On developing method for determining materials properties and combustion system structural elements of launch vehicles separated parts

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Abstract The article considers a new class of problems, which studies the issues of burning the launch vehicle (LV) separating structures made from polymer composite material, including fillers and carbon fiber. As illustrated by the structure of the payload fairing (PF), which must undergo forced burning after the mission, four concepts for determining the materials properties are proposed. In conducting experiments in the wind tunnel with the implementation of the actual conditions of high-speed flow, the PF structural model is introduced in the consideration. The results of theoretical and experimental studies performed to determine the properties of the materials that make up the filler and carbon fiber are presented.

1. Introduction
To date, the world devotes great attention to the problem of space launch vehicles (LV) separating parts. Separating parts are the first and second stages of the LV, payload fairings (PF), interstages (IS) and aft-interstages (AIS). All these components, after performing their functions in flight, are separated from the LV, fall to the Earth surface, and as a result, significant areas for the impact zones must be allocated. It should also be noted that for each launch path, the largest area is formed by the impact zones of PF, AIS and IS. So, for the "Soyuz" type LV, the total area of impact zones for exhaust boosters (side blocks and central block) is ~ 35% and impact zones for PF and AIS are ~ 65 %; for “Zenit” LV, impact zones area for the 1st stage booster is ~ 19 – 20% and the impact zones for PF are ~ 80 - 81 %; the “proton-M” LV impact zones area for the 1st stage booster is ~ 28 %, and for PF it is ~ 23 % (if special impact zone is allocated), the impact zones area for the 2st stage booster is ~ 49 %.

An option for a partial solution to this problem is to use a controlled descent for the exhaust boosters of the LV first stages, followed by their repetitive reuse. Currently, a reusable booster of the “Falcon” LV first stage is successfully operated [3], and a reusable booster of the “Shepherd” LV first stage is in the stage of flight tests [4]. Experimental studies and LV launches to test the parachute rescue system of the PF for the “Falcon-9” LV are in progress.

The peculiarity of the PF, IS and AIS motion along the trajectory of their descent after the separation from the LV is that the atmosphere entry velocity at an altitude of ~100 km is 1.0 – 1.5 km/s [5], which is several times less than the entry velocity of the second stage spent boosters, and spacecrafts when they descend from the working orbits (6 – 8 km/s). They burn almost completely when moving in the atmospheric phase of the descent trajectory [6 - 8].

The descent scheme of the LV spent boosters, PF and AIS, as well as the spacecraft descending from the working orbits is shown in figure 1.
Figure 1. The descent scheme of the separating parts of the “Soyuz-2.1b” LV in the active part of the launch trajectory.

Thus, the presence of the separated parts during the LV flight in the active phase of the launch trajectory leads to a number of scientific and technical problems, including predicting impact zones coordinates for separating parts and fragments, minimizing the areas and the number of impact zones, etc. The above given examples for the reusable boosters of the "Falcon-9" and “Shepherd” LV first stages, and PF, based on a controlled flight when moving along the descent trajectory, are one of the ways to reduce the areas and the number of the impact zones. However, the solution to the problem of the impact zones of PF, IS, AIS currently remains relevant.

Publications [9, 10] propose technical solution to reduce the impact zones areas for PF, AIS and IS based on the combustion of their structures during the motion in the atmospheric phase of the descent trajectory. The necessary additional heat to start the combustion process in the structural elements of the LV separating parts is obtained by placing an additional energetic material (EM) such as pyrotechnic compositions in the structures [11, 12].

2. Problem statement
For further analysis of the combustion conditions for the LV separating structures on the example of the PF type [13], the function describing the existing structures is considered, in the form of:

\[ f(M_F^0, M_C^0, 0)_0, \]

Where \( M_F^0, M_C^0 \) are generalized coordinates describing the filler and carbon fiber material, respectively, index 0 is the existing material, \( f, c \) indices indicate the filler and carbon fiber, respectively. Figure 2 shows a scheme of the existing PF three-layer structure with aluminum honeycomb core.
Figure 2. Scheme of the existing PF three-layer structure: 1 – aluminum honeycomb core; 2 – outer carbon fiber layer; 3 – inner carbon fiber layer [13].

