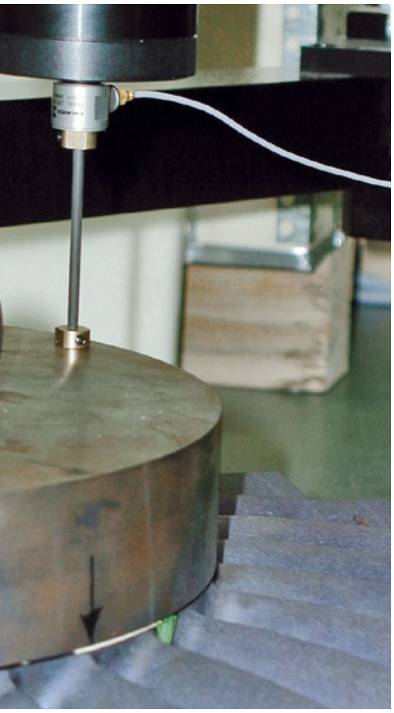


Advancing Aircraft Engine Technology
Analyzing Structural Vibrations in Compressor Wheels
Application Note

Scanning Vibrometers Visualize Localized Structural Vibrations in Integrally-Constructed Compressor Wheels (Blisk).

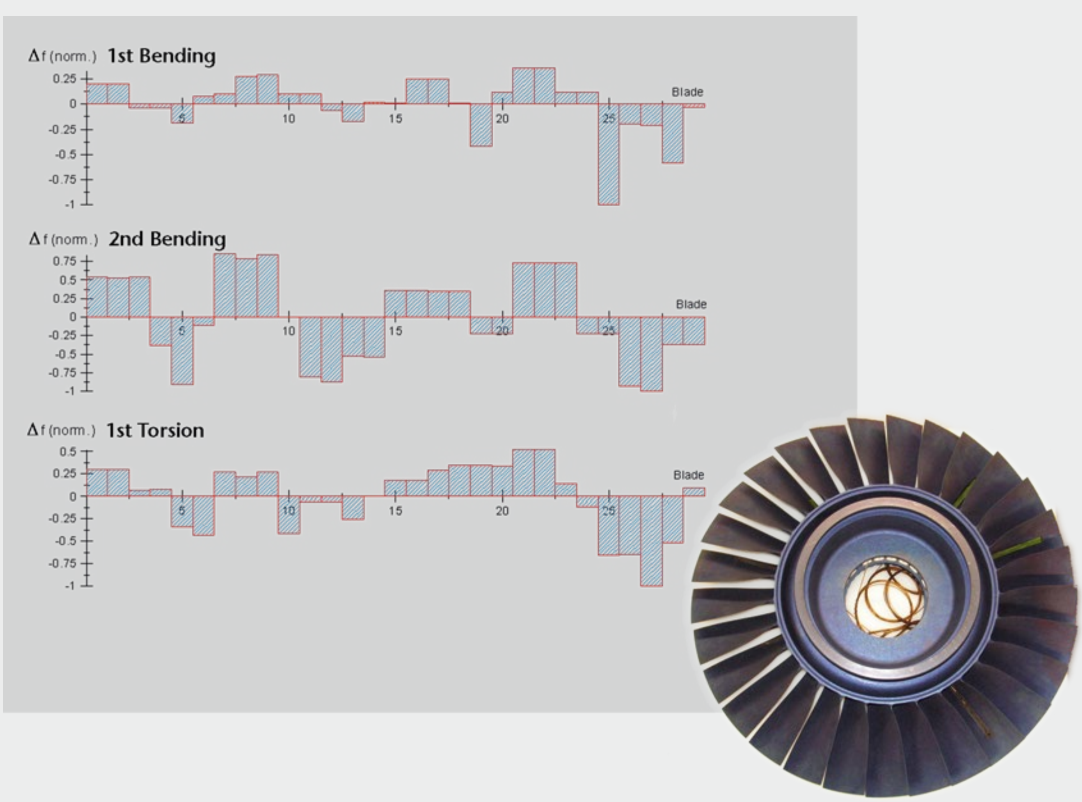
Compressor wheels for aircraft engines are increasingly being produced using integral construction. This innovative design poses a special challenge for the investigation and interpretation of vibration phenomena relevant to the service life of the wheel. A PSV scanning vibrometer makes an essential contribution to this process, since it can visualize the major modes of vibration directly.

