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(R) Balancing Machines: Tooling Design Criteria

RATIONALE

This document provides guidance for design of aerospace balance tooling for horizontal and vertical processes. Rotating tooling used for balancing aerospace components must be designed and manufactured much differently than general assembly tooling due to the required precision of measurement and machinery used to perform the measurements.

Revision of the document is due to the changing requirements of the gas turbine engine industry requiring tighter tolerances and evolving component complexity.

FOREWORD

Tooling for balancing machines is a complex subject with many requirements that have been developed over a considerable period of time. The definition of balancing tooling covers a wide range of items from drive shafts and bearings to complete fixtures for locating engine modules. Any hardware used to facilitate mounting a rotor in a particular balancing machine, or driving the rotor once it is mounted, can be considered as "tooling."

Tooling is meant to provide the rotor with a rotational axis that is consistently as close to the rotor's designed spin axis as required to ensure the rotor has been balanced to its required tolerance. Since tooling is not part of the final rotating assembly, any influence should be minimized. The tooling designer's goal should be to make the tooling as invisible to the process as possible.

This document was prepared by the SAE EG-1A Committee; it supersedes ARP1382.

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1. SCOPE

This document establishes general design criteria, tolerances, and limits of application for tooling, fixtures, and accessories for mounting and driving gas turbine engine rotors on horizontal and vertical balancing machines.

1.1 Purpose

This document describes tooling and accessories to adapt the engine component to the balancing machine.

This document provides a set of tooling and fixture design parameters for balancing machine tooling that will facilitate the understanding of the high degree of readout accuracy and precision balance required for turbine engine rotors and will assist in achieving compliance with the testing requirements as listed in the applicable ARP specifications for balancing.

1.2 Equipment Selection for Specific Applications

The following are determining factors when selecting balancing machine and the required tooling:

- Rotor type
- Rotor size
- Rotor mass
- Rotor moment of inertia
- Rotor windage
- Datum locations
- Datum and/or journal dimensions
- Allowable correction methods
- Allowable correction locations
- Rotor balance tolerance and speed
- Drive method and location of drive interface

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 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.

ARP4048	Balancing Machines - Description and Selection, Horizontal, Two-Plane, Hard-Bearing Type for Gas Turbine Rotors
ARP4050	Balancing Machines - Description and Evaluation, Vertical, Two-Plane, Hard-Bearing Type for Gas Turbine Rotors
ARP5323	Balancing Machines - Description and Evaluation, Vertical, Single-Plane, Hard-Bearing Type for Gas Turbine Rotors
ARP6217	Balancing Machines - Description and Evaluation, Vertical, Single-Plane, Non-Rotating Type for Gas Turbine Rotors
ARP6911	Horizontal Balancing Systems - Isolating Repeatability Issues in Challenging Applications

2.2 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

2.2.1 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.

ARP587	Balancing Machines - Description and Evaluation, Horizontal, Two-Plane, Soft-Bearing Type for Gas Turbine Rotors
ARP588	Balancing Machines - Description and Evaluation, Vertical, Single-Plane, Soft-Bearing Type for Gas Turbine Rotors
ARP1202	Balancing Machines, Dynamic, Ball Type Slave Bearings for Rotor Support
ARP4162	Balancing Machine Proving Rotors
AS8617	Balancing Machines - Verification Test Requirements

3. METHODS OF ROTOR SUPPORT IN A HORIZONTAL BALANCING MACHINE

3.1 Twin-Roller Bearings (see Figure 1)

A twin-roller bearing assembly supports a rotor journal on a pair of rollers mounted to a plate or carriage, which attaches to the balancing machine support. Crowned outer surfaces of the rollers, or another alignment mechanism, are required to eliminate errors from misalignment. The rollers that are designed with a crowned outer diameter provide Angular Contact Freedom with the ability to tolerate workpiece misalignment, allowing for rotor dynamic measurements (refer to ARP6911). Twin-roller bearing supports are usually adjustable to accommodate a range of journal diameters.