The material and design parameters of the PF are selected according to the appropriate technique, involving the determination of the PF materials and design parameters under thermal-force loading at the LV active path, for example, [14]. This approach for selecting the materials and design parameters of the LV, including the separating parts, is traditional and does not provide for their subsequent combustion after the mission when moving in the atmospheric phase of the descent trajectory.

The purpose of this research stage is to determine the material properties (including a polymer compositional and energetic materials in its composition) of the filler and the carbon fiber for the subsequent PF design, for example.

To systematize the process of finding the materials properties, the following concepts are considered:

\[ f(M_F^0, M_{EMF}, M_C^0, 0)_1, \]

– Study Concept (I) provides for the saving of the filler material and the introduction of a self-burning energetic material into the filler structure, while other components of the structure function (1) remain unchanged.

\[ f(M_F^*, M_{EMF}, M_C^0, 0)_II, \]

– Study Concept (II) provides for a change in the filler material and the introduction of a self-burning energetic material into the filler material, while the carbon fiber components remains unchanged.

\[ f(M_F^*, M_{EMF}, M_C^*, 0)_III, \]

– Study Concept (III) provides for a change in the filler material and the introduction of a self-burning energetic material into the filler material, and the use of another carbon fiber material.

\[ f(M_F^*, M_{EMF}, M_C^*, M_{EMC}^*)_IV, \]

– Study Concept (IV) provides for the modification of both filler and carbon fiber materials and the introduction of a self-combustible energetic material into the materials.
In figure 3 the graphic representation of the described concepts of PF structure change is given.

Figure 3. Conceptual model of the PF combustion system problem.

Theoretical and experimental studies to determine the properties are proposed to be carried out on the structural model (SM) of the PF structure. It is assumed that in the case of determining the materials properties providing SM combustion,

\[ f(M_F^*, M_{EM_F}^*, M_{EC}^*, M_{EM_C}^*)_{ign} \]

the obtained materials properties will be used in the PF design in accordance with [14].

The mass of SM structure made from the filler material and carbon fiber can be presented as:

\[ m_C = m_F + m_C, \]

Where, \( m_F \) and \( m_C \) is the mass of the filler and carbon fiber, respectively.

The filler mass is taken as an additive linear mass model:

\[ m_F = k_1 \cdot m_{EM_F}^f + k_2 \cdot m_{B}^F. \]

Where, \( k_1, m_{EM_F}^f, k_2, m_{B}^F \) are the coefficients determining the percentage composition of the filler EM \( m_{EM_F}^f \), the binder filler \( m_{B}^F \) and their masses, respectively.

The carbon fiber mass is taken as:

\[ m_C = z_1 \cdot m_{F}^{C} + z_2 \cdot m_{B}^{C} + z_3 \cdot m_{EM}^{C}. \]

Where, \( z_1, z_2, z_3, m_{F}^{C}, m_{B}^{C}, m_{EM}^{C} \) are the coefficients determining the percentage composition of carbon fiber \( m_{F}^{C} \), carbon fiber binder \( m_{B}^{C} \), carbon fiber EM \( m_{EM}^{C} \) and their masses, respectively.

Mixtures (8), (9) must meet the following requirements:

- High caloric value during combustion;
- The possibility of initialization with low energy losses, for example, from an incandescent spiral;
- With minimum solid phase of combustion products;
- Saving of physical and chemical properties up to a temperature of 500K;
- Fire and explosion safety in the manufacturing process of composite material, in the manufacture and strength testing of PF, IS;
- Allow storage as a part of PF, IS, transportation by land, sea and air transport, and also on the LV active path;
- Must provide specified binding and strength properties, etc. (10)

In general, the problem statement can be formulated as follows:
There are existing materials used in the initial SM (1), it is necessary to determine the composition of materials ensuring the condition of their combustion during the flight on the PF descent path for a given time interval \( \Delta T \) and a given altitude interval \( \Delta H \) (11).

Limitations, assumptions and criteria:
- Combustion of the filler material (8) is initially initiated without oxygen of the incoming flow;
- The filler (8) should light up with a minimum composition of the oxidizer and have a maximum of calorific value;
- Combustion products (8) must contain a minimal amount of solid phase, the excess fuel in the combustion products (8) is burned in the system: combustion products (8) + combustion products (9) + oxygen of the incoming air flow with the release of sufficient heat to burn the system (7);
- The criterion of the effectiveness for the problem solution is:

\[
\min \left[ m_{EM}^F + m_{EM}^C \right]_{\text{min}}
\]

(12)

The solution of the problem is carried out by choosing EM and binder from admissible sets \( \{ EM_F^{per} \}, \{ EM_C^{per} \}, \{ B_F^{per} \}, \{ B_C^{per} \} \), and coefficients \( k_1, k_2, z_1, z_2, z_3 \).

