Tooling Management, Audit, & Control

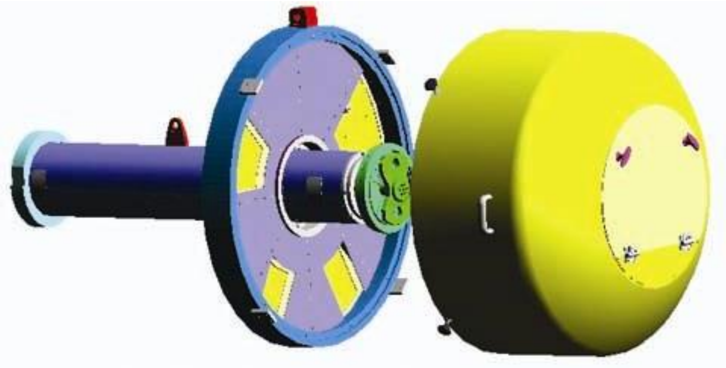
Recommendations for jet engine applications

1. Scope

Balancing machines are used to measure unbalance on rotating bodies. They have high measuring accuracies, and, along with their function as production equipment, are primarily measuring equipment. With jet engine applications, additional balancing devices (tooling) are frequently used.

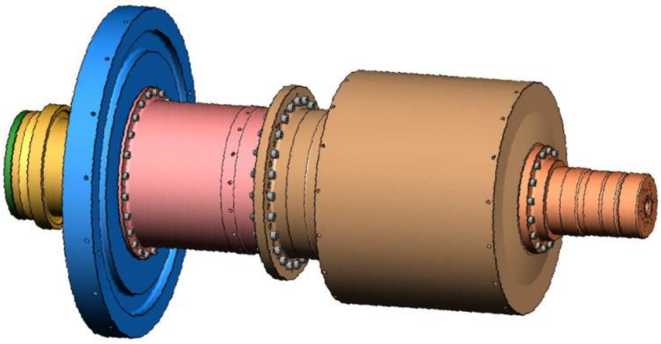
This document provides recommendations for handling and testing balancing devices. Two groups are to be considered here:

I. **Fixtures**
The main task of balancing fixtures is to establish a rotational axis for components for balancing that most closely resembles the axis of rotation of the assembled jet engine in operation.



Devices with spindle bearings and a chuck, like the one shown here for an LPC booster subassembly, enable components to be balanced in which the adapter surfaces that determine the rotational axis cannot be supported directly on the balancing machine. As tools for a measurement operation, these devices also fulfill the function of measuring equipment[1].

II. **Rotor Simulators**
These balancing devices not only establish the rotor's rotational axis on the balancing machine, but also replicate specific physical measures and material characteristics of engine components including mass, center of gravity, and moment of inertia.



[1] Measuring instruments, measuring equipment, reference materials, measurement standards and tools that are required for metrology (DIN 1319-2, 10.5, No. 3.1.).

HPC-HPT dummies, for example, form part of this group. Along with their function as a fixture, they represent a certified and traceable measure representing the mating engine component for correct determination of the dynamic unbalance. These devices are therefore categorized as calibrated measuring equipment.

2. Recommended Standard Practices

Balancing devices are an integral part of the overall system, which consists of a balancing machine and a rotor that is to be balanced during unbalance measuring. Each balancing process includes an inevitable stacking error, which is reflected in the measurement results. Where possible, the stacking error must be minimized and accounted for in the measurement results and therefore controlled by means of suitable weights and measures.

This necessitates process monitoring in compliance with a suitable quality management system that references relevant quality standards (e.g. ISO 9001, EN/AS 9100, ISO/TS 16949 etc.).

Among the core requirements of these standards is control of monitoring and measuring equipment. In particular, an effective and efficient calibration conducted at regular intervals is required by means of measurement standards that can be traced to international or national measurement standard(s).

With fixtures as per Group I, an evaluation of system-level errors must be conducted to determine if the effect upon measuring results is of consequence. If the error stack is significant and the affect on unbalance results is unacceptably high, the fixture must then be classified as measuring equipment. As such, measuring equipment is then subject to monitoring as defined in the referenced quality standards.

Dummy rotors in Group II shall always be inspected at specified intervals in accordance with established procedures. Inspection results shall be documented and corrective actions where required shall be implemented in order to ensure valid measurement results.

3. Inspection Recommendations

In contrast to true measuring instruments, i.e., scales or length measuring systems, balancing devices are not truly "calibrated"[2].

