Application Aspects of Steam Turbines for Combined Heat and Power Generation

PANNDAGARNA 2015

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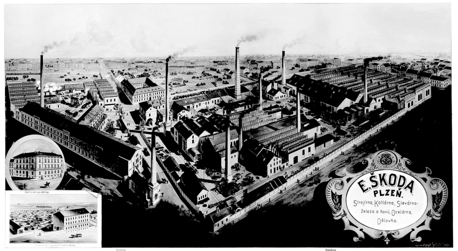
L.Prchlík, Doosan Skoda Power, Plzen, Czech Republic

Presentation Overview

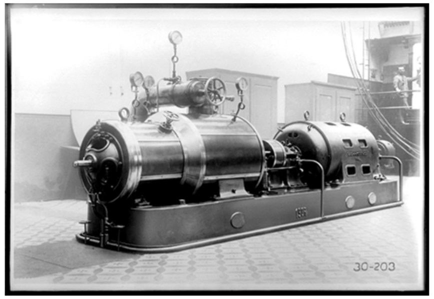
- Introduction
- Skoda steam turbine portfolio
- Examples of combined heat and power installations
- Wet steam considerations for extraction steam turbines
- Summary and future trends

Škoda History Timeline and Technical Key Milestones

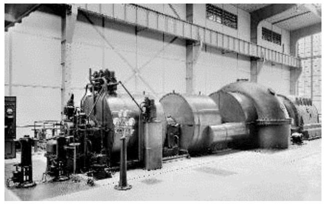


1859 – *Count Wallenstein founded the original engineering workshop*

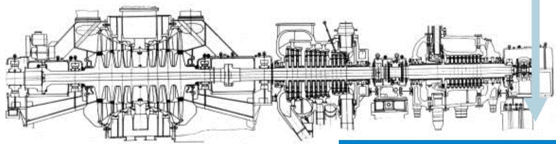
1869 – *Emil Skoda bought the works*



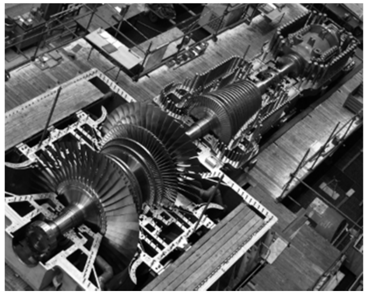
1904 – *First steam turbine 550 HP*



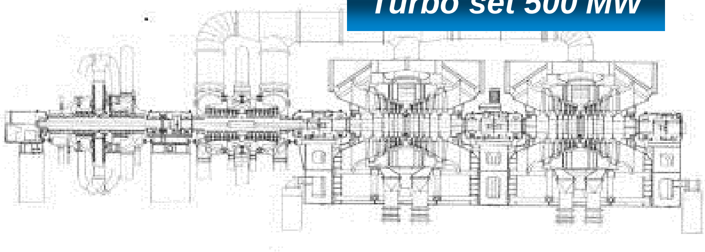
1932 – *23 MW steam turbines with steam reheating*



1959 – *Turbo set 110 MW*

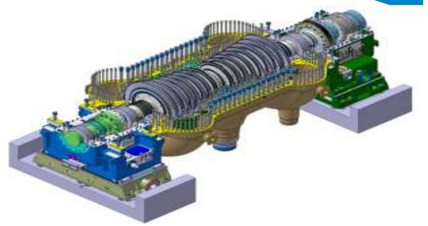


1966 – *Turbo set 200 MW developed*



1978 – *Turbo set 500 MW*

1992 – *Turbo set 1000 MW*



2008 – *USC 660 MW for Ledvice project developed*

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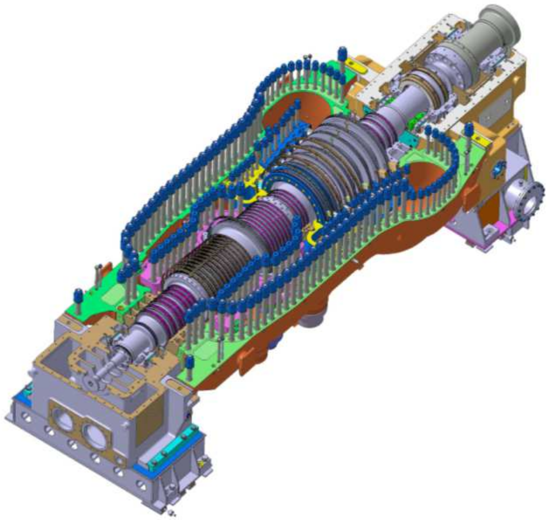
DOOSAN

Doosan Skoda Power in Plzeň

- **Plzeň – the city of industrial tradition**
  - Location
    - 90 km south-west of Prague
    - 80 km south-east of Karlovy Vary
  - Fourth largest city in the Czech Republic with ca. 165,000 inhabitants
  - Qualified personnel and local technical university
  - Doosan Skoda Power follower of former „Skoda Turbines“ and „Skoda Energo“



- **Dooan Škoda Power premises total area of 65,000 m^2**
  - Manufacturing area of 37,000 m^2
  - Office area of 5,000 m^2
  - Ca. 1,300 employees
  - Proximity to main highway (5km) and connection to airport (80km), railroad line to factory
  - Proximity of suppliers: Brush SEM, ZAT Controls, Škoda Machine Tool, Czech Precision Forge, Saarschmide, Boehler

Doosan Škoda New Build Business

From steam turbogenerator to machine-hall for different applications

Products and applications
- Fossil fuel
- Cogeneration
- Combined cycle
- Nuclear
- Waste incineration
- Biomass
- Solar

Main Design Features
- Solutions based on modular design (MTD 20 to MTD 80)
- Modules concept allows effective customization
- Power range 10 – 1,200 MW , temperature 230 – 610°C, pressure 30 – 270 bar
- Turbines for drive of generators, feed water pumps, compressors
- Up-to-date Škoda design combines advantages of impulse and reaction technology
- Wheel and diaphragm solution with optimized reaction
- Drum type rotor for smaller HP sections

Doosan Škoda Power Main STG Models

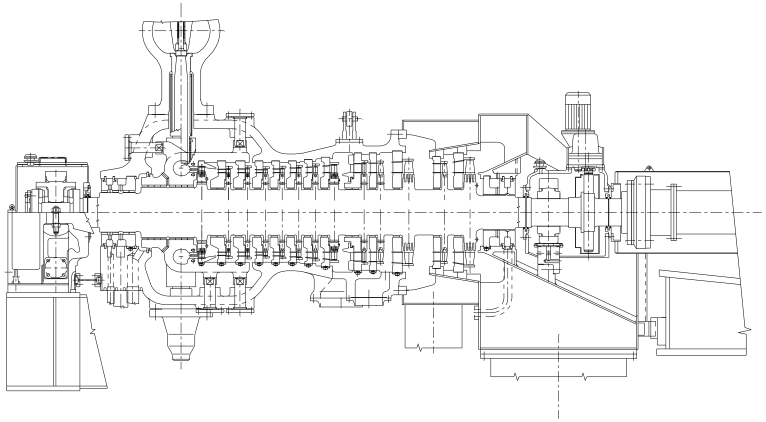
Type	Power output [MWe]	Configuration	Nominal TG speed [rpm]	Max. Pressure/Temper. [bar/ºC]
MTD20	10-30	Single casing geared	8 000	140/540
MTD25	20-40	Single casing geared	6 500	140/540
MTD30	30-55	Single casing geared	5 500	140/540
MTD40	50-180	Single casing (SH/RH)	3 000/3 600	140/570
MTD50	80-210	HP and IP/1 LP flow	3 000/3 600	180/580
MTD60	130-380	HIP and 2 LP flows	3 000/3 600	200/600

All models steam extraction process/DH ready.

