DAQUA – Development of a measuring method for the determination of steam quality in power systems

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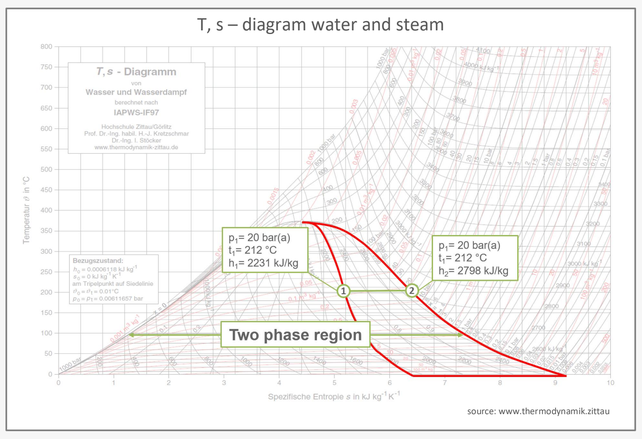
motivation

Determination of the steam quality for optimization and increased efficiency of:

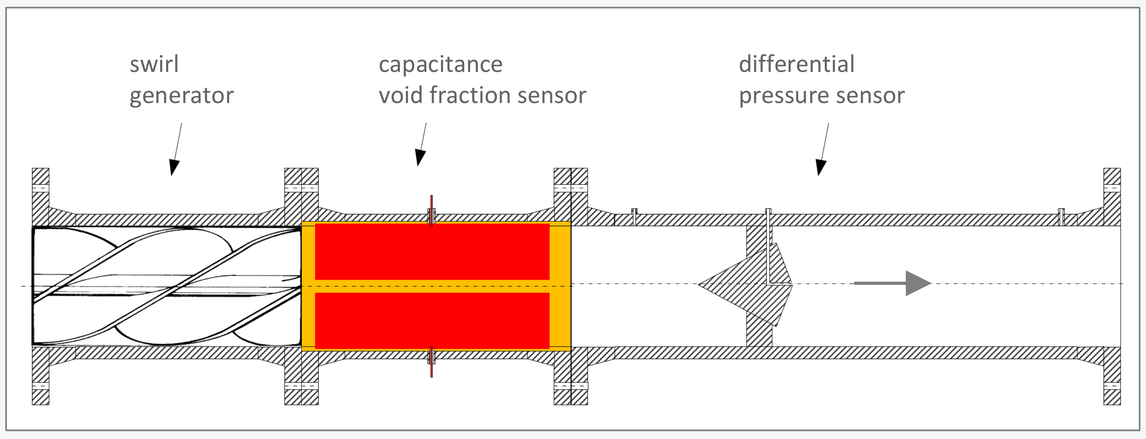
- heat pumps
- heat engines
- heat exchangers (condenser, evaporator)
- economic piping systems
- PTES - pumped thermal energy storages (Carnot batteries)

T, s – diagram water and steam



source: www.thermodynamik.zittau

modular draft of hybrid sensor



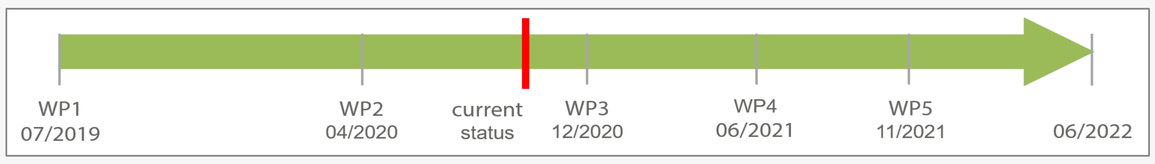
content and work plan

goals:

- development of a hybrid measuring method for the determination of the vapor/liquid content (steam quality), the flow rate and the entahlpy of two-phase steam flows
- combination of electrical, thermo- and fluid dynamic measuring principles
- graduation and transfer of knowlege into teaching

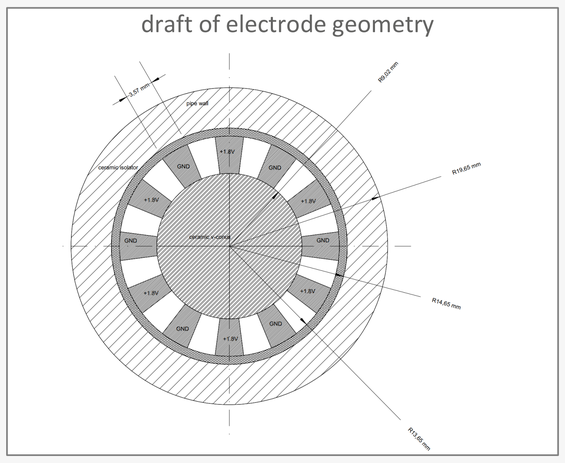
work plan:

WP1: development of a test rig for experimental investigation an validation
WP2: development of a hybrid measurement solution
WP3: CFD simulations
WP4: preparation of dynamic balances
WP5: design prototype an validation

