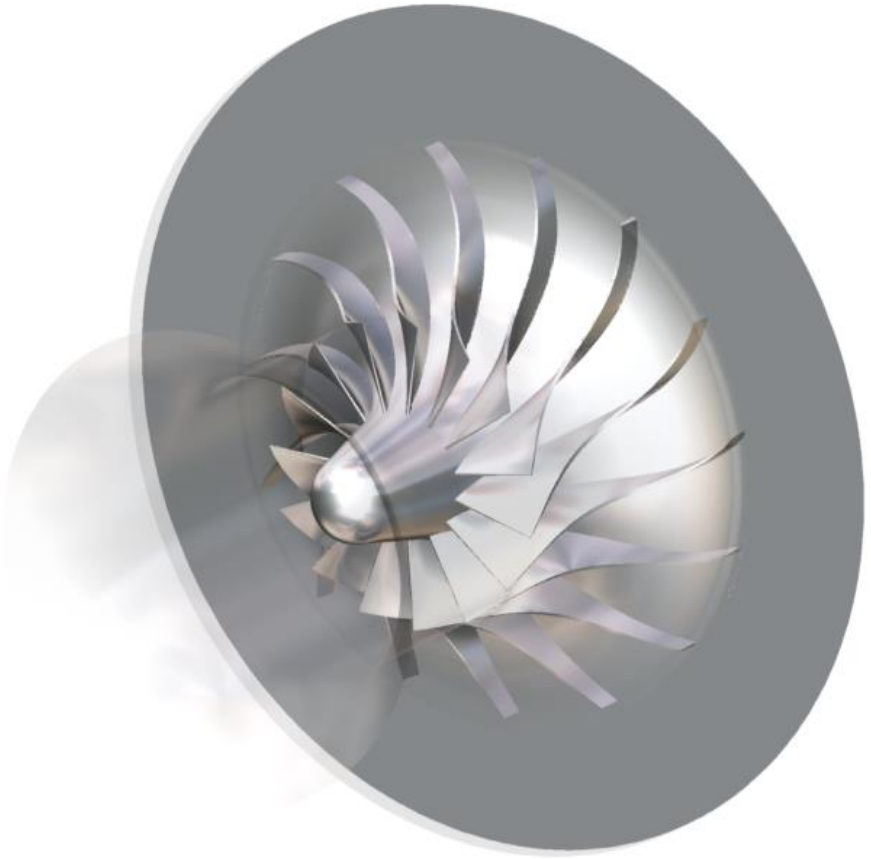
April 12, 2018

Assessment and optimisation of efficient turbo compressors for light gases (Neon-Helium mixtures)

