Mechanical Properties of Polymer Composites Based On Modified Polytetrafluoroethylene

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Abstract. This article presents the results of deformation and strength studies of polymer composite materials based on modified polytetrafluoroethylene (PTFE). The modified polymer matrix consists of 10 % activated polytetrafluoroethylene and 90 % initial polymer. The fillers are magnesium aluminate spinel (MAS) and carbon material Sibunit. It has been found that the addition of 10 wt. % of activated PTFE to PTFE results in increased tensile strength and elongation at rupture by 20-35%. Deformation and strength characteristics of polymer composites based on modified polymer matrix are 10-30% higher. Perspective of using modified fluoroplastic matrix for obtaining filled composites with improved deformation and strength properties is shown.

1. Introduction

The use of polymer composites (PC) is an important factor in increasing the successful development and efficiency of leading industries. However, modern technology increasingly requires physical and mechanical properties of PC, so it is relevant to study the influence of various factors on the properties of the materials being developed. Recently, polytetrafluoroethylene (PTFE) PC production has increasingly employed modification of polymers and fillers by various physical methods. This provides an increase in surface energy of polymers and fillers, accompanied by their structural activity.

Such methods include mechanical activation of powder materials, the prospects of which are related to low energy consumption of equipment, simplicity and safety of the process [1-4].

Numerous experimental and theoretical studies have established the variety of phenomena accompanying the process of mechanical activation of substances. The following processes are registered: electromagnetic wave emission, heat generation, electron emission, formation of elastic and plastic deformations, slow relaxation of deformations and excessive stresses in solid bodies [5,6]. This leads to preservation of excess energy by the substance, change of thermodynamic characteristics of the substance, increase of its reactivity.

2. Objects and research methods

Polytetrafluoroethylene (PTFE) of the PN brand (GOST 10007-80), which is a loose, white powder with density of 2170-2190 kg/cm³, melting temperature 327 °C, was used as the modified polymer. It exhibits high chemical and thermal resistance, has a rather low coefficient of friction, good water-repellent and electrically insulating properties.
The fillers of PC were magnesium aluminate spinel (MAS) and Sibunit. Magnesium aluminate spinel is a double oxide with the general formula \( \text{MgO} \cdot \text{Al}_2\text{O}_3 \). A feature of this filler is high dispersion (average particle size 70 nm) and developed specific surface area (170-200 m\(^2\)/g). Sibunit is a synthetic carbon material combining the advantages of both graphite (chemical stability, electrical conductivity) and active coals (high specific surface area, adsorption capacity) [7].

The modified polymer matrix consists of 90 wt.% initial PTFE and 10 wt.% of activated PTFE in a planetary mill Fritch "Pulverizette 5". The main disk speed of 400 rpm for 5 min. Polymer composites (PC) were prepared by dry mixing the modified polymer matrix and filler in a blade mixer. The technological scheme of production of PTFE-composites with mechanically activated components is given in Figure 1.

![Diagram](image_url)

**Figure 1.** Technological scheme of production of PTFE-composites with mechanically activated components.

Test samples were prepared by cold molding at a specific pressure of 50 MPa followed by sintering to 380°C in a muffle furnace and free cooling to room temperature according to standard PTFE composites processing technology.

The mechanical properties of the samples were determined during tensile and compression tests on a fracturing machine UTS-20K as per GOST 11262-80.

**3. Results and discussion**

It is known that when even a small amount of filler is added to PTFE, the values of the deformation and strength characteristics of PC are reduced compared to the initial polymer [8]. Therefore, it was decided to use a fluoroplastic mixture of 5-10 wt.% PTFE activated in a planetary mill as the polymer matrix.
Values of physical and mechanical indices depending on concentration of mechanically activated PTFE are given in Table 1.

**Table 1.** Dependence of deformation and strength characteristics PTFE from activated PTFE concentration.

| Composition                  | Tensile strength, MPa | Elongation at rupture, % | Elastic modulus, MPa | Compressive strength, MPa | Compressive modulus, MPa | Density, g/cm³ |
|------------------------------|-----------------------|--------------------------|----------------------|---------------------------|--------------------------|---------------|
| PTFE                         | 20-22                 | 300-320                  | 513                  | 25                        | 317                      | 2.18          |
| PTFE+10 wt.% act.PTFE        | 24-25                 | 410-430                  | 610                  | 26                        | 453                      | 2.18          |
| PTFE+5 wt.% act.PTFE         | 23-24                 | 370-390                  | 574                  | 26                        | 397                      | 2.18          |

It has been shown that the addition of 5 wt.% and 10 wt.% of activated PTFE to PTFE results in some increase in tensile strength and elongation at rupture per 20-35%. Values of strain-strength indices of PTFE in polymer mixture with content of 10 wt.% of activated PTFE are higher than in mixture with 5 wt.% of injected PTFE. Therefore, in further studies, a polymer mixture with 10 wt.% of activated PTFE was used as the polymer matrix.

The results of deformation and strength studies of PC based on modified PTFE and activated Sibunit, as well as PC based on PTFE and Sibunit are given in Table 2.

