THE DYNAMIC EFFECTS AND SHOCKS IN ELECTRONICS

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ABSTRACT - The paper describes the methods and means of measurement and study of vibrations, stresses and shocks affecting electronic equipment during its use and in the testing stage as well as original units to determine shapes and frequencies of vibrations of functional boards. Particular attention has been given to the development of methods and means to protect structures against vibrations and shocks.

1. INTRODUCTION

The tendency to reduction of products and systems weight and dimensions at the expense of high density of assembling and application of new materials existing in electronic engineering leads to appearance of not-hard constructions, for which the strength problem connected with the availability of dangerous resonance states within the operating frequencies zone is highly urgent.

Frequently, these systems are installed on mobile objects such as: helicopters, planes, ships, automobile and caterpillar machinery, rockets, satellites, etc. - and they operate, as a rule, under the influence of group of complex destabilizing factors. Vibration and impact loads, acoustic influences, road bumping, unbalancing of quick - rotating details, impact wave sharp blasts of wind, quick turbulent flows, etc. refer to the most dangerous of these factors.

Tentative meanings of vibrations parameters we and other authors received at statistic generalization of experimental data for some types of mechanic forces, are given in table 1.

Table 1 Vibration Parameters Influencing the Electronic Equipment, Installed or (and) Transported on the Mobile Objects.

The type of means of transportation	Excitating oscillation frequencies up to [Hz]	Acceleration, up to [g]	Amplitude up to, {mm}	
			Low frequencies	high frequencies
Automobile wheel Machinery	3...100	5	150	80
Transportations Means of Caterpillar Type	400...1000	-	0,25	-
Ships	2...50	o,4...2	10	0,2
Planes, Helicopters	3...1000	0,2...20	3	0,02
Railroad Transport	2...100	1,5...2	25	0,05
Rockets	30...1000	5-70	Acoustic 130db	vibrations

Active loads can lead to separate electronics details and joints (resistors, capacitors, board plane micromodules and other details) destruction either to the changing of parameters of electronic elements and joints (out-balancing of contours, microphone effect and etc.), that leads to the reduction of the equipment functioning accuracy and to the interference in the data transmission channels or to the products refuses.

For example, radar and scanning antenna can have reflector deviations owing to the vibrations of drive elements and clearances in connections, as a result the intermittent antenna decorations from its normal position and the irradiator and reflector oscillations can appear, that might cause complete station perturbance.

The mechanic forces exercise the significant influence on electronics products strength and reliability and cause from 30 to 50% and in aviation up to 80% of all refuses, and worsen accuracy and other equipment parameters. Incidentally the whole product reliability, its steadibility of functioning is determined, in many respects, by its components reliability. It should be taken into consideration, that the number of elements in electronic equipment for every 5 years increases in 2...5 times.

The intensity of vibration and impact influences increases together with growth of mobile objects speeds. If to add to it the wide employment of new materials with mechanic properties not enough investigated, so it'll be clear why such an abundance of refuses out of external forces occurs.

The consequences of such refuses happen to be too expensive. So, for instance, the destruction of one of the resistors 5 dollars worth caused the destruction of the rocket more than 10 million dollars worth.

Fig. 1 shows the diagram of distribution of electronic elements refuses, and table 2 generalizes information about the refuses out of mechanic damage of one of micromodules.

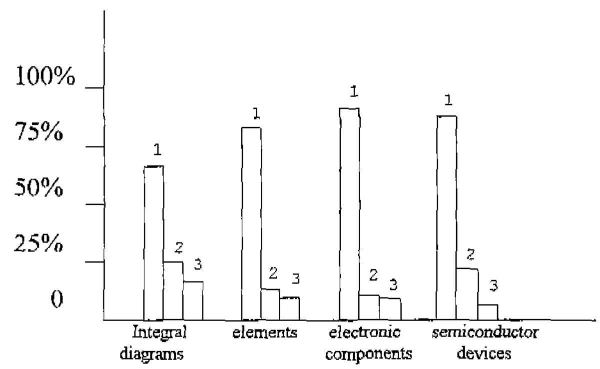

Figure 1 Distribution of refuses according to their types at the tests on mechanic influences:

1 - mechanic damage;
2 - electric parameters passing;
3 - perturbance.