The integral construction of compressor wheels is of great importance when it comes to meeting the demand for more environmentally friendly and higher-performance aircraft engines.
Making these structures from a single piece or using friction welding enables manufacturers to forgo weight-intensive blade root constructions. The “blisk” (blade integrated disk) construction is therefore capable of achieving higher rotation speeds and a better compression ratio than the conventional design. This does, however, give rise to a series of questions regarding its structural dynamic behavior. It is particularly important not to neglect the influence of production tolerances (mistuning), since this gives the individual blades differing vibration characteristics (Figure 1). These conditions make it possible for localization phenomena to manifest in the oscillation modes as well, which can lead to high levels of strain on the blades due to aerodynamic stimulation.

Localization Phenomena

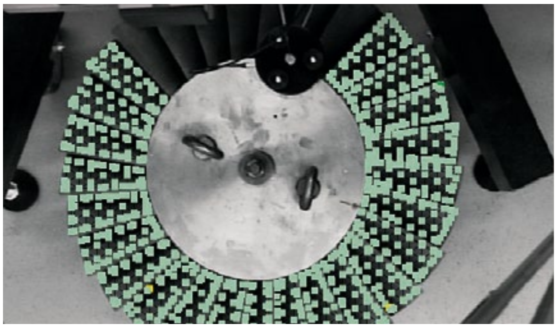
If a localized vibration is triggered during operation, the vibration amplitude will experience sharpness by a factor of 2 and will be higher than that of the ideal design. Special consideration must be given to the deformation level of individual blades affected by localization phenomena, since it has a significant negative impact on the service life.

This reduction in service life is amplified by extremely low damping, which due to the integral construction, is only comprised of pure material damping. Polytec's Scanning Laser Vibrometry is especially suitable for the visualization of modes of vibration, and thus, localization phenomena.