Basic Types of STGs for Combined Heat and Power Generation

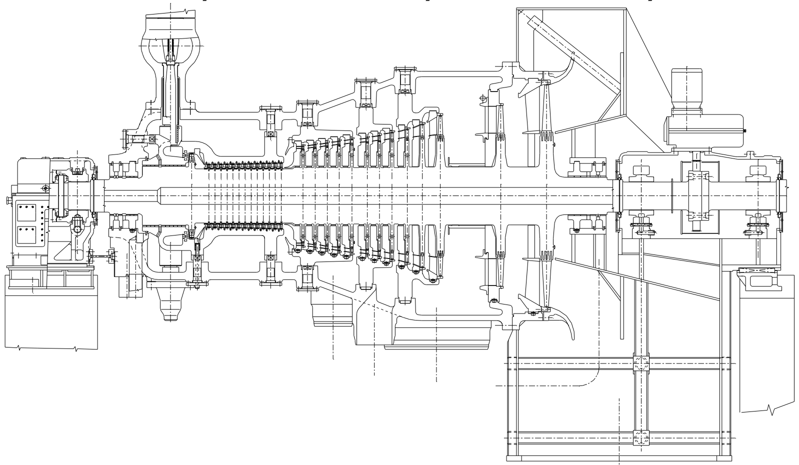
Back-pressure turbines

(MTD20B, MTD25B, MTD30B, MTD40B)

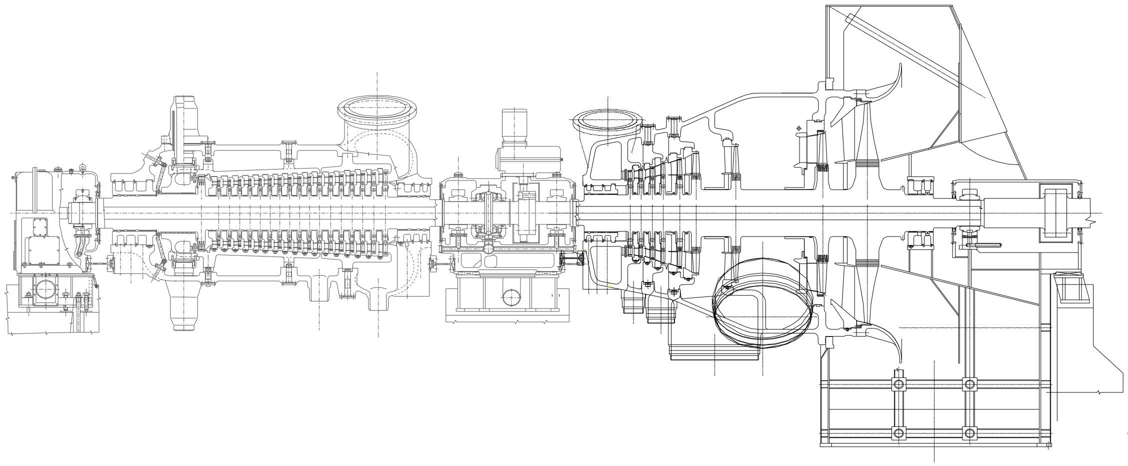


Condensing extraction turbines

(MTD20CE, MTD25CE, MTD30CE, MTD40CE)



Two casing turbines with a large controlled extraction from cross-over piping (MTD50CE)



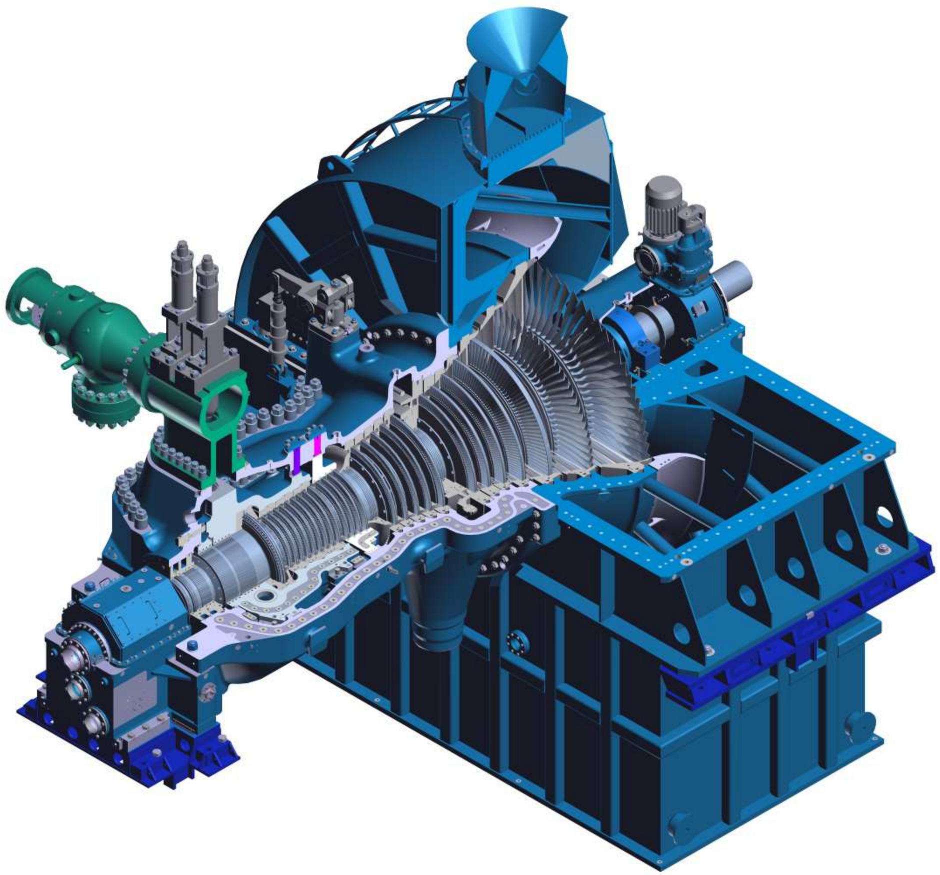
Skoda Steam Turbines for District Heating (Cooling)