Table 2 Failures by Consumers have, Caused by Mechanic Damage of Micromodule.

Causes of Failures	1974	1975	1976	1978	1979	1980	1981
Mechanic Damage	301	314	492	583	596	521	332
Resistors Cracks of OMLT-0,125, OCMLL-0,25, C2-23-0,06 type	22	12	11	308	82	65	61
Metallization of capacitor contact platforms	40	10	1	36	47	3	13
Inductivity Breaking off	17	10	14	19	21	18	8
Diode Flask Chipping off	15	10	3	55	32	17	9

In the process of such equipment designing the necessity of dynamic calculation with the aim of determination of the constructions safety factors appears as well as resonance frequencies calculations and amplification coefficients on them, calculations of loads having an effect on elements and joints of electronic equipment. Such problems refer to the three - dimensional, non-statitonary basic problems of the elasticity theory and their solutions are rather complicated.

Polymer materials applied in electronic are not enough investigated, and selection of their composition is often made on the basis of empirical data. Data on physic-mechanic characteristics received from different references of the same polymer materials have essential difference. The real difference of such important strength characteristics as: strength limit, flow limit, modulus of elasticity reaches 500%.

Methods and means of investigation of static and dynamic strength existing in general machine engineering, frequently, cannot be transferred into electronics as they introduce essential changing into mass and rigidity of investigated products.

That's why working out of experimental and calculating methods and means of investigation of electronic products dynamic strength is of great importance at the stage of their designing as well as at the stage of their manufacturing operation and employment.

Lots of electronics products are subjected to impact influences. Acceleration developed at the impact can reach big meanings (thousands of «g»), that's why the construction elements of electronic machinery at the impact happen to be overloaded and the dent or crack appears at the place of impact

However, if the mounting or undercarriage is sufficiently rigid, the impact is entirely transferred on electronic elements.

Usually elements of constructions with console fixings undergo this destructive influence. The elements located under the high mechanic tension are also subjected to the impact influence, for instance, cables, resistors, capacitors, inductivity outputs, etc., which happen to be broken off under the impact influence.

2. THE DEPENDENCE BETWEEN THE GIVEN VIBRATIONS IN THE FIXING PLACES OF ELECTRONIC PRODUCTS BODIES AND VIBRATIONS OF THE DETAILS AND JOINTS INSTALLED IN THEM

Owing to complexity of oscillations phenomenon of electronic products, it'll be reasonable to note, that the vibrations control carried out by vibrotransmitters installed on a vibrostand or on a products body cannot characterize completely the dynamic process existing inside the product.

That's why, it's necessary to know, for preventing of all harmful phenomena of vibrations, about the dependence between oscillations given to the product and oscillations of boards and other details located inside. Let's show, that oscillation of vibrostand table, appliances for products fixing, product body itself don't characterize either boards motion even in simple cases or vibration state of other details and joints of electronic products.

Suppose we have a product, body of which has mass (m), fixed firmly for example, on a vibrostand, giving vibrations with excitating force Q-sinωt (fig.2).

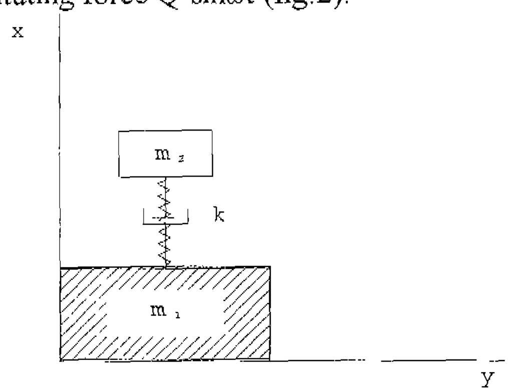

Figure 2 Calculating scheme

Let's see the oscillations of the body foundation and of board «m_2» attached to it with rigidity «k».

