

Microlinear piezo drive experiments

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Abstract. The article embraces the experimental description of the micro linear piezo drive intended for the peripheral cord tensioner in the reflecting surface shape regulator system for large-sized transformable spacecraft antenna reflectors. The research target is the experimental investigation of the micro linear piezo drive to determine the stable oscillatory system operating modes which would include improved energy conversion parameters. The following points are briefly presented: test stand construction-design of the peripheral cord tensioner; the determined frequency characteristics and the identified resonant and actual frequencies of an oscillatory system under inertia load. A series of experiments has been conducted for both different preliminary voltages and inertia mass values.

1. Introduction

The problem involving the reduction of spacecraft (SC) system mass-dimension parameters is especially acute in the space field. One current solution is to replace electro-mechanical drives in different SC units for piezo drives which, in its turn, would decrease the mass-dimension parameters n -fold times [1–4]. The peripheral cord tensioner unit (PCTU), a system regulating the reflecting surface shape for large-sized transformable spacecraft antenna reflectors, provides the preliminary tension of the spacecraft reflector surface itself. The peripheral cord tension is $F_{tens} = 300$ N, the unit mass – 250 g, the total reflector spoke mass – 40 kg and the pushrod displacement with an increment of $X_{tens} = 12$ μ m.

2. Problem statement

The problem targets involve the following: conducting micro linear piezo drive experiments based on PZT Stack APM-2-7 in inertia load modes under different inertia load values; identifying the characteristic oscillatory system frequencies; and determining oscillatory system (OS) resonant frequencies and vibration displacement amplitudes within resonant frequencies.

3. Test stand construction-design description of the peripheral cord tensioner

The oscillatory system of the test stand was calculated on the basis of 3D and one-dimension mathematical models [5, 6]. This test stand is designed to investigate the micro linear piezo drive (MLPD) operation modes (figure 1). Micro linear piezo drive (MLPD) operation modes depend on the following OS parameters: the type and the power of PZT Stack; the weight (loads) mass; preliminary stack voltage forces; voltage on PZT Stack; PZT Stack current; the frequency effect [7–10]. Operation mode parameters are recorded as electrical signals in the experiment testing of MLPD:



voltage on PZT Stack; PZT Stack current; signal strength from the PZT Stack sensing unit; vibration acceleration weight (loads). Another important parameter to be considered is preliminary tension force.

The following data were obtained during the MLPD experiment:

- weight (loads) frequency responses;
- weight vibration displacement frequency responses;
- frequency responses of forces acting on weight.

Based on the results of these frequency responses, the operating OS resonant frequencies and vibration displacement amplitudes were determined.

Varying the OS parameters and frequency exposure on the test stand, numerous system operation modes were investigated. Based on the test results, the optimal frequency exposure to given load was determined, at which the maximum forces acting on loads, maximum vibration displacement load and maximum power acting on loads were observed.

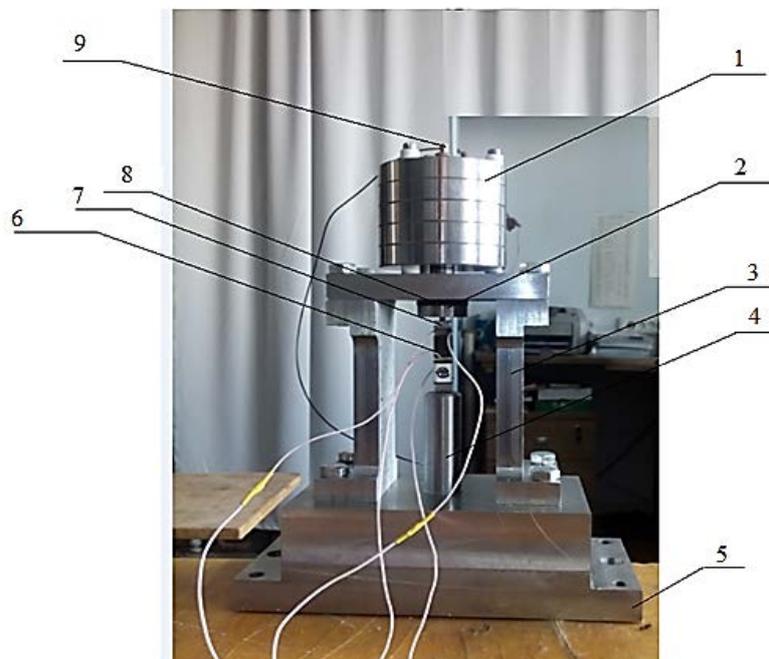


Figure 1. The test stand, operating MLPD under the inertia load: 1 – inertia load mass (weight); 2 – pushrod; 3 – support structures; 4 – adjustment screw; 5 – frame; 6 – PZT Stack APM- 2-7; 7 – force sensor; 8 – rigidity; 9 – accelerometer AR 1019.

