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Thales Cryogenics

Compressor development for MTG pulse tube cryocooler

M. Meijers, J. Mullié, Th. Rijks,
F. van Wordragen, A. Göbel,
B. Schalkwijk, N. Sanchez-Ciudad,

5th European Space Cryogenics Workshop

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- **Introduction**
  - Thales Cryogenics
  - Large Pulse Tube Cooler Compressor history
- **LPTC compressor features & test results**
  - Efficiency
  - Lifetime
  - Self-induced vibrations
- **Summary & Questions**

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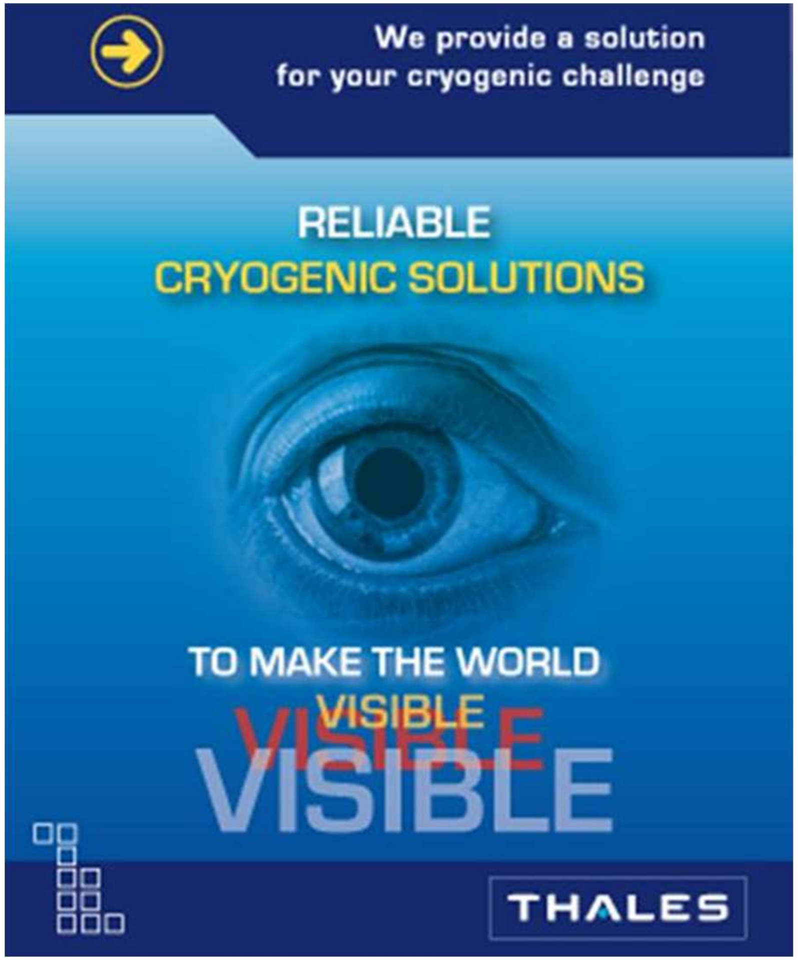
Introduction



- Thales Cryogenics develops and manufactures cryogenic coolers for military, civil and space applications.
- Wide range of cryocooler products and cooler drive electronics:
  - Linear Stirling,
  - pulse tube and
  - Rotary coolers and electronics
- World leader in extremely high-reliable cryocoolers
  (life time > 100.000 hours demonstrated)
- Space flight heritage at cooler level in US defense satellites
- Delivery of required ground support equipment.

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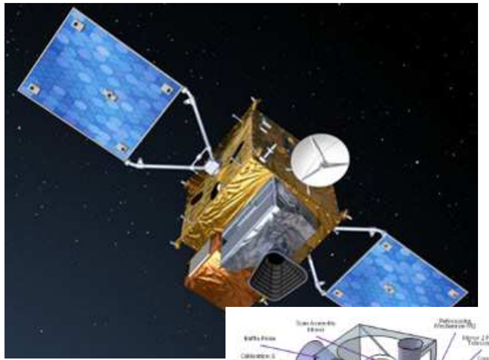
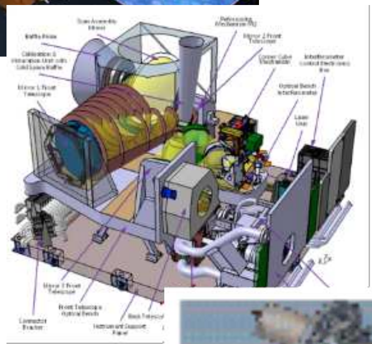
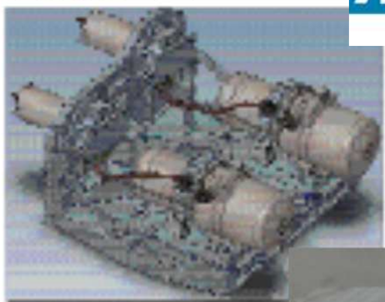
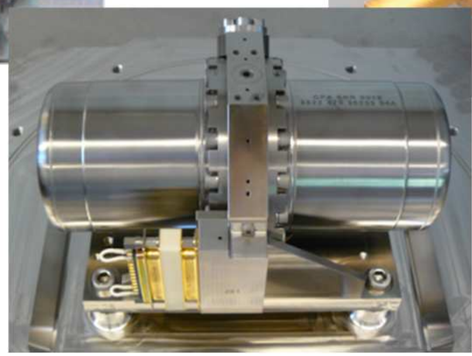
Introduction









EUMETSAT

esa

OHB SYSTEM
An OHB Technology AG Company

KAYSER-THREDE
An OHB Company

ThalesAlenia Space

cnes

MINISTÈRE DE LA DÉFENSE

ASTRIUM
AN EADS COMPANY

ThalesAlenia Space

AIR LIQUIDE
ADVANCED TECHNOLOGIES

?