ESR15 - Maxime Podeur, MSc
ITSM, University of Stuttgart



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Background

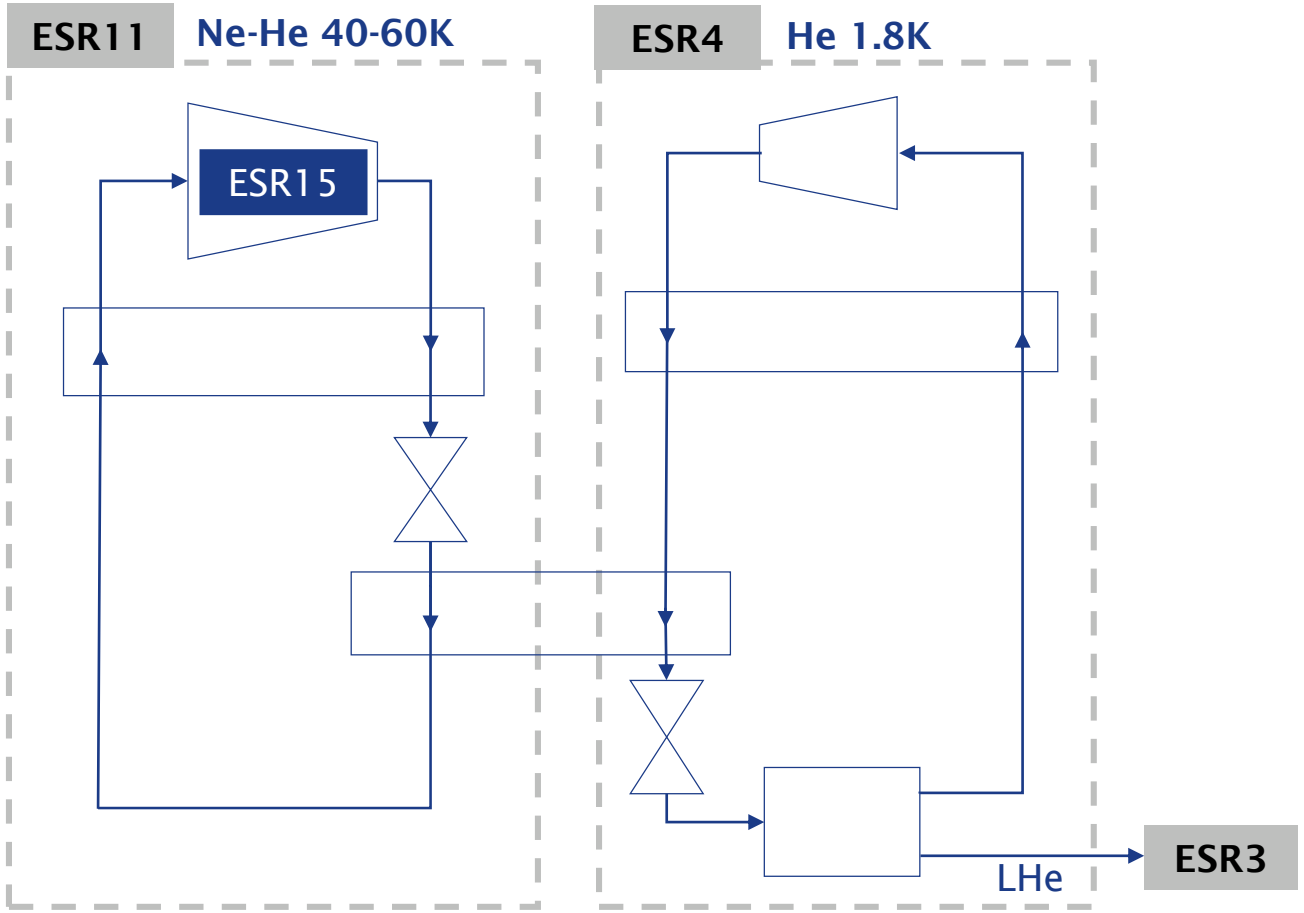
WP4: Cryogenics

ESR3 (Andrea): Design of superconducting magnet coils

ESR4 (Jakub): Design of the Helium cryogenic cycle

ESR11 (Sofiya): Design of the Nelium precooling cryogenic cycle

ESR15 (Maxime): Design of a turbo compressor for the Nelium cycle



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Background

Compressor point of view

- Helium alone too light
  - Low pressure ratio per stage
  - Complex multistage compressor
- Helium leads to high rotational speed and small compressor
  - Low efficiency

→ Increase the amount of Neon

Cryogenic cycle point of view

- Neon has poor thermodynamic properties at low temperature
  - Larger heat exchangers
  - Higher temperature difference
  - Higher pressure drop

→ Decrease the amount of Neon

A compromise will have to be found!

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Research topic

Main Objective

Design a turbo compressor optimized for the operation with light-gases (Nelium) and for cryogenic cooling application

Tasks

- Study the impact of light gases on cryogenic cycle and turbomachine performance
- Quantify static and dynamic stresses of the machine
- Qualify different materials and propose design solutions that are suitable for operation with light gases
- Give guidelines for the aerodynamic and mechanical design of the compressor and the manufacturing techniques to be applied

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Work plan

1st year

- Design of a turbo compressor test rig
- Development of a 0D and 1D model
- Analysis of the impact of light gases on the compressor geometry
- Commissioning of the turbo compressor test stand

2nd year

- Experimental and numerical measurements of first design
- Study of the effect of varying the gas mixture and implementation in models
- Application on large scale turbo compressors
- Design of two compressors at different gas mixtures

3rd year

- Stay at MAN and work on improvement of concepts
- Experimental and numerical measurements of second and third design
- Fine-tuning of the models
- Reporting

