technische universität dortmund

Fakultät Bio- und Chemieingenieurwesen

Lehrstuhl für Anlagen- und Prozesstechnik

Lehrstuhl für Chemische Verfahrenstechnik

Nitinol Bolide

Werkstätten des bci

ingpuls Innovationsdienstleistungen

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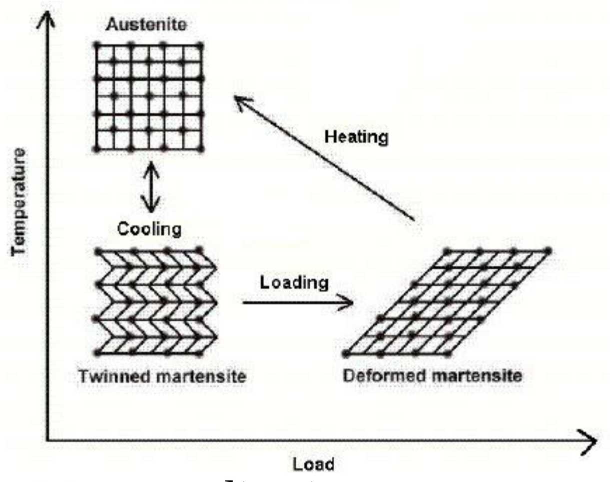
Motivation

Introduction

- Nitinol is a Nickel-Titanium-Alloy (55% Ni, 45% Ti)
- As a memory alloy it belongs to the smart materials
  - First developed in 1958
  - Biocompatible
  - Noncorrosive
  - Flexible



- twinned martensite structure for T < Mf
- Martensite structure gets deformed/detwinned
- transformation to austenite structure caused by heating

[1]

- Many applications
  - Medicine (flexible instruments or implants)
  - Aerospace (thermal couplings)

Nitinol as Spring

- Made from nitinol wire
  - Different diameters
  - Endless number of turns possible
    - → High actuator stresses and strokes
- Springs can pull or push, depending on working principle
- Resulting force depends on diameter, number of turns and start temperature

Left spring:
- Memory shape of the spring
- Spring changes to memory form once heated up to 85°C

Right spring:
- Deformed spring
- Energy is stored in spring
- Energy is released if the spring reaches the start-temperature

Innovative Power Unit

- Every heat producing source can be used
  - Use of sources without any dangerous emissions (no greenhouse gases)
  - No fossil fuel needed
  - Re-usable
- Highly flexible smart material
  - Two-shape-memory forms are possible
  - Change of memory shape possible
  - High volume specific force
  - Small constructions possible
- Many different initiators
  - Heat, electricity, magnetic field
  - Wide range of start-temperature
- Low pressure and temperature compared to combustion engine

Energy Source

Chemical Reaction

- Catalytic decomposition of hydrogen peroxid to water and oxygen

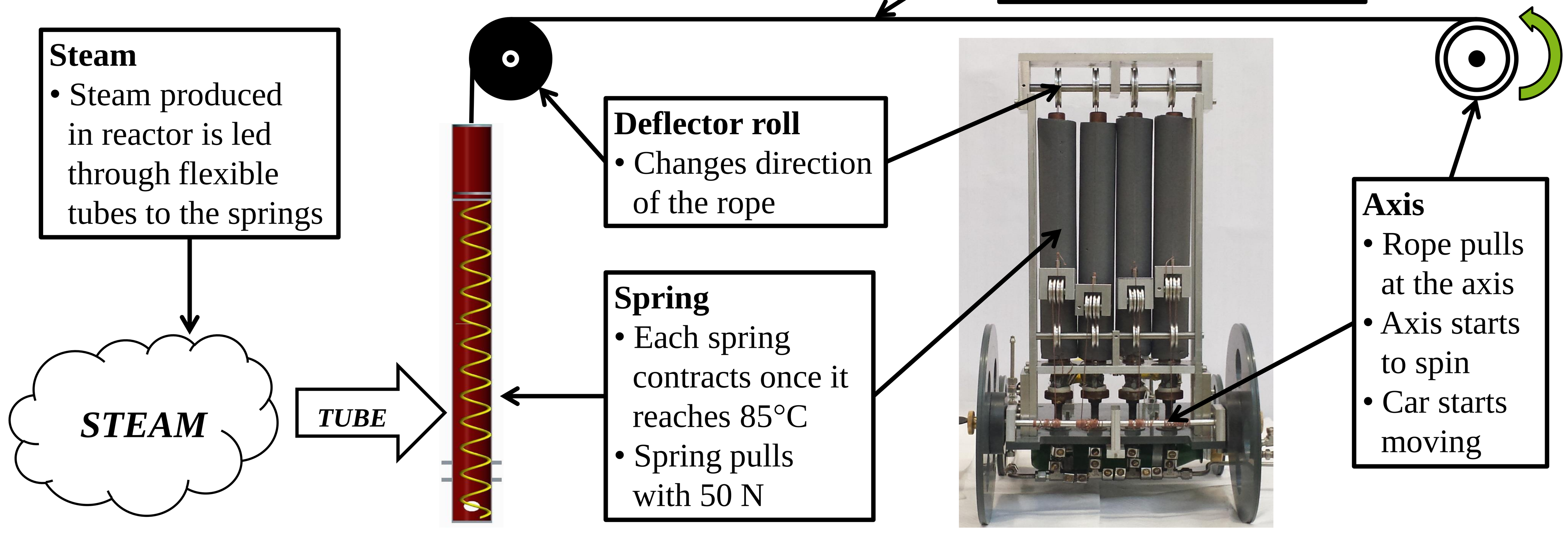
$$2\,H_2O_2 \xrightarrow{Cat.} 2\,H_2O + O_2\,;\quad \Delta h^R = -98\ \text{kJ/mol}$$

