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Using Cell Phone Videos to Diagnose Machinery Faults

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ABSTRACT

Nearly everyone carries a cell phone in their pocket, including field technicians, engineers, and plant managers. Extracting vibration signals from a cell phone or tablet video offers a low-cost alternative to traditional methods for monitoring the health of plant operating equipment.

In this paper two case studies are presented where vibration signals are extracted from cell phone videos and used to diagnose machinery faults. It is shown how time-based or frequency-based Operating Deflection Shapes (ODS's) of a machine or structure can be used to visualize and analyze machine faults.

In each case study, diagnosis of a real-world machine fault is presented. In the second case study, the video results are compared with accelerometer results to confirm the validity of this new non-contacting measurement method.

KEYWORDS

Operating Deflection Shape (ODS): The deflection of two or more points and directions on a machine or structure

Time Waveform (TWF): A time waveform in digital form, extracted either from frames of a video or from an analog accelerometer signal

Digital Fourier Transform (DFT): A DFT is calculated from a TWF using the Fast Fourier Transform (FFT) algorithm

ODS-FRF: a frequency domain function with magnitude equal to the Auto spectrum of a response signal combined with the phase of the response relative to a fixed reference response.

INTRODUCTION

Most power plants, oil refineries, and manufacturing plants worldwide have implemented route-based machinery health monitoring programs for accessing the health of their rotating machinery and equipment. Digital vibration signals are typically acquired and processed to detect and diagnose faults in operating equipment.

Traditionally, machine health monitoring has been done by attaching accelerometers to the surfaces of the operating equipment, and vibration signals are acquired from the accelerometers with a portable digital spectrum analyzer. This method of acquiring data is expensive, time consuming, and cannot be used on hot or inaccessible parts of a machine or structure.

Over the past 20 years, Optical Flow algorithms [1], [2] have been developed for extracting dynamic features and time waveforms from a high-speed video recording. These algorithms are now being used in many new applications, including autonomous vehicles, robotic vision, and other non-contacting measurements such as vibration.

In a previous paper [3], we presented this new method of extracting time and frequency waveforms from frames of a video. Time or frequency waveforms can then be used to deform points in each frame of a video so that the Operating Deflection Shape (**ODS**) [4]-[6] of an operating machine can be visualized in animation.

If this paper, two different case studies are discussed, and the video processing capability in the MEscope software package [7] is used to derive and present the results.

Video ODS Analysis

MEscope Video ODS™ is a vibration analysis software package the extracts TWFs, DFTs, and ODS-FRFs from a high-speed digital video recording. A video clip is processed with the Optical Flow Algorithm [1], [2] which enhances the subtle displacements and re-scales the amplitudes.

This processing allows the user to **"see"** what the human eye cannot perceive in a raw video playback; either because the event is too fast, or because the displacements are too small, or both.

Video ODS makes vibration analysis visible and understandable to customer's entire management team so everyone can be involved in defining and implementing asset management solutions to machinery health problems.

Time-Based Sweep Animation

A time-based Video ODS is animated by sweeping a line cursor through a set of TWFs extracted from a video.

Frequency-Based Dwell Animation

A frequency-based Video ODS is animated with sinusoidal modulation at the frequency of the line cursor in a set of DFTs or ODS-FRFs.

CASE #1 - Induced Fan Vibration Analysis

This unit was located in a power plant. Data was captured with a Cell Phone Camera mounted on a tri-pod.

Video Camera: iPhone 10 SE
Frame Rate: 240 fps
Resolution: 1080p HD
Video Mode: "Slo-Mo"
Trigger: Blue Tooth (start/stop)
Clip Duration: 15-20 sec

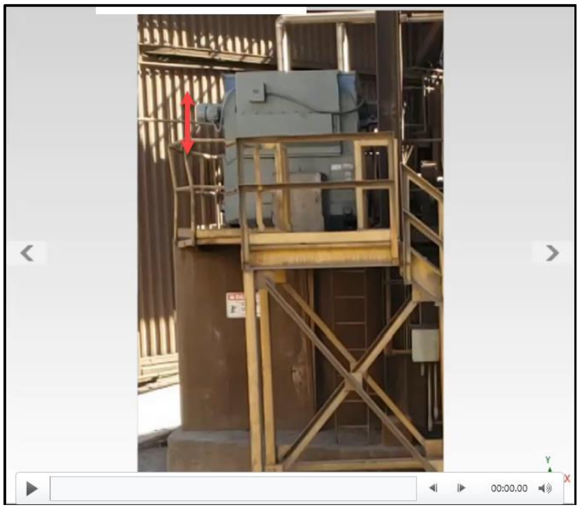

Figure 1. Vertical Motor Motion

Figure 2. Horizontal Motor List

Signal Processing

Time Domain (TWF): extracted from the video using the Optical Flow algorithm

Frequency Domain (DFT): Each DFT was calculated from a TWF

Operating Deflection Analysis (ODS-FRF): Each ODS-FRF was calculated from a TWF

Overlap Processing: 25 spectrum averages with 95% overlap processing between averages

