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Schrumpfschlumpf

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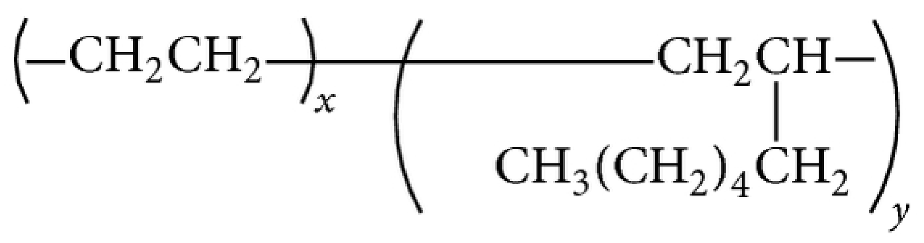
MOTIVATION

This years TU Dortmund's ChemCar concept makes use of the **SHAPE MEMORY EFFECT (SME)** of polymers. The SME of polymers is a research topic at the laboratory of biomaterials and polymer science at the department of biochemical and chemical engineering. Shape memory polymers, as the used ethylene-1-octene copolymer (EOC), change their dimensions as a reaction to a change in temperature or other impulses. The used EOC changes its dimension when exposed to elevated temperatures, the mechanical energy will be used to move the ChemCar. By heating up the polymer to a specific temperature range the elastically stretched polymer stripe triggers back to its initial shape. The heat is supplied by the **OXIDATION OF SODIUM THIOSULFATE**. The reaction generates steam which heats up the polymer, thereby causing the SME to shrink which leads to movement of the ChemCar. The amount of reactants determines the heat generation.



structural formula of ethylene-1-octene copolymer [1]

CONCEPT

① EXOTHERMIC REACTION

To provide sufficient energy for steam production an exothermic reaction is used. In this reaction sodium thiosulfate is oxidized by the oxidizing agent hydrogen peroxide in the following reaction scheme:

$$S_2O_3^{2-} + 4\,H_2O_2 \rightarrow 2\,SO_4^{2-} + 3\,H_2O + 2H^+ + \Delta H_R$$

$$\Delta H_R = -586.2\ kJ/mol$$ [2]

To prevent the formation of sulfur and sulfur dioxide in an acidic environment tri-potassium phosphate is added to the reaction to capture the formed protons.

$$S_2O_3^{2-} + 2H^+ \rightarrow S + SO_2 + H_2O$$

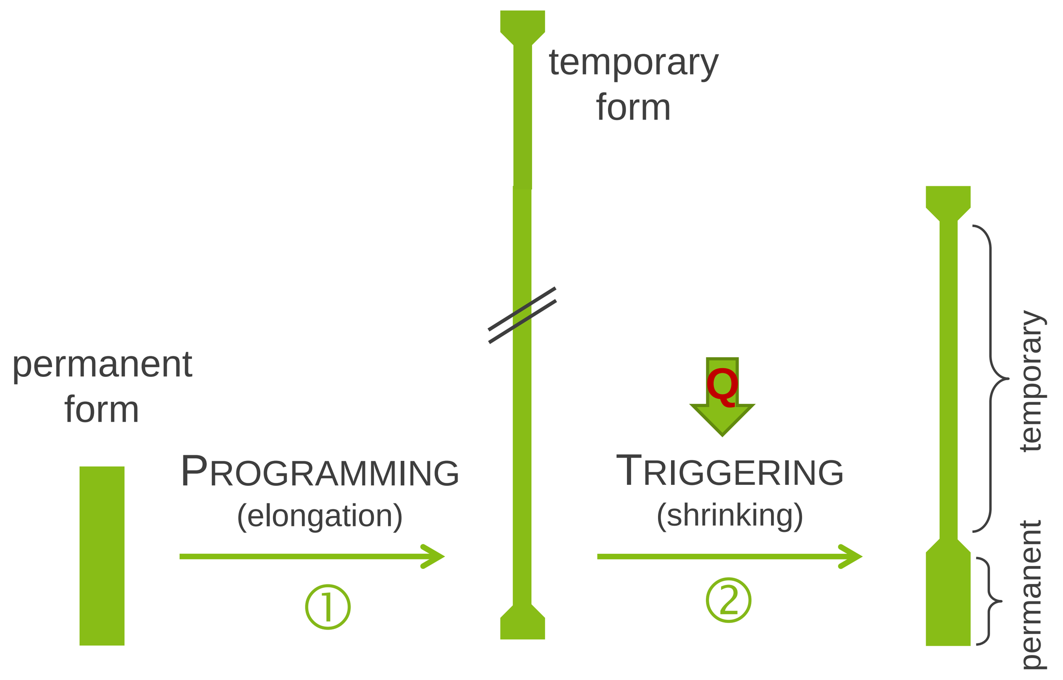
A defined solution of sodium thiosulfate and tris-potassium phosphate is stirred in the reaction tank. On startup a set amount of oxidizer immediately enters the tank to fasten the temperature increase to the operating temperature of 100 °C.

