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Research of Physico-Chemical and Mechanical Properties of Polymer Waste

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Annotation

The article presents the results of experimental and test work for the processing of secondary polymers to obtain plasticized polymer materials by modification. The physicochemical and mechanical properties of the obtained samples were determined by modern control methods and important conclusions were drawn.

Keywords: multiplicity of processing, plasticizer, stabilizer, viscous-flow indicators (MFR), soap stock, dioctyl phthalate (DOP), softening temperature of polymers, temperature of dissolution and recrystallization of polymers.

Physico-mechanical and technological properties of the material change significantly during the processing of polyethylene (PE), polypropylene (PP) and polyvinyl chloride (PVC) waste. In the secondary processing, the polymer is additionally subjected to such effects as mechanochemical and thermooxidation, and the change in its properties depends on the number of its processing (кратность).

As mentioned above, the change in polymer properties in PVX, PE and PP waste recycling processes is related to the number of recycles, and research in this area shows that 3-5 times polymer recycling results in very few changes (much more than primary raw material). low). However, when processed 5-10 times, a significant decrease in durability can be observed. It is recommended to increase the injection temperature by 3-5% during the processing of secondary polyethylene obtained at high pressure, or the number of turns of the augers during extrusion can be increased by 4-6%. It should also be noted that the molecular mass of polyolefins decreases during recycling, especially under the influence of atmospheric oxygen. This leads to a sharp increase in the brittleness of the materials. Multiple reprocessing of other types of polyolefins, such as PP, usually increases its viscosity (PTR), but does not cause abrupt changes in its strength. Therefore, the waste generated in the manufacture of parts from PP, as well as the parts themselves can be used to produce a new type of product by mixing with the primary raw material after the end of their service life.

This work is based on the possibility of obtaining materials with the desired physical and mechanical properties under optimal processing conditions by processing the secondary PE, PP and PVC mixtures previously studied, obtaining products for technical purposes by adding targeted additives such as primary PVC, as well as plasticizers, stabilizers and fillers. was obtained.

1. Softening temperatures of polymers. Softening temperatures of polymers were studied in the laboratory device Vicat / HDT in accordance with GOST 15088-2014 (ISO 306: 2004).

Primary and secondary PE, PP, PVX wastes obtained for the experiment and the softening temperatures of their plasticized compositions in different proportions were studied and analyzed.

Experiment 1.1. Softening temperatures of secondary PE, PP and PVX mixtures in different ratios:

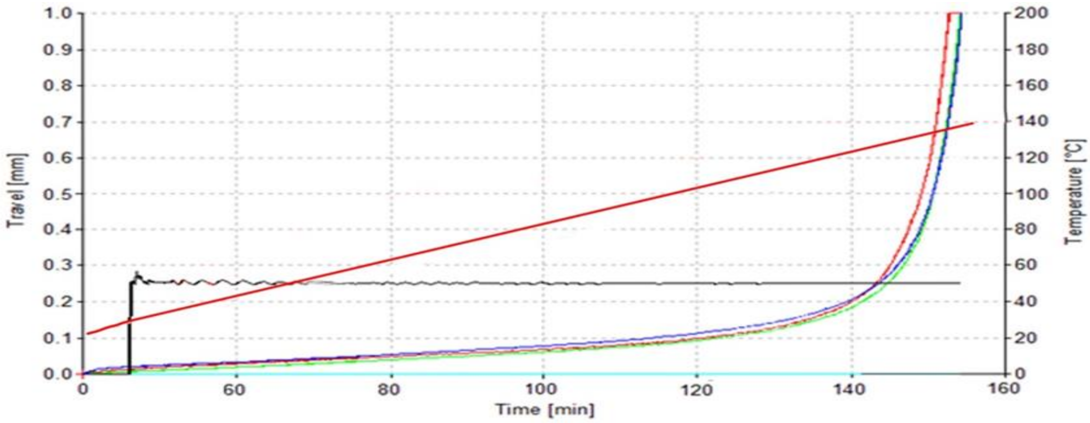

Figure 1.1. Softening temperatures of secondary PE, PP and PVX mixtures.