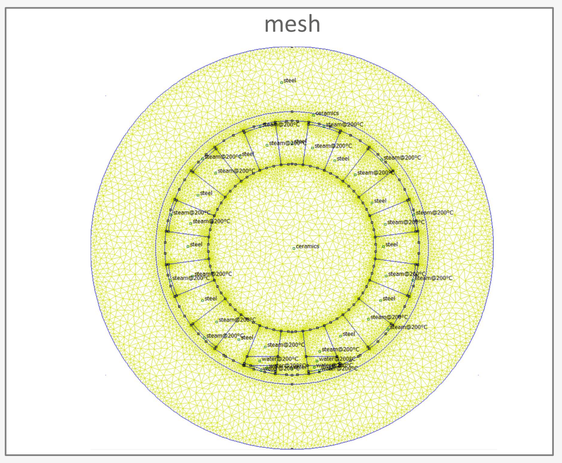


first electrostatic simulation of electrode geometry

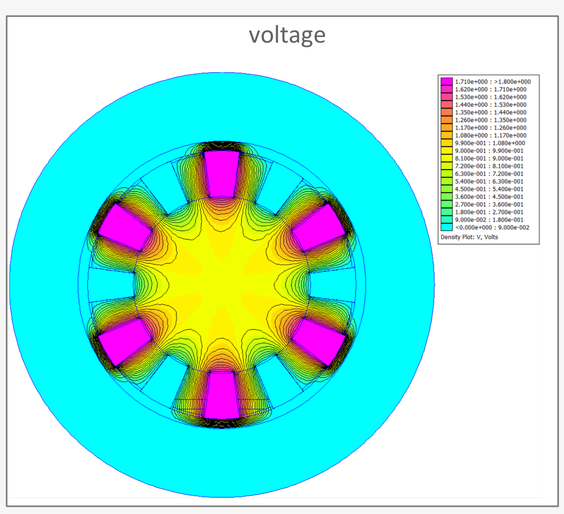
draft of electrode geometry



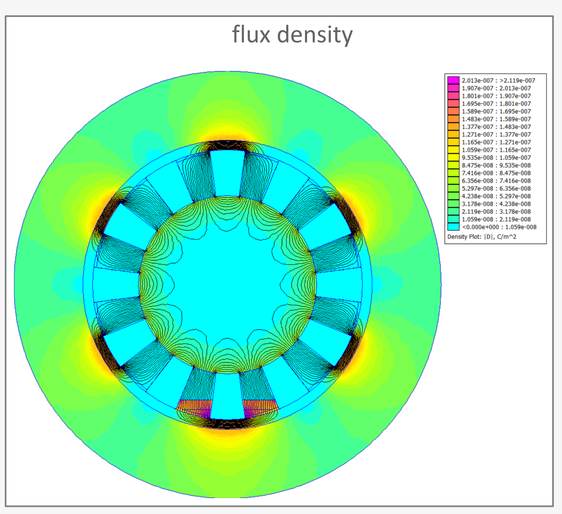
mesh



voltage



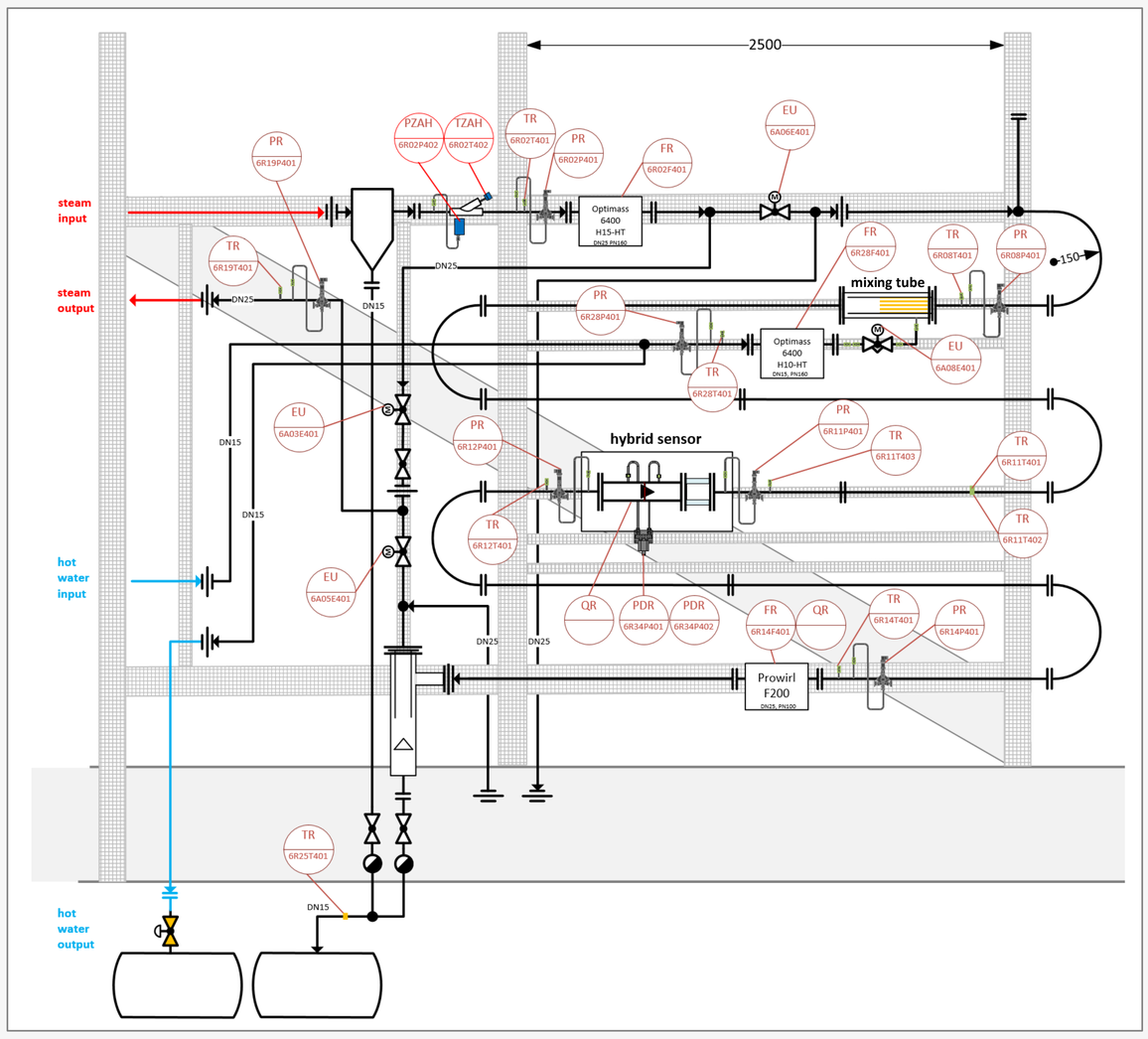
flux density



state of the art – high pressure wet gas flow measurement

- currently **no industrial and commercial measurement system is available** for the combined direct measurement of phase fractions and phase velocities for wet steam
- **cross correlation methods** for combined phase fraction and velocity determination have been **developed**
- wet gas differential pressure measuring instruments with measurement of the phase fraction are available, but with high measurement uncertainties
- the **systematic overestimation** of the volume flow rate in differential pressure-based measuring instruments can be **corrected by** using **compensation methods** (e.g. Venturi tube k-factor)
