SECTION 4. ELECTRICAL ENGINEERING

4.1 Determination of critical mechanical loads on flexible connection structures as part of a mobile robotic platform

There is a need to improve the commutation system of mobile robotic platforms (MRP) using flexible structures – printed circuit boards and cables [179-180]. Flexible printed structures (FPS) provide several advantages over traditional mounting technologies using bulky wires and printed circuit boards on rigid bases [181]. Due to their use, it is possible to obtain a significant gain in overall dimensions and mass indicators, ensure the dynamic flexibility of electronic modules and, at the same time, increase reliability under constant mechanical influences conditions such as impacts, bends, vibrations, etc [182-184]. The objective of the study is to mechanical strength determine for the experimental samples that can be used as part of the MRP.

In this work, the following types of mechanical loads on the FPS were studied: tension; bends and torsions; cyclic loads; resistance to mechanical wear under the abrasive friction action [185-189].

The parametric model of the mechanical action on tension can be written as follows:

$$D_{ts} =< v_{ts}, F_{ts}, \alpha >,$$

where v_{ts} is impact speed, mm/sec; F_{ts} is impact force, kN; α is axis relative to sample.

The parameter of the mechanical effect on bends and torsions is the bend radius.

The cyclic loads parametric model can be written as:

$$D_{cl} =< f, A, K_{cl} >,$$

where f is load frequency, *Hz*; A is load amplitude, *mm*; K_{cl} is set of parameters characterizing the mechanics of certain load.

To simulate mechanical influences, the COMSOL Multiphysics 4.2 software was used. Using the COMSOL Multiphysics allows to consider coupled or “Multiphysics” phenomena.

To study mechanical loads, a flexible cable model was developed (Fig. 1). Foiled polyimide was chosen as the main material. Material characteristics and impact parameters were added to the model (Fig. 2).

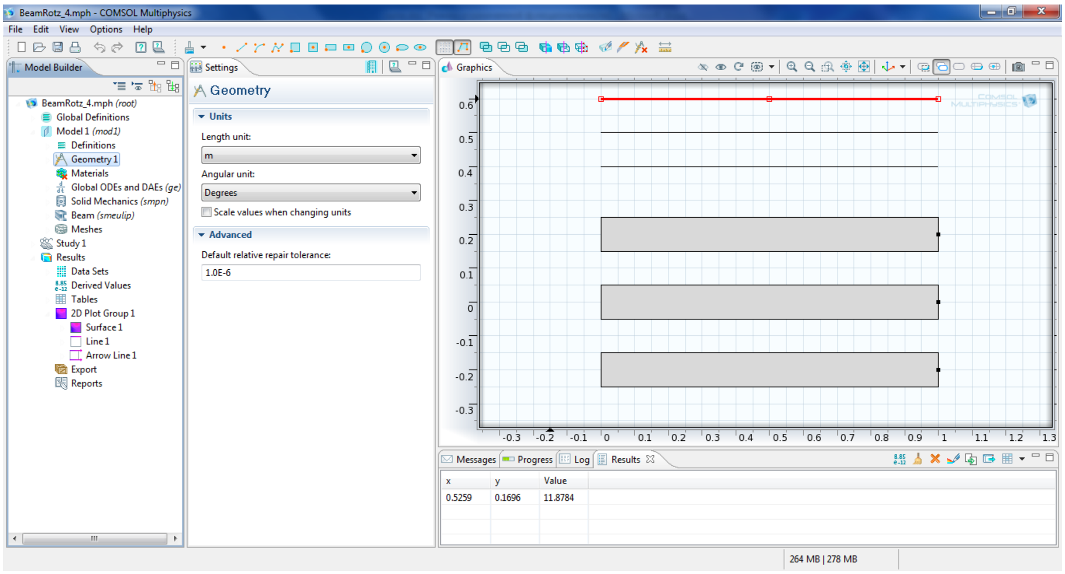

Figure 1. Development of a FPS geometric model.