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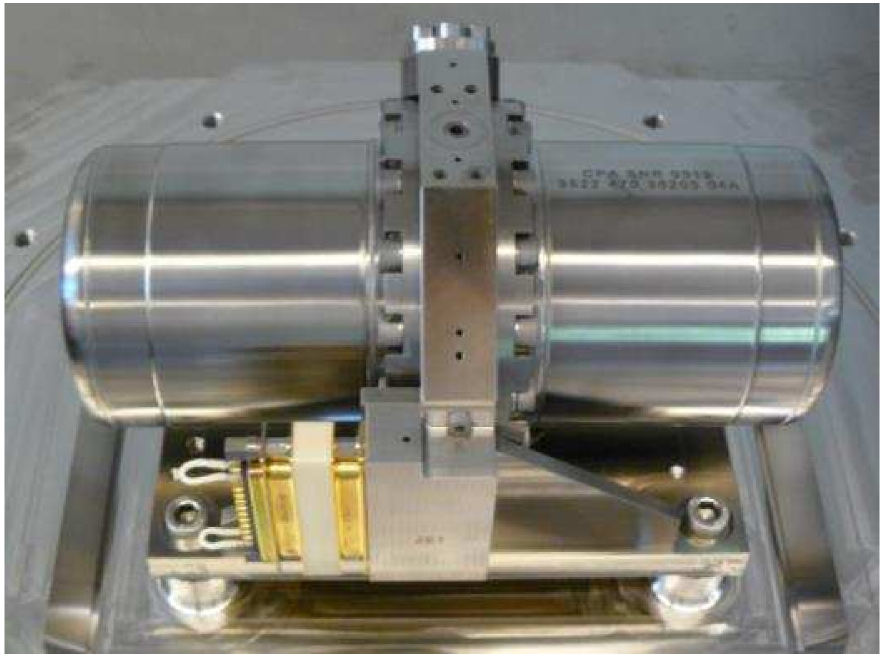
THALES CRYOGENICS

Introduction



Primary function	PV power generation
Max input power	180 W
Resonance frequency	55 – 60 Hz
Mechanical power	120 W
Filling pressure	31 - 34 bar
Mass	4.9 kg
Max. swept volume	3.77 cc

- Dual opposed pistons
- Moving magnet
- Flexure suspended pistons
- Dynamic pressure seal
- Ti6Al4V pressure vessel
- Dismountable motors on central bracket

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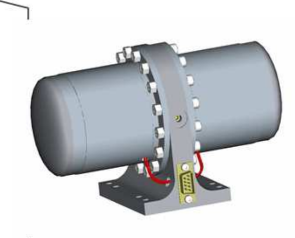
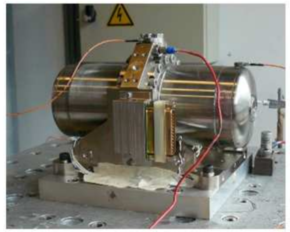
Introduction

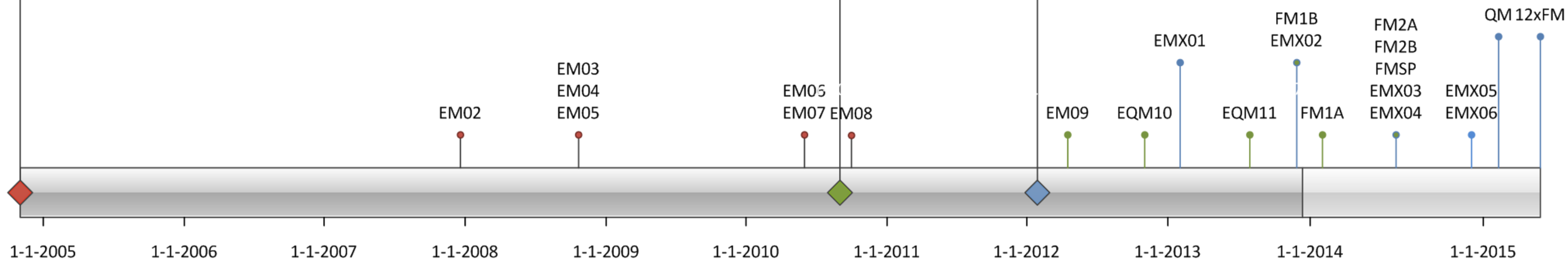
1-11-2004
LPTC TRP

1-9-2010
Start CSO-MUSIS
Program

27-1-2012
Start MTG
Program







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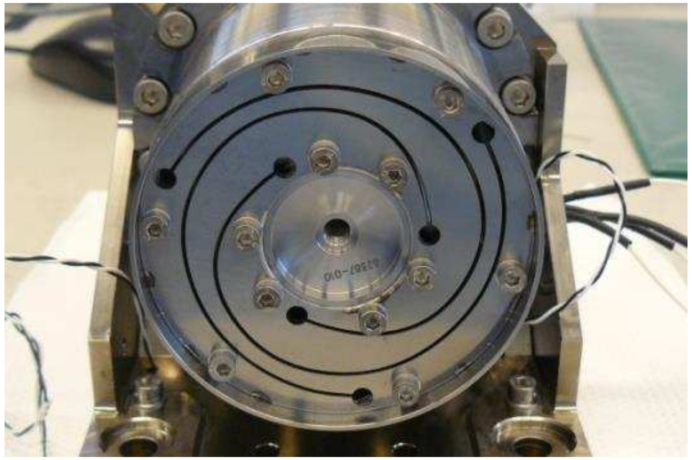
LPTC compressor features & test results

High Efficiency



- **Linear motor design**
- **High motor constant:**
  - NdFeB magnets
  - High coil filling factor
- **Minimizing eddy currents:**
  - Powder composite material stators
  - Ti6Al4V structural parts
- **Minimizing flow losses**
  - Very small piston gap providing dynamic pressure seal.
  - Piston with liner suspended in flexures
    - Minimizing contact forces
    - Minimizing friction forces