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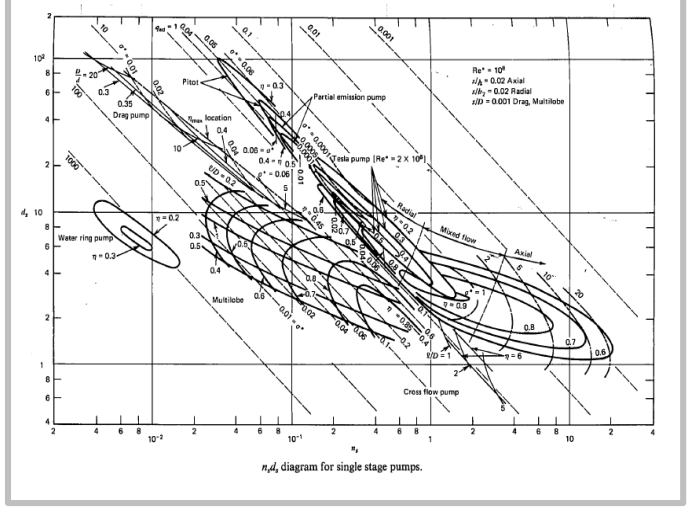
Compressor design

Boundary condition

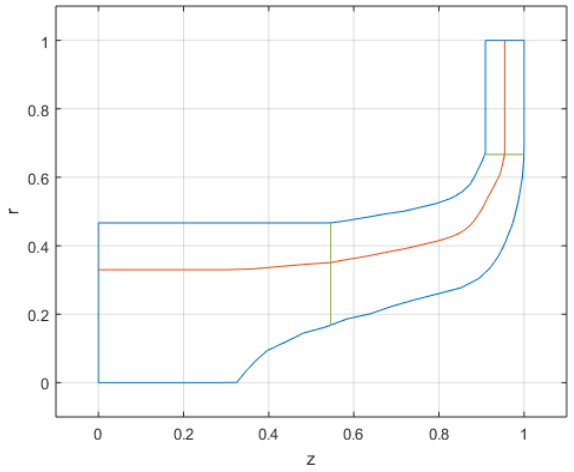
0D model



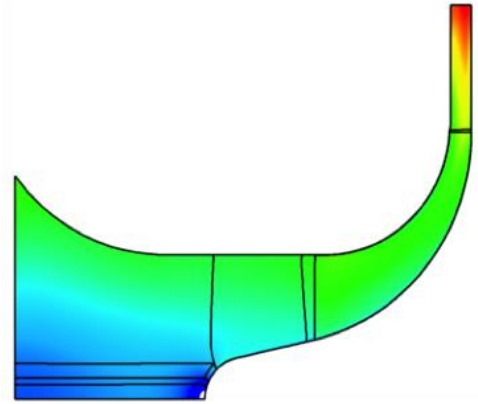
n, d_s diagram for single stage pumps.

2D-quasi3D model

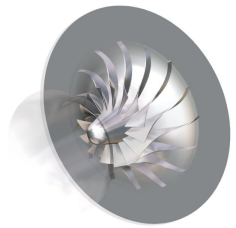
1D model



3D CFD



Final design



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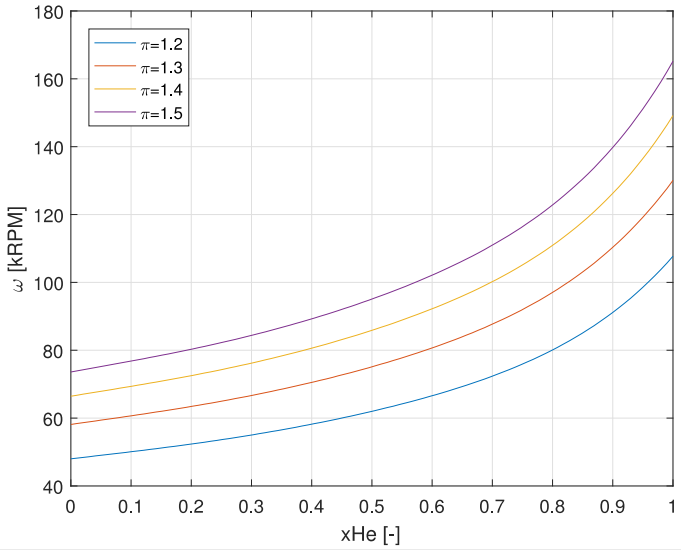
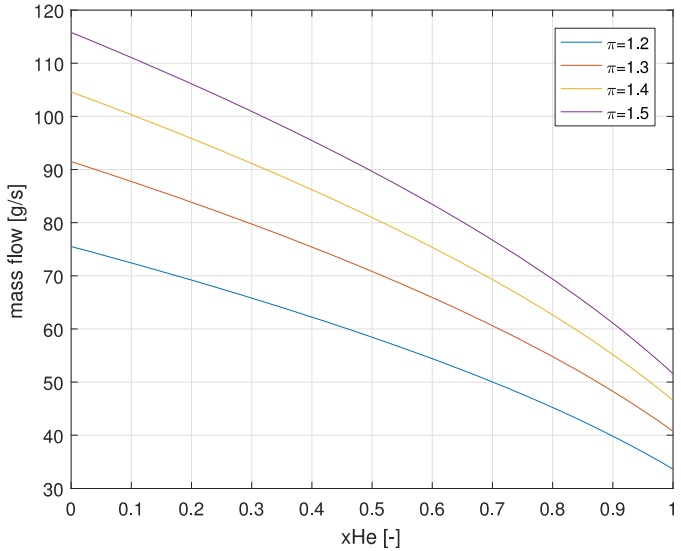
Challenges