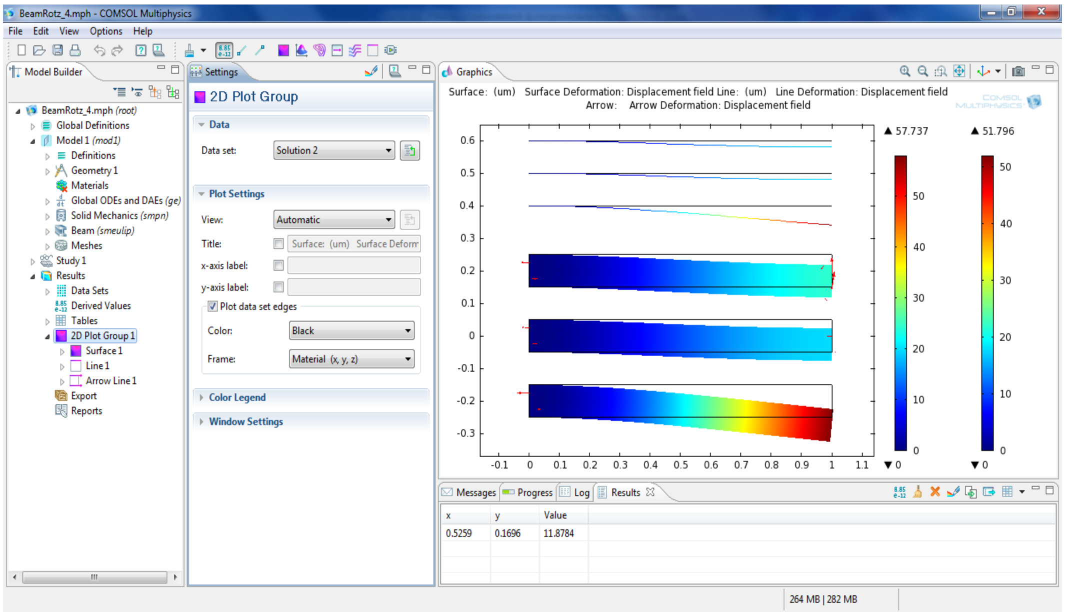

Figure 2. Simulation of the one cable end curvature.

The result of simulation the mechanical action on the curvature with a force of 15 *N* is shown in Fig. 3.

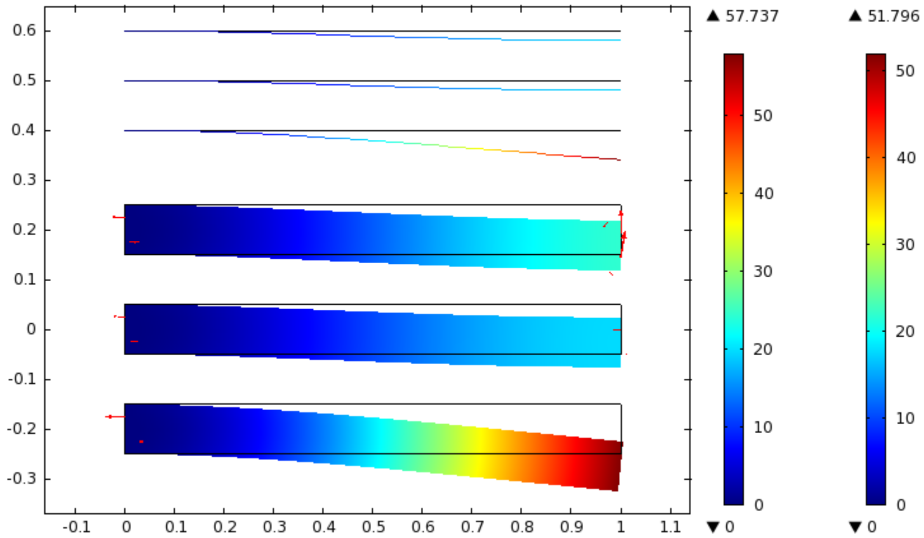

Figure 3. The result of simulation the curvature force of a flexible cable.