More oxidizer is then added at a constant flow rate to maintain the reaction for the desired time, thereby determining the driving distance.

② POLYMER

SHAPE MEMORY EFFECT

The SME of Polymers is based on the prevention of their recovery from the stretched state caused by their characteristic mechanical behavior of rubber elasticity. The SME can be divided in two steps:



① **PROGRAMMING PHASE:** The polymer is transferred from an initial (permanent) shape into a transition shape storing the applied energy.

② **TRIGGERING PHASE:** This describes the recovery back to the permanent shape, which also releases the stored energy.

PREPARATION

The polymer (EOC*) is prepared with the crosslinking reagent dicumylperoxide (0.6 phr). The specific trigger temperature range of EOC* lies between 40 °C and 80 °C with an increasing restoring force at higher temperatures [3].

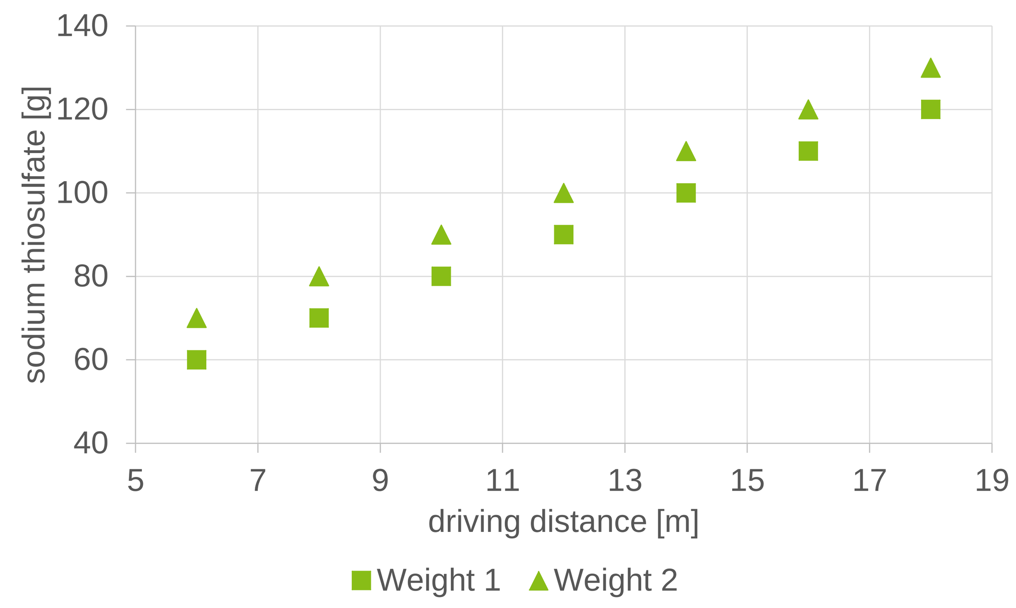
③ DRIVE

The run is initiated by opening the main valve. To deliver the starting torque a lower gear will be used for the acceleration phase. The car will shift into a higher gear automatically after a set distance.

With the termination of the reaction the steam production ends and the heat transfer to the polymer is no longer sufficient. As the temperature drops beneath the trigger-temperature the polymer stripe no longer relaxes and the ChemCar stops.

