

AEROSPACE INFORMATION REPORT

AIR6966™

Issued 2020-12
Reaffirmed 2026-06

Conducting Measurement Systems Analysis for Rotor Balancing Tasks

RATIONALE

Conducting a measurement systems analysis (MSA) study for balancing tasks is important to correctly assess the balance measurement system and is a key component for establishing, improving, and maintaining quality systems. A rotor balancing measurement system consists of balancing machines, rotors/parts to be measured, and personnel taking the measurements. A MSA study enables process planners to design experiment in which the level of process variation is attributed to the balancing machine, operator, parts, and operator-part interaction.

This Aerospace Information Report (AIR) outlines the major variables to consider and applicable data analysis methods to utilize when conducting a MSA study for rotor balancing tasks.

AIR6966 has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE

This AIR provides a general guideline on how to perform effective measurement systems analysis study (MSA) for rotor balancing tasks. The document also includes applicable data analysis methods and result interpretation.

1.1 Purpose

This new AIR document is prepared to help process planners to identify and reduce sources of variation in a rotor balance measurement system. The measurement systems analysis study (MSA) and data analysis results can help to determine what needs to be improved or fixed if the balance measurement system is unacceptable.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM E456-96 Standard Terminology for Relating to Quality and Statistics

2.1.2 Other Publications

Mason, R. L., and Young, J. C. (2002). Multivariate statistical process control with industrial applications (Vol. 9). Siam.

Montgomery, D. C. (2001). Gage and Measurement System Capability Studies. Introduction to Statistical Quality Control, 377-388.

Sweeney, S. (2007). Analysis of two-dimensional gage repeatability and reproducibility. Quality Engineering, 19(1), 29-37.

Voelkel, J. G. (2003). Gauge R&R analysis for two-dimensional data with circular tolerances. Journal of quality technology, 35(2), 153.

Sweeney, S. K., and Fisher, K. J. (2005). Reduction of rotating imbalance measurement variation resulting from test apparatus redesign. In ASME 2005 International Mechanical Engineering Congress and Exposition (pp. 427-434). American Society of Mechanical Engineers.

Measurement Systems Analysis, MSA 4th Edition – Reference manual, AIAG-Work Group, Daimler Chrysler Corporation, Ford Motor Company, General Motors Corporation, 2010.

2.2 Definitions

GAGE: A device used as part of the measurement process to obtain measurement results (also, refer to ASTM E456-96).

GAGE REPEATABILITY (GAGE R): Evaluates short-term/current gage repeatability or gage precision.

GAGE REPEATABILITY AND REPRODUCIBILITY (GAGE R&R): Quantifies the combined effect of equipment variation and appraiser variation.

MEASUREMENT SYSTEM: The collection of instruments or gages, standards, operations, methods, fixtures, software, personnel, environment and assumptions used to quantify a unit of measure; the complete process used to obtain measurements.

PART VARIATION (PV): Represents the expected part-to-part variation for an established process.

REPEATABILITY (EQUIPMENT VARIATION): The variation in measurements obtained with one measurement instrument, by the same operator, measuring the same characteristic on the same part at the same period in time.

REPRODUCIBILITY (APPRAISER VARIATION): The variation in multiple measurements of the same part between different appraisers (operators) using the same measuring instrument and method in a stable environment.

TOOL COMPENSATION (INDEXING): A process by which the balance machine distinguishes the rotor and the tooling fit variation and compensates for the tooling fit variation and unbalance in the final measurement.

TOTAL VARIATION (TV): The combination or sum of part variation, equipment variation, and part-to-part variation.

3. INTRODUCTION: MEASUREMENT SYSTEMS ANALYSIS

Quality of a rotor balance measurement data can be defined by the statistical properties of multiple measurements obtained from a balance system operating under stable conditions. Variations in a balance measurement system can originate from three main sources: the parts being measured, the operator taking the measurements and the equipment used to perform the measurements. The results from a measurement system analysis study quantify the system capability and can help determine if the measurement system is acceptable for its intended use. The study also shows which part of a measurement system is contributing the most to variation of measurements and helps personnel plan improvement to the system.

Gage repeatability (Gage R) and Gage repeatability and reproducibility (Gage R&R) studies are commonly used to assess quality of a rotor balance measurement system. Gage R study is mostly used to evaluate short-term gage repeatability such as comparing different tool clamping methods. In a Gage R&R study, the first R, repeatability, is the evaluation of variation attributed to the process elements such as balancing machines and other devices used in the measurement process. Repeatability is often denoted as "EV" for equipment variation. The second R in Gage R&R, reproducibility, is evaluation of variation that is attributed to human influences in the measurement process. Reproducibility is denoted as "AV" for appraiser variation. Gage R&R in general is used to evaluate all contributions to the total variation in a measurement system.

4. BALANCING MACHINE AND TOOLING REQUIREMENTS

4.1 Balancing Machines

- A balancing machine is used to detect the amount and location of the unbalance mass on a rotor.
- Balancing machines shall be calibrated per manufacturer or industry standards after the initial machine setup and/or repair before conducting the MSA study.

4.2 Balancing Tools/Fixtures

- Tooling described in this document is used with reference to tooling used to locate, hold, and orient a rotor with respect to the appropriate rotor datum.
- Conformance to design: balancing tool design shall be reviewed for compliance with applicable standards and suitability for the application prior to initiating the study.
- Mounting datum: make appropriate use of the rotor datum to avoid and/or minimize non-repeatable results. Verify that both tooling and part datum contact areas are free of flaws and meet print dimensions as it leads to non-repeatable results.
- Looseness - any loose item in the rotor or in the balance tooling shall be avoided.