DWT®
DarkWave Thermo® diagnostic & reliability excellence

EPFL

IRIS M
Enhancing Vision

Motion Amplification®
The new era in vibration measurement & root cause analysis

EPFL Lausanne - 6th May, 2024

Dipl. Ing. Luca Del Nero
DarkWave Thermo Schweiz KLG

Official Partner
itc INFRARED TRAINING CENTER

RDI TECHNOLOGIES | SEEING IS BELIEVING

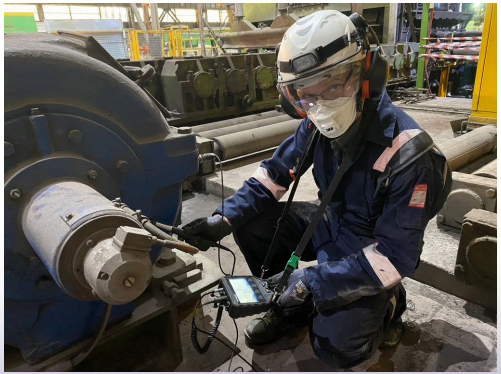
SPM
[Licensed SPM Partner]

DWT®

DarkWave Thermo® diagnostic & reliability excellence

EPFL

DWT®



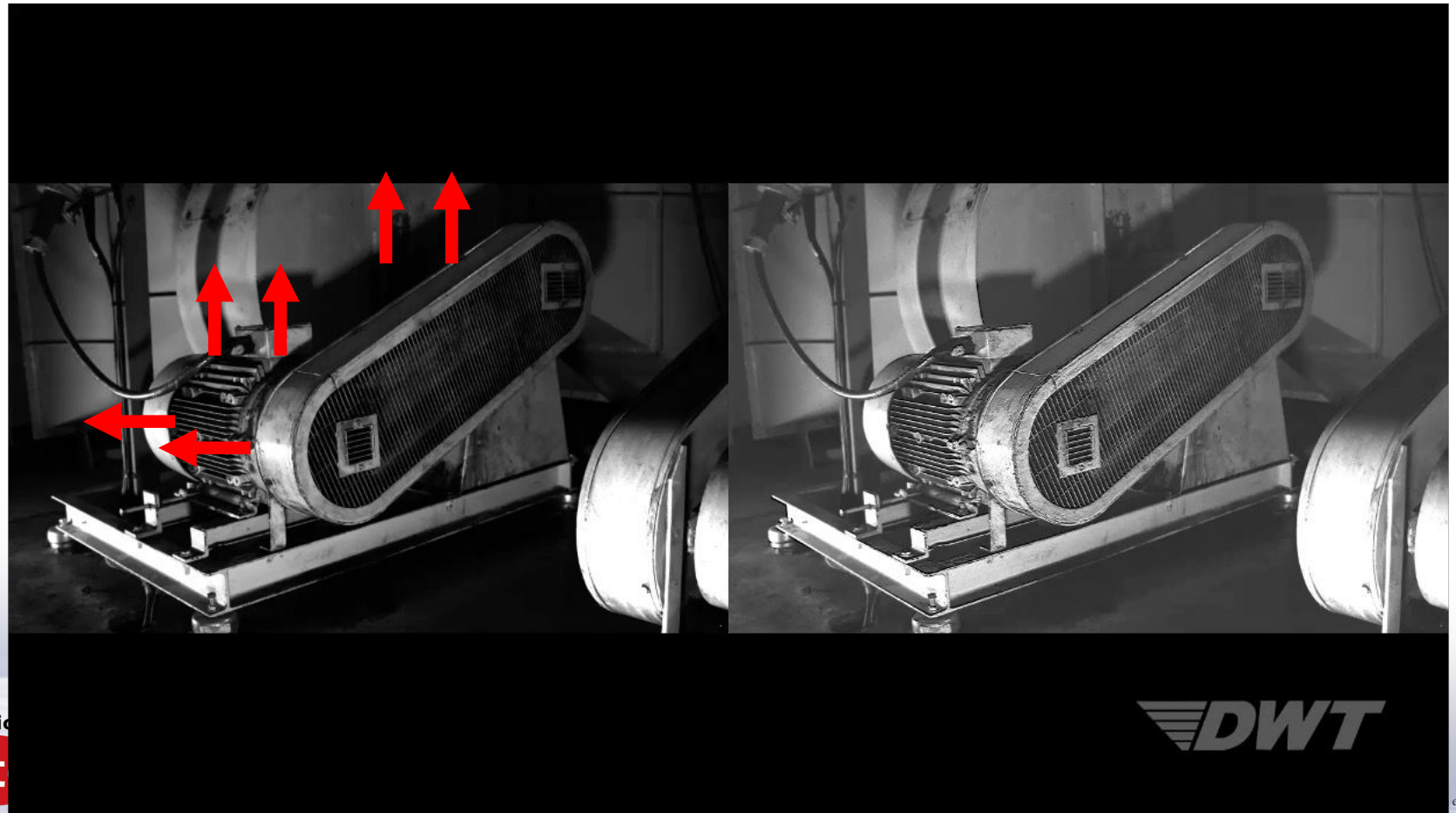
Official Partner

itc INFRARED TRAINING CENTER

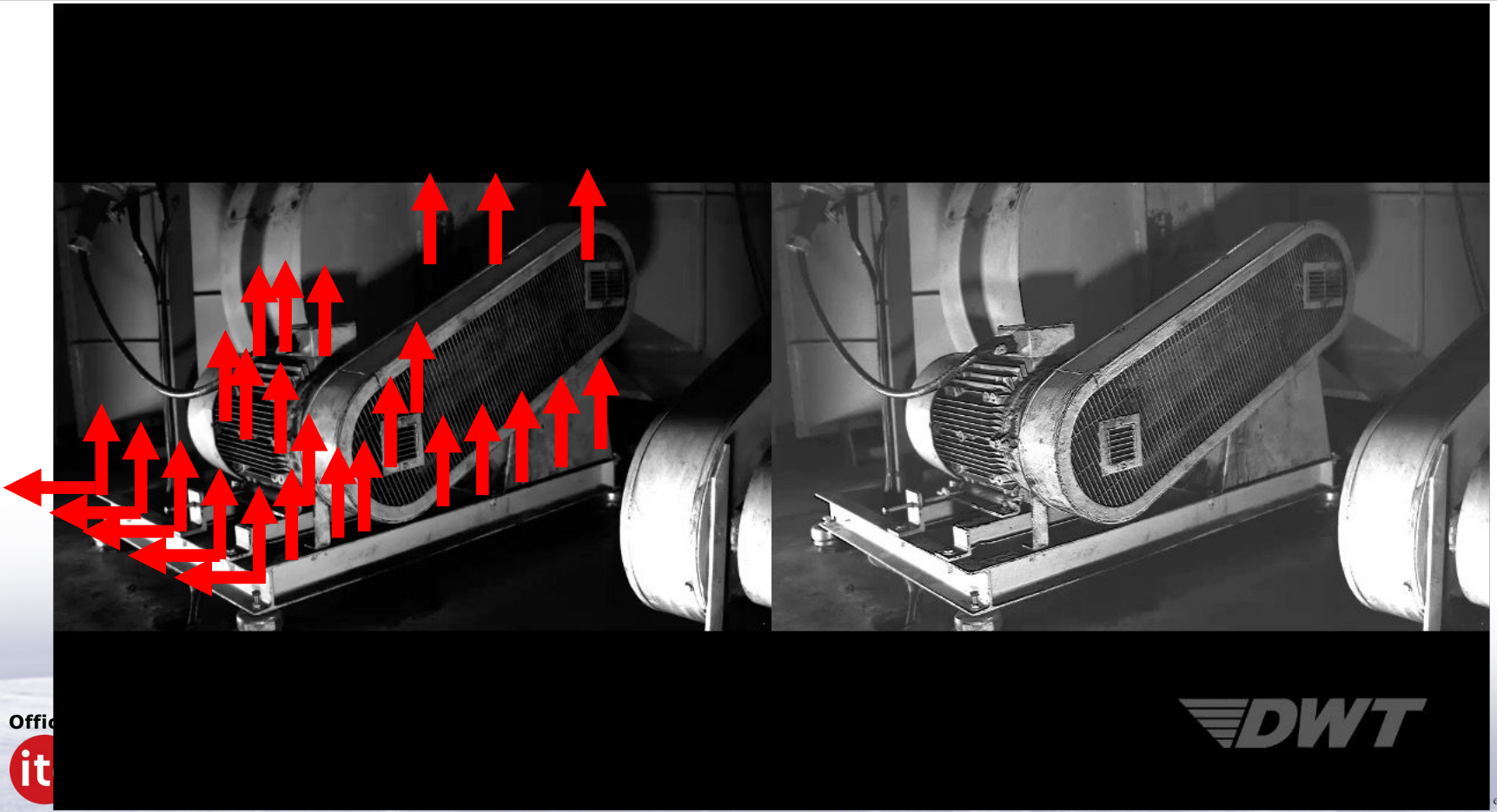
RDI TECHNOLOGIES | SEEING IS BELIEVING

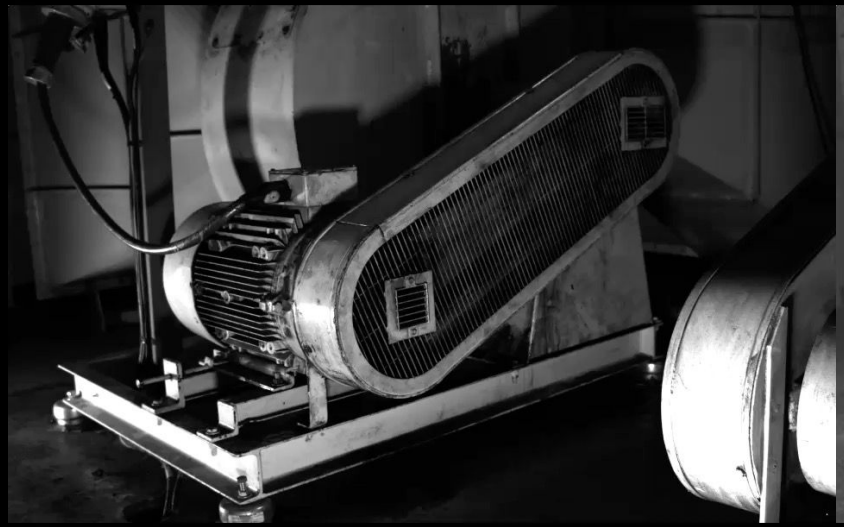
SPM [Licensed SPM Partner]

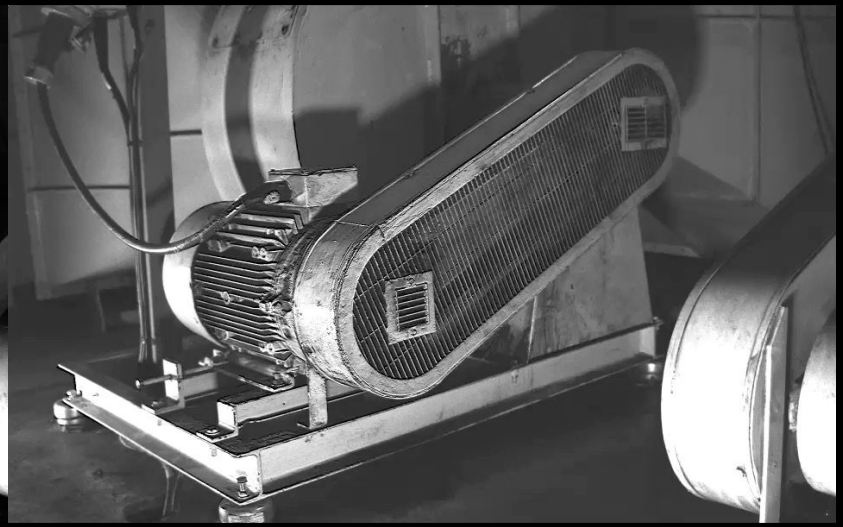
What is Motion Amplification®?


DWT

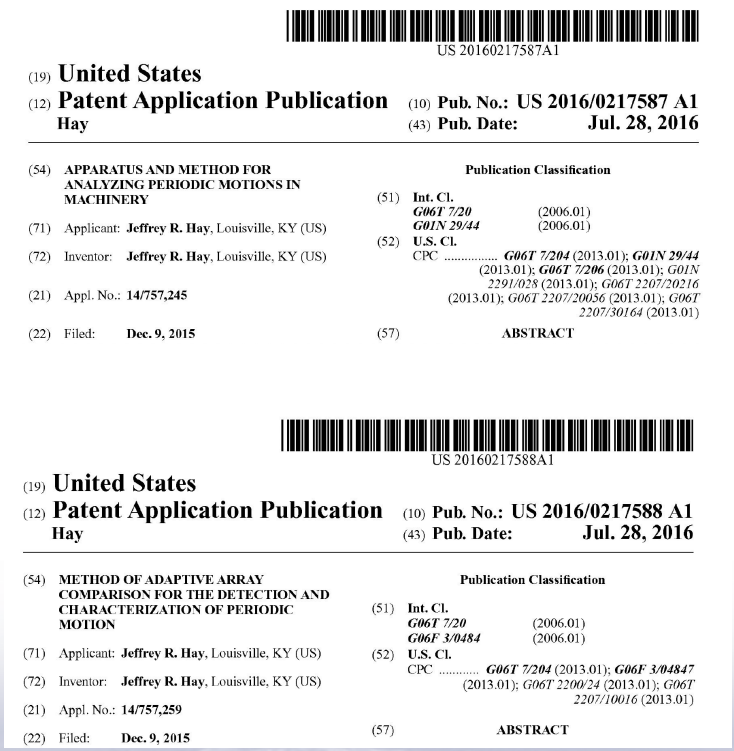
The Motion Amplification® turns EVERY PIXEL into a SENSOR that MEASURES MOTION


DWT





- Motion Amplification® is a technology capable to show and measure movements not visible to the human eye
- It applies a standard video technology and high speed machine grade camera together with an outstanding analysis software
- It applies patented methods and algorithms to extract and analyse data
- It is capable of sub-pixel measurement
- It is capable to enhance the motion
- Suitable for different fields of application and different types of motion analysis



US 20160217587A1

(19) **United States**

(12) **Patent Application Publication**
Hay

(10) **Pub. No.: US 2016/0217587 A1**
(43) **Pub. Date: Jul. 28, 2016**

(54) **APPARATUS AND METHOD FOR ANALYZING PERIODIC MOTIONS IN MACHINERY**

(71) Applicant: **Jeffrey R. Hay**, Louisville, KY (US)

(72) Inventor: **Jeffrey R. Hay**, Louisville, KY (US)

(21) Appl. No.: **14/757,245**

(22) Filed: **Dec. 9, 2015**

Publication Classification

(51) **Int. Cl.**
G06T 7/20 (2006.01)
G01N 29/44 (2006.01)

(52) **U.S. Cl.**
CPC ***G06T 7/204*** (2013.01); ***G01N 29/44*** (2013.01); ***G06T 7/206*** (2013.01); *G01N 2291/028* (2013.01); *G06T 2207/20216* (2013.01); *G06T 2207/20056* (2013.01); *G06T 2207/30164* (2013.01)

(57) **ABSTRACT**

US 20160217588A1

(19) **United States**

(12) **Patent Application Publication**
Hay

(10) **Pub. No.: US 2016/0217588 A1**
(43) **Pub. Date: Jul. 28, 2016**

(54) **METHOD OF ADAPTIVE ARRAY COMPARISON FOR THE DETECTION AND CHARACTERIZATION OF PERIODIC MOTION**

(71) Applicant: **Jeffrey R. Hay**, Louisville, KY (US)

(72) Inventor: **Jeffrey R. Hay**, Louisville, KY (US)

(21) Appl. No.: **14/757,259**

(22) Filed: **Dec. 9, 2015**

Publication Classification

(51) **Int. Cl.**
G06T 7/20 (2006.01)
G06F 3/0484 (2006.01)

(52) **U.S. Cl.**
CPC ***G06T 7/204*** (2013.01); ***G06F 3/04847*** (2013.01); *G06T 2200/24* (2013.01); *G06T 2207/10016* (2013.01)

(57) **ABSTRACT**

The Patent applicant stated…

- "Analyse the video file by an adaptive array comparison technique to find a selected number of pixels that have the most intensity variation over time, i.e., the most physical movement."
- "Find the best frames to use (i.e., optimal frame spacing) to maximize the frame differences and best determine the periodicity of the movement."
- "Apply various mathematical functions, such as fast Fourier transform analysis (FFT) to derive richer physical information from the observed movement waveform."
- "To isolate and reject wanted and unwanted signals respectively."

