47TH TURBOMACHINERY & 34TH PUMP SYMPOSIA
HOUSTON, TEXAS | SEPTEMBER 17-20, 2018
GEORGE R. BROWN CONVENTION CENTER

Use of Motion Amplified Video to Diagnose Pump Vibration

Maki M. Onari
Mechanical Solutions, Inc.

Mechanical Solutions, Inc.
Engineering Analysis, Test & Technology

TEXAS A&M UNIVERSITY

TURBOMACHINERY LABORATORY
TEXAS A&M ENGINEERING EXPERIMENT STATION

Maki M. Onari

MSI Machinery Testing Manager

Graduated from Zulia University in Venezuela

Was Machinery Maintenance Engineer 8 Years at PDVSA

Co-Author Mechanical Behavior Chapter Pump Handbook

Alternate Member ISO TC108 Machinery Vib Committee

Abstract

Use of Operating Deflection Shapes (ODS) has become an accepted method for understanding and diagnosing pump and other turbomachinery vibration problems.

The data acquisition can take a long period of time, and requires a large number of expensive probes, with associated FFT analyzer channels.

New video magnification techniques can supplement or replace ODS, although there are pluses & minuses to each method.

ODS Allows You to “See” Vibration

- Operating deflection shape (ODS)
  - Acquire vibration data from various points on machine (hundreds of vibration measurements)
  - Database of amplitude vs. frequency and phase angle
  - 3-D CAD model assigning motion from each individual vibration data point
  - Amplify/filter and create animations of the equipment

Pump ODS Case History

- Application: Multi-stage Barrel Nuclear Charge Pump
- Speed: 4,800 rpm (80 Hz)

