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Electrical driven pyrolysis reactor retrofit for indirect concentrated solar heat

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ABSTRACT

Aiming for a climate-neutral economy, and the associated transition towards fuels produced from alternative feedstock, and to overcome some biomass pyrolysis unsuitable properties for the conventional combustion devices, plastics pyrolysis also produces oils, whose main compounds are also hydrocarbons, that can be used in conventional engines without so complex and costly upgrading processes.

Most of the chemical reactions found in a pyrolysis process are endothermal thus, to fulfill that energy demand, the retrofit of a 4 kW electrical furnace pyrolysis reactor to indirect solar driven energy was assessed aiming to adapt it to a central receiver solar tower with up to 100 kW$_{th\text{-}peak}$, using air as heat transfer fluid.

The heat demand along a typical pyrolysis test was experimentally assessed and a heat transfer mathematical model was defined to address the working constraints of the reactor. Additional analysis considering new design parameters were performed, namely sensitive analysis to the length of the new heating coil and its overall heat transfer coefficient, the reactor temperature set point, the inlet and outlet (to the atmosphere) gas temperature and working mass flow rates and temperatures were found to provide the same heat demand and minimize the waste heat.

Considering both the heat source facility and the reactor constraints, it was found that the retrofit is possible providing that the product of surface area by the overall heat transfer coefficient (A·U) yields more than 17.7 W/K, for a reactor temperature set point of 450 °C and a maximum temperature inlet of 700 °C.

Introduction

A countermeasure against climate changes is the decarbonization of the transportation sector. An analysis of the end use of energy in the EU in 2019 disclosed in Eurostat [1] reveals that transports is the largest category with 30.9 % of share. While the electrification of cars is a feasible option which is thought to have the potential to replace the internal combustion engine, analyses show that, for long-range travel (e.g. aviation), it is very likely to rely on hydrocarbon fuels in the future as the specific energy of batteries is limited [2].

Given the significance of the transport sector towards climate neutrality and considering liquid fuels higher energy density, ease of storage and transport, and the widespread availability of existing infrastructures and vehicles for distribution, renewable liquid fuels can also play an important role, namely for long-range road travel [3].

The thermochemical pyrolysis process has been extensively used in research using a wide range of feedstock materials suitable to produce liquids and gaseous compounds of combustible nature or chemicals. Those extend from biomass to polymeric-based materials, from bituminous coal to oil shale, and to all materials or feedstock that require a reaction medium in absence of oxygen independently of reactor configurations or catalysts types. Pyrolysis offers the possibility to transfer the chemical energy contained in a solid-fuel type feedstock mostly into liquid energy carriers, although some gaseous and solid materials can also be found at room temperature [4]. Whenever mechanical or physical recycling cannot be applied, pyrolysis technology has been widely applied for the energy recovery of biomass and plastic wastes and the liquids produced can be used directly (e.g., in boilers and in some stationary engines) or refined into chemical and/or petrochemical industries for higher quality uses. This is more prone to occur with plastics, that holding a petrochemical origin have inherently high calorific value and, thus, they can be converted back to useful energy [3].

Moreover, in EU countries, 42.6 % of plastic waste is treated for energy recovery, 32.5 % is recycled and 24.9 % is landfilled [5]. As part of the Green Deal, 55 % of plastic packaging waste should be recycled by

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