

Application of digital image correlation to vibration mode shape analysis of composites during acoustic load

4a Technologietag – Leichtbau und Composites

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Introduction Sobriety s.r.o.

- Sobriety s.r.o. is the private company established in 2002 as the engineering company (The Skoda auto cooperation)
- The first DIC system was released in 2012 for shaker motion measurements of turbocharger variable geometry cartridge of company Honeywell
- High speed rotational machines based on gas lubricated bearings technology acquisition in 2014 and follow up development of rocket propellant pumps for ESA in 2017
- 2018: cca 70 employes, 3 departments:
 - R&D, CFD, Measurement technic

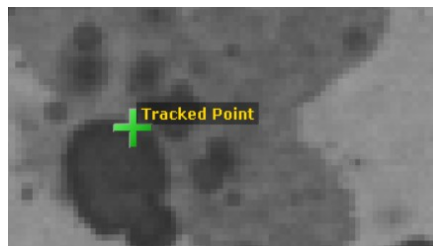
MONET 3D

- 3D measuring system based on Mercury RT
- In-house development
- Variability
- Universality
- Digital Image Correlation (DIC)

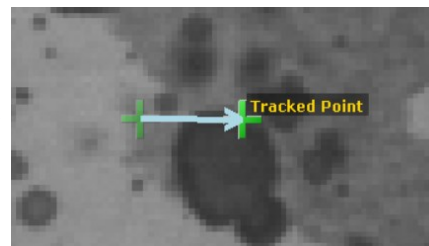
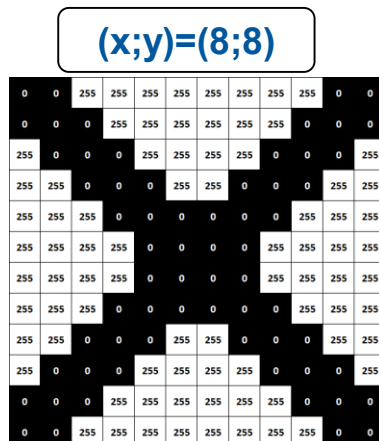


DIC

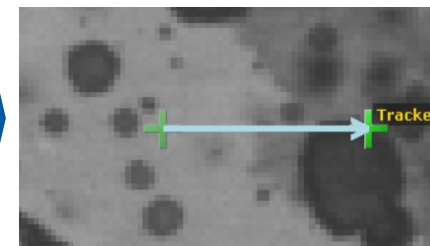
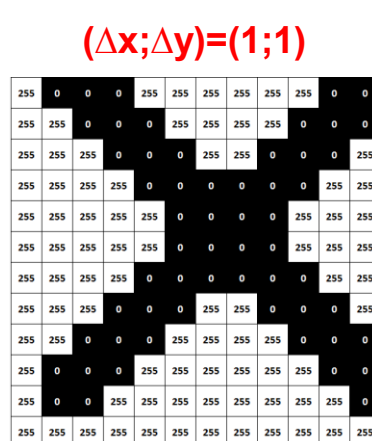
■ Principle