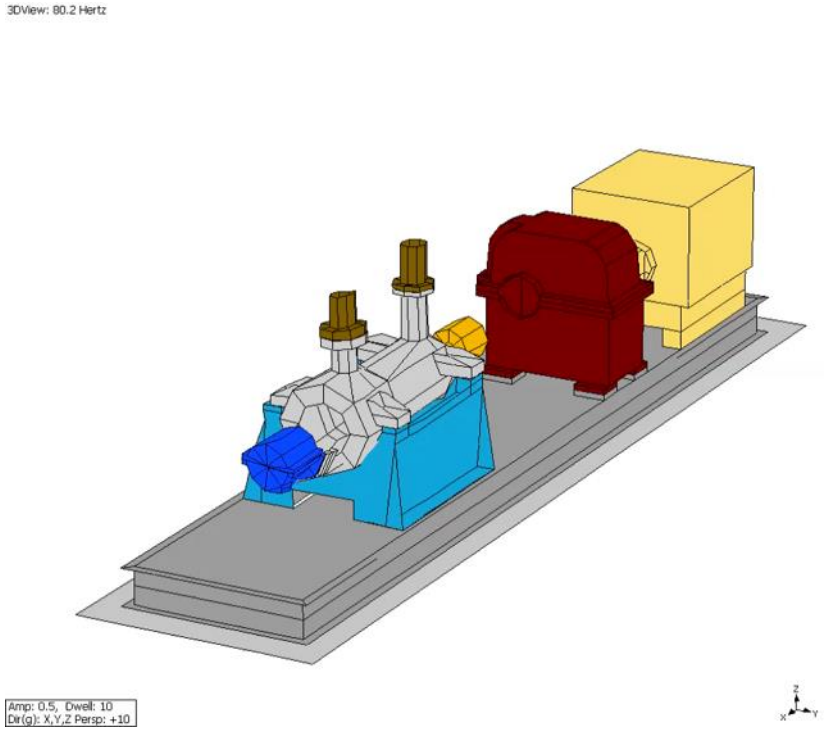
The Problem

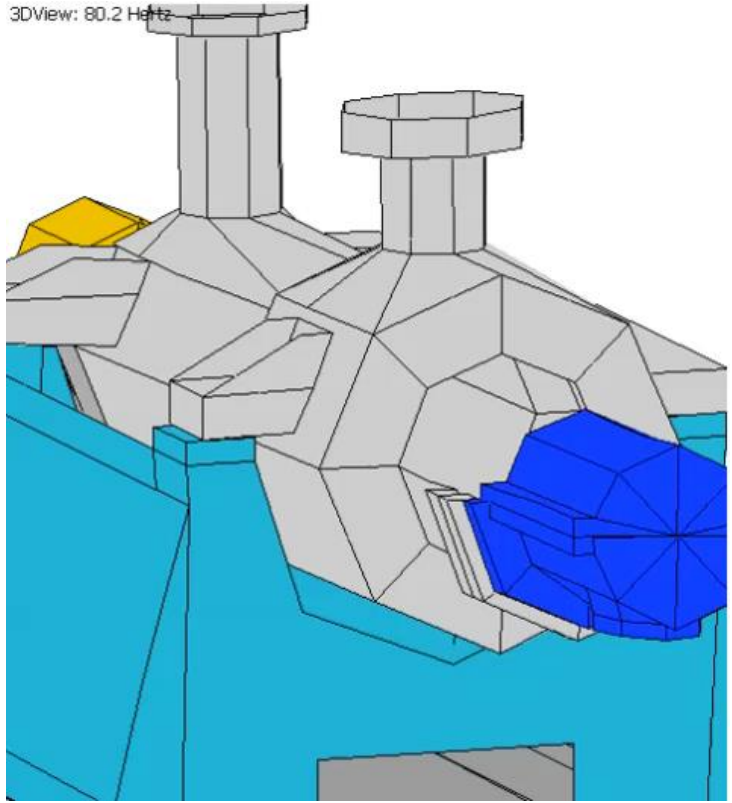
- Inconsistent vibration levels up to 0.6 ips peak
- Varying phase angle readings up to 180°

Testing & Analysis Approach

- Impact modal testing during operation
- 200-point 3-D ODS of pump/driver/foundation

ODS Animation at 1x rpm





Conclusions and Recommendations
(After 2-1/2 Days of Testing & Evaluation)

- Soft foot condition
  - Responsible for shifting natural frequency down to operating range
  - Validated through FEA model
- Tighten pump foot contact
  - Resolved the vibration problem
  - A simple solution that had eluded the plant until the detailed "bird's eye" type visual information from ODS

Lessons Learned: Accelerometer-Based ODS Pros and Cons

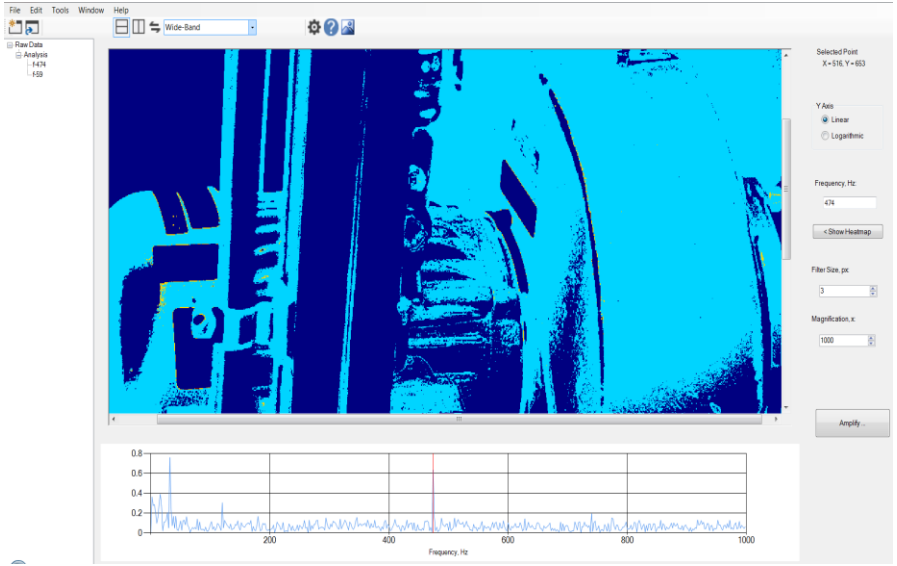
- ✓ Powerful and intuitive diagnostic tool, showing vibration
- ✓ Proven over decades of application
- ✗ Time consuming
  - Data acquisition – 100's of points, & post-processing
- ✗ Potential for bookkeeping error
  - Match all data points to appropriate place on model
- ✗ Requires proximity – not appropriate for restricted access
  - Heat, radiation, accessibility/scaffolding requirements