- Optimized steam cycle/STG design crucial for balanced energy use in all operating regimes
- In-house optimized component and plant engineering design
  - Turbogenerator w. auxiliary systems
  - Condenser and reg. heaters
  - Machine hall P&I and layout
  - District heating stations
- Robust turbine design based on verified features
  - Robust root attachments, 3D flow path, active/passive erosion protection
  - Integrally shrouded LP blades
  - Control diaphragm
  - Abradable/retractable seals
- Advanced operation monitoring
  - Rotor deformation (eccentricity) monitoring for fast start-up
  - Remote monitoring incl. LP blades

Selected Skoda Turbines for Combined Heat and Power Generation

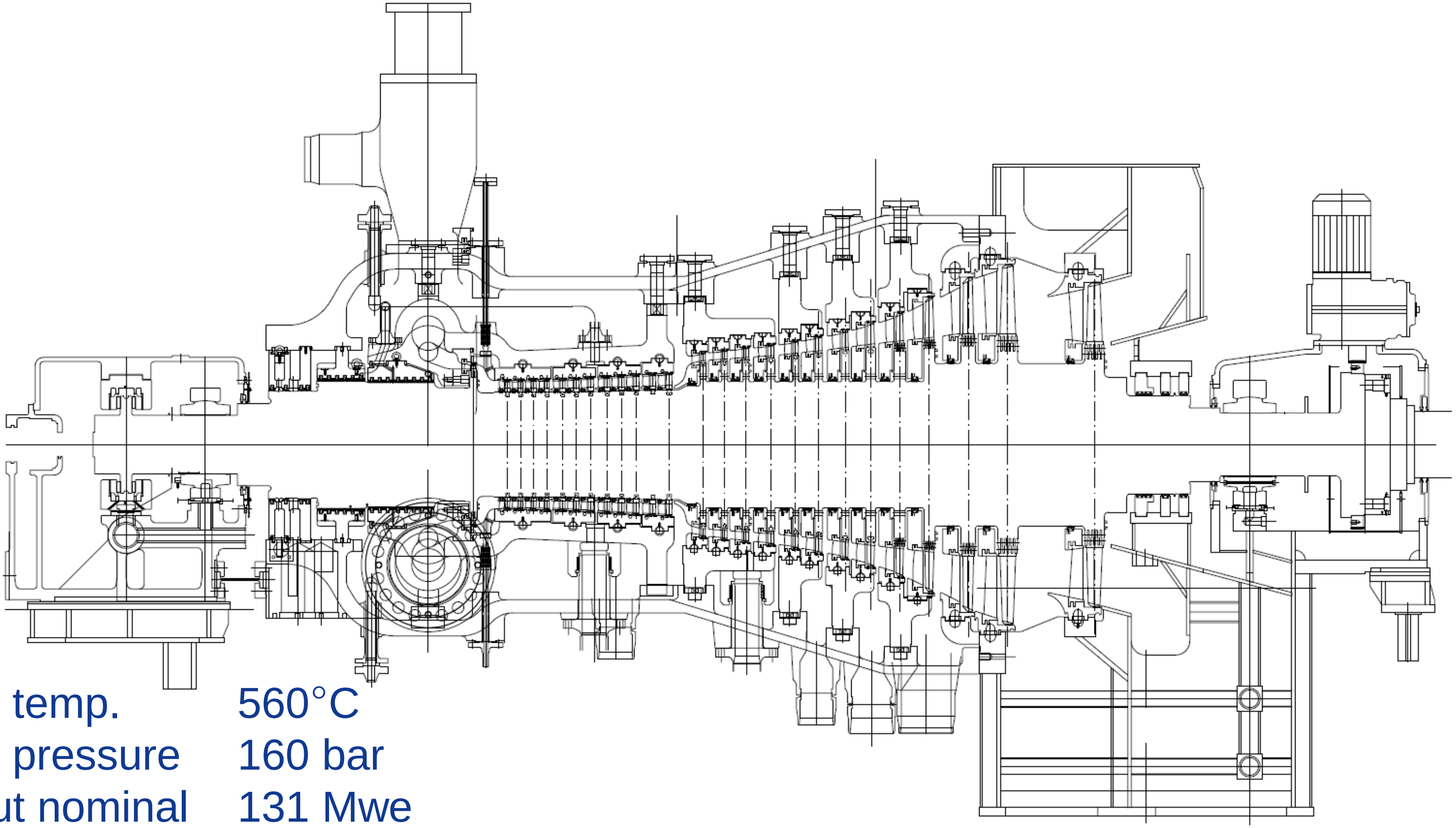
			[MWe]	[MWt]
Dunamenti	(1998)	Hungary	60	85
Plzeň	(1999)	Czech Rep.	72	90
Katowice	(2000)	Poland	120	210
Tornio	(2008)	Finland	41	68
Bucuresti	(2009)	Romania	60	157
Riga	(2009)	Latvia	150	250
Tušimice	(2009)	Czech Rep.	200	80
Tereshkovo	(2011)	Russia	75	170
Kojuhovo	(2011)	Russia	75	170
Sredneuralskaya	(2011)	Russia	140	240
Kuopio	(2012)	Finland	46	84
Lund	(2014)	Sweden	39	73
Vaxjo	(2015)	Sweden	39	65