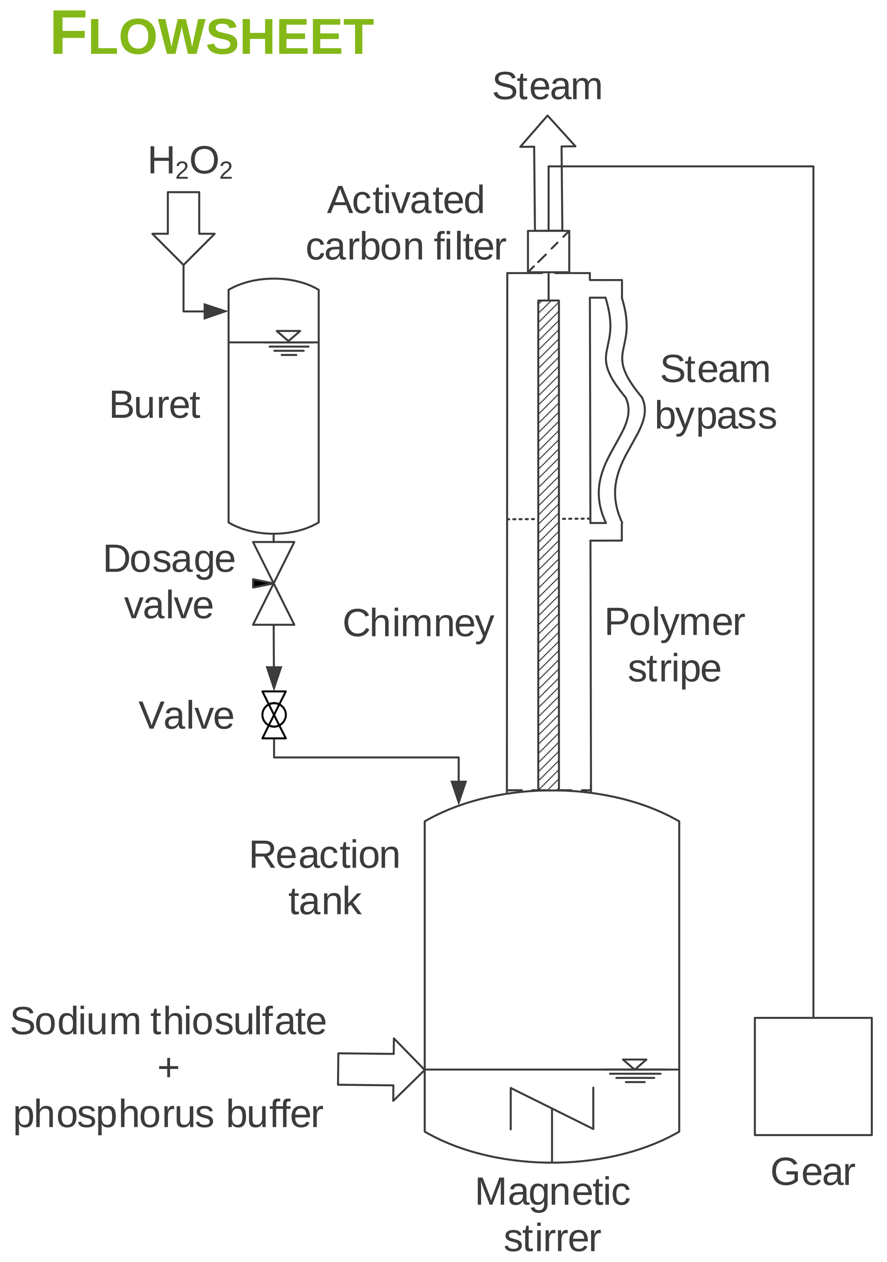
EACH POLYMER WILL BE PROGRAMMED IDENTICAL INDEPENDENT OF THE DESIRED DRIVING DISTANCE. By limiting the steam supply time the polymer will only be triggered a certain amount, allowing for shorter distances.

