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Sofia – sCO_2 facility for Supercritical Brayton Cycle Research

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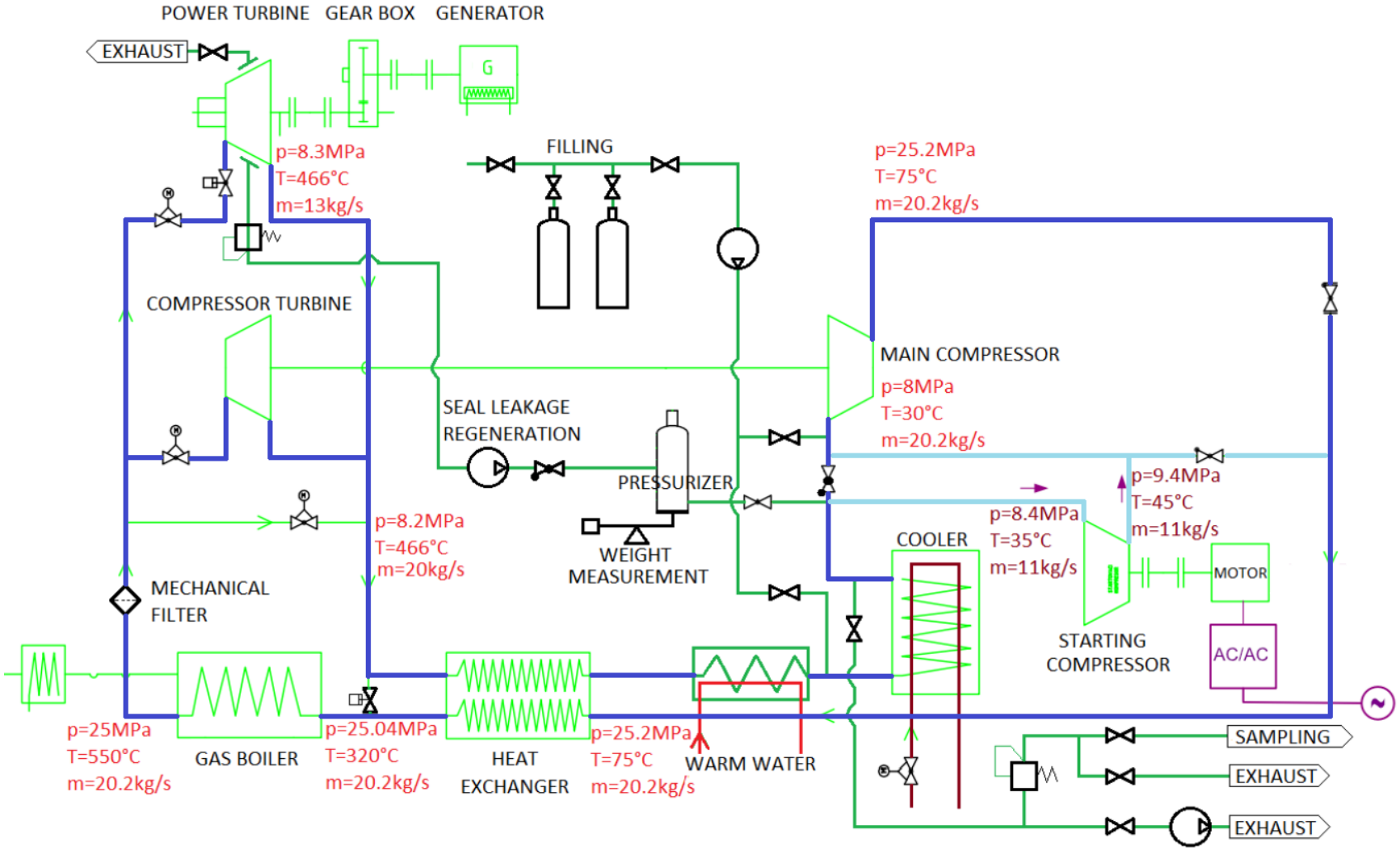
Context, project sCO2 Efekt and Sofia facility

- sCO2 Efekt (sCO2 Effect) is a research project supported by TAČR (Czech Technological Agency)
- Sofia is the name of the experimental facility to be developed in the frame of sCO2 Efekt project
- Project partners – CVR, UJV, Doosan
- Main goal of the project – development of the conceptual design of the effective Energy Storage System and verification of its key components

