Catalytic oxidation of VOC – modelling, reactor design and industrial off gas treatment

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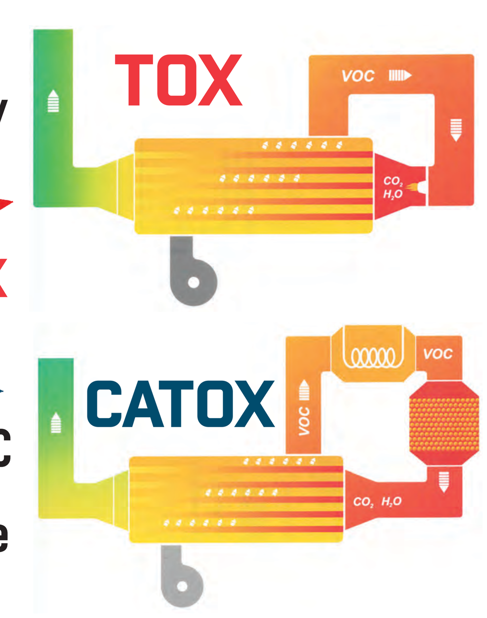
Introduction & Methods

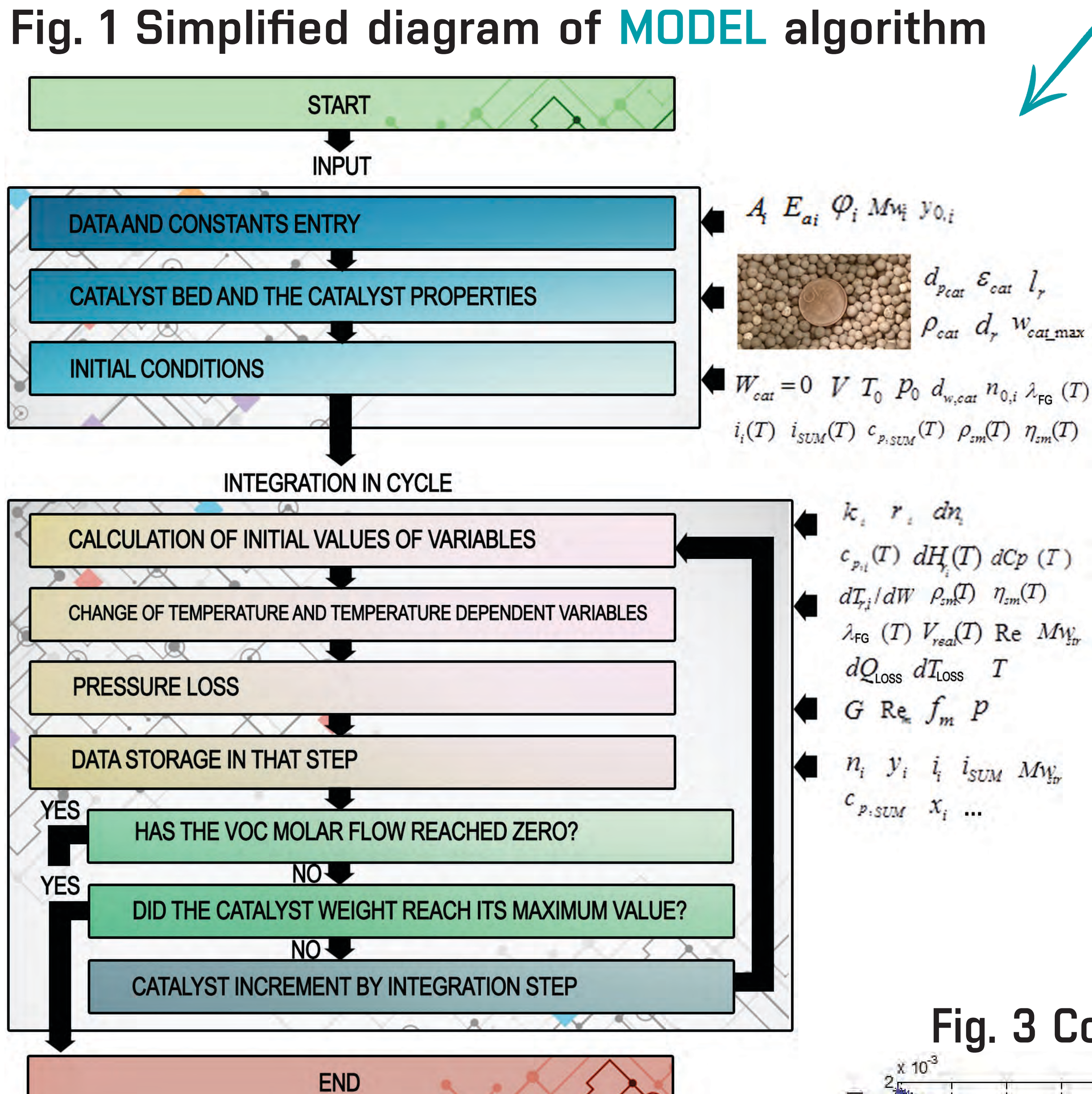
- Treatment of industrial off gas that contains VOC.
- Industry -> Frequently done by thermal oxidation by simply burning the VOC with NG.
- Often possible to change the technology -> thermal OX -> catalytic OX and reduce operating costs.
- Stable gas flow and no sudden changes in VOC concentration loads must be met to get reasonable reactor dimensions and IRR.
- Modelling of the process in pilot scale and fullscale -> the isothermal reactor can't be used, and instead, the adiabatic or even better, the non-isothermal reactor with heat dissipation should be considered.