3. Experimental base and the experimental studies results

Experimental studies in accordance with Concept I were considered in [15], where mechanoactivated (MA) mixtures of Ti + 1.1C and Ti + 2.1B were used as a variant of EM in experiments. According to these data, the temperature at the beginning of heat release is almost independent of the MA time and is equal to 600 ± 200°C. The values of the maximum reaction temperatures are reduced from 2100°F ± 200°C to 1800°F ± 200°C with an increase in the duration of MA from 3 to 10 minutes. In the future, the use of MA is not considered as promising, because it is not satisfied by a number of restrictions (10).

Mechanically activated B,C-Ti EM allows implementation of the so-called "gas-free" combustion mode, as gas release can lead to the removal of heat from the hot gas.

To prepare the initial reaction mixtures, the following was used: titanium grade AGR (99.38% Ti) and boron carbide B,C. Mechanical activation of the initial reaction mixtures was carried out in the planetary ball mill AGO-2 with water cooling [3]. The volume of each of the two steel mill shells is 160 cm³. The diameter of the balls is 8 mm, the mass of the balls in each shell is 200 g, the mass of the sample is 10 g. The centrifugal acceleration of the balls is 400 ms⁻² (40 g). To prevent oxidation during mechanical activation, the sample shells were filled with argon. After mechanical activation, the samples were unloaded from the shells in the box with argon. Activation time was 7 minutes.

According to the results of experimental composition studies, the combustion rate of the pressed samples is 8÷10 mm / s, the maximum temperature in the combustion wave reaches 2350°C (figure 4). For measurements, a tungsten-rhenium thermocouple with a diameter of 50 μm inserted on the interface of two flat pressed samples was used, ignition was carried out using a CO₂ laser.
Figure 4. Thermogram of the pyrotechnic B₄C-4Ti composition combustion in the air.

Experimental studies on the combustion of small PF structural models samples were carried out for three cases:

1. Single-layer cladding from carbon fiber with sizes (9x28.4x2.1 mm) and a mass of ≈ 1 g was placed in a powder filling of mechanically activated sample B₄C-4Ti having mass 10 g.
2. B₄C-4Ti was added to aluminum honeycombs located on the surface of the carbon fiber.
3. B₄C-4Ti with the addition of a small amount of plasticizer (3% solution of polyvinyl alcohol) was stuffed with a small seal in aluminum honeycombs located on the surface of the carbon fiber.

As a result of the experiments, it was found that, regardless of the experiment organization method, there is a complete burnout of the polymer component from the carbon fiber. There remain thin plates of the original graphite base that are easily separated from each other. In addition, in experiments with the structure, the burnout of aluminum honeycombs is registered (figure 5).

Figure 5. Experimental results.

Experimental studies in accordance with Concept II are given in [16 - 18].

As a combustible filler, structures with a single wall and 20% filling in the form of a gyroid with dimensions of 40x40x15 mm were printed due to additive technology. Then, with the help of epoxy composition, carbon fiber plates were glued on both sides (figure 6).
The most promising compositions for combustible fillers are those with ammonium perchlorate (AP), as they allow the largest of all polymer filling to be used. This ensures the highest strength of the composite material and the lowest melt viscosity, which can allow for three-dimensional printing by layer-by-layer deposition at high speeds. The composition of 35%PLA + 65% AP was prepared, since according to thermodynamic calculation this is the maximum content of polylactide (PLA), at which a self-sustaining combustion mode should still be realized.

Experiments to evaluate the combustion process of the manufactured sample under the conditions of the incoming flow were carried out on a specially created experimental stand. The stand is a gas-balloon wind tunnel with the possibility of supplying heat to the working part to initiate samples combustion [16].

The experiments were carried out at normal atmospheric pressure and ambient temperature of 293.15 K.

Samples were burned at flow rates of 30, 50, and 70 m/s. They were subjected to thermal loading by means of an oxygen-propane burner, with the parameters of the mixture having a temperature of ~1900 K. Experiment time was ~ 5 minutes.

