Application example

Consider an example of an application where octane is burned in an internal combustion engine. The fuel and air are at 25ºC. The air has a relative humidity of 90% and an atmospheric pressure of 1 atm. An excess of air of 15% was considered. It is assumed that $Q_{out} = 75000kJ/kmol$ and $W_{out} = 120000kJ/kmol$.

Combustion analysis

Considering the molar mass of octane and the respective multiplicative factors, the following values for the theoretically necessary air were obtained for a stoichiometric combustion:

- $O_2 = 3{,}5kg/kg_{fuel}$
- Dry air = $11{,}53kg/kg_{fuel}$

Based on these values, the water vapour present in the air is considered, taking into account the dry bulb temperature, relative humidity and atmospheric pressure mentioned above. The excess air of 15 per cent is applied, giving the following values for the air:

- $O_2 = 4{,}025\ kg/kg_{fuel}$
- Dry air = $13{,}259\ kg/kg_{fuel}$
- $H_2O = 0{,}239\ kg/kg_{fuel}$

The combustion products for this excess air condition will be:

- $CO_2 = 3{,}080\ kg/kg_{fuel}$
- $H_2O = 1{,}659\ kg/kg_{fuel}$
- $N_2 = 9{,}234\ kg/kg_{fuel}$
- $O_2 = 0{,}525\ kg/kg_{fuel}$

Figure 1 represents the evolution of the weight composition of the dry fumes as a function of the excess air obtained with the application, where identical values to those previously calculated.

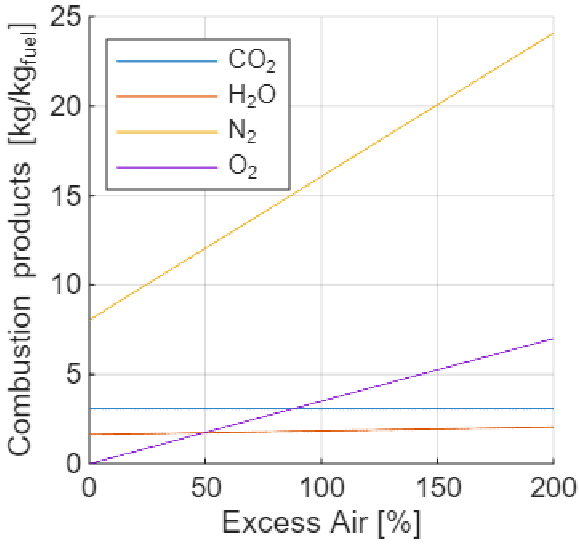

Figure 1 – Evolution of the weight composition of dry smoke as a function of excess air.

Product temperature analysis

To analyse the temperature of the combustion products, the previous analysis was taken into account and that $Q_{out} = 75000 kJ/kmol$ and $W_{out} = 120000 kJ/kmol$, obtaining a temperature for the combustion products of $T_p = 1733{,}41ºC$, by realising the following energy balance from Equation 1.

$$75000 + 120000 + \sum N_P\left(\overline{h_f^o} + \overline{h} - \overline{h^o}\right)_P = Q_{in} + W_{in} + \sum N_R\left(\overline{h_f^o} + \overline{h} - \overline{h^o}\right)_R \quad (1)$$

Figure 2 represents the evolution of the temperature of the combustion products as a function of the excess air obtained with the application for the case under study.

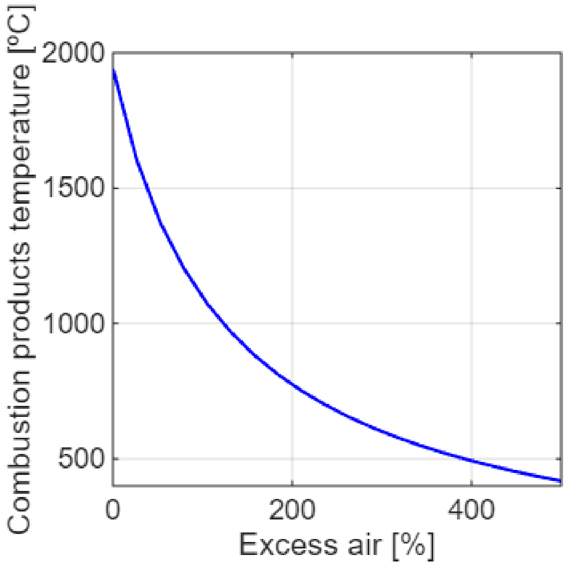

Figure 2 – Temperature of combustion products as a function of excess air.

