Researches Concerning the Ultrasonic Energy's Influence over the Resistance at Extraction of the Metallic Insertion from the Rubber Matrix

GHEORGHE AMZA[1], DAN DOBROTĂ[2]* , AUGUSTIN SEMENESCU[1], DUMITRU IANCULUI[3]

[1] Politehnica University of Bucharest, 313 Splaiul Independentei, 060042, Bucharest, Romania

[2] "Constantin Brâncu°i" University, 3 Geneva Str., 210136, Târgu-Jiu, Romania

[3] " Politehnica University of Timisoara, 1 Mihai Viteazul Blvd., 300222, Timisoara, Romania

The work presents the main results obtained at the application of the ultrasonic energy in the separating process of the rubber on the metallic insertions in the case of the transporting belts. Results refer mainly at the influence ultrasounds' application has over the specific resistance at extraction of the metallic insertion from the rubber matrix, and these are quantified through an efficiency coefficient at extraction. The importance of the results presented in the work derives from the fact that the separating processes of the rubber on the metallic insertions are complex enough and big energy consumers, and the results presented in the work can be applied in practice and they allow a substantial increase of the economic profitability for the capitalization processes of the wastes of transporting belt reinforced with metallic insertion

Keywords: belts, ultrasonic energy, rubber, metallic insertions

The mechanism of the reduction of the contact abrasion between two ultrasoundously activated surfaces, was very much studied, taking into account the special practical importance it has. This reducing process of the abrasion forces was studied especially in the case of the processing process through plastic deformation of materials [1-3].

Thus, there are unanimously accepted the works written at the Birmingham University where there are considered 5 possible mechanisms for reducing the contact abrasion. The first possible mechanism admits a reduction of abrasion in the separating process of the contact surfaces due to the relative movement between them. This separation can reestablish the lubricant coat if the slide takes place at a flow and it can shorten the contact time between surfaces.

Another possible mechanism admits the abrasion's reversal that consists in the reduction of the abrasion force when the oscillating speed exceeds the moving relative speed of the surfaces in contact. The other mechanisms of abrasion's reduction (area's heating, flattening of the asperities in contact and lubricants' pumping) cannot be treated as base effects of big energies ultrasounds in solid environments, being secondary effects.

Nowadays, in the productive practice, for separating the rubber from the metallic insertions, it is applied a series of variants of technologic procedures [4-5] that implies the use of very big mechanical energies with inadequate technical and economic effects. For obtaining a reduction of the necessary efforts for separating the rubber from the mechanic insertions, it is aimed the application of ultrasound energies over the rubber wastes and especially over those coming from transporting belts.

Ultrasounds use in the separating process of the rubber from the metallic insertions are based on the properties that ultrasound waves have, namely:

-small wave lengths;

-very big acceleration of the particle, it can reach 10^5 the gravity's acceleration;

-possibility of leading in the wanted direction of a narrow ultrasound fascicle;

-possibility of concentrating and focusing the ultrasound energy in a limited space without affecting the environment in which it is propagated;

-the phenomena that appear at the propagation of the ultrasound energy through which, first, cavitation is placed.

Experimental part

The acting mechanism of the ultrasound over the contact abrasion is conditioned by the variation of the sliding kinematics on the contact surface, by the character of the interaction of the surfaces in contact, by the efficacy of the action of the oiling substances and mostly by the way of introducing the ultrasound oscillations in the contact area. The scheme of introducing the ultrasound oscillations in the deformation source is, in fact, determined through the oscillations direction in relation with the vector of the abrasion forces and the contact surface.

The ultrasounds efficacy over the contact surface can be appreciated with an efficiency coefficient "n" [6], given by the relation:

$$n = \frac{\mu f - \mu u}{\mu f} \qquad (1)$$

where:

n – is the efficiency coefficient;

μf, μu – the abrasion coefficient without and in the presence of ultrasounds.

The process of breaking the rubber wastes is due especially to the stretching efforts [7-8] and, on these terms, the ultrasounds effects over the reduction of the abrasion between the metallic insertion and rubber can be appreciated also through another efficiency coefficient at "s" extraction [9], given by the relation:

$$s = \frac{R - R_u}{R} \qquad (2)$$

where:

s- is the efficiency coefficient at extraction;

R, R_u – the extraction specific resistance of the metallic insertion without and in the presence of ultrasounds.

