Exploration of strength characteristics quadrocopter frame structure obtained using 3d printing technology

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Abstract. This article discusses the use of 3D printing technology for manufacturing the frame structure of a quadrocopter. The strength of the plastic frame structure is calculated. The results obtained allow us to draw conclusions about the possibility of using this technology for the production and operation of aircraft of the quadrocopter type.

1. Introduction
The application of 3D printing technology affords ample opportunities for different fields of application; one of such fields implies small aircraft building. The prototyping, printing of units and parts makes it possible to obtain new configurations of devices bringing about the improvement of existing devices.

The quadcopters – the small remote-controlled aircraft have become widespread over the last few years. The quadcopter design includes the following elements - motors, speed controller, propellers, board, sensors (GPS, gyroscopes, etc.), frame [1]. Depending on the applied tasks and required fixturing there are quadcopters with different frame designs (figure 1).

Figure 1. Configurations of quadcopters H, X (cross), hybrid X, quadrate (box).
The principle of quadcopter operation is based on the counter rotation of propellers, owing to this the flight becomes smooth, stabilized, and a vehicle is well-controlled (figure 2).

![Tilt and rotation](image)

![Turning](image)

![Rising and falling](image)

**Figure 2.** Capabilities of changing space attitude of a quadcopter.

Taking into account peculiarities of spatial movement and load created by equipment, the following requirements are produced to the frame structure:

- **ruggedness** – a well-designed frame should be rugged, hold up well in case of accidents. If the bars become bent or warped, the copter will be prone to vibrations and fluctuations. As a result it will be difficult to adjust and calibrate it. The flight controller will also suffer, it will be more difficult for it to stabilize the flight, finally, the motors may become overheated;
- **weight** – reduction of frame weight without decreasing mechanical characteristics of the structure will help carry out further structure improvements and increase the time of aircraft operation;
- **longevity**;
- **robustness**.

Printing of parts using 3D printer helps solve technological tasks and meet the produced requirements to the structure. In particular, for production of parts with preset geometrical parameters, the non-recurrent blanks are cheaper than flow-line production. But in spite of an important advantage of printing an issue of structure strength remains less than fully investigated, in particular, the strength characteristic of aircraft of certain configurations. The strength analysis of quadcopter frame structure for static strength has been conducted in this work.

2. **Investigation methods**

The investigation of strength characteristic of quadcopter frame structure has been carried out in Free Cad software system with the use of finite elements method. A common frame type has been selected as an analytical model – a flat cross with holes for motors and a platform for flight controller and storage battery (figure 3). Frame overall dimensions: distance between opposite motors - 180 mm, dimension – distance between neighboring motors: 127.28 mm. The necessary values pertaining to PLA plastic have been taken from works [2, 3] which are obtained using [4, 5].
PLA plastic (polylactide) has been chosen as the material. The properties are given in table 1.

![Figure 3. Model of quadcopter frame of x-shaped configuration.](image)

![Figure 4. Distributing forces applied vertically to the frame upper planes, simulated gravity force and propelling force of motors.](image)
Table 1. PLA plastic properties.

| Property                          | Value                        |
|----------------------------------|------------------------------|
| Density                          | 1.240 kg·m⁻³                |
| Modulus of elasticity            | 3.640 MPa                    |
| Thermal conductivity factor      | 0.13 W·(m·K)⁻¹              |
| Expansion coefficient            | 41 C⁻¹                       |
| Specific heat capacity           | 1.800 J·(kg·K)⁻¹             |

The forces applied vertically to the frame upper planes have been distributed, gravity force and propelling force of motors have been simulated. The propelling force of one motor should equal 50% of quadcopter weight. This implies that the total propelling force of all four motors should exceed the weight of the copter proper twice. The conventional values of applied forces have been selected taking into account this condition. It stands to mention that the forces simulating weight include the frame weight and the weight of such elements as storage battery, flight controller and motors.

3. Results

Results of static calculation are shown in figure 5 and table 2.

Figure 5. Visual result of static calculation.

Table 2. Calculation results.

|                         | Minimum value | Average value | Maximum value |
|-------------------------|---------------|---------------|---------------|
| Absolute displacement, mm | 10.00         | 16.24         | 26.84         |
| Main stresses (von Mises), MPa | 0.008         | 6.5           | 39.39         |
| Shearing stresses, MPa  | 0.005         | 3.32          | 20.06         |

Comparing the calculation data with the earlier-acquired results of testing samples [2, 3], it is possible to conclude that the printed frame structures can be used in the course of building and developing quadcopters without any loss of the main characteristics of small aircraft.
4. Conclusions

Proceeding from the performed investigation it is possible to make the following findings:

- frame structures made with the use of technology of 3D printing from PLA plastics can be used in building small aircraft (quadcopters);
- values of absolute displacement at the preset design load are admissible (limiting displacement value for frame of x-shaped configuration equals 45 – 50 mm);
- values of design stresses are below the values received experimentally (41.8 MPa) [2].

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