EFFICIENCY AND SAFETY IMPROVEMENT OF LARGE-SCALE HYDROSTATIC BEARINGS

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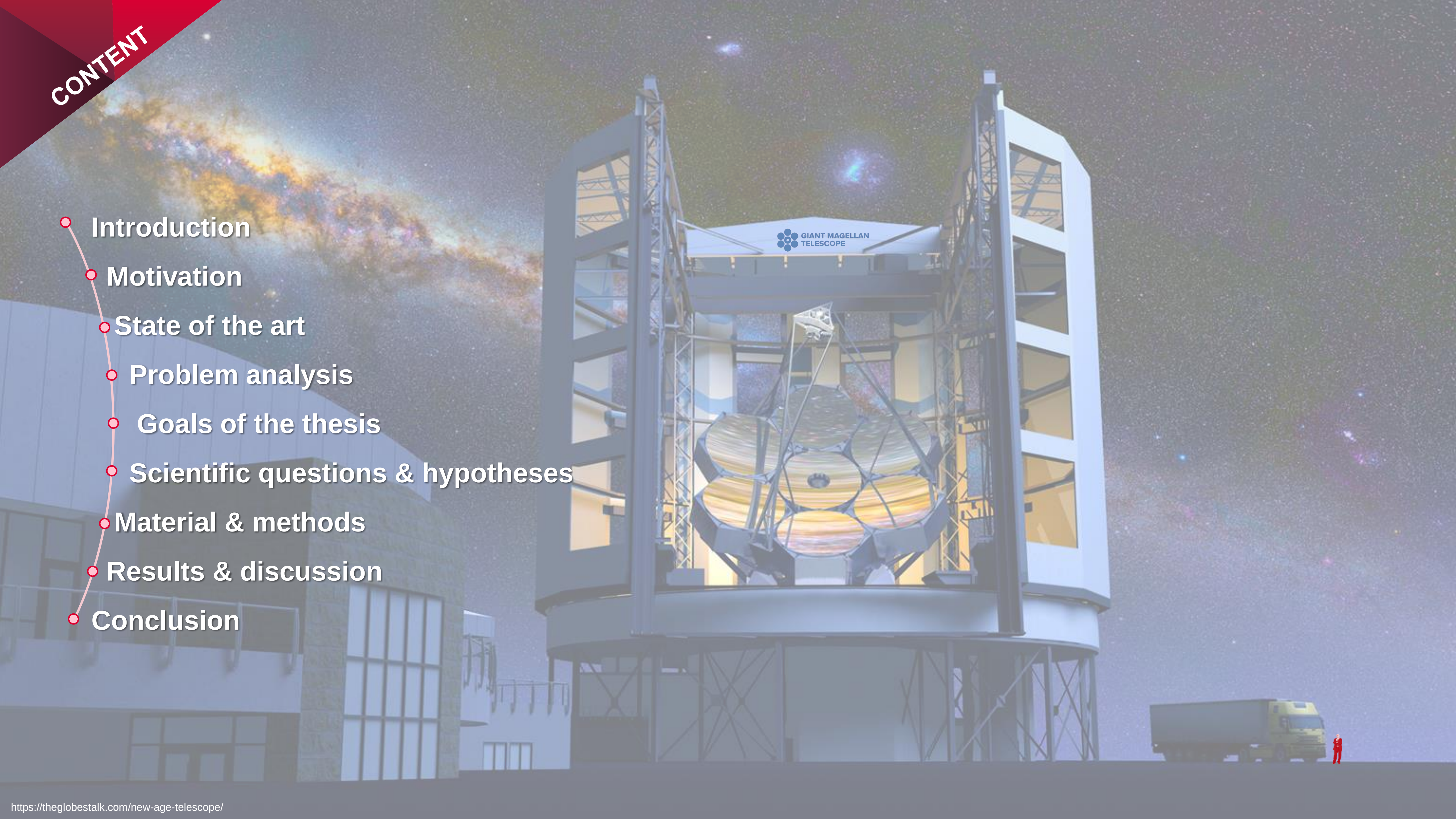
Faculty of Mechanical Engineering
Brno University of Technology

Brno, 7.2.2024

INSTITUTE OF MACHINE AND INDUSTRIAL DESIGN

CONTENT

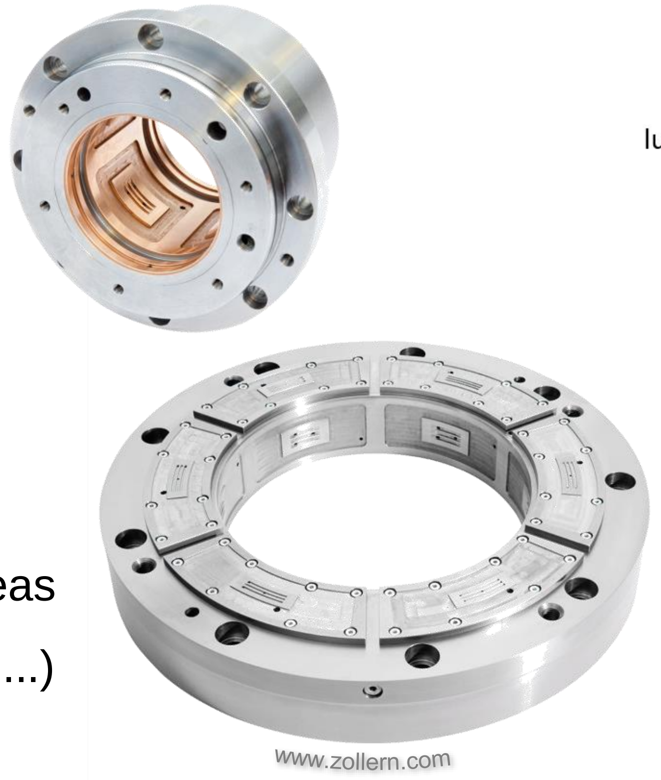


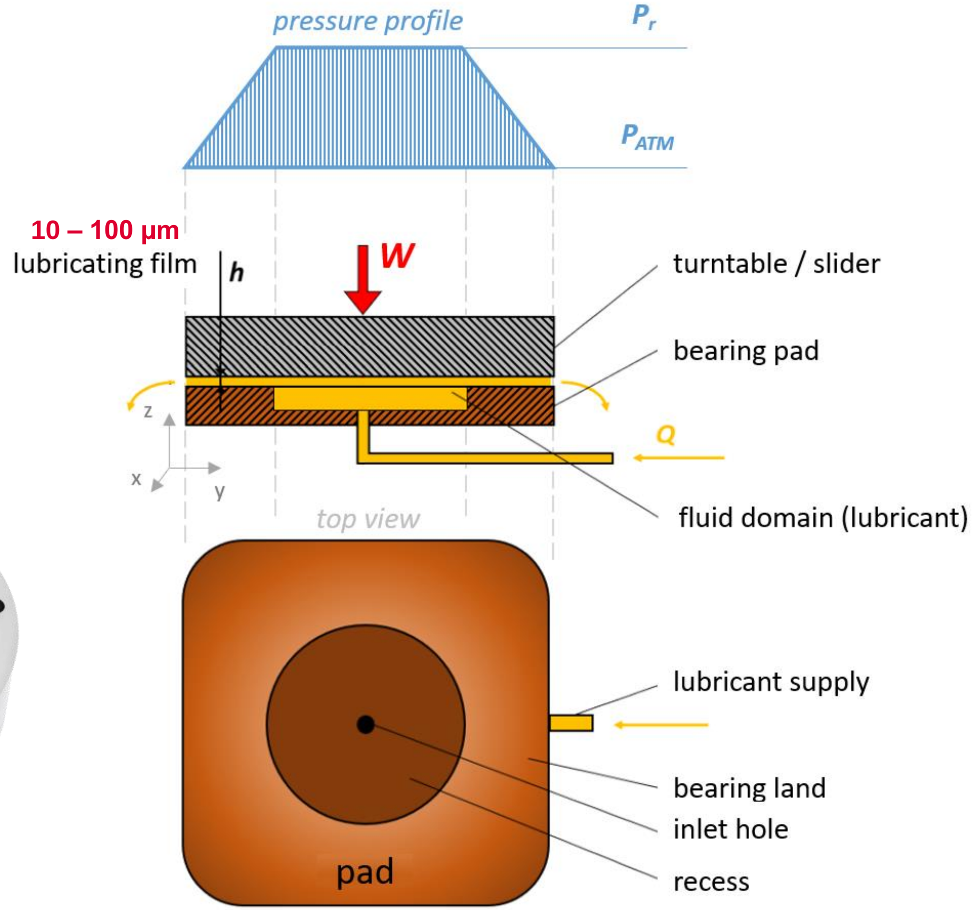
https://theglobestalk.com/new-age-telescope/

HYDROSTATIC BEARINGS

Applications:

- Machining centres
- High-precision machines
- Turntables
- Industrial guideways
- Antennas & telescopes
- Potential use in high-demand areas (energetics, logistics, production,...)

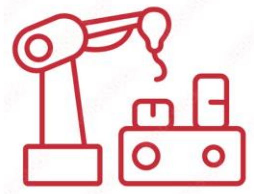


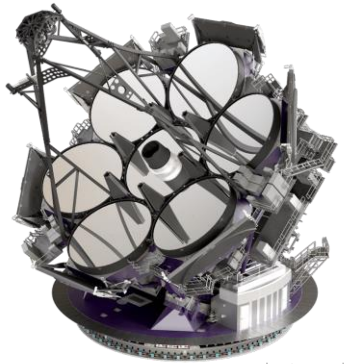


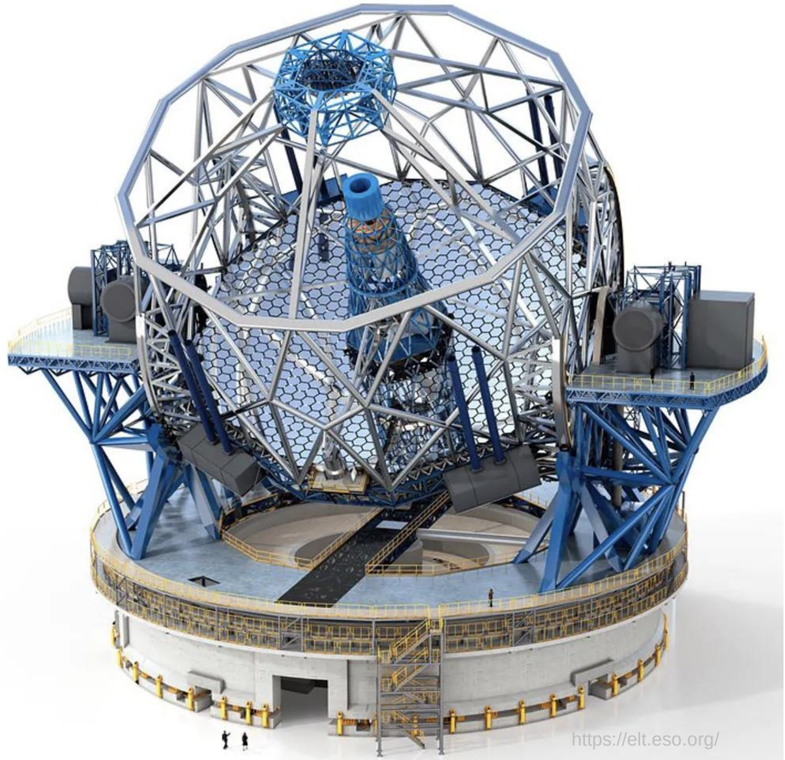
LARGE-SCALE HYDROSTATIC BEARINGS

CHALLENGES

- Manufacturing
- Transport
- Assembly





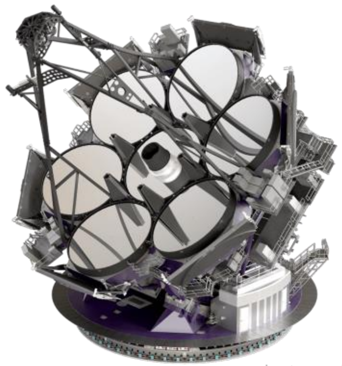


2 m rotary table	20 m GMT	50 m ELT	*bearing size*
30 t	*900 t*	*3700 t*	*load capacity*
10 l/min	*150 l/min*	*720 l/min*	*flow rate*

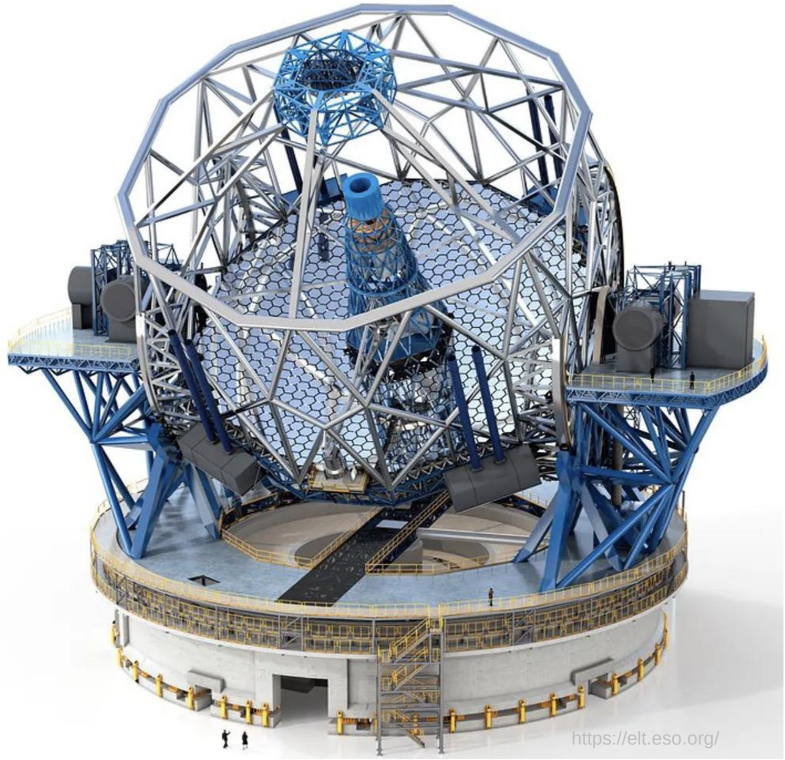
LARGE-SCALE HYDROSTATIC BEARINGS

Challenges:

- High initial and **energetic demands** (ELT est. 100 000 € / year)
- High **maintenance costs** (HSB repair 1.15 milion €, NASA 2010)
- Limited **market availability**
- High potential for **megaprojects**



www.giantmagellan.org



https://elt.eso.org/

	2 m rotary table	20 m GMT	50 m ELT
bearing size	2 m rotary table	20 m GMT	50 m ELT
load capacity	*30 t*	*900 t*	*3700 t*
flow rate	*10 l/min*	*150 l/min*	*720 l/min*

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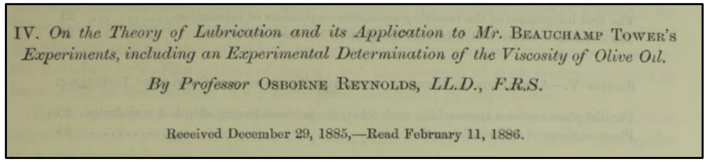
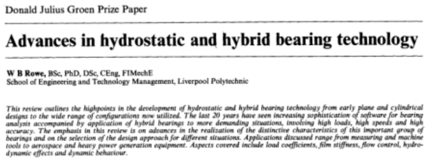

IV. On the Theory of Lubrication and its Application to Mr. BEAUCHAMP TOWER'S Experiments, including an Experimental Determination of the Viscosity of Olive Oil.

By Professor OSBORNE REYNOLDS, LL.D., F.R.S.

Received December 29, 1885,—Read February 11, 1886.


Donald Julius Groen Prize Paper

Advances in hydrostatic and hybrid bearing technology

W B Rowe, BSc, PhD, DSc, CEng, FIMechE
School of Engineering and Technology Management, Liverpool Polytechnic

This review outlines the highpoints in the development of hydrostatic and hybrid bearing technology from early plane and cylindrical designs to the wide range of configurations now utilized. The last 20 years have seen increasing sophistication of software for bearing analysis accompanied by application of hybrid bearings to more demanding situations, involving high loads, high speeds and high accuracy. The emphasis in this review is on advances in the realization of the distinctive characteristics of this important group of bearings and on the selection of the design approach for different situations. Applications discussed range from measuring and machine tools to aerospace and heavy power generation equipment. Aspects covered include load coefficients, film stiffness, flow control, hydrodynamic effects and dynamic behaviour.