Figure 1 illustrates the test stand. PZT Stack (6) is installed in frame (5) on adjustment screw (4), through which force sensor (7) rests upon pushrod (2), then pushrod (2) through rigidity (8) acts on inertia load (1) (weight). Accelerating inertia load (1) is measured by accelerometer (9). Through adjustment screw (4), the preliminary PZT Stack tension force is established. Force sensor PZT Stack calibration, accelerometer calibration and the preliminary tension setting procedure require a more detailed description which is impossible to include in the present paper.

The detailed diagram of the test stand is illustrated in figure 2, where minor details are included – energy cheeks and the MLPD oscillator, as well as the power source (alternating current 12 and direct current 13), data acquisition and storage system 11.

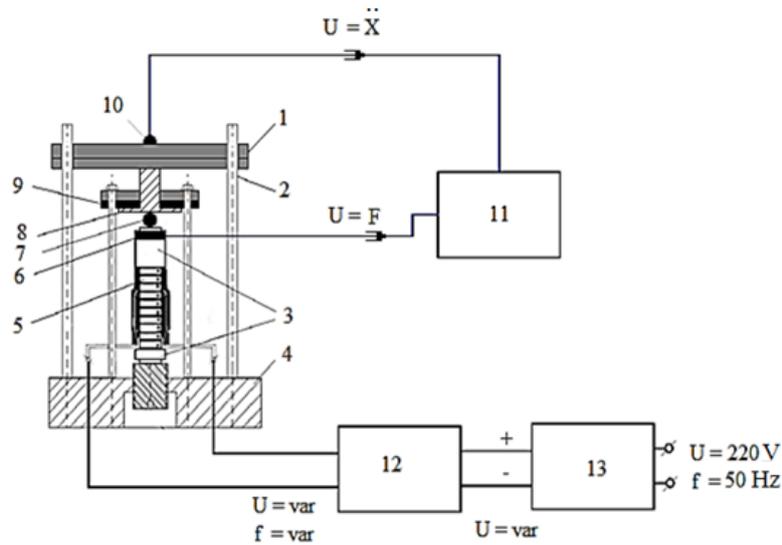


Figure 2. The layout diagram of the experimental test stand for prototype MLPD: 1 – inertia mass load (weight); 2 – guiding weight; 3 – energy cheeks; 4 – frame; 5 – PZT Stack; 6 – force sensor; 7 – oscillator; 8 – pushrod; 9 – preliminary tension rigidity; 10 – accelerometer; 11 – data acquisition and storage system; 12 – AC power source; 13 – DC power source.

4. Experiment results

Varying the AC frequencies input to PZT Stack, the PZT Stack generates the disturbance force, which, in its turn, through the oscillator-pushrod acts on the inertia load imposing vibration at a given frequency. Oscillograms are presented in figure 3 a, b. Measuring the inertia load acceleration, the vibration displacement acceleration is determined. Based on the experiment results, frequency-response characteristics are plotted. PZT Stack current was maintained at 0.5 A, whereas the power supply decreased proportionally to PZT Stack capacitance. Parameters for the 1st operation mode (figure 3a): $f = 10.7 \text{ kHz}$, $I = 0.5 \text{ A}$; preliminary tension force $F_0 = 240 \text{ H}$; force sensor signal $F_f = 2.82 \text{ H}$, $\ddot{X} = 57 \text{ m/s}^2$; weight force $G_{wf} = 0.4 \text{ kg}$; $X = 0.012 \text{ }\mu\text{m}$. Parameters for the 2nd operation mode (figure 3b): $f = 1400 \text{ H}$, $I = 0.5 \text{ A}$; preliminary tension force $F_0 = 240 \text{ H}$, $F_f = 2.82 \text{ H}$, $\ddot{X} = 57.4 \text{ m/s}^2$; weight force $G_{wf} = 3 \text{ kg}$, $X = 0.742 \text{ }\mu\text{m}$.