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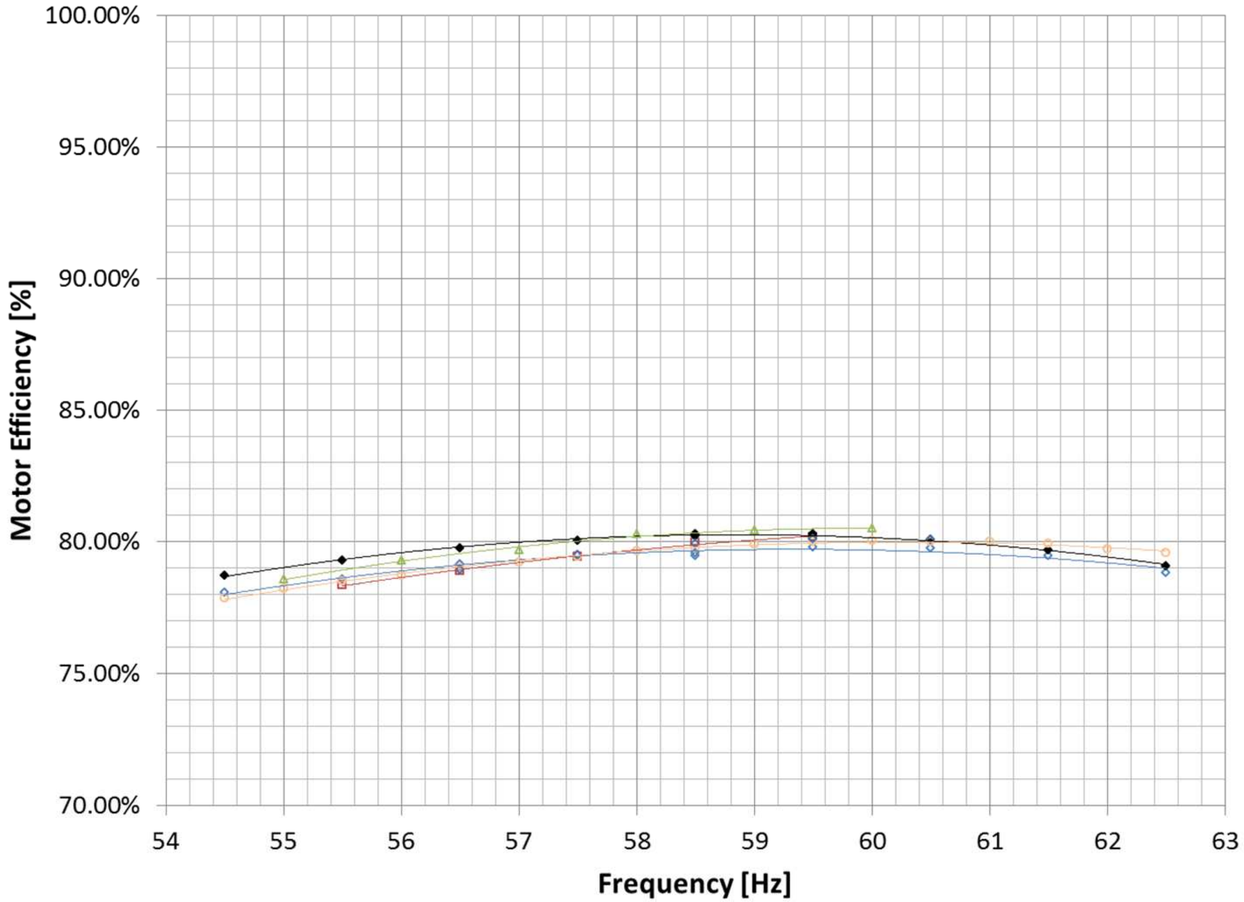
LPTC compressor features & test results

Measured motor efficiencies for delivered compressors



- Tested against a representative pulse tube delivering ± 2W at 50K
- Motor efficiency defined in this graph as $\eta = \frac{P_{in} - I^2 R}{P_{in}}$
- Input power 160 W

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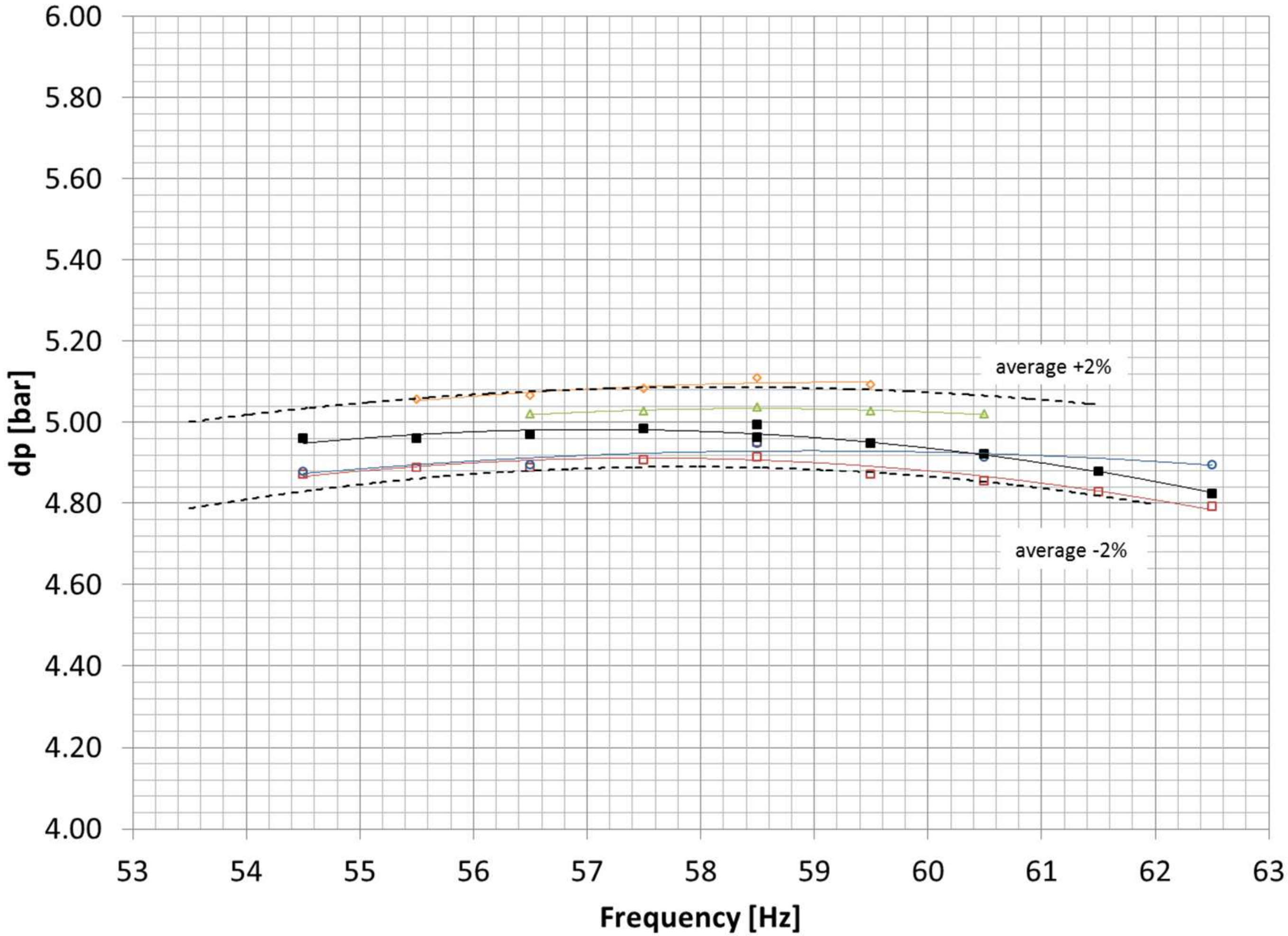
LTPC compressor pressure wave

Measured pressure waves for delivered compressors



- Tested against a representative pulse tube delivering ± 2W at 50K
- Input power 160 W

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LPTC compressor features & test results

long lifetime

- **Leak tightness**
  - Minimising number of seals by EB-welding as much as possible
  - Using metallic C seals when unavoidably (requirement on motor accessibility)
- **Low off-gassing to He working gas**
  - Coils outside the pressurized part containing He working gas
  - Encapsulated stators
  - Effective cleaning processes, bake-outs, flushes, etc.