Review Article

The Research Status and Progress of Heavy/Large Hydrostatic Thrust Bearing

Xibing Li, Xun Wang, Ming Li, Yunshi Ma, and Ying Huang

School of Mechanical Engineering, Qiqihar University, Qiqihar 161006, China

Correspondence should be addressed to Xibing Li; liguogongyong@163.com

Received 5 December 2013; Accepted 28 January 2014; Published 13 March 2014

www.giantmagellan.org

O. Reynolds

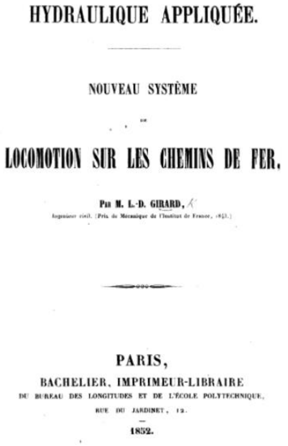
Rowe

Li et al.

GMT
2004-2029

1852 | 1886 | 1918 | 1989 | 1992 | 2014 | 2017 | **2023** | 2028 | 2029

L. D. Girard


HYDRAULIQUE APPLIQUÉE.

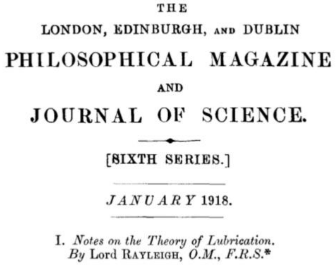
NOUVEAU SYSTÈME

LOCOMOTION SUR LES CHEMINS DE FER.

PAR M. L.-D. GIRARD,

PARIS,
BACHELIER, IMPRIMEUR-LIBRAIRE
DU BUREAU DES LONGITUDES ET DE L'ÉCOLE POLYTECHNIQUE,
RUE DU JARDINET, 12.
1852.

Lord Rayleigh

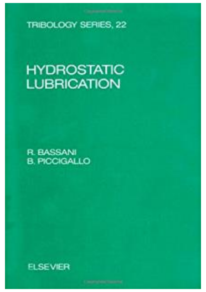

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[SIXTH SERIES.]

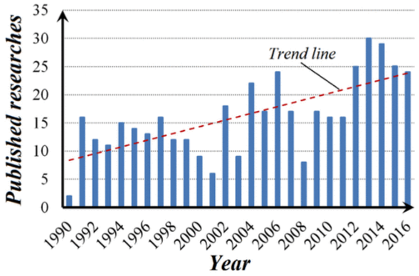
JANUARY 1918.

I. *Notes on the Theory of Lubrication.*
By Lord RAYLEIGH, *O.M., F.R.S.**

Bassani & Piccigallo



Liu et al.



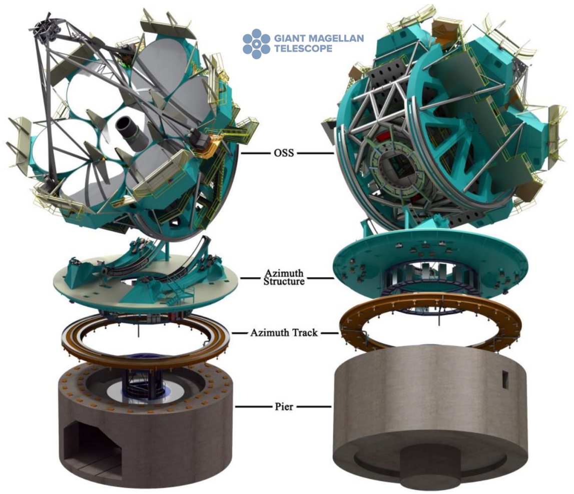
ELT
2015-2028

https://elt.eso.org/

STATE OF THE ART

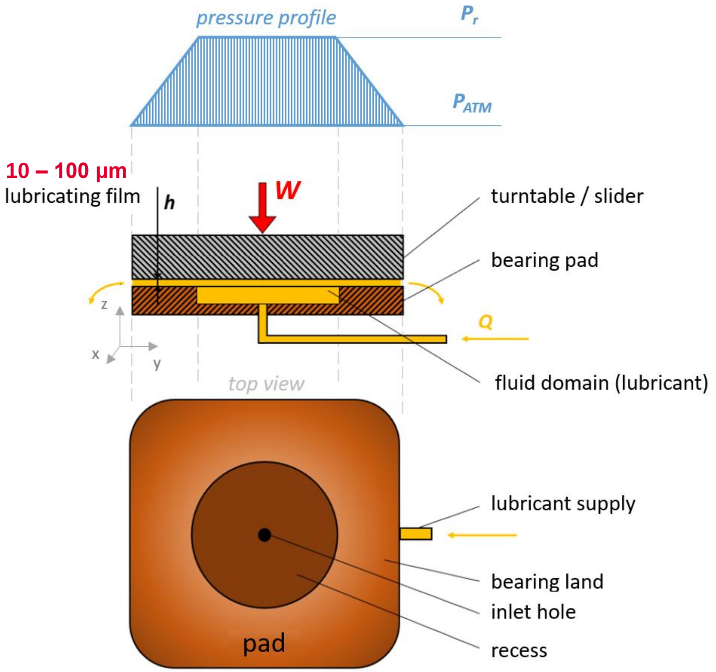
LARGE-SCALE HYDROSTATIC BEARINGS

ADVANTAGES	DISADVANTAGES
+ low friction, no wear	- high cost
+ zero speed operation	- continuous supply
+ precise & smooth movement	- energy consumption
+ damping	- misalignment sensitivity



$$W = \frac{3\mu Q (R_2^2 - R_1^2)}{h^3}$$

- W – Load capacity
- μ – Dynamic viscosity
- Q – Supplied flow
- $(R_2^2 - R_1^2)$ – Pad geometry
- h – Film thickness



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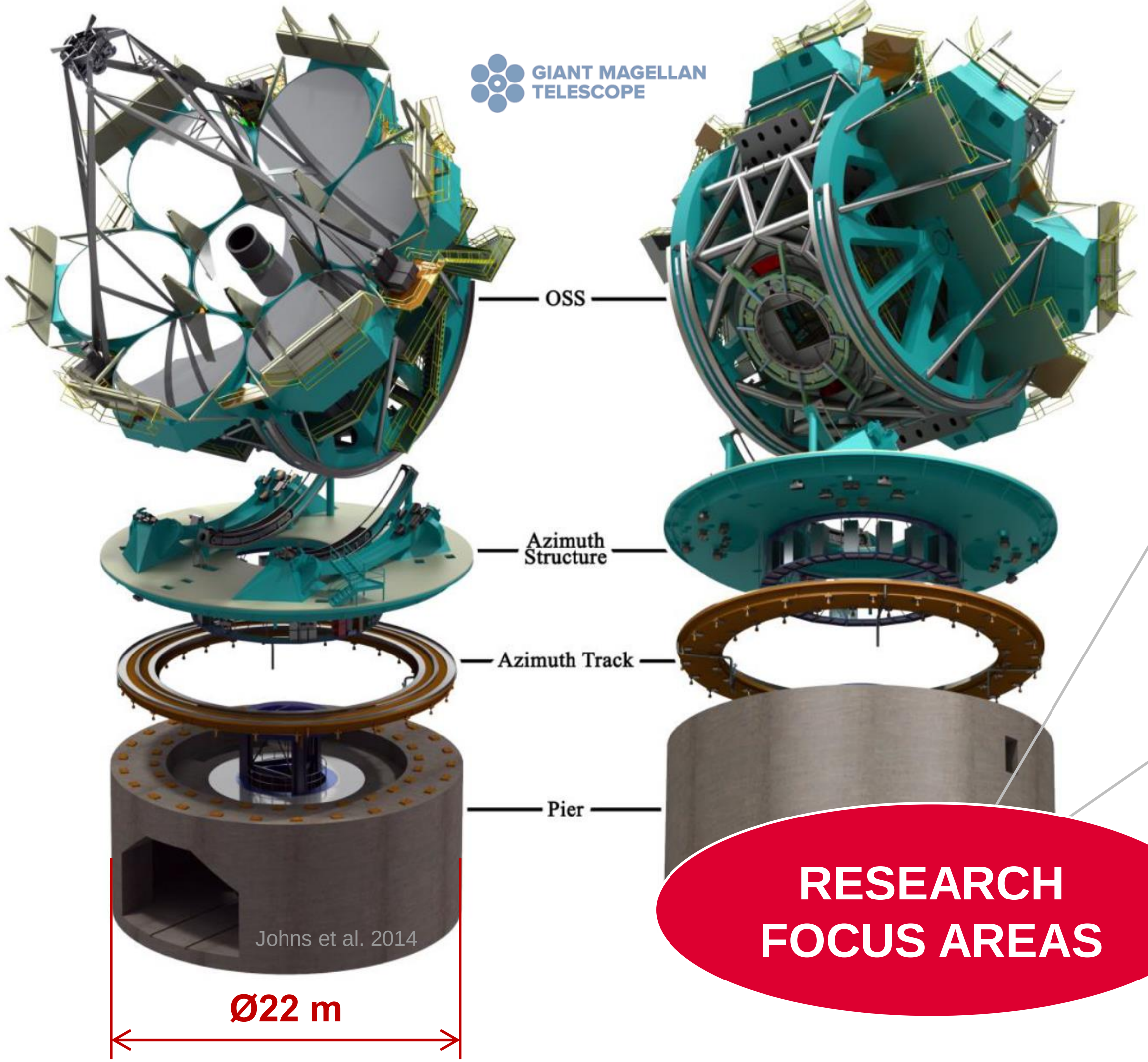
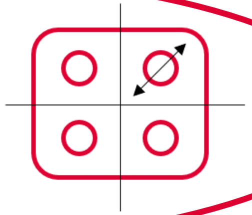
STATE OF THE ART

LARGE-SCALE HYDROSTATIC BEARINGS

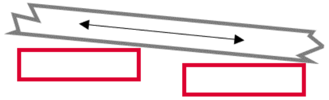


RESEARCH FOCUS AREAS

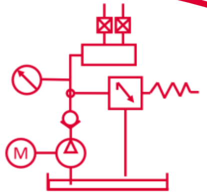
PAD GEOMETRY OPTIMIZATION



ALIGNMENT & MOVEMENT PRECISION

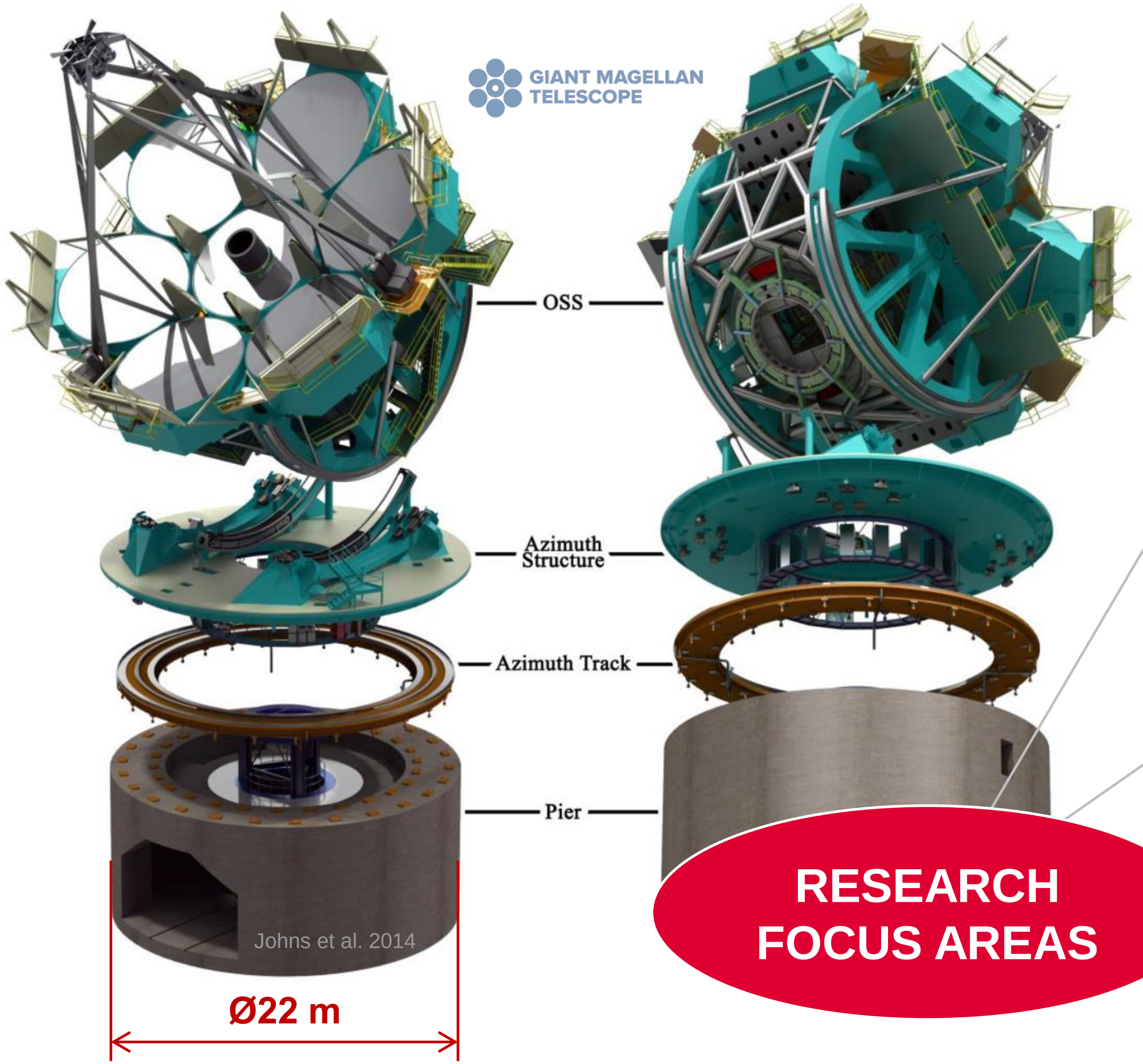


SUPPLY SYSTEM



STATE OF THE ART

LARGE-SCALE HYDROSTATIC BEARINGS



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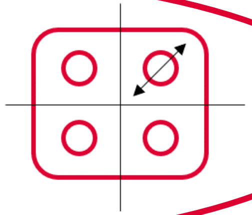

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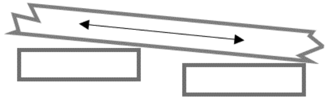
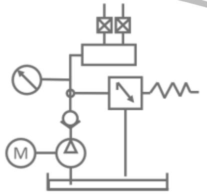


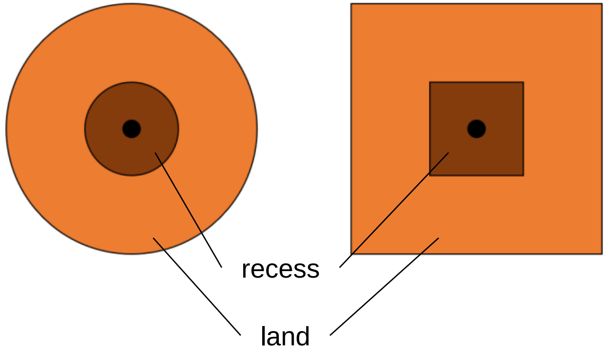
SUPPLY SYSTEM



PAD GEOMETRY OPTIMIZATION

Analytical approach

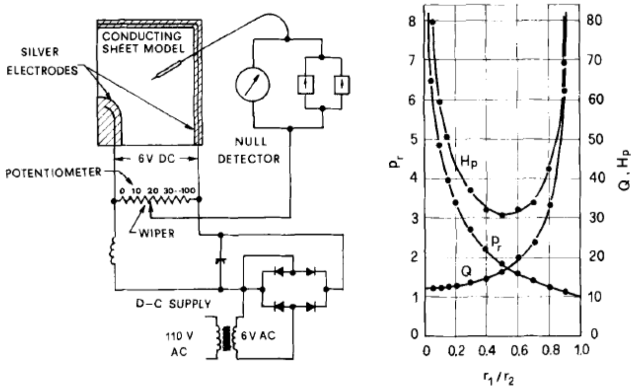
- Based on *N-S* equation
- Simplifications – Reynolds
- Only for simple geometry
- Recommended *H/h* (20-50x)
- Methodology on HSL design (Bassani & Piccigallo 1992)