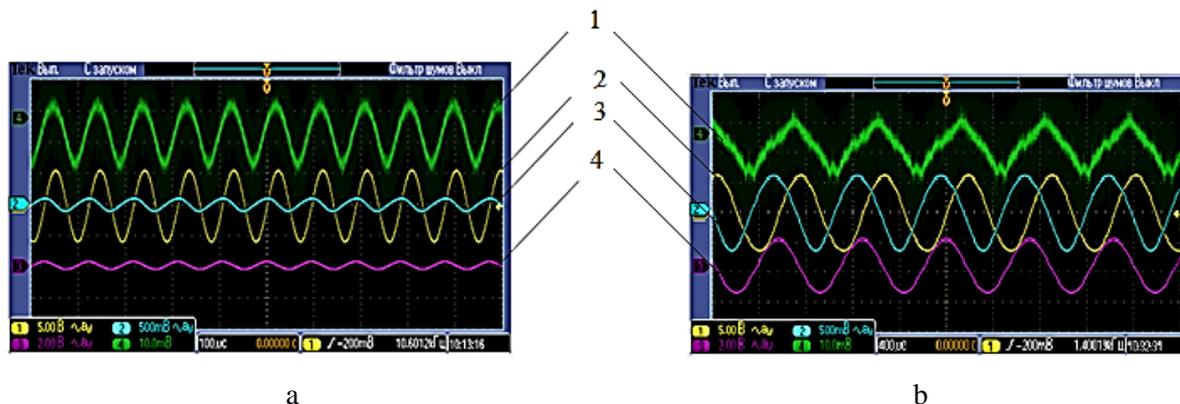


Figure 3. Signal distribution from the oscillatory system transducer to the electron oscillograph screen: a – 1st operation mode; b – 2nd operation mode. 1 – acceleration; 2 – PZT Stack current; 3 – PZT Stack force; 4 – PZT Stack voltage.

MLPD frequency-response characteristics without preliminary tension and mass load of 0.5 kg are illustrated in figure 4. These characteristics have four distinct resonances. This effect could be based on the fact that separate PZT Stack elements in SC resonate differently and the system does not have a unified operation mode. The most energetic SC mode is at the frequency of 750 Hz (at current $I = 0.5$ A and load mass $G_{wf} = 0.5$ kg). It is within the range of this frequency that the vibration displacement and forces acting on the load are more significant (figure 4). In the specific frequency points, the vibration displacement has the following values: 1 – 29 μm , 2 – 9.32 μm , 3 – 0.735 μm , 4 – 0.002 μm , 5 – 0.0013 μm , 6 – 0.0013 μm .

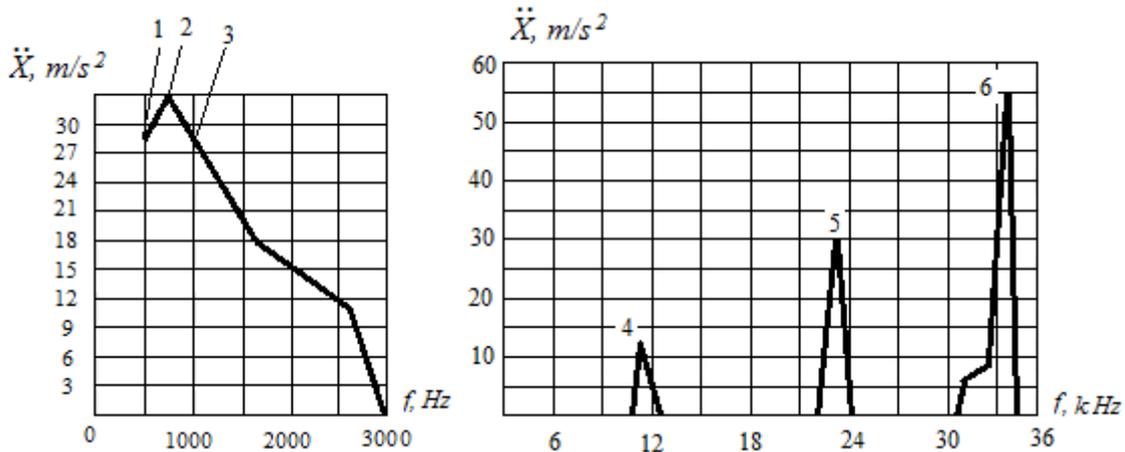


Figure 4. Frequency characteristics of MLPD vibration acceleration, operating under inertia load without preliminary tension

Increasing inertia load further decreases resonant frequency and increases vibration displacement (figure 5), at current $I = 0.5$ A and preliminary tension $F_0 = 240$ N.