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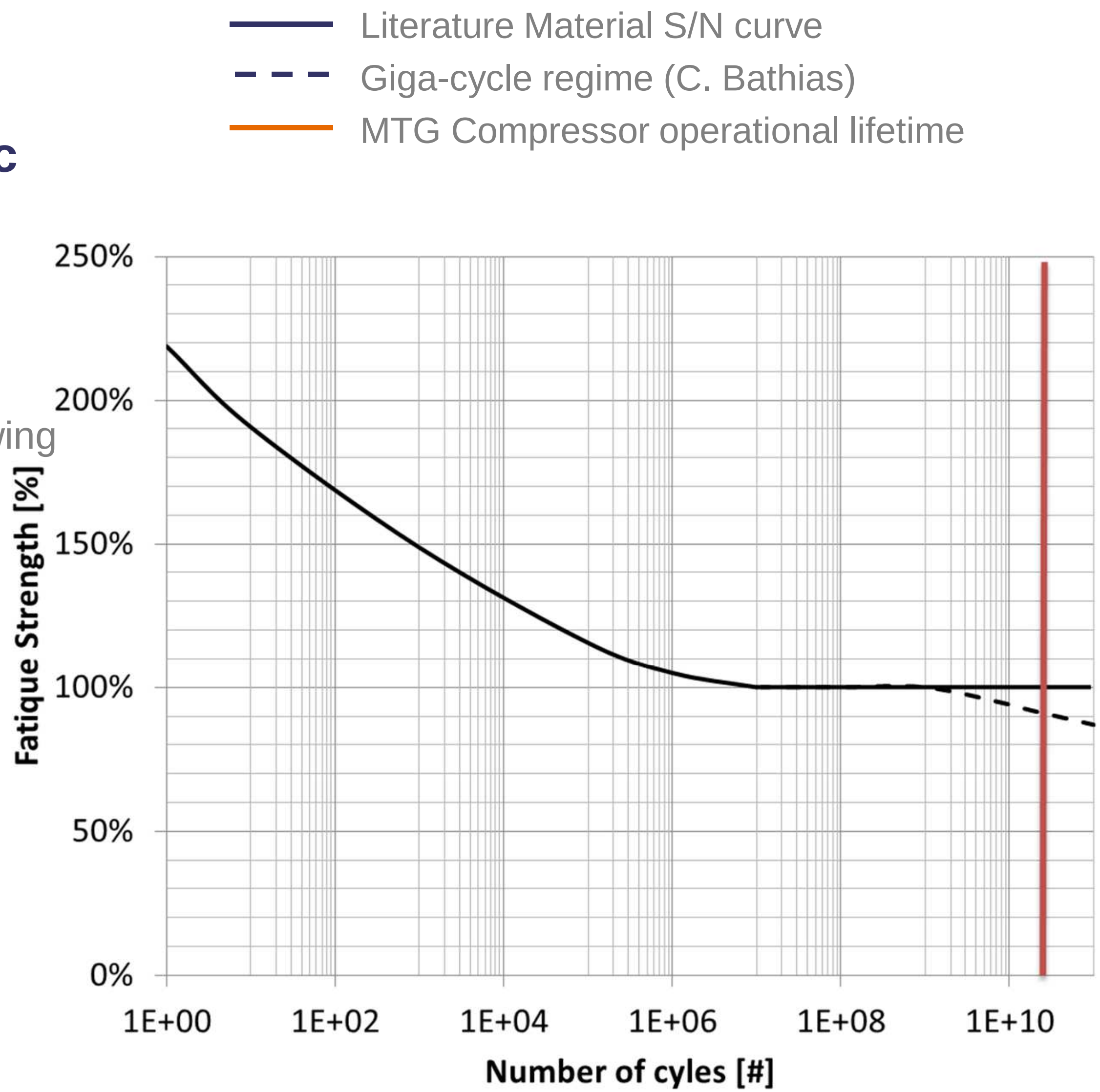
Long lifetime

- **Minimise risk on dynamic loaded structures**
  - No moving coil leads
  - Conservative flexure design:
    - Use of flexure material allowing high fatigue loads
    - High design margins
    - Photo-etching: minimizing manufacturing stresses
  - Thorough crack analyses of dynamically loaded welds



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LPTC compressor features & test results

