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PECULIARITIES OF ASSESSMENT OF ERROR AND UNCERTAINTY AT CARRYING OUT OF TESTS OF OBJECTS OF ROCKET AND SPACE TECHNIQUE ON BROADBAND RANDOM VIBRATION

Methodology is developed, and assessments of errors and uncertainty of measurement results at carrying out of tests of objects of rocket and space technique on broadband random vibration are obtained. Analysis of basic components of error and uncertainty affecting on quality of measuring results is carried out. Values of total error and expanded uncertainty for measurement results of vibration overload (acceleration spectral density) are obtained. Graphs of functional dependence of vibration overload from frequency at which tests are carried out are constructed.

Key words: *broadband random vibration, acceleration spectral density, vibration overload, error, uncertainty.*

Introduction

Test on influence of random vibration is a complex type of testing. In this type of test is frequently used such term as «acceleration spectral density (ASD)» which is a spectral density of acceleration of random vibration expressed in units of «acceleration squared divided on frequency (g^2/Hz)». Spectrum of ASD determines a law of variation of ASD within the frequency range [1].

Purpose of tests is determination of products ability, elements and equipment to stand an influence of random vibration of given rigidity degree, and also identification of possible mechanical damages and/or degradation of specified products characteristics for solution of issue about suitability and operability of a sample. Proceeding from requirements of requirements specification during the tests a sample is exposed to random vibration with a specified level within a wide band of frequencies. Owing to complicated mechanical reaction of a sample and its fixing this test requires a special care in its preparation and carrying out.

There are three methods of tests on influence of broadband vibration [1]:

– influence of broadband random vibration;

– narrow-band random vibration at fixed frequencies;

– random vibration by sweep-frequency method.

These three methods of tests on influence of vibration are not considered as equivalent and therefore must be submitted as separate tests. Broadband tests are considered first of all. In addition, from a technical point of view this type of test is the most perfect.

New control system (CS) with software that allows you to automate all process of tests of equipment and to improve quality of obtained results is developed by specialists of «Hartron-Arkos» Research and Production Enterprise for the purpose of carrying out of tests on sinusoidal and random broadband vibration for the test stand of UVE-100/5-3000 vibration equipment presented in fig. 1. And methodology of assessment of error and uncertainty of vibration overload measurement is developed. Purpose of this methodology is to assess a quality of obtained results.

Fig. 1. Equipment of UVE-100/5-3000 for testing on broadband random vibration

Control system with software of «Generator-Analyzer of sinusoidal and broadband random signals» is intended for carrying out of vibration tests and realizes the following functions:

1) formation and delivery of sinusoidal signals with a constant and variable parameters in time on analog output of control system;

2) formation and delivery of broadband random signals with specified spectral density on analog output of control system;

3) formation and delivery of mixed (sinusoidal and broadband random) signals with specified frequency composition on analog output of control system;

4) record of signal through an analog input of control system;

5) octave analysis (oscillogram of signal development in time) of analog signals recorded in various formats;

6) spectral analysis of complex harmonic signals in various formats.

In accordance with requirements of National agency on accreditation of Ukraine (NAAU) an assessment of error and/or uncertainty of measurements is compulsory condition for all organizations having the right to issue of certificates on carrying out of various type of tests.

As a rule, assessment of error of measurements consists of several stages and includes definition of random component and systematic respectively [2]. Concept of expanded uncertainty which includes two types of uncertainties: type A and type B is used at assessment of uncertainty of measurements [2]. However, in spite of existing mathematical apparatus of determining of quantitative metrological characteristics of measurement results a methodologies for each specific type of tests are significantly different.

1. Peculiarities of assessment of error and uncertainty at carrying out of tests on broadband random vibration

For the purpose of approbation of methodology of errors and uncertainties determination at carrying out of tests on broadband random vibration the measurements of vibration overload values (acceleration spectral density) were carried out for complex of rocket and space equipment of «Gimballess astro-inertial unit with accelerometers» in two modes.

Measurements of vibration overload are implemented using vibration sensors in several points of test equipment. Error calculation is done for each of specified points of device in which vibration sensors are located.