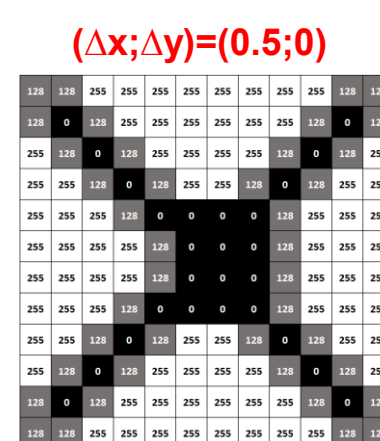
Time t_0



Time t_1



Time t_2





Software - Mercury RT

■ Software modules

RT

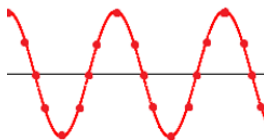
**Real Time
measurement**

Plus

**Advanced
functionalities**

Vibrography

**Vibrations
measurement**



Enter

Recomputation

3D

**3D
functionalities**

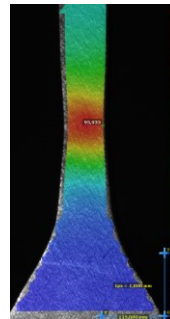
Crack

**Crack
measurements**



FullField

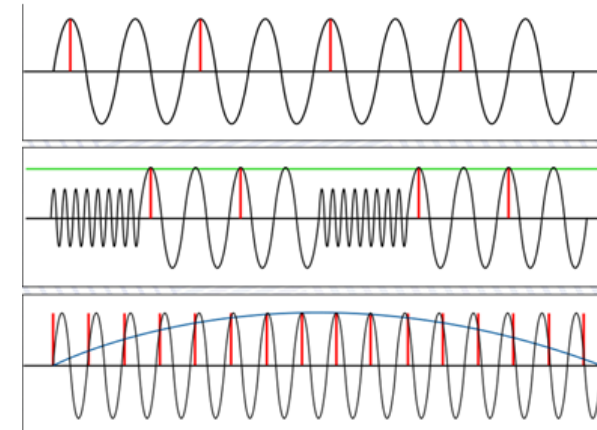
**Area strain
measurement**



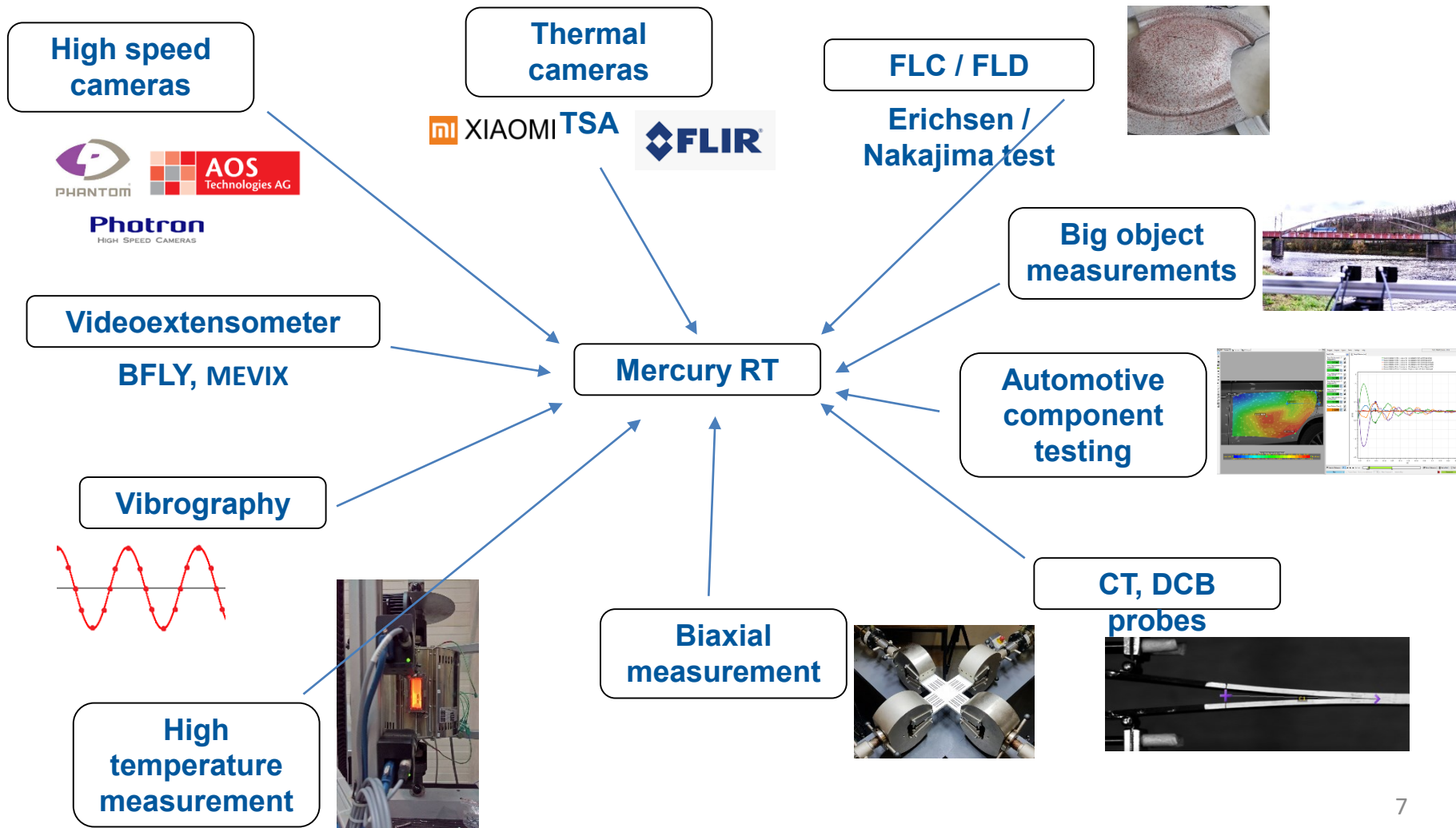
Hardware

- Calibration plates
- Cameras
- Lights
- Data transfer
- HW development
e.g. Synchronisation Box

- 1) Single phase mode
 - constant phase shift
- 2) Voltage level mode
 - triggering when voltage level reached
- 3) Phase sweep mode
 - specific phase shift
 - stroboscopic effect
- 4) Generator mode
 - embedded generator used



Applications



Introduction

- L-39 (Aero Vodochody Aerospace) - single-engine, advanced jet trainer
- The most widely used jet trainer in the world (1th flight 1968) – more then 2,800 produced, 30 air forces around the world.
- L-39NG - modified airframe, avionics.
- Wet wing, no wing tip fuel tanks, FJ44-4M Williams engine (weight 305 kg, Thrust 16.89 kN, FADEC (Full Authority Digital Engine Control), Electrical starter)
- air inlet ducts from polymer composite

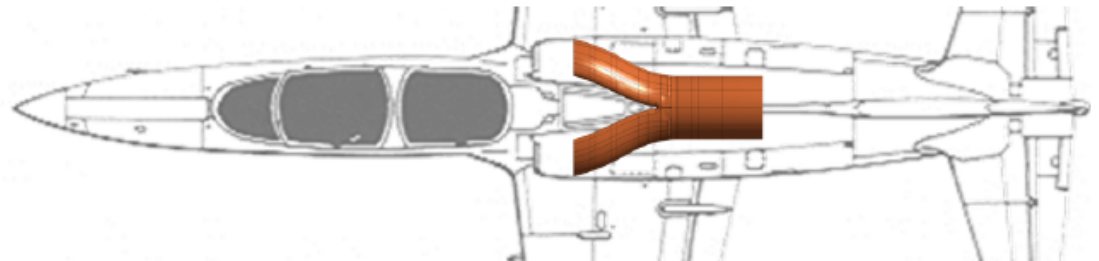
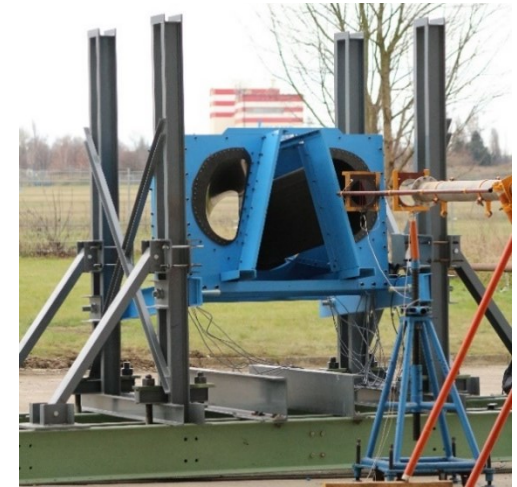


<https://www.armadinoviny.cz/l-39-next-generation.html>

Introduction

Air intake requirements

- Aerodynamical
 - Regular and sufficient air intake in all flight regimes
- Structural resistance
 - Flight load (landing impact, aerobatics (+8g/-4g))
 - Hail impact (25, 50 mm - 770 km/h)
 - bird strike (1kg - 600 km/h)
- Fatigue resistance
 - Mechanical loading
 - Acoustic loading