Similarly, a mechanical load simulation with a force of 4 *N* acting perpendicular to the flexible structure was carried out (Fig. 4).

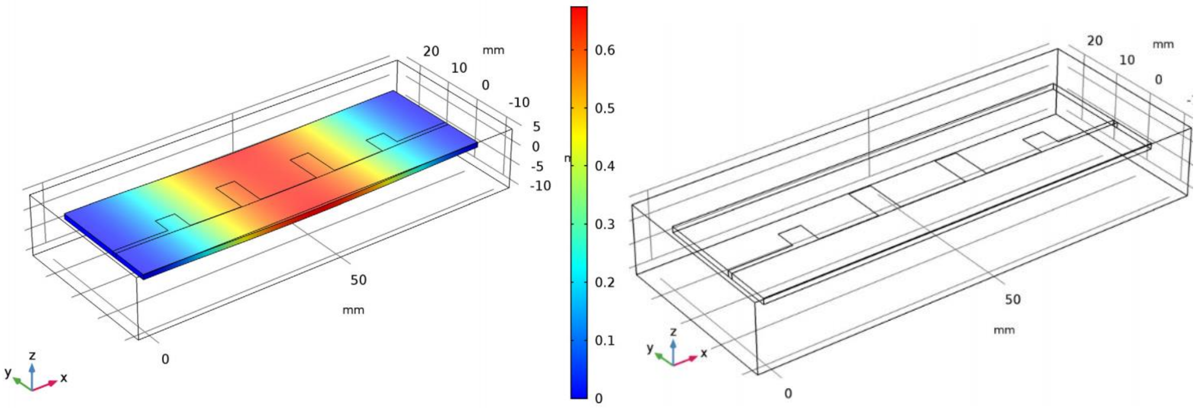

Figure 4. The result of mechanical load simulation perpendicular to the FPS.

Also, using a special package of this program, a simulation of the vibration impact on a flexible cable was performed (Fig. 5). For a more loads visual distribution on the base material, slots were made in it perpendicular to the longitudinal axis.

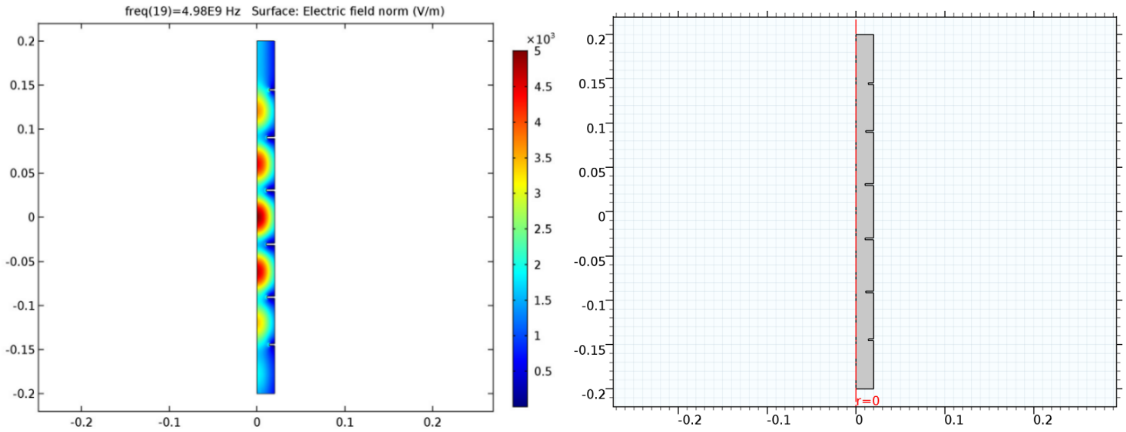

Figure 5. Vibration simulation result.

