AEROSPACE RECOMMENDED PRACTICE

ARP4048™ REV. A

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Superseding ARP4048

(R) Balancing Machines - Description and Selection Horizontal, Two-Plane, Hard-Bearing Type for Gas Turbine Rotors

RATIONALE

Hard-Bearing Balancing Machines used to balance Gas Turbine Rotors in the Aerospace Industry have specific requirements that need to be maintained. This document provides these technical specifications required for horizontal rotating type, Hard-Bearing Balancing Machines used for unbalance measurement of Gas Turbine Rotors. The document's intention is to provide the Manufacturer with the minimum requirements that these machines need to provide and a guide for the specifications required by the End User.

This document has been revised to update the selection criteria and remove the evaluation criteria that is now contained in AS8617.

FOREWORD

Hard-Bearing Balancing Machines have been used for balancing Gas Turbine Rotors for many years and have largely replaced Soft-Bearing Balancing Machines. Hard-Bearing Balancing Machines have a balancing speed range below the Natural Frequency of the combined rotor and support system, while Soft-Bearing Machines operate above. Hard-Bearing Machines also provide a type of Permanent Calibration rather than the Rotor Specific Calibration required by Soft-Bearing Machines, which provide simpler operation to the Balancing Technicians.

This document was prepared to provide general specifications and requirements to ensure the capability of balancing equipment for balancing Gas Turbine Rotors. The standardization of rotor supports and drive systems is intended to enable an assortment of rotors and/or tooling to be used on a variety of machines in one capacity range.

This is a general specification document for the selection of balancing equipment to ensure suitability of horizontal balancing machines for Gas Turbine Rotors. Additional information on balancing equipment can also be referenced in ISO 21940-21.

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1. SCOPE

1.1 This document provides the specifications of horizontal hard-bearing balancing machines, which make such machines suitable for gas turbine rotor balancing.

1.2 This document specifies:

- General Performance Requirements
- Rotor Support System Requirements
- Drive System Requirements
- General Machine Dimensions and Capacities

NOTE: Refer to ISO 21940-2 for any definitions of balance process specific descriptions used throughout this document.

2. 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 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

AIR6975 Hard Bearing Balancing Machine Technology - Proper Use of Rotor Type-Specific Calibration

ARP4162 Balancing Machine Proving Rotors

ARP4163 Balancing Machines: Tooling Design Criteria

AS8617 Balancing Machines - Verification Test Requirements

2.2 ISO Publications

Copies of these documents are available online at https://webstore.ansi.org/.

ISO 21940-2 Rotor Balancing Vocabulary

ISO 21940-21 Balancing Machines - Description and Evaluation

ISO 21940-23 Balancing Machines - Enclosures and Other Safety Measures

3. GENERAL PERFORMANCE REQUIREMENTS

3.1 Gas Turbine Balancing Machines shall be able to pass the Performance Test Procedures as described in AS8617.

3.1.1 Proving Rotors and associated Test Mass requirements for the AS8617 Performance Tests are described in ARP4162.

3.2 Static and Couple Unbalance Separation

3.2.1 The balancing machine shall measure and indicate the magnitude and angular location of both the Static and Couple Unbalance for the rotor under test.

3.2.2 The measurement shall be displayed as a Dynamic Unbalance Measurement in Two Planes, or separately as a Static and/or Couple Unbalance Measurement, dependent on the user selected rotor configuration.

3.3 Plane Separation

3.3.1 The balancing machine shall indicate the amount and angle of the unbalance in each of one or more selected planes in the rotor.

3.3.2 The Machine OEM Calibration shall separate the rotor unbalance onto the selected correction planes and minimize the effect between each measurement plane.

3.3.3 The quality of Plane Separation is measured through Unbalance Reduction Ratio (URR) Testing in accordance with AS8617.

3.4 Unbalance Indication

3.4.1 Unbalance Measurement shall have a resolution of at least 10% of one A-unit. (Refer to AS8617 for A-Unit Calculations.)