Introduction

Construction

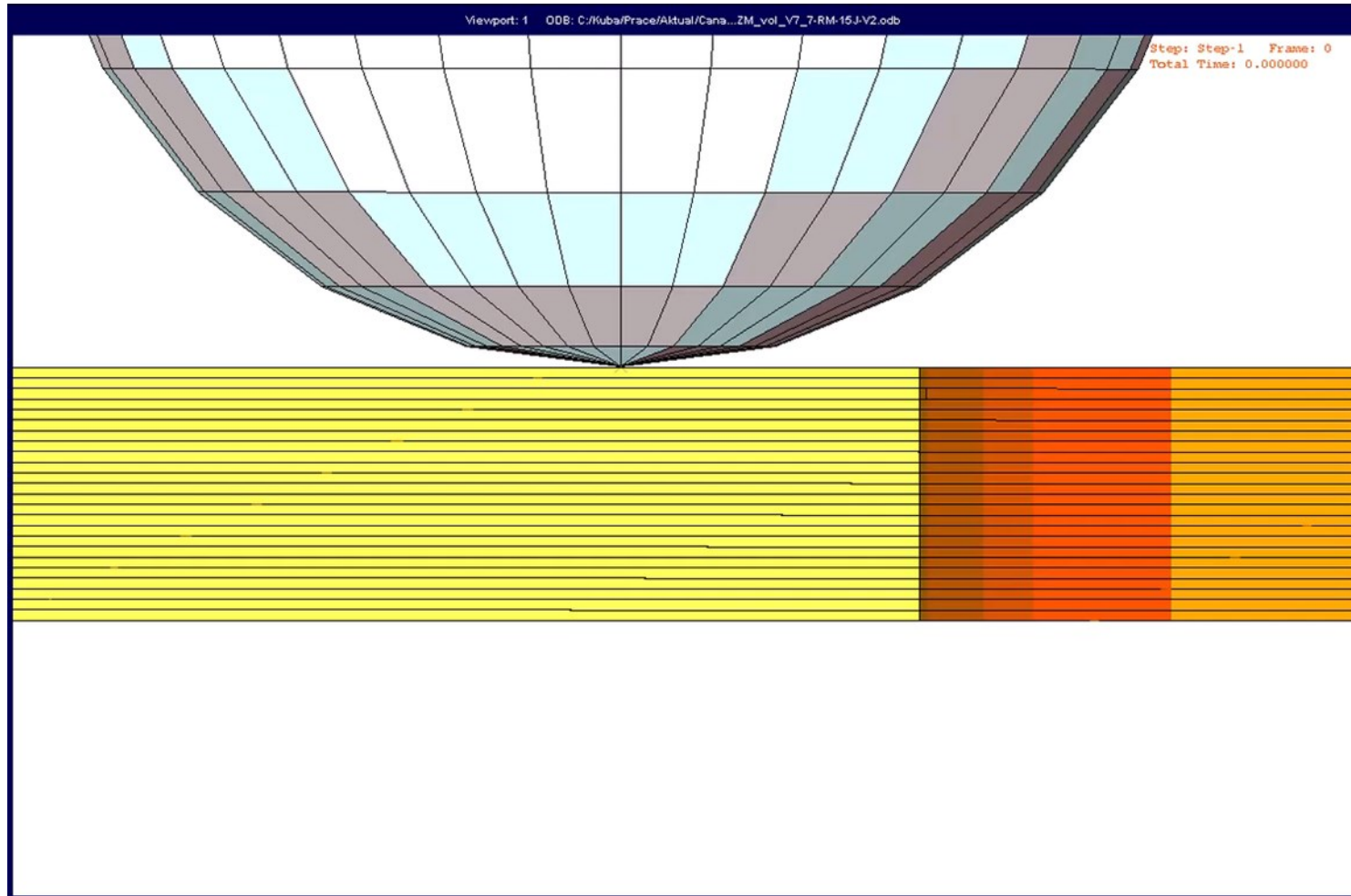
- Composite instead of aluminium alloy
- Reason:
 - Intensive sound vibrations from Williams engine
 - Composite - better attenuation and resistance to fatigue

