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Co-Gasification of Petroleum Waste and Waste Tires: A Numerical and CFD Study

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Abstract : The petroleum industry generates significant amounts of waste in the form of drill cuttings, contaminated soil and oily sludge. Drill cuttings are a product of the off-shore drilling rigs, containing wet soil and total petroleum hydrocarbons (TPH). Contaminated soil comes from different on-shore sites and also contains TPH. The oily sludge is mainly residue or tank bottom sludge from storage tanks. The two main treatment methods currently used are incineration and thermal desorption (TD). Thermal desorption is a method where the waste material is heated to 450ºC in an anaerobic environment to release volatiles, the condensed volatiles can be used as a liquid fuel. For the thermal desorption unit dry contaminated soil is mixed with moist drill cuttings to generate a suitable mixture. By thermo gravimetric analysis (TGA) of the TD feedstock it was found that less than 50% of the TPH are released, the discharged material is stored in landfill. This study proposes co-gasification of petroleum waste with waste tires as an alternative to thermal desorption. Co-gasification with a high-calorific material is necessary since the petroleum waste consists of more than 60 wt% ash (soil/sand), causing its calorific value to be too low for gasification. Since the gasification process occurs at 900ºC and higher, close to 100% of the TPH can be released, according to the TGA. This work consists of three parts: 1. a mathematical gasification model, 2. a reactive flow CFD model and 3. experimental work on a drop tube reactor. Extensive material characterization was done by means of proximate analysis (TGA), ultimate analysis (CHNOS flash analysis) and calorific value measurements (Bomb calorimeter) for the input parameters of the mathematical and CFD model. The mathematical model is a zero dimensional model based on Gibbs energy minimization together with Lagrange multiplier; it is used to find the product species composition (molar fractions of CO, H2, CH4 etc.) for different tire/petroleum feedstock mixtures and equivalence ratios. The results of the mathematical model act as a reference for the CFD model of the drop-tube reactor. With the CFD model the efficiency and product species composition can be predicted for different mixtures and particle sizes. Finally both models are verified by experiments on a drop tube reactor (1540 mm long, 66 mm inner diameter, 1400 K maximum temperature).

Keywords : computational fluid dynamics (CFD), drop tube reactor, gasification, Gibbs energy minimization, petroleum waste, waste tires
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