Experiment 1.2. Secondary PE, PP and PVX mixtures + plasticizer in different proportions (1:0,1 m.b.):

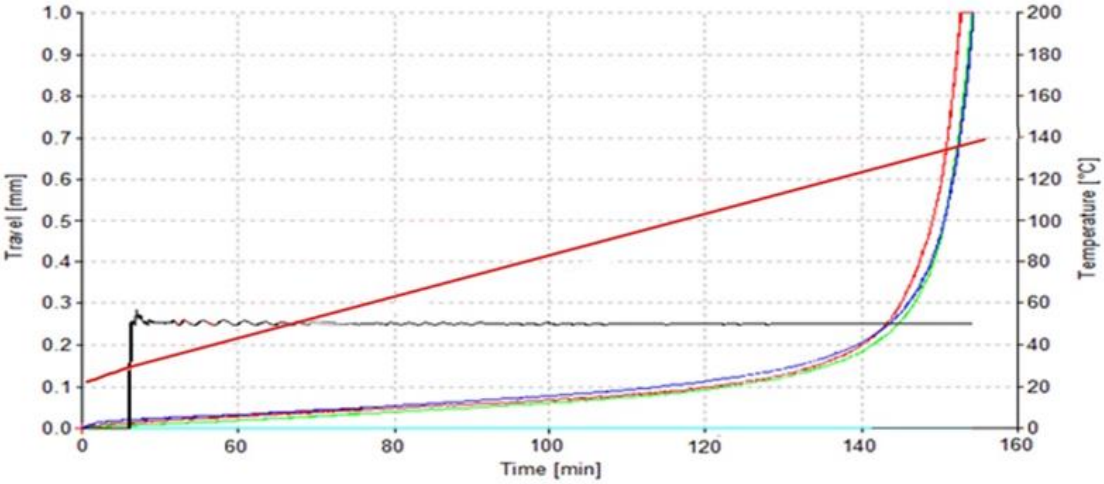

Figure 1.2. Secondary PE, PP and PVX mixtures + plasticizer in different proportions (1:0,1 m.b.) softening temperatures of.

Experiment 1.3. Secondary PE, PP and PVX mixtures + plasticizer in different proportions (1:0,3 m.b.):

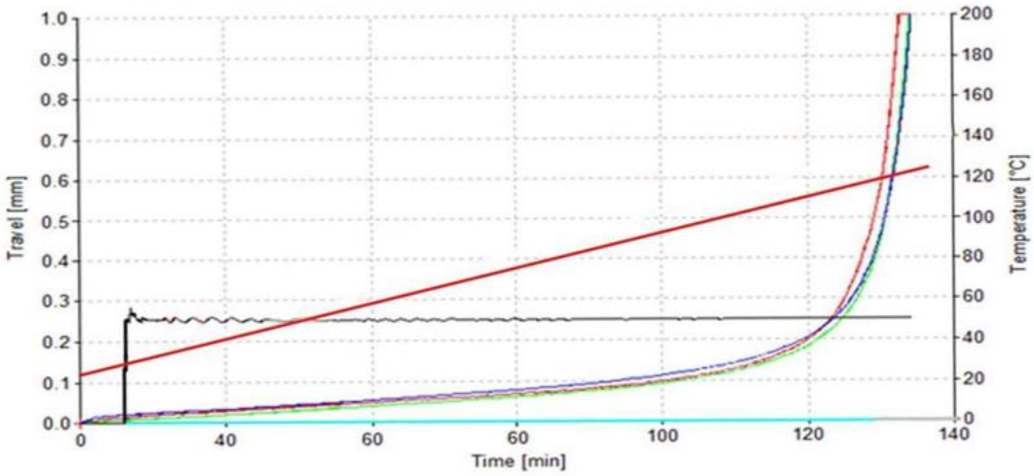

Figure 1.3. Secondary PE, PP and PVX mixtures + plasticizer in different proportions (1:0,3 m.b.) softening temperatures of.