An Alternative Method to "See" Vibration: Motion Amplified Video

- Uses high-speed, high resolution video
  - Millions of accelerometer-type data points, 1 per pixel
- Analyzes/quantifies motion
  - Frequencies
  - Displacement (however- only 2-dimensional)
- Algorithms amplify motion to human visual threshold
  - Filterable by desired frequencies, like ODS

Video Motion Amplification: Slow Motion – Magnified Amplitude

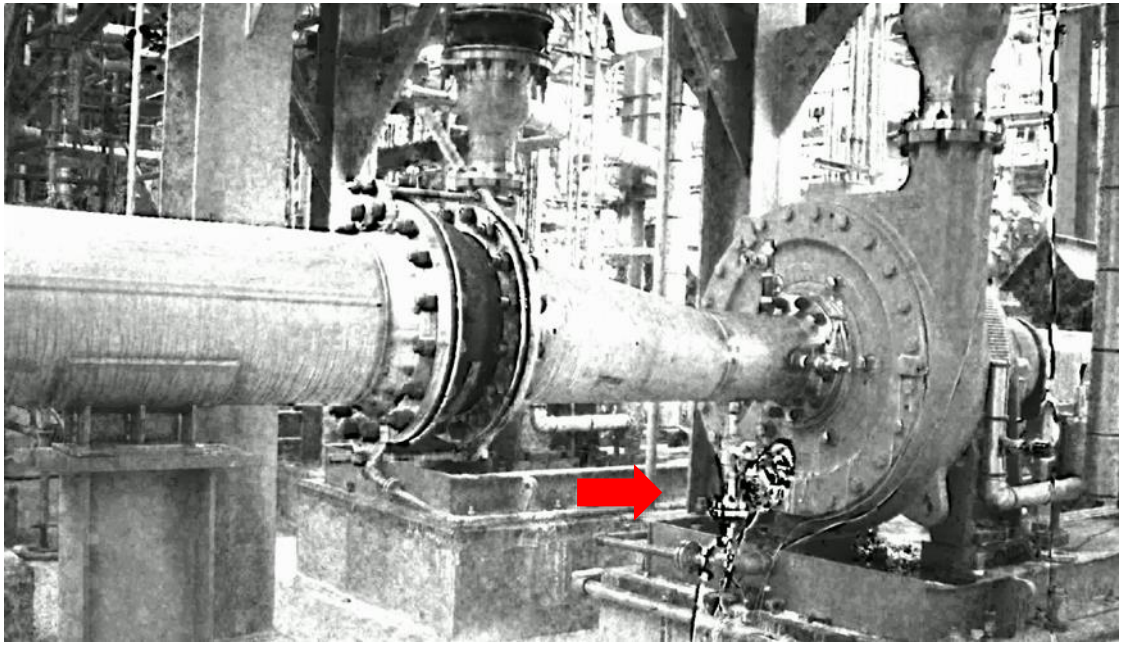
- High-speed, high-resolution video frames
- Specialty Software
  - Analyzes pixels for vibration signature
  - Locates frequencies of interest
  - Amplifies as well as slows motion at key frequencies



MAV Case History: Petrochemical Process Pump with Process Line Vibration at 59 Hz Causing Fatigue

- The line was breaking at the neck.
- Video shows problem was cantilever vibration at vane pass.
- Pressure pulsation indicated low-flow suction recirculation provided the forces.
- **Fix (see motion in video at arrow)**: A simple brace to detune the fn.