Cell Phone Frame Rate: 240 fps → 240 Hz

FMAX of the FFT: 120 fps → 7200 RPM

Figure 3. Torsional Vibration

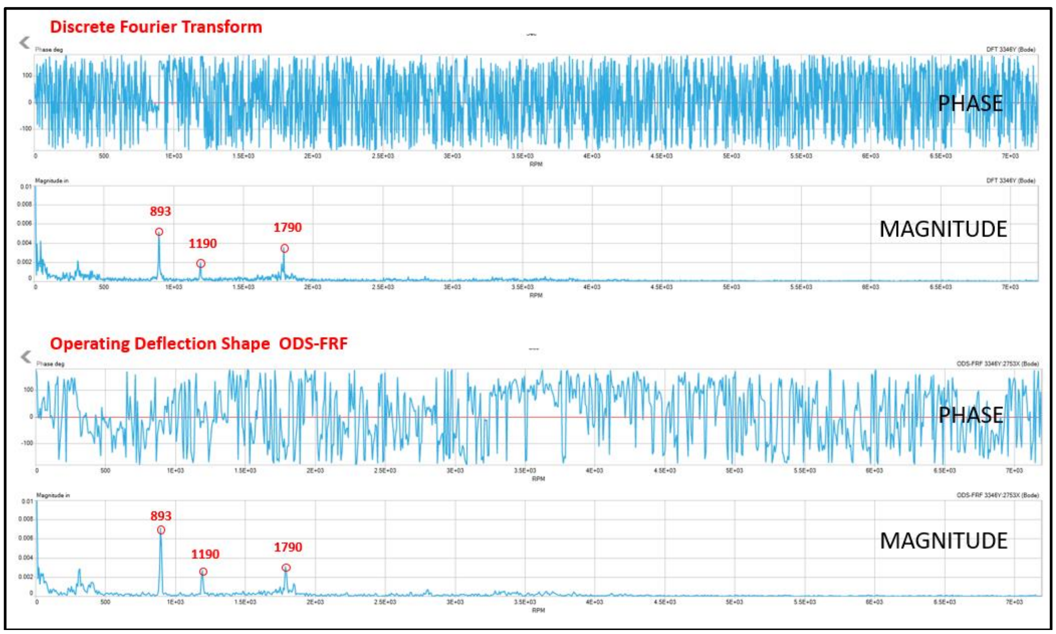

Figure 4. DFTs and ODS-FRFs

Case #1 Analysis Summary

The customer noticed elevated and increasing vibration levels in the outboard motor location. The Video ODS analysis quickly pin-pointed an odd vertical motion in the motor (Figure 1). The perpendicular (axial) view suggested a horizontal "list" in the motor (Figure 2). The elevated vantage point (Figure 3) showed an overall torsional response in the motor.

The Video ODS Analysis quickly pin-pointed a soft foot issue at the motor outboard mount.

Even though it was late in the day and the unit was **"in shadow"**, no external lighting was required.

Most applications require only a cell phone camera and do not require additional lighting.

Figure 4 shows that both the DFT and the ODS-FRF identified the running speed, or first order, of the machine at **893 RPM**. The second order peak is also very prominent at **1790 RPM** in both frequency functions

The Video ODS Analysis indicated a **horizontal twisting response** in the motor.

The Video ODS Analysis quickly pin-pointed a soft foot issue at the motor outboard mount.

CASE #2 Concentrator Processing Vessel Vibration Analysis

This unit was located in a Sugar Refinery. Data was captured with a Cell Phone Camera mounted on a tri-pod.

Video Camera: iPhone 10 SE
Frame Rate: 240 fps
Resolution: 1080p HD
Video Mode: "Slo-Mo"
Trigger: Blue Tooth (start/stop)
Clip Duration: 15-20 sec

Figure 5. 70 Foot-Tall Sugar Refiner

Figure 6. Column with Light Attached

The customer noticed vibration problems initially from the lights mounted on the framework. The size of this structure was challenging by way of traditional accelerometer-based ODS analysis. The six I-beam columns were 70 feet tall. Overall, the structure was 70 x 35x 15. The Video ODS made easy work of defining the structural natural frequencies. A traditional accelerometer-based analysis of the structure verified the frequencies and amplitudes.

Asset Description

This tower is the main part of a Concentrator Process. There is no rotating equipment on the framework platform or internal agitation. The only source of vibration is internal turbulence in the process itself or possible wind loadings that might induce unstable vortex shedding around the tanks.

Video Analysis

A series of cell phone video clips were acquired at various locations and direction on the tower. The camera was an iPhone 10 with frame rate set to 240 frames-per-second (fps). The 1080p videos was set to "Slo-Mo". The video clips were processed with the MEscope Video ODS™ software.

Analysis Summary

The Video ODS analysis revealed a definite frame and tank motion at 180 CPM (3 Hz). The excitation source was likely random wind gusts, (vortex shedding).

Traditional ODS Analysis

A traditional Operating Deflection Shape (ODS) analysis was performed on the tower structure. This analysis is a accelerometer-based vibration analysis. Roving vibration measurements were acquired which provided amplitudes and phases throughout spatial locations on the tower structure. A fixed reference accelerometer response is compared to each roving response to define the magnitude and phase of its motion relative to the reference. When the data is animated, a visual ODS of the structure immerges.