Figure 6. Structural model of a PF three-layer element with a filler of energetic material 35%PLA + 65% AP.

Figure 7. Scheme of thermal and aerodynamic loading in experimental studies for the structural model of Concept II: 1 – the carbon fiber; 2 – the combustible filler; 3 – oxygen-propane burner; 4 – wind tunnel diffuser.
As a result of the experiments with the PF structural model sample, the combustion process of the energetic filler was 3-5 seconds. There was a partial destruction of carbon fiber (with the total mass of the sample decreasing by ~70%, which practically corresponds to the initial mass of the filler). It was found that during combustion in the air flow at a velocity above 10 m/s there was a sharp increase in the intensity of the combustion reaction and the process was accelerated several times compared to combustion without an incoming air flow. At the same time, 98% of the filler mass during combustion passed into the gas phase and the heat released as a result of the combustion reaction was carried away by the incoming air flow. The mass of the samples was ~14 g, including the filler ~9 g, and in this case, the mass burning rate for the filler was ~2.25 g/s.

Figure 8 shows the fragments of the experiment conducted on the combustion of the sample (figure 6) made in accordance with Concept II under the conditions of the incoming flow.

![Image](https://example.com/image.png)

**Figure 8.** Fragments of the experiment for the sample burning: the filler burning after initialization with a gas burner (left); sample after the experiment (right).

### 4. Theoretical studies

For analytical evaluation of possible materials compositions for concepts III and IV, Terra software package was used [19]. As possible coefficients (8) for materials, $M_F$ is taken from reference materials [20], and the number of used compositions $n=8$.

Table 1 shows the calculation results for the temperature and composition of the combustion products (CP) for different variants $M_F$ at a pressure of 1 atm. The purpose of the calculation was to determine the percentage of substances $M_F$, whose combustion products have the lowest condensed phase.

| № | Investigated $M_F$ | Temperature of CP (K) | The composition of the combustion products (%) |
|---|-------------------|----------------------|-----------------------------------------------|
| 1 | 90% L1* +10% PE   | 1896                 | $H_2$ - 2.6; $H_2O$ - 0.1; $N_2$ - 16.6; C (c) - 13.2; CO - 67.2; CO$_2$ - 0.2; CH$_4$ - 0.1 |
| 2 | 90% L2 + 10%PE    | 1827                 | $H_2$ - 2.7; $H_2O$ - 0.1; $N_2$ - 21.7; C (c) - 11.8; CO - 63.5; CO$_2$ - 0.1; C$_2$H$_2$ - 0.1 |
| 3 | 77.2% L3 + 22.8%PE| 1677                 | $H_2$ - 4.3; $H_2O$ - 1.4; $N_2$ - 32.3; CO - 60.9; |
As follows from the results for the CP under consideration, $M_F$ has the following composition: the gas phase – carbon monoxide 47 – 71%, nitrogen 12 – 36%, the solid phase – carbon 11 – 14%.

For further evaluations we consider an interaction of the CP given in table 1, with components $M_C : PE + L1 + \frac{C_C}{fib}$.

Table 2 shows the temperature and composition of the combustion products, the condensed phase (c) during combustion of considered $M_C$ with the combustion products $M_F$ from table 1.
Table 2. The temperature and composition of the CP, the condensed phase (c) during combustion considered $M_C$ with the combustion products $M_F$ from table 1.