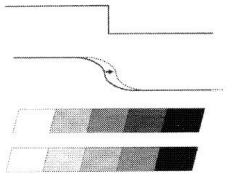


FIG. 20A

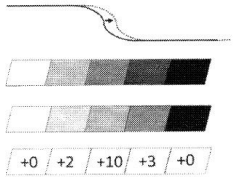


FIG. 20B

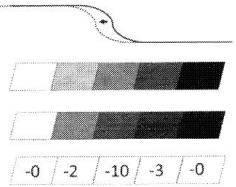


FIG. 20C

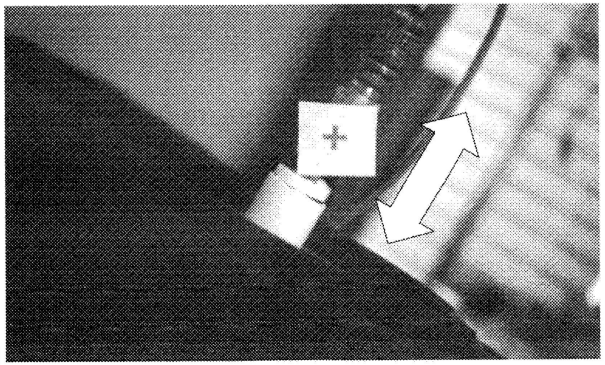


FIG. 6

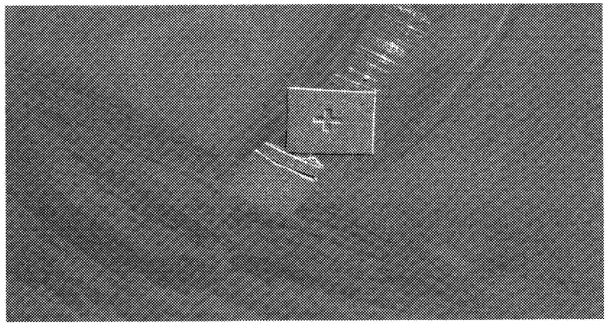


FIG. 7

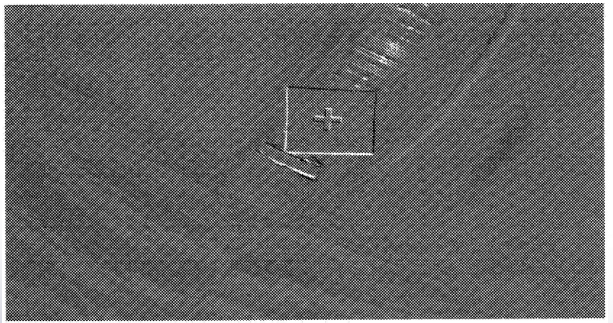


FIG. 8

DWT®

DarkWave Thermo® diagnostic & reliability excellence

EPFL

Specification

Motion Amplification™	
Available Lenses	6mm, 12mm, 25mm, 50mm, 100mm
Acquisition System	i7 processor, 16 GB RAM, 500 GB SSD, dual batteries, lightweight, MIL-STD-810G standard drop protection, 3 yr accidental damage protection*
Sample Rate	**Iris M:** 120 fps default, up to 1,300 fps at reduced resolution **Iris MX:** 1,400 fps default, up to 29,000 fps at reduced resolution
Frequency Range	**Iris M:** Up to 3,600 cpm @ 120 fps default Maximum 39,000 cpm @ 1,300 fps with reduced resolution **Iris MX:** 42,000 cpm @ 1,400 fps default Maximum 870,000 cpm @ 29,000 fps with reduced resolution
Minimum Displacement	0.1 mil (2.5µm) at 3.3 ft (1m) with 50 mm lens at max brightness
Motion Amplification™ Factor	1-50x
Ethernet Gigabyte Cable with USB Adapter	9.84 ft (3m)
Optional Accessory Kit	LED light: 14,000 Lux @ 1m, Li-ion light battery, light stand, extra vibration pads, computer stand

IRIS M
Enhancing Vision

IRIS CM™

IRIS MX™
Enhancing Vision

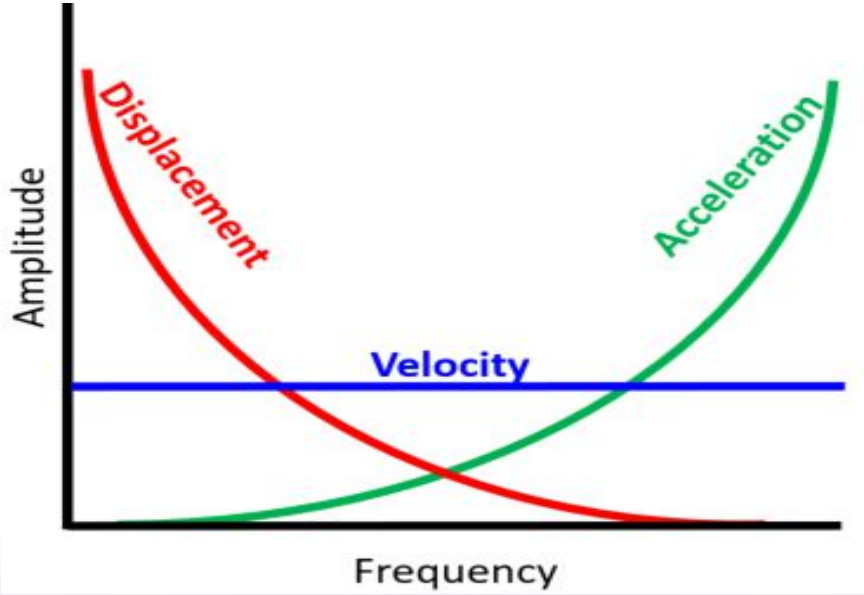
Official Partner

itc INFRARED TRAINING CENTER

RDI TECHNOLOGIES | SEEING IS BELIEVING

SPM
[Licensed SPM Partner]

The Stereo Vision:
3D measurement head



We can then use the MA for:

- Typical low and middle frequency issues (imbalance, misalignment, resonance, …)
- Periodical or non periodical motions
- Large motion analysis
- ODS and Modal Analysis
- …but normally NOT for bearings and gearboxes issues (very high frequencies and very low displacement)

Which displacement can be resolved, with standard lenses?

Target distance from camera	Lens focal lenght	Displacement resolution
2 meters	25 mm	1 micron
2 meters	50 mm	0.5 micron
1 meter	50 mm	0.25 micron
100 meters	100 mm	12.5 micron

What Motion Amplification® is not?

It IS NOT ALWAYS a Vibration analysis replacement


Leanova
SPM

It is NOT ALWAYS a replacement for "old fashion" vibration analysis!

It is something that sometimes replaces and sometimes integrates standard measurement technology.

PROS...

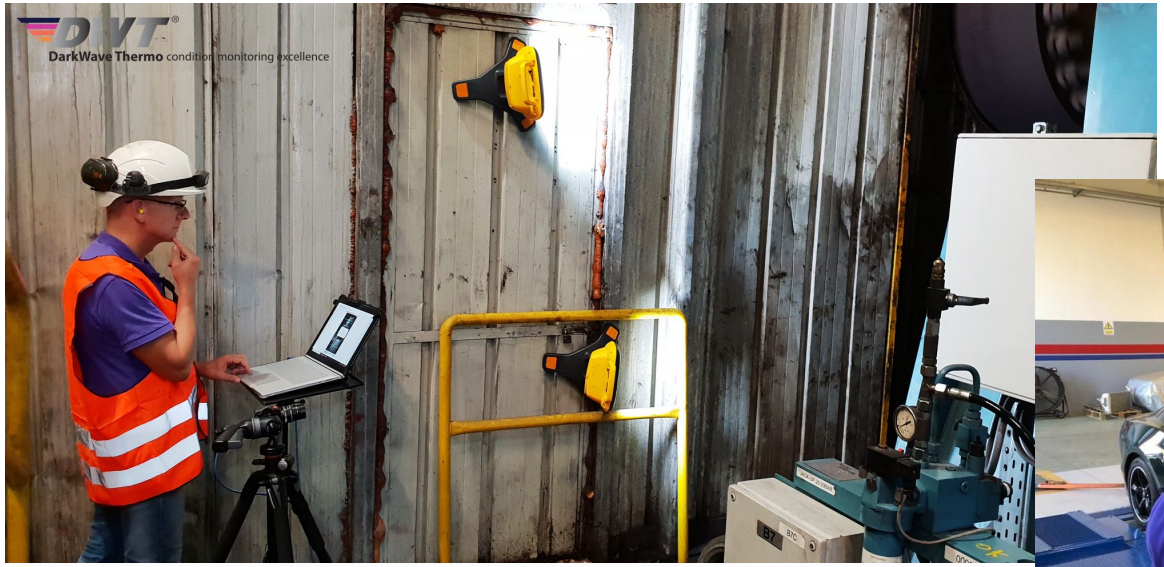
- ✓ Allows motion frequency separation
- ✓ Provide quick analysis on high complexity systems
- ✓ Measurement points can be quickly moved
- ✓ Can be used at a distance, on dangerous components, on high temperature surfaces, ...
- ✓ It is the only viable mesurement & analysis system in several situations
- ✓ Improve communication dramatically

CONS...

- ✓ Continuous light is necessary
- ✓ Frequency range is limited by camera, light, displacement
- ✓ It is less accurate than accelerometers or laser
- ✓ Long term acquisitions require stable light condition
- ✓ Spot checks are less repeatable between inspections, due to differences in positioning
- ✓ Data size can be an issue

Motion Amplification® is the
faster, easier and more exhaustive method
to find the cause of a problem

And a way to measure what, yesterday,
couldn't be measured


DWT®
DarkWave Thermo condition monitoring excellence

It simplifies dramaticaly:

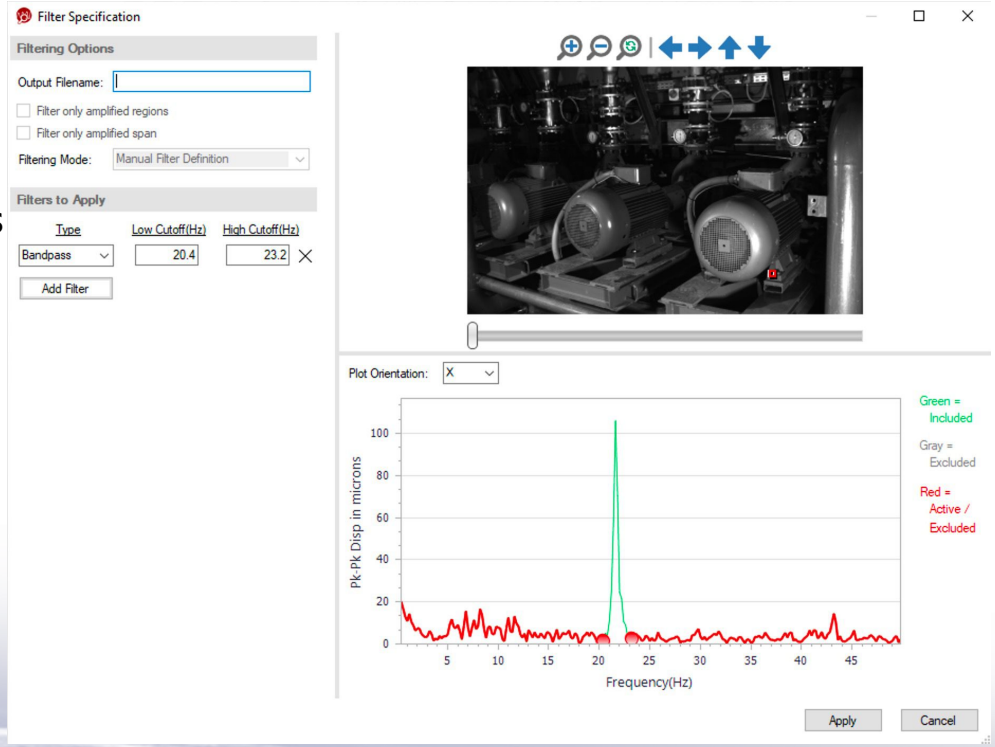
- **General machine vibration evaluation**
- ODS – Operational Deflection Shape
- Modal Analysy
- **Root cause analysis**
- Data collection in difficult points
- **Measurement at a distance**