- methods for measuring the phase fractions with **electrical measurement principles are available** (capacitance, impedance, microwave and gamma ray attenuation)
- tomographic, acoustic and high frequency electromagnetic methods are the subject of research

developed wet steam test facility



flow pattern in horizontal high pressure pipes

parameters test facility:

- mass flow rate: 360 kg/h
- pipe diameter: 26.5 mm (DN25)
- steam flow content: x > 0.7
- inclination angel: 1 °

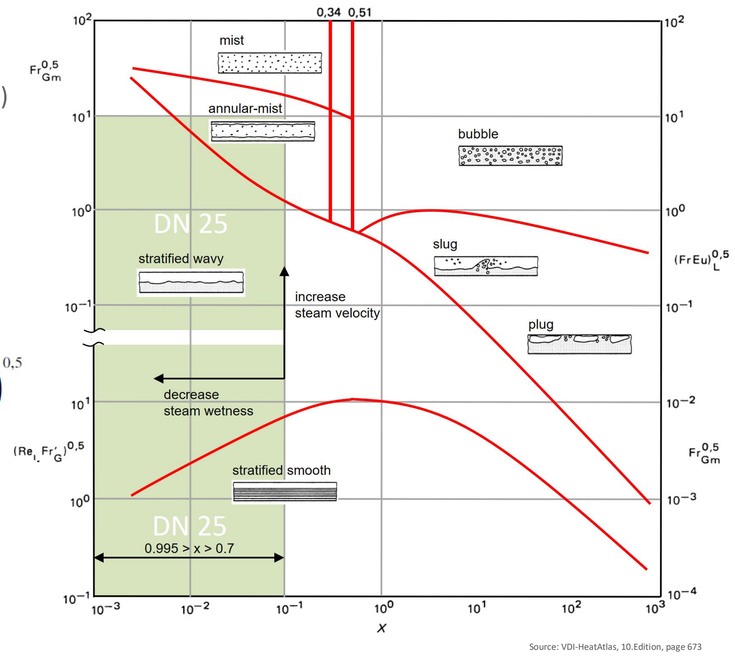
modified Froude-numbers:

$$Fr_{Gm}^{0,5} = \left(\frac{\dot{m}^2\, \dot{x}^2}{g\, d\, \rho_L\, \rho_G} \right)^{0,5}$$

$$(Re_L\, Fr'_G)^{0,5} = \left(\frac{\dot{m}^3\, \dot{x}^2\, (1-\dot{x})}{\rho_G\, (\rho_L - \rho_G)\, \eta_L\, g\, \cos\, \Theta} \right)^{0,5}$$

Lockhard-Martinelli parameter:

$$X = \left(\frac{1-\dot{x}}{\dot{x}} \right)^{0,875} \left(\frac{\rho_G}{\rho_L} \right)^{0,5} \left(\frac{\eta_L}{\eta_G} \right)^{0,125}$$



Source: VDI-HeatAtlas, 10.Edition, page 673

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