Differential equations determining the motion of the given system are:

$$m_1 \ddot{x}_1 + k(x_1 - x_2) = Q\sin\omega t$$

$$m_2 \ddot{x}_2 + k(x_2 - x_1) = 0$$

where x_1 - is a vertical transference of mass m_1; x_2 - of mass m_2;

Mack up the

Let $x_1 = X_1 \sin\omega t$

$x_2 = X_2 \sin\omega t$

Them

$$X_1(-m_1\omega^2+k)+X_2(-k)=Q;$$
$$X_1(-k)+X_2(-m_2\omega^2+k)=Q,$$

from it

$$X_1 = \frac{Q(k - m_2\omega^2)}{m_1m_2\omega^4 - k(m_1 + m_2)\omega^2};$$
$$X_2 = \frac{Qk}{m_1m_2\omega^4 - k(m_1 + m_2)\omega^2};$$

$$\frac{X_1}{X_2} = 1 - \frac{m_2}{k}\omega^2 = 1 - \frac{\omega^2}{\omega_0^2},$$

where $\omega_0^2=\frac{k}{m_2}$ - is a quadrate of oscillation frequency of systems with mass m_2 at rigidity «k».

Hence we see, that body and board oscillations (of board and point-to-point wiring parts) may differ from each other and be in phase as well as in antiphase. Thus, the body oscillations don't characterize the oscillations of board and other details.

The conducted experimental tests of series of electronic products confirm the conclusion given above.

In connection with that there are tasks of not only correct designing of the electronic products constructions themselves but also of correct organization and conducting vibrations and impact tests. Frequently, these tests are conducted without consideration of transmitting appliances resonance states and possible resonances of tested constructions, on account of that the products breakage and refuses occur in the testing process.

It's very difficult even impossible sometimes to design the appliance transmitting vibrations from the vibrostand to the tested block without distortion within wide frequency range.

By the way, that's perfectly possible, that the appliances for vibration tests of products must not have resonances within the frequency range on which the tests are being conducted. If it's impossible for constructive reasons, then the connection between vibrations given to the vibrostand by vibrations and vibrations on the whole appliance volume of appliance must be arranged, to organize correctly the testing process itself on this basis, and not to allow overstationing or understationing of vibrations inside the tested products.

We have worked out the construction of «without resonance» appliance for the functional boards fixing, which consists of a casting cube of aluminum alloy, the rib length of which is 100 mm, and 2...3 layers of sheet material of thickness δ = 2 mm riveted on the edges, between which the mastic layer of type УТ-32 or LN is packed.

Such construction allows to fix tested products at once at three planes and simultaneously to test up to 5 products. Resonance frequency f_p of the appliance in kH_z is determined by formula:

$$f_p = \frac{800}{\lambda},$$

where λ- is the rib cub length, mm.

Such appliance has been made and, as the conducted tests showed, it doesn't have resonances and vibrooverloads on its area are constant within frequency range of 10...5000 H_z.

The construction appliance for tested products fixing with resonance oscillation frequency $\geq$ 10 kH_z also has been worked out (fig. 3). It consists of octagon foundation assembled out of few sheet materials layers of approximately 2 mm thickness between which the mastic layer of OT-32 or LN type is packed. The sheet are riveted in few series. The second element of appliance of the layer structure either is fixed to the foundation by T-pattern.

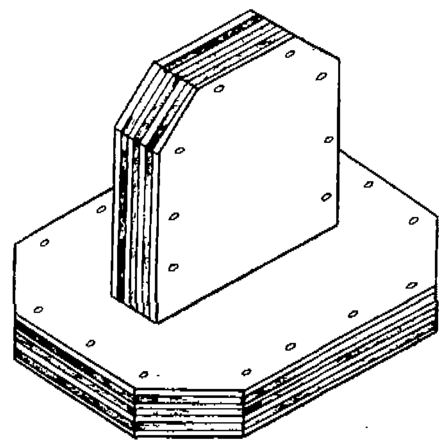

Figure 3 Construction appliance

If it's necessary to test large-dimensions products, the appliance should be made in the state of square plate, the side length of which is determined by number and dimensions of tested products.

If plate fixing is being carried out in 4 points so its thickness must be determined according to the formula:

$$d = \frac{a^2 \cdot f_p}{4500},$$

where f_p - is plate resonance frequency, kHz.

a - is the square side.

For general case the methods of conducting the certification of the appliances for conducting vibration and impact tests have been worked out and they provide, specifically, the choice of «control points» at which the testing regime will be given as well as the determination of common center of gravity of product and appliance, fixing condition of the appliance to the stand and the product to the appliance and other sides which provide the given overloads level at the places of the product fixing.

