**Summary**

# MOOC Week 4: Internal Combustion Engine

**General Description of this module**

The aim of this week is to give an introduction to the operation of internal combustion engines and to their impact on society and environment. The working process of the internal combustion engine is divided into 5 topics.

**Overview / Engine Mechanics**

A fundamental requirement for the engine is to be supplied with energy, which is chemically bound. It is made up of two essential components: carbon and hydrogen. For the combustion, oxygen is needed. During combustion, the carbon and oxygen is converted into carbon dioxide (or CO2) while the hydrogen reacts with oxygen to form water (H2O). Through combustion, chemical energy is converted into heat on the one hand, and into work on the other. We transfer this work from the engine to the driven wheels: in other words, we create a propulsive force so that the vehicle can cover distance and this is how we drive the car.

A summary of engine mechanics is given in the videos available in English and German.

**Fuels for Engines**

We can distinguish two main ICE architectures depending on the fuels powering them:

1. Spark ignited engines, which can use
   1. Gasoline
   2. Alcohols: (bio --) ethanol, methanol
   3. Gaseous Fuels: Compressed Natural Gas (CNG ); Liquefied Petroleum Gas (LPG); biogases (Methane and Carbon Dioxide mixture); Hydrogen

* Ignition needs to be supported by a spark plug

1. Compression ignited engines, which can use:
   1. Diesel, Biodiesel or Rapeseed Methyl Ester (RME)

* Self-ignition when temperature and pressure is high enough

Refineries are able to extract from crude oil many different types of fossil fuels each with its specific chemical and physical properties and thus applications. When compared to Gasoline, Diesel properties make IC engines still preferable from fuel consumption (and then CO2 also) point of view. Crude oil is and will remain in the mid-term time horizon cheap to produce and transport while electricity and H2 infrastructures still need vast improvement from the logistical and economical point of view. Synthetic fuels and bio fuels can be very good alternatives for the transition period, fighting the global warming phenomenon and still letting time for technological progress. Hydrogen seems to be the most appealing solution over the long term horizon combined with renewable sources and a deeply improved production.

**Mixture Preparation & Combustion**

Mixture processes and combustion processes define the quality of the power deployment and the emission outcome. The task of the fuel mixture-generation system is to guarantee for each operating condition (engine speed and torque) the correct air/fuel ratio in the cylinder, so that to have enough fuel to supply the desired torque and enough air (oxygen) to complete combustion process. A big variety of mechanical injection system has been developed in the past becoming more and more complex. Finally, by the help of electronic control they became simpler. The control intelligence was transferred into software to realize more efficient devices in many different operating conditions. Basically, gasoline and diesel combustion processes in the chamber are completely different. Gasoline combustion (diffusion combustion) is very homogeneous, whereas Diesel combustion occurs in inhomogeneous conditions.

**Exhaust Gas Aftertreatment**

Most of ICE exhaust emissions (80%) consist of N2 and CO2, then water vapor, oxygen and other gases follow. Only a very little part, nowadays in the range of a few ppm (parts per million) after catalyst, are toxic emissions. Although more than 2000 substances are emitted by the ICEs, the legislation only limits: CO, Hydrocarbons (total and non-methane), nitrogen oxides (NOx – a summarized value of mainly NO and NO2 ), and particulates (number in sizes). Today, where all ice engines are equipped with an aftertreatment system, most of the emissions occur in the first minute after start, when the catalyst system does not work due to missing temperature. Modern and advanced systems now include both catalytic converter and particulate filter as part of the exhaust system.

**Social and Environmental Impact of ICE**

ICE and related infrastructure take many advantages from almost 130 years of development and optimization. Our prosperity and economic growth is based on our existing mobility solutions and any sudden changes might endanger this success. Therefore, a transition phase is needed where ICE has still a place. Due to the affordability and convenience achieved and the resulting high number of ICE vehicles worldwide (yearly production about 100 millions) the environmental effects cannot be ignored any longer (especially climate change) and alternatives need to be brought into the market. Electric propulsion in/for all vehicles promises to be a good solution especially on local level in the upcoming mega cities all over the world. It improves dramatically the local emissions (toxic and noise) situation. Over longer distances electric propulsion powered or supported by hydrogen operated fuel cells seem to be the proper solution. Life Cycle Analysis – as the only scientific approach – shows that electric vehicles will improve significantly the CO2 footprint only when used for a long time or kilometric distance. Concerning production and recycling, the EV is inferior to conventional vehicles. The positive effect of EVs in the ‘’use-phase“ is better when electricity is produced by renewables (wind, water, solar). To make e-mobility a success and a real benefit for the environment, our complete energy system must rely on renewable sources. An H2 based energy system might be the long term solution. All problems related to mobility and personal usage can only be solved by new transport solutions and by adapting our personal behavior.