A classical bend simulation under the force action of 10 *N*, acting perpendicular to the FPS, was also carried out (Fig. 6).

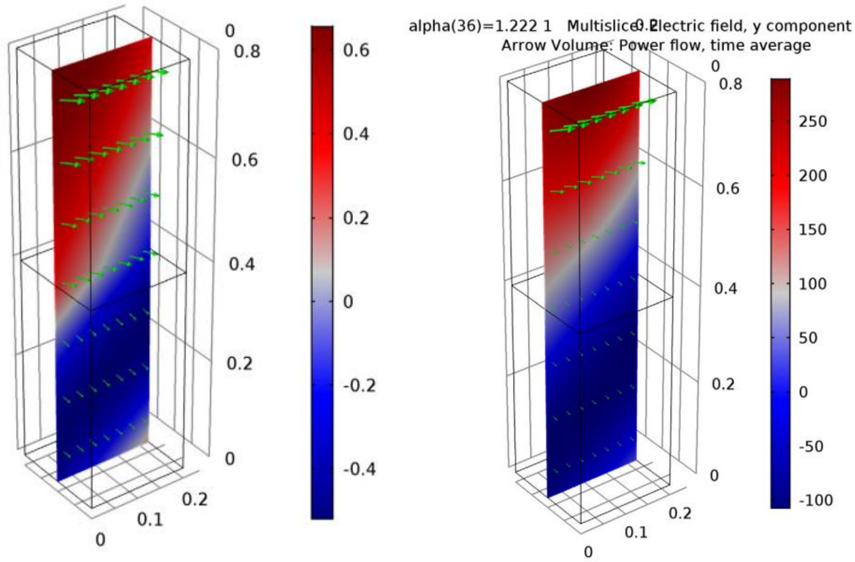

Figure 6. A perpendicular bend simulation result to the FPS.

Also, shift tests of FPS with a complex design were carried out, as well as a simulation of the mechanical load on the conductor layer elements of the cable, which constructively rotates in a plane (Fig. 7).

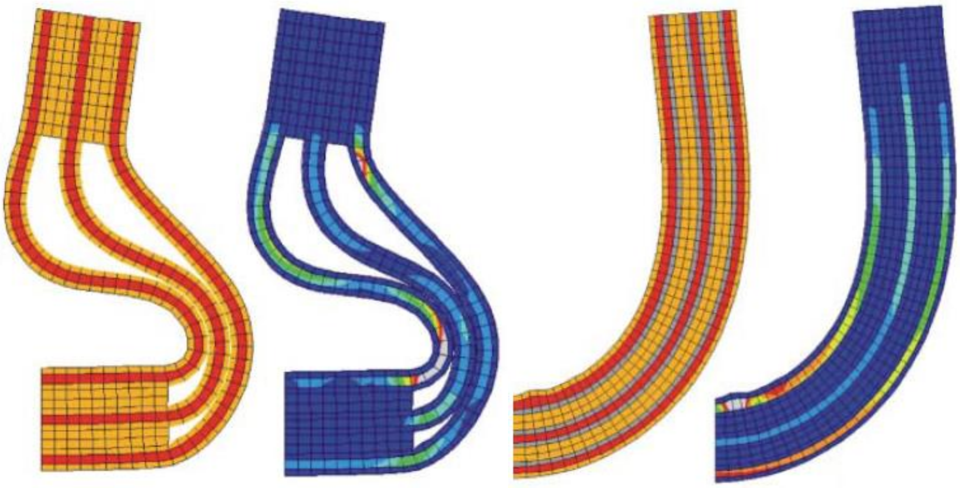

Figure 7. Simulation results.

For an experimental study of the destructive force on the break effect, several types of FPS test samples were selected (Fig. 8). In Fig. 8, the upper and lower samples are made of polyimide, and the test sample in the middle has a black colored polyether base.

Figure 8. FPS test samples.