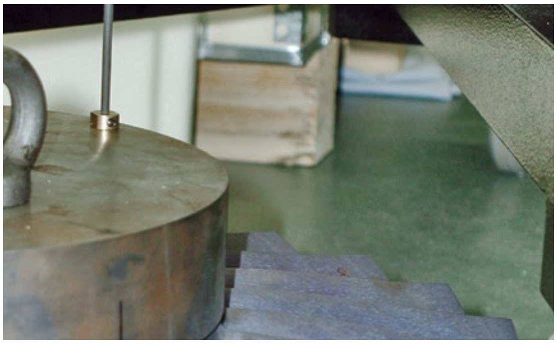


1
Test blisk and blade-alone frequencies (unrolling) in relation to individual blades

2
Arrangement of the 1128 measurement points and SG instrumented blades



3
Shaker connection



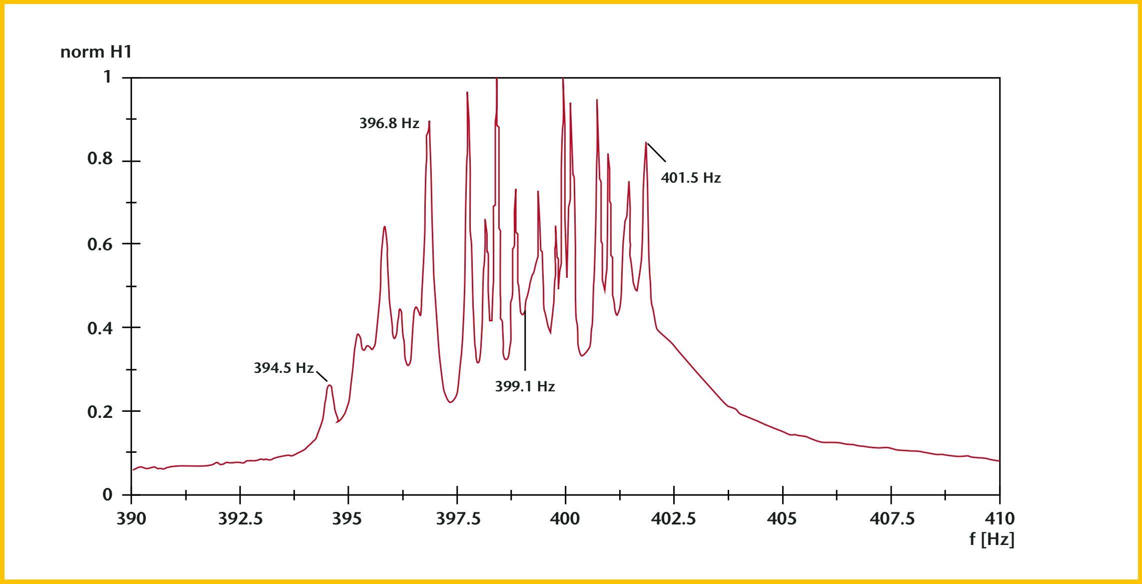
Measurement Setup

The underlying blisk (Figure 2) possesses 29 blades, of which blades 3, 9, 12, 18, 26, and 29 are equipped with strain gauges (SG). Since they inevitably introduce additional mass, damping, and stiffness, the influence of the SG on the vibration characteristics must be considered.

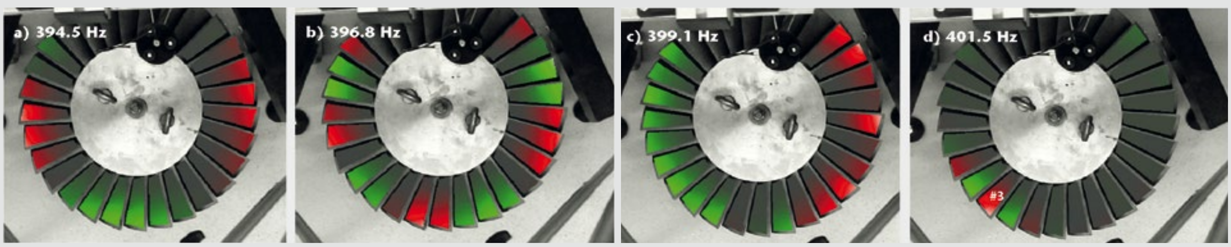
During the course of later test runs, monitoring the SG signals ensures reliable operation. It is excited using an electrodynamic shaker connected via a fastening device and and driven by a swept sine wave covering the fundamental bending frequency for the blades. The connection is designed with a reference force sensor to measure the input transmission function.

Due to shadowing effects, the coverage with the PSV Scanning Vibrometer is initially limited to 22 blades. In order to complete the mode of vibration information in the circumferential direction, measurements for a closed ring near the edges of the blades are measured in an additional scan.

4
Averaged transmission function



5
Selected Modes of Vibration



Results

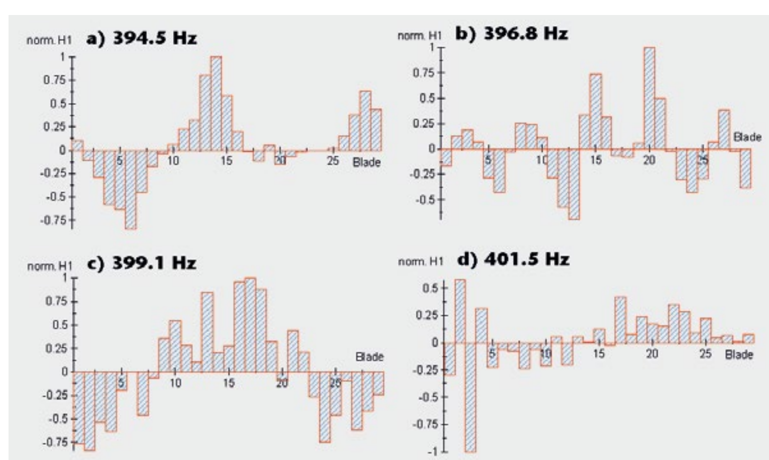
The depiction of the transmission function averaged out from all scan points (Figure 4) shows a series of peaks in the examined frequency band, resulting partially from the mistuning of the blades and partially from certain vibration modes of the coupled disk/blade movement. In figures 5 and 6, a 2D visualization of the corresponding modes of vibration is shown for a few select cases. Examples a), b) and c) are characterized by strong coupling of disk and blade movements, which manifests in the occurrence of nodal diameter lines.

