Harnessing conventional fuel production using solar-actuated pyrolysis reactor from waste plastics in developing countries.

Okocha Stephen, M.Sc.,
Okonkwo Ebenezer, Ogbonna Joel, & Nwosi Hezekiah;
World Bank African Centre for Excellence (ACE), Oilfield Chemicals, University of Port Harcourt (UNIPORT), Nigeria

Statement of problem: It is estimated that only about 10% of the 9 billion tonnes of plastics being produced is being recycled. Its abandonment after use in the environment has enormously contributed to flooding, loss of aquatic lives and gives an unsatisfying look to the environment. Although this is very recommending, it requires a lot of energy to achieve which hinders developing countries from actively participating due to their low power generating capacity.

Introduction: the possibility of performing the pyrolysis reaction of waste plastics in developing countries using the solar energy. The actuation was achieved by a concentrated radiation from the sun and backed up with flue Pyrolysis Gas when required. A process flow configuration which involves the reactor, solar lenses, vacuum pump, solar panel, inline components and the condenser is set up to perform the thermal gasification and condensation of waste plastics in the reactor. The chioce of using solar is due to the high solar irradiation experienced across Nigeria ranging from the mean monthly global solar radiation of 6.35KWh/m2, 5.08 KWh/m2 and 4.74 KWh/m2 for high, medium and low zones in Nigeria respectively at an average time period of 12 hours per day(Abdulsalam et al, 2012)

The study of harnessing conventional fuel production using solar-actuated pyrolysis reactor from waste plastics can be achieved using experimental setup and numerical approach to understand what happens inside the pyrolysis reactor

The purpose of this study is research is to determine if through solar concentration, the waste plastics in developing countries can be recycled

The intensity of sunlight is around 1kW/m2 around the world but varies in Nigeria, the exact value depends on latitude, season, time of day, cloud cover, etc. All the light falling on your lens is being concentrated into the radius image of the Sun, so if the radius of your lens is rl the power per unit area

$$I = \left(\frac{r_l}{r}\right)^2 . I_s \qquad (1)$$

where I = Solar Irradiation amplified from the lens, Is= Solar Irradiation directly from the sun, r= radius of the reflected sun's image

Through conduction, heat is transfered to the waste plastics which collects heat energy via the latent heat of fusion and vaporization to change the state of the waste plastics to vapor. The energy through radiation per time taken is expressed as:

$$q = \varepsilon\, \sigma\, (T_h^4 - T_c^4)\, A_c \qquad (2)$$

where Th = the abosolute temperature of the hot body (K), Tc = the abosolute temperature of the cold receiving body (K), Ac = area of the object (m2)

The essesnce of the vacuum pump is to reduce the presure inside the reactor so as to enable quicker boiloing rate experienced by the melting of the plastics in the transition from soilid to liquid phase.

$$P_v = Pa_i - Pa_o \qquad (3)$$

The condenser uses a direct contact of the pyro-gas with water. This occurs in a bubbling state where the gas is allowed to bubble into the water

$$\Theta(x) = \frac{T_H - T(x)}{T_H - T(0)} \qquad (4)$$

The process involves crushed plastics inserted into the reactor where a solar panel converts light energy into electricity used in powering the vacuum pump at a current of 8A. With a direct focus of lens on the base of the reactor, heat is being transfered through radiation, raising the temperature of the reactor to about 855oC as described by Stephen et al (2018).

Methods: The reactor design is being initialized using the Computational fluid dynamics (CFD) approach which involves designing the reactor 3D model using the Autodesk Inventor software. The model is then exported using the STEP file into Ansys (Fluent) software. The model was meshed using the tetrahedron mesh type with a minimum size of 8.2778e-005 m. A total of 25088 nodes and 129900 elements.

Results: The interior of the reactor exhibits an internal temperature of 773oC, which is enough to perform the pyrolysis reaction. A back flow of temperature occurs at the outlet due to turbulent fluxes occurring

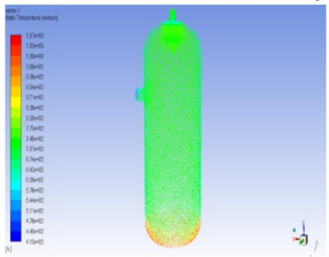

Table 1- Physico-Chemical Properties of the Pyro-oil

Property	Unit	Value
C	wt%	46
H	wt%	7
N	wt%	< 0.01
O (Balance)	wt%	47
Water content	wt%	25
Ash content	wt%	0.02
Solids content	wt%	0.04
Density	kg/Ltr	1,2
LHV	MJ/kg	16
LHV	MJ/Ltr	19
pH	-	2.9
Kinematic viscosity (40 °C)	cSt	13

Fig. 1- Temperature distribution of the Pyrolysis reactor

The density was checked of the pyro-oil which was about 1154 kg/m3. This happens to be denser than the conventional fuel oil and also denser than the density of the waste plastics. The higher heating value (HHV) attained in the pyrolysis process was at 23.4MJ/l as compared to fossil fuel estimated around 37 MJ/l.

Conclusions: The products that were obtained from the process were Liquid (pyro-oil), solid (char), and Gas (pyro-gas). This was obtained from a solar-actuated pyrolysis reactor where solar energy was concentrated to act as the heating source for the pyrolysis reaction. Computationally (using CFD), it was attained that the inside temperature of the reactor was stipulated at 773oC which is enough to perform pyrolysis. The liquid part of the pyrolysis products contains about 80% per kg of waste plastic processed which also contains a some organo-oxygen compounds.