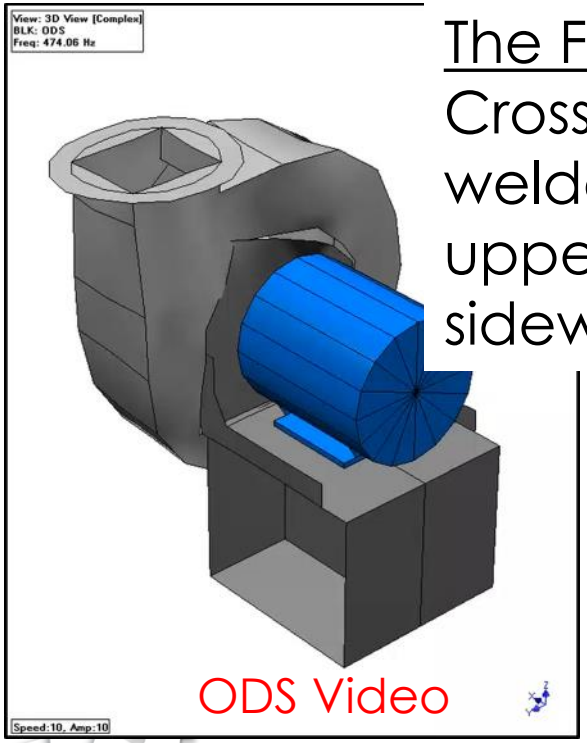
Note: Video will play during presentation



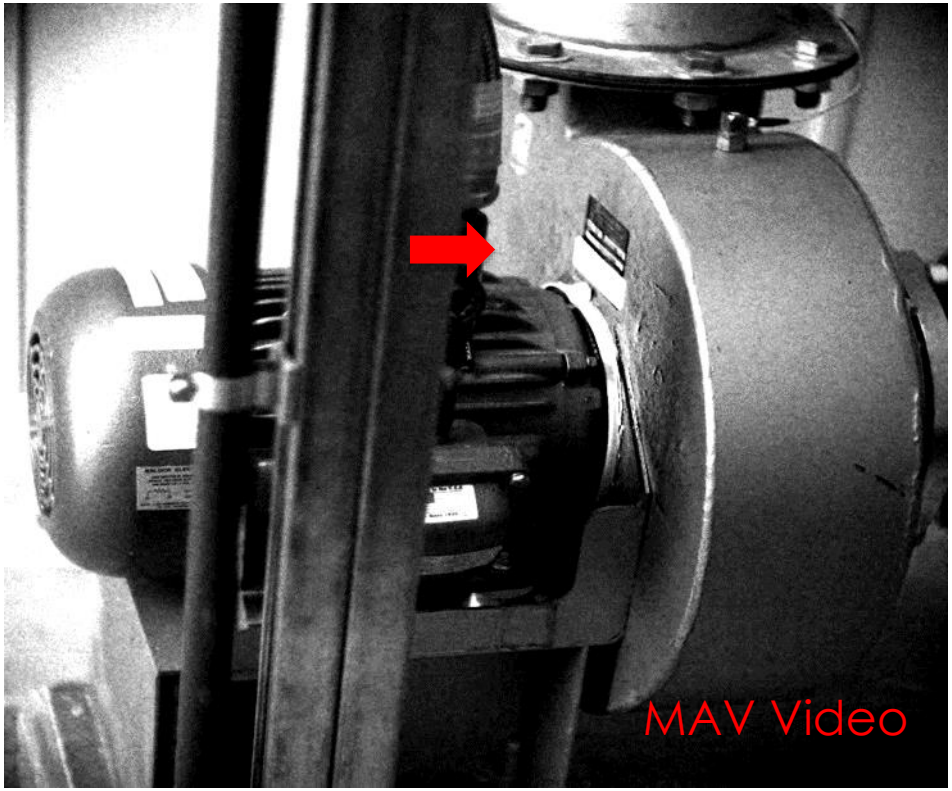
MAV Pumping Plant Case History 2: Constant Speed Blower in Wastewater Pump Plant