Delivery Approach for Condensing Extraction Turbine Island



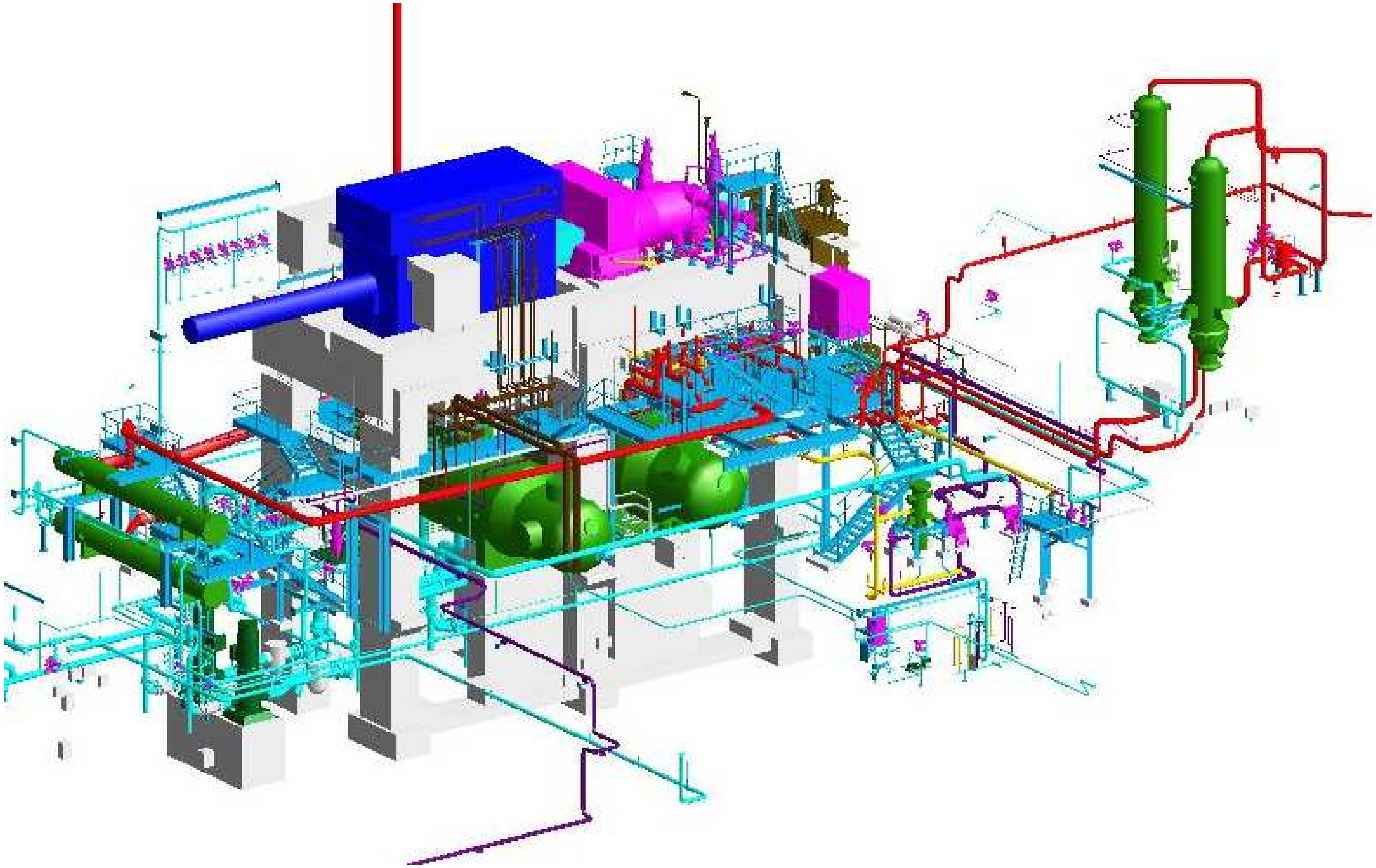
- Parameterized semi-automatic flow path generation by in-house SW
- Standardized STG sections (inlet chamber, valves, LP exhaust hood&blades, bearings, glands, oil system, HPH system, servo drives)
- Customized steam extraction sections
- Pre-designed P&ID of STG and auxiliaries
- Skid mounted gland steam system, VSC, vacuum pump
- In house designed HPHs, LPHs. DHs
- Minimized requirements for STG foundation and machine hall structures
- Localization of civil and structural design based on in-house basic design

Biomass fired CHP KVV8 Vartan - Skoda MTD40 STG Cross Section



HP Inlet steam temp.	560°C
HP Inlet steam pressure	160 bar
Electrical output nominal	131 Mwe
Electrical output max.	151 MW
Thermal output max.	332.6 MWt
DH in/out temp.	81/59 °C