Circular and rectangular pad geometry

Experimental approach

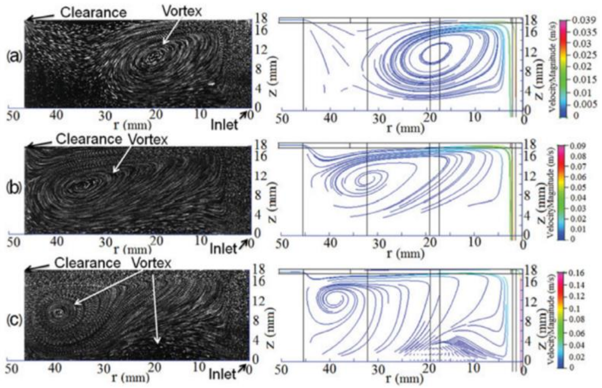
- Real behaviour of the bearing
- Validation of derived equations
- Demanding for time and cost
- Electric field analogy (Loeb, 1957)



LOEB and RIPPEL (1958)

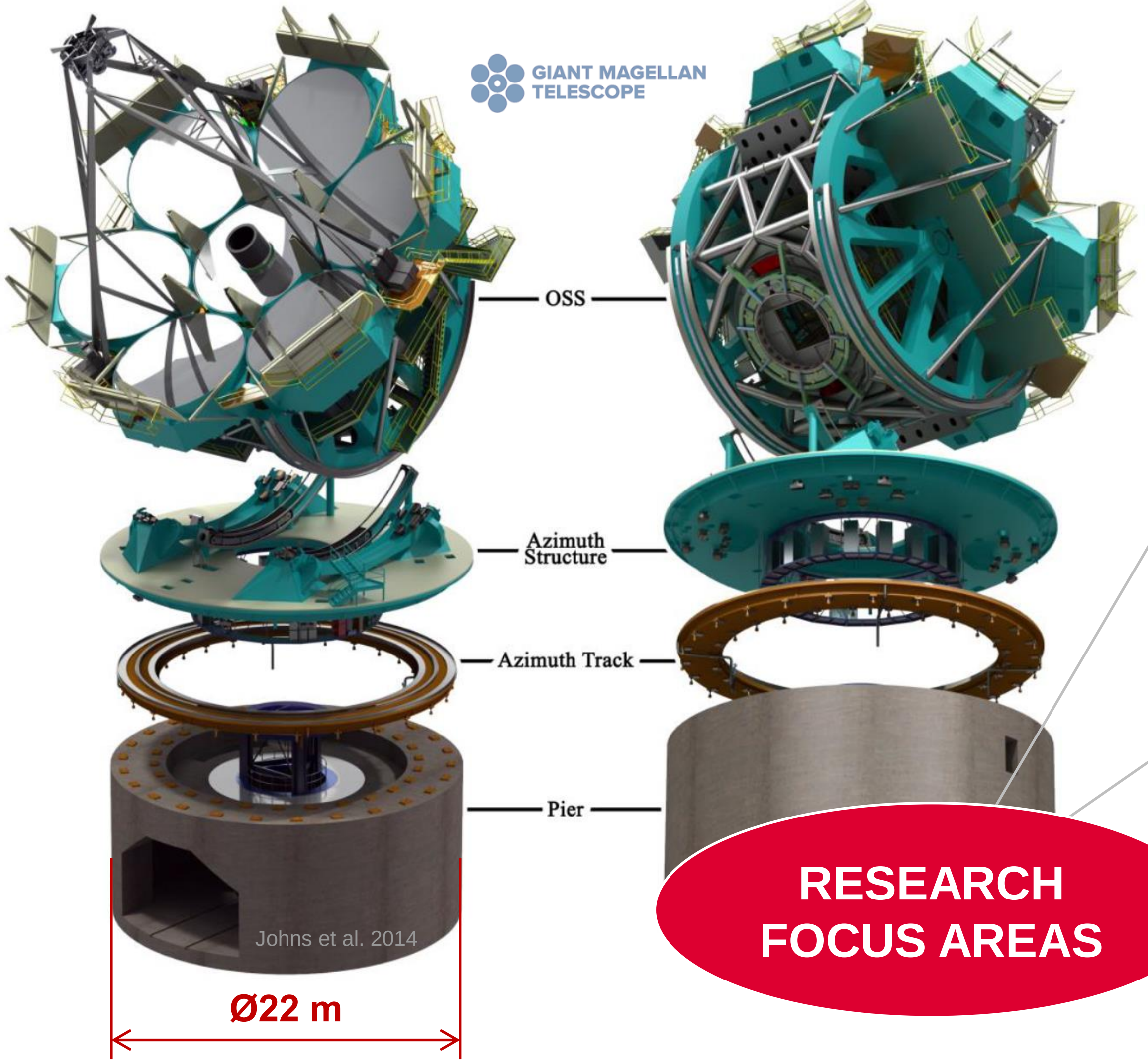
Numerical approach

- Modelling of any geometry
- Time and cost efficient
- Reduction of development costs
- Model verification (Horvat, 2011)



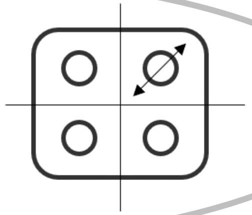
SHEN et al. (2014)

LARGE-SCALE HYDROSTATIC BEARINGS

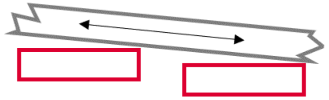


RESEARCH FOCUS AREAS

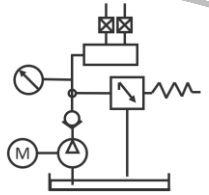
PAD GEOMETRY OPTIMIZATION



ALIGNMENT & MOVEMENT PRECISION



SUPPLY SYSTEM



STATE OF THE ART

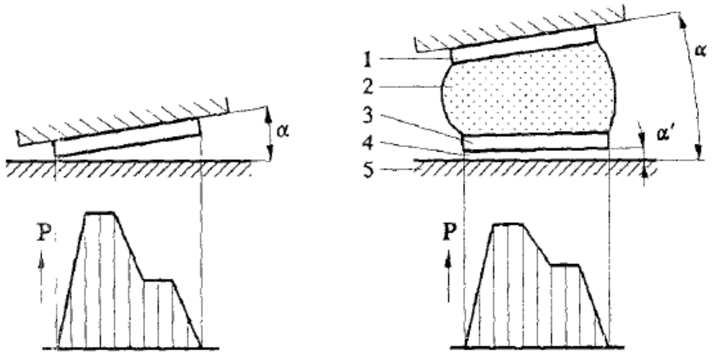
ALIGNMENT & MOVEMENT PRECISION

- Challenging manufacturing, trasportation & assembly
- Film thickness in range **20-100 µm**
- Pad misalignment might lead to surface damage & seizure

SELF-ALIGNING

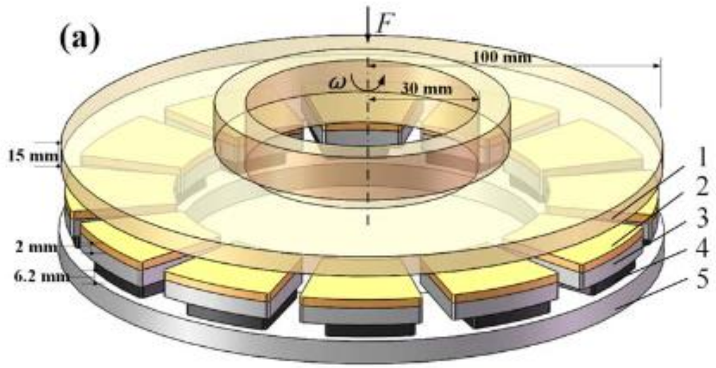
Van Beek et al. (1996)

- Numerical model
- More uniform pressure distribution



Liang et al. (2019)

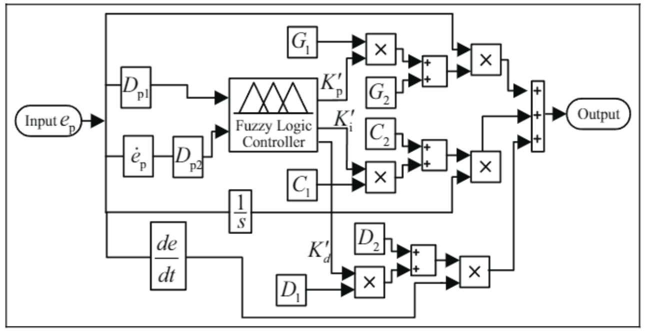
- Numerical & experimental model
- HD pad compliant support



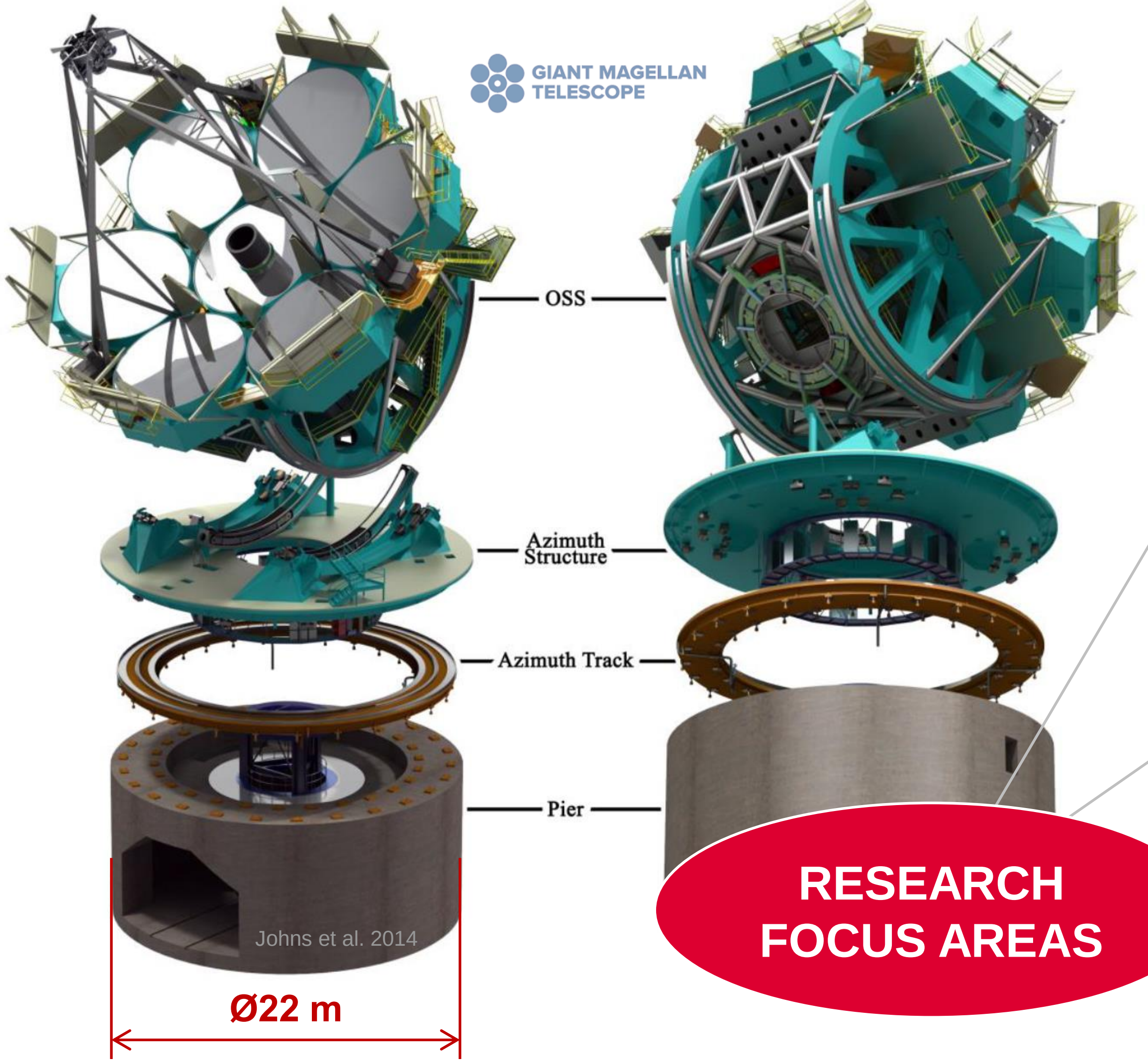
FEEDBACK CONTROL

Rehman et al. (2019)

