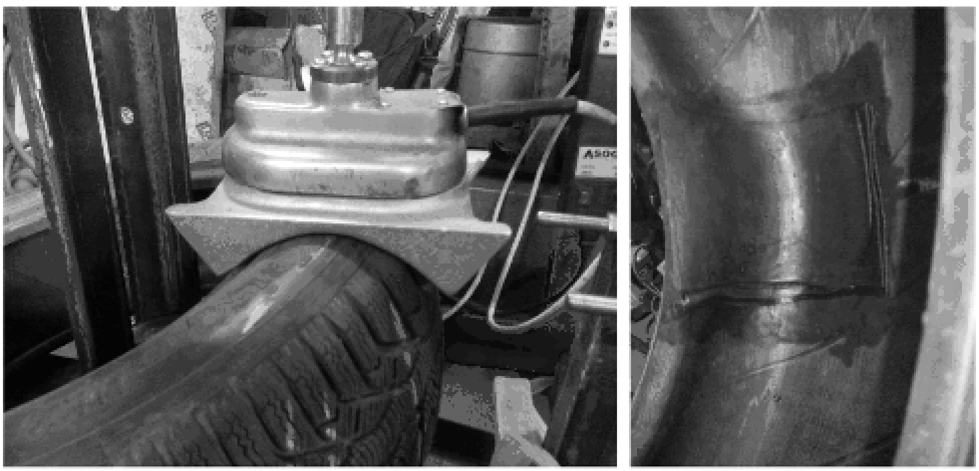

Figure 6 – The control automobile tire vulcanization

Conclusions. In experimental investigation result of the automobile tires vulcanization process with the vulcanizer «Asogis EVU-3MP» help, the mathematical relationship between the temperature welding surfaces at heating element temperatures and the clamping force in a regression equation was received which is suitable for vulcanization modes optimization.

Practical recommendations for improving the automobile tires vulcanization process are developed, depending on the pressing force and heating element temperature.

During the work, the frame «Asogis EVU-3MP» structure was developed, and additional equipment for local tire repair was developed too.

References

1. *Завьялов Ю. П. Прогрессивные способы ремонта крупногабаритных шин / Ю. П. Завьялов, Ю. С. Грачев. – М. : Химия, 1989. – 42 с.*
   ISBN 5-7245-0228-3
2. *Исакова Н. А. Контроль производства синтетических каучуков / Н. А. Исакова, Г. А. Белова, В. С. Фихтипольц. – Л. : Химия, 1980. – 240 с..*
   ISBN 81.80.2803090200
3. *Matador Rubber s.r.o. Test methods of rubber materials and products // Education and Culture: Leonardo da Vinci, 2007. – 118 p.*
4. *Теплообмен и массообмен при послевулканизационном жидкостном охлаждении гуммировочных покрытий / Ю. Р. Осипов, С. Ю. Осипов, В. В. Павлов, Т. Н. Чурина. – Вологда: ВИПЭ ФСИН России, 2010. – 95 с.*
   ISBN 978-5-94991-147-1
5. *Елисеева И. М. Структура и свойства материалов на основе резины / И. М. Елисеева. – Мн: БГПУ , 2007. – 222 с.*
   ISBN 978-985-501-406-6
6. *Cengel Y. Thermodynamics: An Engineering Approach / Y. Cengel, M. Boles. – McGraw-Hill, 2007, 960 p.*
   ISBN 978-0-07-339817-4
7. *Кушнырев В. И. Техническая термодинамика и теплопередача / В. И. Кушнырев, В. И. Лебедев, В. А. Павленко. – М. : Стройиздат, 1986. – 464 с.*
   ISBN 2303010000-662
8. *Cengel Yu. Heat transfer: a practical approach / Yunus A. Cengel. – McGraw Hill, 2004. – 908 p.*
   ISBN 0-07-245893-3
9. *Vanhatalo E. Towards improved analysis methods for twolevel factorial experiments with time series responses / E. Vanhatalo, B. Bergquist, K. Vannman // Quality and Reliability Engineering International. – 2013. – № 29(5). – P. 725 –741.*
10. *Vanhatalo E. Using factorial design and multivariate analysis when experimenting in a continuous process/ E. Vanhatalo, K. Vannman // Quality and Reliability Engineering International. – 2008. – №24(8). – P. 983 – 995.*
11. *Мухачёв В. А. Планирование и обработка результатов эксперимента: учебное пособие / В. А. Мухачёв. – Томск: ТГКСУР, 2007. – 118 с.*
    ISBN 966-552-118-7 : 325.60
12. *Вулканизатор ЭВУ 3МП. [Электронный ресурс]. – [Цит. 2016, 20 октября]. – Режим доступа: http://starsto.com.ua/t82–vulkanizator–evu–3mp.*