CALIBRATION



TECHNICAL REALIZATION

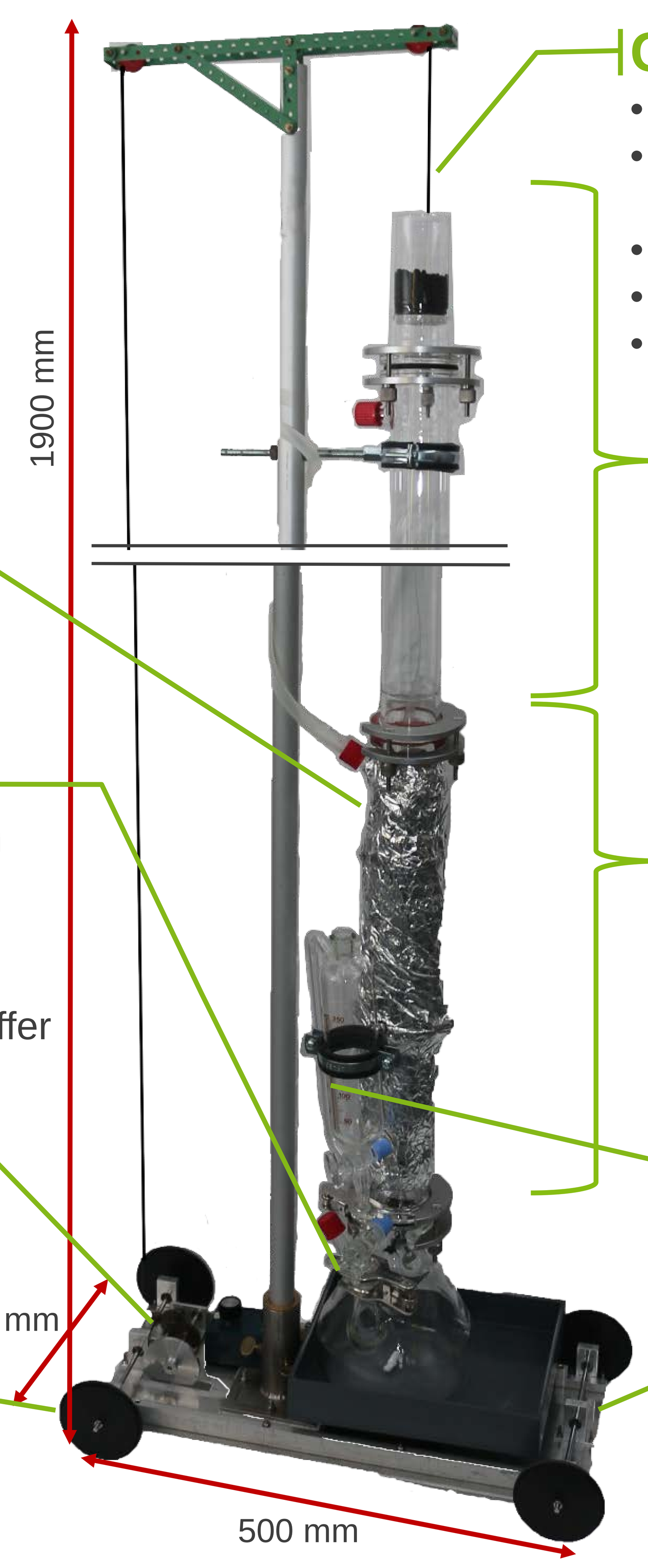
FLOWSHEET



SPECIFICATIONS

Weight [kg]	~ 8.5 kg
Dimensions [mm]	500 x 1900 x 240
Speed [m/s]	1
Range [m]	< 20
Operating pressure [bar]	1
Operating temperature [°C]	100

CONSTRUCTION



CHIMNEY

- Fixed polymer stripe
- activated carbon filter integrated
  → Preventing emissions other than steam
- Open System
- Diameter: 50 mm, Length: 1300 mm
- Material: Borosilicate glass

COLD PART

- Length: 800 mm
- A septum separates the cold from the hot part

INSULATION

- Material: Foamed polystyrene
  → Minimization of heat losses
  → Prevention of hot surfaces

REACTION TANK

- Diameter: 100 mm, Height: 230 mm
  →Volume: 1 L
- Material: Borosilicate glass
- Filled with thiosulfate solution
- System buffered with phosphate buffer

HOT PART

- Length: 500 mm
- Polymer is drawn into the hot part
  → Triggering of the polymer

GEAR

- Transmission ratio start:1:12.5
- Transmission ratio drive: 1:19

BURETTE

- Filled with hydrogen peroxide
- Material: Borosilicate glass

WHEELS

- Ball bearings
  → minimize friction
- Rubber surface
  → prevent wheelspin

BASEPLATE

- Material: Aluminium
- Collection tray around reaction tank

REFERENCES:

[1] Tesarikova, A., Merinska, D., Kalous, J., Svoboda, P. (2016), Ethylene-Octene Copolymers/Organoclay Nanocomposites: Preparation and Properties. In *Journal of Nanomaterials 2016 (8)*, pp. 1-13.

[2] Lo, S. N.; Cholette, A. (1972): Experimental study on the optimum performance of an adiabatic MT reactor. In *Can. J. Chem*. Eng 50 (1), pp. 71–80.

[3] Hoeher, R., Raidt, T., Rose, M., Katzenberg, F., Tiller, J. C. (2013), Recoverable Strain Storage Capacity of Shape Memory Polyethylen. In *J. Polym. Sci. Poly Phys* 51 (13) 1033-1040

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