- Experimentally verified
- Higher precision than PID controller

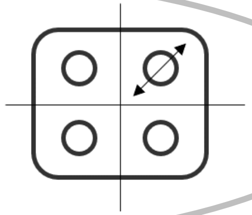


LARGE-SCALE HYDROSTATIC BEARINGS

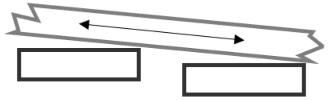


RESEARCH FOCUS AREAS

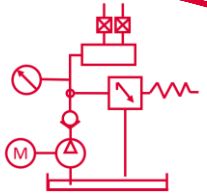
PAD GEOMETRY OPTIMIZATION



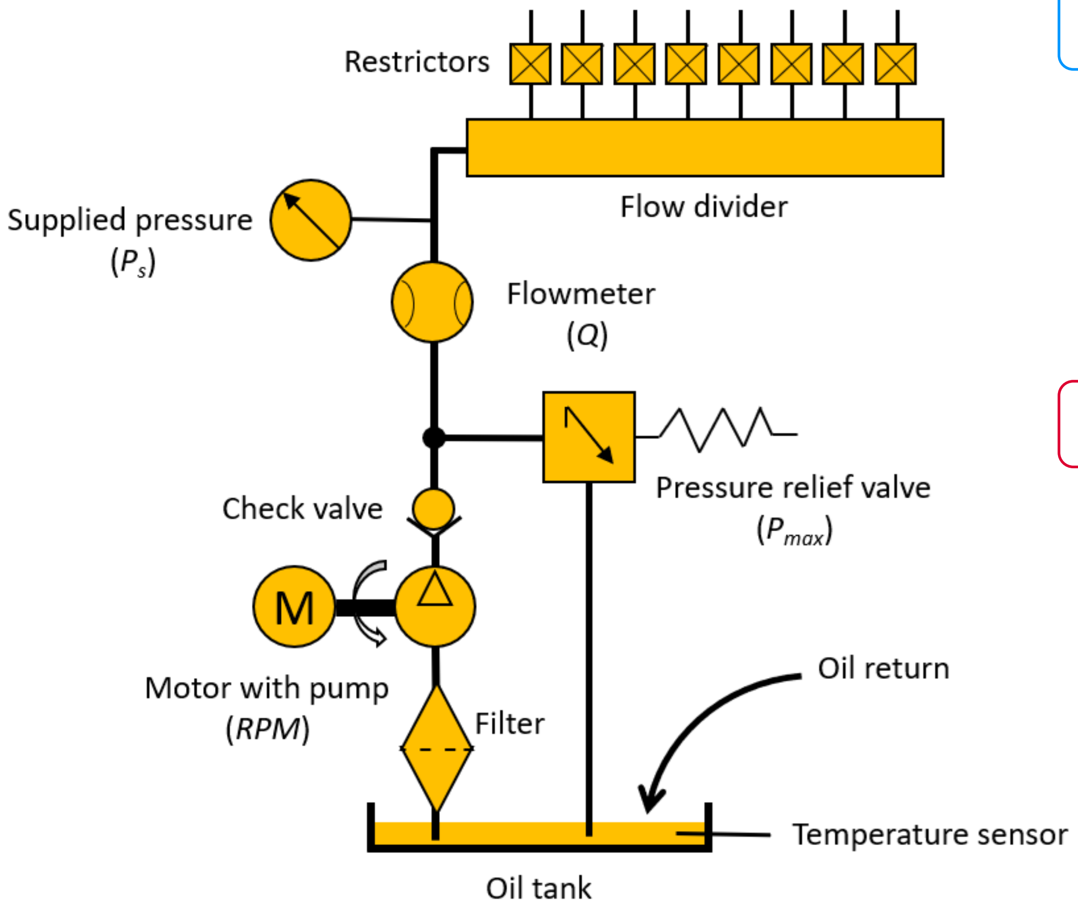
ALIGNMENT & MOVEMENT PRECISION



SUPPLY SYSTEM



HYDROSTATIC BEARING LUBRICATION SYSTEM



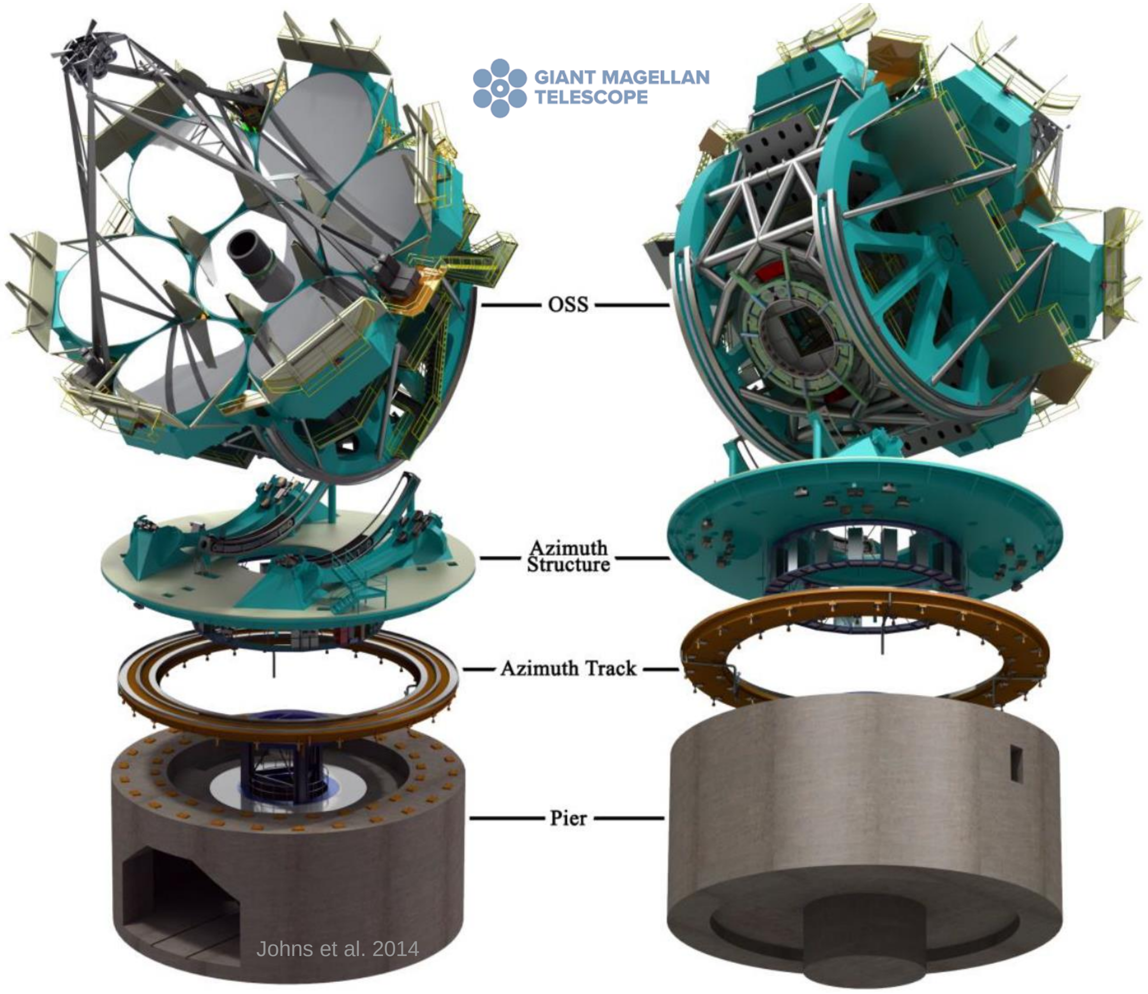
PRESSURIZED OIL SUPPLY

- Continuous supply of pressurized lubricant
- Flow control & adjustment (Rehman 2021)
- Research mainly focused on restrictors (Childs 2019)

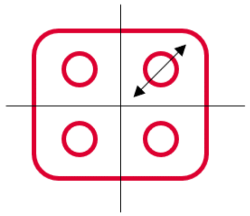
RESTRICTORS

- Necessary in multi-pad single-pump HSB systems (Khonsari 2017)
- Most common types (Bassani & Piccigallo 1992):
  - a) **Fixed:** Orifice, capillary
  - b) **Variable – passive:** compliant elements, control valves
  - c) **Variable – active:** EM valves

SUMMARY OF LITERATURE REVIEW

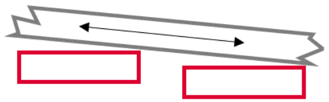


Pad geometry optimization



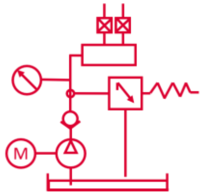
- ✓ Optimization methods
- ✓ Multi-criteria optimization
- X Multi-parametric shape optimization

Alignment & movement precision



- ✓ Surface topography influence
- X Compliant support experiments
- X Assembly error tolerancing

Supply system



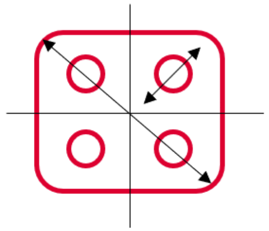
- ✓ Flow control devices
- ✓ Feedback systems
- X Energy consumption reduction

AIM OF THE THESIS

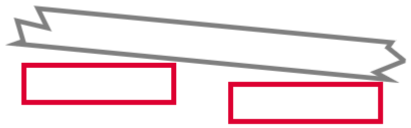
Introduce **performance** and **safety** improvements to the large-scale hydrostatic bearing design methodology.

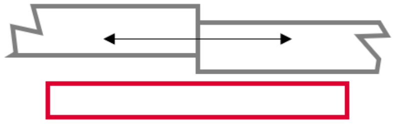
SCIENTIFIC QUESTIONS:

1. What is the influence of hydrostatic bearing recess position and size on the bearing performance?



2. How is the hydrostatic lubricating film affected by assembly errors of the bearing bodies?



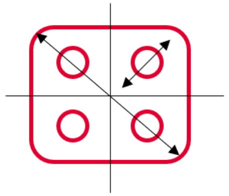


SCIENTIFIC QUESTIONS

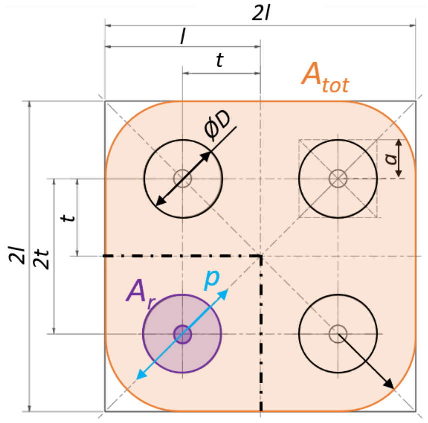
1. What is the influence of hydrostatic bearing recess position and size on the bearing performance?

HYPOTHESIS 1 (SQ 1):

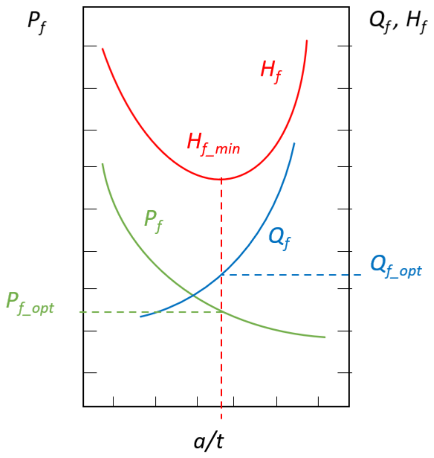
Recess size and layout optimization are usually done according to one parameter classical approach, in which the geometric parameters are linked together. Separating the two parameters, size and layout, can lead to improved pad performance and lower energetic losses.



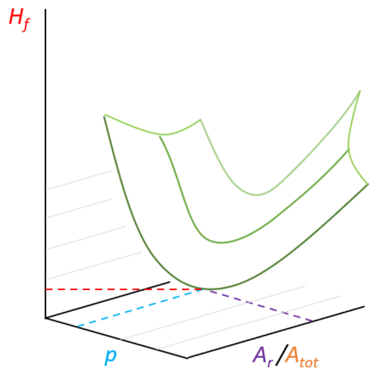
PAD GEOMETRY



CLASSIAL



MULTI-PARAMETRIC

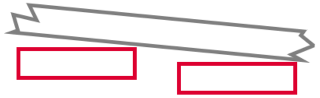


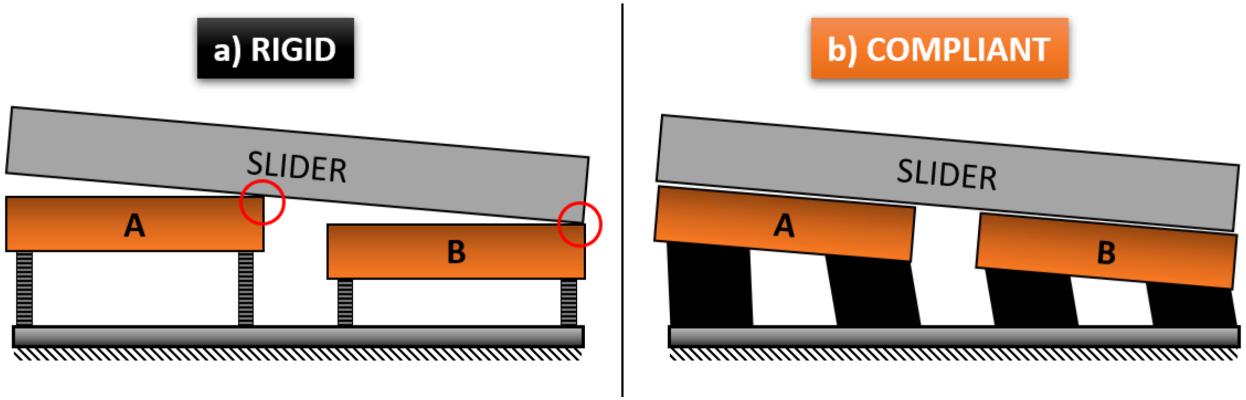
SCIENTIFIC QUESTIONS

2. How is the hydrostatic lubricating film affected by assembly errors of the bearing bodies?

HYPOTHESIS 2 (SQ 2):

Pad misalignment can significantly affect the generation and uniformity of the HS lubricating film. The lubricating film is able to compensate certain magnitude of pad misalignment. The bearing performance during eccentric loading can be improved using a compliant member. But the compliant support is also able to compensate larger misalignment compared to rigid support.



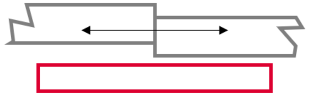


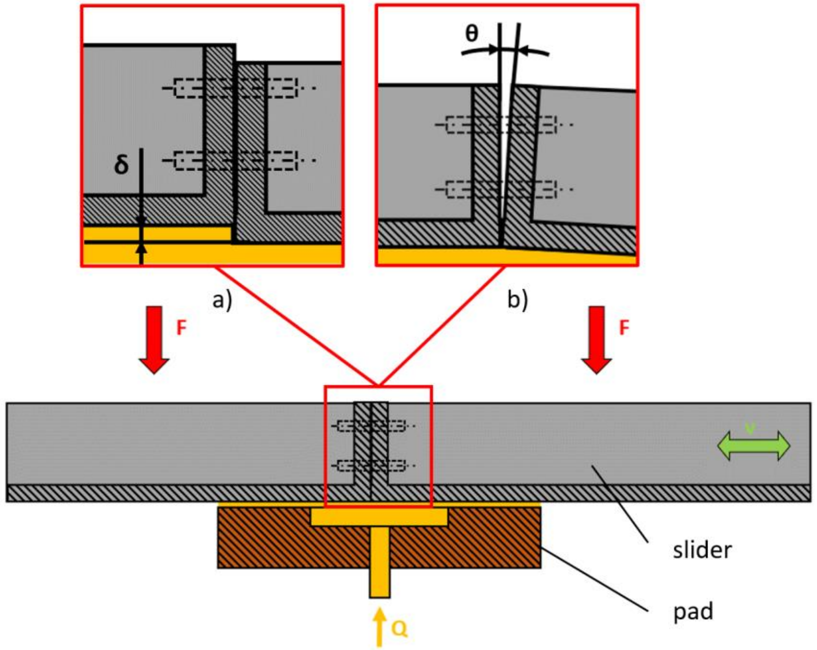
SCIENTIFIC QUESTIONS

2. How is the hydrostatic lubricating film affected by assembly errors of the bearing bodies?

HYPOTHESIS 3 (SQ 2):

Assembly errors of segmented sliders were not studied, even though HS bearings have a great potential in large-scale applications. Assembly errors of a segmented slider can lead to HS lubricating film non-uniformity and disruption. The maximal allowed error of the segmented sliders must be smaller than the film thickness to secure safe operation of the bearing.





MATERIALS & METHODS

EXPERIMENTAL

APPROACH

2-PAD

DATA FOR MODEL CALIBRATION

OBJECTIVES

Offset, tilt and incline of pads.

PAD MISALIGNMENT

Offset of slider bodies.

SLIDER ASSEMBLY ERROR

EVALUATION

Measured data from sensors:

- Load
- Film thickness
- Recess pressure
- Supplied flow
- Lubricant temperature

MODELLING

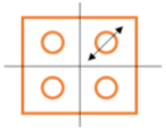
APPROACH

CFD

MATLAB

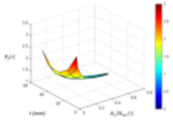
OBJECTIVES

Recess position and size variation.



GEOMETRY OPTIMIZATION

3D chart interpretation.



DATA EVALUATION

EVALUATION

Obtained data:

- Recess pressure
- Resulting force
- Pressure patterns

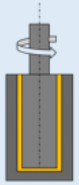
Data post-processing :

- Performance factors
- Power loss evaluation
- Data interpolation
- Searching for minimum

SUPPLEMENTARY

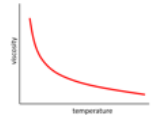
APPROACH

RHEOLOGY



OBJECTIVES

Rotational viscometer measurement.



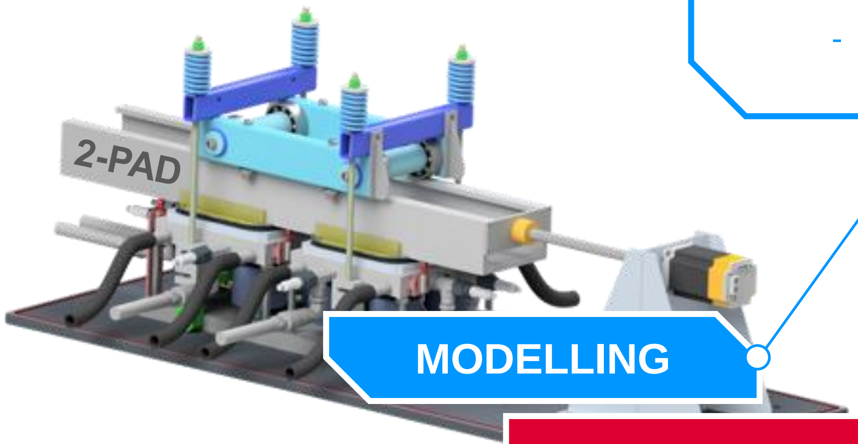
DYNAMIC VISCOSITY

EVALUATION

Measurement procedures:

- Oil shear force measurement
- Data fitting
- Temperature-viscosity dependence

SOLUTION METHODOLOGY



MODELLING

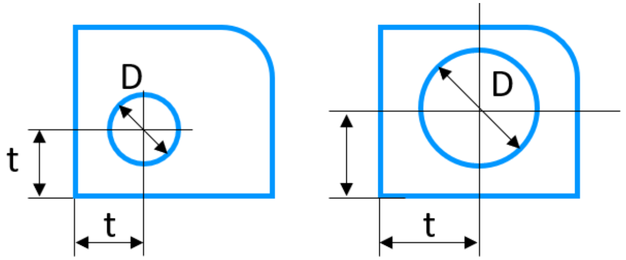
EXPERIMENTAL

CFD MODEL VALIDATION

BEARING EFFICIENCY

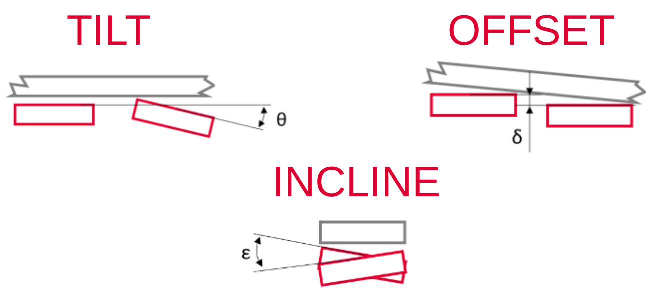
PAD GEOMETRY OPTIMIZATION

- STATIC



PAD MISALIGNMENT

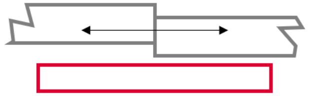
- STATIC



BEARING SAFETY

SLIDER ASSEMBLY ERROR

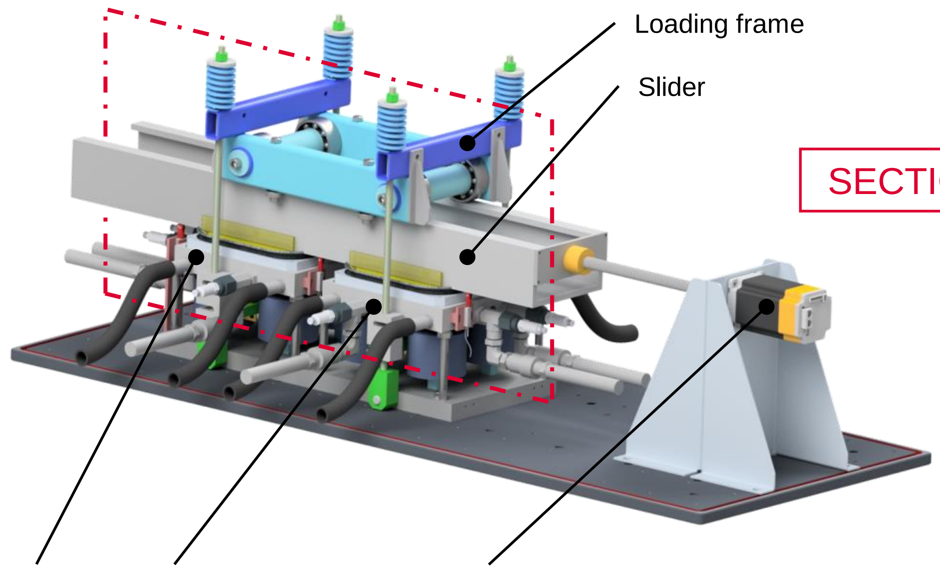
OFFSET



- STATIC
- LOW-SPEED *(38 mm/s)*

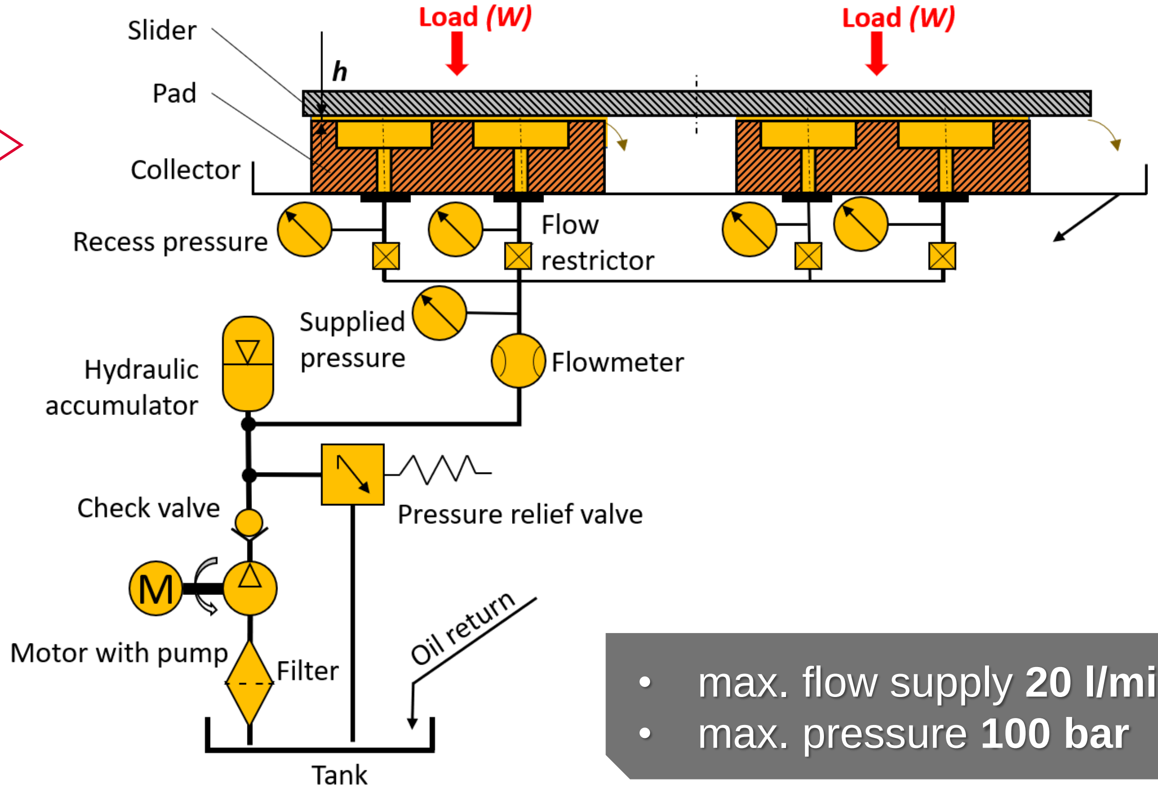
EXPERIMENTAL DEVICE – 2PAD

THE BEARING



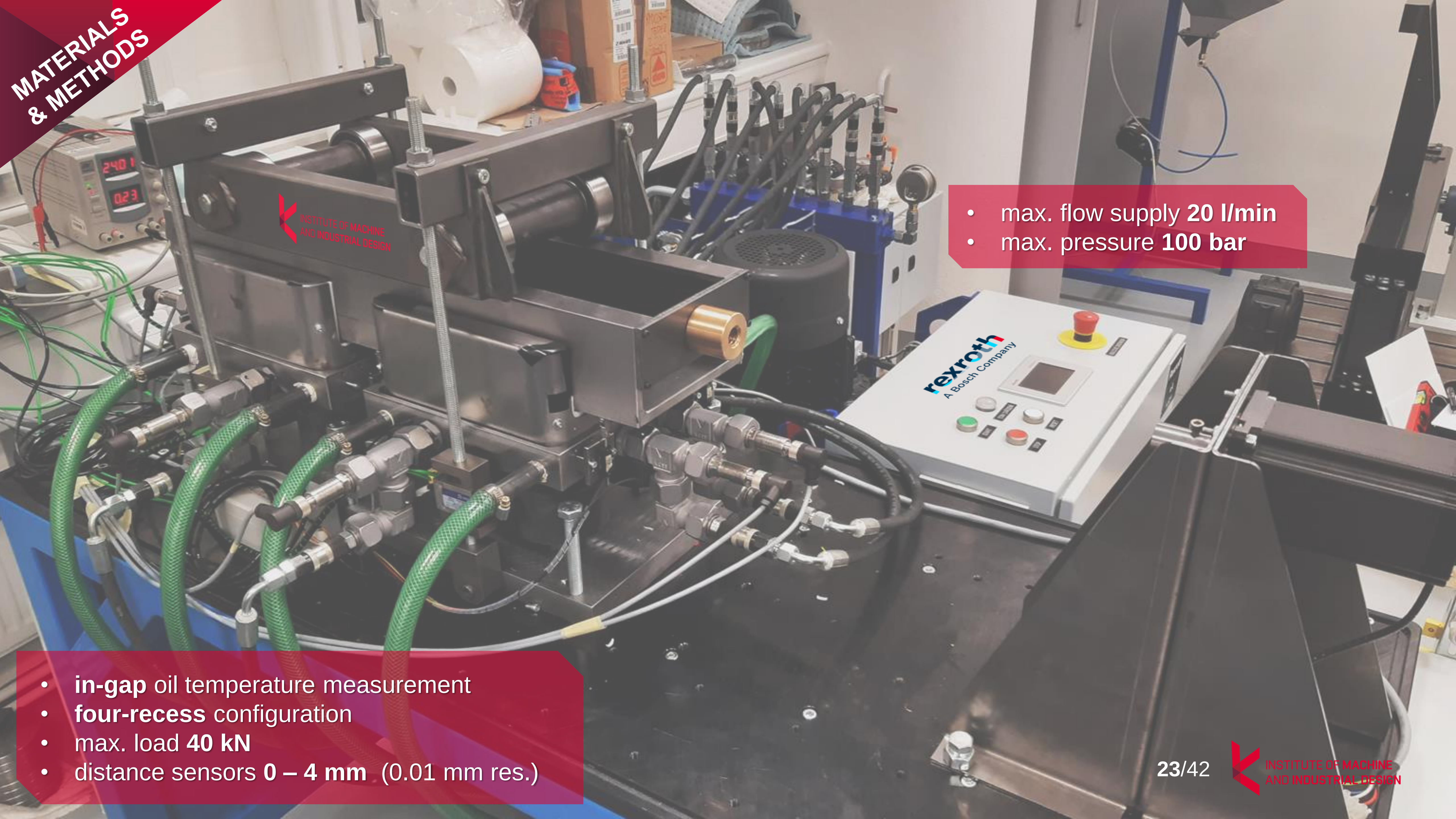
SECTION VIEW

HYDRAULIC CIRCUIT



- **in-gap** oil temperature measurement
- **four-recess** configuration
- max. load **40 kN**
- distance sensors **0 – 4 mm** (0.01 mm res.)

- max. flow supply **20 l/min**
- max. pressure **100 bar**



- max. flow supply **20 l/min**
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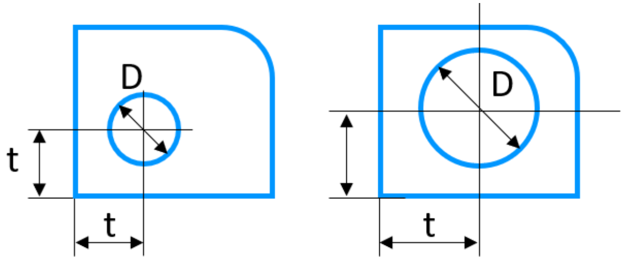
- **in-gap** oil temperature measurement
- **four-recess** configuration
- max. load **40 kN**
- distance sensors **0 – 4 mm** (0.01 mm res.)

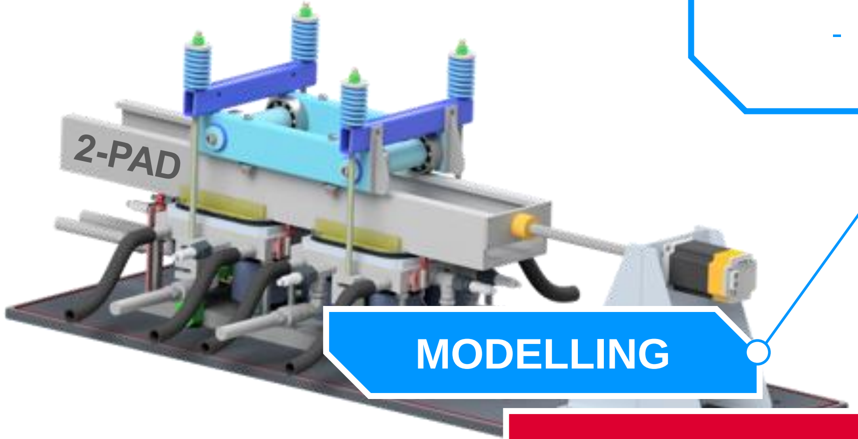
SOLUTION METHODOLOGY

BEARING EFFICIENCY

PAD GEOMETRY OPTIMIZATION

- STATIC





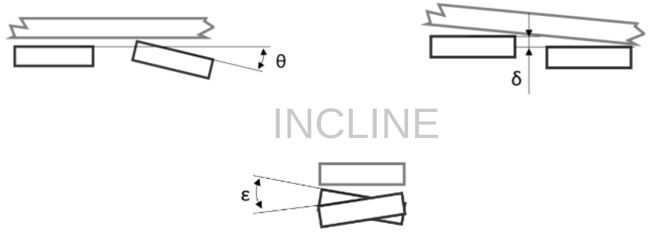
MODELLING

EXPERIMENTAL

CFD MODEL VALIDATION

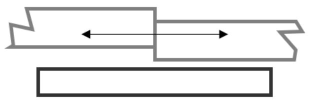
PAD MISALIGNMENT

- STATIC



BEARING SAFETY

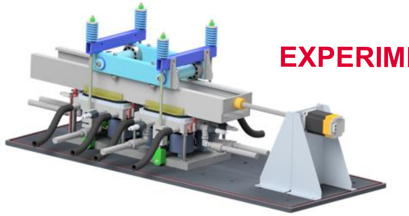
SLIDER ASSEMBLY ERROR



- STATIC
- LOW-SPEED *(38 mm/s)*

RESULTS

PAD GEOMETRY OPTIMIZATION

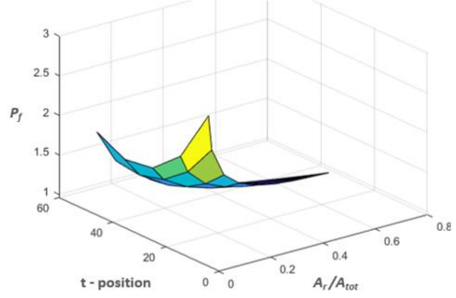


EXPERIMENTAL DATA

PARAMETRIZATION

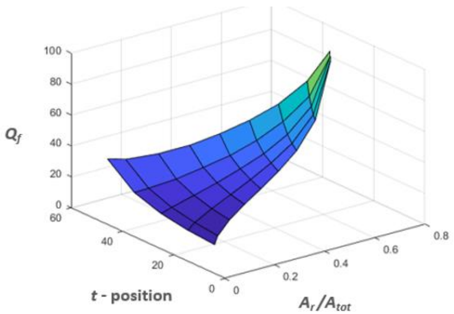
Ansys

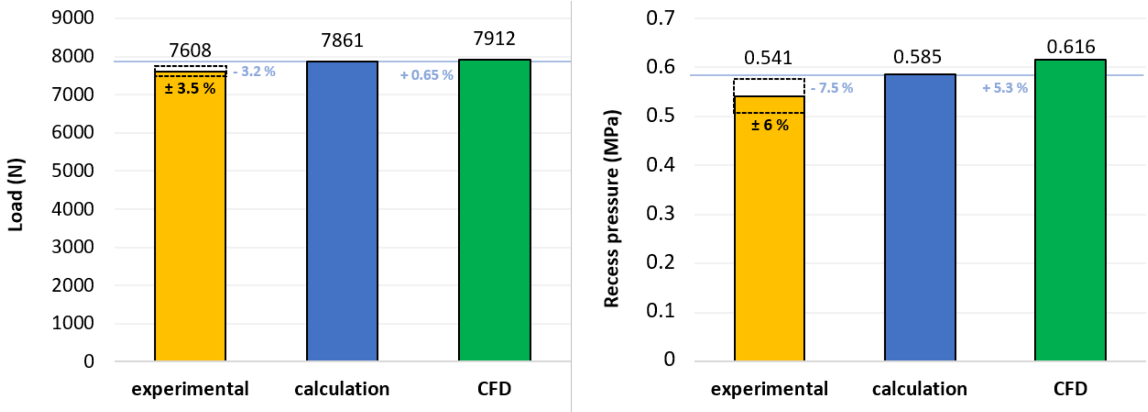
PRESSURE FACTOR



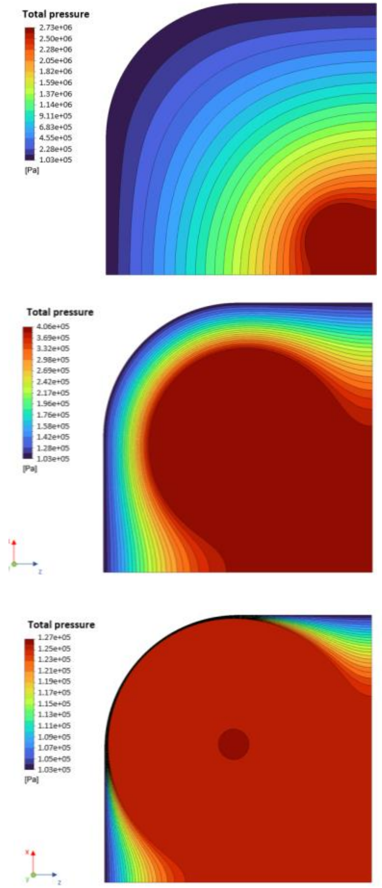
- Static conditions
- Total load: **16 kN**
- Total supplied flow: **8.5 l/min**

FLOW FACTOR





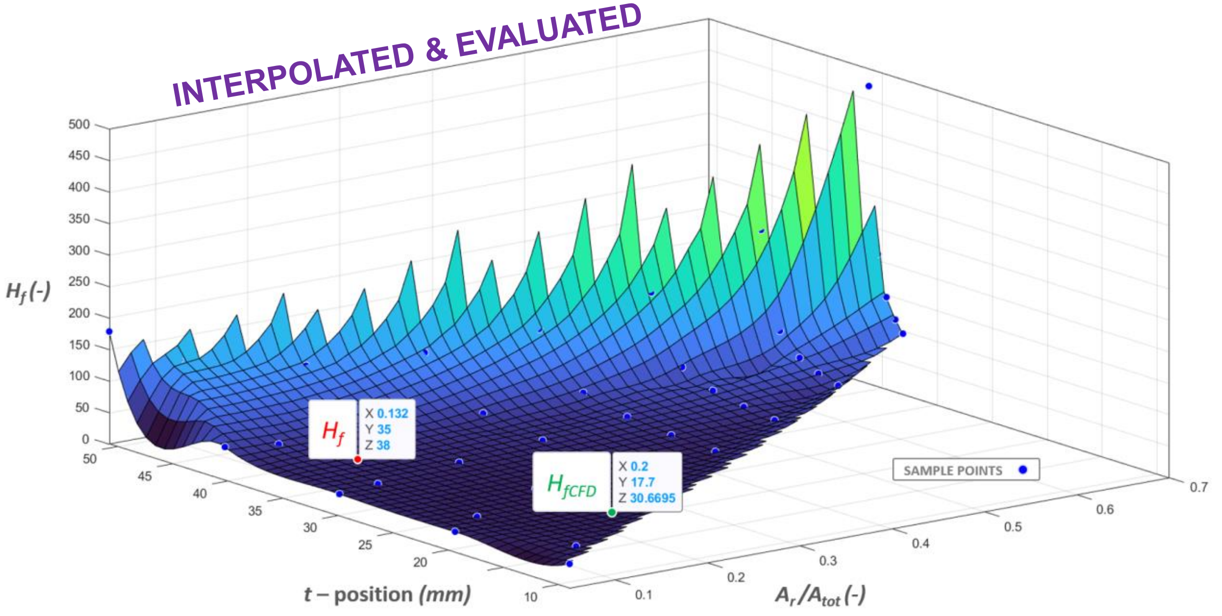
Comparison of results for initial pad geometry.