Damage of composite

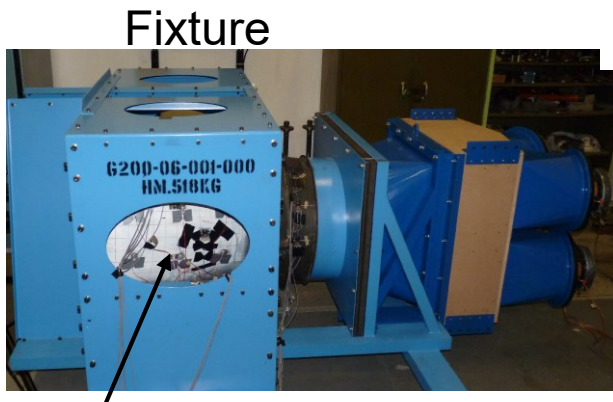
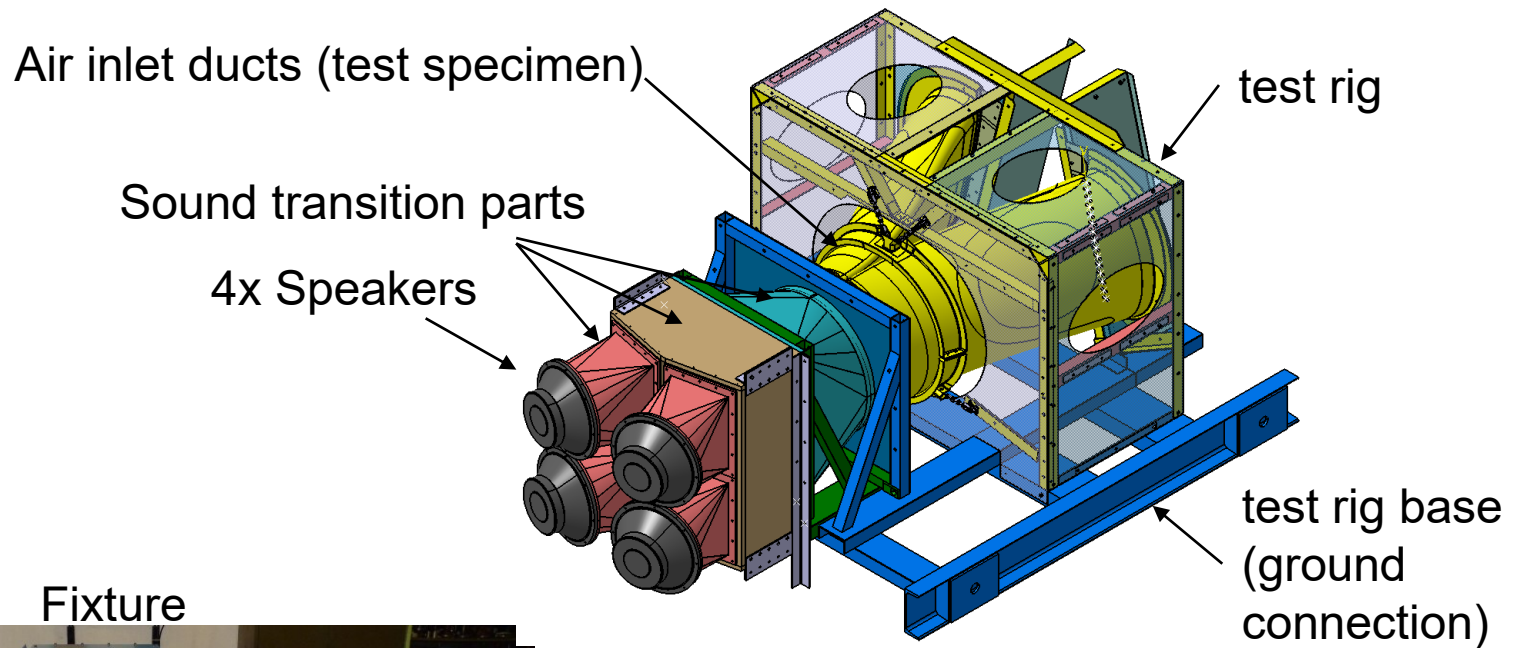
- Manufacturing flaw or impact
- Delamination between plies
- (BVID)



Barely visible impact damage (BVID) simulation



Acoustic Test Rig



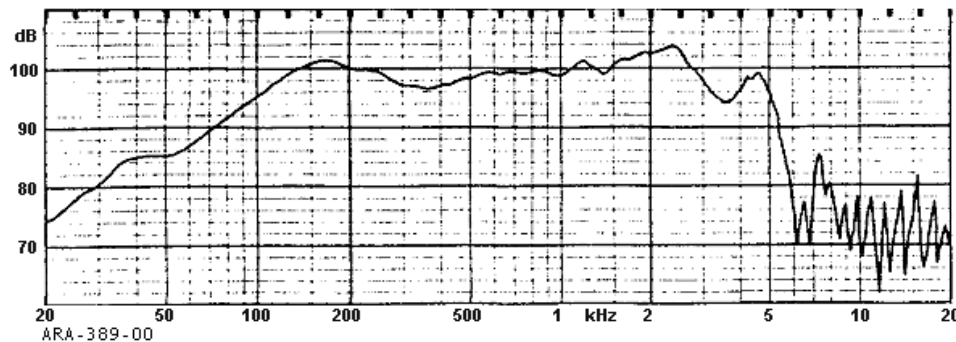
Air inlet

Test equipment

- Speakers: 4x Tesla TVM ARA-389-00/4
- Peak power 300W, frequency range 40-5000Hz
- Speaker sensitivity 100dB (1m,1W)

Amplifier unit Dynacord S1200:
Max power 880W/4Ω

Acoustic sensitivity characteristic



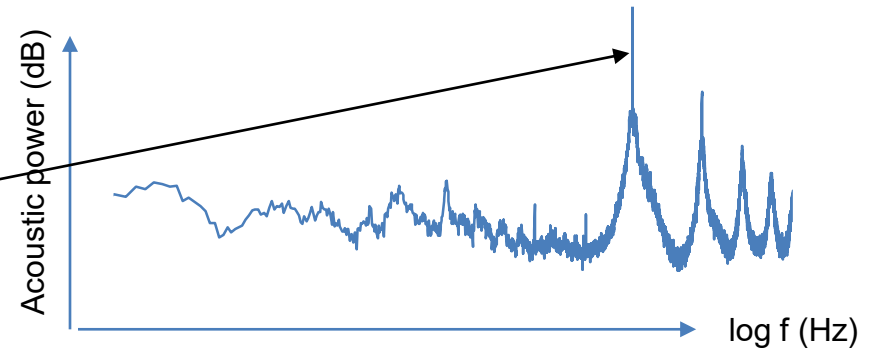
frequency range for 100dB:
150-3000Hz



Acoustic loading

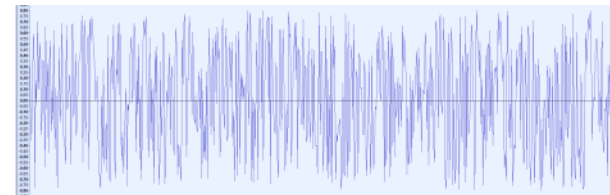
■ Engine acoustic spectra

- Resonance frequencies present



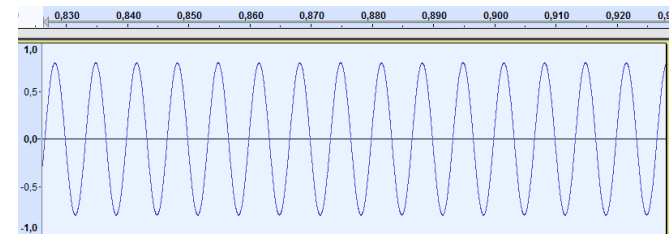
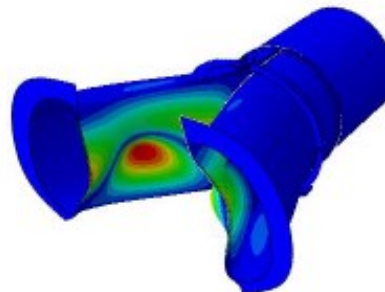
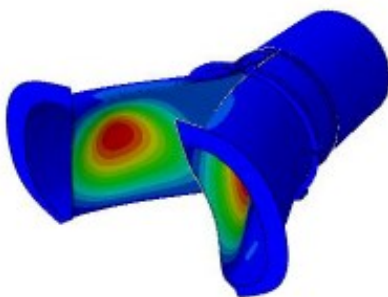
■ Resonance frequency of the ducts

