Nanocarbon Additives Application in the Polyvinyl Chloride Siding Panels Manufacture

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Abstract. With the development of building technologies, there is a need for new finishing materials that must meet the requirements of modern standards. This concerns not only the pricing policy, but also the high quality of promising materials, that first of all, is manifested in strength characteristics. In order to strengthen and preserve the heat-insulating properties and corrosion resistance, it is proposed to introduce schungite of type III of various grades in the formulation of siding panels made of polyvinyl chloride (PVC). The analysis of the quality indicators of PVC panels was carried out and three main indicators were identified: melt flow rate; Charpy impact strength; bending stress. PVC siding panels with the addition of schungite were produced by injection molding. As a result of experimental studies, the dependence of the Charpy impact strength of PVC panel samples without notching and bending stress on the bulk density of schungite was revealed, and scattering diagrams of the dependence of the melt flow rate on the polymerization time and the melt flow rate on the PVC concentration were constructed. The effect of schungite concentration of various grades on the melt flow rate was revealed. The dependence of schungite application as a reinforcing filler on the decrease in the melt flow rate in comparison with the traditional filler is determined.

1. Introduction

In the conditions of human society urbanization one can observe a transition to a new generation of construction technologies that increase the construction industrialization [1,2]. Modern building materials should have lightness, strength, corrosion resistance, presentable appearance, thermal insulation properties, be environmentally friendly, require less energy for their production. These requirements are met by building materials made on the basis of polymers [3-6].

Recently, various mineral fillers have been used to obtain desired properties, increase economic efficiency and environmental safety in the formulation of composite materials. Research work in this field indicates its promise [7-10].

PVC siding panels are widely used in modern construction as finishing materials [11]. However, Russian siding panels still lag behind the requirements of international standards at the technical level [12,13]. So the problem of making technological adjustments in the production process aimed at their quality indicators improving arises [14,15]. One of the drawbacks of the soft profile for PVC siding panels is the tendency to curvature. To eliminate such disadvantages, it is necessary to introduce reinforcing dispersed additives, one of which may be carbon black [16,17]. Natural mineral carbon-containing materials have recently found wide application in industrial practice [18,19]. Method of
polymer compositions strengthening with ultrafine carbon materials based on nanotechnology is proposed for use in the article [20]. These materials are polymer chains modifiers, have chemical activity and serve as reinforcing additives [21, 23].

2. Aims and objectives
The aim of the study is the transition from soft to hard PVC; reducing the thickness of PVC siding panels with an increase in their strength.

The objective is to study the effect of shungite on the physico-mechanical characteristics of the mixture for polyvinyl chloride obtaining and its properties control.

3. Methods and materials
Shungite of type III of various dispersiveness and carbon content of 20-35% of Novocarbon grades - 10, 20, 40 and 80 (N-10, N-20, N-40, N-80) was used as a strengthening additive [22]. PVC was selected as the polymer matrix for the reinforcing agent.

Charpy impact strength was determined on five panel samples. They were cut from the front side along the longitudinal axis with a thickness of at least 2/3 of the wall thickness. The final result was the arithmetic mean value of the test results for the five samples studied so that each result was at least 10 kJ/m².

The method for determining the bending stress consisted in the fact that the test sample of rectangular cross-section was supported and was bent in the middle at a constant speed until it collapsed or to a predetermined deflection value. During the test, the load of the sample and the deflection values in the middle between the supports were determined. The samples had the following parameters, in mm:
- length (80 ± 2);
- width (10.0 ± 0.2);
- thickness (4.0 ± 0.2).

For the samples studied, it is not allowed that the deviation in thickness from its average value is more than 2%, and the deviation in width is more than 3%, the cross section is rectangular, without rounding the corners in the central third of the length. All test samples were obtained by injection molding. During the test, the width (measurement error ≤ ± 0.1 mm) and the thickness (measurement error ± 0.01 mm) in the center of the test sample were measured (Figure 1).

![Figure 1. Cross section of an injection molded sample with a contraction pattern due to shrinkage.](image)

The average thickness \( h_{av} \) for the tested samples of this batch was calculated. Those samples in which \( h \) differed by more than 2% from the average value became unusable and went to rejection, and samples of another batch were used instead. The thickness result for \( h \) with a deviation from \( h_{av} \) of not more than 0.1 mm due to shrinkage was accepted (Figure 1). The distance between the supports was calculated by the formula \( L=(16±1) \times h_{av}, \text{ mm.} \)

Then, the test sample was symmetrically mounted on the supports with the wide side and a preliminary load was applied in the middle between the supports, taking into account the speed of the movable crosshead of 1 mm / min. Then the results of the deflection measuring system were reset. The modulus of elasticity was determined with a standard test speed.