To perform the experiment, a universal tensile testing machine UIT STM 010 (Fig. 9) was used along with the SmartTension software.

Initially, a sample based on polyimide with copper conductors was chosen for the experiment. The experiment speed of 5 mm/min was chosen. The break of the sample occurred when loading is 130 kgf and after elongation by 14 mm.

In Fig. 10 a graph of the break is shown, and in Fig. 11there is the flexible cable state at the break point.

Figure 9. Universal tensile machine UIT STM 010.

A second experiment was also carried out with a test sample based on polyether with aluminum conductors. The tensioning speed was also 5 mm/min. For this sample, the maximum load was 160 kgf, and the elongation was about 40 mm. In Fig. 12 there is a graph of the break, and in Fig. 13 the FPS state at the break point is shown.

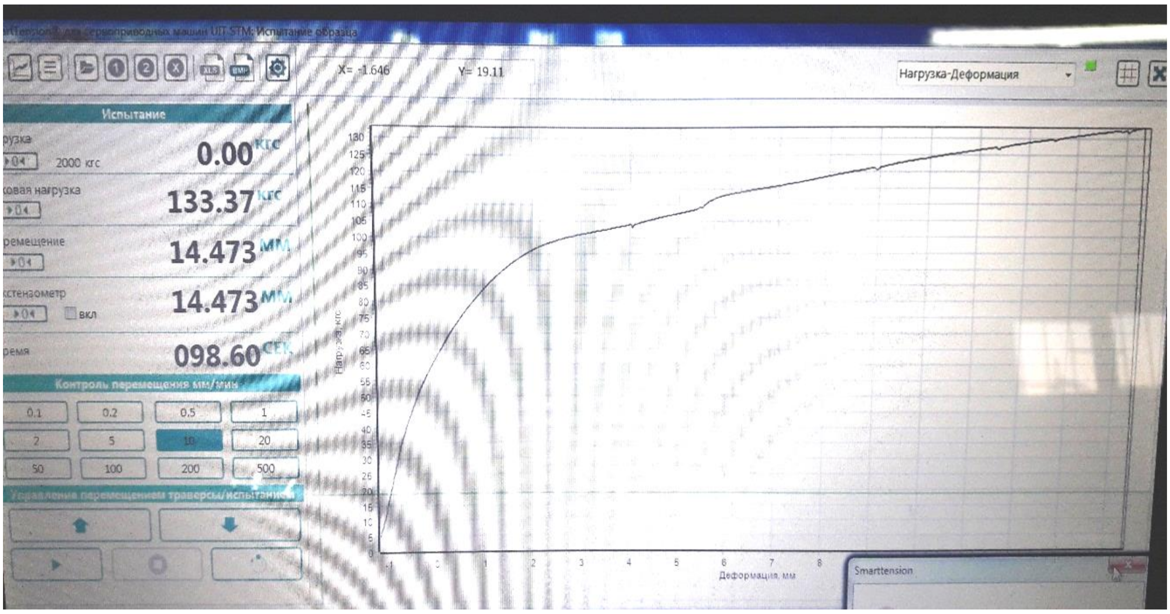

Figure 10. Breakout plot for polyimide sample with copper conductors.