Biomass fired CHP KVV8 Vartan STG Island



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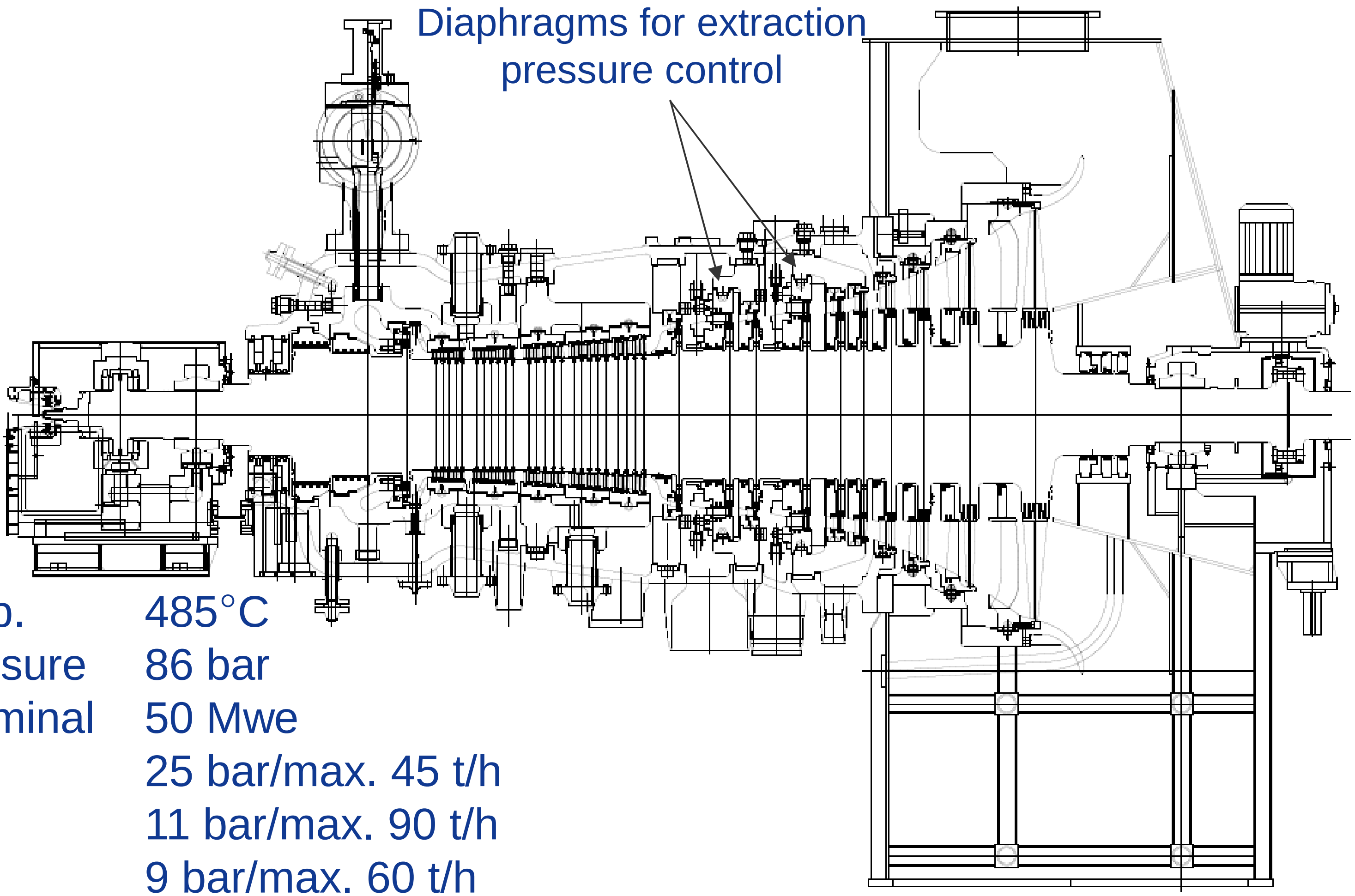
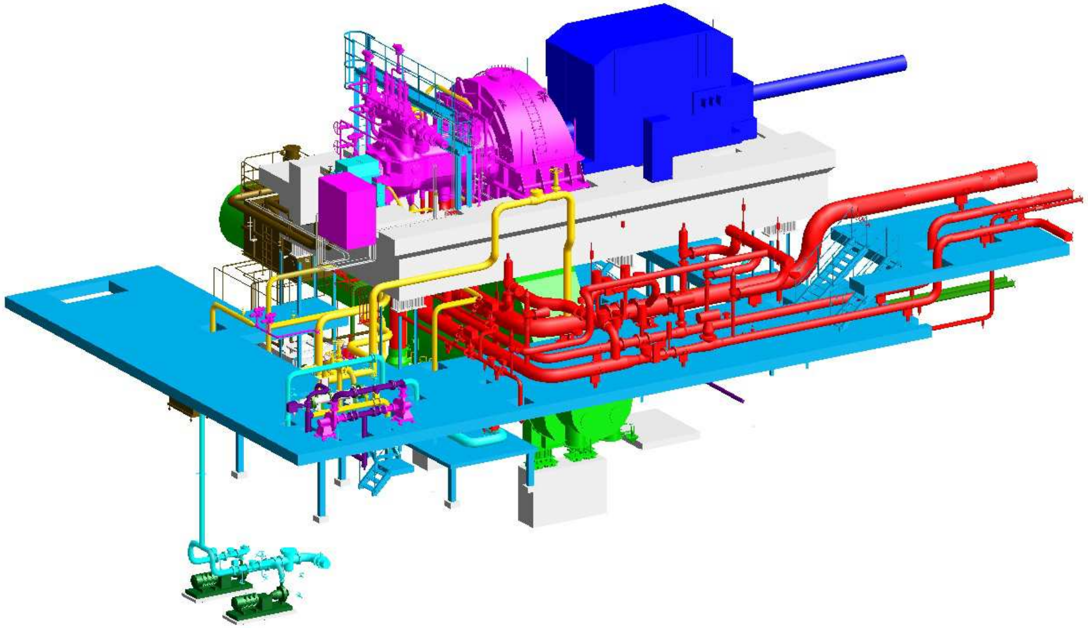
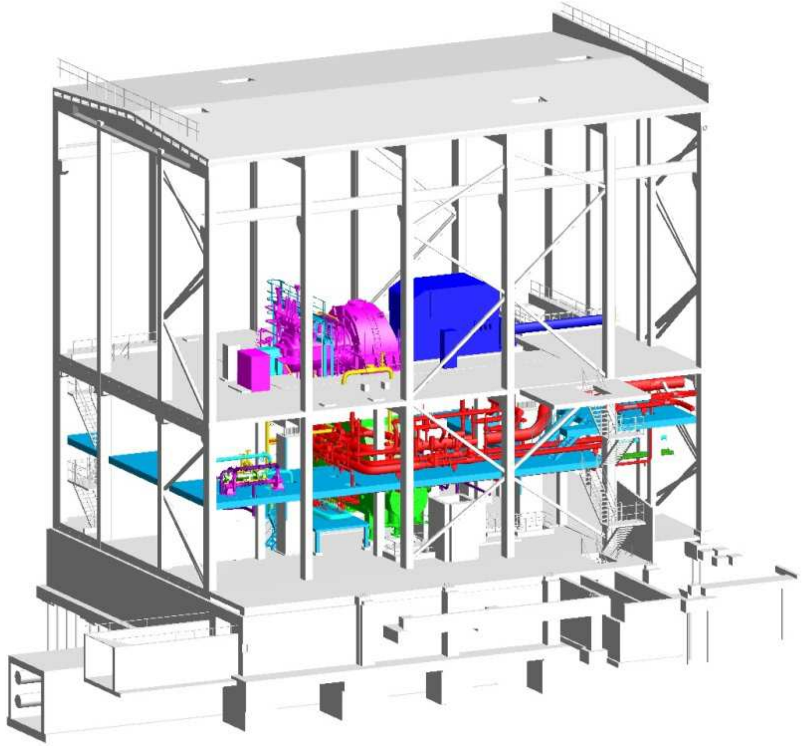
Värö turbine 31 – Skoda MTD40 STG Cross Section



HP Inlet steam temp.	485°C
HP Inlet steam pressure	86 bar
Electrical output nominal	50 Mwe
Bleed 1	25 bar/max. 45 t/h
Bleed 2	11 bar/max. 90 t/h
Control extraction 1	9 bar/max. 60 t/h
Control extraction 2	4,2 bar/ max. 145 t/h
Cooling water temp.	10-23°C normal range

Värö Turbine 31 - STG Island & Machine Hall





Skoda MTD60CE design - CHP STG RIGA 150 MW

CONDENSING EXTRACTION STEAM TURBINE WITH REHEAT

– HP steam inlet pressure	140 bar
– HP steam inlet temperature	545°C
– Thermal output	250 MWt
– Electrical output	150 MWe

