Working out of an effective energy-saving technology for crushing of worn out tires on a hammer mill

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Abstract. The article discusses the development of an effective technology for the conversion of worn out tires from the sight of energy consumption and depth, by preproduction in various types of solvents, followed by crushing. The use of methods of physical impact on the material, in particular, the procedure of the use of aggressive media, is justified. The results of experimental researches showed that breakage reduces energy consumption, improves the separation of metal and textile from rubber, increases the yield of rubber under the influence of various aggressive media (solvents).

1. Introduction
Today, one of the massive polymer wastes are taken out of service tires. According to some data published in Europe and the USA, in recent years there have been formed from 2 till 2.8 million tons of tires per year. Intensive growth in the worn out tires quantity has led to the necessity of development a program within the European Community, which is based on the following tasks [1]:

- reduction in the estimated amount of tires by 10%;
- increase the proportion of tires with a retreat protector to 25-30%;
- increase the proportion of recycled tires up to 60%;
- termination of the export of tires to landfills.

The issue of tire recycling in Russia is a very serious problem both from an environmental and economic points of view.

Worn out tires are formed and accumulate in auto farms, industrial enterprises, tire assembling and car service enterprises, as well as in the private sector [2].

The vast majority of worn out tires are removed on landfills, often on unorganized ones. Thus, tires located in landfills for a long time and highly resistant to external factors (sunlight, oxygen, ozone, microbiological influences) begin polluting the environment gradually. This is due to the fact that in places of accumulation of tires, especially in hot climatic conditions, an enabling environment is formed for the reproduction of a large number of insects, rodents and other carriers of various diseases [3].

Cost-effective tire recycling will not only solve environmental problems, but also ensure high profitability of processing industries. At the same time, the elimination of landfills where accumulations of worn out tires are located will make it possible to absolve a considerable amount of land occupied by them.
One of the directions of growing importance is the use of waste in the form of dispersed materials. The caoutchouc and other polymers contained in the waste retain their primary structure and properties during crushing to the fullest extent possible. [4].

Crushing is one of the oldest methods used to perform polymer destruction. Methods of tires crushing:

- by crushing temperature: at positive temperatures, at negative temperatures;
- by mechanical impact: stroke, abrasion, compression, compression with shear, cutting.

2. The objectives of research

The authors analysed the various types of destruction of polymeric materials (figure 1), the method of mechanical destruction is the most economically reasonable. It has been established that this method is implemented in hammer-type grinders [1].

![Types of polymer metal destruction](image)

**Figure 1.** Destruction of polymeric materials.

In different industries, including chemical, hammer mills are widely used for crushing. This is due to the fact that they are convenient in service due to their simple design and maintenance. Such crushers provide the main technological and technical indicators: equability of granulometric texture of the crushed materials; efficiency of material extraction from the working chamber; crushing thickness adjustment; minimal dust formation; the possibility of automated process control; quick replacement of worn out parts; low energy intensity [5].

3. Equipment and research methods

At the Chemical and Food Productions Machinery and Equipment Department of Orenburg State University, a number of research were conducted on old car tires crushing on a hammer mill - "MOLOT - 200/400 produced by the INFEL plant (Russia, Chelyabinsk) with a 10 mm diameter sieve installed (figure 2-3, table 1).
Figure 2. Hammer crushers “MOLOT - 200/400”: 1 - batcher; 2 - schroud; 3 - foundation; 4 - electric motor; 5 - rotor with hammers.

Figure 3. Crusher equipment “MOLOT - 200/400” (Rotor with hammers with door opened).

Table 1. Technical characteristics of the MOLOT - 200/400 crusher manufactured by the INFEL plant (Russia, Chelyabinsk).

| Overall dimensions, mm |  |
|------------------------|--|
| -length                | 600 |
| -width                 | 400 |
| -height                | 1200 |
| Mass (not more), kg    | 30  |
| Working power max, W   | 1100 |
| Rotor speed, r/min     | 2850 |
| Sieve openings diameter, mm | 0,1;5;10 |

As a result of the undertaken research, it was found that the most advantageous and cost-effective in relation of productivity and power consumption of the hammer crusher is to process soaking of the worn out tires before crushing in various solvents.

Thus, the aim of the study was to develop an effective technology for the processing of worn out tires from in relation of energy consumption and depth, by preproduction in various types of solvents, followed by crushing.

4. Materials of the research

The object of the research were worn out tires KAMAZ 43118-46 and GAZelle 322132.

The experimental research methodology was as follows:
- First, we prepared samples of rubber waste with a size of 4 x 10 cm, 4 x 5 cm, 3 x 5 cm and 3 x 2.5 cm.
- Further a hinge of rubber waste cut to a predetermined size of different mass, varying in the dependence of tire types was weigh out.
- The prepared samples were kept for 30-60 minutes in organic solvents (figure 4).

![Figure 4. Samples of rubber placed in solvents for the soaking process.](image)

Samples prepared in this way were crushed on a mill with installed sieves with a diameter of 10 mm, productivity and power consumption were measured during crushing. Evaluation of the quality of the obtained product was carried out according to standard methods.

Tables 2-3 show the experimental results of the effect of the soaking time on the tires crushing process in a hammer mill.

**Table 2.** Influence of soaking time on the tires crushing process of a Kamaz automobile in a hammer mill (sieve diameter 10 mm).

| Solvent brand | Stage 1 (0 min) | Stage 1 (30 minutes) |
|---------------|----------------|----------------------|
|               | Shore hardness number, IRHD | N, kW | Crushing time t, s | Shore hardness number, IRHD | N, kW | Crushing time t, s |
| Acetone       | 80              | 0,55                | 0             | 68              | 0,528  | 3                   |
| Galoshha      | 80              | 0,55                | 0             | 33              | 0,524  | 3                   |
| Solvent 645   | 80              | 0,55                | 0             | 56              | 0,528  | 1                   |
| White-spirit  | 80              | 0,55                | 0             | 44              | 0,528  | 3                   |
Table 3. Influence of soaking time on the tires crushing process of a GAZelle automobile in a hammer mill (sieve diameter 10 mm).

| Solvent brand | Stage 1 (0 min) | Stage 1 (30 minutes) |
|---------------|-----------------|----------------------|
|               | Shore hardness number, IRHD | N, kW | Crushing time t, s | Shore hardness number, IRHD | N, kW | Crushing time t, s |
| CH₃COOH       | 40              | 0,528               | 5,5       | 66               | 0,582 | 6,0             |
| NaHCO₃        | 60              | 0,528               | 2,0       | 51               | 0,539 | 7,0             |

The thickness of the hammer is determined depending on the type of raw material and can vary from 3 to 5 mm.

This combination of the cutting and sawing process allows efficient crushing of rubber-yielding and rubber-containing waste, as well as polymeric materials of various origins.

5. Conclusion

Experimental research has shown that the preliminary use of various types of solvents that are used for recycling tires (chambers) can reduce their hardness, which affects the energy intensity and productivity of the crushing process.

After conducting a research, it was found that gasoline brand "Galosha" (BR-1) is the most satisfying all the requirements for solvents of non-polar caoutchouc. Other solvents are more toxic, stronger smell, high cost. A significant advantage of this brand of gasoline from other gasolines is a narrower temperature range for boiling and a minimum content of aromatic hydrocarbons. Gasoline withstands the test for the formation of an oil stain (the residual after fractional distillation of gasoline applied on filter paper should not give an oil stain), does not contain mechanical impurities and water.

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