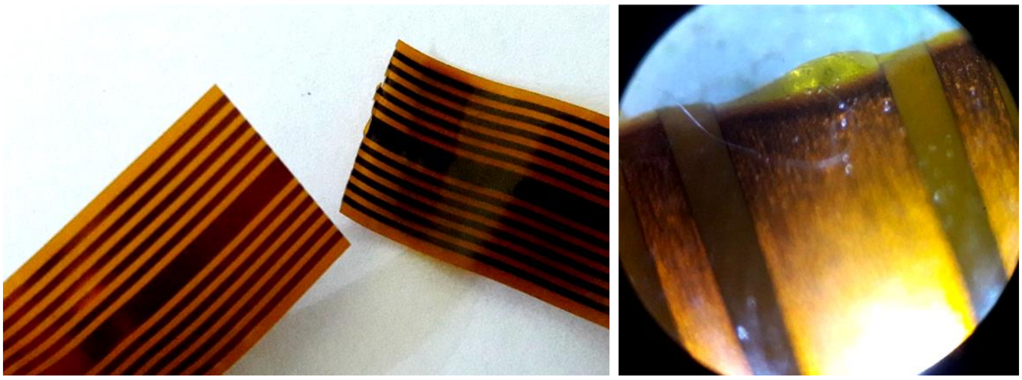

Figure 11. Flexible cable based on polyimide with copper conductors at the break point.

After analyzing the graphs of copper and aluminum break (Fig. 14), we can conclude the graphs similarity with component FPS.

Therefore, based on the experiments results, the following conclusions can be formulated:

– in the case of a polyimide-based cable with copper conductors, the base was stretched more than the conductor layer;

– in the case of a polyether-based cable with aluminum conductors, it turned out to be less plastic than the conductor layer;

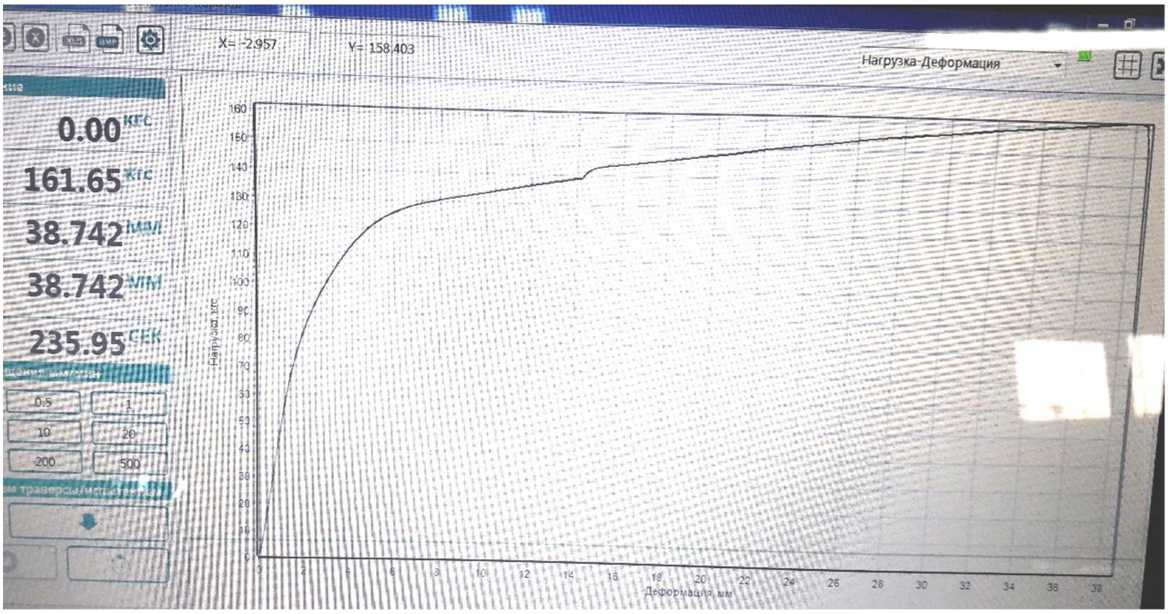

Figure 12. Breakout plot of polyether-based sample with aluminum conductors.