– Two casings, combined HP-IP, double flow LP, 3000 rpm

– HI-IP, LP double shell design

– District heating in two stages from LP

  »Controlled extraction to DH1

  »Uncontrolled extraction to DH2

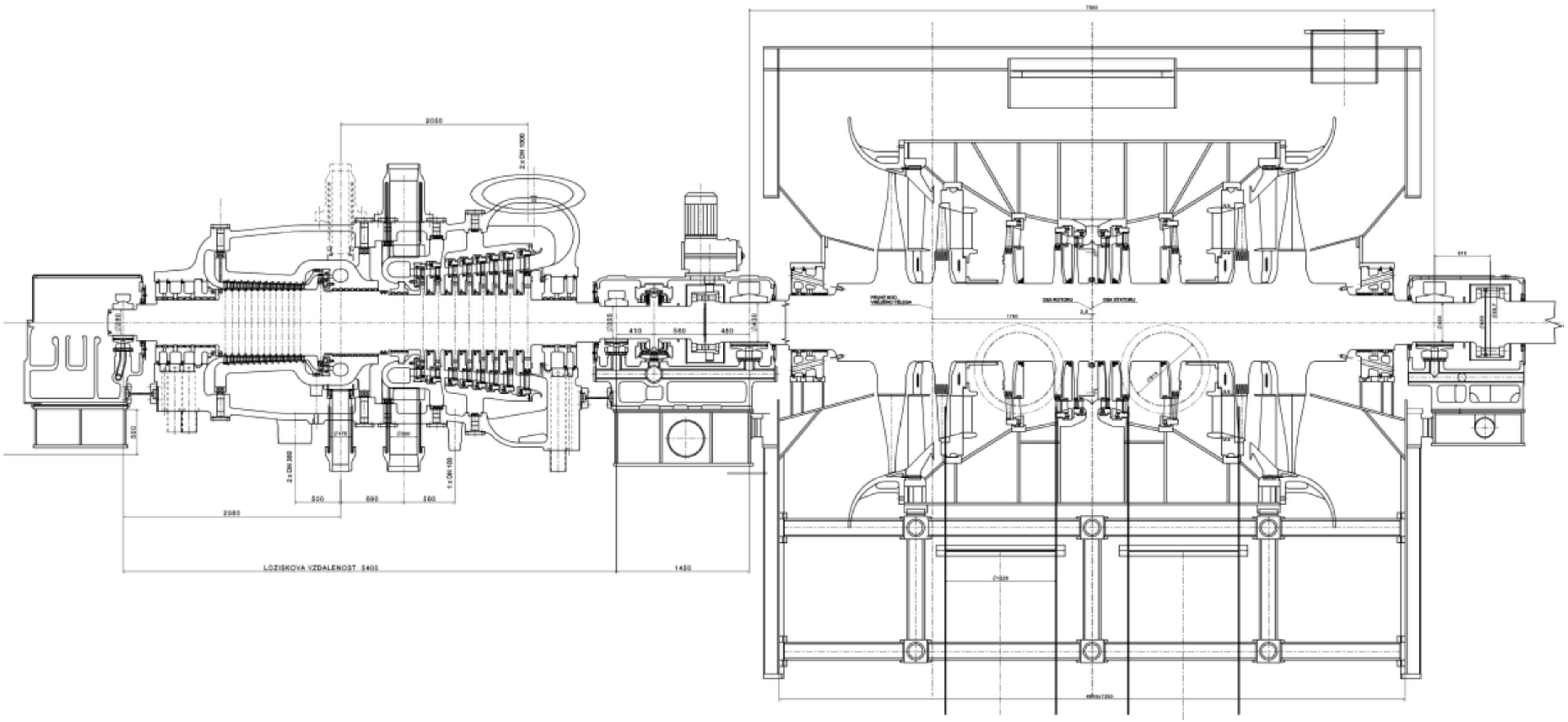
– Downward exhaust to main condenser

– Spring supported condenser, expansion joint is not applied

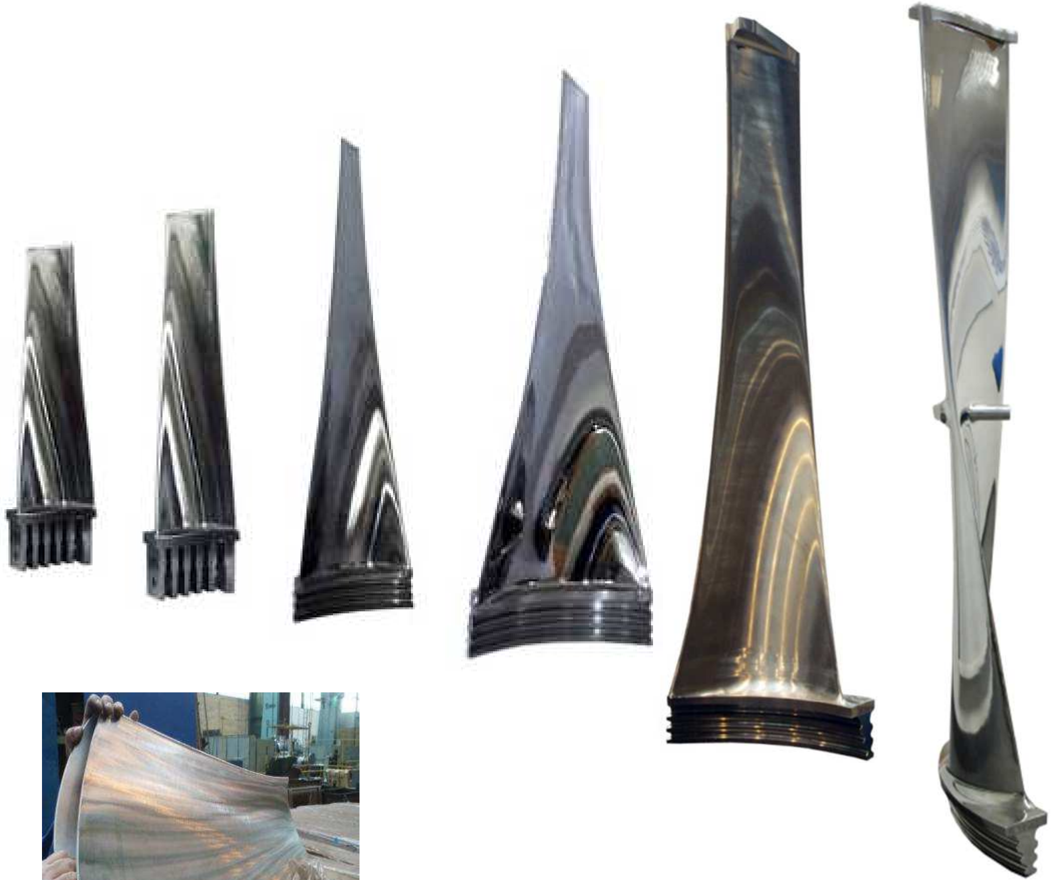
– Rigid connection to generator rotor

– Main oil pump turbine rotor driven

CCPP RIGA 150 MW Cross Section



LSBs for Skoda Doosan Steam Turbines



Robust LSB design

Free standing solution up to 33,5“

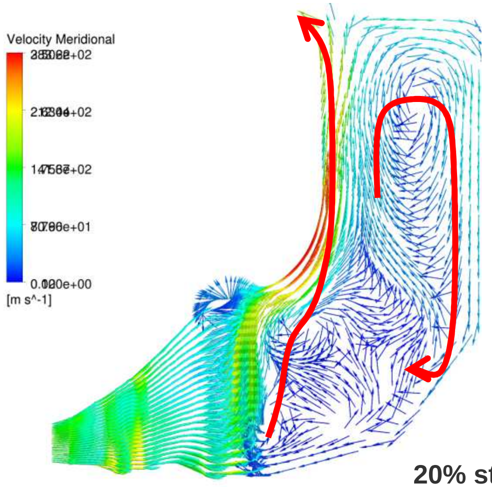
LSBs in broad range of field aplications