Wide variety of operating gas

Rotational speed



Mass flow rate



Test rig conception

- Helium leakage
- Close loop test rig
- Test rig to build from scratch
- Numerical and experimental measurements in parallel

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Risks and mitigation

Risk	Probability	Severity	How to mitigate them
Difficulty for the compressor manufacturer to meet **technical and financial requirements**	Medium	Medium	• Early contact • Readiness to design it ourselves
Logistical issues with the **delivery** of test rig components	Medium	Low	• Early order • Possible delay taken into account in schedule
Failures and defects on test rig components	Low	Medium	• Preparation of alternative components • Possible delay taken into account in schedule
Logistical difficulties with the **room preparation**	Low	Medium	• Close follow up • Possible delay taken into account in schedule
Logistical and manufacturing issues of **in-house components**	Low	Medium	• Close follow up • Possible delay taken into account in schedule
Challenges encountered in the **assembly** of the test rig	Low	Medium	• Close follow up • Possible delay taken into account in schedule
Communication and coordination challenges with other EASITrain team members	Low	Medium	• Regular meeting • Communication • Definition of the work boundaries

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Status

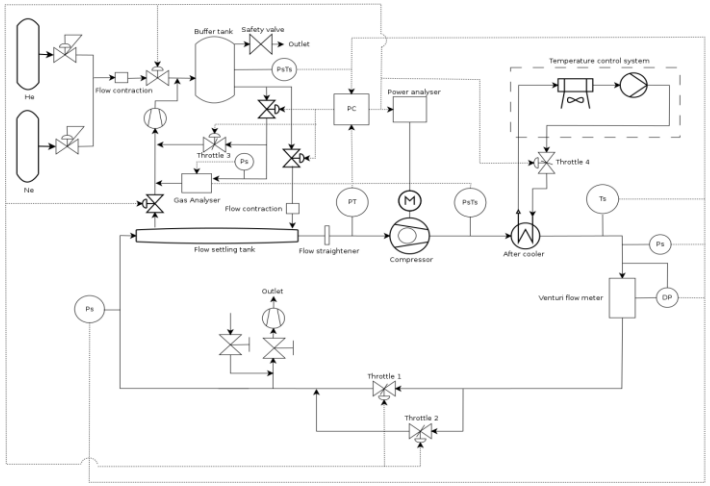
1st year

- Design of a turbo compressor test rig
- Development of a 0D and 1D model
- Analysis of the impact of light gases on the compressor geometry and performance
- Assembly and commissioning of the turbo compressor test stand