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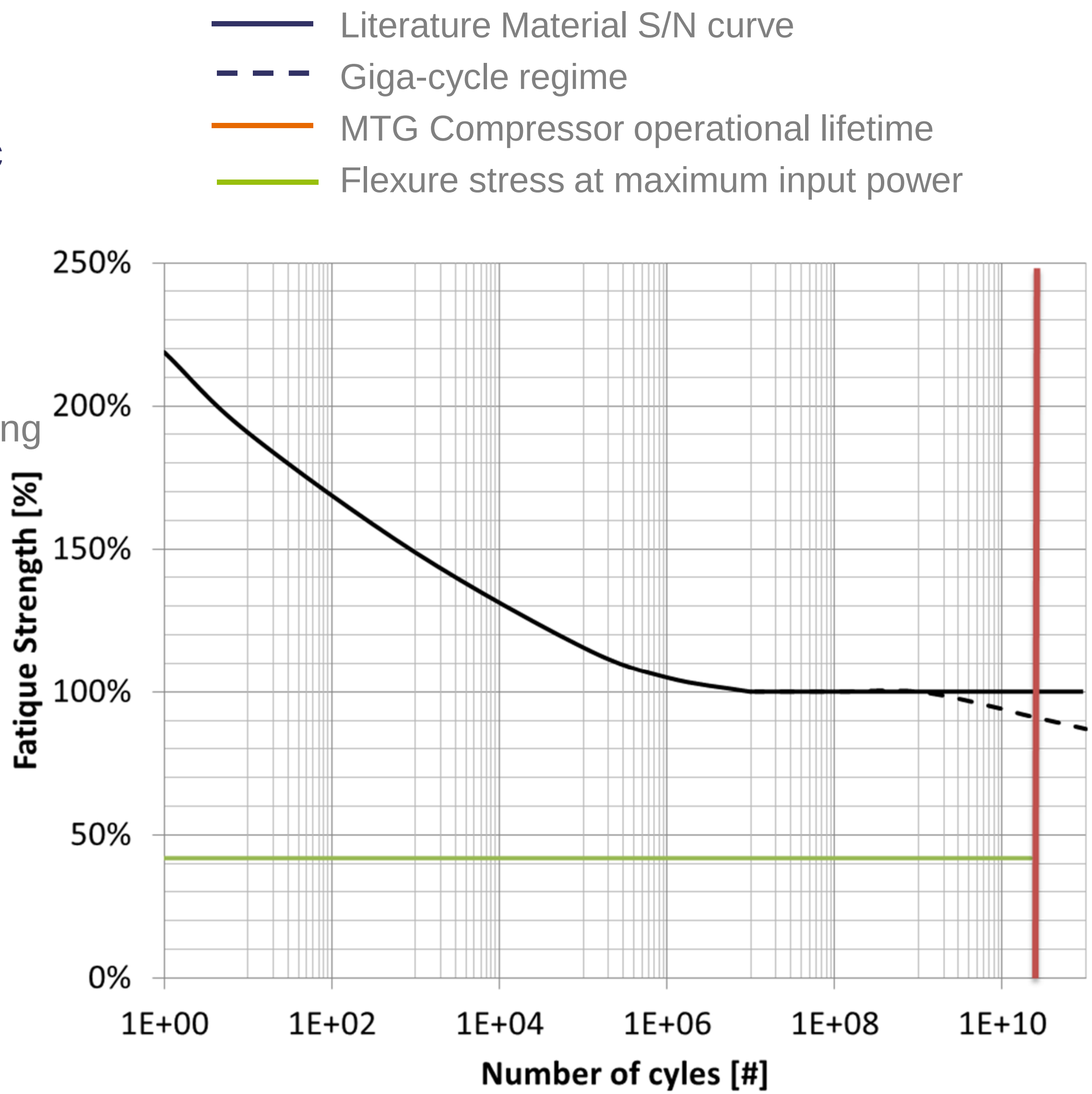

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LPTC compressor features & test results

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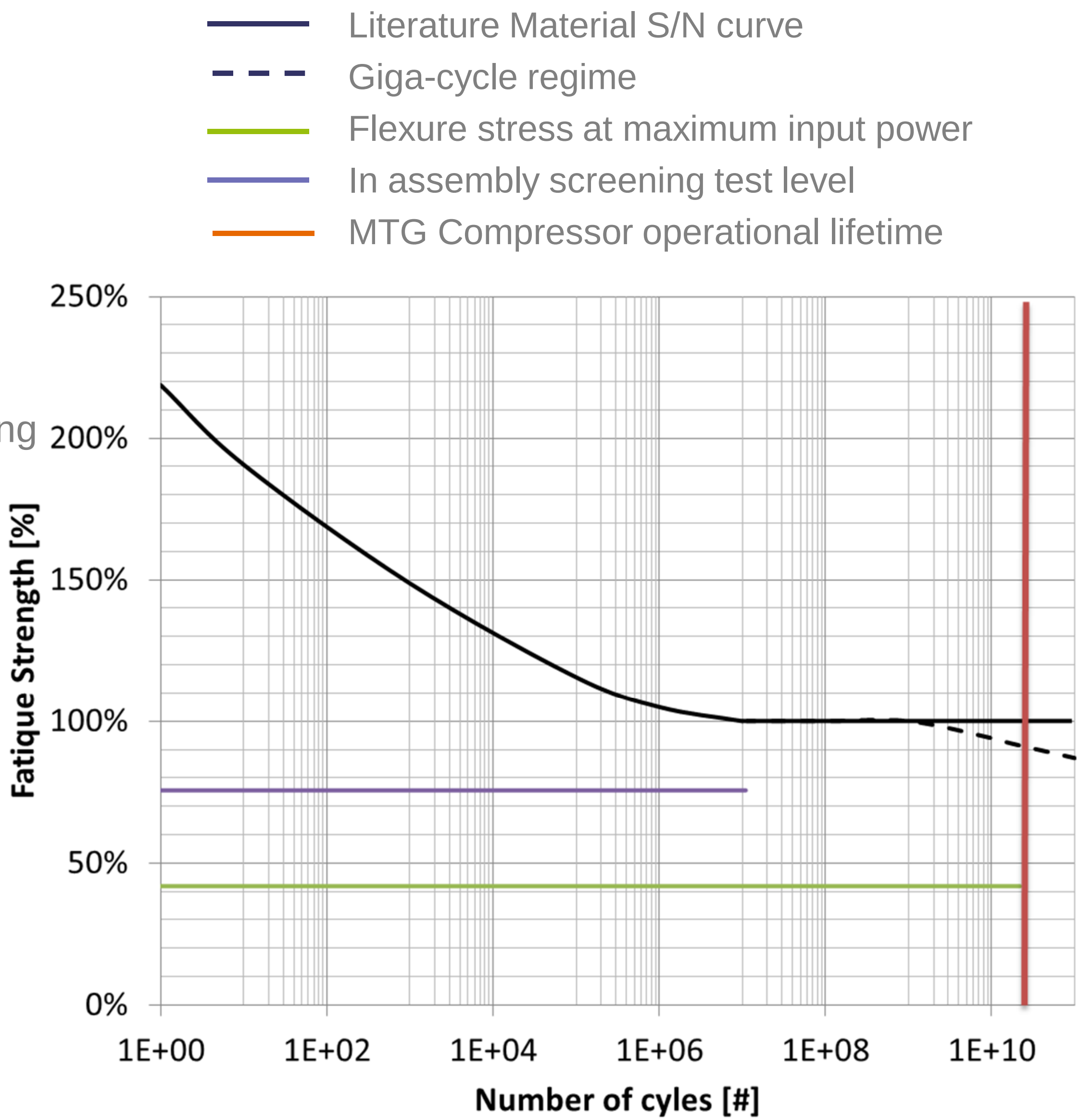