Context, project sCO2 Efekt and Sofia facility

- The Energy Storage System being developed is based on the TES (Thermal Energy Storage) principle
- Aluminium - Silicon eutectic alloy AlSi12 is used as a thermal storage media
- Most of the heat is stored in the form of latent heat of AlSi12 alloy
- sCO2 power cycle is used for the reverse power production
- The details about the Storage tank are included in another presentation – "Thermal design of latent heat thermal energy storage facility with supercritical CO2" to be introduced by Tomas Melichar on Wednesday at 11:00

Layout of the Sofia facility



Main components of the Sofia facility and its parameters

- Compander
- Starting compressor
- Power turbine
- Pressurizer
- Heat source, heat exchanger and coolers

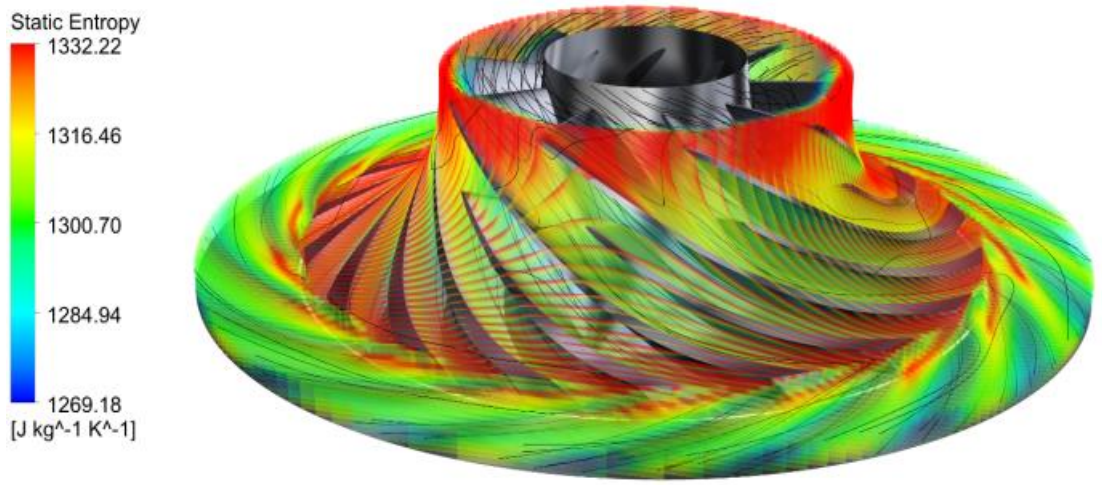
Compander

- Compander is the main compressor driven by its centrifugal turbine
- It is not equipped with a motor
- During the start-up procedure, the main compressor works in series with the starting compressor
- The shaft is mounted in two radial and one thrust gas bearings
- Main parameters measured during the operation are:
  - Rotation speed, rotor vibrations, global vibrations, internal pressure and axial force

Compander – main compressor

- Main parameters of the compressor at the design point are:

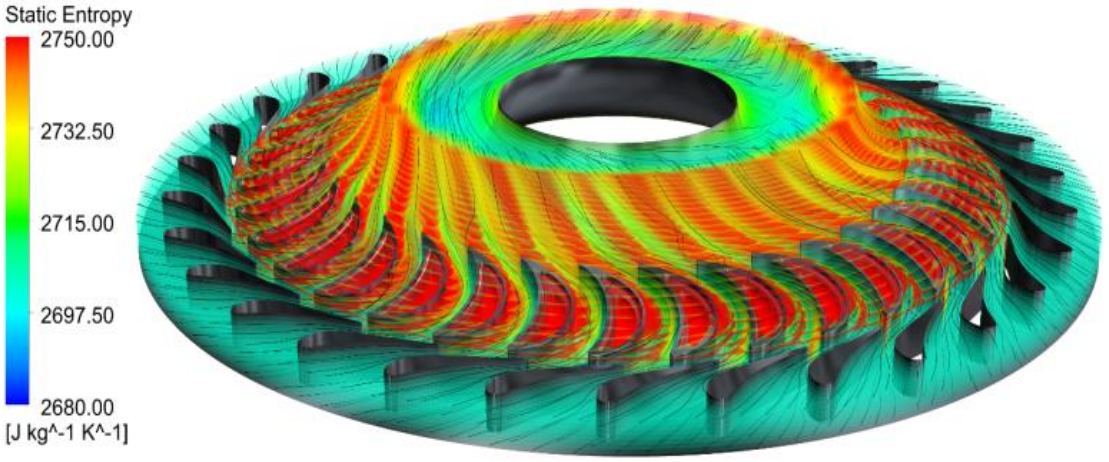
Pressure inlet	8 MPa
Pressure outlet	25.5 MPa
Inlet temperature	30 °C
Mass flow rate	20.9 kg/s
Rotational speed	68 000 rpm
Total efficiency	78 %
Mach number	< 0.93
Axial force	-2.26 kN