Pad geometry variations of recess size and position.

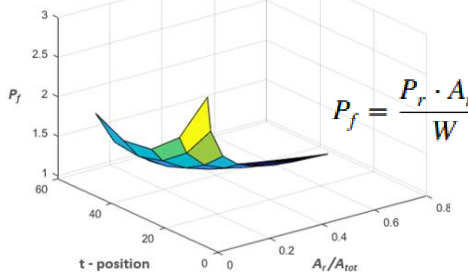
PAD GEOMETRY OPTIMIZATION

SIMULATION RESULTS → **PERFORMANCE FACTORS** → **CALCULATION & INTERPOLATION**



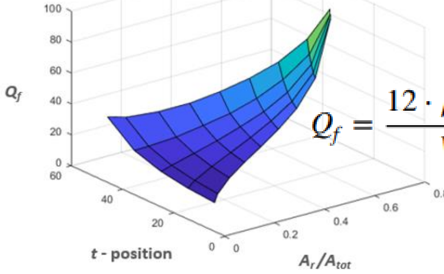
Interpolated power loss factor data with optimal recess size and position using novel and classical approaches.

PRESSURE FACTOR



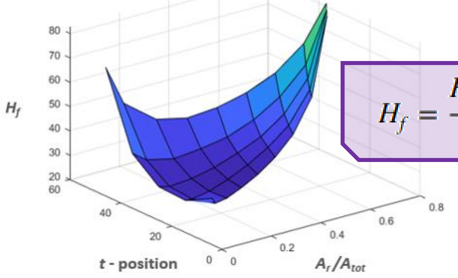
$$P_f = \frac{P_r \cdot A_{tot}}{W}$$

FLOW FACTOR



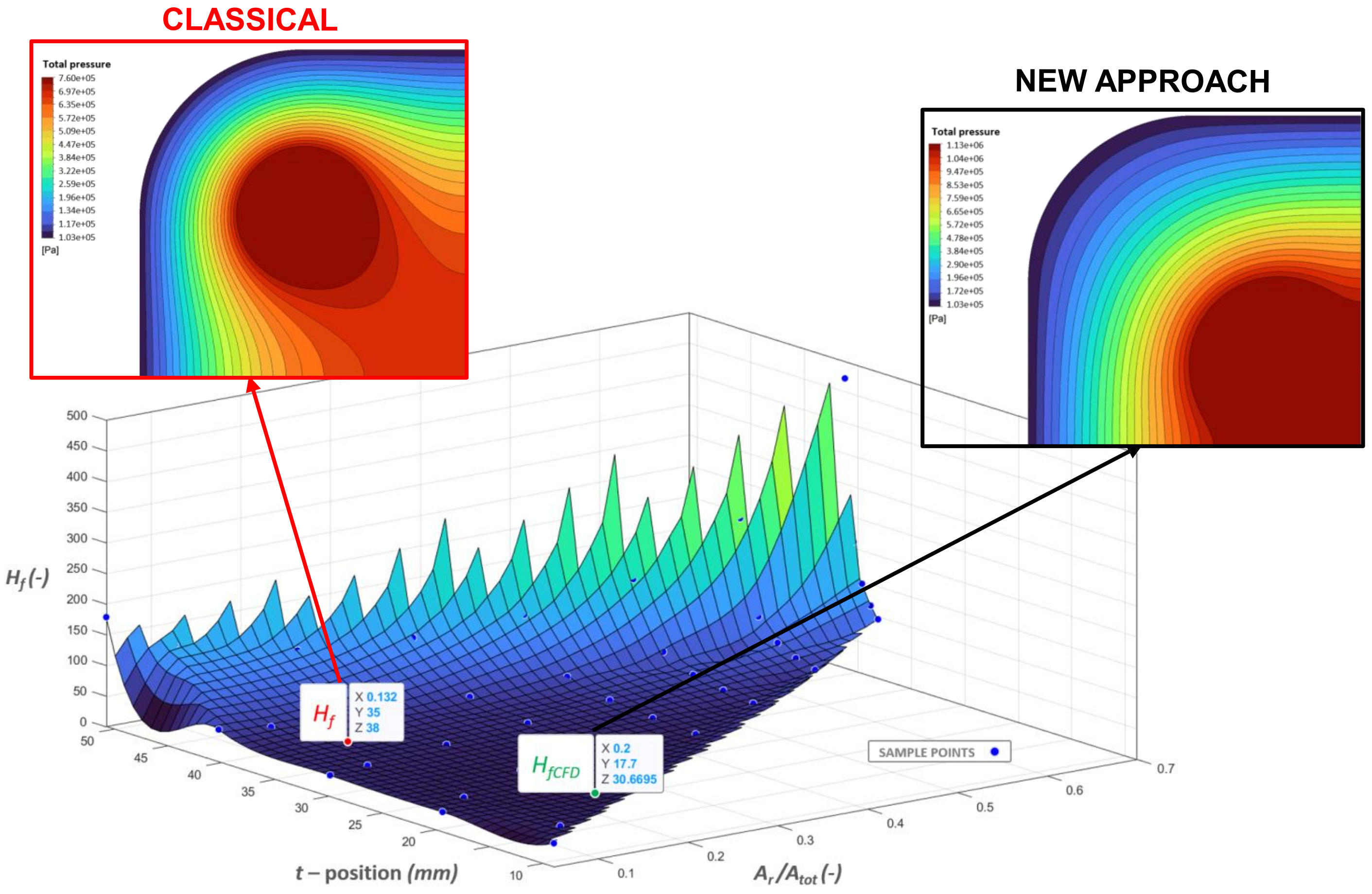
$$Q_f = \frac{12 \cdot \mu \cdot Q \cdot A_{tot}}{W \cdot h^3}$$

POWER LOSS FACTOR



$$H_f = \frac{P_f \cdot Q_f}{\eta}$$

PAD GEOMETRY OPTIMIZATION



Interpolated power loss factor data with optimal recess size and position using novel and classical approaches.

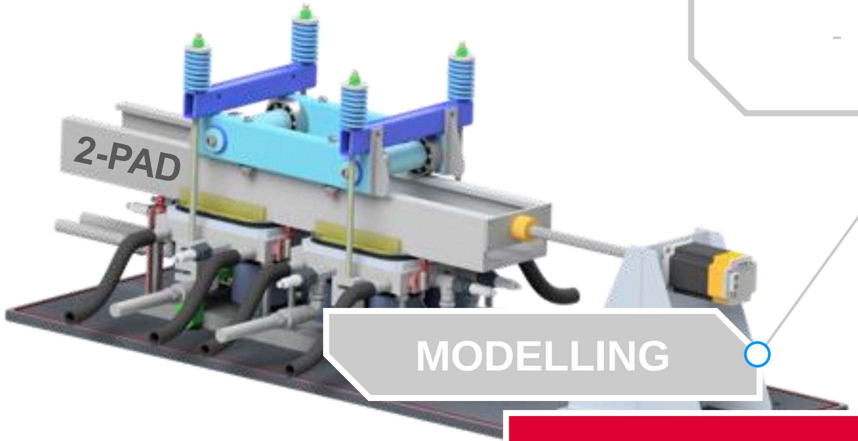
PROS:

- \+ 20 % lower power loss
- \+ Uniform pressure distribution
- \+ Usable for any shape
- \+ Suitable for any software

CONS:

- \- Connected recesses
- \- Require decent hardware

SOLUTION METHODOLOGY



MODELLING

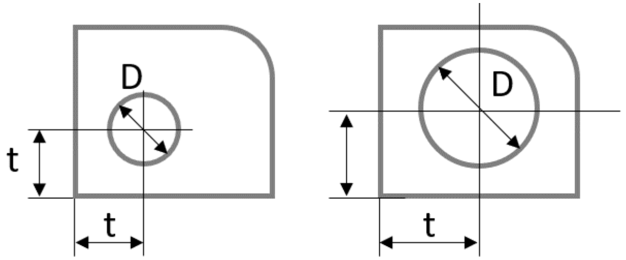
EXPERIMENTAL

CFD MODEL VALIDATION

BEARING EFFICIENCY

PAD GEOMETRY OPTIMIZATION

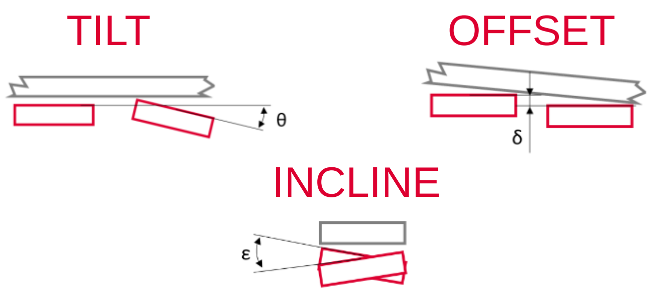
- STATIC



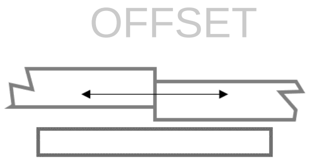
BEARING SAFETY

PAD MISALIGNMENT

- STATIC



SLIDER ASSEMBLY ERROR

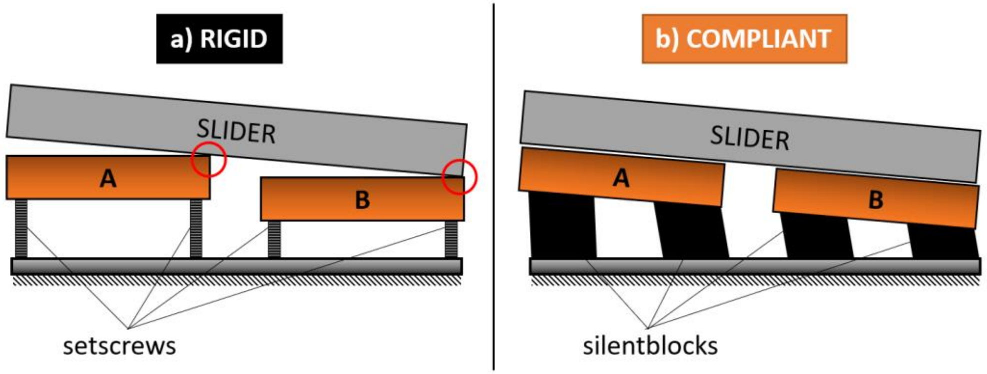


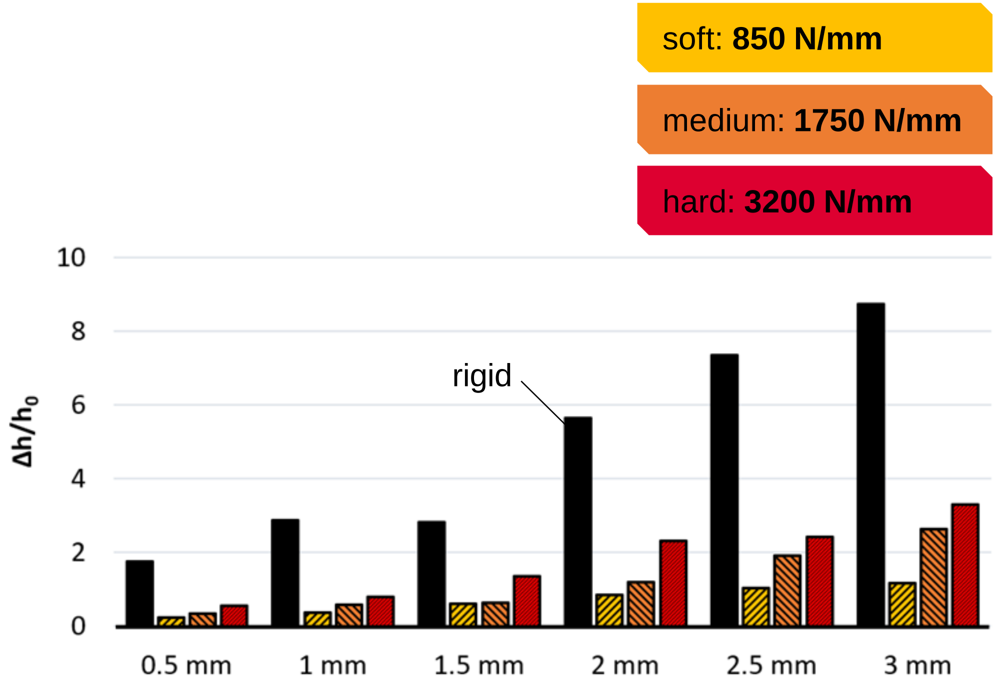
- STATIC
- LOW-SPEED *(38 mm/s)*

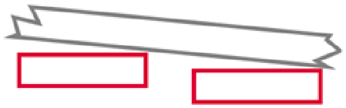
PAD MISALIGNMENT – SUPPORT STIFFNESS

COMPLIANT SUPPORT STIFFNESS

- Slider adjustment to the misalignment
- Relative change in film thickness
- Film stiffness: **17 kN/mm**