Hardened inlet edge (erosion resistant), material BÖHLER T552

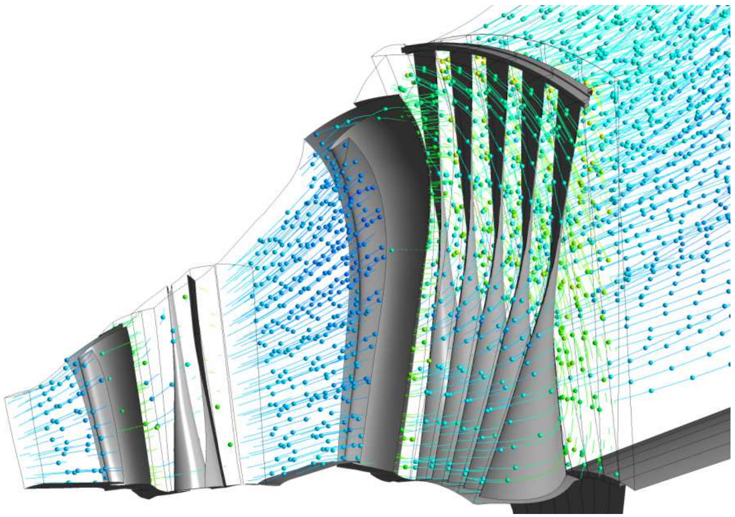
Integrally shrouded LSBs for LSB 43“, 48“, material BÖHLER T671 or similar, ultra-hard laser cladding possible

Hollow blades for high erosion loading applied on L-0 and L-1

L-0, L-1 Blade Reliability Aspects



20% steam load



Ensuring Robust design of LP blades

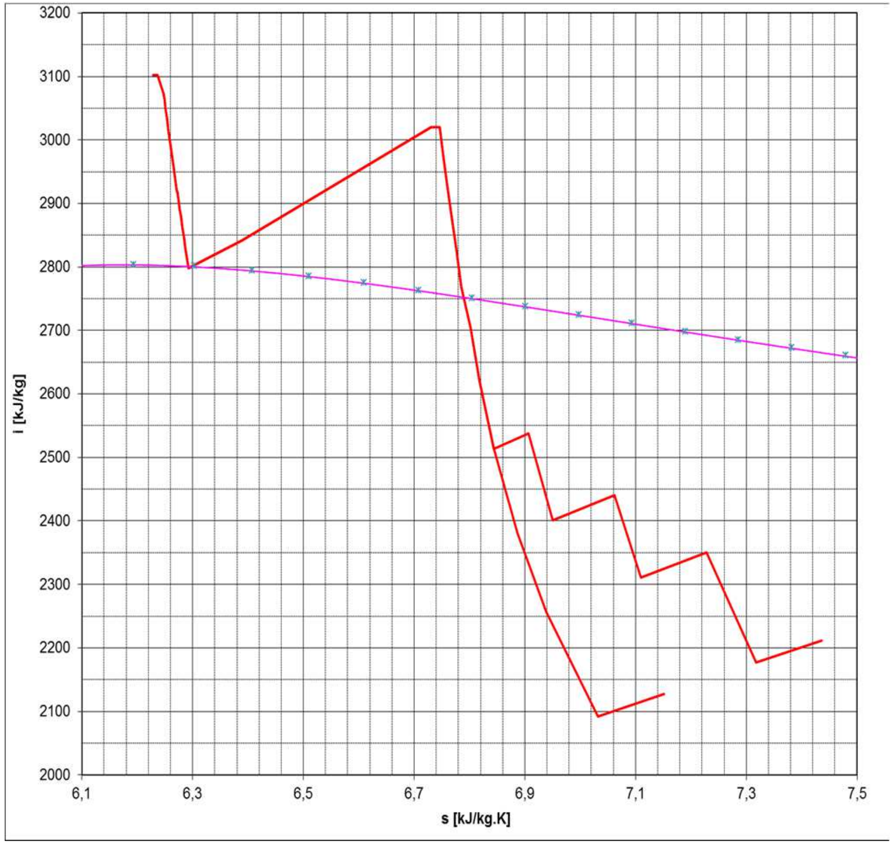
Erosion loading

- Through flow or CFD calculations for nominal and partial load operations
- Evaluation of erosion loading/damage based on material erosion database
- Sizing and position of spray nozzles for island- or house-load operation

Dynamic loading

- Unsteady CFD for partial load operations – aero-loading forced response
- Dynamic response and damping of blade row measured in vacuum chamber using magnetic non-harmonic excitation
- On site monitoring of vibrations in low load operation by tip-timing technique – creating LSB back-pressure/mass-flow application diagram

Aspects Influencing Safe Operation in Wet Steam Region



In some incineration/biomass plants need LP stages to resist high levels of wetness due to relatively low inlet temperatures and low CW temperature.

Example of expansion line of incineration plant steam turbine into wet steam region

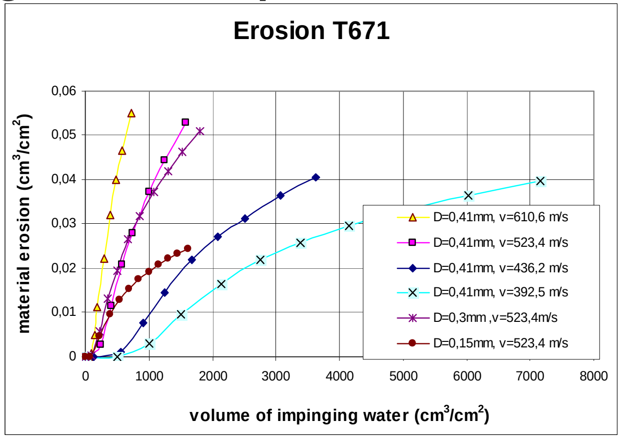
- Moisture separation & live-steam reheater used to reduce wetness at IP stage entry
- Further moisture separation n last 3 stages
- ELEP at levels ca. 18% steam wetness
- Actual operation of LSB up to 15% of wetness represents typical limit for LSBs
- Detailed evaluation of erosion number required