3.4.2 Angle Resolution shall be at least 1 degree.

3.4.3 Magnitude and Angle Indication shall be simultaneous in two planes.

3.4.4 Measurement settings, such as but not limited to radius and length, shall be fully selectable and editable.

3.4.5 Measurements shall be available in Imperial units, SI units, or any combination thereof.

3.4.6 Unbalance indication shall be available for clockwise and counterclockwise direction of rotation.

3.5 Software Capabilities

3.5.1 Balancing Machines should include digital processors that provide multiple software capabilities.

3.5.2 Tooling Compensation should be included to remove error introduced using arbors to recreate the rotor spin axis.

3.5.3 The ability to document measurement results, program setups, and calibration data shall be available in digital or hard copy format.

3.5.4 Additional software capabilities that can be optionally included to aid in the Balancing Process:

- Run History Marking
- Multi Run Averaging
- Bode Plotting
- SAE Performance Testing
- Rotor Type Specific Calibration

3.6 Balancing Machine Rotor Supports

3.6.1 The standardized rotor support systems for gas turbine rotor balancing machines can be supplied with are Roller Supports and/or Saddle Supports depending on process.

NOTE: At a minimum, the Balancing Machine shall be supplied with Rotors Supports capable of supporting the required Proving Rotor (refer to ARP4162) for Calibration Testing (refer to AS8617).

3.6.2 Additional Support Systems can be designed for product specific requirements. Refer to ARP4163 for further details and options.

3.6.3 Roller Supports

3.6.3.1 Used where the rotors are to be balanced on their own bearing journals, duplicating the rotor spin axis during operation.

3.6.3.2 Rollers should come with specific contact diameter support ranges with height adjustment ability to maintain rotor Spin Axis location.

3.6.3.3 The Rollers shall be designed with a crowned outer diameter that provides Angular Contact Freedom with the ability to tolerate work piece misalignment (refer to ARP4163).

3.6.4 Saddle Supports

3.6.4.1 Used where the rotors are to be balanced in stators or cradles and are fitted or supported with various bearing designs to enable rotor rotation.

3.6.4.2 Carriages will come with radius specific support designs based on the classification of balancing machine (see Figure 1).

3.6.4.3 Designed with the Vertical Axis of Freedom built into the Saddle Support and typically are rigidly connected between supports using, but not limited to, Tie Bars and Cradles.

3.6.4.4 Additional Saddle Systems can be designed for product specific support requirements as required by the Engine OEM.

3.7 Rotor Drive

3.7.1 The standardized drive systems for gas turbine rotor balancing machines are Belt and End Drive.

3.7.2 Additional Drive Systems can be designed for product specific drive requirements, such as but not limited to Air Drive.

3.7.3 The Drive System should include all components necessary to drive the rotor under test.

3.7.4 The Drive System should be functional in both directions of rotation.

3.7.5 End Drive equipment should provide a Universal Drive Shaft and Drive Shaft Interface that conform to the requirements in ARP4163.

3.7.6 Belt Drive equipment should provide for the application of the belt drive along the length of the machine either between or outside the supports over the length specified in Figure 1.

3.7.7 Belt Drive systems should be adjustable for adequate belt tension.

3.7.8 Influence of the Drive System to the rotor unbalance measurements, such as End Drive Thrusting and Belt Misalignment, should be mitigated and/or compensated through good design practices.

3.8 Drive Motor and Controls

3.8.1 The Drive System should be designed with Variable Speed capabilities within the range shown in Table 1.

3.8.2 The speed should be manually adjustable and selectable, with a maximum 1% Speed Stability within the operating range of the machine.

3.8.3 The acceleration and deceleration should be adjustable and selectable to achieve a constant and stable rate.

3.8.4 The Motor Horsepower requirements should fall within the minimum requirements shown in Table 1.

3.8.5 Automated Drive Systems are optional and may contain such features as Duty Cycle, Cycle Time, and Dependent Control requirements.