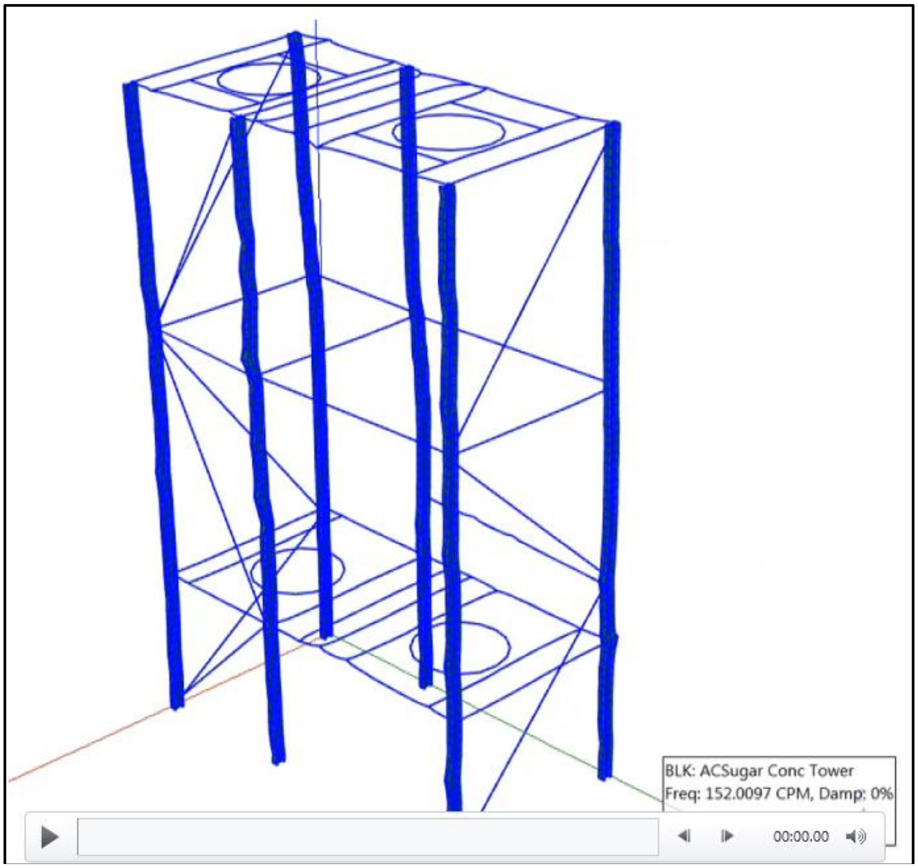

Figure 7. ODS of the Tower from Accelerometers

ODS Analysis Summary

A resonance peak was identified in this spectral response of the tower at **152 CPM (2.53 Hz)**. The ODS of this response confirmed this mode shape as the first bending (1B) mode shape of the frame structure.

CONCLUSIONS

Most rotating machines and attendant structures have phase-related problems such as unbalance, eccentricity, looseness, mis-alignment, bent shafts, and resonance amplification. Video ODS analysis is ideal for detecting and defining these phase-related problems.

To analyze phase-related vibration below **120 Hz (or 7200 CPM),** a cell phone is more than adequate as a low-cost non-contacting device for acquiring data and displaying it in animation as a Video ODS. Another benefit is that artificial lighting is not required in most cases.

Time waveforms (**TWFs**) can be extracted from ***any digital video recording*** **using the MEscope Video ODS™** software. Both time-based and frequency-based ODS's can be extracted from this data and displayed in animation on frames of the video to give a quick look at vibration problems in any operating machine or its attendant structure. When ODS data is used in this way, deflections of the test article are clearly seen, giving plant maintenance engineers, vibration analysts, and management a clear picture of a machinery health problem.

Video ODS makes vibration analysis visible and understandable to the entire management team so everyone can be involved in defining and implementing asset management solutions to machinery health problems.

REFERENCES

[1] - Farnebäck G. (2003) Two-Frame Motion Estimation Based on Polynomial Expansion. In: Bigun J., Gustavsson T. (eds) Image Analysis. SCIA 2003. Lecture Notes in Computer Science, vol 2749. Springer, Berlin, Heidelberg

[2] - https://nanonets.com/blog/optical-flow/

[3] - B. Schwarz, S. Richardson, J. Tyler, R. Spears, M. Richardson, "Post-Processing ODS Data from a Vibration Video" IMAC XXXVIII Houston, TX, February 10-13, 2020.

[4] - M.H. Richardson, "Is It a Mode Shape or an Operating Deflection Shape?" Sound and Vibration magazine, March 1997.

[5] - B. Schwarz, M.H. Richardson, "Measurements Required for Displaying Operating Deflection Shapes" Proceedings of IMAC XXII, January 26, 2004

[6] - B. Schwarz, M.H. Richardson, "Introduction to Operating Deflection Shapes" CSI Reliability Week, Orlando, FL, October 1999

[7] - MEscope™ is a trademark of Vibrant Technology, Inc. www.vibetech.com