Instead, they must be subjected to several inspection sequences that in part place requirements on traceability[3]. Only through a traceable inspection with an indication of the measuring uncertainty that was determined with the balancing devices, can the effect upon the measurement results be assessed fully.

Because of the tight balancing tolerances that are demanded in aviation and aerospace, as well as the complicated assembly processes, it is usually necessary to include the complete balancing process in the assessment. A more exact picture of the quality of the complete process arises from an assessment of the interaction of the influencing variables pertaining to the balancing machine, fixtures and rotating tooling, personnel and rotor assembly.

[2] Operation to establish a relation between the outputted values of a measuring instrument or measuring equipment or the values represented by a solid measure or a reference material and the corresponding values of a measuring variable stipulated by measurement standards under given conditions (International Vocabulary of Basic and General Terms in Metrology).

[3] Property of a measurement result or of the value of a measurement standard that can be related to suitable measurement standards, generally international or national measurement standards, through an unbroken chain of comparative measurements, each contributing to the measurement uncertainty (International Vocabulary of Basic and General Terms in Metrology).

For this reason, a strategy has been established based upon two pillars: frequent self-verification in production as a preventive measure and periodic verification of conformance to critical characteristics with traceable calibrated measurement standards by appropriately qualified or accredited[4] institutions or test laboratories.

3.1 In-house checks as a preventive measure

A test only reflects the one-time, momentary status of the tested object. This means that, with longer intervals, changes due to wear or damage are detected too late. A closely-monitored in-house inspection is therefore essential, and can be instituted economically by monitoring selected characteristics in real time that fits within the framework of rotor production. In this way, effective ongoing monitoring of the balancing process is enabled such that a possible negative influence upon the balancing result, or perhaps even upon the subsequent test cell result, will be avoided.

An added benefit of in-process quality monitoring is that certain characteristics of the balancing tooling can only be completely evaluated with an original workpiece. Otherwise, an ideal substitute, referred to as a rotor simulator (dummy rotor) must be employed to evaluate those particular tooling characteristics.

3.1.1 Scope and implementation

In-house checks should comprise visual and functional checks of the following characteristics:

For periodic evaluations:

(1) Presence and completeness of the operating instructions
(2) Identification of wear during visual inspection
(3) Completeness of the fixture/tooling components
(4) No damage or corrosion of functional tooling elements (e.g. drive spline/dogs, clamping surfaces, clamping elements, safety elements)
(5) Checks of geometric surface controls, including radial and axial run-out
(6) Functional check of the bearings (heating up, noise development)
(7) Evaluation of sufficiently high clamping accuracy (repeatability)
(8) A sufficiently small tooling compensation error
(9) Influence upon unbalance measurement of the rotor simulator (dummy rotor) or of the actual engine part to be balanced.

During production operations:

(1) Visual assessment of the general condition of the tooling / fixture
(2) Documentation and evaluation of process data with regard to:
    a. Sufficiently high clamping accuracy (repeatability)
    b. A sufficiently small tooling compensation error

The operating instructions for the tooling and balancing machines must be followed with regard to handling and safety instructions. We recommend that checks are controlled on-site through incorporation in the user's process instructions and conducted by trained qualified personnel.

[4] Confirmation by a third party that shows formally that a conformity assessment body has the competence to carry out specific conformity assessment tasks (DIN EN ISO/IEC 17011).

3.1.2 Documentation and administration

We recommend the following tools for in-house audit checks:

- **Checklists**
  A suitable form with one or more relevant checklists is to be used for documentation during periodic checks. Section 0 contains an example.
- **Tooling management software**
  Software is available for the latest Schenck measuring instruments, such as the CAB 925 Aero, that tracks tooling compensation values for a specific balancing tool design using the balancing machine instrumentation. The Tooling Management software extension collects all the relevant tooling data pertaining to a specific rotor file that employs one or more identical rotating tools.
- **Data recording and administration software**
  Schenck offers suitable software for conducting balancing machine performance tests, monitoring performance of specific tools, and for conducting statistical analysis to assess control of a specific balancing process.

3.1.3 Review of audit checks

Some of the monitored characteristics, for example repeatability and tooling error during indexing, must be assigned permissible limit values to evaluate the performance of the balancing tooling. Limit values are either designated in the technical documentation or can be established using current process data from production rotors.

If limit values are exceeded, the user must take corrective actions to restore performance and permit the continued availability of the tool / fixture, if possible. We recommend publishing the required corrective actions in an internal procedural instruction. This instruction will usually contain the following steps:

(1) Blocking the particular tooling / fixture concerned (referenced by serial number) from further use
(2) Analysis of the cause of the limit value being exceeded
(3) Overhaul, repair or replacement of the suspect tooling elements involved
(4) Validation of the corrective actions through a new test
(5) Release for use following validation to an acceptable performance condition.