- Catalyst: $Fe(NO_3)_3$
- Catalytic concentration: 20 g $Fe(NO_3)_3$ /100 ml H_2O
- Reaction starts immediately
- Exothermal reaction
  - Emerging water heats up and evaporates
  - Maximum temperature of 100°C due to phase change
- Steam production stops immediately if no hydrogen peroxid is added
- No side products are formed
- Used chemicals are not harmful to the environment

→ **Reaction is easy to control and reproducible**

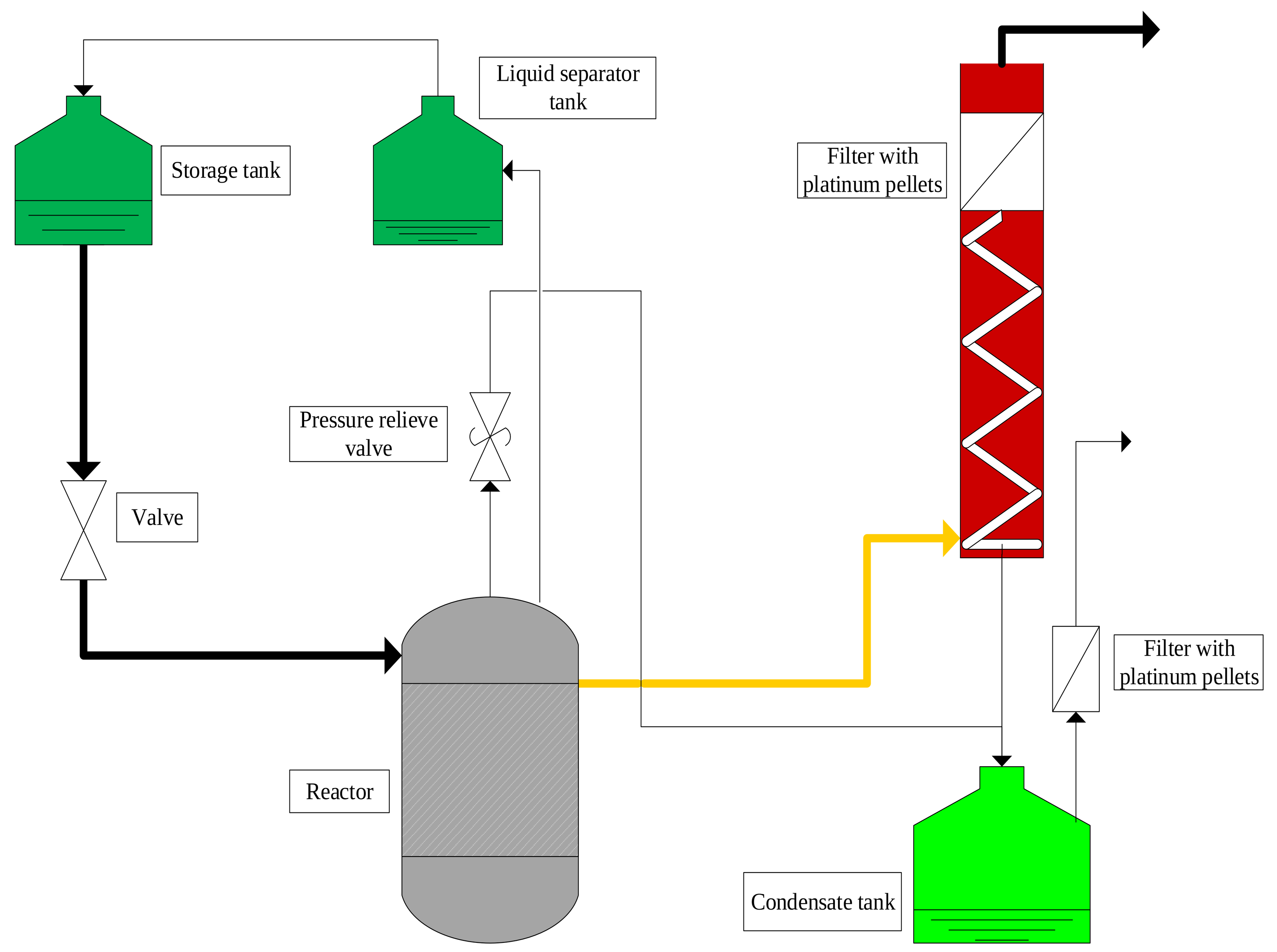
Transformation to Mechanical Energy

- Direct transformation from heat to mechanical energy
- Decoupled from the reaction room by using steam
- Four springs parallel connected