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Experiment 1.4. Secondary PE, PP and PVX mixtures + plasticizer in different proportions (1:0,5 m.b.):

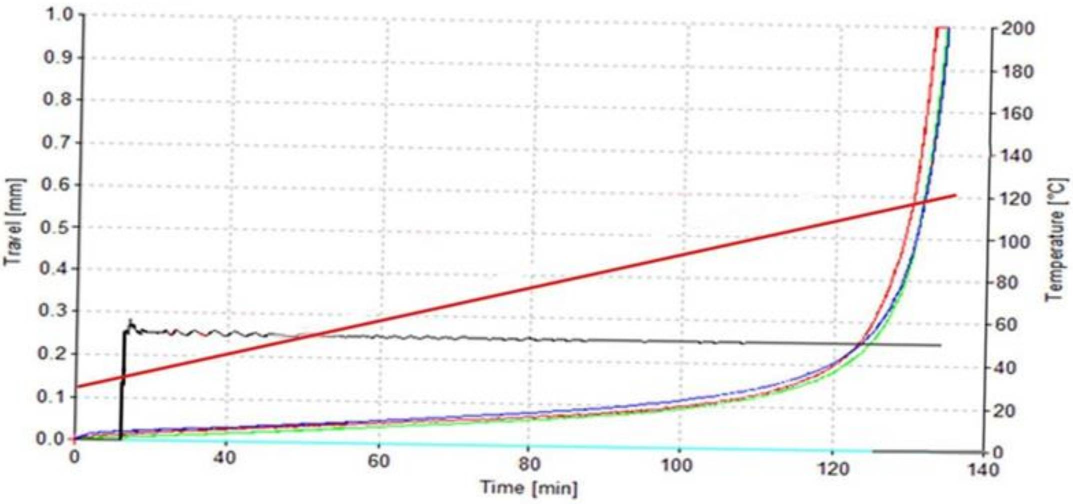

Figure 1.4. Secondary PE, PP and PVX mixtures + plasticizer in different proportions (1:0,5 м.б.) softening temperatures of.

The results obtained during the above studies are presented in Table 2:

Table 2

Softening temperatures of primary and secondary PE, PP, PVX waste and their plasticized compositions

Names of polymers and derived ratios of plasticizers	**Soft temperature, ^{0}C**
P-Y342 granules	120
Secondary PE	109,3
PE + plasticizer; 1 : 0,1	104,2
PE + plasticizer; 1 : 0,3	100,1
PE + plasticizer; 1 : 0,5	95,5
Polypropylene	140
Secondary PP	135,4
PE + plasticizer; 1 : 0,1	129,5
PE + plasticizer; 1 : 0,3	124,3
PE + plasticizer; 1 : 0,5	120,1
PVX resin	105
Secondary PVX	125,8
PVX + plasticizer; 1 : 0,1	121,2
PVX + plasticizer; 1 : 0,3	119,1
PVX + plasticizer; 1 : 0,5	116,8
Secondary PE, PP and PVX compounds	142
Secondary PE, PP and PVX compounds + plasticizer; 1 : 0,1	136,7
Secondary PE, PP and PVX compounds + plasticizer; 1 : 0,3	130,2
Secondary PE, PP and PVX compounds + plasticizer; 1 : 0,5	128,4

Application. *Secondary mixture Soapstock and dioctylphthalate (DOF) mixture for plasticization of PE, PP, PVX waste 1:1 obtained in proportion.*

As can be seen from Table 2, the softening temperatures of primary PE, PP and PVX raw materials are higher than the softening temperatures of secondary PE, PP waste, and the softening temperatures of PVX waste are much lower, except due to various additives in it. The composition of this secondary waste 1:0,1; 1:0,3; 1:0,5 % plasticizer in proportions (soapstock and DOF) it can be observed that their softening temperatures decrease when introduced.