Measurements of vibration overload are related to direct measurements. Methodology of direct measurements is used for measurement result processing. Measurements of vibration overload take place during a specified period of time, and the vibration overload is a function from frequency.

For the purpose of obtaining of necessary number of statistic data when assessment of error and uncertainty of vibration overload measurement results is done it is necessary to select from all time interval specified in a program of carrying out of tests five moments of time in which the power of a signal spectrum and appearance of signal have the closest values. Moments of time between measurements are selected so that the intervals between them were the same. Error and uncertainty of vibration overload measurement results is estimated at frequency range from 21 Hz to 2000 Hz. At frequencies from 0 Hz to 20 Hz a significant influence on measurements results have noises, in this regard, this frequencies range is not considered at carrying out of metrological assessments. Result of assessment of error and uncertainty appropriate to represent in the form of graph showing a dependence of error and uncertainty of vibration overload measurement respectively from frequency. Besides, it is necessary to display maximum value of error and uncertainty corresponding to a certain frequency.

2. Assessment of error at carrying out of tests of rocket and space objects on broadband random vibration

Results of vibration overload measurement for two modes of «Gimballess astro-inertial unit with accelerometers» with different mean square value are shown in fig. 2, 3.

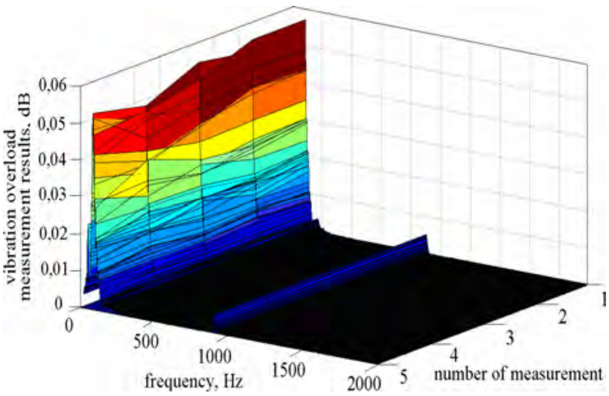

Fig. 2. Results of vibration overload measurement for the mode with mean square value (MSV)=5,2 g

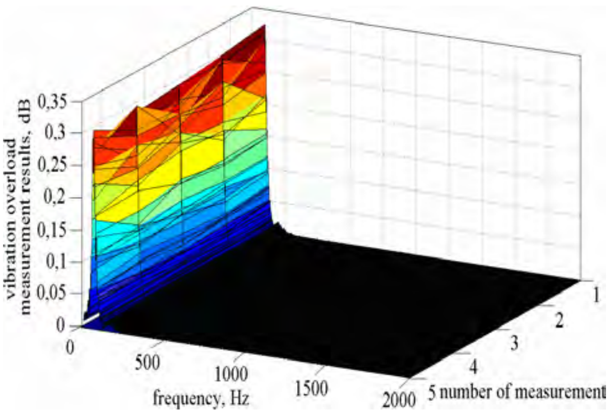

Fig. 3. Results of vibration overload measurement for the mode with mean square value (MSV)=9,1 g

Random and systematic components of error have a significant influence on vibration overload measurements.

Algorithm of assessment of error of vibration overload measurement consists in the following:

1) specification of measurements is formed: measurement scheme, information about conditions of carrying out of measurement, metrological characteristics of applied equipment is analyzed;

2) observations of values of measured value are made;

3) for obtaining of valid value of vibration overload its mean value is calculated in each point of frequency;

4) random error of vibration overload measurement is determined (standard deviation is estimated);

5) systematic error of vibration overload measurement is determined;

6) total error of vibration overload measurement is determined;

7) graph of dependence of total error of measurement from frequency is constructed;

8) maximum value of total error of all measurement process is determined.

Graphs of dependences of total error of vibration overload measurement from frequency are constructed proceeding from the carrying out of analysis of tests results and they are presented in fig. 4, 5. Total error does not exceed a limit value on each frequency.