The rubber wastes reinforced with metallic insertion, that are the most important, are represented by the transporting belts [10] within which the metallic insertion has a very big volume and quantity. The structure and properties of the transporting belts, manufactured nowadays, are presented within the standard SR EN ISO 15236-1: 2006.

* *email ddan@utgjiu.ro; Tel. 0253/237252; 0722446082*

Table 1
TYPES OF TRANSPORTING BELTS DEPENDING ON THE RESISTANCE CLASS

Low resistance	ST 500	ST 630	ST 800	ST 1000	ST 1250	ST 1600
Average resistance	ST 2000	ST 2250	ST 2500	ST 2800	ST 3150	
High resistance	ST 3500	ST 4000	ST 4500	ST 5000	ST 5400	

Table 2
MECHANICAL FEATURES OF DIFFERENT TYPES OF TRANSPORTING BLETS

Type of belt	Diameter of cable mm [max]	Resistance at breaking [N/mm]	Specific resistance at extraction [N/mm]
ST 800	4,3	800	70
ST 1000	4,3	1000	70
ST 1250	4,3	1250	70
ST 1600	6,0	1600	85
ST 2000	6,0	2000	85
ST 2500	7,5	2500	100
ST 3150	8,5	3150	110
ST 4000	9,5	4000	120

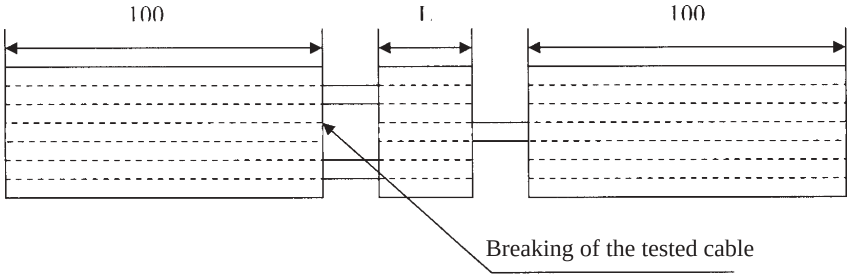

Fig. 1. Shape of the test tube used for establishing the cable's extraction specific resistance

The transporting belts reinforced with steel cables can be divided, depending on the resistance class, in more categories, meaning in: belts of low resistance, belts of average and high resistance, according to table 1.

Among the transporting belts presented in table 1, the most frequently used in practice are: ST 800, ST 1000, ST 1250, ST 1600, ST 2000, ST 2500, ST 3150, ST 4000. The main mechanic features of these transporting belts for the delivery state, according to SR EN ISO 15236-1: 2006, are those presented in table 2.

For separating the rubber from the metallic insertions, it is aimed a considerable reduction at the extraction specific resistance between these component parts by applying the ultrasound energy. The establishment of the ultrasound energy effect over the resistance to extraction, in case of transporting belts wastes, will be made using test tubes with the shape of those presented in figure 1 and that are sampled from different used transporting belts.

The sampled test tube should have, in its structure, 3 cables, and the length L is delimited by cutting the rubber up to cables and, in the same time, the middle cable is sectioned in one of the cuts that delimit the pulling out length of the test tube and the lateral cables in the other cut. The extraction length of the cable, for the new transporting belts, as well as for the used transporting belts, has different values depending on the type of transporting belts, and these are presented in table 3.

For the experimental researches, it was used a universal device for testing metallic and non-metallic materials, controlled by PC of type ATS 1630 CC. The experiments were made by taking into account also an additional preparation of the test tube, meaning that, in the attaching area, a removal of the covering layer happened, being settled the moving speed of the testing device's jaws at a value of 100mm/min, and for setting the cable's extraction specific resistance it was used the relation:

$$R = \frac{F}{L} \tag{3}$$

where:

F – extraction force [N], L – extraction length (50 mm or 100 mm)

Results and discussions

For obtaining experimental results as conclusive as possible, it was found the extraction specific resistance of

Table 3
EXTRACTION LENGTH OF THE CABLE FOR DIFFERENT TYPES OF BELTS

Type of belt	Extraction length [mm]
ST 800	50±2
ST 1000	
ST 1250	
ST 1600	
ST 2000	100 ±2
ST 2500	
ST 3150	
ST 4000	