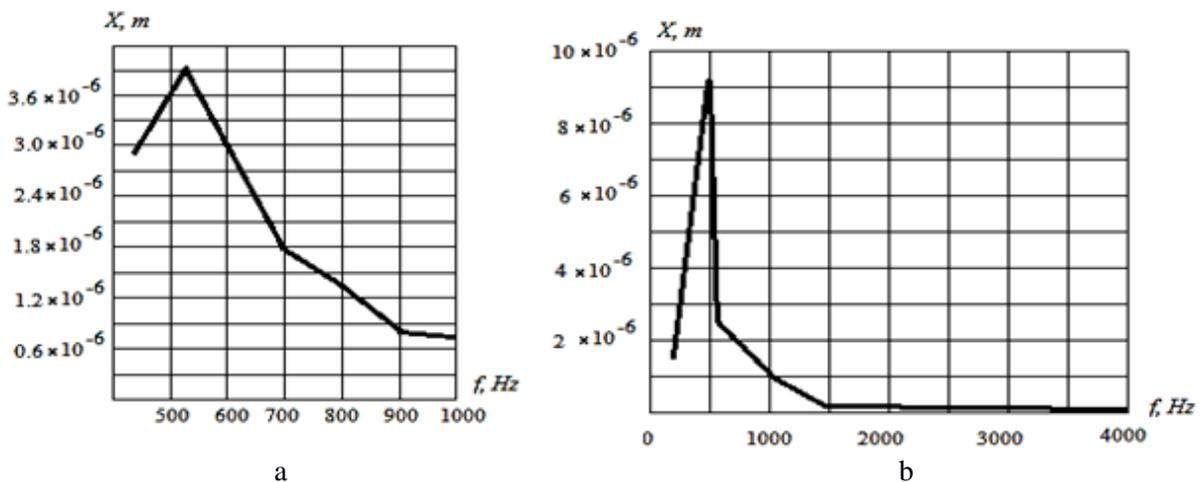


Figure 5. Frequency-response characteristics of operating MLPD at different inertia loads and preliminary tension: a – mass load $G_{wf} = 0.4$ kg; b – mass weight $G_{wf} = 0.5$ kg.

If inertia mass is 3 kg, the resonant frequency is 300 Hz, load force — $F_0 = 550$ N (figure 6, curve 2) and vibration displacement — 12 μm (figure 7, curve 1). Experimental resonant frequency characteristics and vibration displacement amplitudes depending on inertia mass weight values are illustrated in figure 7 a, b.

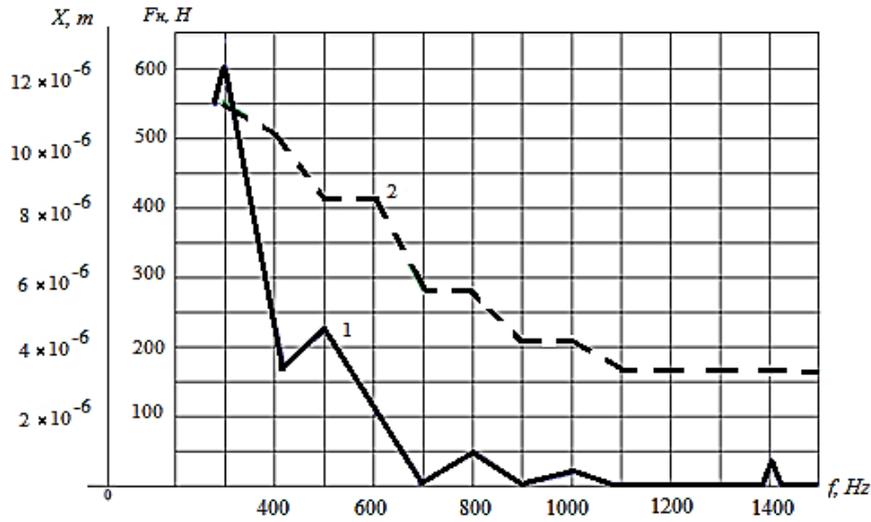


Figure 6. Experimental frequency characteristics of vibration displacement load and forces acting on load of operating MLPD: $I = 0.5$ A and $G_{wf} = 3$ kg. Preliminary voltage $F_0 = 240$ N. Frequency effect interval – 100 Hz