- Determined from white noise response
- Two lowest resonance frequencies chosen for the experiment (84 Hz, 118Hz)



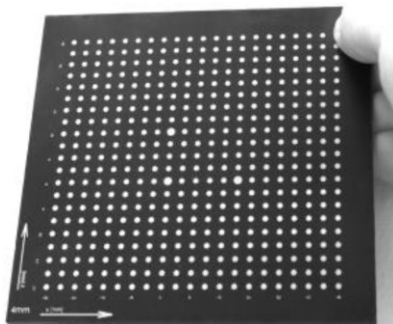
FEM: 1th mode

2nd mode



Optical measurement

- CCD high speed cameras (Phantom v1212-Full frame and Miro 26x16 mm)
 - 1280 x 800 pixels - 1Mpx
- 2000 fps used for measurement:
- Calibration plate

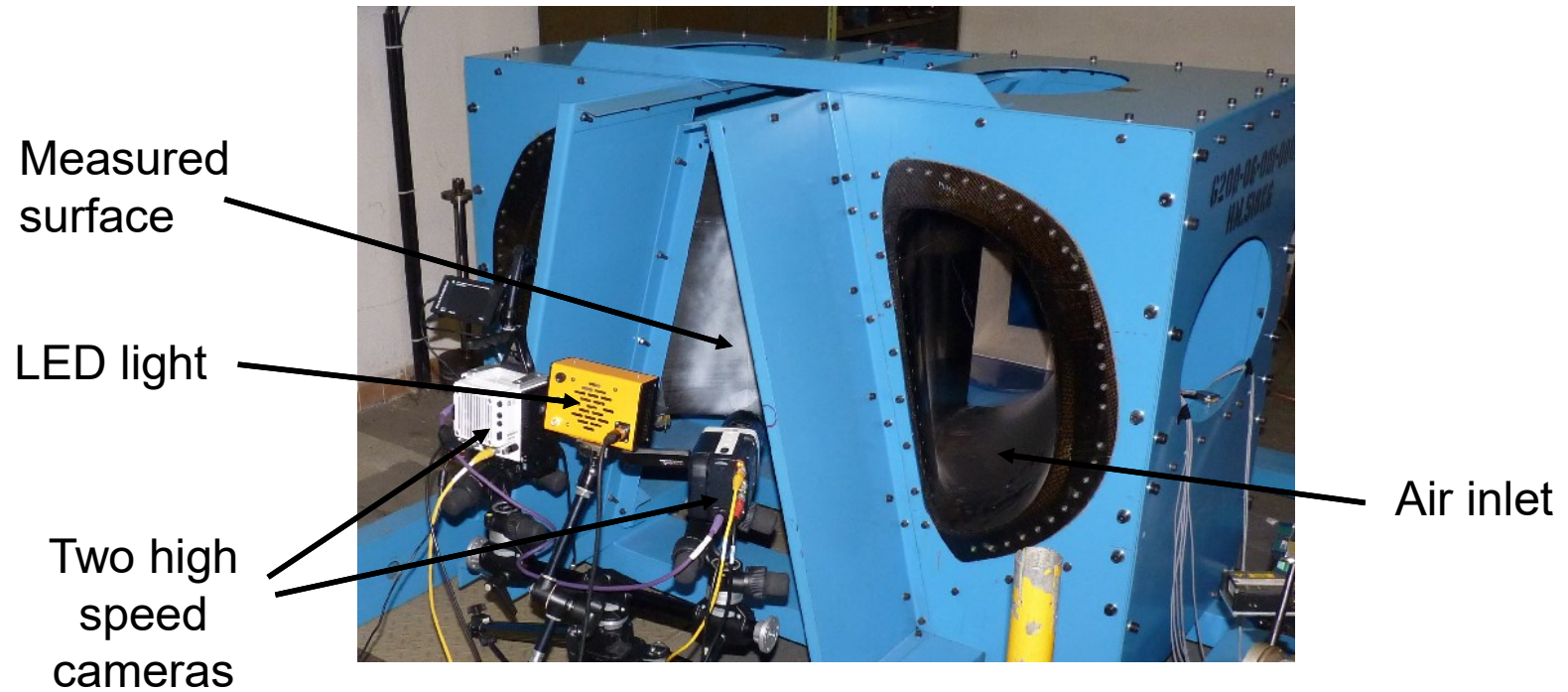


v-series

Phantom cameras

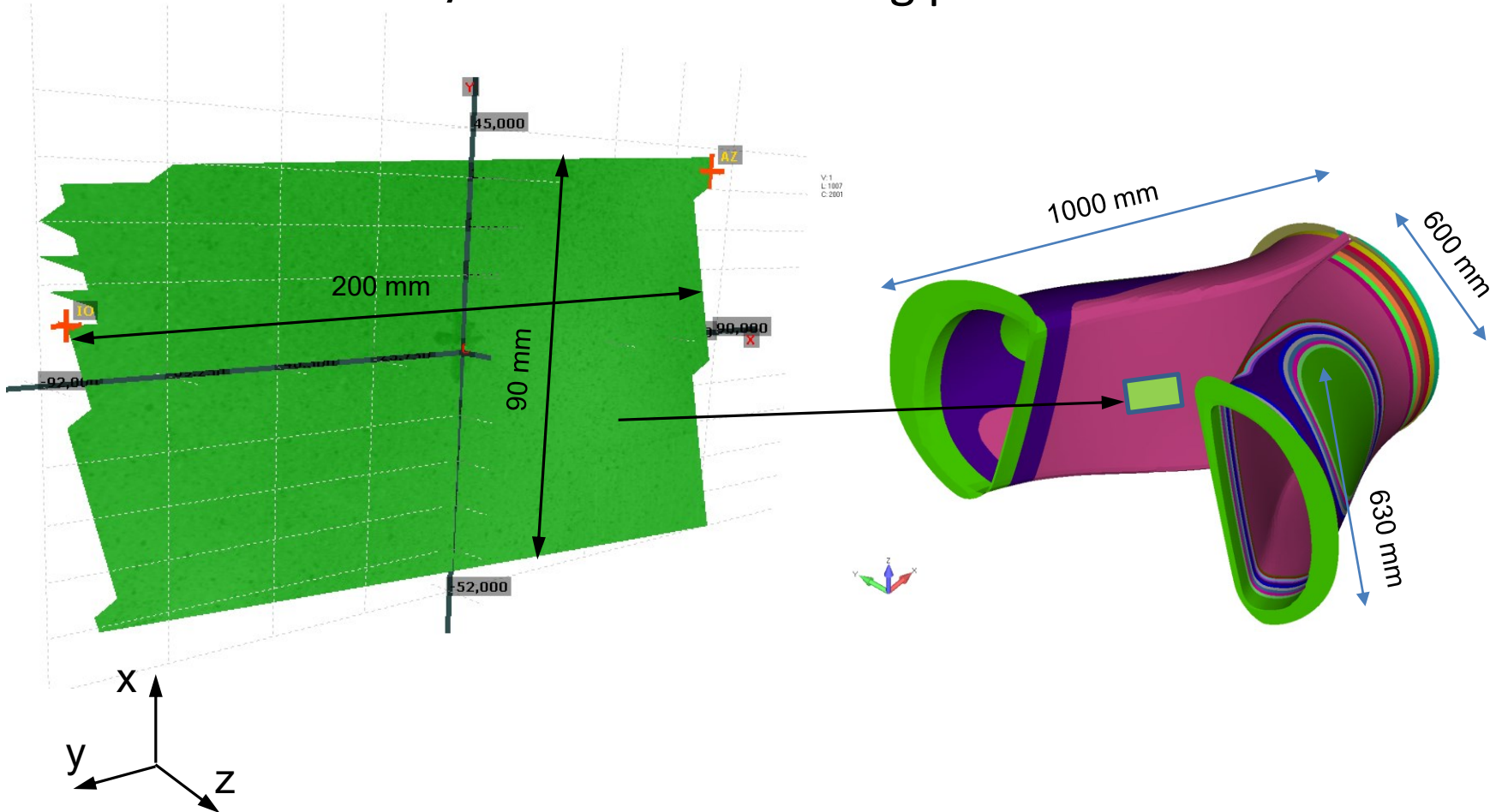
Miro

Acoustic Test set-up



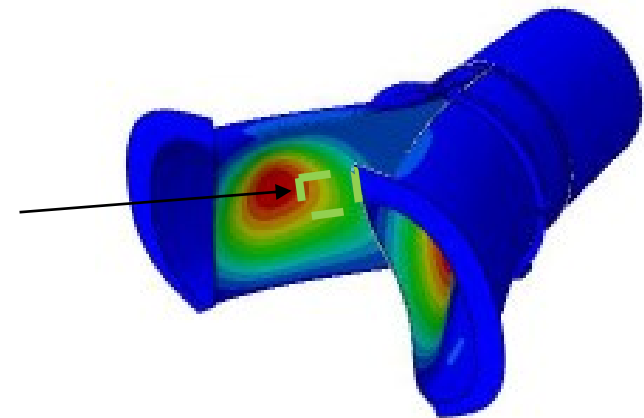
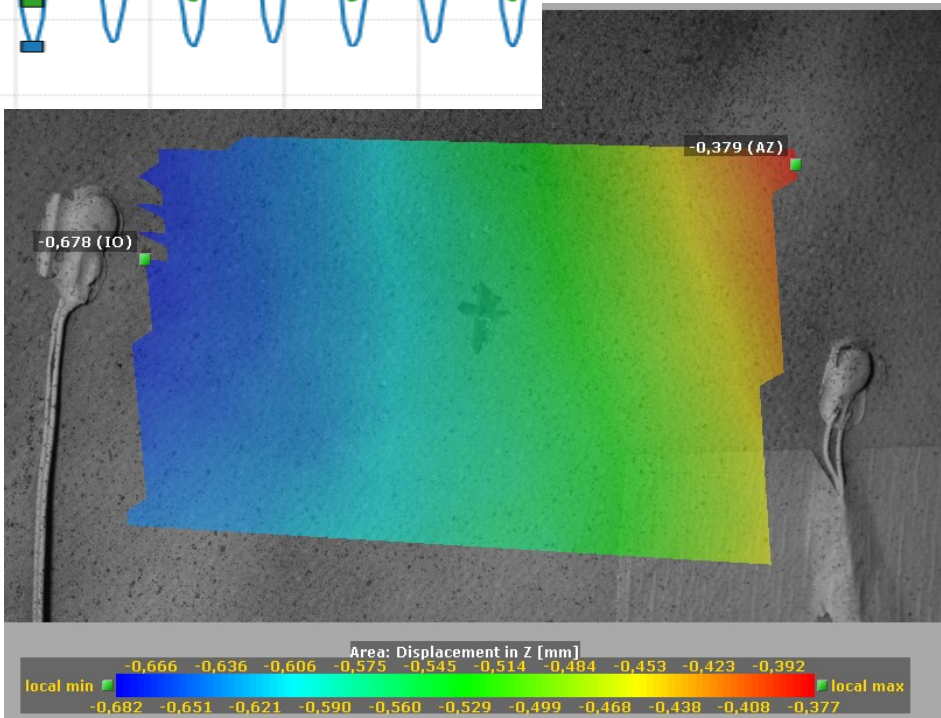
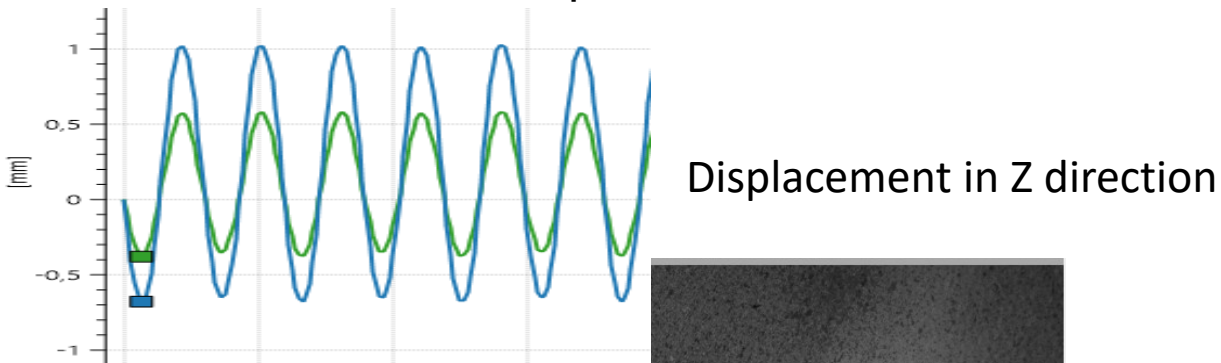
Optical measurement results