To eliminate the influence of any eccentricity or unbalance of the rollers on the unbalance measurements, the roller diameter should differ from the journal diameter by more than 10%. The contact angle between the journals and the rollers is $45 \text{ degrees} \pm 15 \text{ degrees}$.

The roller bearing alignment affects the axial thrust of the rotor and, consequently, can adversely affect the unbalance measurement.

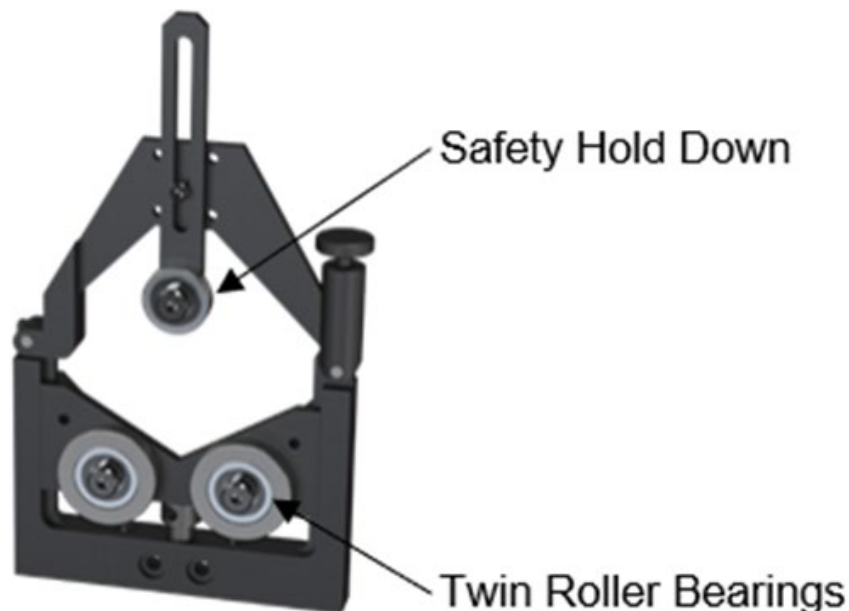


Figure 1 - Twin-roller bearing support with safety hold down

3.2 Saddle Supports (see Figure 2)

Saddle Supports (e.g., Swivel Bearing Bridges) consist of semicircular supports providing torsional freedom about the vertical centerline of the support. These enable the balancing machine to give correct two plane unbalance readings when operated with cradles, stators, or tie bars. Refer to the dimensional requirements of ARP4048.