Case a) corresponds to a mode of vibration with two nodal diameter lines, known as “cyclic symmetry mode 2” (CSM 2), which is deformed to a certain extent due to mistuning, therefore deviating (Figure 6) from the ideal sinusoidal shape.

Modes of vibration b) and c) correspond to the modes CSM 5 and CSM 1, while d) can no longer be readily allocated. In d), the mode of vibration is localized near blade #3, which can generally be explained by mistuning.

Furthermore, this type of vibration mode is characterized by the largely isolated movement of one blade, and in some instances of the directly adjacent blades. Blade #3 is equipped with an SG, so that tuning is further compromised by its added mass and stiffness. In preliminary experiments it was possible to prove that the associated vibration frequency of the “blade alone frequency” corresponds to the instruments of blade #3.

6
Unrolling of selected modes from figure 5 at the edge of the inlet edge



Non-contact Laser Scanning Vibrometry is Essential for Direct Analysis of True Structure Vibrations and Efficient Life Cycle Calculations

Conclusion

Non-contact investigations utilizing a laser with a Polytec's PSV Scanning Vibrometer can be utilized to identify the localization effects on compressor wheels caused by mistuning of the blades during manufacturing. Detecting such phenomena is critical to understanding and accounting for their effects in blisk service life calculations.

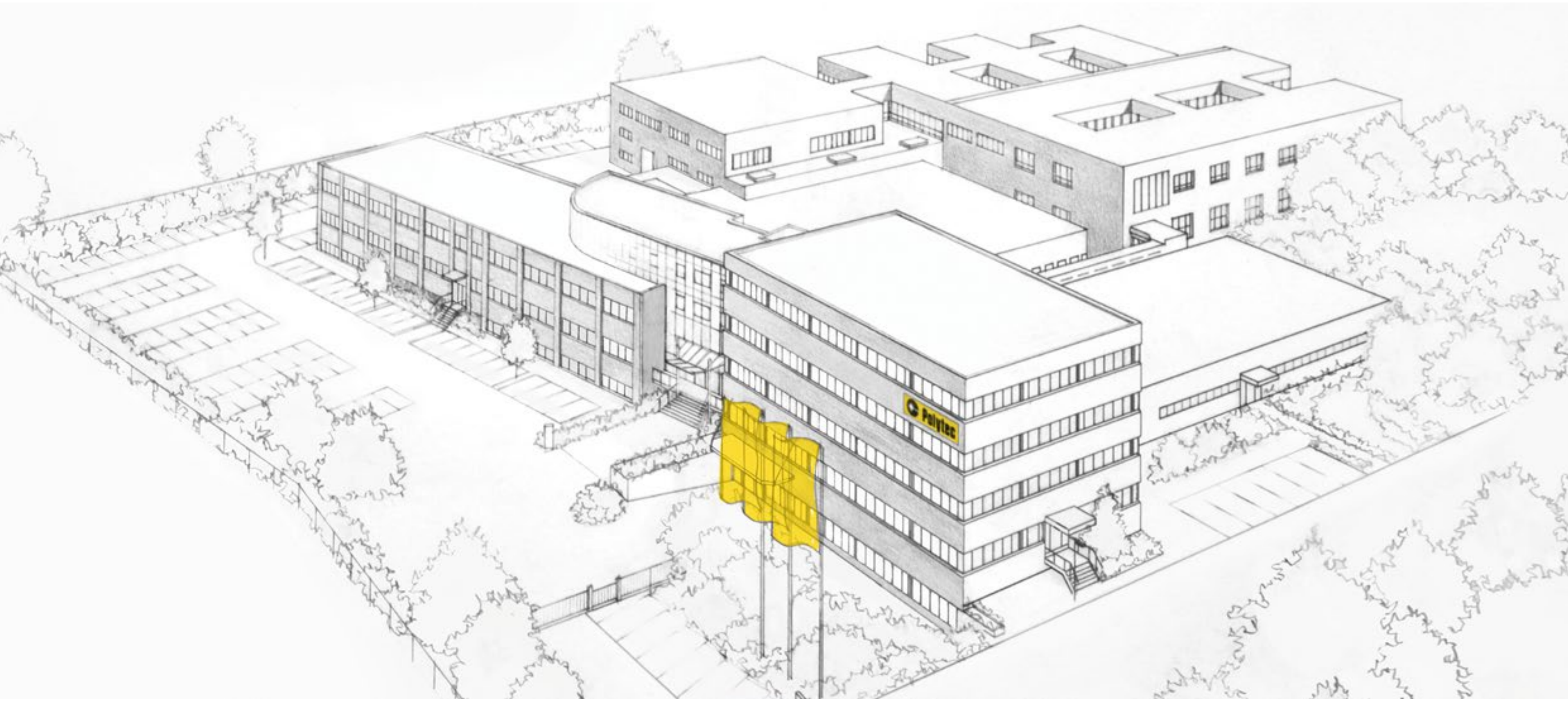
Acknowledgments