- Coordinate system and measuring plane



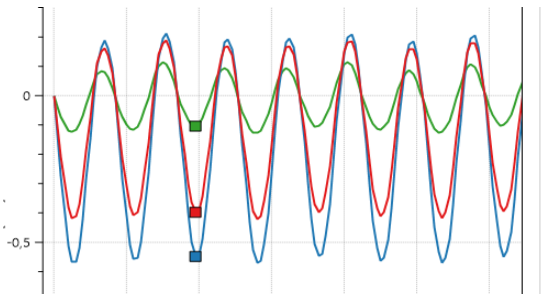
Vibrography results

■ 84 Hz - 2000 fps

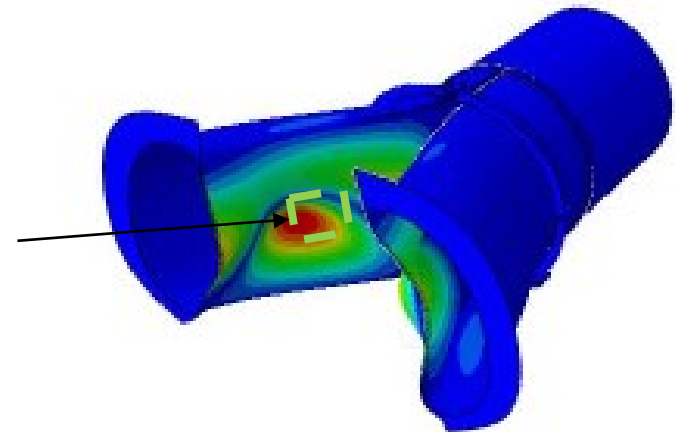
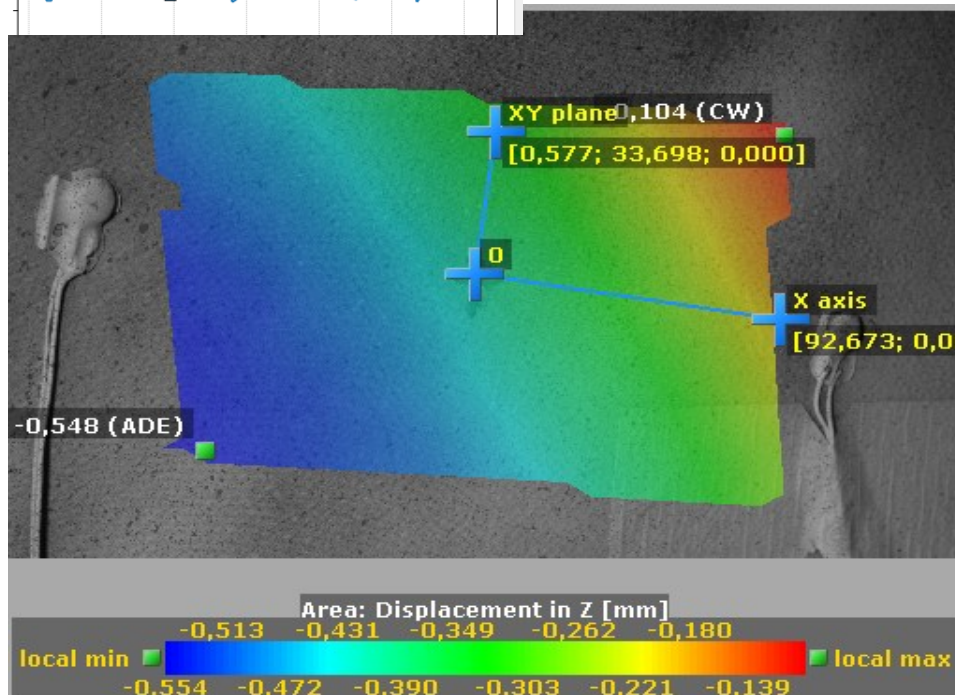