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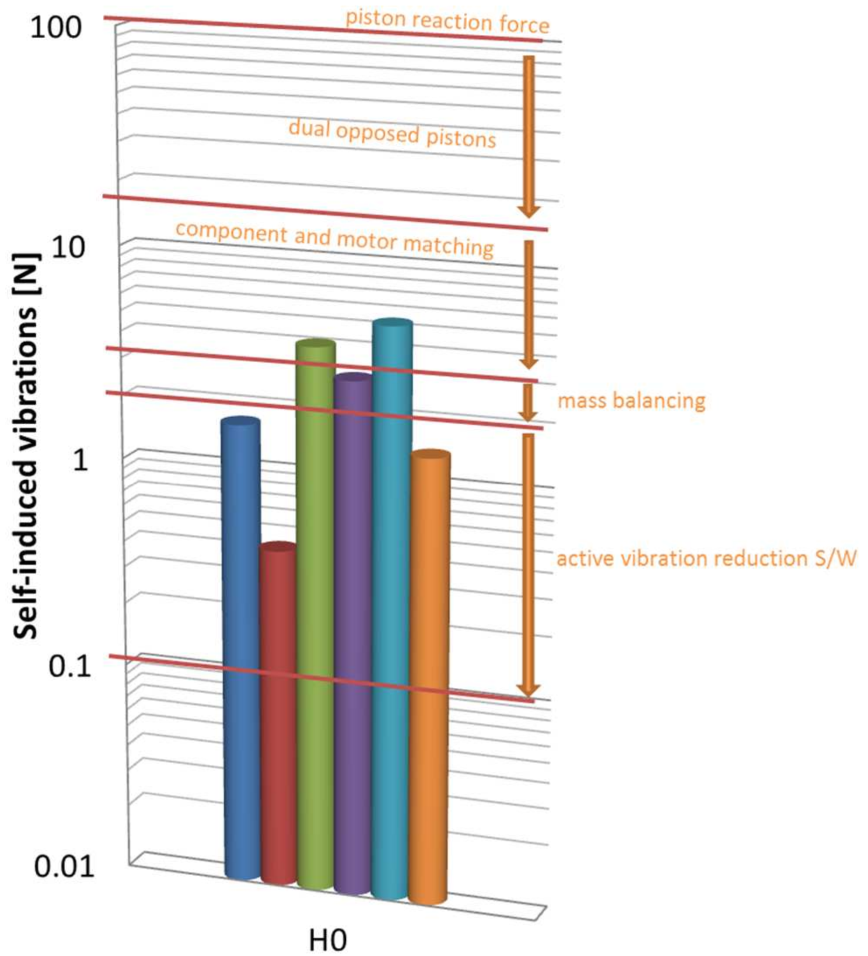
LPTC compressor features & test results

Low self-induced vibrations

- **Design**
  - Dual opposed pistons
- **Assembly Strategy**

  Minimize piston force amplitude and phase differences between opposing motors by
  - matching of motor components
  - matching of motors
  - mass balancing of motors
- **Potential further reduction**
  - Application of active vibration reduction algorithms



Measured piston axis self-induced vibrations for delivered compressors

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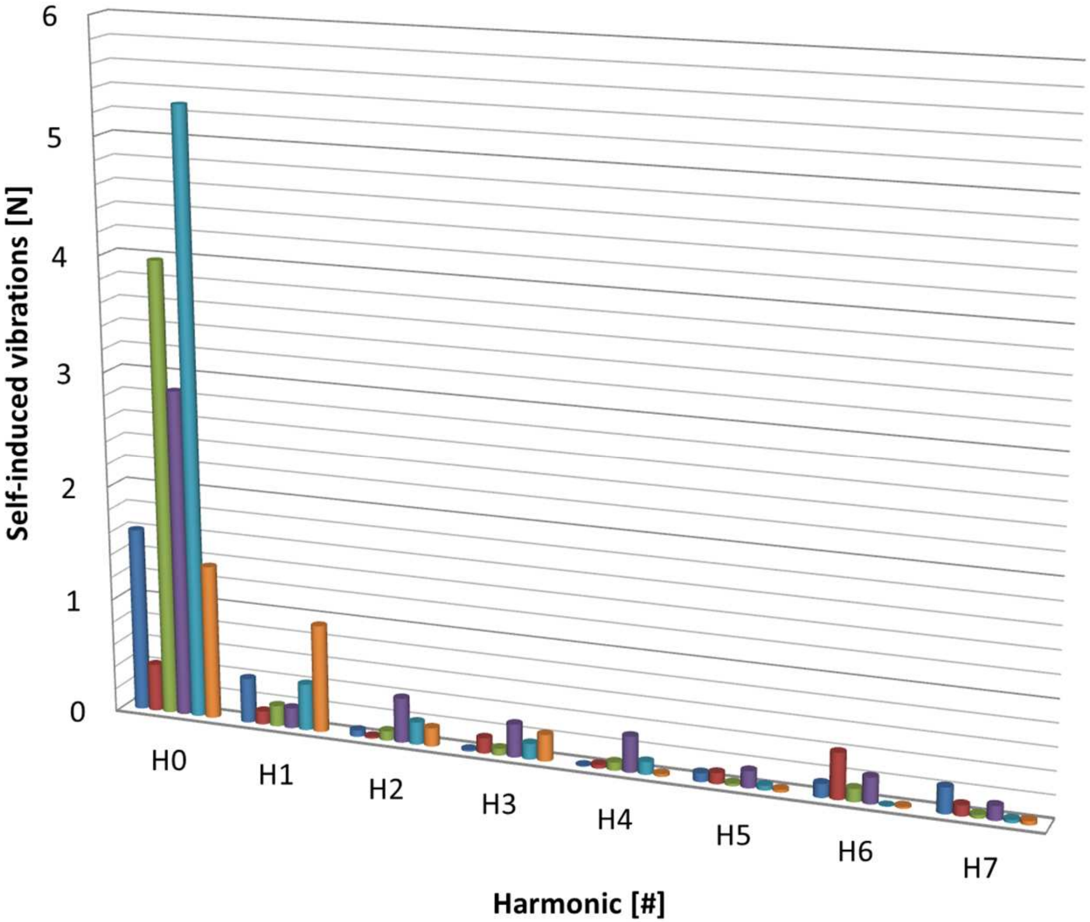
LPTC compressor features & test results

Piston axis self-induced vibrations



- Tested against a representative pulse tube delivering ± 2W at 50K
- Input power: 160 W
- Drive frequency: 58.5 Hz

