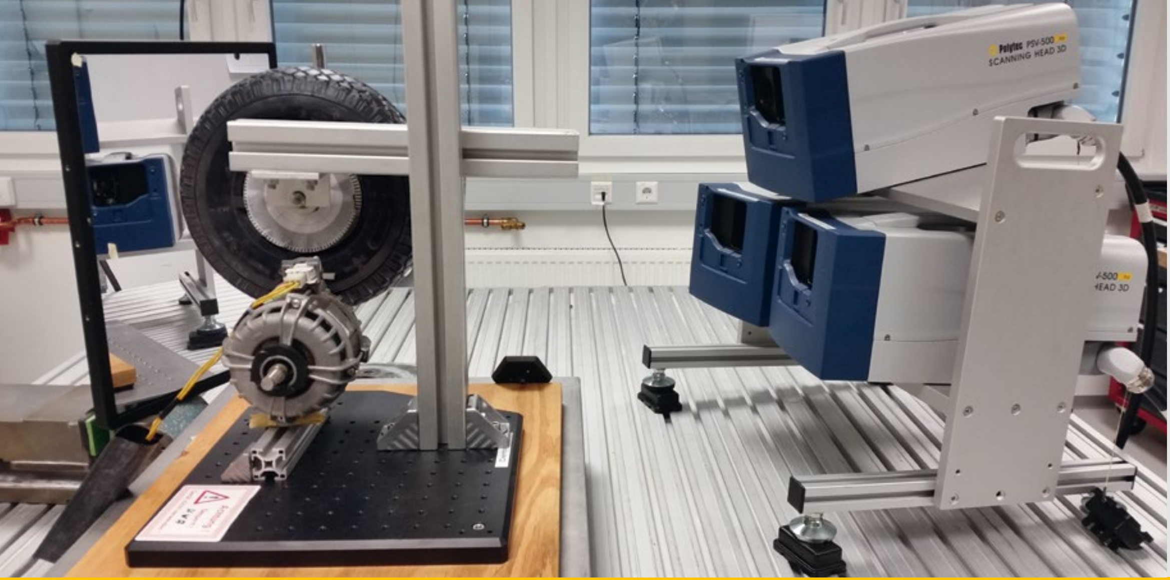
Understanding Road Noise

Xtra 3D Scanning Vibrometry on Rolling Tires

Application Note



1

Laboratory Setup. The three Vibrometer Sensor Heads are mounted to a common frame (right side). The roller test bench is to the left with the tire on top and the motor on the bottom. The mirror on the far left is used to simplify the repositioning of the vibrometer scan pattern.

Dynamic 3D Operational Deflection Shapes Captured with an Xtra Scanning Vibrometer Help Reveal the Source of Rolling Tire Noise.

For a wide range of driving conditions, rolling tires stimulate a significant amount of passenger car noise (NVH) within and external to the passenger cabin. This rolling tire noise must be addressed for three important reasons:

- Road noise from rotating tires reduces the driving experience and disturbs neighborhoods along the roadway.
- New regulations limiting tire noise are expected in many countries concerned with urban area noise.
- With no internal combustion engine noise, the exceptional quiet of electric cars can be ruined by tire-generated noise.

Consequently, to limit the amount of tire noise, a better understanding of the dynamic mechanism producing the noise is critical and, for that understanding, the precise measurement of the vibration behavior of the rotating tire surface is mandatory. Classical measurements that use simple microphones to quantify the noise amplitudes inside and outside of a car provide almost no insight into the precise physical origins of the noise. Even accelerometers placed at critical locations can't give the spatial and frequency resolution needed for accurate characterization. Basically, classical NVH measurements and methods are not helpful to solve this problem.

Non-contact 3D Scanning Vibrometry as Measurement Solution

For modal testing on tires, the full-field or Scanning Vibrometry is the ideal choice. And in this application the upgrade option with the Xtra optical sensitivity shows its full potential, allowing measurements directly on black rubber without the need of surface preparation. Here, the Xtra Polytec Scanning Vibrometers enabled measuring on rotating tires with rotational speed equivalent to a driving speed of about 100 km/h.