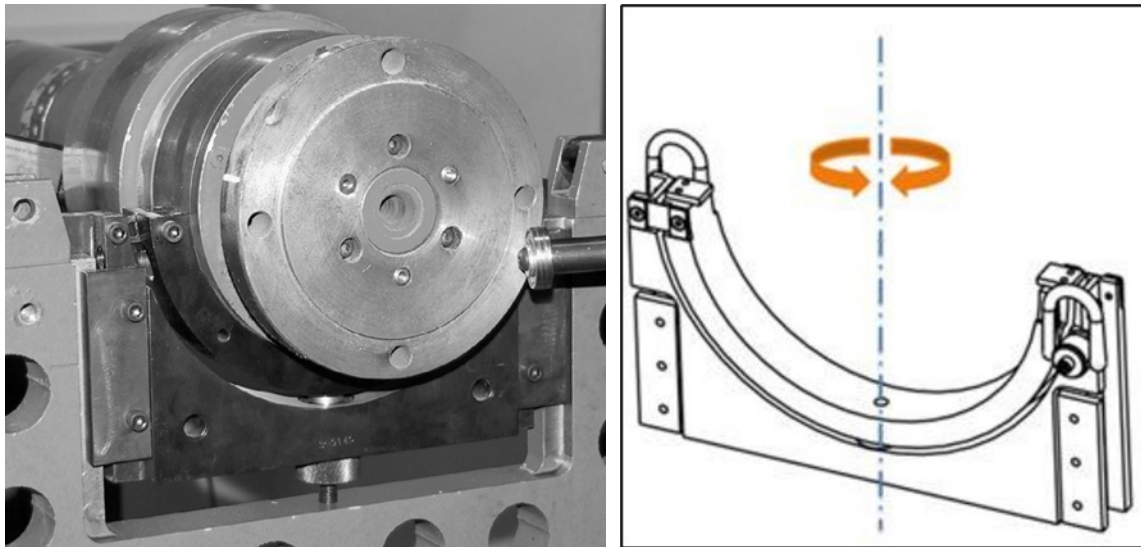


Figure 2 - Saddle support

3.3 V-Type Roller Carriages (see Figure 3)

V-type roller carriages support the rotor journal or bearing by two-point contact. These bearings are typically used for light loads or for supporting rotors in their own bearings.

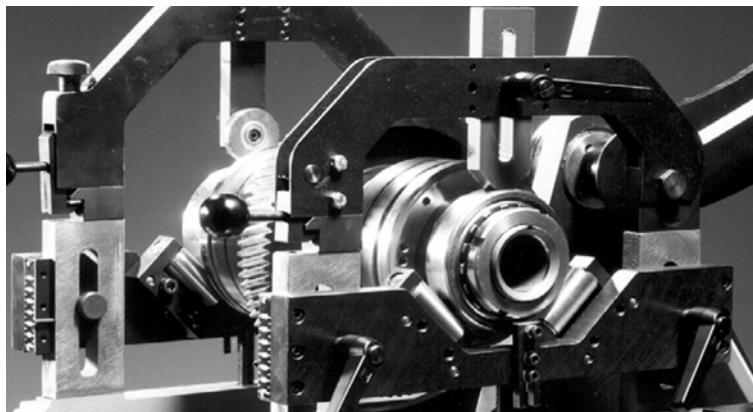


Figure 3 - Rotor shaft bearing on V-rollers

3.4 Engine Bearings

Engine bearings can be used for balancing rotor assemblies; however, their large radial clearance at ambient temperature adversely affects balancing accuracy.

3.5 Slave Bearings (see Figure 4)

Rolling element bearings, e.g., Balance Bearings, are used in place of engine bearings to support the rotor in the balancing machine. Slave bearings are variants of engine bearings designed to have minimum clearances at ambient temperature.

In the case of roller bearings, the engine bearing inner race and rollers may be used in conjunction with a slave bearing outer race.

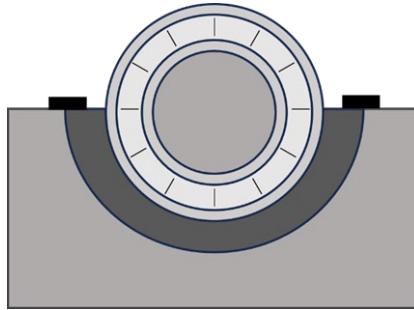


Figure 4 - Slave bearing diagram

3.6 Slave Races

Precision inner races that are mounted on engine journals to protect the journal surfaces from damage during the balancing process.

3.7 Sleeve Bearings

Sleeve type bearings are nonrotating journal supports which are fitted to specific journals. Sleeve bearings may be self-lubricating or have a liquid or gaseous supporting medium. Contact area, alignment, and overall stiffness, including the stiffness of the supporting medium, are critical factors in sleeve bearing design.

3.8 Negative Load Devices (see Figure 5)

Negative load devices are used to support the rotor when the rotor geometry produces an upward force at one of the balance machine pedestals. Design parameters for negative load devices are identical to positive load devices.

NOTE: Safety hold-down devices are not sufficient for negative load devices.