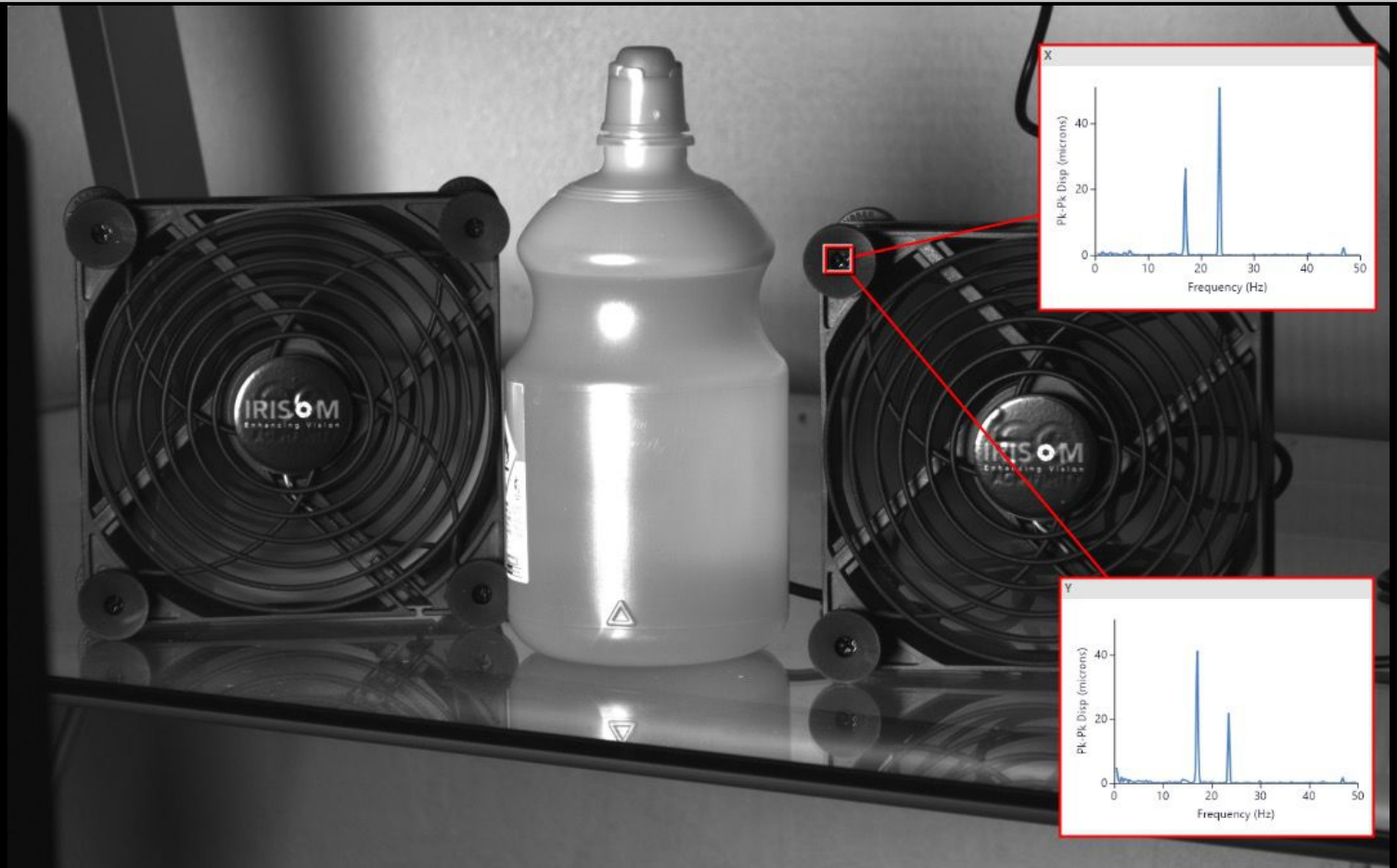
THE GREAT ADVANTAGE…

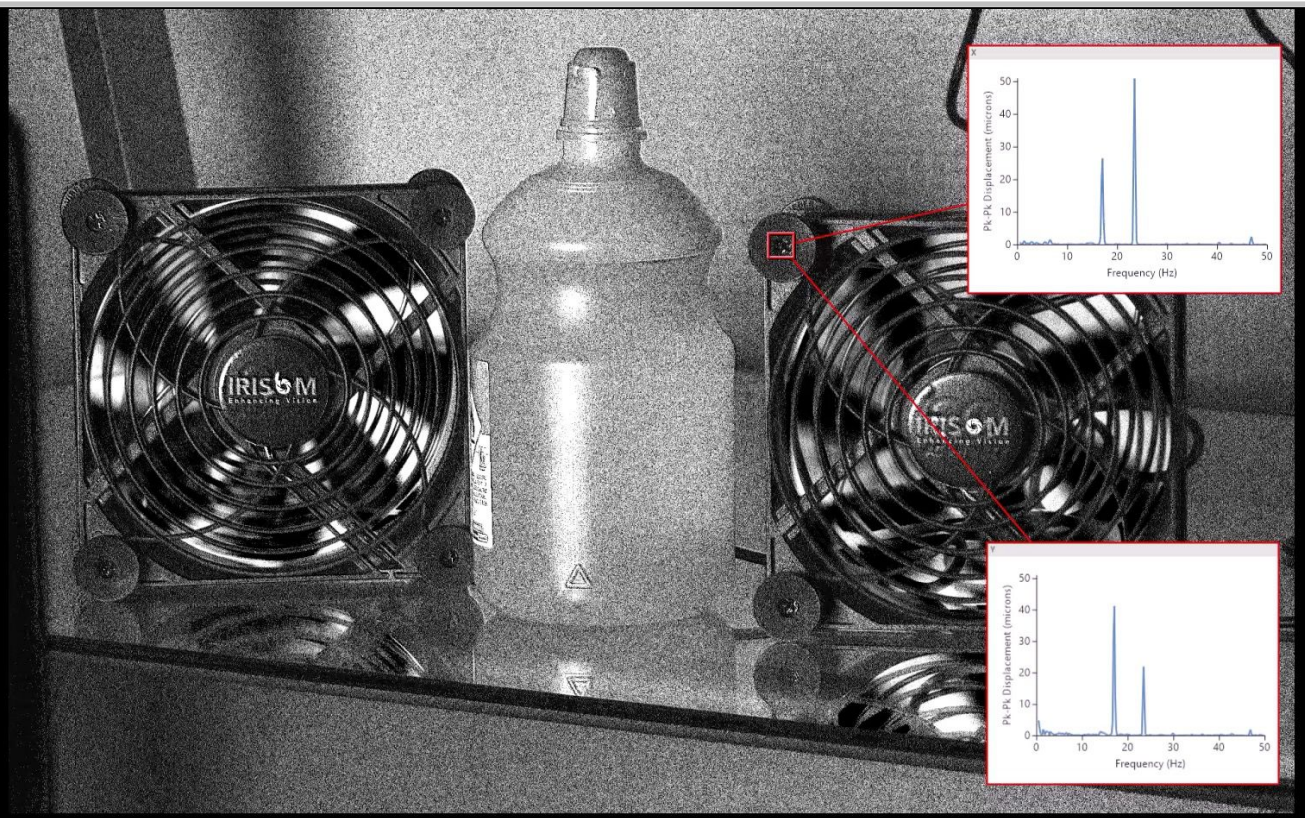
It is possible to play with the complete video, SPLIT and RECONSTRUCT different frequencies…

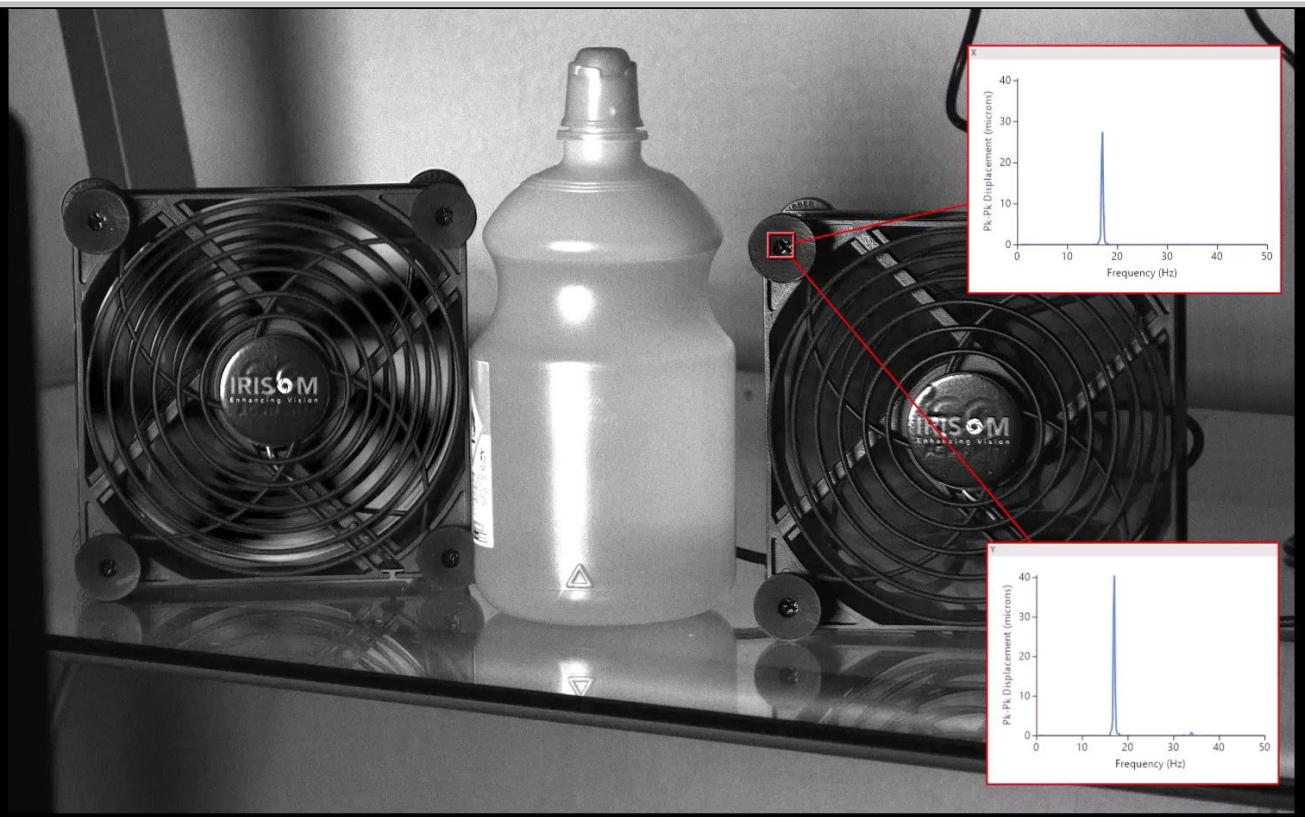
The MA allows, in fact:

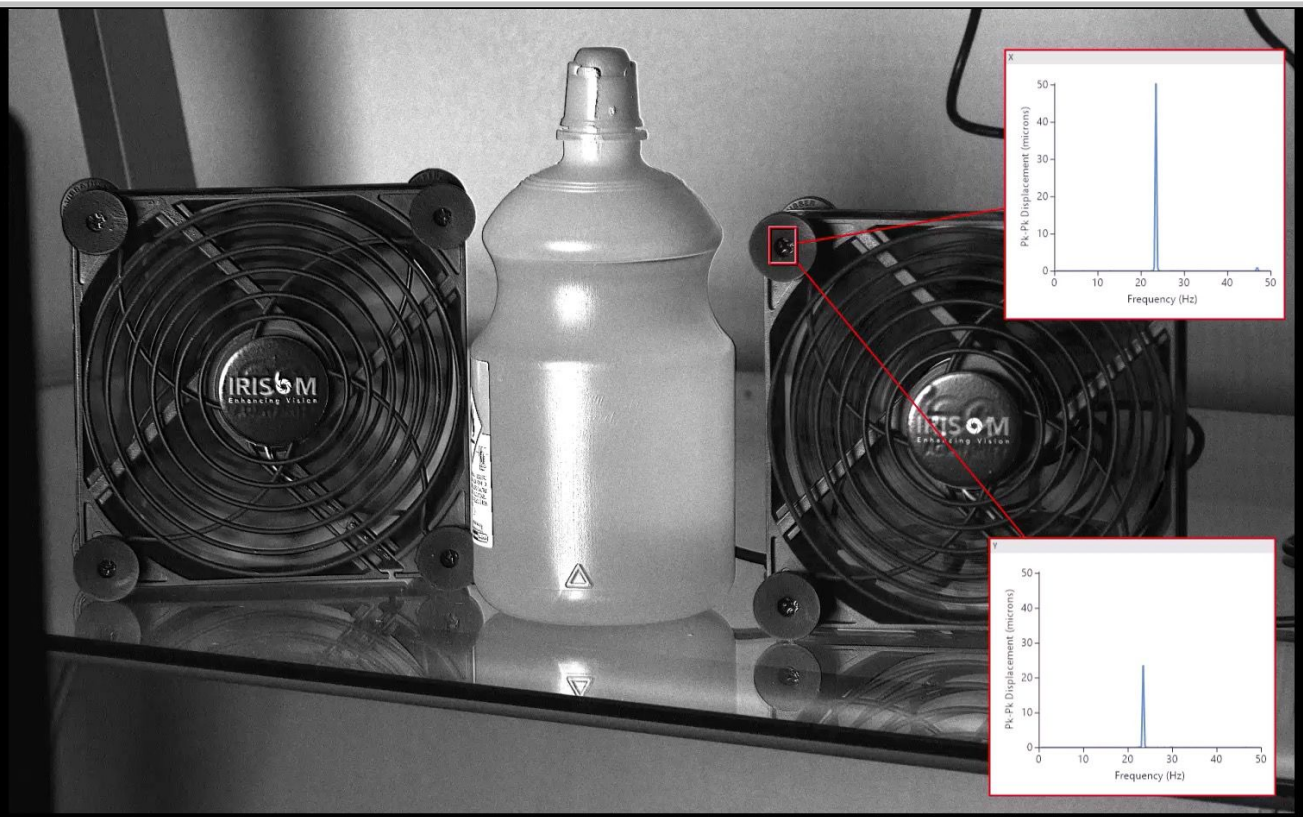
- to verify spectra and wavevorms
- filter in frequency
- rebuild the motion
- amplify and slow down
- ...and much more...




X
Pk-Pk Disp (microns)
40
20
0
0
10
20
30
40
50
Frequency (Hz)
Y
Pk-Pk Disp (microns)
40
20
0
0
10
20
30
40
50
Frequency (Hz)


Pk-Pk Displacement (microns)
Frequency (Hz)
Pk-Pk Displacement (microns)
Frequency (Hz)


IRIS6M
Enhancing Vision
IRIS6M
Enhancing Vision
X
Pk-Pk Displacement (microns)
40
30
20
10
0
0
10
20
30
40
50
Frequency (Hz)
Y
Pk-Pk Displacement (microns)
40
30
20
10
0
0
10
20
30
40
50
Frequency (Hz)


x
Pk-Pk Displacement (microns)
0
10
20
30
40
50
0
10
20
30
40
50
Frequency (Hz)
y
Pk-Pk Displacement (microns)
0
10
20
30
40
50
0
10
20
30
40
50
Frequency (Hz)

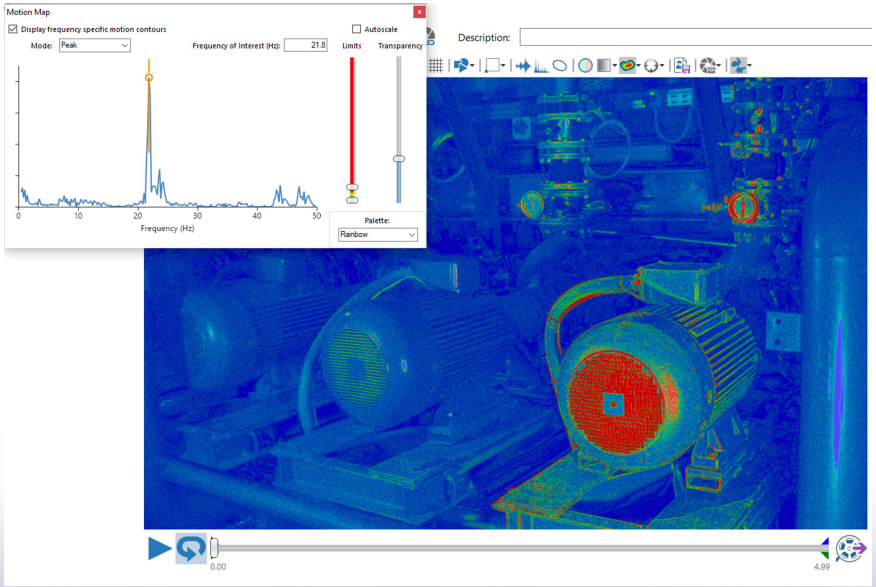
So, the two different forcing frequencies can be analysed SEPARATELY.

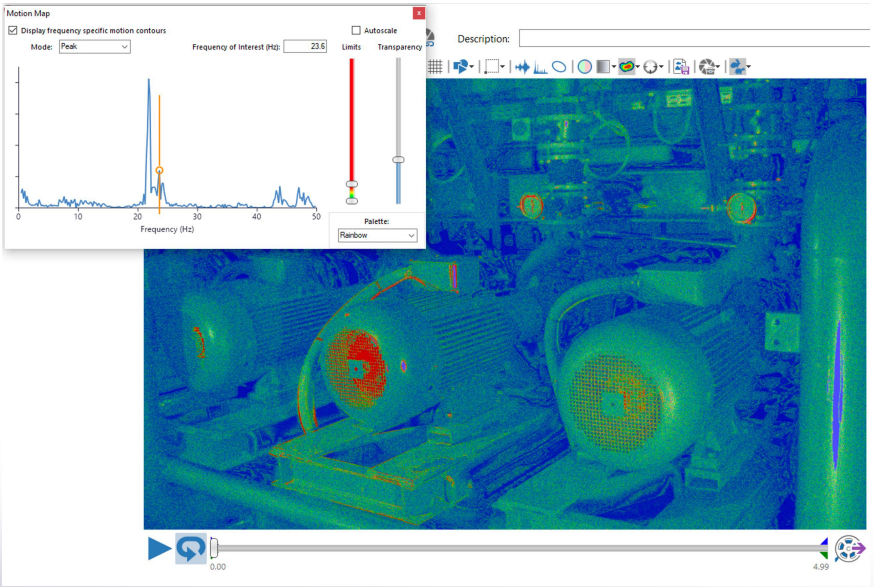
(and this can be done for every frequency)

This is fantastic for diagnostics.