Hence, the mixture of plasticizers penetrates between the polymer macromolecules and their intermolecular attraction (Vander-Vals) weakens the forces and, as a result, increases the flexibility of the polymer to a certain extent, improves the molding properties during processing and reduces the softening temperatures..

It can be seen that the inclusion of plasticizers in secondary PE, PP and PVX-based wastes allows the production of various types of products from polymer wastes..

2. Temperatures of liquefaction and recrystallization of polymers.

Liquidation and recrystallization temperatures of the secondary PE, PP and PVC wastes under study were carried out on a differential scanning calorimeter (DSC) according to the method D 3417-99.

The following experiments show the liquefaction temperatures of secondary PE, PP and PVX mixtures obtained in different proportions and their mixtures with plasticizers.

Experiment 2.1. Liquid temperatures of secondary PE, PP and PVX mixtures in different ratios:

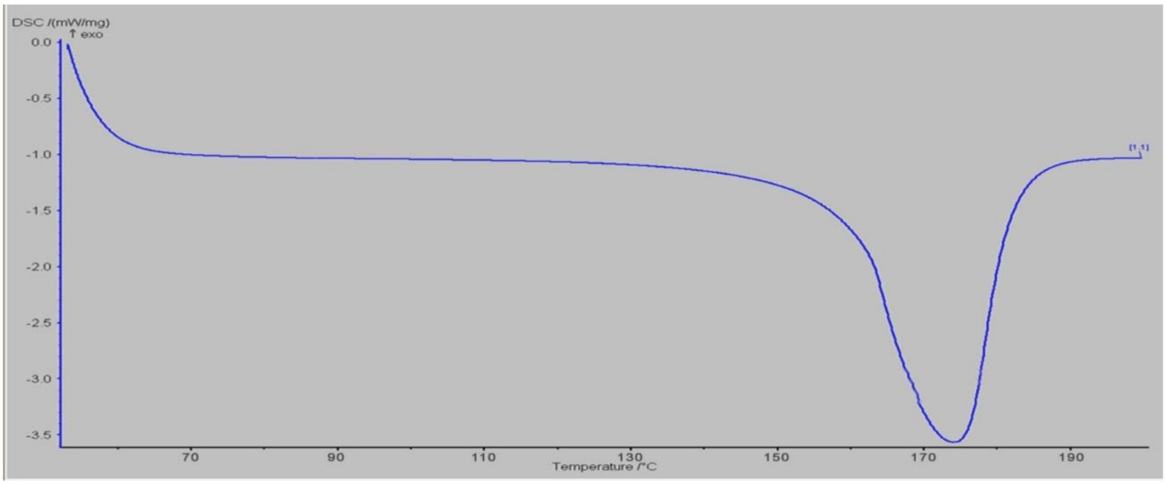

Figure 2.1. Liquid temperatures of secondary PE, PP and PVX mixtures in different ratios.

Experiment 2.2. Liquidus temperatures of secondary PE, PP and PVX mixtures + plasticizer (1: 0.1 m.b.) in different ratios:

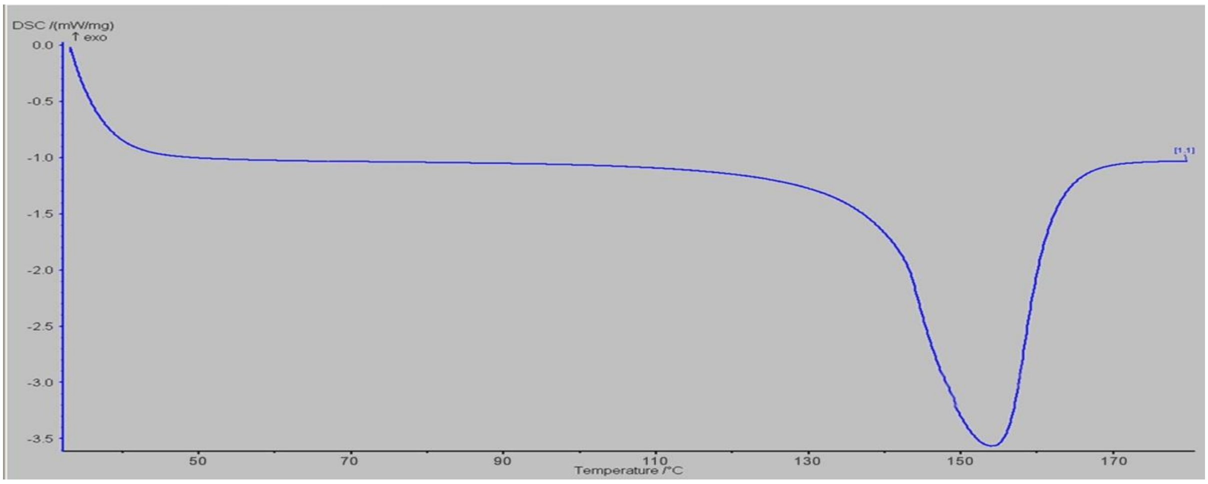

Figure 2.2. Liquidus temperatures of secondary PE, PP and PVX mixtures + plasticizer (1: 0.1 m.b.) in different ratios.

Experiment 2.3. Liquidus temperatures of secondary PE, PP and PVX mixtures + plasticizer (1: 0.3 m.b.) in different ratios:

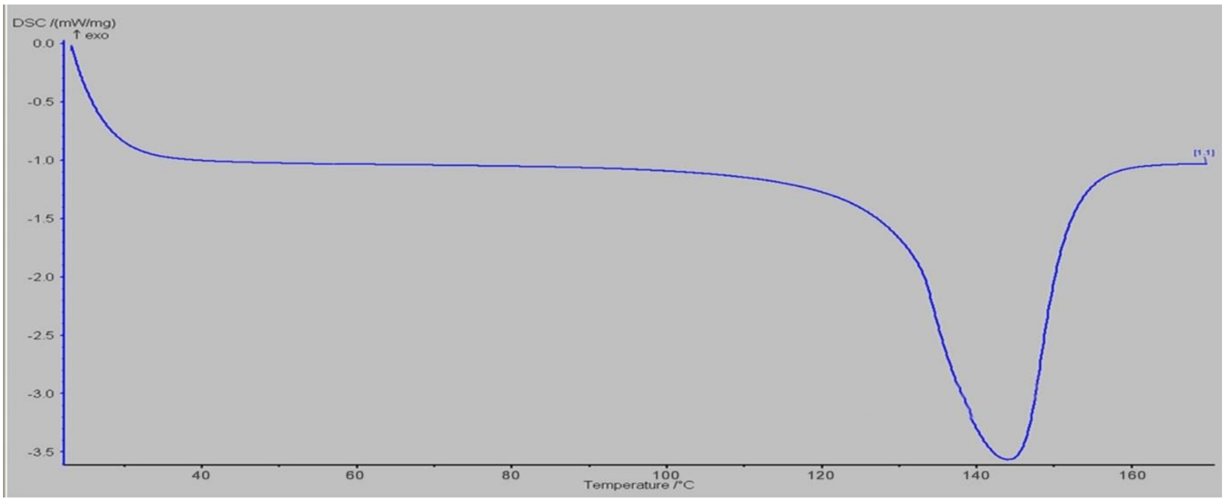

Figure 2.3. Liquidus temperatures of secondary PE, PP and PVX mixtures + plasticizer (1: 0.3 m.b.) in different ratios.