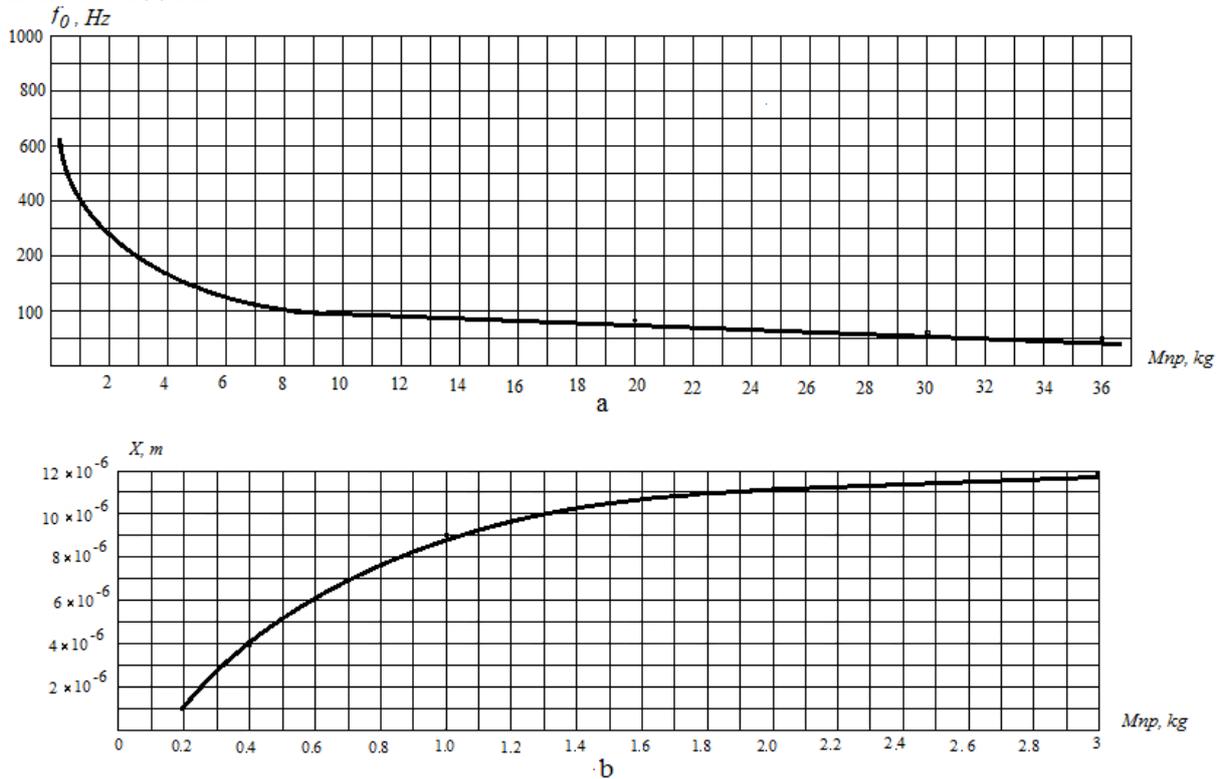


Figure 7. Experimental dependence: a – dependence of operating MLPD resonant on mass weight; b – dependence of weight vibration displacement of operating MLPD resonant on mass weight. Mass weight – up to 3 kg.

The basic MLPD operating frequency interval will be 50 – 100 Hz for a SC with the corresponding peripheral cord tensioner unit (PCTU) load parameters, as this is the most energetic operating interval

of this frequency system. In this case, the excitation force on the load itself would be more than 550 Hz, the vibration displacement interval – more than 12 μm .

5. Conclusion

1. The experiment showed that the test stand is designed as a spacecraft (SC) involving only inertia load, however, the operating SC modes are quite similar to the operating modes with combined loads. SC resonant frequencies decrease with the increase of the inertia mass (typical for inertia load), while vibration displacement amplitudes increase with the decrease of the inertia load, which indicates the fact that the elastic component exists in the SC, i.e. preliminary tension elasticity, elasticity of stand supporting legs, PZT Stack elasticity which, in its turn, is characteristic of combined load.

2. The basic MLPD operating frequency interval will be 50–100 Hz for a SC with the corresponding peripheral cord tensioner unit (PCTU) load parameters, the vibration displacement interval of more than 12 μm .

3. Experimental data are in good agreement with the numerical experiment results on 3D and one-dimension mathematical models. In case SC has inertia load and is a resonant system, according to calculation results, it is possible to match the MLPD design to desired operating frequency resonant intervals.

4. The analysis of experimental data and numerical experiments showed that designed MLPD specifications could meet the requirements applicable to the peripheral cord tensioner unit in the reflecting surface shape regulator system for large-sized transformable spacecraft antenna reflectors.

Acknowledgments

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