Table 4
THE VALUES OF THE EXTRACTION AVERAGE SPECIFIC RESISTANCE
FOR THE USED TRANSPORTING BELTS

Type of belt	R extraction average specific resistance [N/mm]
ST 800	63
ST 1000	63,3
ST 1250	64,6
ST 1600	98,3
ST 2000	99
ST 2500	102,6
ST 3150	111
ST 4000	132,3

the metallic insertions for different types of belts by sampling test tubes from the used transporting belts, because in this type of belts a series of structure faults appears, as for example the microfissures that can set a reduction of the extraction specific resistance value compared to the values obtained for a new belt. Researches were made by taking 3 test tubes from every type of belt, being set the extraction force for every type of belt as an average of the value established for the 3 test tubes, being obtained a series of experimental results that allowed the determination, with the help of relation 3, of the average extraction specific resistance, and these are presented in table 4.

Analyzing the data presented in table 2 and table 4 as well, it can be noticed a reduction of the values of the extraction average specific resistance for the used transporting belts, but these are big enough, what makes that the separating process of the rubber from the metallic insertions be very difficult and, with this purpose, for future, the ultrasound energy will be used for being obtained a reduction of the extraction specific resistance.

From the researches made, it was noticed that once the ultrasound energy is applied, it is obtained a bigger reduction of the extraction specific resistance in the same time with the abrasion force and a smaller effect is obtained by introducing the perpendicular ultrasound oscillations on the abrasion force and parallel to the contact force and the smallest effect by introducing the perpendicular ultrasound oscillations on the abrasion force and the contact surface. Also, the best results of the reduction of the abrasion coefficient at pulling off are obtained by applying ultrasound waves with a frequency between 18 and 22 kHz.

By taking into account this thing, for a considerable reduction of the extraction specific resistance in the test tubes of rubber belts, there were introduced sound oscillations parallel to the abrasion force. Thus, for the experiments it was used an ultraacoustic system specific for pulling off, made from a magnetostrictive translator of window shape and an exponential concentrator (fig. 2).

The ultrasound waves used for experiments, introduced in the metallic insertion through the ultraacoustic system, had a frequency of 20 kHz. The test tubes used for experiments were sampled from the same type of used belts for which it was established the extraction average specific resistance. The experimentation conditions were the same with those previously mentioned, when the ultrasound energy was not used, the difference consisting in the fact that the traction cable is attached with the help of an elastic jack bound at an ultrasound system. The average values of the extraction specific resistance obtained in the framework of the experimental researches for every type of belt, using the ultrasound energy, are presented in table 5.

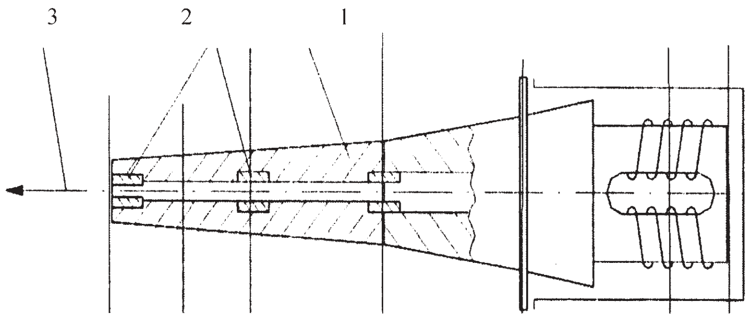

Fig. 2. Ultraacoustic system for pulling off
1 – concentrator with ultrasound energy; 2 – elastic jack used for attaching the metallic insertion, 3 – pulling off direction

Table 5
THE VALUES OF THE EXTRACTION AVERAGE SPECIFIC RESISTANCE FOR THE USED TRANSPORTING BELTS USING THE ULTRASOUND ENERGY

Type of belt	R_u extraction average specific resistance [N/mm]
ST 800	21
ST 1000	22,3
ST 1250	22,6
ST 1600	28,6
ST 2000	29,3
ST 2500	30,3
ST 3150	31
ST 4000	32,6

Table 6
THE VALUES OF THE EFFICIENCY COEFFICIENT AT THE "s" EXTRACTION

Type of belt	efficiency "s" coefficient at extraction
ST 800	0,66
ST 1000	0,64
ST 1250	0,65
ST 1600	0,60
ST 2000	0,59
ST 2500	0,66
ST 3150	0,69
ST 4000	0,70