3.1.4 Technical support

Checks may only be carried out by specially trained and authorized personnel. Schenck RoTec GmbH offers training for qualifying these personnel.

Schenck can also offer support in the selection of suitable software for data recording and monitoring in accordance with end user requirements.

If the necessary knowledge for a complete review of a particular process is unavailable in-house, our technical personnel can review process control data and validation checks. This service will be invoiced in accordance with Schenck Terms of Service and comprises basically:

- Analysis of test and process data acquired by the user
- Review on the basis of standard key data or known limit values
- Recommendation on usability
- Documentation by means of an acceptance test certificate 3.1 in accordance with DIN EN 10204 by designated acceptance representatives.

3.2 Inspection to verify conformity

For a balancing process that is in control and conforms with standards, we recommend that balancing tooling can be inspected in detail using longer inspection intervals by a qualified agency. It is important that only appropriately qualified personnel are commissioned with this inspection responsibility, that suitable and validated methods are applied, and that traceable measuring equipment and measuring standards with a current calibration are employed.

Schenck’s test laboratory for balancing technology can provide this service if such a service is not available within the user's organization. Schenck’s laboratory possesses the necessary competence, and is accredited in accordance with DIN EN ISO/IEC 17025. Contact data:

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Laboratory procedures are adapted to the respective tooling type and, depending upon the laboratory resources that may be required, can be carried out on site at the user's premises or in the laboratory. The basis of each review is evaluated against established target values and permissible deviations. Compliance with the lower specification limits (LSL) and upper specification limits (USL) that are defined in each case is verified and validated in the laboratory. These are frequently multiple measurements with subsequent statistical evaluation of scalar or vectorial variables.

3.3 Verification interval

There are no normative specifications or standard practice for the periods between individual verifications, because only the user can assess how often each tooling / fixture is used and the extent to which each tool is loaded. The period will usually be stipulated by consultation between quality management and production. It should not be too long, so that changes can be detected at an earlier stage to preclude release of non-compliant and poorly-performing rotors.

In the absence of published guidance, verifications should be conducted annually at first, or as a result of a defined frequency of use. The interval can be extended if no significant changes to metrological characteristics occur after several verification cycles. In contrast, if there are clear changes to metrological characteristics, an increase in the frequency of the inspection interval must be adopted.

Verifications between established inspection intervals are necessary if damage or unusual wear conditions are detected during normal use.

4.0 Appendix

The following checklist is an example only, and does not claim to incorporate all inspection criteria or claim to be usable for individual balancing tools. It is for reference purposes only.

Checklist for tests of balancing devices

Name			
Manufacturer			
Inventory number			
Test interval	*xx months*	*Next test*	*xx.201x*

The following tests must be carried out at the designated interval, where applicable:

Test step	*OK*	*NOK*	*NA*
***Marking** complete and correct?* *(Identification plate, pictograms, load data, tooling/inventory number)*	☐	☐	☐
***Completeness** (in accordance with the parts list)?*	☐	☐	☐
***Damage** (paintwork, dents, scratches, etc.) to external surfaces that indicate incorrect handling?*	☐	☐	☐
***Ease of movement** (covers, chuck, moving parts)?*	☐	☐	☐
***Cleanness** guaranteed (no dirt, rust on contact points between the device and the balancing machine or balancing piece or drive)?*	☐	☐	☐
***Wear** not detected (friction marks, dents, cracks on the chuck, bearing points, drive elements and connections)?*	☐	☐	☐
***Function of frequently actuated fastening elements** normal (screws, clamping lever)?*	☐	☐	☐
***Function of the bearings** normal (e.g. easy rotatability, clean sliding or running surfaces, no unusual heat or noise development)?*	☐	☐	☐
***Function of the chuck** in order (clamping by means of control ring, leak tightness, no escaping oil)?*	☐	☐	☐
***Device unbalance** through measuring without a rotor in order?*	☐	☐	☐
***Unbalance effect of clamping errors** acceptably low?* *Effect measured through reversal balancing with rotor or dummy.*	☐	☐	☐
***Maintenance** carried out? (Device rebalanced, rust protection through light oiling of the function surfaces, device stored)*	☐	☐	☐

Test passed?	☐	☐
Notes, restrictions		

OK = in compliance; NOK = not in compliance; NA = not applicable

Checked by: *First name, surname*

Date, Signature

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