Compressor entropy and streamlines visualization

Compander – driving turbine

- Main parameters of the turbine at the design point are:
  - Pressure inlet 24 MPa
  - Pressure outlet 8.5 MPa
  - Inlet temperature 550 °C
  - Mass flow rate 6.19 kg/s
  - Rotational speed 68 000 rpm
  - Total efficiency 79 %
  - B2B rel. Mach number < 1.43
  - Shaft power ~ 650 kW
  - Axial force 2.37 kN



Turbine entropy and streamlines visualization

Compander status

- CFD analysis of the comperssor and turbine were performed
- Internal seals and axial forces were optimized
- The axial force needs to be meassured and controlled during operation, as the thrust gas bearing was designed to handle the force <300N
- Stress analyses of the compressor pressure vessel are ongoing
- The detailed design is currently being completed and fabrication begins

Compander 3d model

Starting compressor

- The compressor will be used during the start-up operation only
- It is being designed as a two stage compressor
- The conceptual studdy of the compressor was performed
- It will be hermetical encapsuled motor driven compressor mounted in gas bearings.
- Design parameters ot the compressor are summarized in the following table

Design pressure	10 MPa
Nominal pressure inlet	8.4MPa
Inlet pressure range	5 – 9 MPa
Nominal pressure outlet	9.4MPa
Nominal mass flow rate	11 kg/s
Nominal inlet temperature	35°C
Inlet temperature range	20-40°C
Nominal power of the motor	55 kW
Speed control	Frequency converter
Nominal speed	40 000 rpm

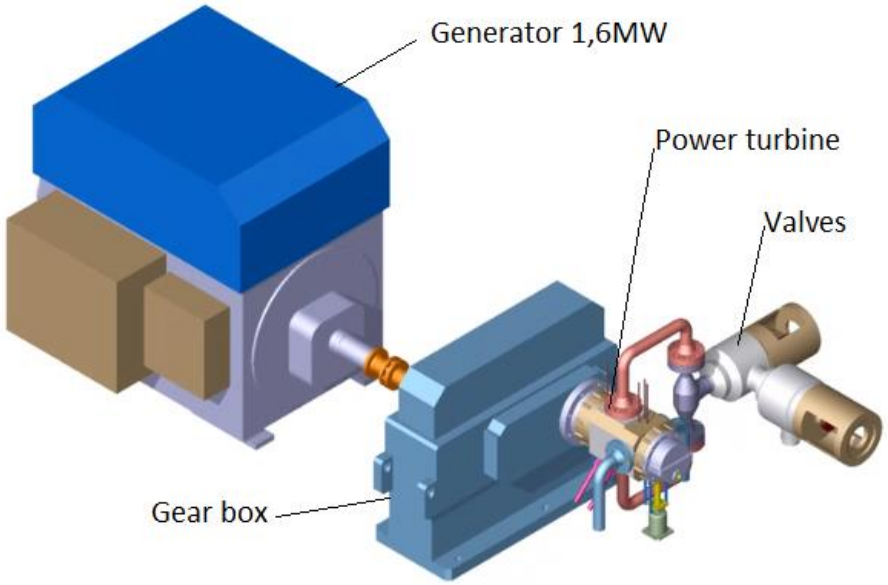
Power turbine (PT)

- The power turbine is designed as the axial one
- The axial type was selected in an affort to get a first experience and operational data of sCO2 axial turbine.
- PT together with the budget limit defined the power of Sofia facility
- Design parameters ot the PT are:

Design pressure	26.5 MPa
Nominal pressure inlet	25 MPa
Nominal pressure outlet	8.5 MPa
Nominal mass flow rate	13 kg/s
Nominal inlet temperature	550 °C
Inlet temperature range	20-40 °C
Nominal power of the turbine	1050 kW
Nominal speed	20 000 rpm
Number of blade stages	5