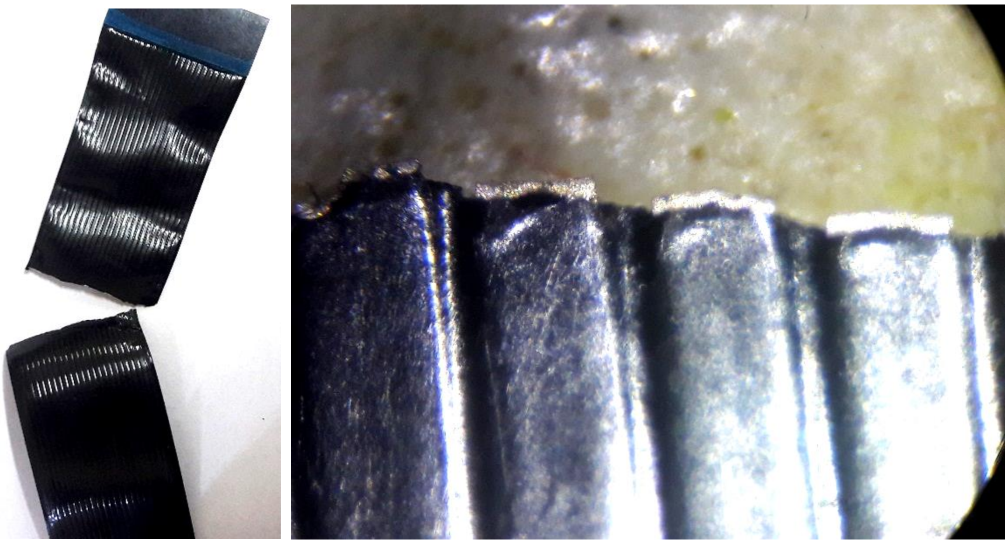

Figure 13. Flexible polyether-based cable with aluminum conductors at the break point.

– thus critical mechanical loads on flexible connection structures as part of a mobile robotic platform were determined. Considering the obtained results, namely the proportional sections of the breaks graphs, we can conclude that the first test sample can withstand non-critical loads up to 40 kgf, and the second – up to 80 kgf.

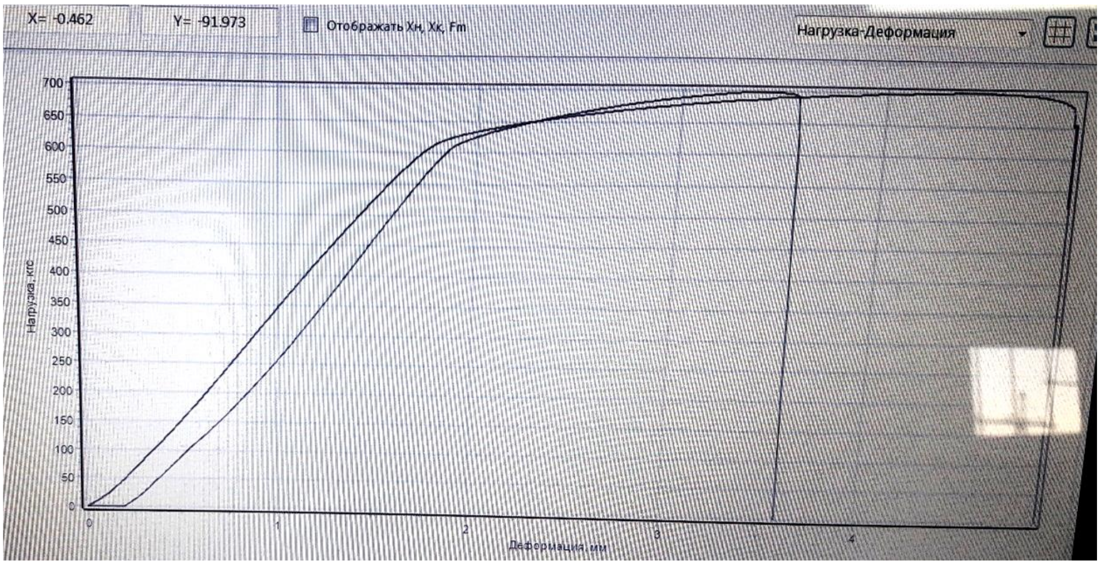

Figure 14. Copper and aluminum break graphs.