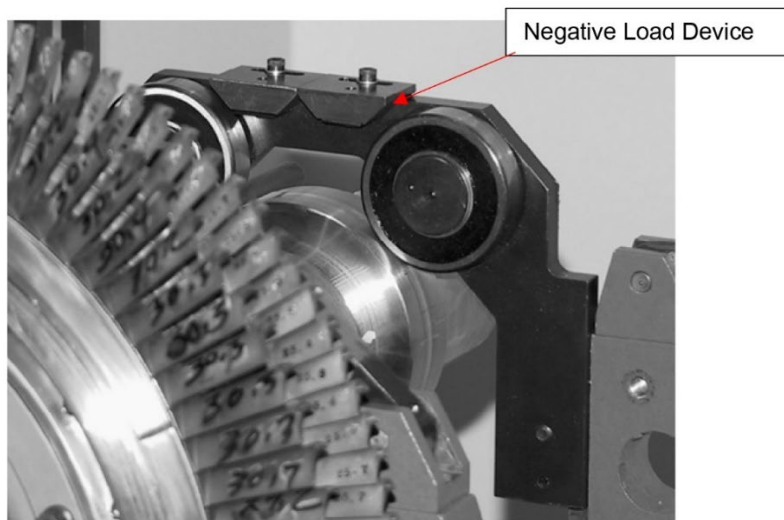


Figure 5 - Twin roller negative load support

3.9 Safety Hold-Down Devices (see Figure 1)

Safety hold-down devices limit the vertical movement of the part to prevent rotor liberation. They are not permitted to contact the part during normal balancing operation and are not acceptable as negative load devices. These devices may have rotating elements such as rollers.

3.10 Axial Thrust Stops (see Figure 6)

If other tooling does not include integrated thrust control, then axial thrust stops must be provided to restrict axial movement of the rotor. Any axial thrust stop, e.g., End Stops, should preferably be attached to the vibrating part of the balancing machine support and may be adjustable in both axial and radial directions. The “vibrating part of the balancing machine” is the portion of the machine above the sensor.

The axial thrust stop should be a single point of contact in order to have a minimum effect on the free rotation of the rotor. Additionally, a steel ball bearing may be added to the rotor to provide a single point of contact for the axial thrust stop. The axial thrust stop should consist of a bearing element in contact with the rotor as close as possible to the center of rotation and on a smooth surface perpendicular to the rotational axis. If two axial thrust stops are used on a rotor, only one axial thrust stop at a time should be in contact with the rotor.

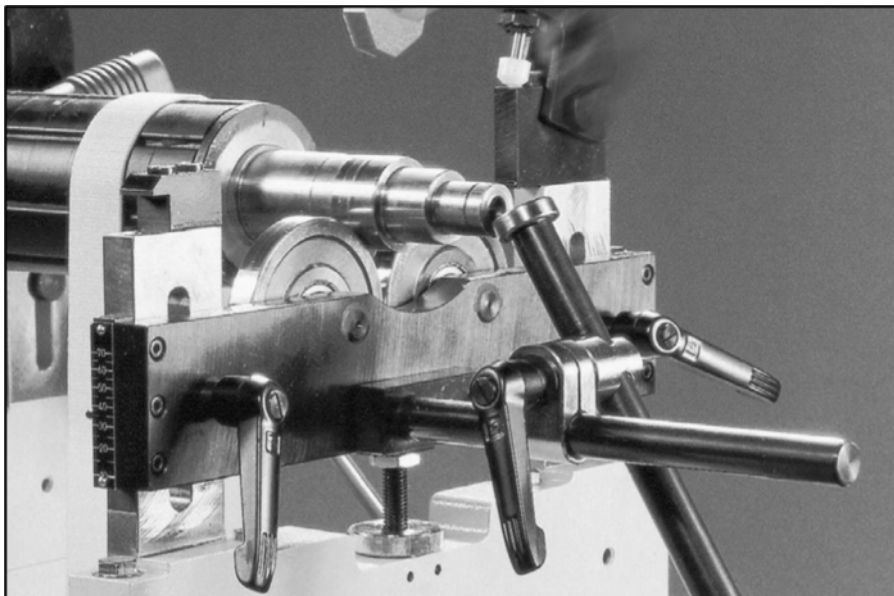


Figure 6 - Axial thrust stop