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IEEE Recommended Practice for Precision Centrifuge Testing of Linear Accelerometers

IEEE Aerospace and Electronic Systems Society

Sponsored by the
Gyro and Accelerometer Panel

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IEEE Aerospace and Electronic Systems Society

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Abstract: This recommended practice provides a guide to the conduct and analysis of precision centrifuge tests of linear accelerometers and covers each phase of the tests, beginning with the planning. Possible error sources and typical methods of data analysis are addressed. The intent is to provide users involved in centrifuge testing with a detailed understanding of the various factors affecting accuracy of measurement, both factors associated with the centrifuge and factors in the data collection process. Model equations are discussed, both for the centrifuge and for a typical linear accelerometer, each with the complexity needed to accommodate the various identified characteristics and error sources in each. An iterative matrix equation solution is presented for deriving the various model equation coefficients for the accelerometer under test from the centrifuge test data.
Keywords: accelerometer, accelerometer test, centrifuge, linear accelerometer

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Introduction

This introduction is not part of IEEE Std 836-2009, IEEE Recommended Practice for Precision Centrifuge Testing of Linear Accelerometers.

This recommended practice was prepared by the Gyro and Accelerometer Panel of the Aerospace and Electronic Systems Society of the Institute of Electrical and Electronics Engineers (IEEE). It is a guide to the conduct and analysis of precision centrifuge tests of linear accelerometers and includes discussions of possible error sources in those tests. It provides guidance for each phase of the tests, beginning with planning and ending with a discussion of typical methods of data analysis.

A discussion of model equations is provided, both for the centrifuge and for a typical linear accelerometer, each with the complexity needed to accommodate the various identified characteristics and error sources in each. This recommended practice also presents an iterative matrix equation solution for derivation of the various model equation coefficients for the accelerometer under test from the centrifuge test data. The matrix solution provides a two-quadrant best fit of the centrifuge data to the chosen model equation.

This recommended practice is intended to provide users involved in centrifuge testing with a detailed understanding of the various factors affecting accuracy of measurement, both factors associated with the centrifuge and factors in the data collection process. Numerical examples are provided so that each factor can be quantitatively evaluated and its contribution to system error compared with a user's required accuracy. This information allows the user to identify and evaluate the factors that are critical to a specific planned test. The matrix equation method of data reduction also provides a means of determining data validity as well as model equation adequacy and yields the confidence intervals for each of the model equation coefficients.

This recommended practice consists of a main text and ten annexes. The main text provides the recommended practice for precision centrifuge testing following a tutorial clause that is intended to provide users with the understanding of critical factors in centrifuge testing as well as the best methods for taking and reducing data.

Annex A is a compilation of the characteristics of known precision centrifuges from data provided from both users and manufacturers. The listing is intended as a guide to available facilities at the time of publication of this recommended practice. Data provided should be considered as merely informative and not as specifications for the listed machines.

Annex B provides a discussion of evaluation of centrifuges with references provided to clauses of this recommended practice that pertain to the attribute discussed.

Annex C provides a more general discussion of fitting theory with particular regard to the often unique character of centrifuge data and corresponding accelerometer performance requirements. It discusses the application of the method of least squares by which matrix solutions are generated. It also describes the ease of understanding and use. These approximate methods generally address some measure of composite error, rather than directly evaluating model equation coefficients. For example, a common specification limits allowable deviations from a straight line determined by two specified points, such as zero-acceleration and some specific value of input acceleration.

Annex D discusses the limitations of and alternatives to centrifuge testing. Problems produced by the acceleration-gradient, the spin rates required, and the difficulty of producing short high-acceleration input pulses are among the problems discussed. Alternatives such as use of dividing heads and the earth's gravity are discussed, along with sled testing and vibration testing.

Annex E discusses the use of the double centrifuge and rate table with tilted axis of rotation for low-frequency transfer function determination. Annex F presents a refined model of the double centrifuge and rate table with tilted axis of rotation.

Annex G describes the processing of dual-proof-mass vibrating beam accelerometer (VBA) centrifuge data. Annex H discusses scale factor calibration for high-acceleration applications on an ultra-centrifuge. Annex I discusses thermal control and data acquisition on the centrifuge arm. Annex J is a bibliography.

The terminology used in this recommended practice conforms to *The Authoritative Dictionary of IEEE Standards Terms* [B6][a] and IEEE Std 528™-2001.[b] The units used in this recommended practice conform to IEEE Std 268™-1992 [B9]. In this recommended practice, the symbol *g* is used to denote a unit of acceleration equal in magnitude to the local value of gravity at the test site. This symbol is distinguished from g, which is the standard symbol for gram.

The following standards were used in the development of this recommended practice:

— IEEE/ASTM SI 10-1997 [B7]

— IEEE Std 260.1™-1993 [B8]

— IEEE Std 315™-1975 [B10]

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[a] The numbers in brackets correspond to the numbers of the bibliography in Annex J.
[b] Information on references can be found in Clause 2.

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Participants

This publication represents a group effort on a large scale. The major contributors to the original version of this recommended practice, IEEE Std 836-1991, were as follows:

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While the development of IEEE Std 836-1991 was a group effort, the contributions of one member were fundamental to its preparation and he clearly deserves special recognition. George H. Neugebauer developed the iterative matrix data reduction technique. In addition, he was extremely active in the development and subsequent refinement of most of the rest of the document. In large measure, the technical quality of this recommended practice resulted from his efforts.

A total of 68 individuals attended 15 meetings of the Gyro and Accelerometer Panel during preparation of the revised IEEE Std 836-2001. The following persons on the Gyro and Accelerometer Panel contributed to the 2001 version of IEEE Std 836:

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When the IEEE-SA Standards Board approved this recommended practice on 17 June 2009, it had the following membership:

Contents

IEEE Recommended Practice for Precision Centrifuge Testing of Linear Accelerometers

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1. Overview

1.1 Scope

This recommended practice describes the conduct and analysis of precision tests that are to be performed on linear accelerometers using centrifuge techniques. The term "precision," in this context, refers to tests that are conducted to evaluate accelerometer parameters, as opposed to tests conducted to establish environmental survivability only. Evaluation may take the form of determining the coefficients of the accelerometer's model equation, except for bias and scale factor, which are most accurately determined by static multiposition tests. Alternatively, evaluation may establish only that the accelerometer output complies with specific error limit criteria.

1.2 Purpose

The principal error sources encountered during precision centrifuge testing of linear accelerometers are described, along with the test practices and data reduction techniques that have been found most efficient in minimizing or compensating for them.