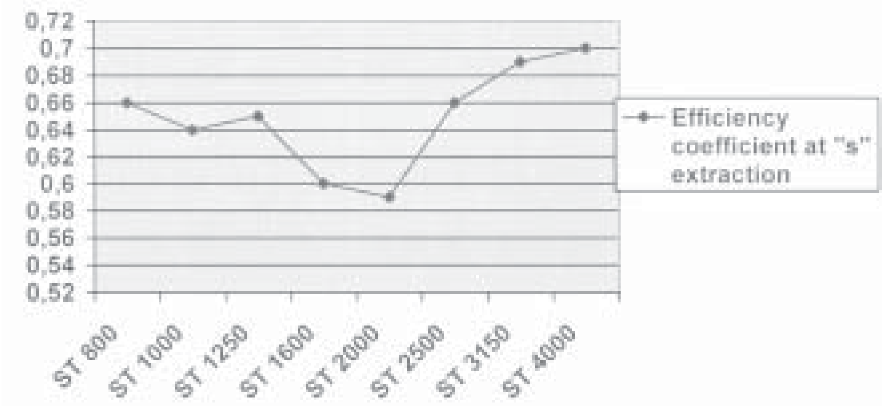

Fig. 3. Evolution of the efficiency coefficient at extraction for different types of belts

Based on the experimental results presented in table 4 and table 5 as well, and with the help of the relation (2), it was found the efficiency coefficient at the "s" extraction of the metallic insertion from the rubber matrix by applying the ultrasound energy, and the values are presented in table 6.

For obtaining a clearer image of the ultrasounds effect over the extraction average specific resistance, the evolution of the efficiency coefficient at extraction for the types of belt used at experiments is presented in figure 3.

By analyzing the data from table 4 and table 5, it is noticed that the application of an ultrasound energy over the transporting belts wastes determines a considerable reduction of the extraction average specific resistance, and by noticing the data from table 6 and the diagram from figure 3 we draw the conclusion that the values of the efficiency coefficient at extraction are big enough, what creates the premises of reducing the energy consumptions that appear in the separating processes of the rubber from the metallic insertions.

Also, the results obtained after the experimental researches prove that the application of the ultrasound energy over the transporting belts wastes represents one of the solutions that contributes to the finding of technological methods adequate to the superior utilization of the wastes of this category, but in the same time the effect of the ultrasound energy can be used for the separation of the reinforcement matrix and in case of other composite materials or multilayer materials.

Conclusions

In the work, it was aimed the influence that the application of the ultrasound energy has over the extraction resistance of the metallic insertion from the rubber matrix, in case of the wastes from the used transporting belts. This influence was quantified through an extraction specific resistance and also through an efficiency coefficient at extraction. Even though the experiments were made using only a single type of ultraacoustic systems and only a certain category of ultrasound waves with a frequency of 20 kHz, very good results were obtained finding that the biggest effect over the decrease of the extraction resistance at the ultrasounds' application is obtained in the case of the low and high resistance belts, and the results presented in the work represent the starting point for future field researches.

References

1. AMZA, GH., The ultrasounds-Active applications, AGIR Publishing House, Bucharest, 2007, p. 283
2. AULD, B., Acoustic fields and waves in solids, New York Wileg, 1, 1993
3. AULD, B., Acoustic fields and waves in solids, New York Wileg, 2, 1993
4. BEDJUK, H., Magnetic Shock Method for Tyre Recycling, Belgium, 2006
5. DOBROTÃ, D., Mat. Plast., **43**, nr. 1, 2006, p. 65
6. AKASAKA, T., Development of Advanced Composite Materials and Their Evolution Techniques, CMC Ltd. Publishing House, Tokyo, 1995
7. VASILIU-OPREA, C., CONSTANTINESCU, A., BÂRSÃNESCU, P., Breaking of polymers. Theory and applications, Technical Publishing House, Bucharest, 1992
8. DOBROTÃ, D., Mat. Plast., **43**, nr. 3, 2006, p. 225
9. AMZA, GH., Intelligent Composite Materials. Simulation and Experiments, Scientific Certificate, Polytechnic University of Bucharest, Series D, **61**, nr.3-4, 1999, p. 264
10. ISMAIL, H., Novel Recycling Process, University Sains Malaysia, 2005

Manusript received: 5.03.2008