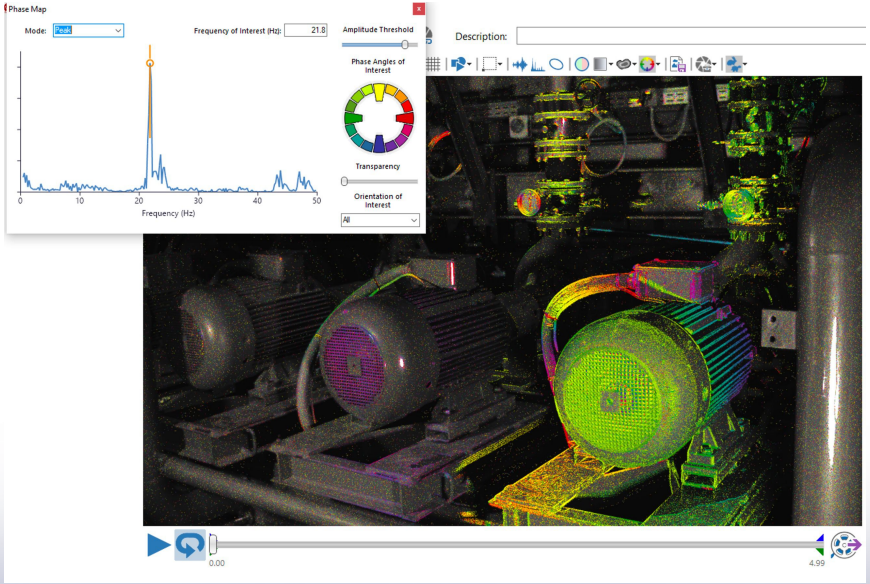
But there is more…

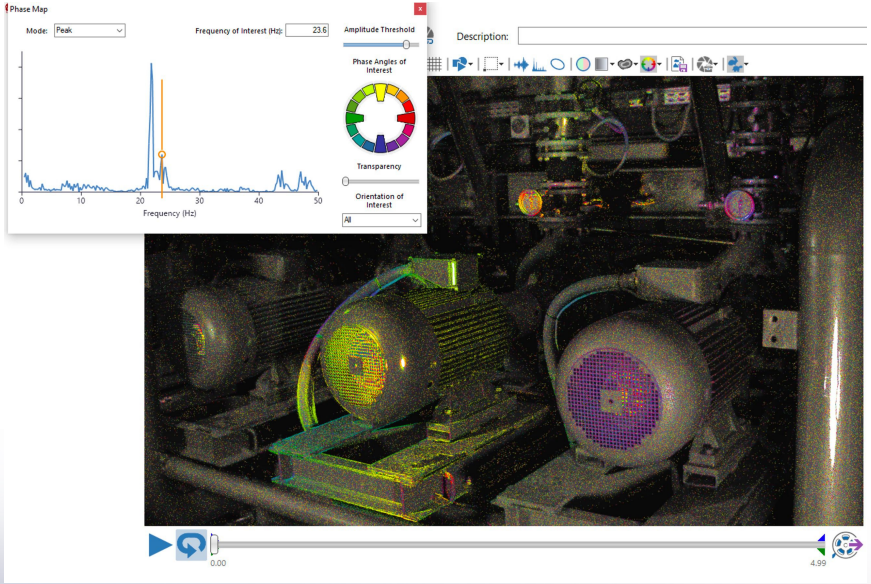
Visual frequency detection...





Visual phase detection...



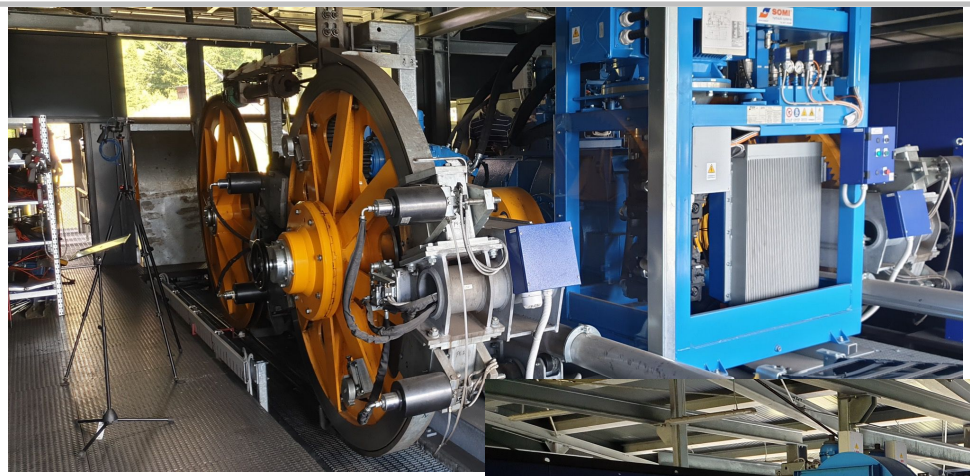


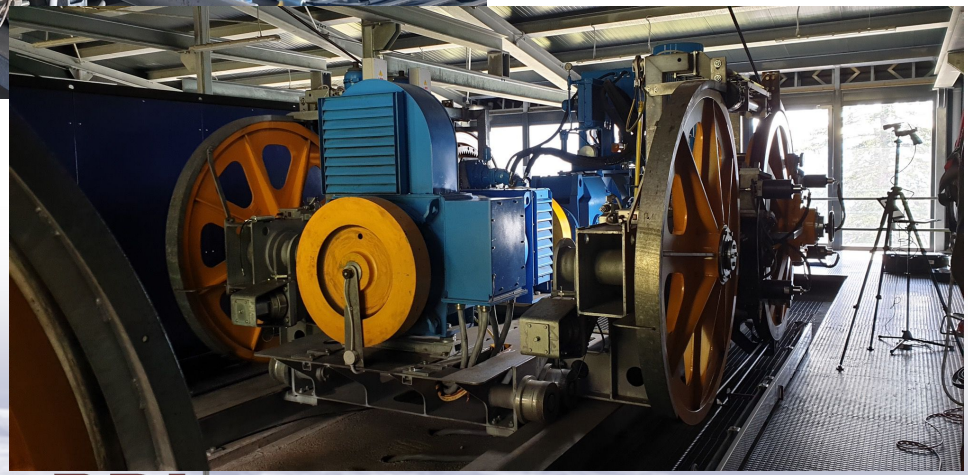
A reasonance problem on a ropeway…

Where we are:

- Ropeway located in the Alps
- At a specific speed, thedrive and gearbox system started to vibrate in an excessive and anomalous way
- Already cheched alignment, unbalance, bearing and gearbox
- No particular risk for customers, but some limitations in the ropeway running speed
- There is a sister driving mechanism for the other part of the ropeway

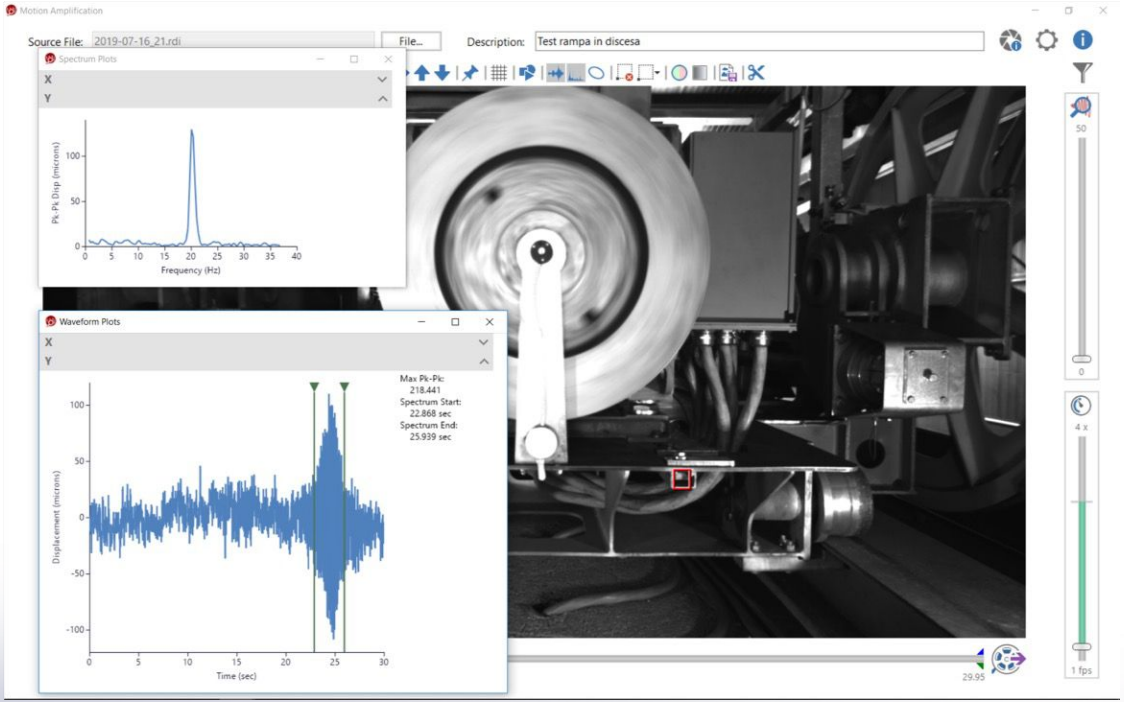
- One day they decided to call us to see if we were able to understand what was wrong…

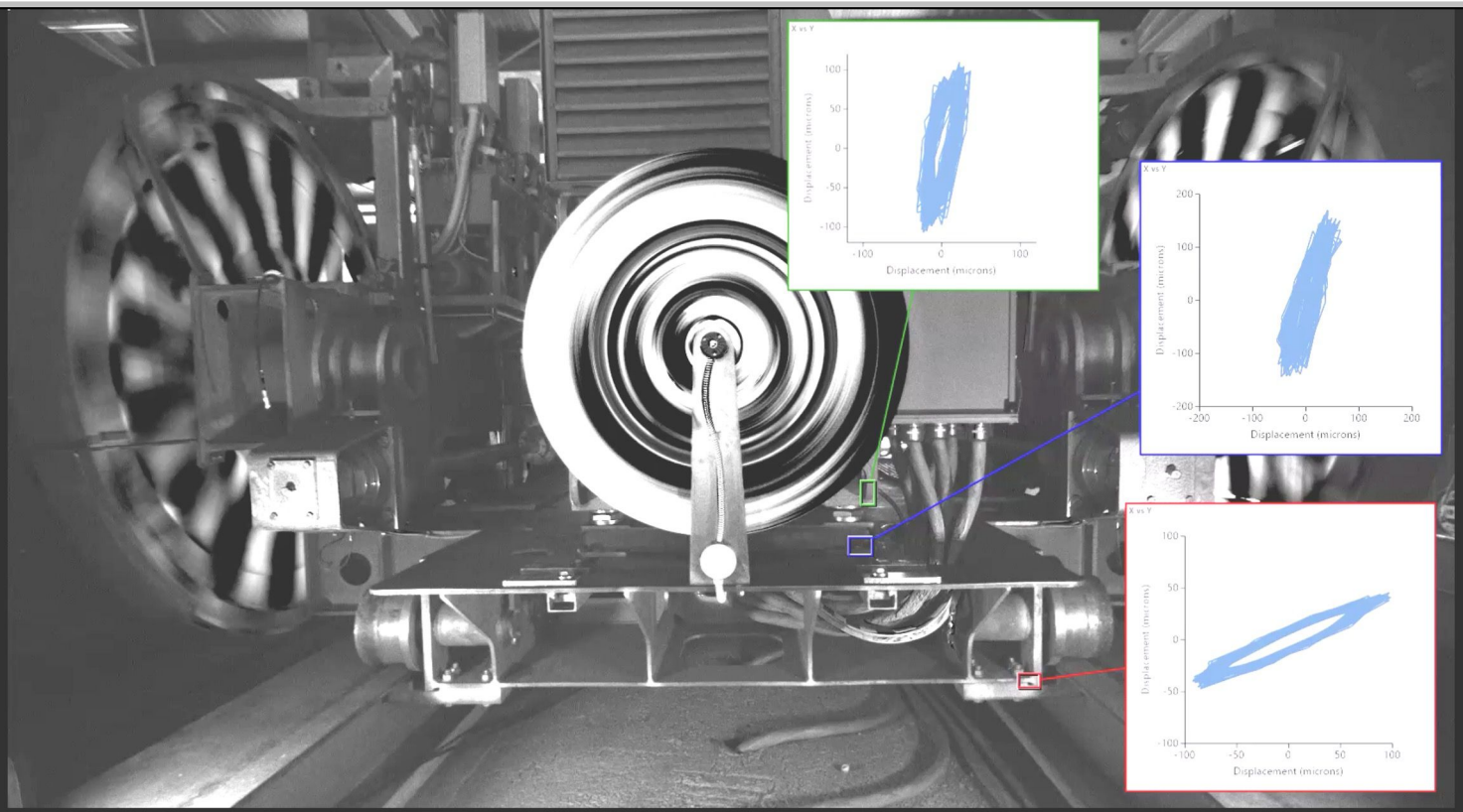


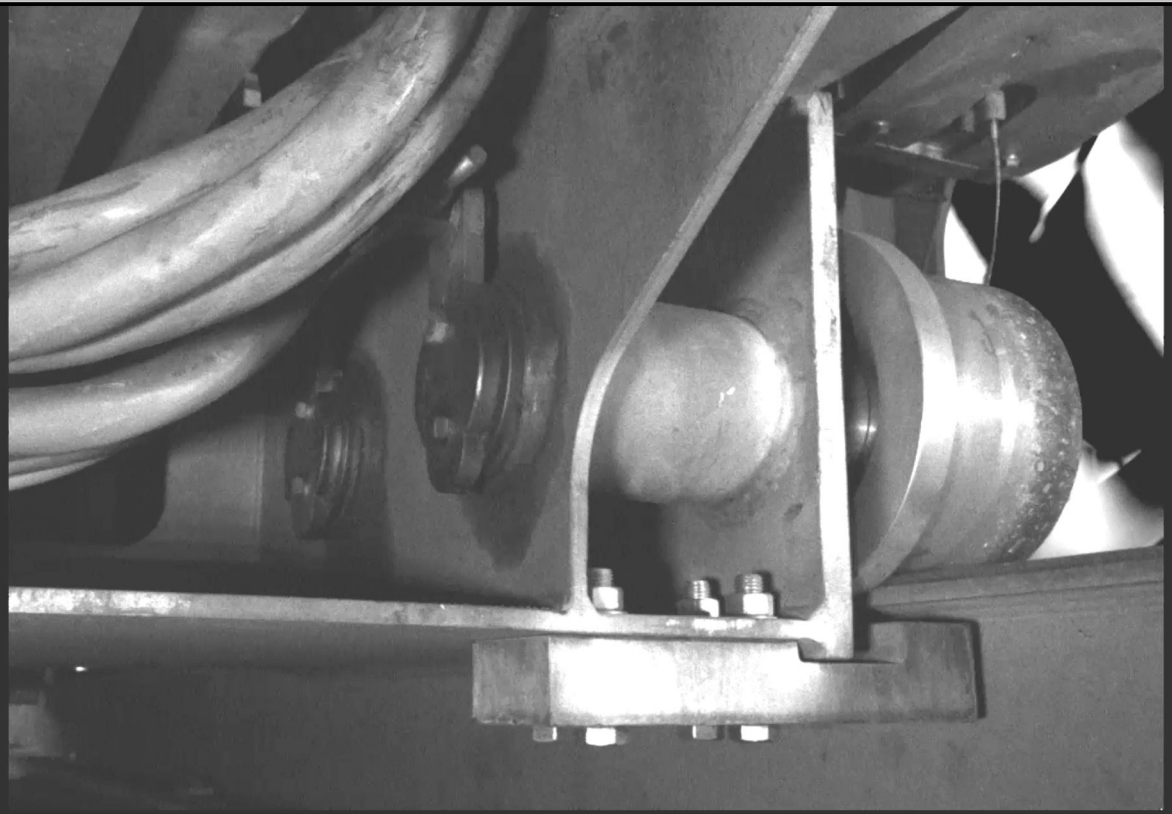


This complete system shakes without a reason, at a certain rope speed.

As a first step, we decided to perform a run up test.
The recorded waveform showed a typical typical resonance behaviour.