| №  | Proportions $M_C$ and $M_F$ in PF structure | Temperature of CP (K) | The composition of the combustion products (%) |
|----|-------------------------------------------|-----------------------|-----------------------------------------------|
| 1  | 90% L1 +10% PE                            | 997                   | $H_2$ - 1; $H_2O$ - 1.5; $N_2$ - 7.9; $C$ (c) - 61.7; CO - 19.9; CO$_2$ - 8 |
| 2  | 90% L2 + 10%PE                            | 994                   | $H_2$ - 1.1; $H_2O$ - 1.6; $N_2$ - 9.2; $C$ (c) - 61.3; CO - 19.2; CO$_2$ - 7.4; CH$_4$ - 0.02 |
| 3  | 77.2% L3 + 22.8%PE                        | 982                   | $H_2$ - 1.4; $H_2O$ - 2.1; $N_2$ - 11.8; $C$ (c) - 58.2; CO - 18.5; CO$_2$ - 7.6; CH$_4$ - 0.4 |
| 4  | 82% L4 + 18%PE                            | 990                   | $H_2$ - 1.2; $H_2O$ - 1.8; $N_2$ - 11.2; $C$ (c) - 58.4; CO - 19.6; CO$_2$ - 7.4; CH$_2$ - 0.4 |
| 5  | 83.6% L5 + 16.4%PE                        | 993                   | $H_2$ - 1.1; $H_2O$ - 1.5; $N_2$ - 11.8; $C$ (c) - 58.4; CO - 19.6; CO$_2$ - 7.4; CH$_4$ - 0.2 |
| 6  | 90% L6 + 10%PE                            | 999                   | $H_2$ - 1.4; $H_2O$ - 1.9; $N_2$ - 7.7; $C$ (c) - 62.1; CO - 20; CO$_2$ - 6.5; CH$_4$ - 0.4 |
| 7  | 90% L7 + 10%PE                            | 978                   | $H_2$ - 1.3; $H_2O$ - 1.9; $N_2$ - 12.6; $C$ (c) - 61.6; CO - 15.7; CO$_2$ - 6.5; CH$_4$ - 0.4 |
| 8  | 88.4% L8 + 11.6%PE                        | 993                   | $H_2$ - 1.4; $H_2O$ - 1.9; $N_2$ - 9.8; $C$ (c) - 58.5; CO - 20.6; CO$_2$ - 7.5; CH$_4$ - 0.3 |

As follows from the results given in table 2, due to the excess fuel in the CP, a high value of the condensed phase remains for the CP with composition $M_C + M_F + CP$. The condensed phase is represented by carbon in the range of 58-63%.

In accordance with the proposed actions, the supply of oxygen to the incoming air flow is provided. Table 3 shows the results of $M_C$ combustion with combustion products $M_F$ with the added minimum amount of oxygen contributing to the minimum (<5%) residue of the condensed phase.
Table 3. The temperature and composition of the CP, the condensed phase (c) during combustion of the considered $M_C$ with the combustion products $M_F$ allowing for the atmospheric air oxygen.

| №  | Proportions          | $M_F$ (2.5%) | $O_2$ (45%) | $M_C$ (52.5%) | Temperature of CP (K) | The composition of the combustion products (%) |
|----|----------------------|-------------|-------------|--------------|-----------------------|-----------------------------------------------|
| 1  | 90% L1 + 10% PE      |             |             |              | 2601                  | $H_2$ - 0.5; $N_2$ - 5.1; C (c) - 1.8;        |
|    |                      |             |             |              |                       | CO - 88; $C_2$H - 2; $C_4$H - 2.6            |
| 2  | 90% L2 + 10% PE      |             |             |              | 2677                  | $H_2$ - 0.4; $N_2$ - 2.3; C (c) - 1.1;        |
|    |                      |             |             |              |                       | CO - 90.8; $C_2$H - 0.4; $C_4$H - 2.5;       |
|    |                      |             |             |              |                       | $C_6$H - 2.5                                  |
| 3  | 77.2% L3 + 22.8% PE  |             |             |              | 2657                  | $H_2$ - 0.4; $N_2$ - 2.6; C (c) - 1.1;        |
|    |                      |             |             |              |                       | CO - 90.9; $C_2$H - 0.1; $C_4$H - 0.5;       |
|    |                      |             |             |              |                       | $C_6$H - 1.3; $C_8$H - 3.1                    |
| 4  | 82% L4 + 18% PE      | 100%        | 49.5% L1 +  |              | 2662                  | $H_2$ - 0.4; $N_2$ - 2.6; C (c) - 1.1;        |
|    |                      |             | 5.5%PE + 45%|              |                       | CO - 91; $C_2$H - 0.1; $C_4$H - 0.5;         |
|    |                      |             | C           |              |                       | $C_6$H - 1.3; $C_8$H - 2.2                    |
| 5  | 83.6% L5 + 16.4% PE  |             |             |              | 2666                  | $H_2$ - 0.3; $N_2$ - 2.7; C (c) - 1;          |
|    |                      |             |             |              |                       | CO - 91; $C_2$H - 0.1; $C_4$H - 0.4;         |
|    |                      |             |             |              |                       | $C_6$H - 1.3; $C_8$H - 2.2                    |
| 6  | 90% L6 + 10% PE      |             |             |              | 2661                  | $H_2$ - 0.4; $N_2$ - 2.3; C (c) - 1.6;        |
|    |                      |             |             |              |                       | CO - 91; $C_2$H - 0.1; $C_4$H - 0.4;         |
|    |                      |             |             |              |                       | $C_6$H - 1.3; $C_8$H - 2.9                    |
| 7  | 90% L7 + 10% PE      |             |             |              | 2658                  | $H_2$ - 0.4; $N_2$ - 2.7; C (c) - 1.4;        |
|    |                      |             |             |              |                       | CO - 90.5; $C_2$H - 0.1; $C_4$H - 0.4;       |
|    |                      |             |             |              |                       | $C_6$H - 1.3; $C_8$H - 3.2                    |
| 8  | 88.4% L8 + 11.6% PE  |             |             |              | 2660                  | $H_2$ - 0.4; $N_2$ - 2.5; C (c) - 1.2;        |