Delivered compressors measurements

- Mass-balanced
- Different levels of motor matching

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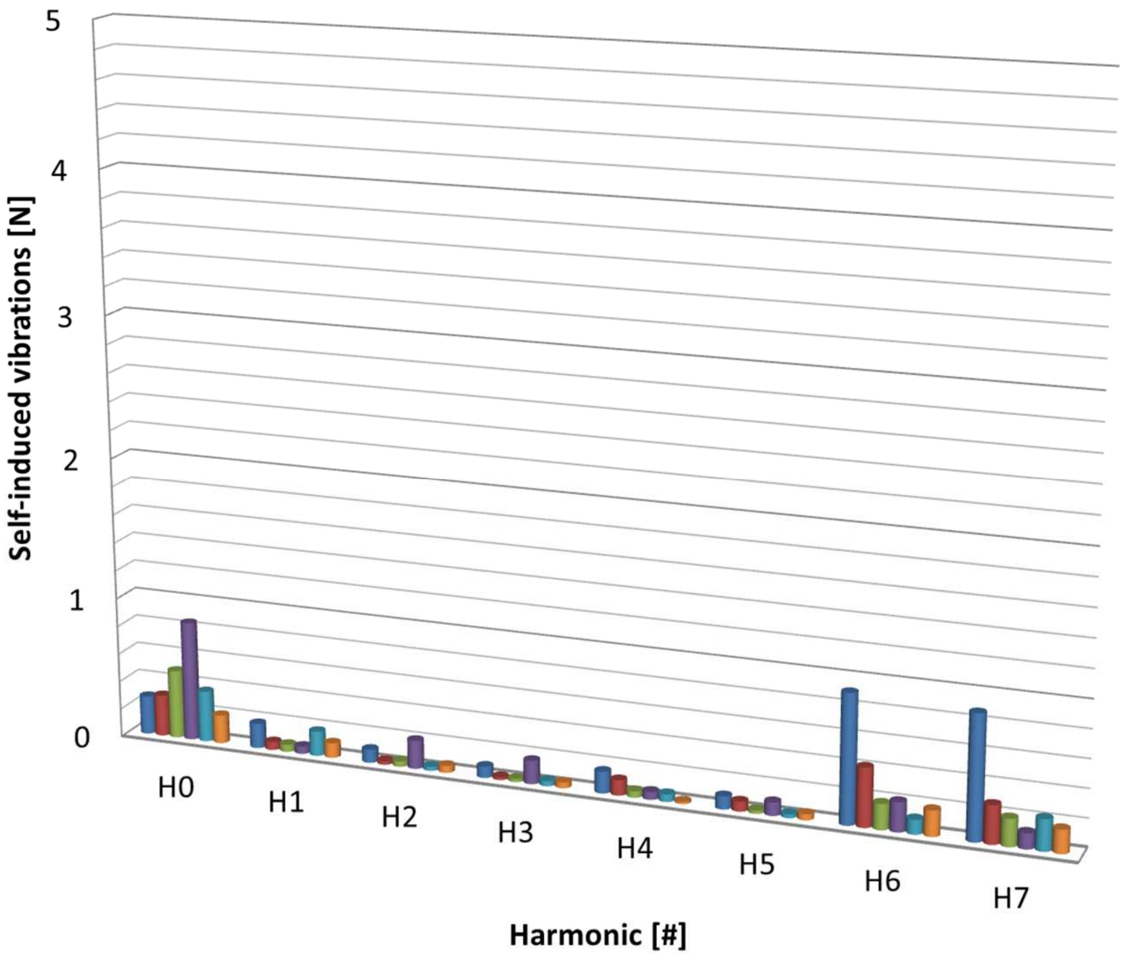
LPTC compressor features & test results

Transverse axis self-induced vibrations



- Tested against a representative pulse tube delivering ± 2W at 50K
- Input power: 160 W
- Drive frequency: 58.5 Hz

Delivered compressors measurements

- No direct relation between piston and transverse axis is found

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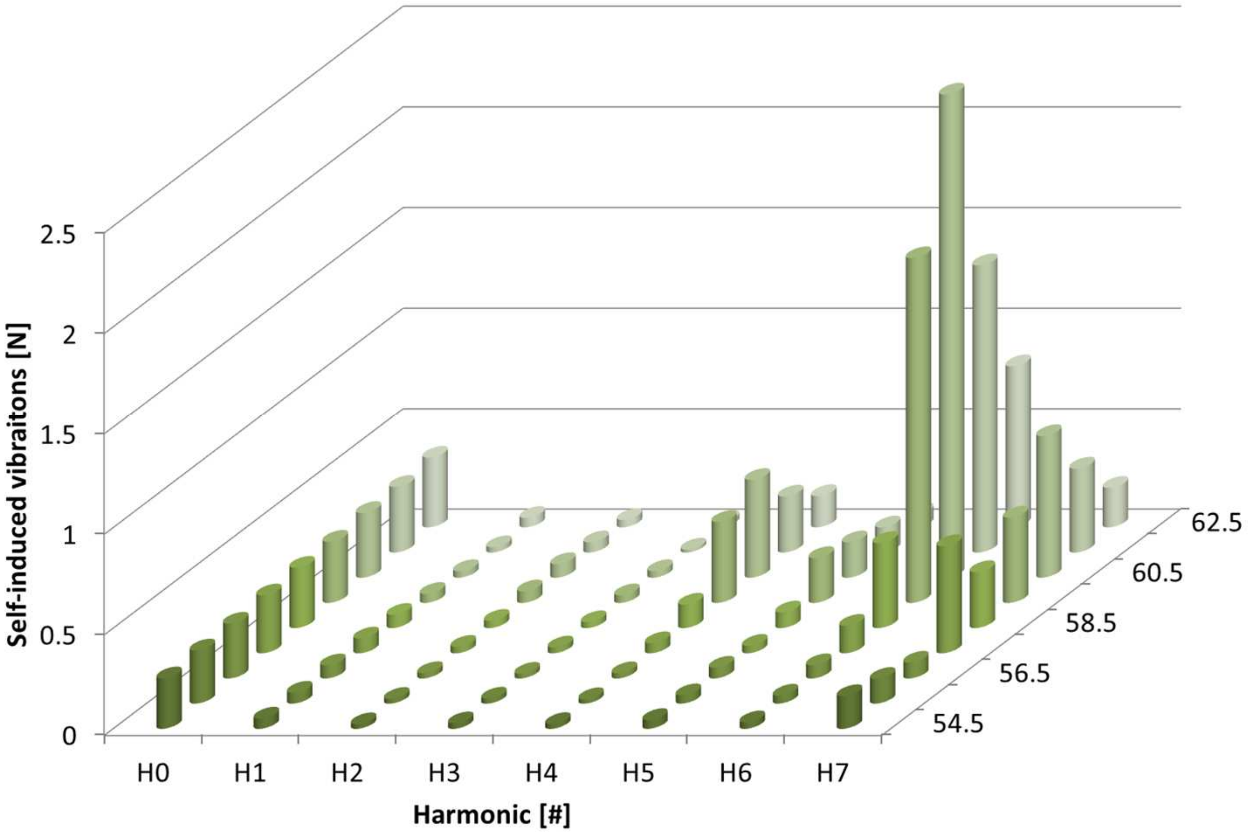
LPTC compressor features & test results