X vs Y
Displacement (microns)
Displacement (microns)
X vs Y
Displacement (microns)
Displacement (microns)
X vs Y
Displacement (microns)
Displacement (microns)



Final summary:

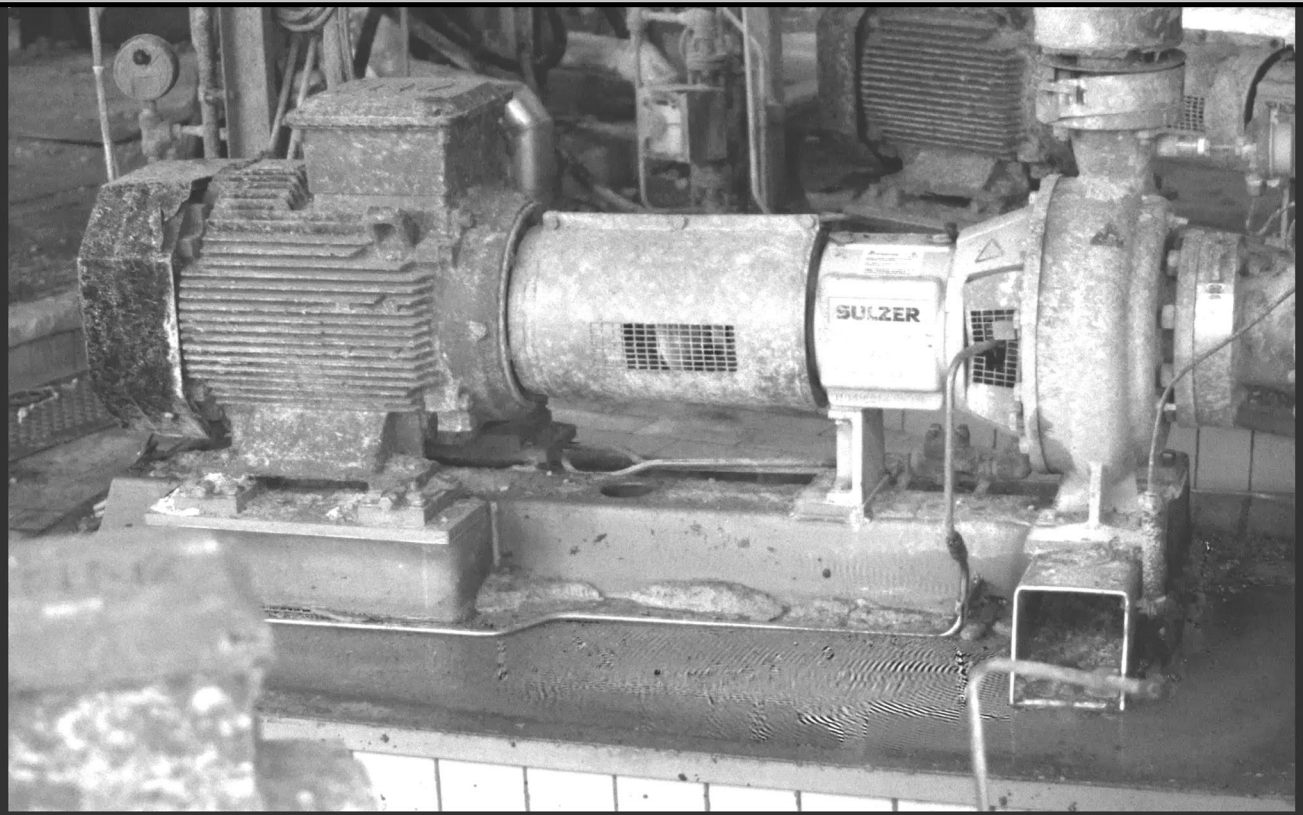
- Due to the vibration, the ropeway was running at 80% speed, at maximum
- This was a potential problem for the winter season, where the maximum trafic of tourists could have been affected
- Several trials to eliminate the vibration have been made: balancing, alignment, mechanical inspections, part replacement, for several months

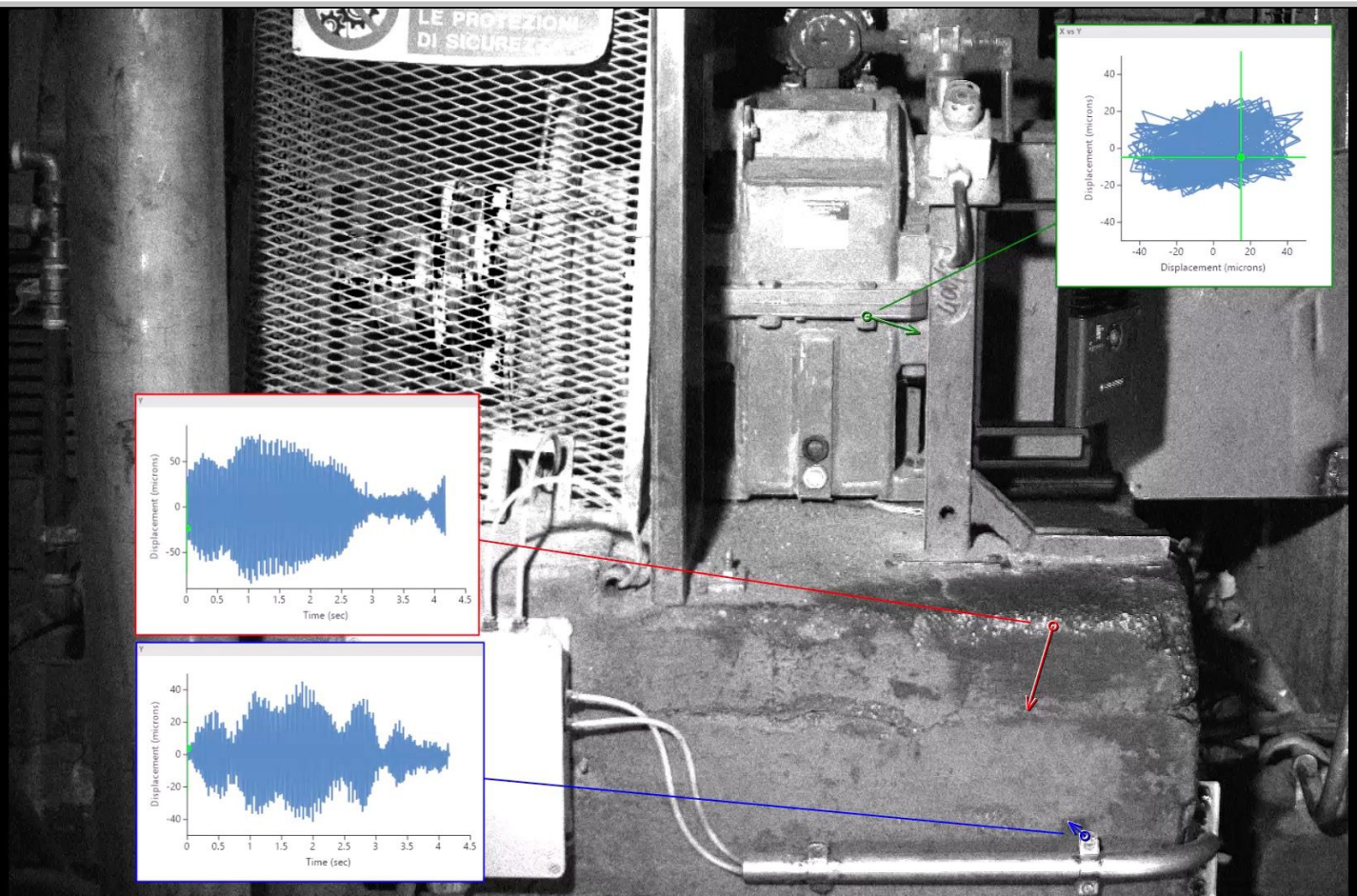
- The cause of the problem has been found in 30 minutes

- Replacement of the indicated bearings and subsequent testing proved that we were right

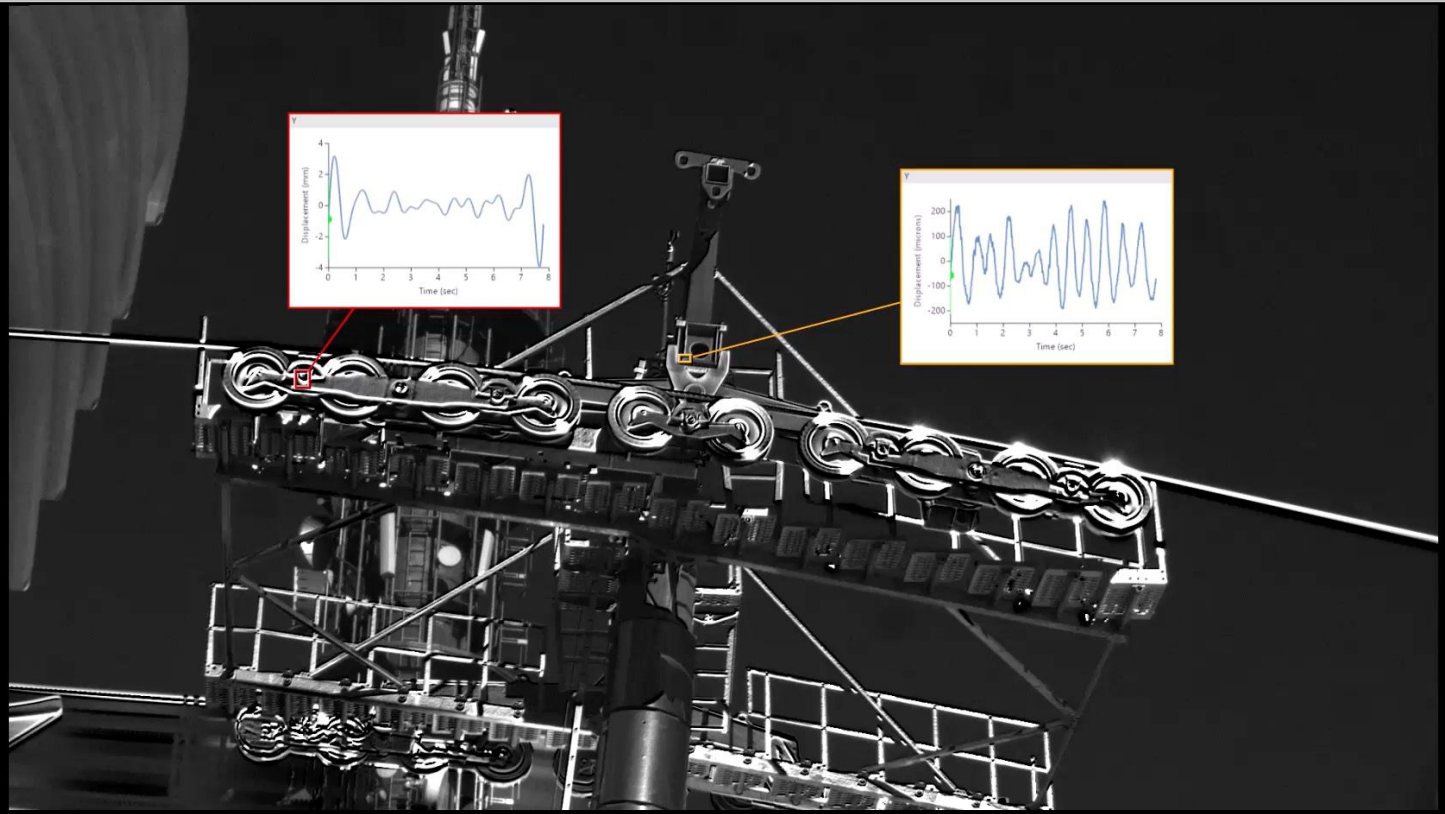
Examples of structural issues


310 MD145

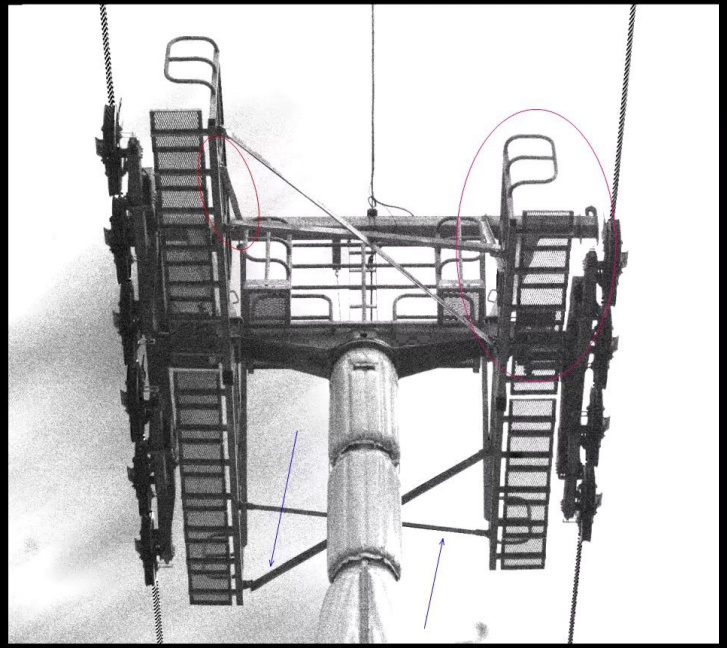

SULZER


X vs Y
Displacement (microns)
Displacement (microns)
Y
Displacement (microns)
Time (sec)
Y
Displacement (microns)
Time (sec)

Examples of measurement at distance


Displacement (mm)
Time (sec)
Displacement (microns)
Time (sec)

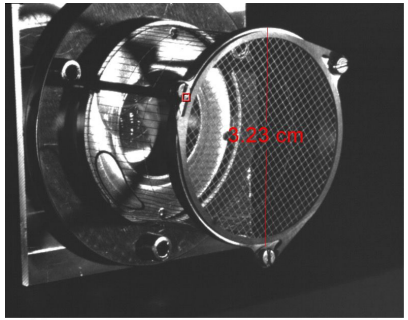
Amplification Factor: 500 Playback Speed: 40 fps

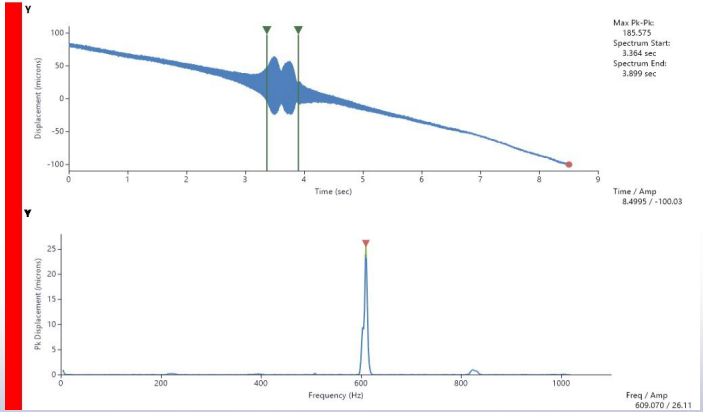


HDR Filtered 74.6 Hz

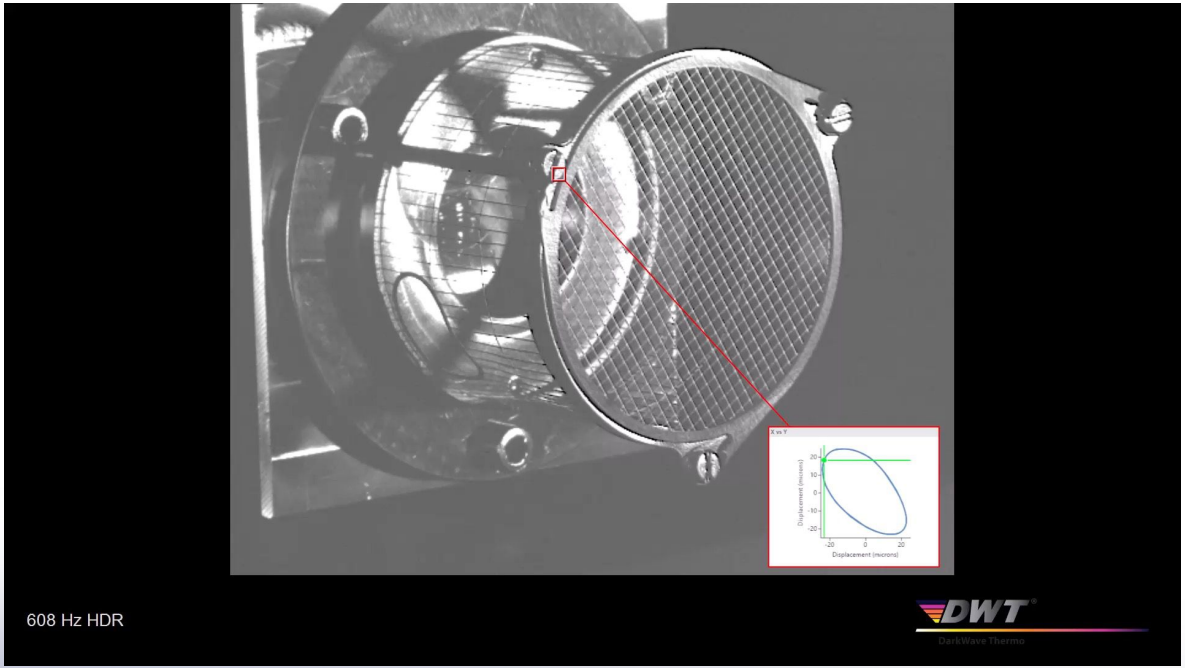
DWT®
DarkWave Thermo® diagnostic & reliability excellence