- Proposed MODEL (considering non-isothermal plug-flow reactor) can predict the achievable conversion and temperature gradient across the reactor, which can help in reactor design, technological design of catalytic bed and scale-up to the full-scale technology.
- Proposed MODEL -> shows changes in gas composition and gas properties due to oxidation reactions, temperature rise due to oxidation reactions and on the other hand temperature decrease due to heat losses and change of pressure due to pressure losses across the bulk catalyst bed.
- Modular design PILOT PLANT was proposed and implemented -> verification of feasibility in industrial case studies of VOC catalytic oxidation and catalyst testing. This unit is scalable and can be used to test the sprinkled catalysts and monoliths both in lab or industrial conditions.

Results & Discussion

Fig. 1 Simplified diagram of MODEL algorithm



MODEL

balance of gas components:

$$\frac{dn_i}{dW} = r_i$$

pressure drop (Levy):

$$\frac{dp}{dW} = \frac{2 \cdot f_m \cdot u_g^{\,2} \cdot \rho_g \cdot L_r \cdot (1-\varepsilon)^{3-N}}{d_p \cdot \Phi^{3-N} \cdot \varepsilon^3}$$

temperature increase by reactions:

$$\frac{dTr_i}{dW} = \frac{\sum\left(-\Delta H_{r,i}(T) \cdot (-r_i)\right)}{\sum (n_i \cdot c_{pi})}$$

temperature drop by heat loss:

$$\frac{dT_{loss}}{dW} = \frac{dQ_{loss}}{m_{SUM} \cdot cp_{SUM}}$$

PILOT PLANT

Fig. 6 Flow sheet of the Modular PILOT PLANT (CATOX reactor)