Transverse axis self-induced vibrations



- At certain drive frequencies, some harmonics coincide with structural resonance frequencies
- Confirmed by compressor vibration tests (shaker)
- Mapping provides tuning possibilities for customers

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LPTC compressor

- **Is in a mature design status**
  - Currently building and delivering FM's for MUSIS-CSO project
  - First 2 EM's delivered for MTG, aiming for qualification mid 2014
- **Measured performance tests results as expected**
- **Lifetime aspects and potential risks are thoroughly reviewed in both projects**
- **Self-induced vibrations**
  - are limited by several passive methods
  - have the potential to be reduced to levels below 0.1 N in the piston axis with active vibration reduction (see presentation 7.1)

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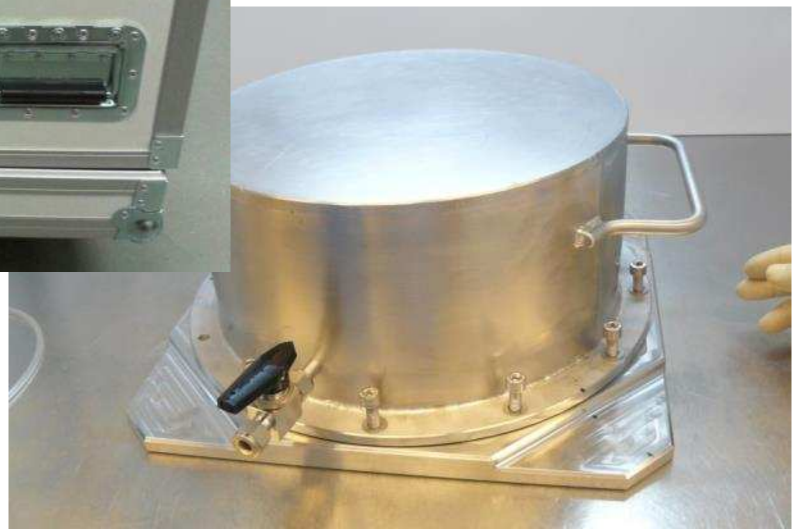
Q&A



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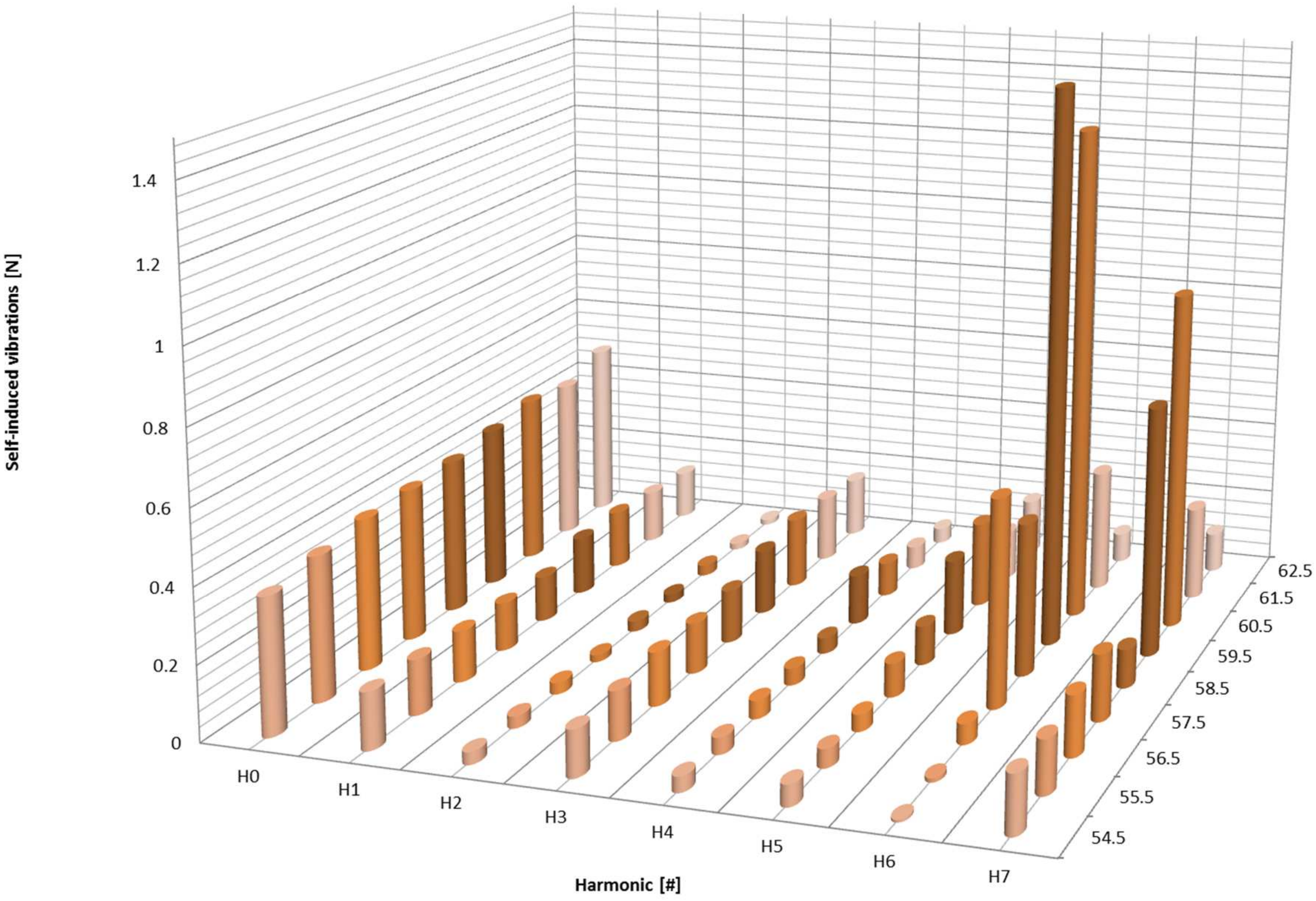
Piston axis self-induced vibrations vs. drive frequency



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