The authors would like to thank Rolls-Royce Germany for its professional and financial support for the investigations described in this article. These investigations are part of the DeSK Blisk Validation plan (FKZ: 80121978), which is funded by the State of Brandenburg and the European Regional Development Fund.

Authors

Dr.-Ing. Bernd Beirow, Brandenburg University of Technology Cottbus, Chair for Structural Mechanics and Vehicle Vibrations, Siemens-Halske-Ring 14, 03046 Cottbus, beirow@tu-cottbus.de

Polytec



Polytec GmbH (Germany)
Polytec-Platz 1-7
76337 Waldbronn
Tel. +49 7243 604-0
info@polytec.de

Polytec GmbH (Germany)
Vertriebs- und Beratungsbüro
Schwarzschildstraße 1
12489 Berlin
Tel. +49 30 6392-5140

Polytec, Inc. (USA)
North American Headquarters
16400 Bake Parkway
Suites 150 & 200
Irvine, CA 92618
Tel. +1 949 943-3033
info@polytec.com

Central Office
1046 Baker Road
Dexter, MI 48130
Tel. +1 734 253-9428

East Coast Office
1 Cabot Road
Suites 101 & 102
Hudson, MA 01749
Tel. +1 508 417-1040

Polytec Ltd. (Great Britain)
Lambda House
Batford Mill
Harpenden, Herts AL5 5BZ
Tel. +44 1582 711670
info@polytec-ltd.co.uk

Polytec France S.A.S.
Technosud II
Bâtiment A
99, Rue Pierre Semard
92320 Châtillon
Tel. +33 1 496569-00
info@polytec.fr

Polytec Japan
Arena Tower, 13th floor
3-1-9, Shinyokohama
Kohoku-ku, Yokohama-shi
Kanagawa 222-0033
Tel. +81 45 478-6980
info@polytec.co.jp

Polytec South-East Asia Pte Ltd
Blk 4010 Ang Mo Kio Ave 10
#06-06 TechPlace 1
Singapore 569626
Tel. +65 64510886
info@polytec-sea.com

Polytec China Ltd.
Room 402, Tower B
Minmetals Plaza,
No. 5 Chaoyang North Ave
Dongcheng District
100010 Beijing
Tel. +86 10 65682591
info-cn@polytec.com

www.polytec.com

OM_AN_VIB_A_002_Turbines_E_42469
2018/01 - Technical specifications are subject to change without notice.