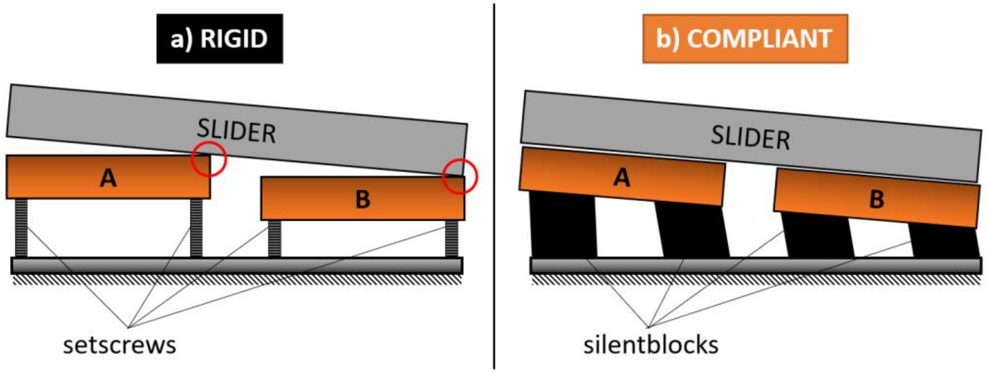


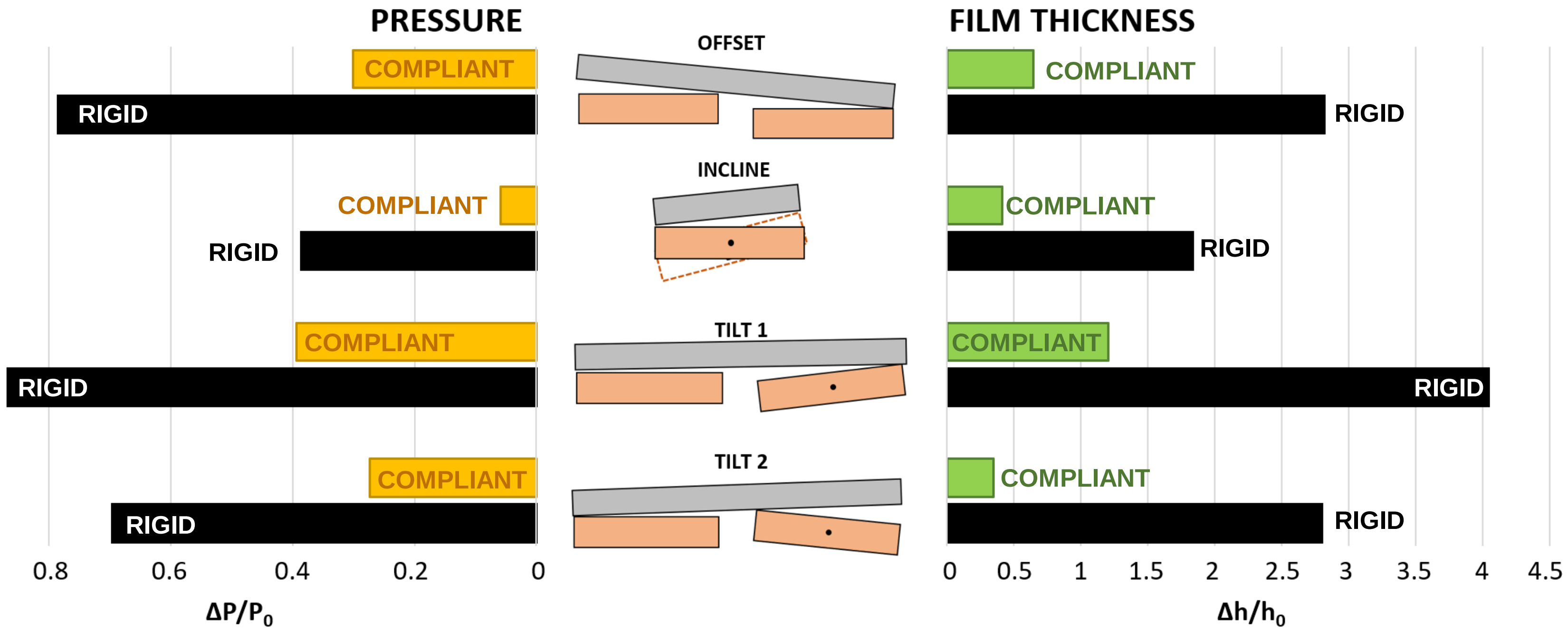


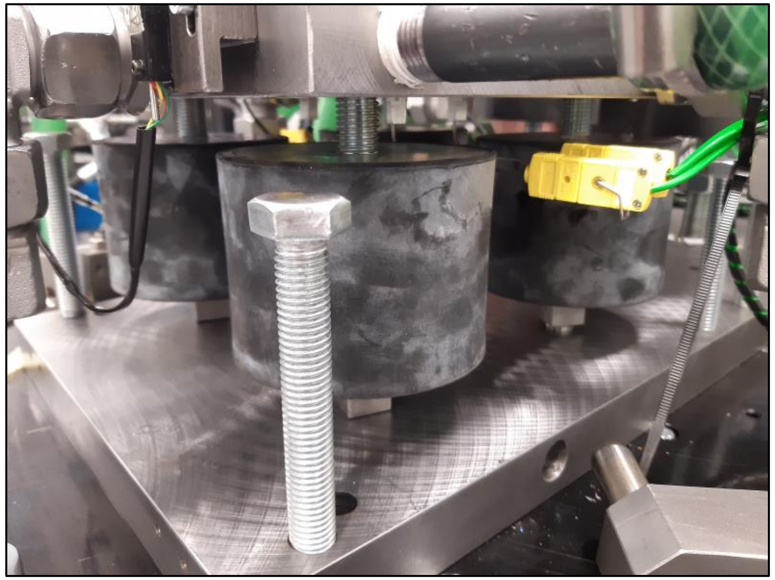
PAD MISALIGNMENT - ASSESSMENT

COMPLIANT SUPPORT

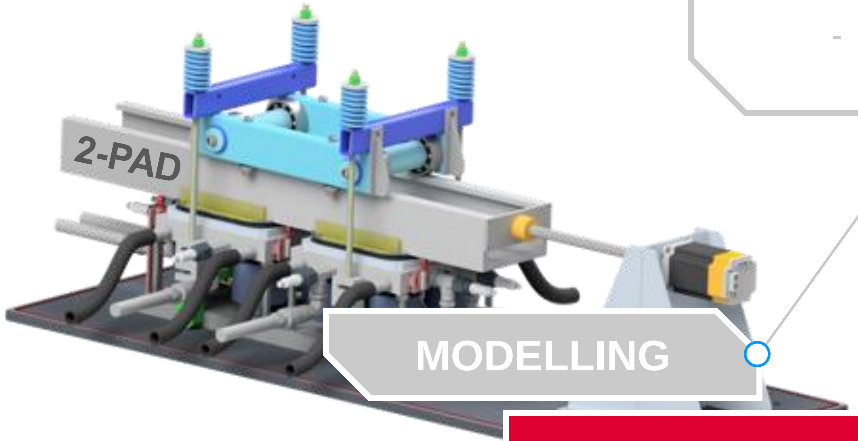
- Self-aligning
- 4-6x better performance
- **Not suitable for high-precision apps**







SOLUTION METHODOLOGY



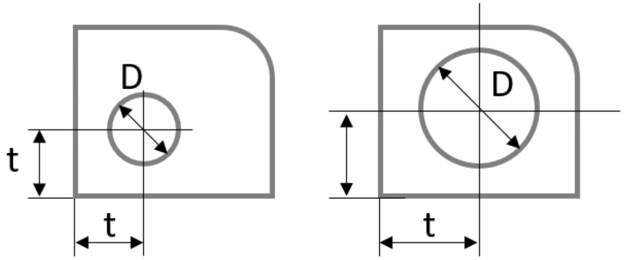
MODELLING

EXPERIMENTAL

CFD MODEL VALIDATION

BEARING EFFICIENCY

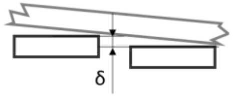
PAD GEOMETRY OPTIMIZATION
- STATIC



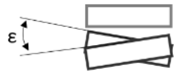
PAD MISALIGNMENT
- STATIC

TILT

OFFSET



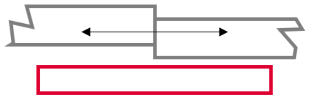
INCLINE



BEARING SAFETY

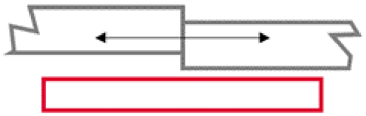
SLIDER ASSEMBLY ERROR

OFFSET

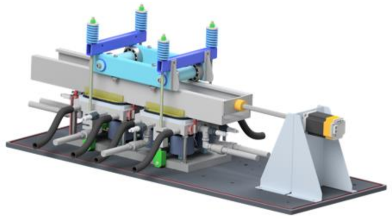


- STATIC
- LOW-SPEED
  (38 mm/s)

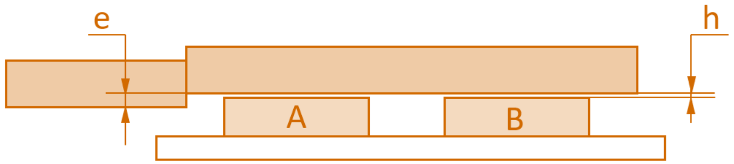
RESULTS

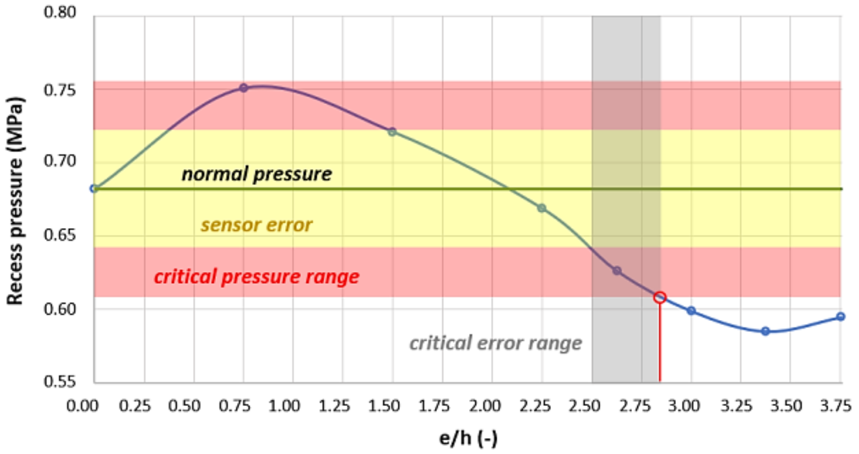


SLIDER MISALIGNMENT - STATIC



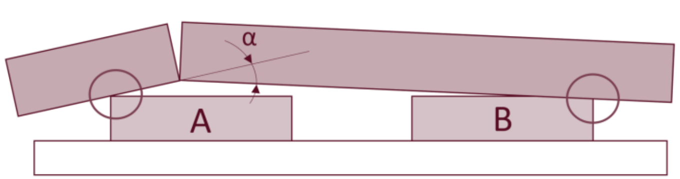
OFFSET

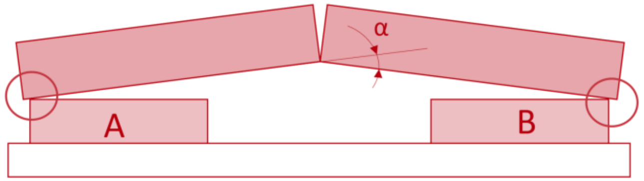


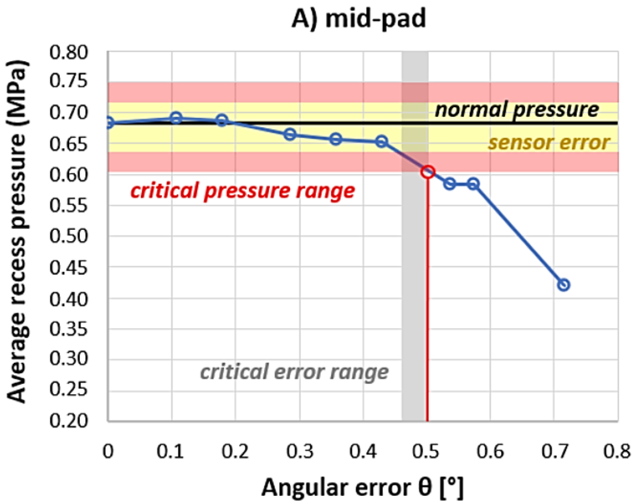


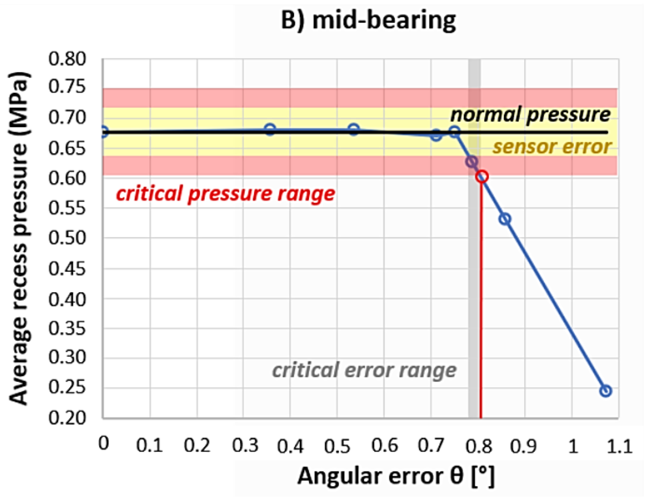
- Critical e/h = 2.75
- **Dependent on connection position**

TILT

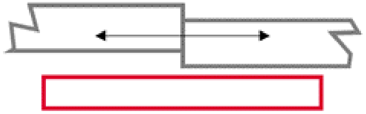




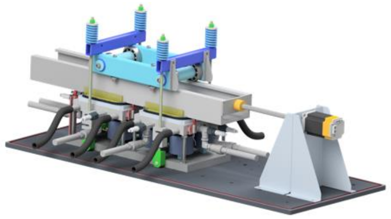




- Limit error 0.46 °
- **Dependent on pad distance**

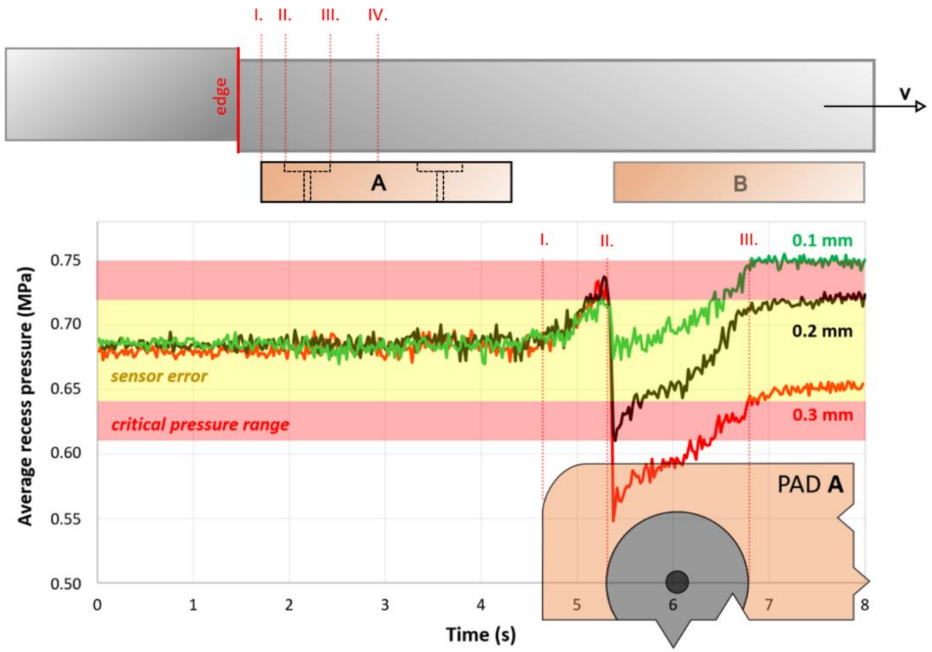


SLIDER MISALIGNMENT - DYNAMIC



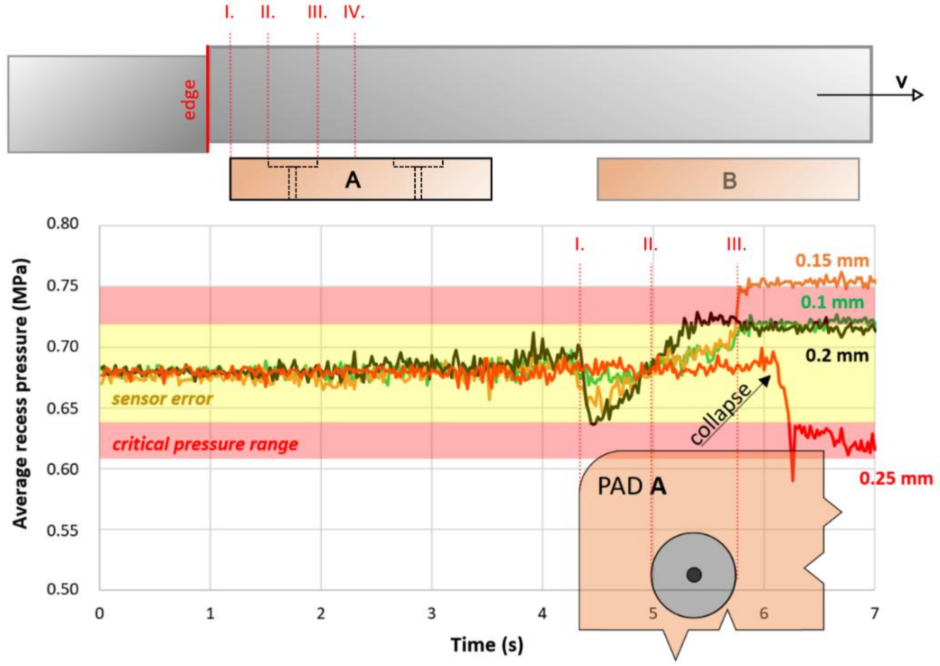
STEP-UP

- Critical e/h = 1.5
- Gradual loss of load-carrying ability

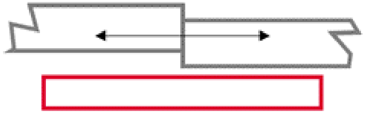


STEP-DOWN

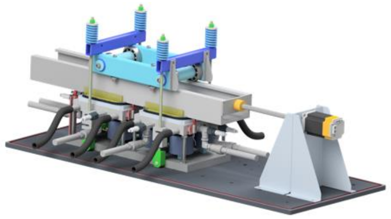
- Critical e/h = 1
- **High risk of collision**