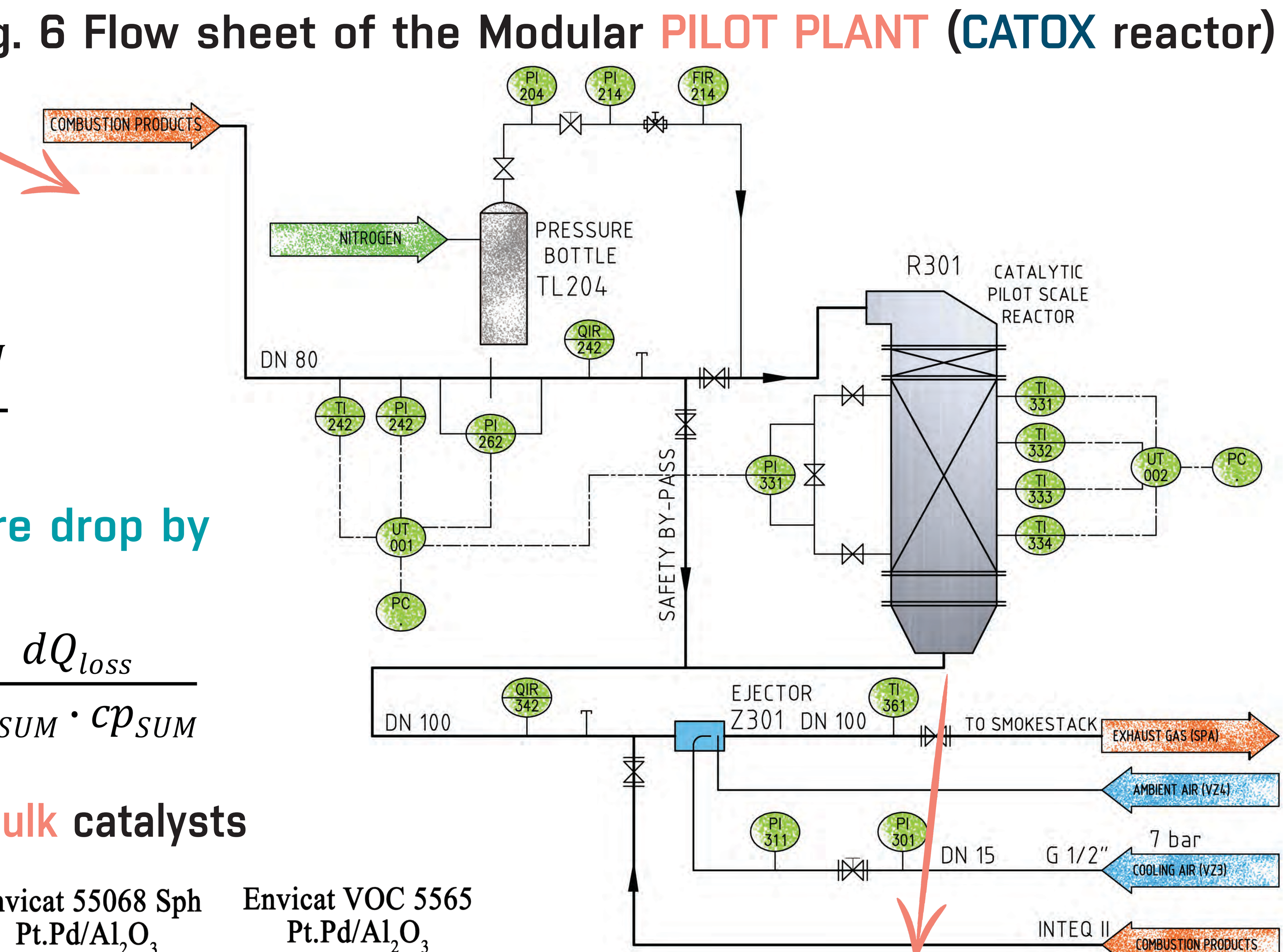


Fig. 5 Tested commercial monolithic and bulk catalysts

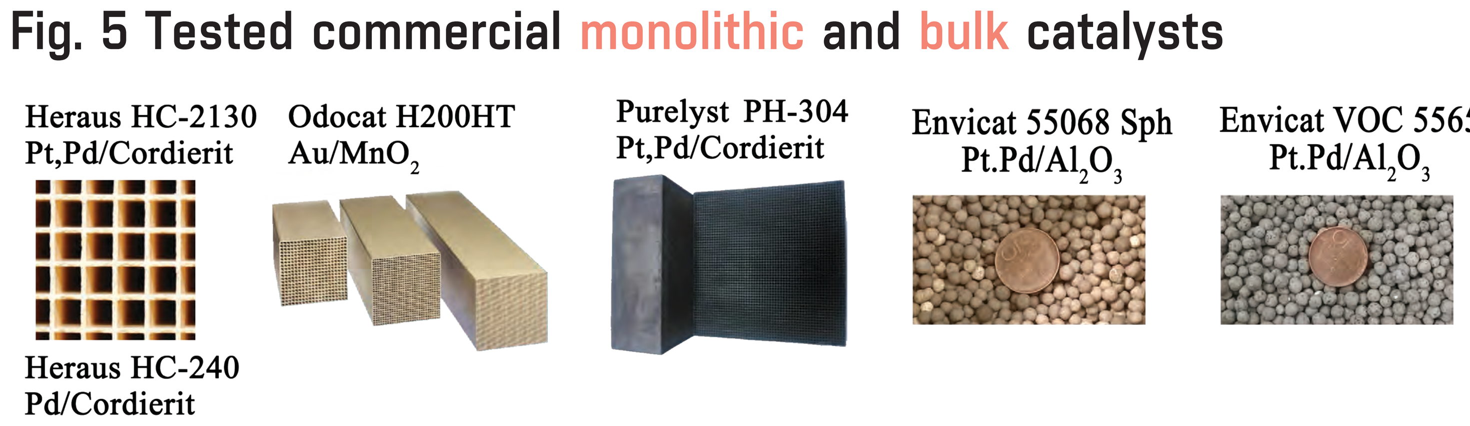


Fig. 7 Modular design - PILOT PLANT

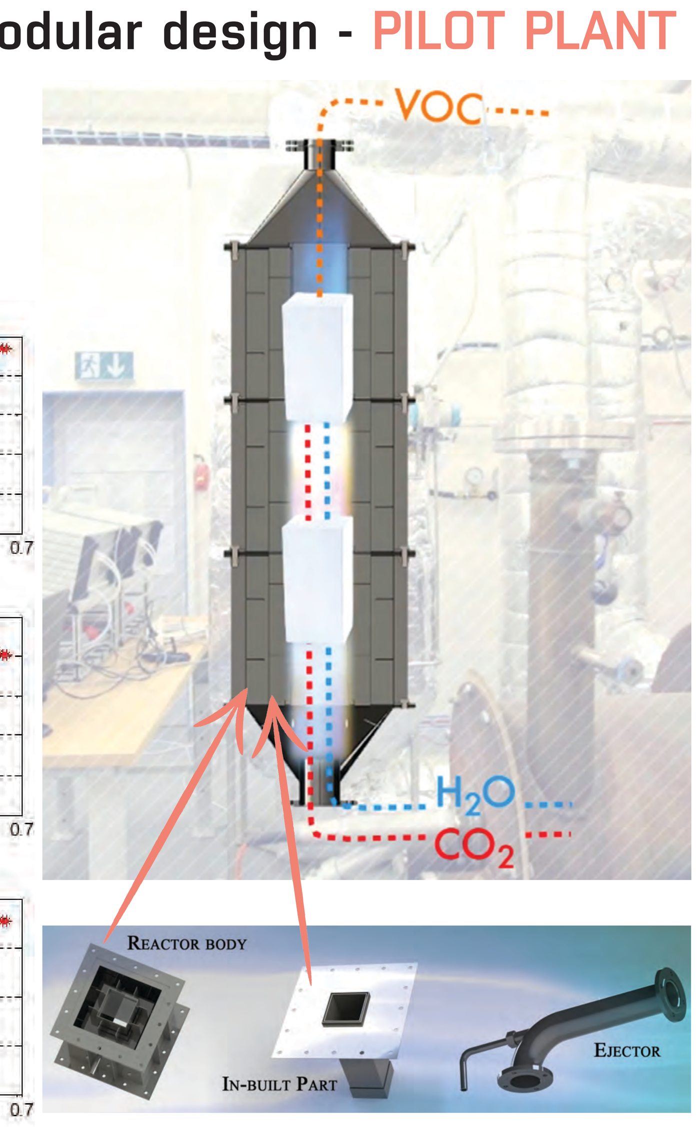


Fig. 2 Conversion and reaction rate of VOC

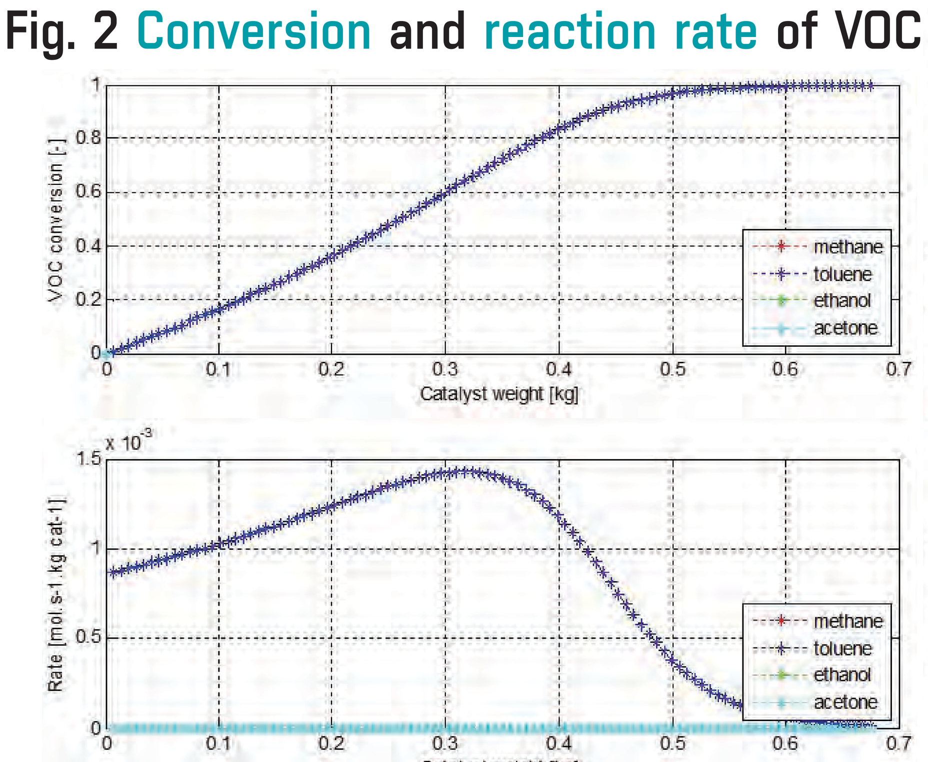