Analysing a combustion test

Afterwards, a test was conducted under the above conditions for fuel and air. Measurements were obtained of the volumetric composition of the combustion products (carbon monoxide and oxygen) for a period of operation shortly after the engine was started cold. Figure 3 represents the installation of the analyser probe for testing in a gasoline-powered car. It was assumed that petrol is completely similar to octane.

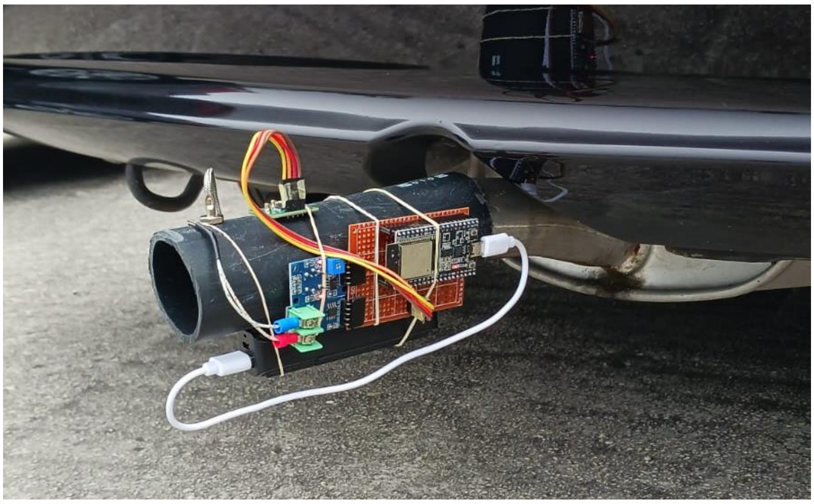

Figure 3 – Assembly of the analyser probe for testing in a car with a gasoline combustion engine.

The probe measurements, using Probe Dashboard, resulted in the Ostwald Triangle in Figure 4.

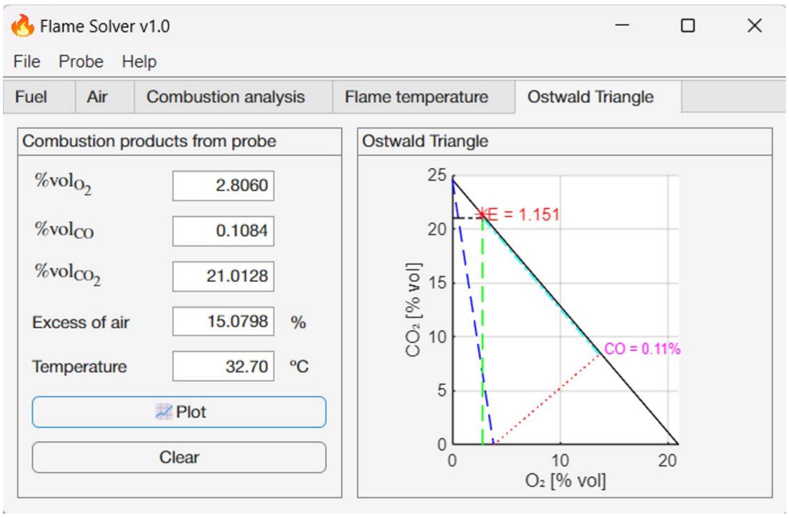

Figure 4 – Plot of the Ostwald Triangle based on the probe measurements.

The engine is operating with around 15 per cent excess air. The volumetric O_2 content has dropped from around 24 per cent to 2.806 per cent compared to when the engine was still idling. The carbon monoxide content is around 0.1084 per cent, an acceptable figure given the probe's upper limit of 0.2 per cent or 2000 ppm. The temperature was higher than the ambient temperature, but not significantly so, which is to be expected given that the engine was only started a short time before the reading was taken. However, it is to be expected that the temperature will not reach the theoretical temperature due to the long exhaust line and its accessories. The Q_{out} and W_{out} values should be corrected to the real or estimated values in order to carry out a more accurate analysis.

However, the Ostwald Triangle for the case study makes it possible to see opportunities for improvement or verification of optimal combustion conditions.