h = 0,14 mm

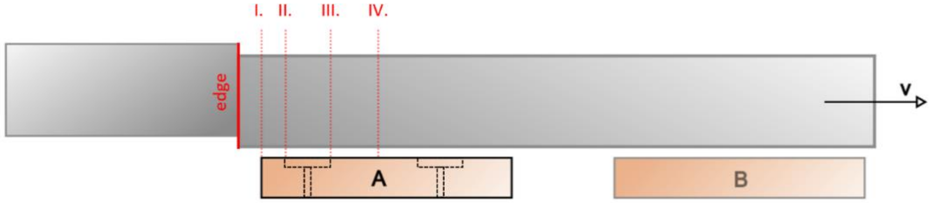


SLIDER MISALIGNMENT - DYNAMIC

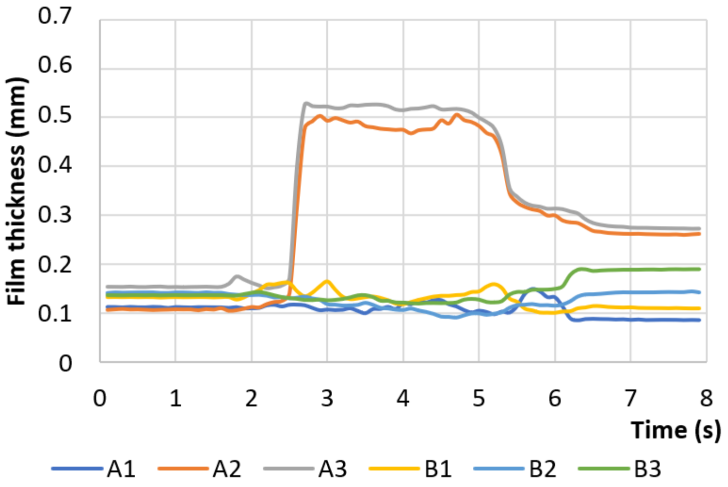


STEP-UP

- Critical e/h = 1.5
- Gradual loss of load-carrying ability

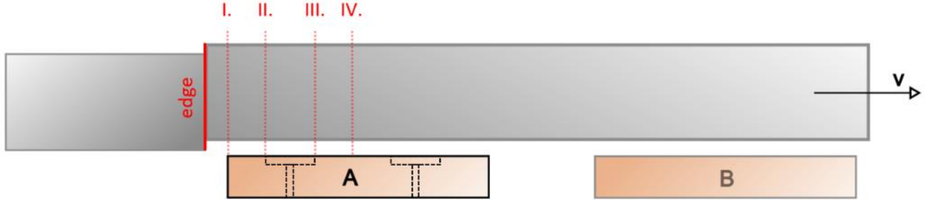


0.3 mm (e/h = 2.15)

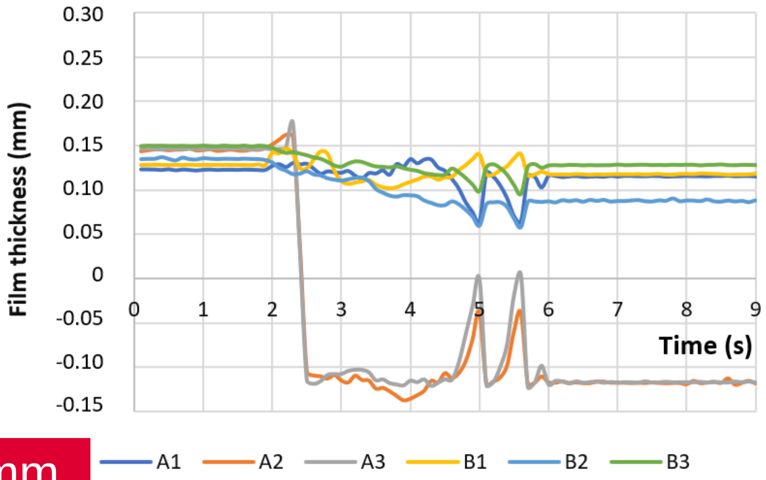


STEP-DOWN

- **Critical e/h = 1**
- **High risk of collision**

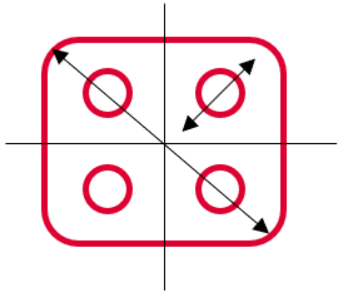


0.3 mm (e/h = 2.15)



h = 0,14 mm

CONCLUSIONS - HYPOTHESES



Q1: *„What is the influence of hydrostatic bearing recess position and size on the bearing performance?“*

H1 (Q1): *„Recess size and layout optimization are usually done according to one parameter classical approach, in which the geometric parameters are linked together. Separating the two parameters, size and layout, can lead to improved pad performance and lower energetic losses.“*

VERIFIED

„HSB pad geometry is one of the key parameters influencing its performance. The proposed two parameter method shows that by adjusting recess size and position separately can reduce energy losses up to 20 %, compared to the classical approach.“

CONCLUSIONS - HYPOTHESES

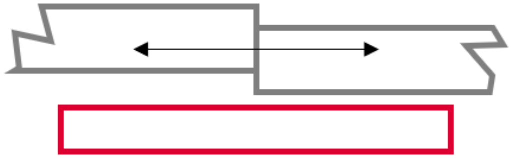
Q2: *„How is the hydrostatic lubricating film affected by assembly errors of the bearing bodies?"*

H2 (Q2): Pad misalignment can significantly affect the generation and uniformity of the HS lubricating film. The lubricating film is able to compensate certain magnitude of pad misalignment. The bearing performance during eccentric loading can be improved using a compliant member. But the compliant support is also able to compensate larger misalignment compared to rigid support.

VERIFIED

„Compared to a rigid support, compliant pad support for multi-pad HSB allows 4 to 6 times larger misalignment depending on the misalignment type."

CONCLUSIONS - HYPOTHESES



Q2: *„How is the hydrostatic lubricating film affected by assembly errors of the bearing bodies?“*

H3 (Q2): Assembly errors were not studied, even though HS bearings have a great potential in large-scale applications. Assembly errors of a segmented slider can lead to HS lubricating film non-uniformity and disruption. The maximal allowed error of the segmented sliders must be smaller than the film thickness to secure safe operation of the bearing.

VERIFIED

The maximal allowed error of slider segmented bodies to avoid collision must be smaller than the film thickness.

THESIS LAYOUT

Literature review

2021

A Review of the Design and Optimization of Large-scale Hydrostatic Bearing Systems

IF: 5.7 (Q1)
AIS: 0.789 (Q2)

New experimental device & compliant support experiments

2022

The prediction of large-scale hydrostatic bearing pad misalignment error and its compensation using compliant support

IF: 3.6 (Q2)
AIS: 0.665 (Q2)

CFD pad geometry optimization

2023

A novel geometry optimization approach for multi-recess hydrostatic bearing pad operating in static and low-speed conditions using CFD simulation

IF: 3.2 (Q1)
AIS: 1.02 (Q2)

Segmented slider assembly errors

2023

Assembly error tolerance estimation for large-scale hydrostatic bearing segmented sliders under static and low-speed conditions

IF: 2.60 (Q2)
AIS: 0.64 (Q3)

STATE-OF-THE-ART

BEARING EFFICIENCY

BEARING SAFETY

LIST OF PUBLICATIONS

Related to the thesis topic:

MICHALEC, M., P. SVOBODA, I. KŘUPKA, M. HARTL. A Review of the Design and Optimization of Large-scale Hydrostatic Bearing Systems. *Engineering Science and Technology, an International Journal*, 2021, vol. 24, issue 4, s. 936-958. ISSN: 2215-0986. [IF = 5.155] (Author's contribution 70 %)

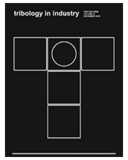
MICHALEC, M., V. POLNICKÝ, J. FOLTÝN, P. SVOBODA, P. ŠPERKA, J. HURNÍK. The prediction of large-scale hydrostatic bearing pad misalignment error and its compensation using compliant support. *Precision engineering*. Elsevier, 2022, vol. 75, 67-79. doi:10.1016/j.precisioneng.2022.01.011. [IF = 3.315] (Author's contribution 40 %)

MICHALEC, M., J. HURNÍK, J. FOLTÝN, P. SVOBODA. Contactless measurement of hydrostatic bearing lubricating film using optical point tracking method. *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, 2022, vol. 237, issue 1, 1-9. doi.org/10.1177/13506501221108138. [IF = 1.674] *(Author's contribution 40 %)*

MICHALEC, M., T. DRYML, D. JAVORSKÝ, L. SNOPEK, M. ČUPR, J. FOLTÝN, P. SVOBODA. Assembly error tolerance estimation for large-scale hydrostatic bearing segmented sliders under static and low-speed conditions. *Machines*. MDPI, 2023, vol. 75, 67-79. doi:10.1016/j.precisioneng.2022.01.011 [IF = 2.6] *(Author's contribution 60 %)*

MICHALEC, M., M. ONDRA, M. SVOBODA, J. CHMELÍK, P. ZEMAN, P. SVOBODA, R. L. JACKSON. A novel geometry optimization approach for multi-recess hydrostatic bearing pad operating in static and low-speed conditions using CFD simulation. *Tribology Letters*. Elsevier, 2023, vol. 71, issue 52, 14pp. doi.org/10.1007/s11249-023-01726-3 [IF = 3.327] *(Author's contribution 65 %)*

Other publications:



MICHALEC, M., P. SVOBODA, I. KŘUPKA, M. HARTL. Tribological behaviour of smart fluids influenced by magnetic and electric field – A review. *Tribology in Industry*, 2018, vol. 40, issue 4, pp. 515-528. ISSN: 0354-8996. [Citescore = 2.4] *(Author's contribution 65 %)*

MICHALEC, M., P. SVOBODA, I. KRUPKA, M. HARTL a A. VENCL. Investigation of the tribological performance of ionic liquids in non-conformal EHL contacts under electric field activation. *Friction*, 2020, 8(5), 982-994. ISSN 2223-7690. Available from: doi:10.1007/s40544-019-0342-y [IF = 5.662] *(Author's contribution 65 %)*

VENCL, A., M. KANDEVA, E. ZADOROZHNAYA, P. SVOBODA, M. MICHALEC, A. MILIVOJEVIĆ a U. TRDAN. Studies on structural, mechanical and erosive wear properties of ZA-27 alloy-based micro-nanocomposites. *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, 2021. https://doi.org/10.1177/1464420721994870. [IF = 2.311] *(Author's contribution 5 %)*

ČERNÁK, M., M. MICHALEC, M. VALENA, M. RANUŠA. Inlet shape optimization of pneumobil engine pneumatic cylinder using CFD analysis. Journal of Physics: Conference Series 1935. *Journal of Physics: Conference Series*, 2021. ISBN: 1742-6588. [Citescore = 0.7] *(Author's contribution 30 %)*

OTHER RESULTS

UTILITY MODEL

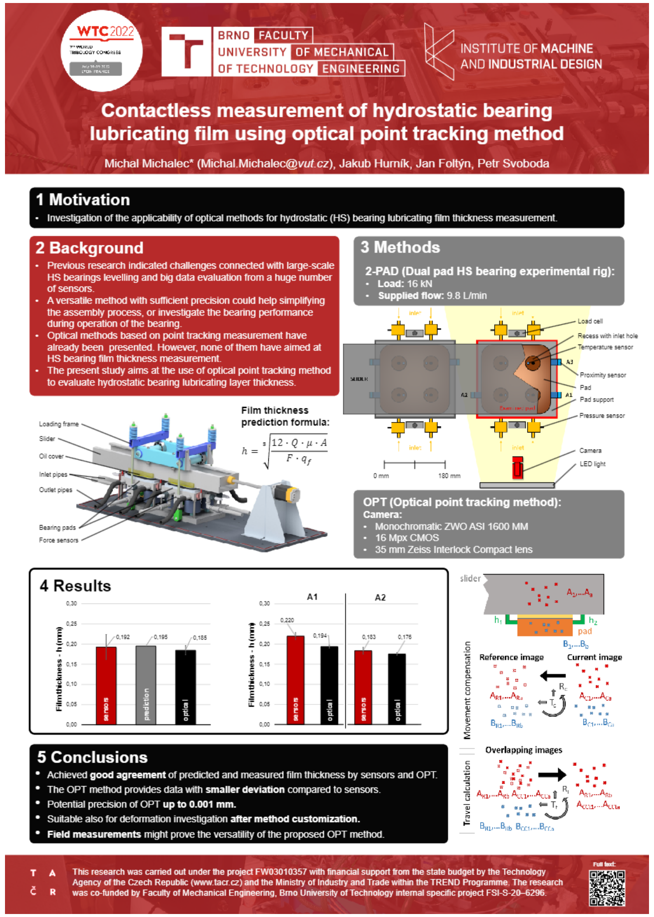
SVOBODA, P.; V. POLNICKÝ, M. MICHALEC, D. ROBENEK. Brno University of Technology, Antonínská 548/1, 60200 Brno, Veveří, Czech Republic, IČ: 216305 (40 %) Bosch Rexroth, spol. s r.o., Těžební 1238/2, 62700 Brno, Černovice, Czech Republic (60 %): Device for testing the operating conditions of segmental axial hydrostatic bearings. 35880, utility model (2022).

FUNCTIONAL SAMPLE

POLNICKÝ, V.; M. MICHALEC, P. SVOBODA, D. ROBENEK: Experimental stand for testing hydrostatic bearing of large structures in the area of special equipment. Laboratory A3/109 Institute of Machine and Industrial Design, Faculty of Mechanical Engineering, Brno University of Technology, Technická 2896/2 616 69 Brno, functional sample (2020).

CONFERENCE POSTER

- WTC 2022, Lyon, FR



PRACTICAL APPLICATIONS OF RESULTS

Potential improvement of large-scale HSL bearings:

- Reduced power consumption by 20 % → 20 000 € (at est. ELT operation 100 000 € / year)
- Simplified design and assembly process – limits of pad & segmented slider assembly errors
- Improved safety (HS bearing repair cost 1.15 million €, made by NASA in 2010)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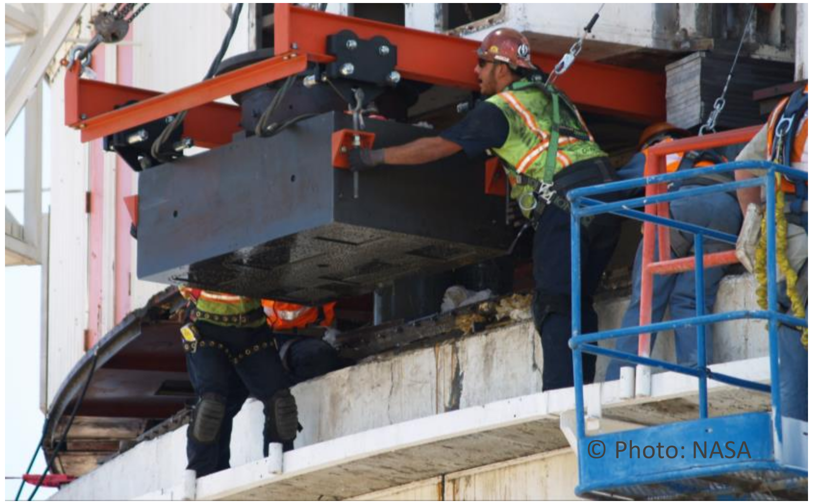
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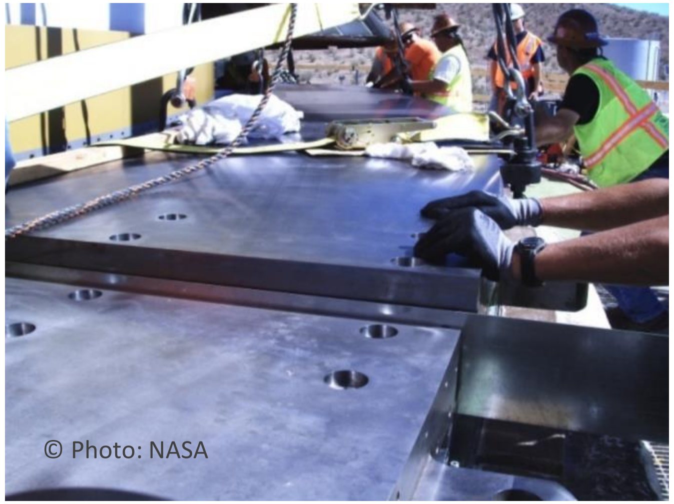
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QUESTIONS, REMARKS, DISCUSSION

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