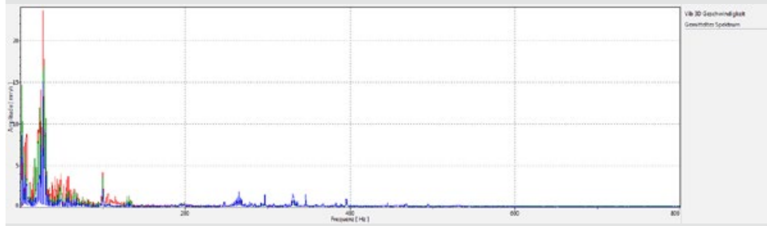
Polytec developed the Xtra Vibrometer using an infrared laser source to facilitate measuring on uncooperative surfaces. The Xtra Vibrometer is still eye safe (class II), has a visible pilot laser and has extra sensitivity as well as a 2.5x increase in maximum velocity up to 30 m/s. Now, the Scanning Vibrometer with this optional Xtra technology can measure deflection shapes of rotating tires much more simply, giving faster and more accurate insight into the origin of tire noise.

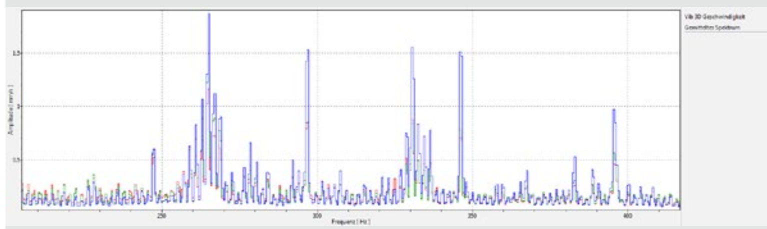
Test Setup

A laboratory version of a "roller test bench" was built to verify the ability of the new Xtra 3D Vibrometer system to improve and simplify the capture of data on a real rolling tire. The rudimentary test fixture consisted of a small 25 cm diameter tire rolling on top of the drive shaft of an electric motor. The Xtra 3D Scanning Vibrometer had its three heads mounted into a common frame and placed on the lab table near the test bench. This common frame simplified the repositioning of the heads when covering different portions of the tire. A large mirror was also used to access different portions of the tire without movement of the common frame.

With this simple measurement setup, similar results were achieved when compared to those obtained with a real car tire on a commercial roller test bench. In Fig. 2, the averaged spectrum over all points along the three directions (see the three different colors) is shown. In Fig. 3, an expanded scale shows the details of the spectrum from 200 Hz to 400 Hz. A comb-like feature is easily distinguished in the spectrum. This feature is also observed in real roller test bench studies using the Xtra Scanning Vibrometers. The peaks in this comb feature occur at multiples of the rotation speed of the tire. For tires with a tread pattern, this can be explained by the periodic contact of the treads (and the air pockets in-between) with the road surface. Clearly, using this measurement setup allows the effect of tread design on the structural resonances of the tire to be seen at different speeds and under different loading conditions.