Power turbine (PT)

- The power turbine is located directly on the gear box
- The turbine is being developed and will be delivered by Doosan Škoda Power including the power generator
- Nominal power of the gear box and generator 1.6 MWe
- The turbine is equipped with the dry gas seals which are connected with the leakage
- The turbine workspace is created by 5 axial stages
- The length of the first blade si about four milimeters
- PT is designed with common oil lubricated bearings
- Detail design of the turbine is beeing finished



3d model of the Turbine assembly

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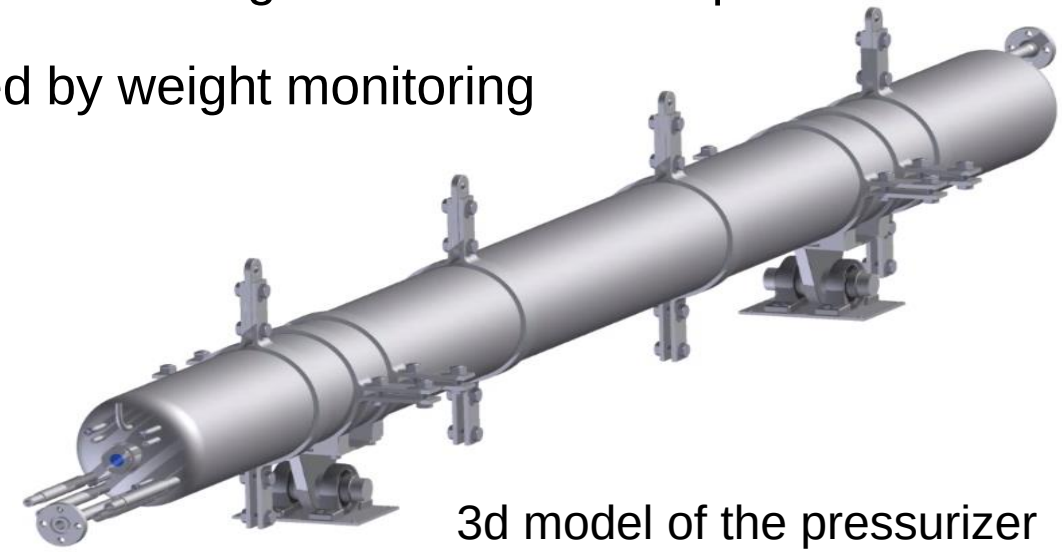
Pressurizer

- Main goals of the pressurizer are:
  - sCO2 storage
  - Keeping of the bottom pressure on the required level
  - Conditioning of the cycle at the beginning of start-up procedure
- The pressurizer enables to store up to 400 kg of sCO2
- Its content is controlled by temperature
- The vessel is equipped with electrical heating rods and two independent cooling systems
- The content of sCO2 is determined by weight monitoring



3d model of the pressurizer

Heat source, heat exchanger and coolers

• The heat source parameters were defined as follows

Design pressure	26.5 MPa
Nominal Pressure	25 MPa
Design temperature	565 ° C
Nominal inlet temperature	320 ° C
Nominal outlet temperature	550 ° C
Nominal CO2 mass flow rate	22 kg/s
Heat power of ignition burner	100 kW
Maximum heating power supplied to sCO2	6000 kW
Total heating power	6850 kW

• Gas boiler was expected to be a heat source, but another solution is currently also being solved

• Heat exchanger will be the PCHX one

• The precooler and cooler (sCO2/water) will be of the plate HX type

• Specific parameters of the cooling system are included in the paper.

Location and experimental plan

• The original plan is to build and operate the Sofia facility at UJV (and CVR) area

• Czech power producer and operator ČEZ expressed the interest in the implementation of the Sofia facility at its power and heating plant

• Feasibility studdy of this modification is intensively addressed

• The goal of the project is to test the compressors and turbines

• The location of the facility at the power plant area will enable long term operation even without further financing (which is expected)

Conclusions

• Detail design of the compander and power turbine is almost finished. The fabrication of the facility as well as the tenders starts at 6/2021

• The facility will be assembled at the end of 2022

• First operational experience will be gained during 2023, when the project Efekt will be finished

• Further modification of the Sofia facility to recompression cycle is discussed

• Utilization of the facility within EU projects is expected

• Any collaboration and/or testing of the cycle components is possible and very welcome

Thank you for your attention!

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