

Shape Optimization in Phosphate Production using SU2

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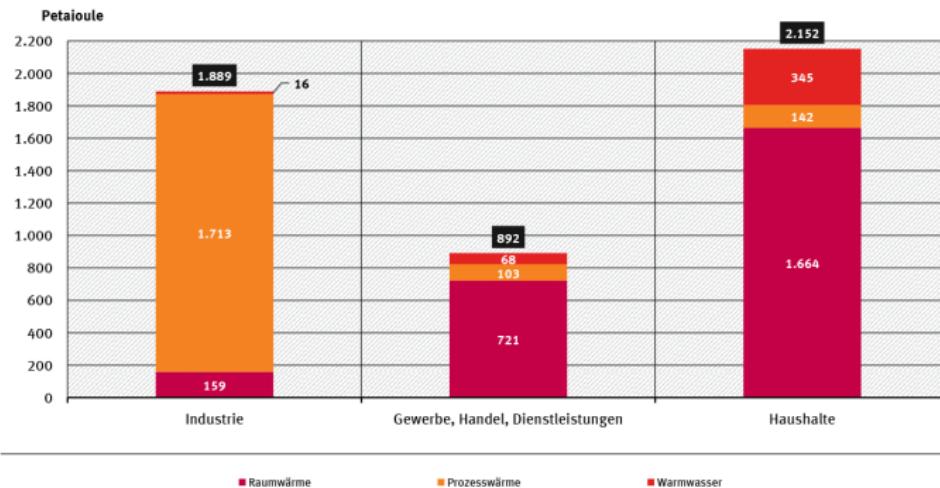
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SU2
code

Motivation

Wärmebedarf der Sektoren* nach Anwendungszwecken 2016



* Ohne Verkehr. Energieverbrauch des Verkehrs für Raumwärme 2016: 12,7 Petajoule

Quelle: Arbeitsgemeinschaft Energiebilanzen, Anwendungsbilanzen für die Endenergiesektoren in Deutschland in den Jahren 2013 bis 2016, Stand 11/2016

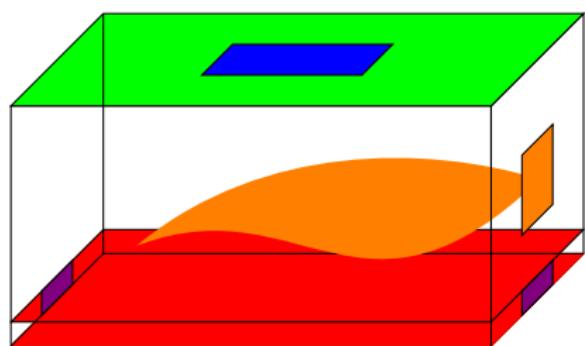
¹<https://www.umweltbundesamt.de/bild/waermebedarf-der-sektoren-nach-anwendungszwecken>

Collaborators



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The Furnace



2

chimney, ceiling, phosphoric acid or phosphate, flame,
left: inflow phosphoric acid, right: outflow phosphate

Radiative Heat Transfer Equation

The coupled system reads:

$$\forall \omega \in \mathcal{S}^2 : \omega \cdot \nabla I = \kappa(aT^4 - I)$$

$$-\nabla \cdot (k \nabla T) = - \int_{\mathcal{S}^2} \int_0^\infty \kappa(aT^4 - I(x, \omega)) d\omega$$

where we further have

- k the heat conductivity
- $T(x)$ the material temperature
- aT^4 radiation contribution via Stefan's Law (a: Stefan-Boltzm. const)

High complexity due to **5 dimensional phase space**, non-local integro-differential equation

Approximate Model

Residual form of the P1 equation, an asymptotic expansion of the RTE using Neumann-Series³,

$$\mathfrak{R}(E) = \nabla \cdot \mathbf{F}^r(E) + \kappa(E - \langle I_b \rangle) = 0$$

where the radiative flux is

$$\mathbf{F}^r(E) = \left(\frac{-1}{3(\kappa + \sigma_s)} \nabla E \right),$$

- E radiative Energy
- κ absorption coefficient
- σ_s scattering coefficient
- $\langle I_b \rangle$ first moment of black body intensity

³Larsen.