2
Complete spectrum averaged over all points. Orthogonal vibrations x,y,z, are represented as separate colors



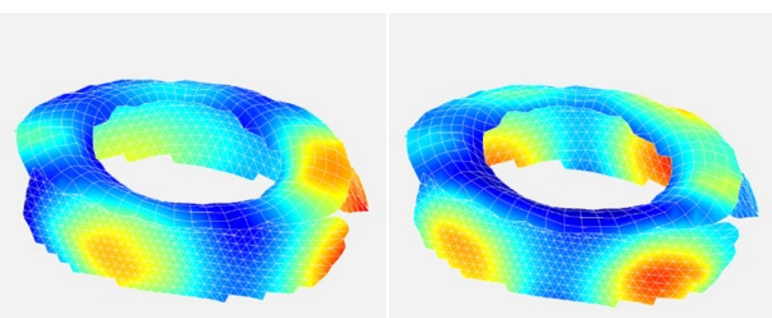


3
Detailed spectrum from Fig. 2 shown centered around 300 Hz

Simplified Capturing of Deflection Shapes

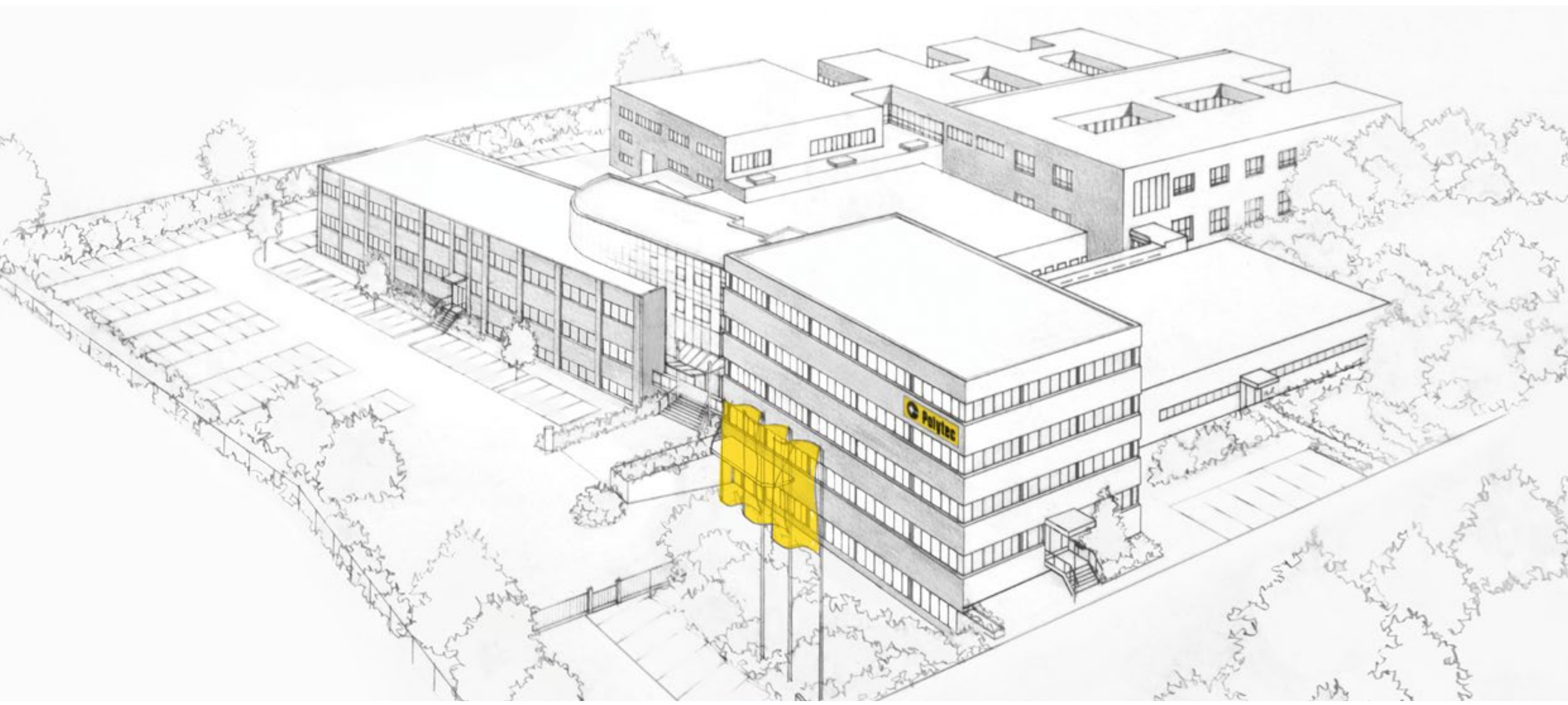
With the Xtra Sensor Heads, a much larger area of the rolling surface can be measured. When the first measurement is completed, the heads are repositioned to capture the second rolling surface. The second position is known relative to the first position by using reference points with known position coordinates detected by a built-in distance sensor. In this way, the results of each surface measurement can be stitched together, leading to only one complete deflection shape and one animation. Using this stitching technique allows even the side wall measurement, facilitated by the mirror, to be included. By extending this technique, the tire can be covered quickly with relatively large surface portions measured with the Xtra Vibrometer Sensor Heads and stitched together. The Xtra option permits an excellent signal-to-noise ratio (SNR) despite the fast rotating black tire surface and the larger measurement areas. Some typical deflection shapes are shown in Fig. 4, respectively at 396 and 468 Hz. The typical pattern of several maxima on the rolling surface can be clearly observed. Very similar results are obtained in commercial tire test stands.

4
Measured deflection shapes at 396 and 468 Hz



In conclusion, the optional infrared sensing technology for 3D Scanning Vibrometers has clearly captured the spectral patterns and deflection shapes of the fast-moving rolling surfaces, yielding important information on the vibration behavior of the tire surface which is at the origin of the emitted noise. These precise results combined with numerical simulations of tires will allow the refinement of FE models and the control and minimization of rolling tire noise through the design of better tires.

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_C_008_Tire_Testing_E_42457
2017/05 - Technical specifications are subject to change without notice.