Experiment 2.4. Liquid temperatures of secondary PE, PP and PVX mixtures + plasticizer (1: 0.5 m.b.) in different ratios:

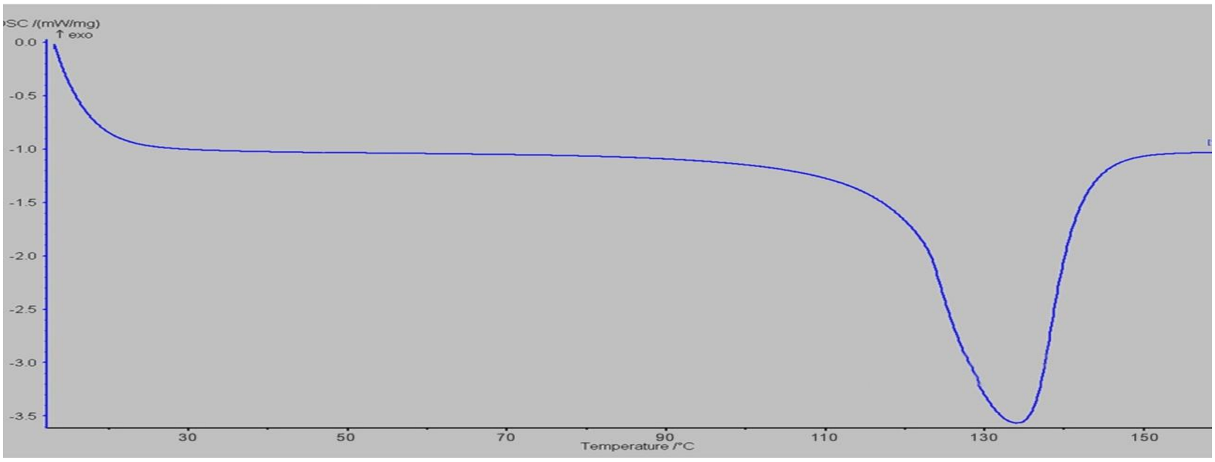

Figure 2.4. Liquid temperatures of secondary PE, PP and PVX mixtures + plasticizer (1: 0.5 m.b.) in different ratios.

The experimental results obtained are presented in Table 3 below:

Table 3

Liquidation and recrystallization temperatures of polymers

Names of polymers	Liquidus temperature, ^0C	Recrystallization temperature, ^0C
P-Y342 granules	130	122
Secondary PE	128	121,1
PE + plasticizer; 1 : 0,1	122,2	117,9
PE + plasticizer; 1 : 0,3	115,5	112,5
PE + plasticizer; 1 : 0,5	108,2	105,2
Polypropylene	176	162
Secondary PP	160,1	151,4

PP + plasticizer; 1 : 0,1	145,4	146,1
PP + plasticizer; 1 : 0,3	138,6	135,6
PP + plasticizer; 1 : 0,5	126,3	122,8
PVX resin	150	143,2
Secondary PVX	144,4	137
PVC + plasticizer; 1 : 0,1	136,3	130,2
PVC + plasticizer; 1 : 0,3	131,1	123,8
PVC + plasticizer; 1 : 0,5	126,5	120,6
Secondary PE, PP and PVC compounds	172	165
Secondary PE, PP and PVC compounds + plasticizer; 1 : 0,1	152,7	146,3
Secondary PE, PP and PVC compounds + plasticizer; 1 : 0,3	140,2	135,2
Secondary PE, PP and PVC compounds + plasticizer; 1 : 0,5	132,4	128,6

From the experimental results given in Table 3, it can be concluded that the addition of soapstock and dioctylphthalate as plasticizers to the production of quality plasticized polymer products used for various purposes by recycling secondary PE, PP and PVX waste reduces the softening temperature of the above polymer. as well as a decrease in recrystallization temperatures. This is technologically feasible.

3. Study of physical and mechanical properties of polymer samples

Based on the above experiments, the physical and mechanical properties of these samples were carried out on the cutting machine "Instron" according to GOST 11262-80 (ST SEI 1199-78).