A couple of difficult measurement

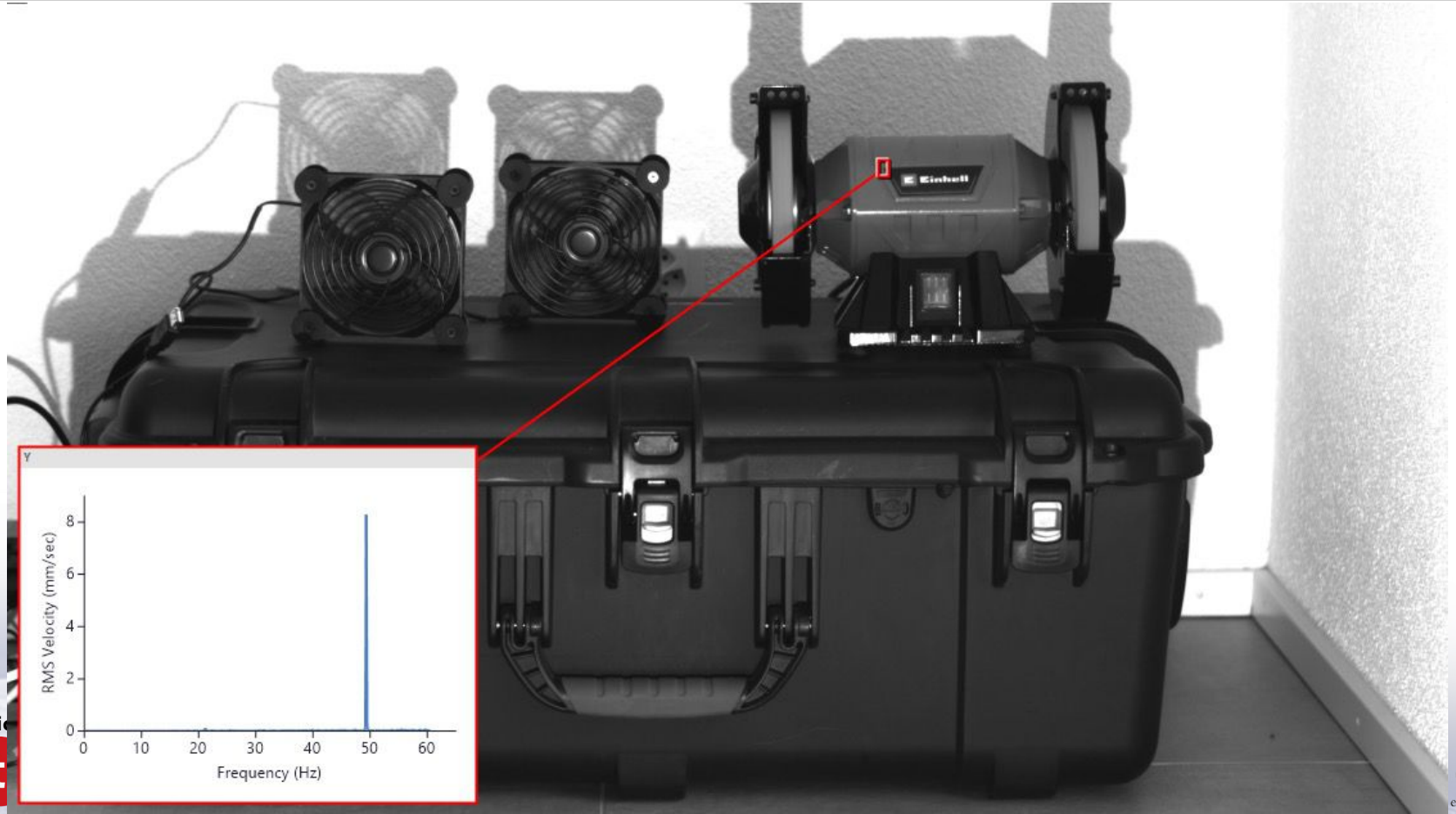


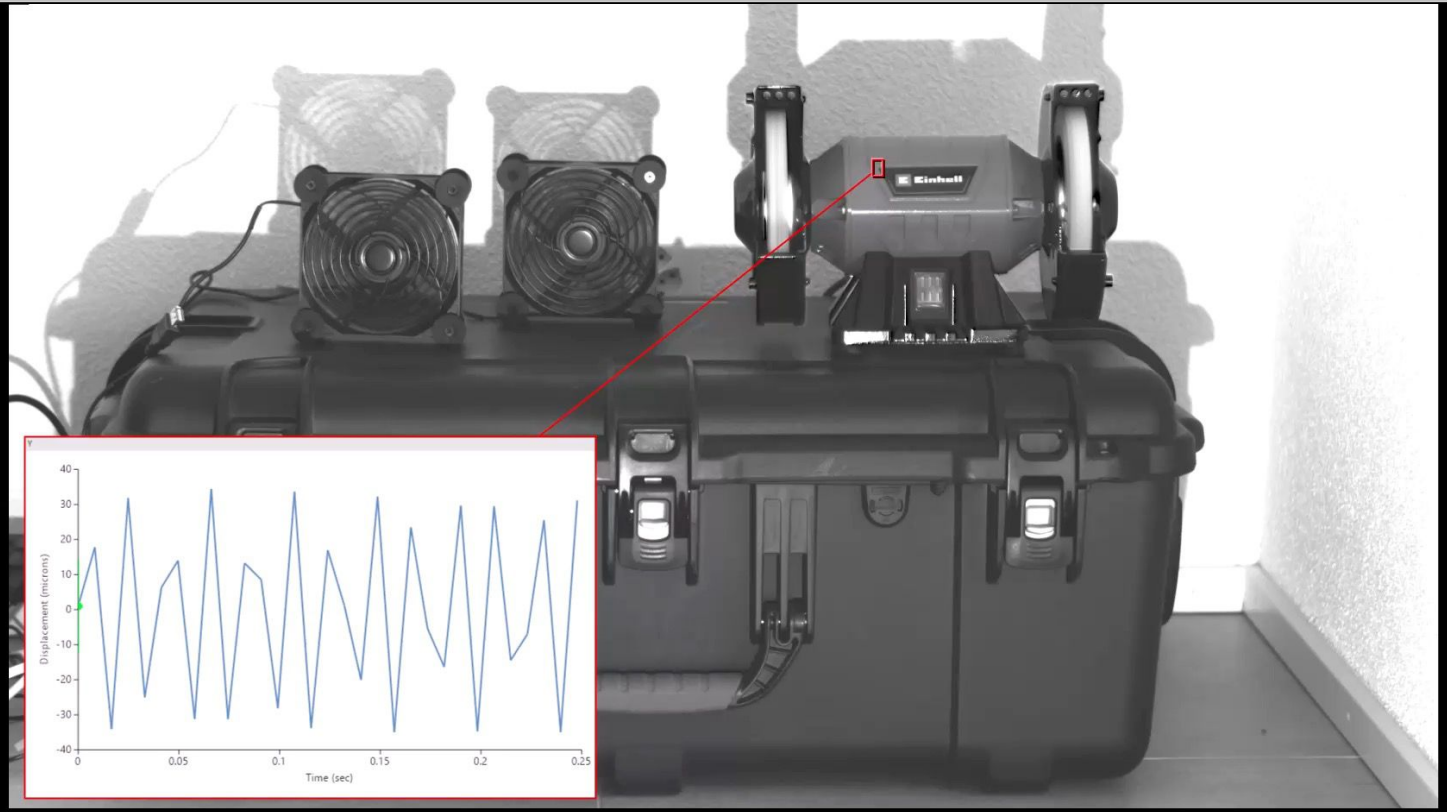


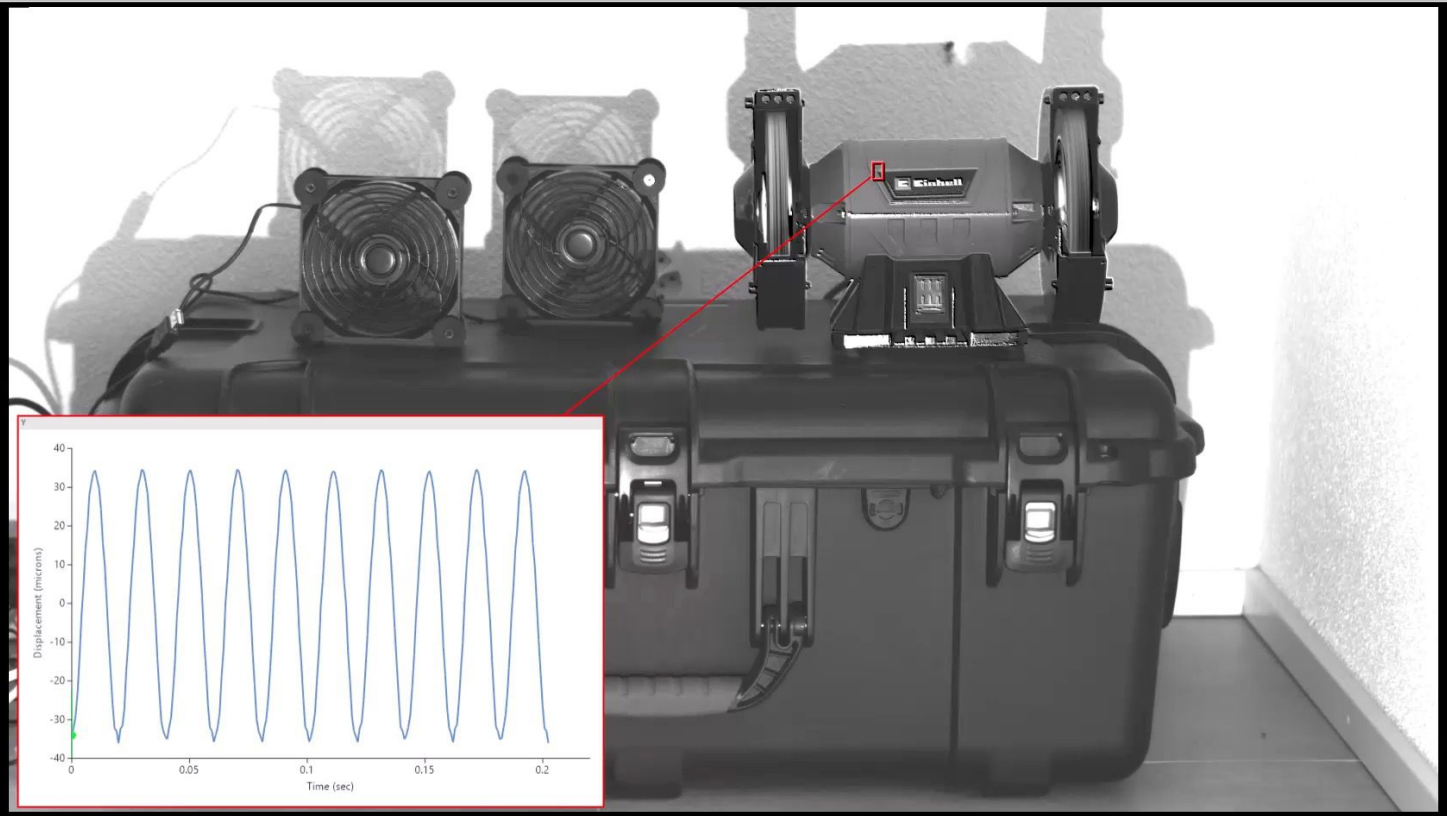
Courtesy of Space Research and Planetology division - University of Bern



HDR Filter


Einhell
Y
RMS Velocity (mm/sec)
0
2
4
6
8
0
10
20
30
40
50
60
Frequency (Hz)


Einhell
Displacement (microns)
40
30
20
10
0
-10
-20
-30
-40
0
0.05
0.1
0.15
0.2
0.25
Time (sec)


Einhell
Displacement (microns)
40
30
20
10
0
-10
-20
-30
-40
0
0.05
0.1
0.15
0.2
Time (sec)

RPM Reading & Shaft Inspection

EPFL

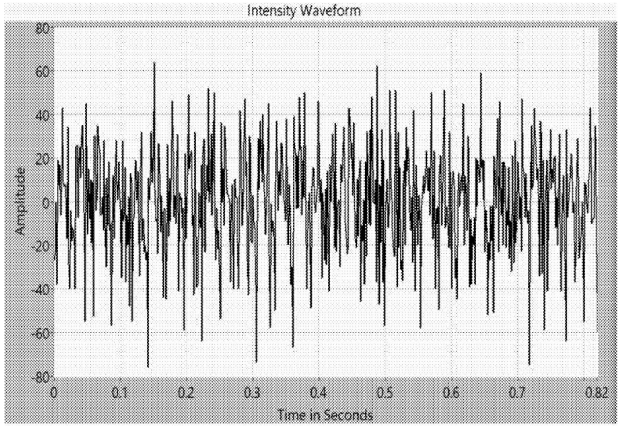


FIGURE 9

Autocorrelation

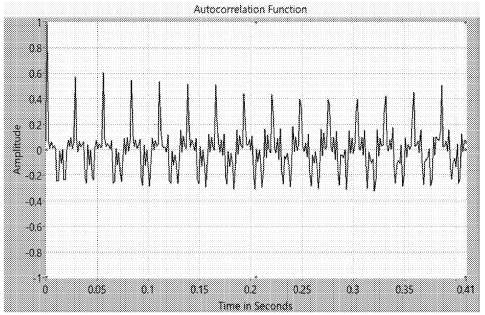


FIGURE 10

FFT Spectrum

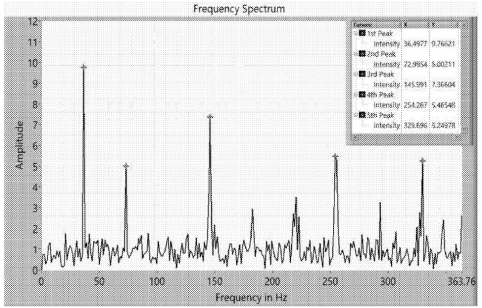


FIGURE 11

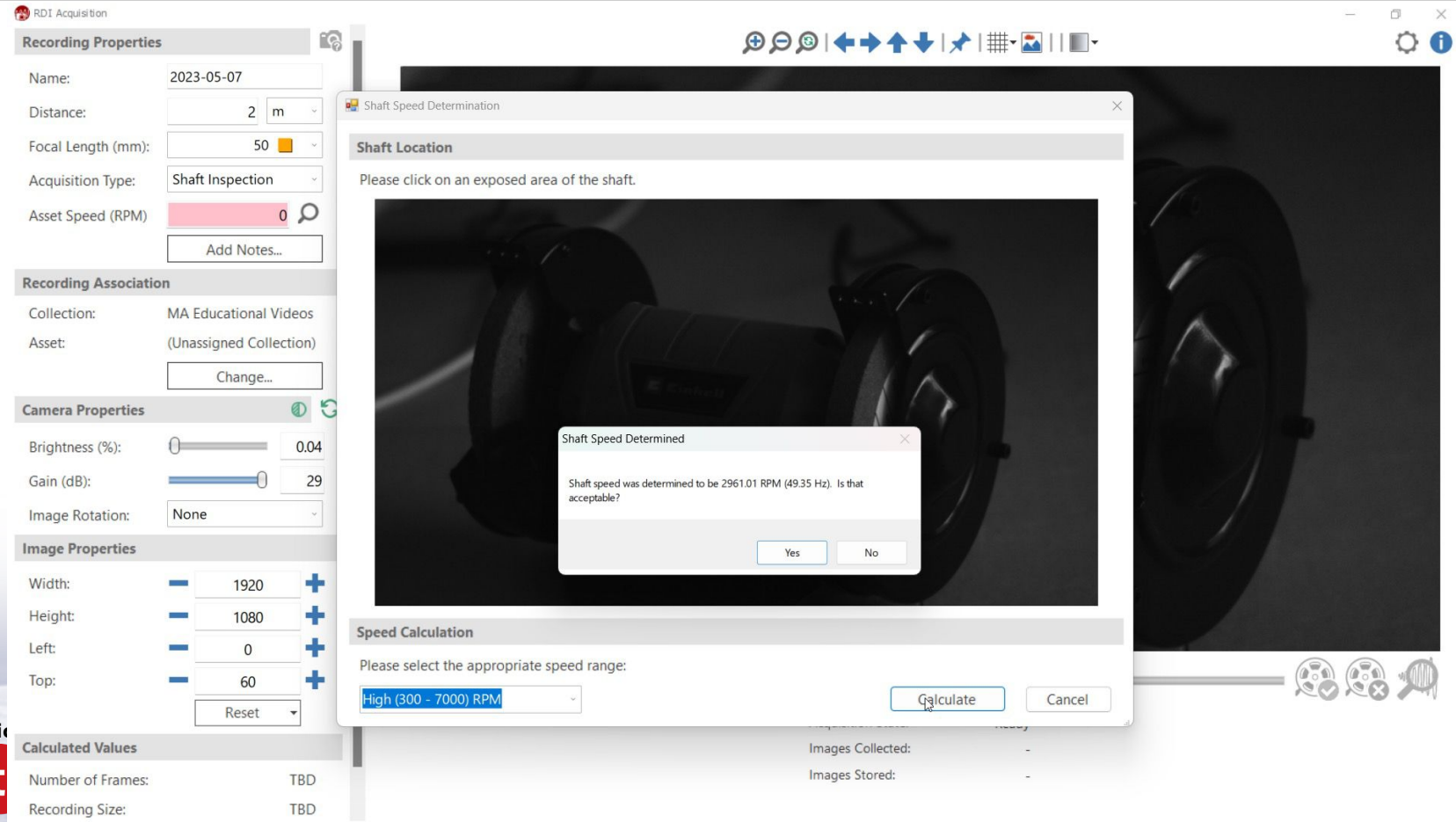

RDI Acquisition
Recording Properties
Name:
2023-05-07
Distance:
2
m
Focal Length (mm):
50
Acquisition Type:
Shaft Inspection
Asset Speed (RPM)
0
Add Notes...
Recording Association
Collection:
MA Educational Videos
Asset:
(Unassigned Collection)
Change...
Camera Properties
Brightness (%):
0.04
Gain (dB):
29
Image Rotation:
None
Image Properties
Width:
1920
Height:
1080
Left:
0
Top:
60
Reset
Calculated Values
Number of Frames:
TBD
Recording Size:
TBD
Shaft Speed Determination
Shaft Location
Please click on an exposed area of the shaft.
Shaft Speed Determined
Shaft speed was determined to be 2961.01 RPM (49.35 Hz). Is that acceptable?
Yes
No
Speed Calculation
Please select the appropriate speed range:
High (300 - 7000) RPM
Calculate
Cancel
Images Collected:
-
Images Stored:
-