Vibrography results

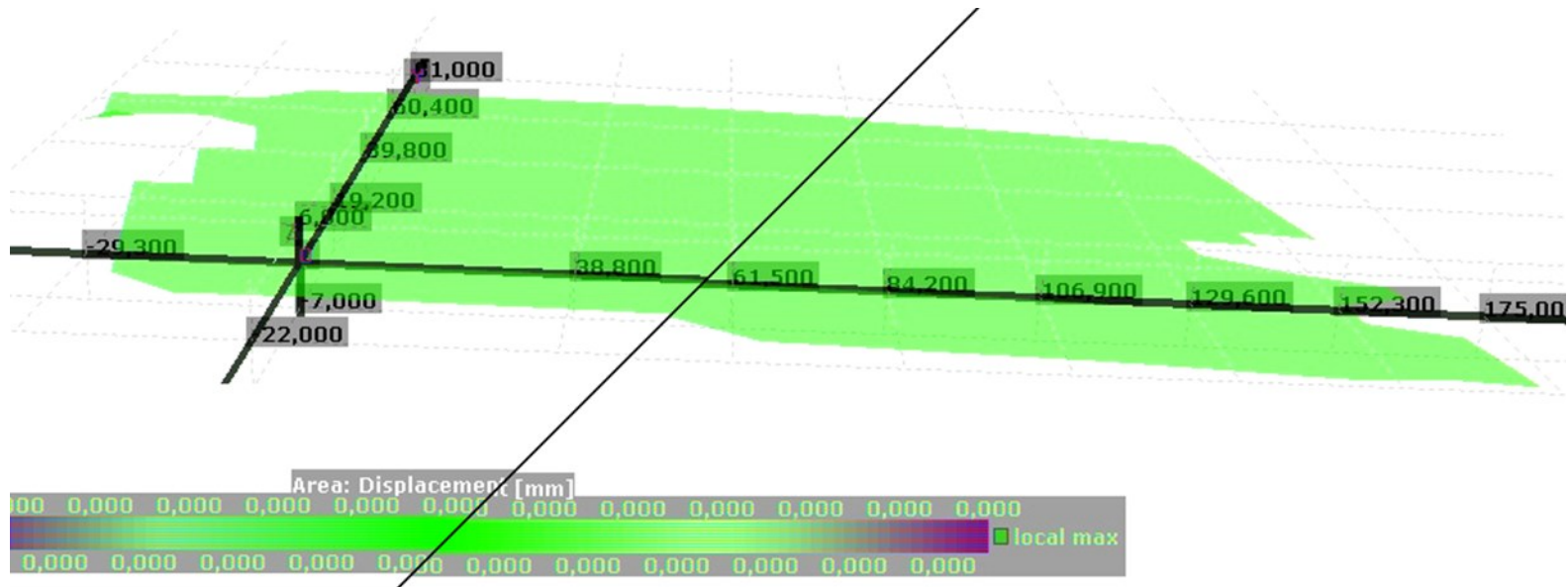
■ 118 Hz - 2000 fps



Displacement in Z direction



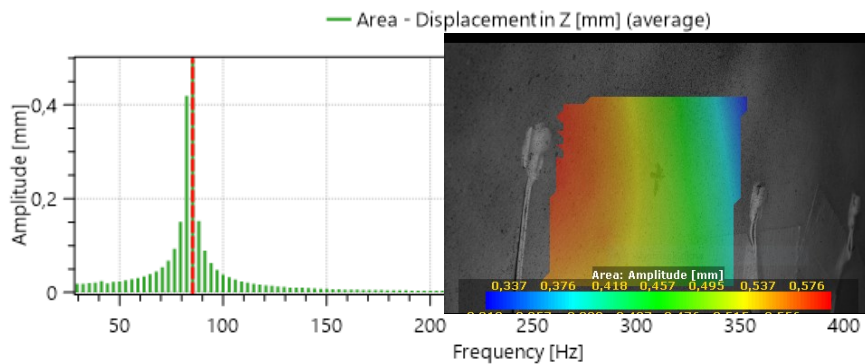
- Vector field in time (video – real time of 0.1 second)



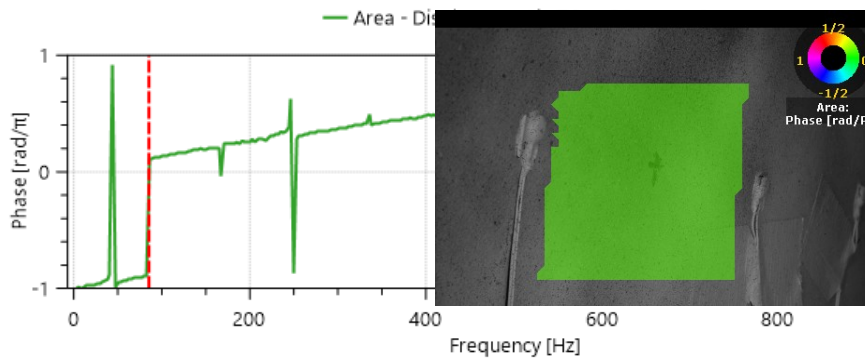
FFT analysis

84 Hz

Amplitude Graph

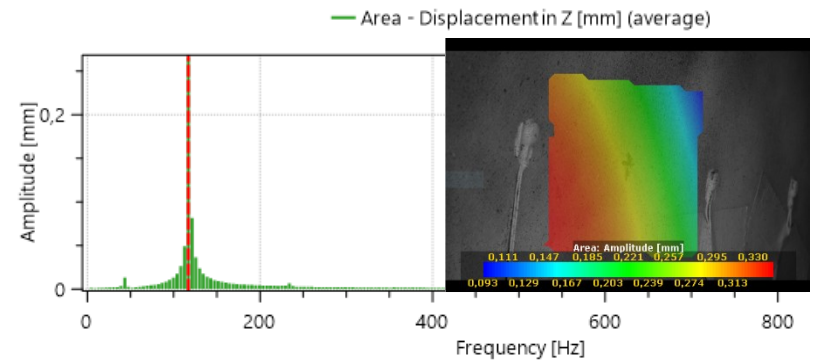


Phase Graph

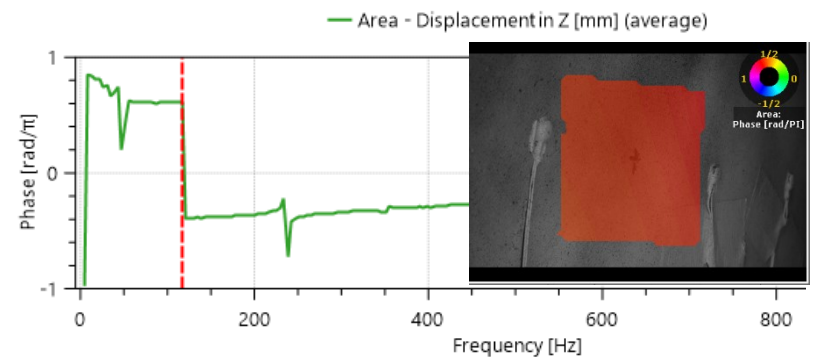


118 Hz

Amplitude Graph



Phase Graph





Conclusion

- Non-contact 3D vibrational measurement carried out using Mercury DIC system
- Two resonance frequencies evaluated
- Full-field local displacements determined
- Other locations for the measurement planned



Thank you for your attention

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