Elongation strength of polymer samples obtained on the basis of secondary PE, PP and PVX mixtures of different ratios and their mixtures with plasticizers ($\sigma_{\text{рм}}$), breaking strength ($\sigma_{\text{рр}}$), elongation fluidity limit ($\sigma_{\text{рт}}$) and the relative elongation at break (ε_{pp}) The indicators were calculated according to the following appropriate formulas:

Elongation strength of the polymer sample ($\sigma_{\text{рм}}$) calculated according to the following formula:

$$\sigma_{\text{рм}} = \frac{F_{\text{рм}}}{A_0}$$

Breakage strength ($\sigma_{\text{рр}}$) calculated according to the following formula:

$$\sigma_{\text{рр}} = \frac{F_{\text{рр}}}{A_0}$$

The limit of readability in elongation ($\sigma_{\text{рт}}$) calculated according to the following formula:

$$\sigma_{\text{рт}} = -\frac{F_{\text{рт}}}{A_0}$$

Here, $F_{\text{рм}}$ - maximum force during elongation, H;

$F_{\text{рр}}$ - power at the time of sampling, H;

F_{pT} – the force at the initial breaking of the sample, H;

A_0 – the initial cross section of the sample, mm^2.

Relative elongation at break (ε_{pp}) calculated according to the following formula:

$$\varepsilon_{pp} = \frac{\Delta l_{op}}{l_0} \cdot 100$$

Here, Δl_{op} – change in sample length at break time, mm;

l_{op} - the initial length of the sample, mm.

The experimental results with the secondary polymer waste are presented in Table 4 below:

Table 4

Physical and mechanical properties of samples

Names of samples	F_{pt}	F_{pm}	F_{pp}	Δ/op
P-Y456	31,07	31,08	12,45	65,4
Secondary PE	17,9	17,9	8,7	62,43
PE + plasticizer; 1 : 0,1	13,4	13,4	6,5	44,3
PE + plasticizer; 1 : 0,3	11,3	11,4	4,8	30,2
PE + plasticizer; 1 : 0,5	10,2	10,1	3,6	28,5
Polypropylene	42,3	42,01	33,2	75,6
Secondary PP	28,8	28,7	27,3	56,4
PP + plasticizer; 1 : 0,1	25,00	25,01	24,8	45,3
PP + plasticizer; 1 : 0,3	22,58	21,67	20,8	25,56
PP + plasticizer; 1 : 0,5	19,4	17,3	16,3	21,22
PVX resin	38,5	37,8	26,1	50,7
Secondary PVX	21,37	20,72	20,8	41,44
PVX + plasticizer; 1 : 0,1	15,68	15,70	15,60	15,8
PVX + plasticizer; 1 : 0,3	13,91	13,91	13,90	12,92
PVX + plasticizer; 1 : 0,5	11,7	10,1	10,05	9,64
Secondary PE, PP and PVX compounds	24,6	23,8	23,0	36,7
Secondary PE, PP and PVX compounds; 1:0,1	18,3	17,9	18,5	27,0
Secondary PE, PP and PVX compounds; 1:0,3	17,0	16,8	17,5	24,7
Secondary PE, PP and PVX compounds; 1:0,5	14,2	13,4	13,1	21,2

As can be seen from Table 4 above, P-Y456 tensile strength of branded primary polyethylene ($\sigma_{рм}$), breaking strength (σ_{pp}), elongation fluidity limit ($\sigma_{рт}$) and the relative elongation at break (ε_{pp}) When comparing the performance of secondary PE, PP and PVX wastes and their mixtures with plasticizers in different proportions, it can be seen that all of these indicators have decreased slightly. This is the case with plasticizer mixtures containing secondary polymer waste (soapstock and DOF) can be seen to decrease further with the introduction. From this it can be concluded that the physical and mechanical properties of mixed polymer wastes deteriorate during secondary processing. However, the inclusion of a plasticizer in their composition contributes to the transformation of polymer mixtures into a homogeneous, homogeneous mass and the improvement of orientation properties in the structures of polymer mixtures, as well as the molding properties of polymer raw materials.

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