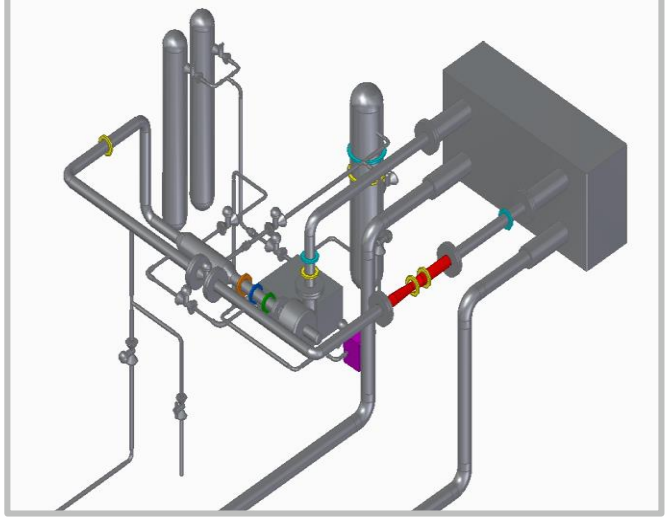
Tasks

- P&ID ✓
- Bill of materials ✓
- Call for offers ✓
- 3D CAD ✓
- Schedule planning ✓

P&ID



3D CAD



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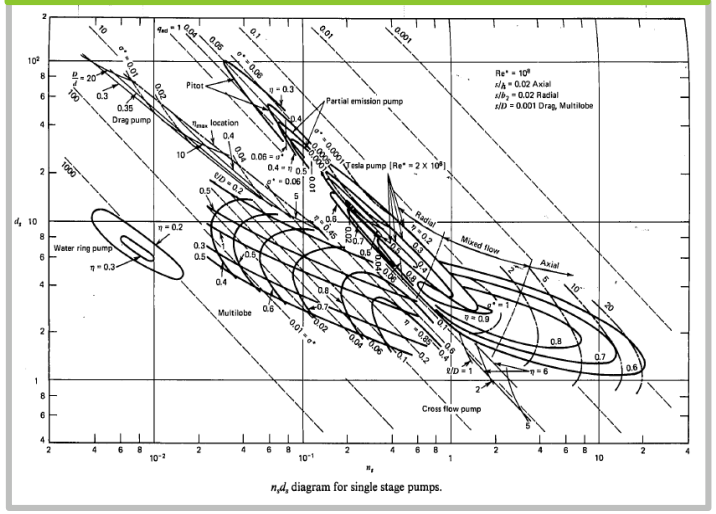
Tasks

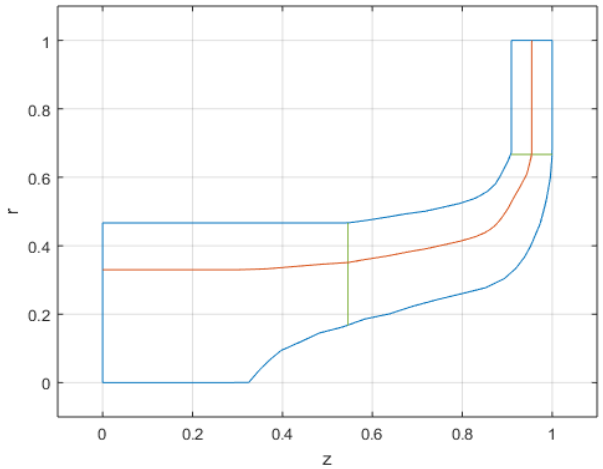
- Litterature review ✓
- Model implementation ON-GOING
- Validation
- Optimisation

0D model



$n_s d_s$ diagram for single stage pumps.

1D model



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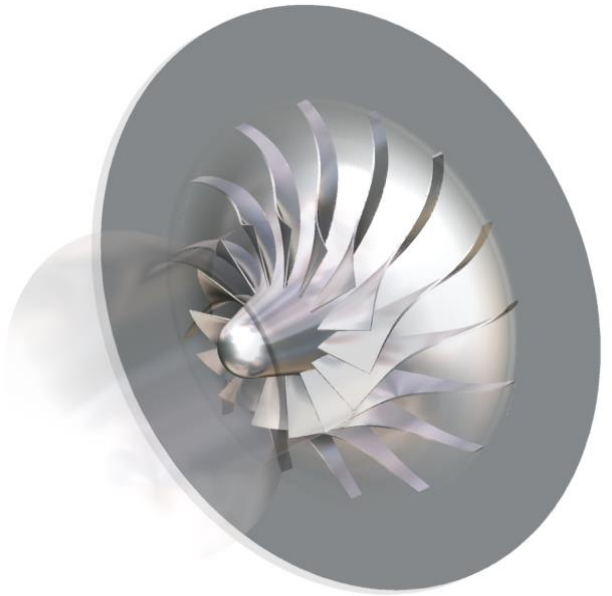
Thank you for your attention!



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