The General 2d-Setting

$$\mathbf{g} = (0, -9.81) \text{ m/s}^2$$

$$\mu = 1.0e-5 \text{ kg/(m-s)}$$

$$\kappa_{\text{th}} = 0.1 \text{ W/(m-K)}$$

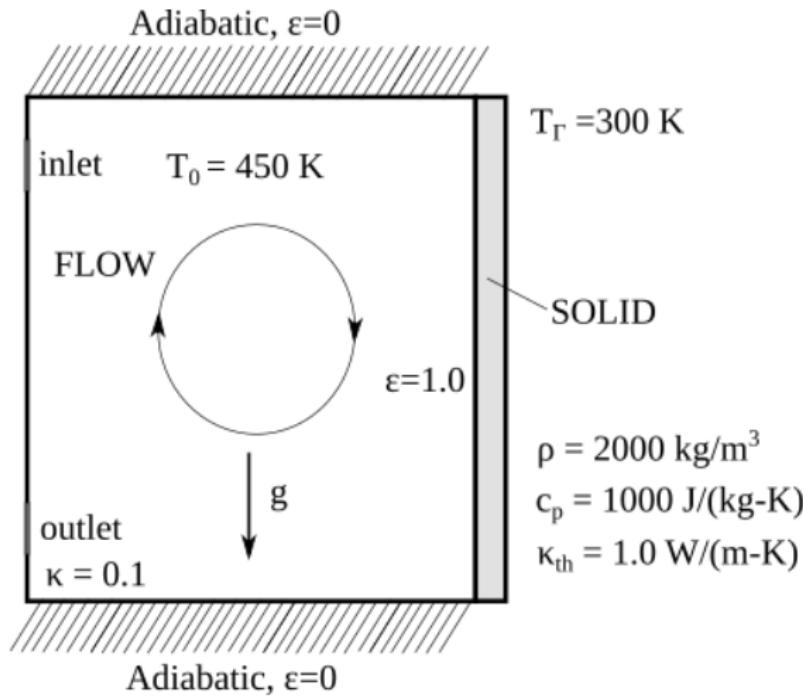
$$c_p = 1000 \text{ J/(kg-K)}$$

$$M = 30 \text{ g/mol}$$

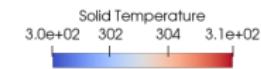
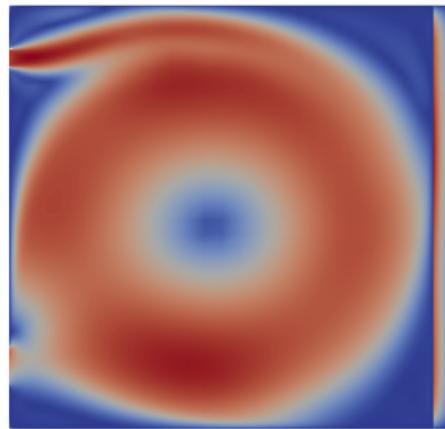
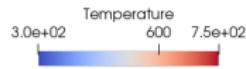
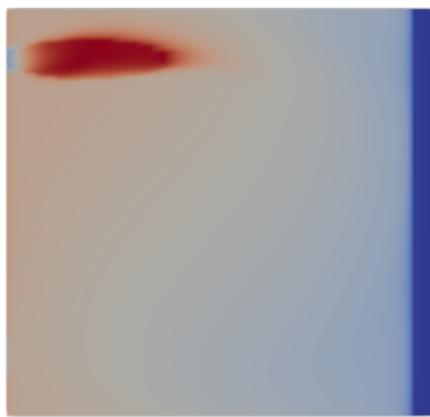
$$\rho = 0.006 \text{ kg/m}^3$$

$$T_1 = 600 \text{ K}$$

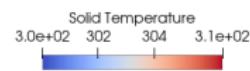
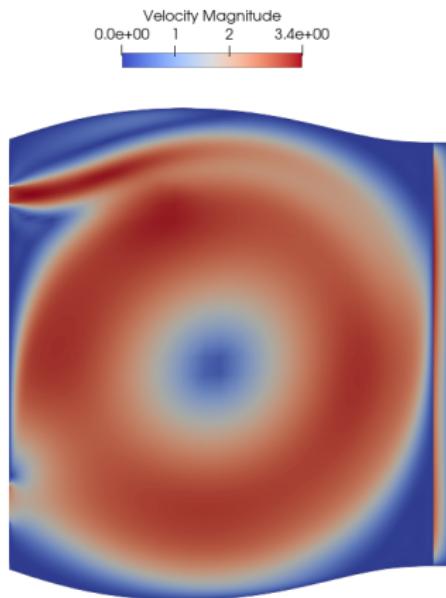
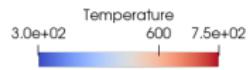
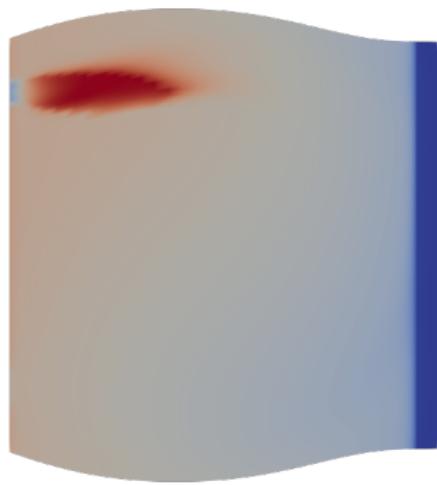
$$\epsilon = 1.0$$



Initial Geometry



Optimized Geometry



Conclusion and Outlook

- Implemented multi physics model simulates high temperature processes sufficiently well
- Shape Optimization using automatic differentiation yields good results
- Large potential for other industrial applications
- Modular implementation allows for easy extension with other radiation models
- Comparison of discrete and continuous optimization approach