FIGURE 1

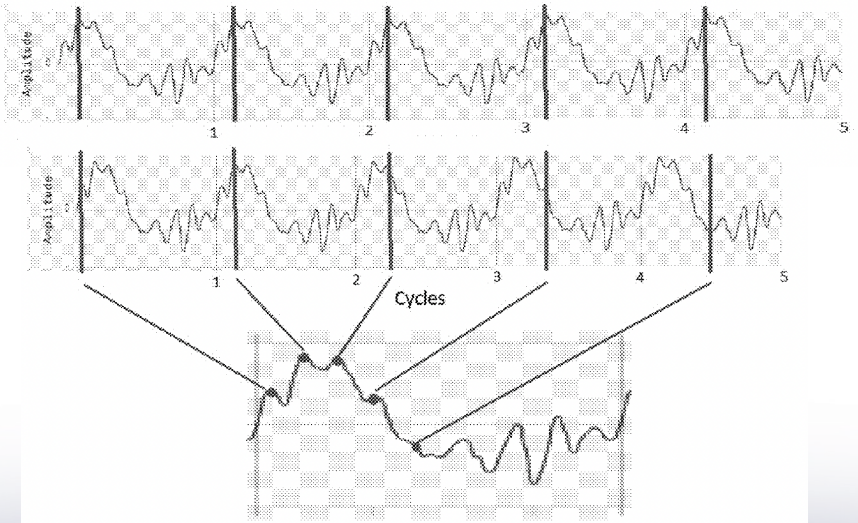


FIGURE 3B

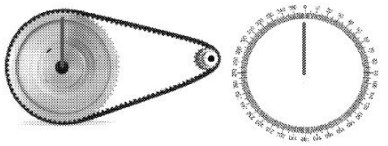


FIGURE 4A

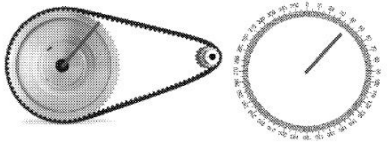


FIGURE 4B

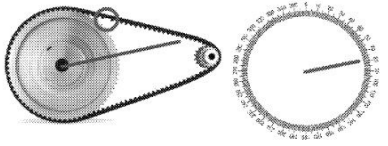


FIGURE 4C

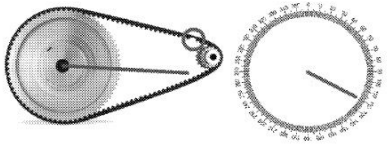


FIGURE 4D

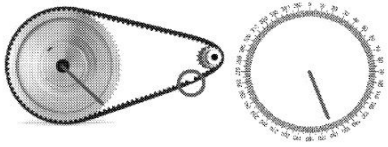
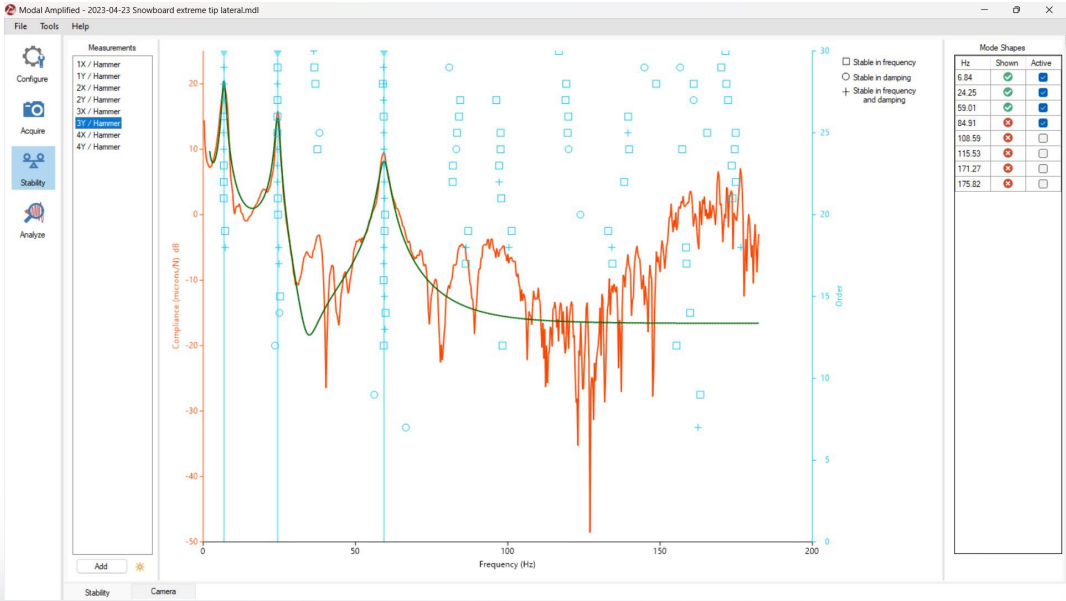
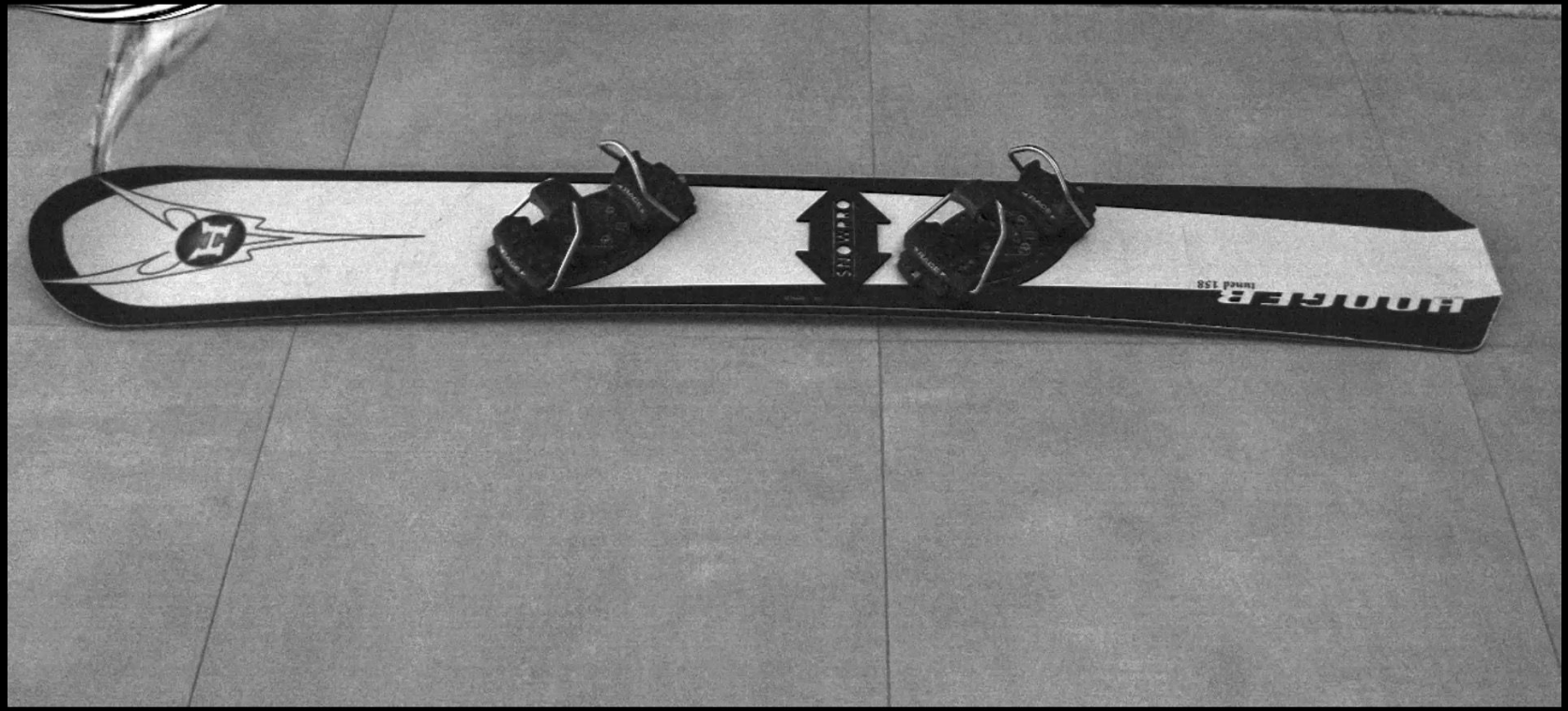


FIGURE 4E

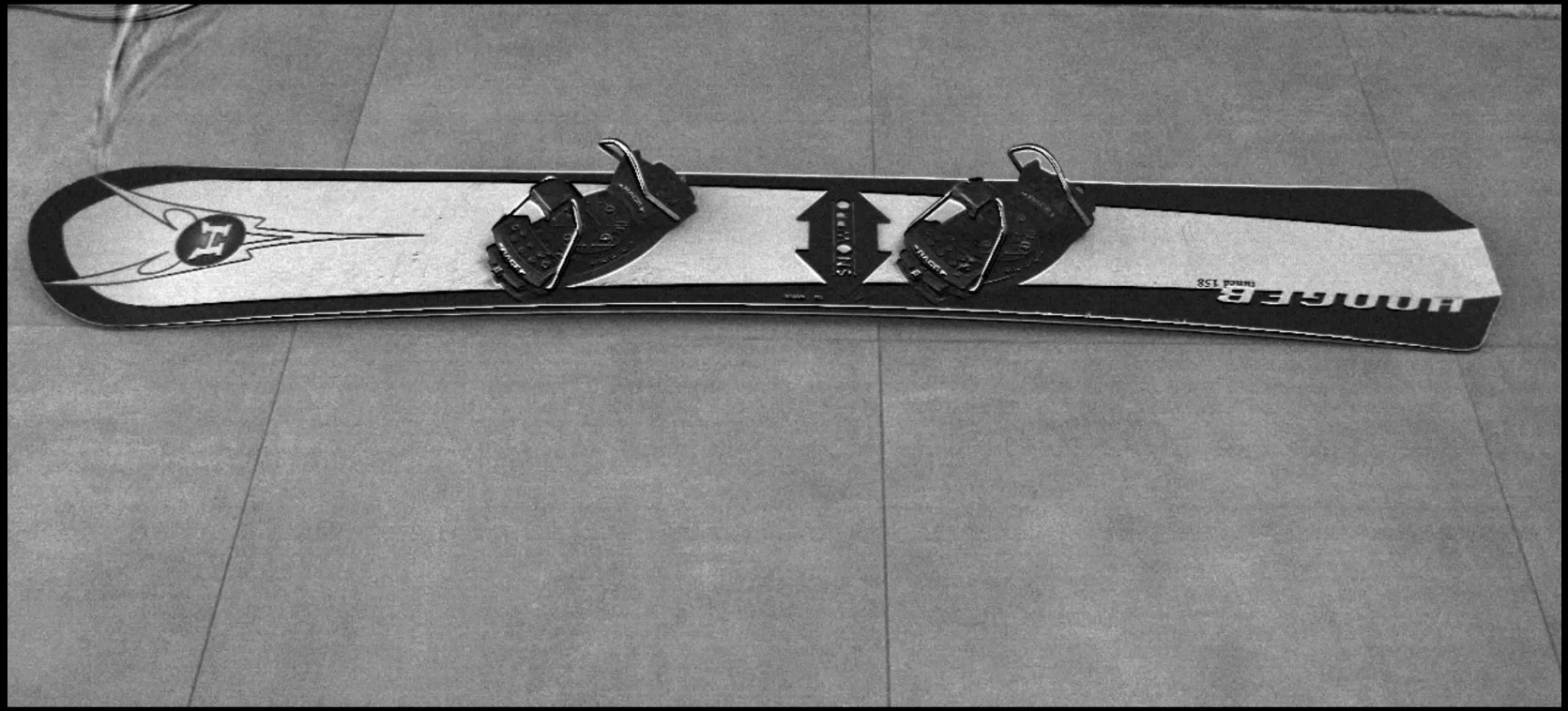

Einhell

Modal analysis

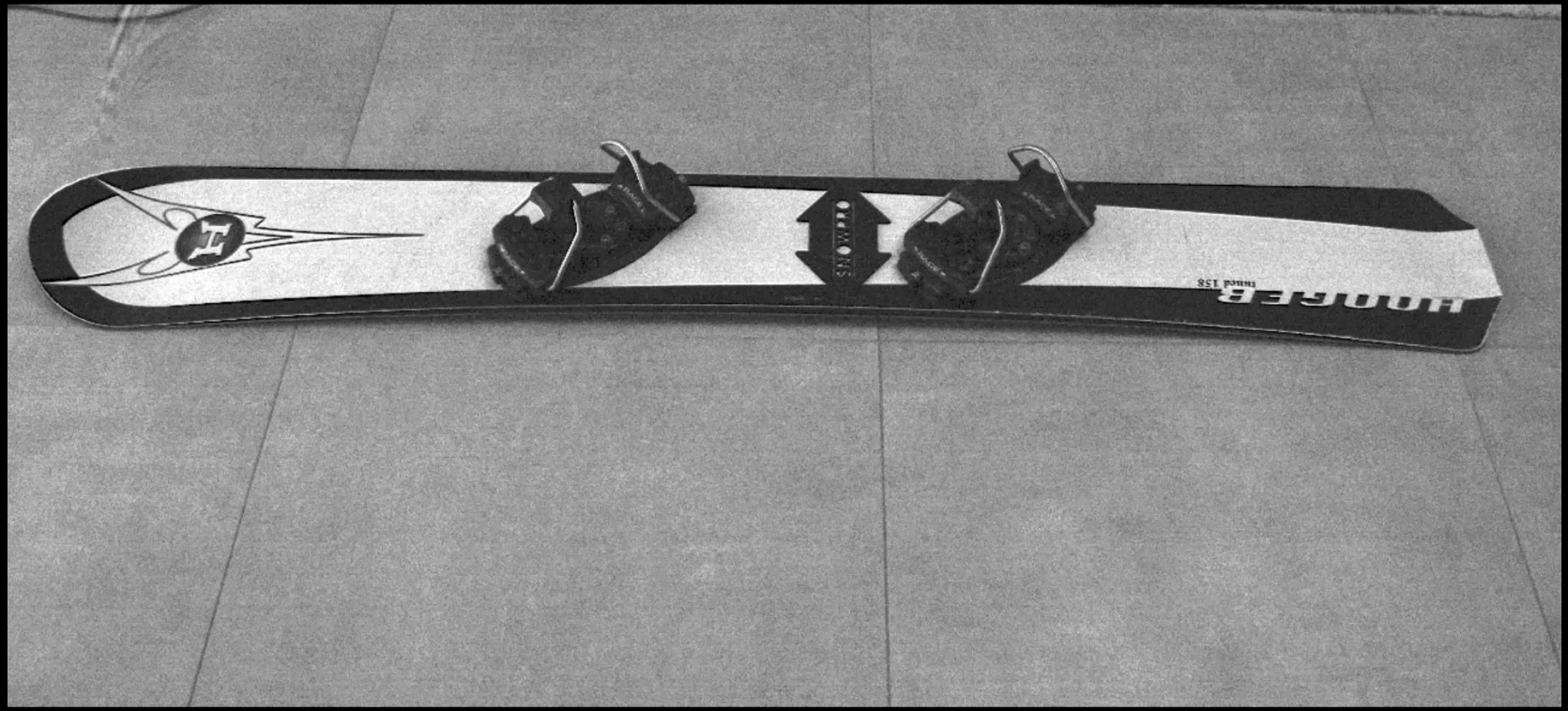

Modal Amplified - 2023-04-23 Snowboard extreme tip lateral.mdl
File
Tools
Help
Configure
Acquire
Stability
Analyze
Measurements
1X / Hammer
1Y / Hammer
2X / Hammer
2Y / Hammer
3X / Hammer
3Y / Hammer
4X / Hammer
4Y / Hammer
Add
Stability
Camera
Stable in frequency
Stable in damping
Stable in frequency and damping
Compliance (microns/N) dB
Order
Frequency (Hz)
Mode Shapes
Hz
Shown
Active
6.84
24.25
59.01
84.91
108.59
115.53
171.27
175.82