**Table 2.** Deformation and strength characteristics of PC based on modified PTFE and Sibunit.

| Composition                  | Tensile strength, MPa | Elongation at rupture, % | Elastic modulus, MPa | Compressive strength, MPa | Compressive modulus, MPa | Density, g/cm³ |
|------------------------------|-----------------------|--------------------------|----------------------|---------------------------|--------------------------|---------------|
| PTFE (PTFE+10 wt.% act.PTFE) | 20                    | 310                      | 513                  | 25                        | 317                      | 2.18          |
| +0.5 wt.% act.Sibunit        | 22                    | 386                      | 498                  | 24                        | 373                      | 2.14          |
| PTFE+10 wt.% act.PTFE        | 21                    | 327                      | 519                  | 28                        | 476                      | 2.15          |
| +1 wt.% act.Sibunit          | 21                    | 316                      | 501                  | 28                        | 507                      | 2.13          |
| PTFE+10 wt.% act.PTFE        | 20                    | 298                      | 476                  | 24                        | 393                      | 2.14          |
| +0.5 wt.% act.Sibunit        | 15                    | 293                      | 515                  | 25                        | 262                      | 2.14          |
| PTFE+1 wt.% Sibunit          | 14                    | 270                      | 504                  | 25                        | 287                      | 2.13          |
| PTFE+2 wt.% Sibunit          | 12                    | 211                      | 495                  | 25                        | 348                      | 2.09          |

It is shown that PC on the basis of modified polymer matrix has deformation and strength characteristics higher by 10-30% compared to PC on the basis of PTFE. The optimum concentration of filler content is 1 wt.% . It has been found that the activation of Sibunit allows to increase the values of physical and mechanical indices to the level of the initial PTFE. When filling fluoroplastic matrix with activated PTFE, physical and mechanical characteristics are improved: tensile strength increases by 10%, elongation at rupture by 25% compared to initial PTFE. This is apparently due to the fact that the
modified matrix is characterized with improved values of deformation and strength characteristics, that when filled it compensates for negative influence of filler on these values.

The results of deformation and strength studies of PC based on modified PTFE and magnesium aluminate spinel are given in Table 3.

**Table 3.** Deformation and strength characteristics of PC based on modified PTFE and magnesium aluminate spinel (MAS).

| Composition | Tensile strength, MPa | Elongation at rupture, % | Elastic modulus, MPa | Compressive strength, MPa | Compressive modulus, MPa | Density, g/cm³ |
|-------------|-----------------------|--------------------------|---------------------|--------------------------|--------------------------|---------------|
| PTFE        | 20                    | 310                      | 513                 | 25                       | 317                      | 2.18          |
| (PTFE+10 wt.% act.PTFE)+0.5 wt.% MAS | 23 | 318 | 594 | 26 | 453 | 2.18 |
| (PTFE+10 wt.% act.PTFE)+1 wt.% MAS | 22 | 318 | 556 | 27 | 450 | 2.17 |
| (PTFE+10 wt.% act.PTFE)+2 wt.% MAS | 21 | 293 | 552 | 28 | 376 | 2.17 |

It has been found that filling the modified polymer matrix with MAS results in 15% increase in strain-strength characteristics compared to the original PTFE. The optimal concentration of filler taking into account the tensile and compressive values is 1 wt.%.

When developing new PC it is necessary to take into account all factors to improve operational properties of materials: dispersion and nature of fillers, mixing methods, technology of activation of components [9]. Table 4 shows the results of PC tests containing 5 wt.% and 10 wt.% co-activated PTFE and MAS. Tensile strength and elongation at rupture of these composites were found to be reduced to 70% compared to the starting polymer and the elastic modulus of increased by almost 1.7 times.

**Table 4.** Deformation and strength characteristics of PC from concentration and ratio, jointly activated PTFE and MAS.

| Composition | Ratio PTFE:MAS | Tensile strength, MPa | Elongation at rupture, % | Elastic modulus, MPa | Compressive strength, MPa | Compressive modulus, MPa | Density, g/cm³ |
|-------------|----------------|-----------------------|--------------------------|---------------------|--------------------------|--------------------------|---------------|
| PTFE        | -              | 20                    | 310                      | 513                 | 25                       | 317                      | 2.18          |
| PTFE+5 wt.% (PTFE:MAS) | 1:1 | 17 | 278 | 626 | 25 | 506 | 2.17 |
| PTFE+10 wt.% (PTFE:MAS) | 1:1 | 12 | 49 | 887 | 25 | 530 | 2.18 |
| PTFE+5 wt.% (PTFE:MAS) | 1:2 | 16 | 281 | 706 | 25 | 503 | 2.15 |
| PTFE+10 wt.% (PTFE:MAS) | 1:2 | 13 | 183 | 668 | 25 | 546 | 2.16 |
| PTFE+5 wt.% (PTFE:MAS) | 2:1 | 17 | 276 | 594 | 26 | 516 | 2.18 |
| PTFE+10 wt.% (PTFE:MAS) | 2:1 | 15 | 215 | 656 | 25 | 597 | 2.18 |
4. Conclusions

It has been shown that the addition of 10 wt.% of activated PTFE to PTFE results in some increase in tensile strength and elongation at rupture per 20-35%. It is shown that PC based on modified polymer matrix and magnesium aluminate spinel has deformation-strength characteristics higher by 15% compared to the initial PTFE. The optimum concentration of filler content is 1 wt.%.

It was found that PC based on modified polymer matrix and Sibunit has deformation and strength characteristics higher by 10-30% compared to PC based on PTFE. The optimum concentration of this filler is 1 wt.%.

It has been found that the activation of Sibunit allows to increase the values of physical and mechanical indices to the level of the initial PTFE. When filling fluoroplastic matrix with activated PTFE, physical and mechanical characteristics are improved: tensile strength increases by 10%, elongation at rupture by 25% compared to initial PTFE.

Thus, based on the studies carried out, the perspective of using a modified fluoroplastic matrix to improve the deformation and strength properties of the filled composites is shown.

5. References

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