The stratification method was used to process data on melt flow rate.

The melt flow rate was determined with an extrusion plastomer.
4. Results
At the preliminary stage of the work, the analysis of the most important defects of PVC siding panels with the Pareto diagram was carried out (Figure 2).

![Pareto Diagram](image)

**Figure 2.** Defects of PVC siding panels (Pareto diagram): 1 - melt flow rate; 2 - Charpy impact strength without notching; 3 — bending stress; 4 - Vicat softening temperature (VST); 5 - cracks; 6 - bubbles; 7 - other.

Following the Pareto 80/20 principle in analyzing the diagram (Figure 2), we can conclude that the most significant are deviations from the normative indicators of melt flow, Charpy viscosity and bending stress.

As a result of the study of PVC panels samples produced with the addition of schungite of various grades, the dependences of the change in Charpy impact strength without notching and bending stress (table 1) on the added schungite quantity were obtained. It can be seen from the data presented that with an increase in the filling of schungite, the viscosity increases more and more, and the stress during bending gradually decreases.

**Table 1.** The dependence of the change in Charpy impact strength without notching and bending stress.

| Shungite content, % (mass.) | PVC | N-10 | N-20 | N-30 | N-40 | N-50 | N-60 | N-70 | N-80 |
|----------------------------|-----|------|------|------|------|------|------|------|------|
| Charpy impact strength without notching, kJ/m² | 15  | –    | 10   | 12   | 15   | 16   | –    | 42   | 43   |
| Bending stress, MPa       | 14  | –    | –    | –    | 14   | –    | –    | 44   | 45   |
| PVC                       | 30  | –    | 10   | 12   | 15   | 16   | –    | 42   | 43   |
| PVC                       | 40  | –    | 20   | 26   | 30   | 32   | –    | 37   | 41   |
| PVC                       | 50  | –    | 40   | 50   | 60   | 65   | –    | 35   | 39   |

The scatter plot of the melt flow rate dependence on the polymerization time is shown in Figure 3, and the dependences of the melt flow rate on the PVC concentration are shown in Figure 4.
Using scattering diagrams, it was found that with an increase in the melt flow rate, a decrease in the polymerization time for PVC, as well as an increase in the PVC concentration, is observed. The dependence between melt flow rate and schungite concentration is shown in table 2. To study the effect of schungite influence on the PVC properties, tests on the melt flow rate were carried out and it was concluded that schungite Novokarbon-10 reduces the melt flow rate the least of all grades.

Table 2. The dependence between melt flow rate and schungite concentration.

| Shungite grade | Shungite concentration, % | Melt flow rate, g/10 min |
|---------------|---------------------------|--------------------------|
| N-10          | 10                        | 25                       |
|               | 20                        | 22.5                     |
|               | 30                        | 20                       |
|               | 40                        | 18                       |
|               | 50                        | 16                       |
|               | 60                        | 15                       |
|               | 70                        | 14                       |

The dependence between melt flow rate and schungite concentration is shown in table 3.

Table 3. The dependence between melt flow rate and schungite concentration.

| Filler | Filler concentration, % (mass.) | Melt flow rate, g/10 min |
|--------|---------------------------------|--------------------------|
| Chalk  | 10                              | 25                       |
|        | 20                              | 22.5                     |
|        | 30                              | 20                       |
|        | 40                              | 18                       |
|        | 50                              | 16                       |
|        | 60                              | 15                       |
|        | 70                              | 14                       |
| Shungite| 10                              | 23.5                     |
|        | 20                              | 20                       |
|        | 30                              | 18                       |
|        | 40                              | 16                       |
|        | 50                              | 14                       |
|        | 60                              | 12                       |
|        | 70                              | 11                       |

Table 3 shows that the use of schungite as a reinforcing filler can reduce the melt flow rate to a lesser extent than chalk, which is a traditional filler.

5. Conclusion
The studies revealed that schungite is a reinforcing filler that reduces the melt flow rate, while the decrease in melt flow rate is much lower than that one of a traditional filler. Therefore, it has the best technological properties. According to this, it can be assumed that a greater amount of schungite should be added to the mixture, thereby reducing the cost of the formulation.
The analysis of the dependences of the bending stress and Charpy impact strength without a notching suggests that an increase in the filling of the composite material with schungite improves its quality indicators.

The application of schungite fillers will improve the properties of finishing building materials.

6. References

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