6.84 Hz



24.25 Hz

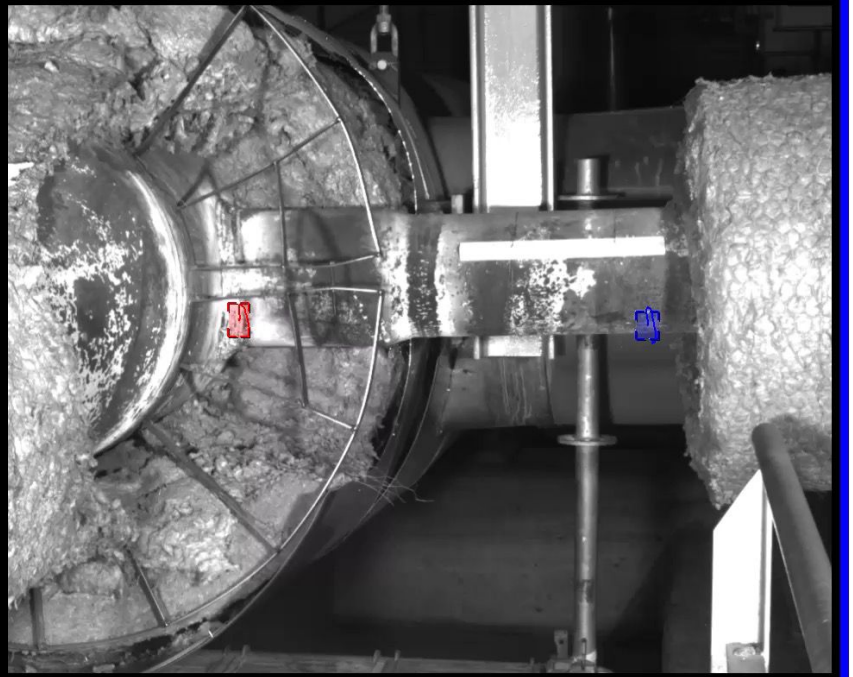


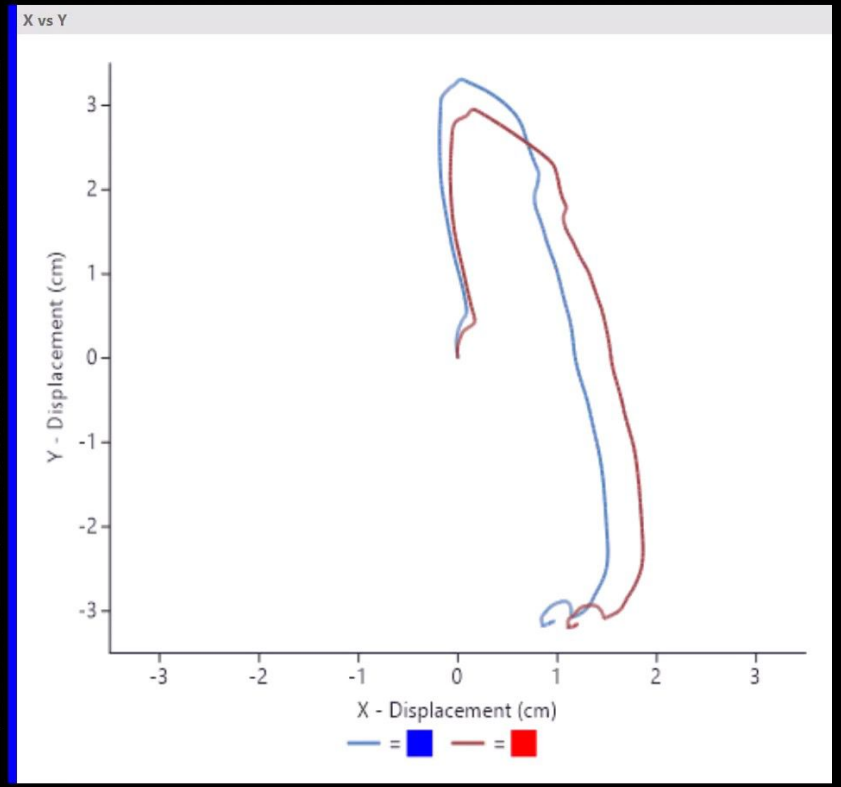
59.01 Hz

1536.28 Hz

Other capabilities

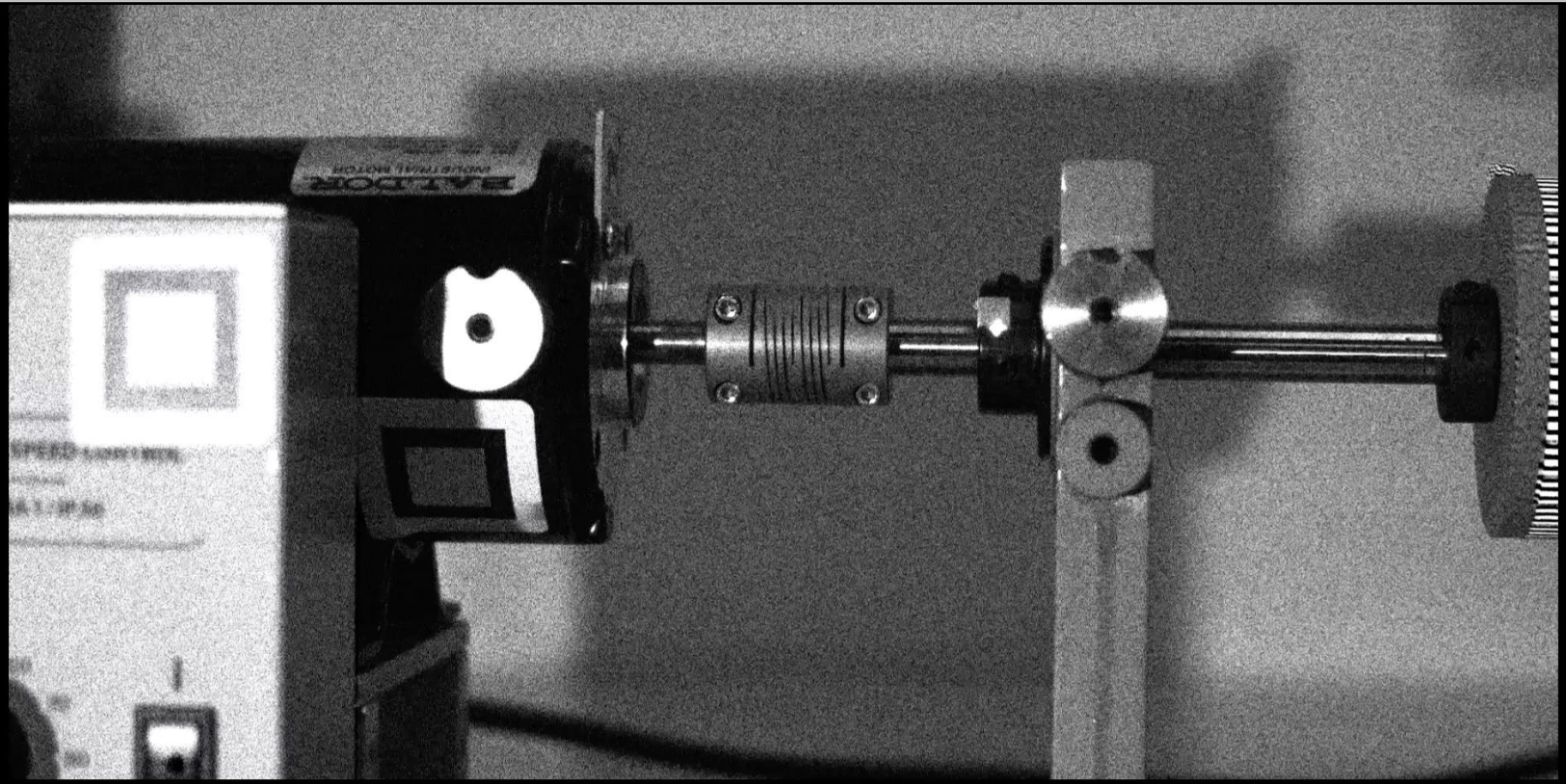
Thermal Growth / Syncronous / Transient

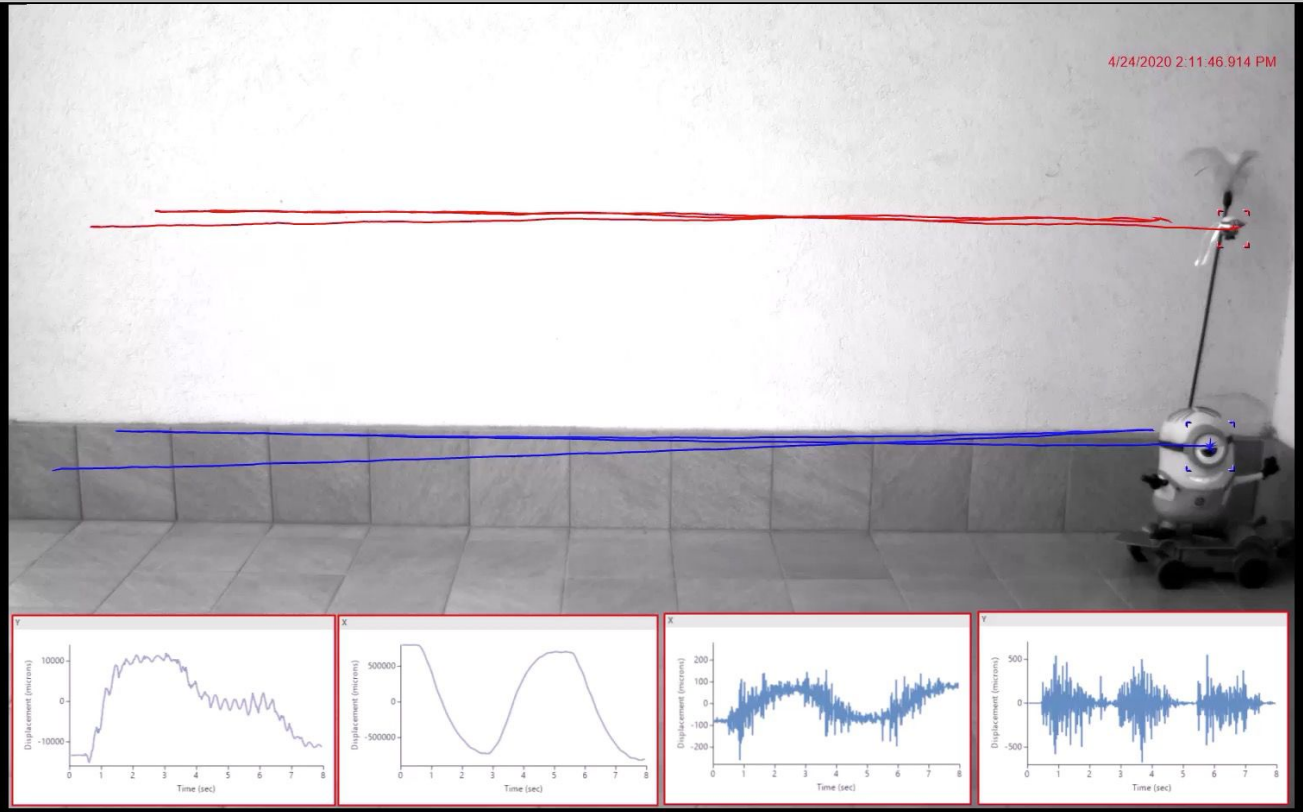




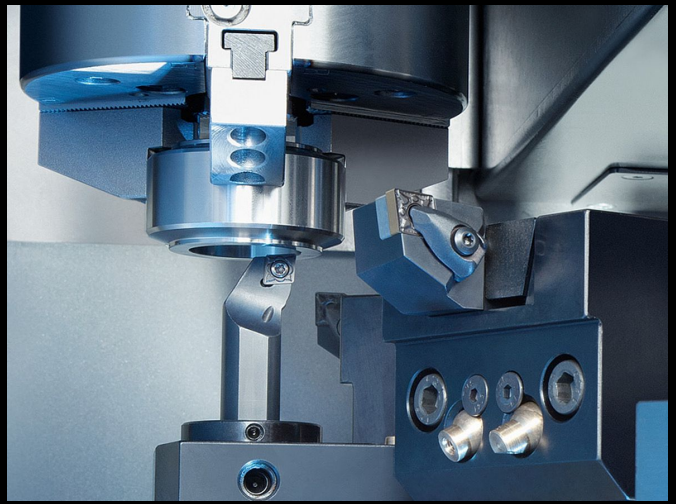
Gas power generation plant: time lapse thermal growth

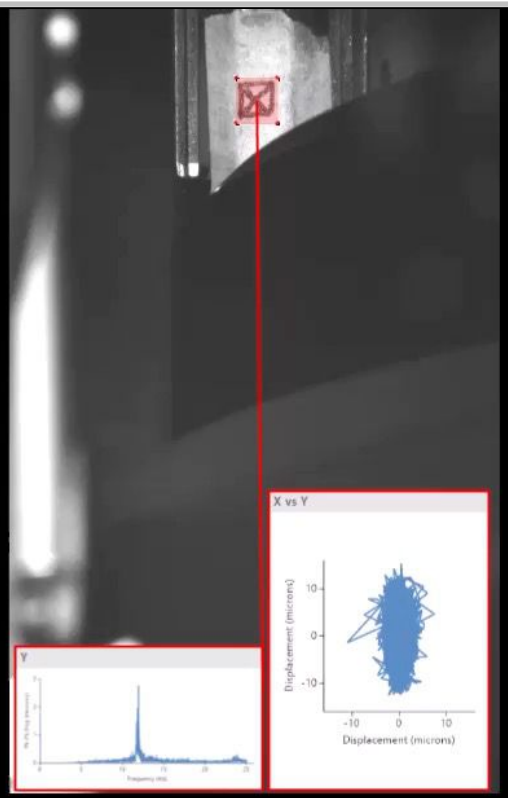

Z24-S01
+2085Z




4/24/2020 2:11:46.914 PM
Y
Displacement (microns)
Time (sec)
X
Displacement (microns)
Time (sec)
X
Displacement (microns)
Time (sec)
Y
Displacement (microns)
Time (sec)

Picture from Emag website





Email: Luca.delnero@darkwavethermo.com
Website: www.darkwavethermo.com