3.9 Axial Thrust Control

3.9.1 The machine should have the ability to control the axial thrust and position of rotors (refer to ARP4163).

3.9.2 Influence of the Axial Thrust Retention Feature to the rotor unbalance measurements, such as Couple Unbalance, should be mitigated and/or compensated through good design practices.

3.10 Alignment

3.10.1 End Drive Systems should be aligned to the Rotor Centerline of Rotation according to the Machine OEM Specifications.

3.10.2 Belt Drive Pulley, Idler Pulleys, and Tension Pulley on Belt Drive Systems should be aligned.

3.10.3 Idler and Tension Pulleys on Belt Drive Systems should be crowned to allow for belt centering and tracking.

3.10.4 Belt Drive Idler Pulleys should be adjustable to allow for perpendicular belt alignment to rotor driven diameter.

3.10.5 Pedestals should be axially adjustable with centerline and perpendicular alignment features to the Machine Bed.

3.11 Safety

3.11.1 Use of Safety Devices and Enclosures should be considered depending on application and local regulatory requirements (refer to ARP4163 and ISO 21940-23).

4. DIMENSIONS AND CAPACITIES

NOTE: See Table 1 for the recommended dimensions and capacity requirements.

4.1 Machine Class

4.1.1 Machine Classification to outline the required dimensions and capacities for various rotor sizes.

4.1.2 All dimensions are approximate guidelines only and can be expanded as required by the Machine OEM.

4.2 Load Capacity

4.2.1 The combined total mass including rotor and any tooling mounted to the Rotor Supports.

4.2.2 Minimum Rotor Limits are generally governed by the support envelope dimensions and the required Minimum Achievable Residual Specific Unbalance (e_{mar}) as specified in AS8617.

4.2.3 The Wn^2 value is the product of the Total Oscillating Mass (W) and the Square of the Rotational Speed (n).

The maximum Wn^2 value is specified by the Machine Manufacturer, used to limit the measuring speed of a Rotor based on Total Oscillating Mass to remain within the Permanent Calibration Range. The Total Oscillating Mass represents the workpiece, rotating tooling, non-rotating tooling, and all machine elements mounted above the Pedestal Spring System.

This limit is specified for Symmetrical Setups. Maximum speed needs to be recalculated for Overhung and Asymmetric Setups. When this Wn^2 limit is exceeded, a different calibration method should be considered, e.g., Rotor Type Specific Calibration (refer to AIR6975).

4.3 Dimensions

4.3.1 These are the minimum requirements for Rotor Support Envelope and Roller Support Shaft Diameter Ranges.

4.4 Drive Requirements

4.4.1 These are the minimum requirements for Drive Motor Power, Speed Ranges, Belt Widths, and Universal Drive Shafts.

Table 1

	Characteristic	Dimensions and Capacities				
4.1	**Machine Class**	**30**	**100**	**300**	**1000**	**3000**
4.2		**Load Capacity (pounds)**				
	Maximum	60	150	450	1500	4500
	Minimum	1	3	10	30	100
	Maximum per Support	30	100	300	1000	3000
	Maximum Negative Load (per Support)	10	30	100	200	700
	Maximum $W{\cdot}n^2$ ($lb{\cdot}RPM^2$)	50×10^6	400×10^6	1000×10^6	1500×10^6	2400×10^6
4.3		**Dimensions**				
	Support Envelope	see Figure 1				
	Roller Support Shaft Diameter Range (inches)	0.3-1.5	0.4-5	0.4-7	1-9	1.5-12
4.4		**Drive Requirements**				
	Motor Power (HP)	0.75	2	10	30	75
	Rotor Speed Range (RPM)	500 3000	500 2500	500 2000	500 1500	500 1000
	Rotor Belt Driven Diameter (inches)	0.5-4	0.8-6	1-10	2-15	3-20
	Maximum Belt Width (inches)	1.0	1.5	2.5	4.5	6
	ARP4163 U-Joint Driver (lb-ft)	N/A	N/A	60 180	60 180 500	180 500 1650