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Tutorial 6 – Ethanol Engines

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ABSTRACT

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Within the global context of reducing greenhouse gases net emissions, the transportation sector is the most difficult to cope with, not only because of its large participation on the overall emissions and its huge installed infrastructure, but also due to the high energy density provided by the presently used liquid fossil fuels.

The main comparative advantage of renewable fuels replacing petroleum derivatives, instead of other more disruptive alternatives like electrification and hydrogen, is that it doesn't demand the substitution of the available industrial and fuel distribution infrastructures. At the same time, the similarity of the renewable fuels with the conventional ones is the biggest difficulty when it comes to the development of combustion engines well adapted to the new fuels, because the global automotive industry prioritizes the prevailing fossil fuels on its new model engines. The particular challenge is not to develop a new engine from scratch to, for instance, ethanol, but how to take advantage of the strong R&D effort going on globally to make vehicles and engines more fossil-fuel efficient and to apply the learned know-how to the ethanol or flex-fuel engine. The knowledge of the physical and chemical properties of renewable and fossil fuels, of their differences and their effects on

performance of engines makes possible to choose the best alternatives in developing engines for renewable fuels.

During the early days of ethanol engines within the Proalcool Program, around years 1977-78, the brake full load energy efficiency of ethanol engines was circa 25% greater than the ones of gasohol engines produced in Brazil at that time. That was possible because the gasohol engines were using very rich fuel-air mixtures at full load and the ethanol ones used higher compression ratios and leaner mixtures to keep the same torque and power of the gasohol engines.

When Brazil established a Program for Fuel Economy - PECO with the full participation of the automotive industry, the fuel consumption results, based on a city and highway test cycle, have shown an energy efficiency bonus for ethanol of around 15% (years 1983-86).

Following the start of implementation of Proconve – the Brazilian Program for Air Pollution Control by Automotive Vehicles (1986) and the reduction of oil prices, the main concerns of power train development was to meet the emission regulations and the PECO Program was set aside. After the Proconve phase L3 took into effect (1996), and all cars and light-duty vehicles had to use a three-way catalyst that required a stoichiometric fuel- air mixture, the ethanol efficiency bonus decreased substantially. Also in the same period oil prices were low and the participation of ethanol vehicles on new car sales was below 5%, what hindered investments on new developments.

In the first years of last decade, the oil prices started going up and ethanol was competitive again, what led to development and launching of new straight ethanol vehicles. When compared to their counterparts that ran on gasohol, according to the official test cycle, they were 3-4% more energy efficient.

After the introduction of the first generation of flex-fuel vehicles into the Brazilian market in 2003, the differences in energy efficiency when running the same vehicle with hydrous ethanol or gasohol became nearly zero in the official test cycle, even though practical tests by car magazines showed some differences favoring the use of ethanol. Since 2003, several generations of flex-fuel vehicles were launched into the Brazilian market and some differences of energy consumption were detected again even in the official test cycle.

After this brief history of renewable fuel use in Brasil, the presentation shows the principles of operation of spark-ignition engines, its technical characteristics, performance, fuel efficiency in use and emissions. Then, the technical characteristics of ethanol are compared with those of gasoline. The introduction neat ethanol as fuel for spark-ignition engines in large scale is presented, with the challenges of logistics of distribution, price formation and quality control strategies.

Next, the presentation gives an overview of the most promising researches, developments and innovations aimed at the improvement of vehicles fuel-efficiency and points out the ones considered to be more adequate for ethanol use. On spark ignition engines, more commonly used in automobiles and light-duty commercial vehicles, there will be discussed: direct fuel injection, downsizing and turbo-charging, variable-valve lift and timing, friction reduction and electrification (mild and full hybrids).

The problem of the substitution of diesel fuel will also be adressed. The principles of operation of compression-ignition engines will be showed; the challenges and strategies to substitute diesel fuel with renewable fuels (ethanol and/or biodiesel) to applications for heavy-duty vehicles will be discussed and the research and development needs will be put in evidence. On compression ignition engines, used in all heavy-duty trucks and buses and, in some countries, also in automobiles, there will be considered: turbo-charging with several stages, increased pressure and control of injection, exhaust gas recirculation and after treatment, controlled auto-ignition and homogeneous charge compression ignition and hybridization.

Besides that, there will be presented and evaluated specific engine solutions that use two separate injection systems for the renewable and fossil fuels, as a mean of exploring the best of the properties of renewable fuels. Some technological alternatives for the use of ethanol as a fuel for heavy-duty engines are also discussed.

Finally, the presentation discusses and suggests public policies needed to accelerate the implementation of high-efficiency solutions with renewable fuels in vehicles.

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