In a number of cases, especially for large dimensions objects, it would be reasonable, to refuse to use vibrostands and to conduct the tests by means of products exciting by eccentrical vibrator, magnetostritors, small dimensions vibroplant which are arranged near the products and influence them through rods.

Owing to small dimensions and weights of microschemes, relay modules, lamps and other electronics products, the vibrotransmitters assembling similar in weight with other tested products is unacceptable and because of that the use of non-contact capacious and inductive transmitters as well as laser systems having besides higher measuring accuracy is advisable.

In a brief report it's impossible to describe in details these works. That's why we're going to dwell upon the protection of electronic engineering products and their elements for impacts and vibrations.

3. VIBRATION DAMPING

As it is known, vibration isolation of electronic equipment is the most effective of struggle against vibrations and shocks.

There exists a multitude of methods of vibration isolation of radio electronic products, but the conducted studies showed that it was impossible to achieve the requires vibration protection and to avoid resonances in the components of the structure of electronic equipment by only one method. Effective vibration protection can be attained only by a complex of methods in which vibration damping plays one of the main roles.

As a result of the conducted studies, a method of attaching of wiring boards which ensures vibration isolation in a wide range of exciting frequencies was found.

To do this, the rigid joint of printed circuit boards with the body of a electronic product was replaced with an absolutely flexible one - a fabric tape, a dry-friction damper being used to dissipate the vibrations.

In such a structure (Fig. 4) functional board 1 is connected with insert 3 by means of fabric tape 4. The inserts enter the T-shaped guides at the point of installation in the unit. Damping is performed by bronze springs 2.

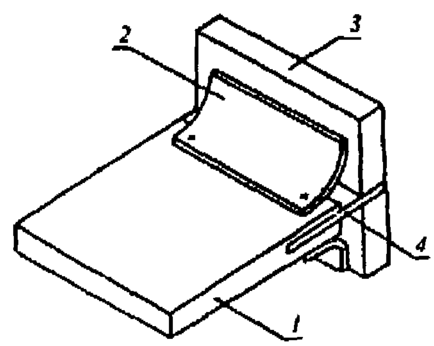

Figure 4 Wiring board on fabric suspension with dry-friction damper

Owing to the flexibility of the tape, the board vibrates in a narrow range of frequencies as a rigid body - without bending strains.

As a result, the wiring components are not subjected to the effect of mechanical factors (tension, bending, shearing), and amplitudes of accelerations are considerably decreased. It is evident that the problem of heat removal, reparability, specific consumption of materials are absent.

The comparative results of the studies of the functional boards in case of various methods of their attaching confirmed high efficiency of the fabric suspension using a dry-friction damper where the dynamic coefficient had not exceeded 1.8 at a resonance.

In other cases, to essentially decrease vibrations of the bodies of the electronic products as well as functional boards with components mounted on them, a seismic suspension of the whole unit was tried, when the resonance frequency of mass on the suspension is low and after passing this frequency, the seismic mass is practically at rest.

Taking into consideration the fact that structures of electronic units are often two-layer (two-body), the seismic suspension was made as follows.

Rubber panels are placed between the internal body and external one alongside of the whole (or a portion of) surface, their design does not prevent passage of pipe unions, wires, plugs as well as many other protruding parts.

He cells are pumped with air so that their surfaces were set against both bodies and an elastic joint was formed between the internal and external bodies.

At the expense of a change in the pressure in the cells, the resonance frequency of the vibrating system can be adjusted, shifting in to the needed side.

If, in case of a change in the exciting frequency, the pressure in the cells changes respectively so that, when approaching the resonance, the natural frequency of vibrations of the system should change, dangerous resonance frequencies can be «by-passed».

Thus, it is possible to obtain a non-resonance structure possessing such a property that, when approaching the resonance, it *changes its rigidity* and, thereby, resonance frequency.

If the pneumonic cells are made with a variable section or throttling is introduced, they will operate as air dampers during vibrations, at the expense of energy losses or air pumping from some cavities into other through the throttled holes.

The conducted experimental study of the damping capacity of the pneumatic *suspension showed its high vibration protective* properties.

In this case, vibration overloads of the functional boards did not exceed the tolerable values practically in the whole range of frequencies of 5 to 500 Hz.