Car Design

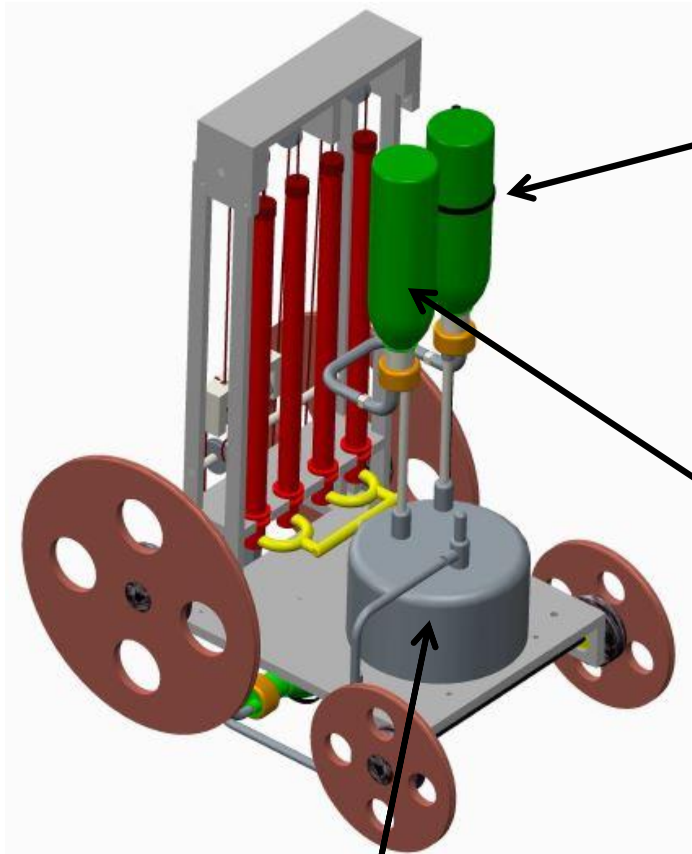
Process Flowsheet



Specifications

Weight [kg]	14,9
Size h x w x d [mm]	660 x 680 x 440
Operating pressure [bar]	1 – 1,5
Operating temperature [°C]	100

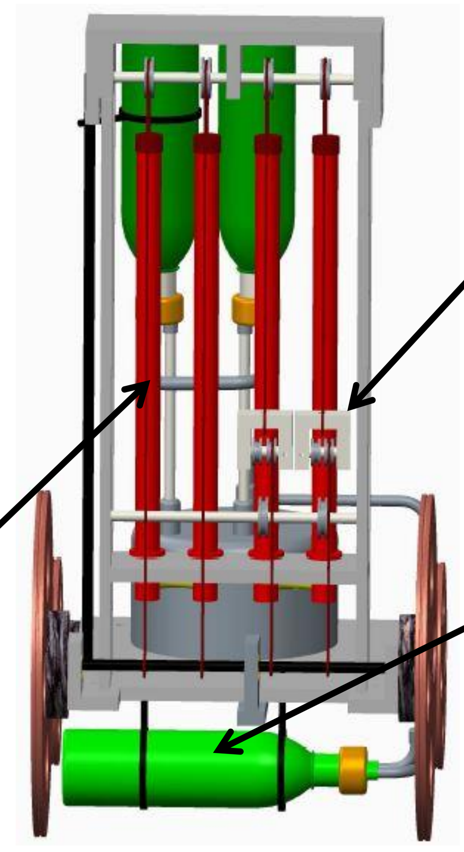
Construction



Storage tank
- Hydrogen peroxide
- Steady flow

Liquid separator tank
- Avoids catalytic solution in the storage tank
- Pressure equalization between storage tank and reactor

Reactor
- Steel reactor
- Completely isolated
- Catalytic solution



Chain-blocks
- Two rolls to quadruplicate the distance

Copper pipes
- Nitinol springs inside
- High steam concentration

Condensate tank
- Collects condensation water
- Connected to the pressure relieve valve

Safety

Preventing the Release of H_2O_2

- Hydrogen peroxide can be dragged into the copper pipes
- Platinum is an excellent catalyst for the decomposition of H_2O_2
- Filter packed with platinum pellets eliminate remaining traces of H_2O_2
  - → Only $H_2O(g)$ and O_2 are released
  - → No H_2O_2 remains in the system

Pressure and Temperature

- Pressure relieve valve limits the system pressure to 2,5 bar absolute
- Pressure relieve valve is connected to the Condensate tank to prevent splashing
- Reactor, tubes and pipes are isolated

Chemicals

- While handling the chemicals the following safety equipment has to be worn:
  - Nitrile gloves
  - Lab coat
  - Protective glasses

References

[1] Werkstoffkunde II Skript, Lehrstuhl für Biomaterialien und Polymerwissenschaften, TU Dortmund, **2014**