From the obtained results, it follows that the use of L1 as a binder $M_C$ leads to incomplete combustion of carbon fiber after the combustion of the system $« M_C + CP »$ and the residue of the condensed carbon phase (table 3 to 2%).

Thus, the principal possibility to choose the composition of mixtures: $EM_F, EM_C, B_F, B_C$ providing the carbon fiber ignition temperatures at acceptable values of the condensed phase residue is shown.

5. Discussion
The problem formulation is provided for the development of the combustion system, the main part of which is the conceptual model, is illustrated by the separated parts of LV – PF. The obtained materials properties will be used in the combustible PF development.

As a result of experimental studies on the replacement of the filler EM $M_F$, for selected EM based on a mixture of boron carbide and titanium $B_4C$-4Ti, the combustion rate of the compressed MA samples, as well as the maximum temperature in the combustion wave, were determined. The analysis of the results obtained due to the combustion of the original PF structural model (aluminum honeycomb core and carbon fiber plates) showed that burnout occurs only for the polymeric component of the carbon plates and the aluminum honeycomb destroys partially, with carbon fiber being almost indestructible. Despite the fact that MA EM $B_4C$-4Ti allows implementation of a “gas-free” combustion mode, and it certainly has a positive impact on the combustion process, it does not
lead to complete combustion of the PF structure combustion. Thus, further application of such EM is recognized as unpromising.

As a result of the experiments on the EM $M_F$ replacement and the type of filler structure $S_F$ (Concept II), the most promising compositions based on ammonium perchlorate are identified, allowing a self-sustaining combustion mode to be implemented. To assess the samples combustion under laboratory conditions close to real ones, the study was carried out on an experimental aerodynamic stand, providing the simulation of the altitude and velocity parameters for the PF motion along the atmospheric descent path at a height of up to 2 km. The analysis of the results revealed some features, including the rapid nature of the combustion process (~2.5 g/s), while the intensity of combustion was several times higher compared to combustion without oncoming flow. Also, 98% combustion of the filler produced by EM is recorded, but due to the high combustion rate, as well as the influence of the incoming flow, the heat does not have a proper effect on the carbon fiber plates of the three-layer PF structural model.

Thus, the concept based on the heat transfer from the filler EM combustion to carbon fiber under the external influence of the incoming flow is ineffective due to the following facts: a) there are significant combustion products losses in the incoming flow, b) low thermal conductivity of carbon fiber, c) high combustion rate of the filler EM.

In this regard, it is recommended to move to concepts III and IV, providing for the chemical interaction of the filler and carbon fiber combustion products.

As a result of preliminary theoretical studies on specific examples in the framework of Concepts III and IV, data on possible compositions of filler materials and carbon fiber are obtained. In further studies, it is necessary to select the optimal materials and their compositions in accordance with (12).

6. Conclusion
1. A new class of problems, which studies the burning process in separating structures of the launch vehicle (LV) made from polymer composite material, comprising fillers and carbon fiber, is considered. The consideration is made on the example of the payload fairing after the mission completion.
2. The problem statement of the materials choice is formulated and four concepts of materials properties definition is proposed, the materials being a part of the filler and carbon fiber, on the example of PF made from three-layer polymeric composite material.
3. The PF structural model is introduced into consideration to conduct theoretical and experimental studies for determining the materials properties that make up the filler and carbon fiber.
4. The results of theoretical and experimental studies for the first and second concepts to determine the materials properties that make up the filler and carbon fiber are presented.

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