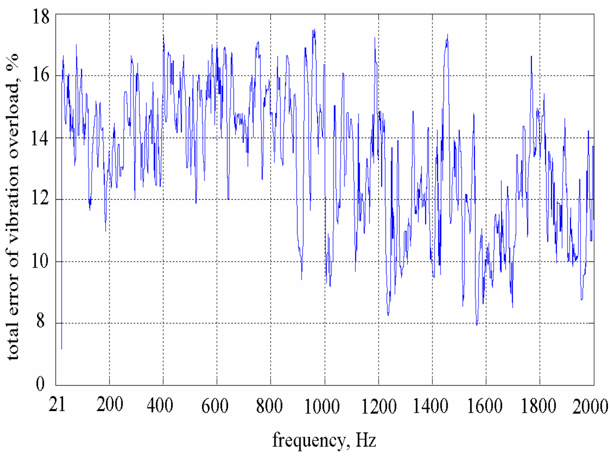

Fig. 4. Total error of vibration overload measurement results from frequency for the mode with mean square value (MSV)=5,2 g

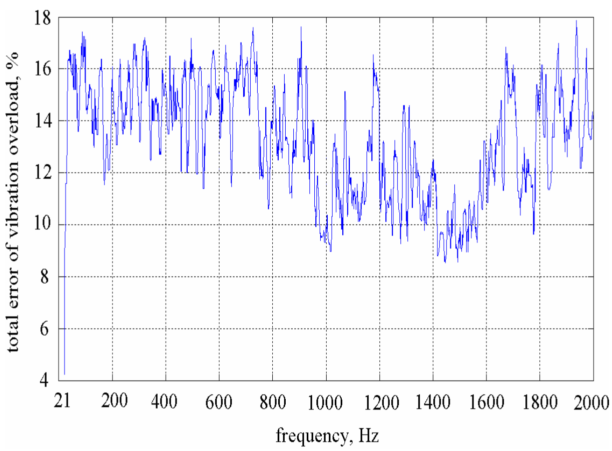

Fig. 5. Total error of vibration overload measurement results from frequency for the mode with mean square value (MSV)=9,1 g

As the number of factors influencing on measurement process is infinitely large, that is why in the capacity of statistical law of vibration overload values is selected a normal (Gaussian) statistical law.

Relative error of vibration overload measurement must not exceed 20 %. In case of excess of specified allowable value of random error a measurement results are recognized as invalid and measurement process needs to be repeated for selected frequency points.

3. Assessment of uncertainty at carrying out of tests of rocket and space objects on broadband random vibration

Uncertainty of measurement is a non-negative parameter that characterizes dispersion of values attributed to measured value on the basis of used information [2].

Algorithm of assessment of uncertainty of vibration overload measurement consists in the following:

1) specification of measurements is formed: measurement scheme, information about conditions of carrying out of measurement, metrological characteristics of applied equipment is analyzed;

2) observations of values of measured value are made;

3) standard uncertainty by type A is determined;

4) standard uncertainty by type B is determined;

5) total uncertainty is determined;

6) expanded uncertainty is determined;

7) graph of dependence of expanded uncertainty of measurement from frequency is constructed;

8) maximum value of expanded uncertainty of all measurement process is determined.

Expanded uncertainty of vibration overload measurement must not exceed 25 %.

Graphs of dependences of expanded uncertainty of vibration overload measurement from frequency are constructed proceeding from the carried out analysis of tests results and they are presented in fig. 6, 7.

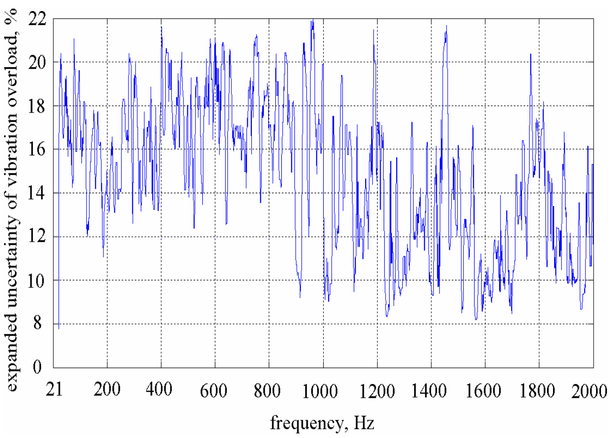

Fig. 6. Expanded uncertainty of vibration overload measurement results from frequency for the mode with mean square value (MSV)=5,2 g