- 59.4 Hz speed, 8 blade fan
- 474 Hz vane pass frequency
- 120 dB noise despite good vibs
- Both video and accelerometer based ODS reveal breathing mode of the volute, like loudspeaker
- Video was much faster & easier.
- The video system had to be high fidelity & high frequency

Vane Pass Frequency ODS vs. Video (474 Hz)



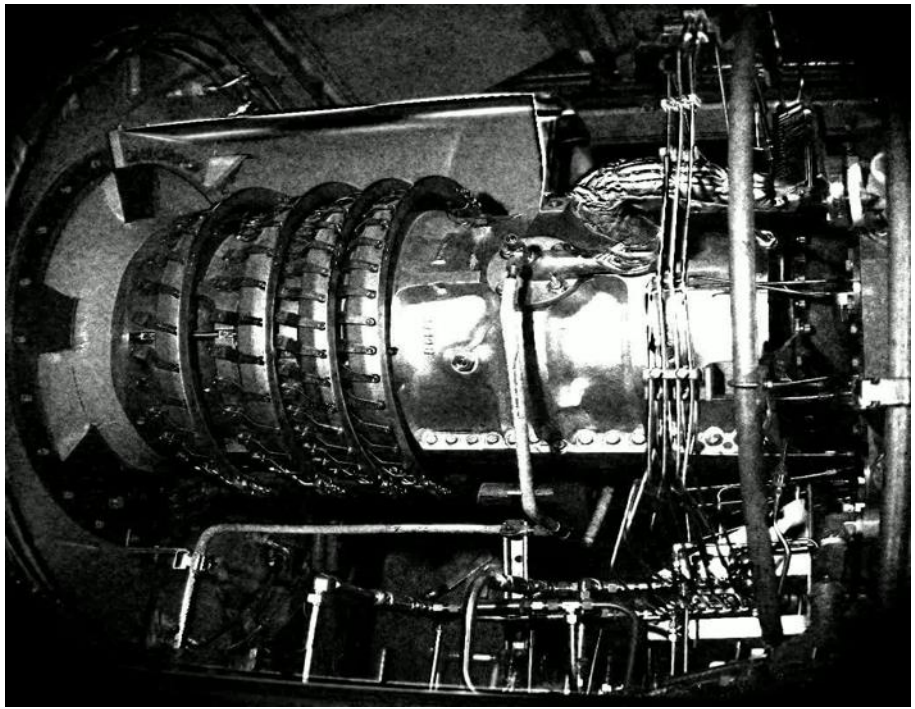
The Fix:
Cross-bar welded to upper sidewalls



Note: Videos will play during presentation

MAV Pumping Plant Case History 3: Gas Turbine at 253 Hz Providing Co-Gen Power to NYC Wastewater Plant

Note: Video will play during presentation



Potential Problem:
Plant concerned about local vibrations being high.

Conclusion:
Motions & stresses acceptable

Motion Amplified Video Benefits

- ✓ Powerful and intuitive diagnostic tool
  - Realistically demonstrates modes and frequencies of vibration
  - Easy for non-experts to understand (management, etc.)
- ✓ Does not require "contact" – perfect for restricted areas
  - Heat, radiation, accessibility/scaffolding requirements
- ✓ Fast
  - Millions of data points ready to view/analyze in minutes, not days. Can help focus detailed ODS, if still required.
- ✗ However, is 2-D only, and may be limited in highest frequency and/ or lowest detectable vibration

Lessons Learned:
ODS vs Motion Amplified Video (MAV)Pros & Cons

- Either is a powerful addition to a large plant's maintenance troubleshooting tool-kit
  - ODS is 3-D, but MAV is typically much faster
- Both are comprehensive, and intuitive
  - Either is sufficient for many applications
  - Either works effectively in tandem with additional tools such as orbits and waterfall plots
- MAV is recently available from various sources