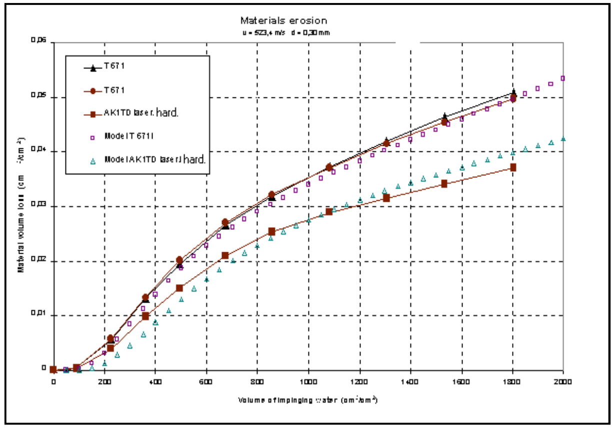
In-House Erosion Testing Database

View of upper section of erosion test rig

Erosion sample

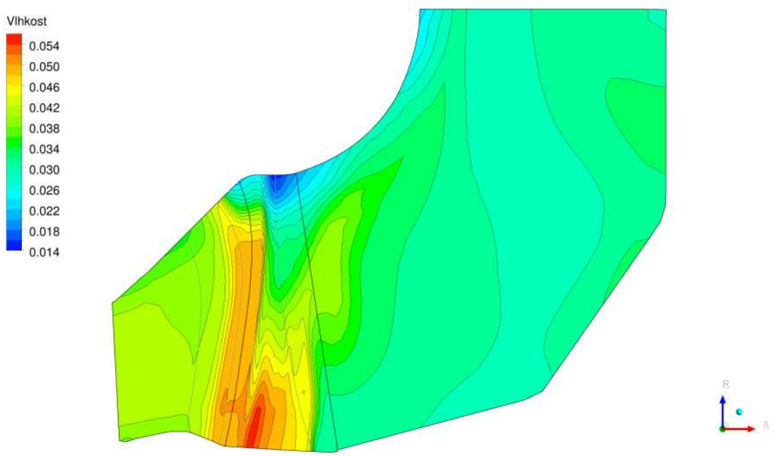
Measurement of erosion rates for various categories of droplet sizes



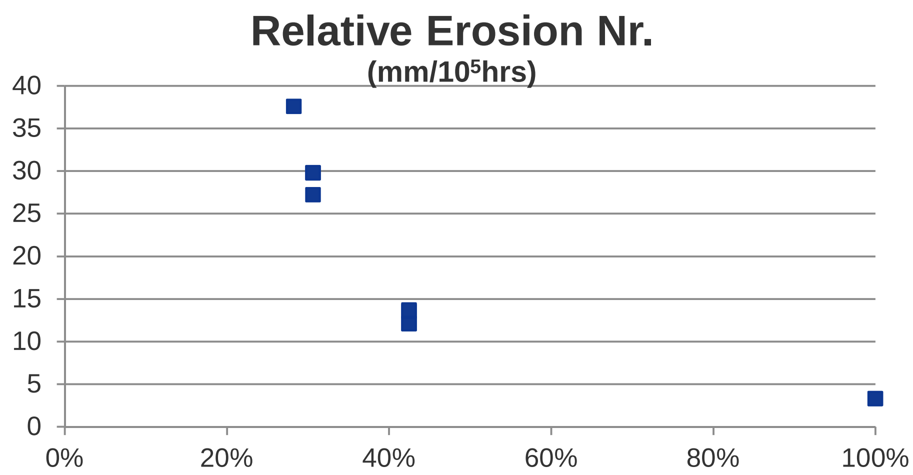


Benchmarking integral erosion models w. tests

Aspects Influencing Safe Operation in Extraction Turbines



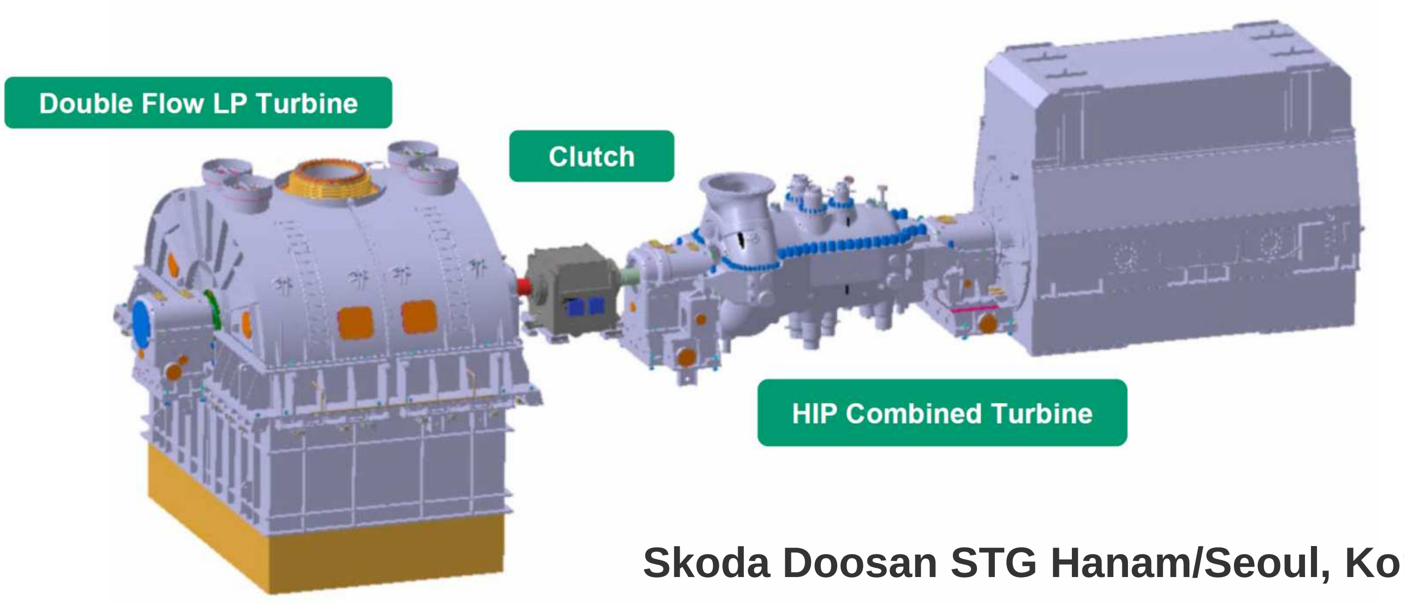
Wetness distribution at 20% steam load



- Dense test-ring and field erosion damage database for nominal operating points of LSBs
- LSB Erosion loading rapidly increases w. decreasing of steam flow/power output
  - lower steam flow reduces back pressure in condenser
  - this leads to further increase of relative wetness
  - lower steam velocities in guide vanes - size of separated droplets increases
  - larger droplets have lower acceleration in steam flow
  - relative impingement velocity of the droplets to LSB increases
- Part-load and low load operation of LP section increasingly required by energy market, grid regulators or process requirements – need to evaluate combined lifetime

Summary

- Nominal operation of last stage blades well described from dynamic and erosion aspects
- Need for Improving methods for unsteady loading of long blades in very-low flow LP stage loading
  - unsteady blade aero-dynamics
  - erosion damage evaluation using CFD based methods
- Application of erosion protection by novel methods
- New STG arrangements – detachable LP sections



Skoda Doosan STG Hanam/Seoul, Korea

Thank you for the attention!