Fig. 3 Conc. of gas components, T and p

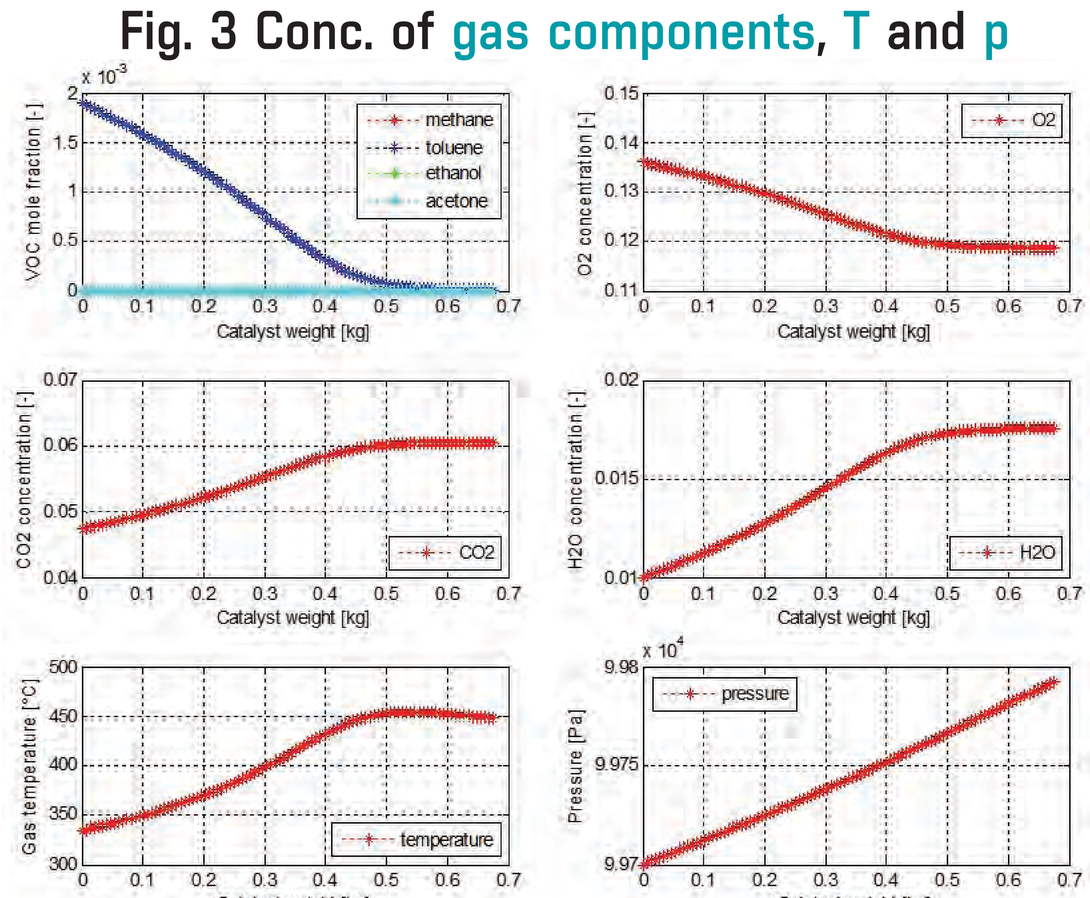
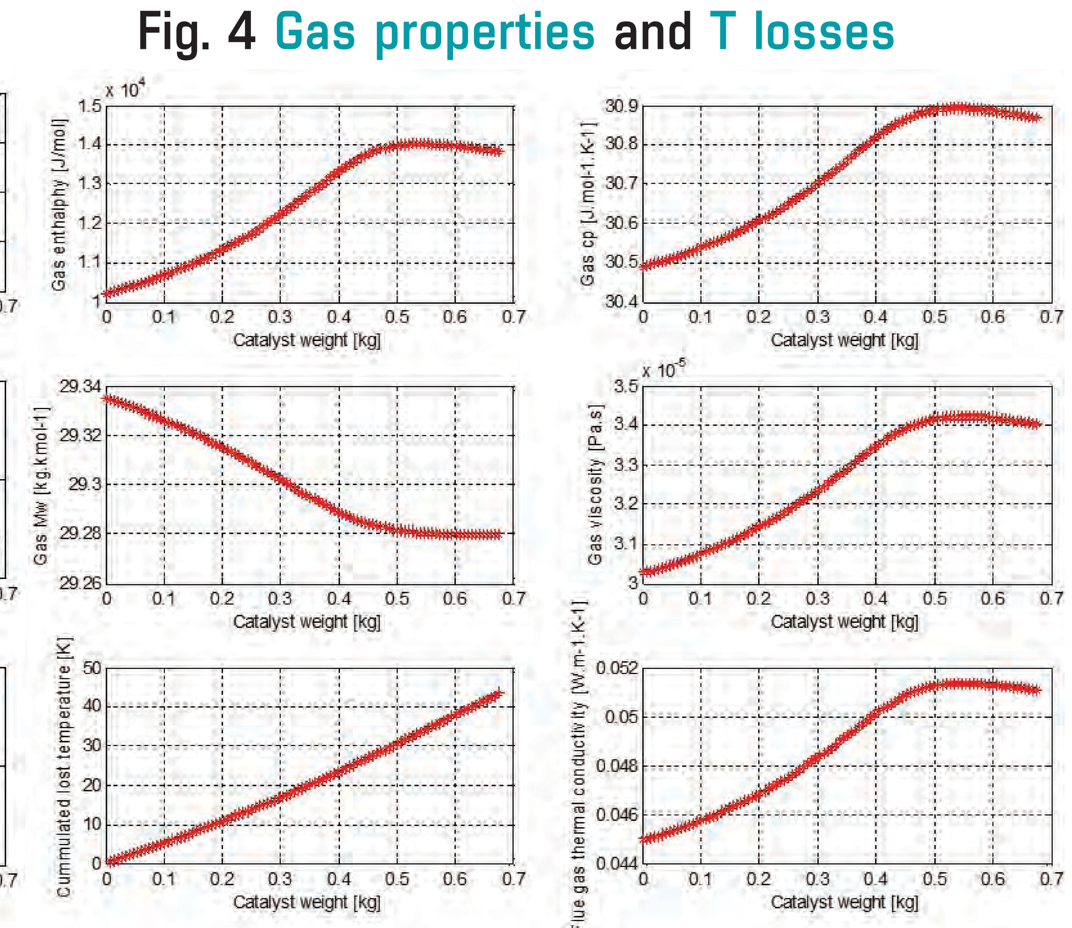


Fig. 4 Gas properties and T losses



Conclusions

- Modular (reactor body and in-built parts) PILOT PLANT was built for new types of catalysts testing and catalysts verification.
- PILOT catalyst testing can significantly reduces the risk of an investment before fullscale implementation.
- A mathematical MODEL of a non-isothermal plug-flow reactor was developed for CATOX of selected VOC. The data obtained from the MODEL were compared with experimental data acquired from the PILOT PLANT.
- Good agreement of data - model vs experiment for the test case (VOC conversion + 2% rel. dev., T_{out} of + 3% rel. dev., Δp of the bed - 62% rel.
- Reactor MODEL (PILOT) - it is not possible to neglect the heat losses of the reactor structures (43 K T_{out} diference - M vs P in test case if neglected)

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