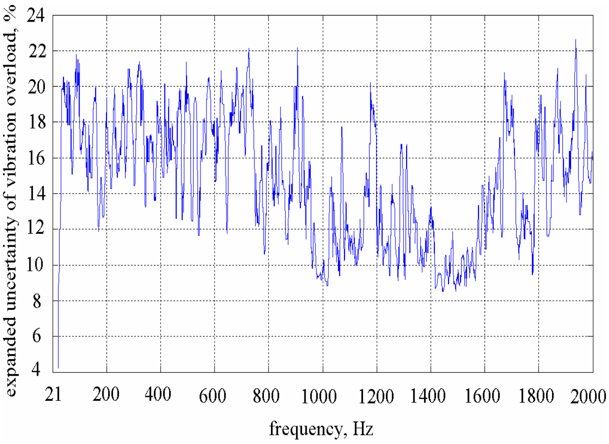

Fig. 7. Expanded uncertainty of vibration overload measurement results from frequency for the mode with mean square value (MSV)=9,1 g

Conclusions

In the article the methodology of assessment of error and uncertainty at carrying out of tests of objects of rocket and space on broadband random vibration is considered. As a result of conducted experimental research by means of developed methodology it is defined that values of total error and expanded uncertainty on considered frequency range do not exceed limit values.

Maximum value of total error of vibration overload on considered frequencies range for the mode with mean square value (MSV)=5,2 g is 19,1 % on frequency of 1771 Hz, and for the mode with mean square value (MSV)=9,1 g is 19,03 % on frequency of 894 Hz. Maximum value of expanded uncertainty of vibration overload on considered frequencies range for the mode with mean square value (MSV)=5,2 g is 24,89 % frequency of 1771 Hz, and for the mode with mean square value (MSV)=9,1 g is 24,78 % frequency of 894 Hz.

Metrological certification of testing stand confirmed obtained results [3]. This fact gives grounds to recognize the methodology as operating and universal within this type of tests. To improve the automation of calculation process an algorithm of this methodology is implemented by software.

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ОСОБЛИВОСТІ ОЦІНКИ ПОХИБКИ ТА НЕВИЗНАЧЕНОСТІ ПРИ ПРОВЕДЕННІ ВИПРОБУВАНЬ ОБ'ЄКТІВ РАКЕТНО-КОСМІЧНОЇ ТЕХНІКИ НА ШИРОКОСМУГОВУ ВИПАДКОВУ ВІБРАЦІЮ

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Розроблено методику, та одержано оцінки похибки та невизначеності результатів вимірювання при проведенні випробувань об'єктів ракетно-космічної техніки на широкосмугову випадкову вібрацію. Проведено аналіз основних складових похибки та невизначеності, що впливають на якість результатів вимірювання. Отримані значення сумарної похибки і розширеної невизначеності результатів вимірювання віброперевантаження (спектральної щільності прискорення). Побудовані графіки функціональної залежності віброперевантаження від частоти, на якій проводять випробування.

Ключові слова: *широкосмугова випадкова вібрація, спектральна щільність прискорення, виброперевантаження, похибка, невизначеність.*

ОСОБЕННОСТИ ОЦЕНКИ ПОГРЕШНОСТИ И НЕОПРЕДЕЛЁННОСТИ ПРИ ПРОВЕДЕНИИ ИСПЫТАНИЙ ОБЪЕКТОВ РАКЕТНО-КОСМИЧЕСКОЙ ТЕХНИКИ НА ШИРОКОПОЛОСНУЮ СЛУЧАЙНУЮ ВИБРАЦИЮ

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Разработана методика, и получены оценки погрешности и неопределённости результатов измерения при проведении испытаний объектов ракетно-космической техники на широкополосную случайную вибрацию. Проведён анализ основных составляющих погрешности и неопределённости, оказывающих влияние на качество результатов измерения. Получены значения суммарной погрешности и расширенной неопределённости для результатов измерения виброперегрузки (спектральной плотности ускорения). Построены графики функциональной зависимости виброперегрузки от частоты, на которой проводят испытания.

Ключевые слова: *широкополосная случайная вибрация, спектральная плотность ускорения, виброперегрузка, погрешность, неопределённость.*