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Alternative Automotive Propulsion Systems – Configurations and Trends

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INTRODUCTION

The worldwide demand for car mobility, characterized especially by high power-to-weight ratio, increases continuously. On the other hand, the availability of energy resources, the ecological impacts and the intensified traffic flow lead to complex requirements to every new vehicle and propulsion system. Between necessities, specific utilization fields, acceptance and limitations – as specified in Fig. 1 - particular configurations and combinations of propulsion systems gain on interest. A benefic support for the combination of power generating modules in efficient propulsion systems is offered by the rapid progress of the electronic onboard networks. The tendency in evaluating the promising propulsion concepts and the utilizable energy forms – involving storage and conversion techniques onboard are marked by increased pragmatism. Different regional conditions regarding infrastructure, technological level, specific energy resources and traffic particularities impose more and more a complex model of propulsion scenario, allowing, the most effective combinations of propulsion units, energy form, storage and conversion.

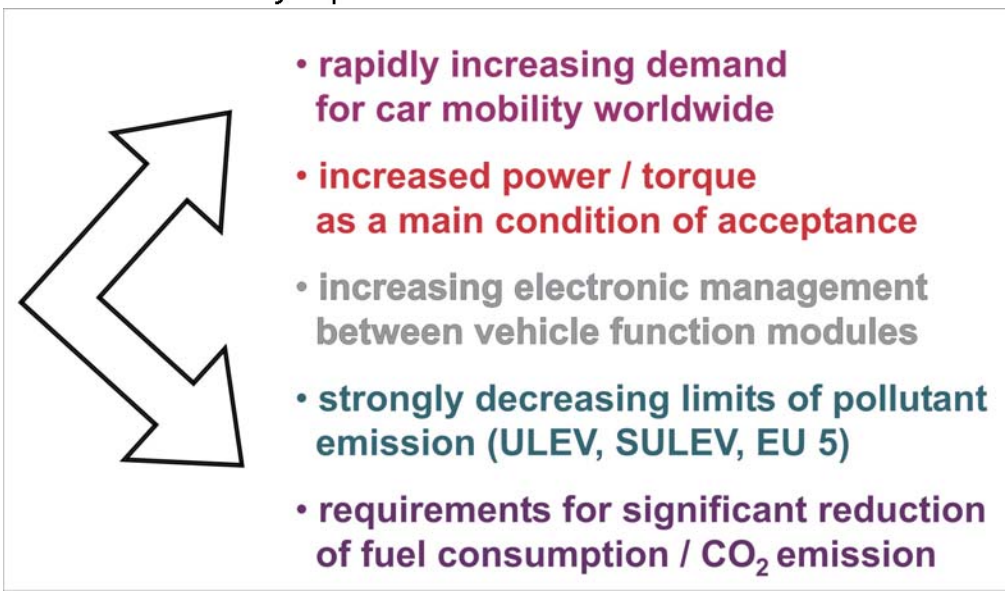

Fig. 1 Development conditions for automotive propulsion systems - criteria of propulsion efficiency

The direct relationship between consumption-and-power-output or emission-and-power-output, both expressed in [g/kwh] - as classical criteria of performances of a propulsion system - become insufficient with regard to the requirements of the future. A more realistic valuation is possible when considering the complete chain of transformation from chemical energy of the primal source to the work transmitted to the wheels. An interesting example is offered by comparing the following two chains:

- Oil exploration, extraction and transport – refinery to gasoline and distribution – combustion in spark ignition engine – work for automobile wheels

- Coal exploration, extraction and transport – coal combustion in power plant – generation and distribution of electric energy – energy storage in lead battery onboard – energy conversion in motor – work for wheels

The local zero emission of the electric propulsion seems to be an interesting argument. But comparing both chains, the CO_2 emission is approximately 5 times higher on the electrical way than on the fuel way, as exemplified in Fig. 2.

The recent development of alternatives components to be involved in a propulsion scenario – such as fuel cells, use of hydrogen or advanced motors – generates different non-conventional combination possibilities.

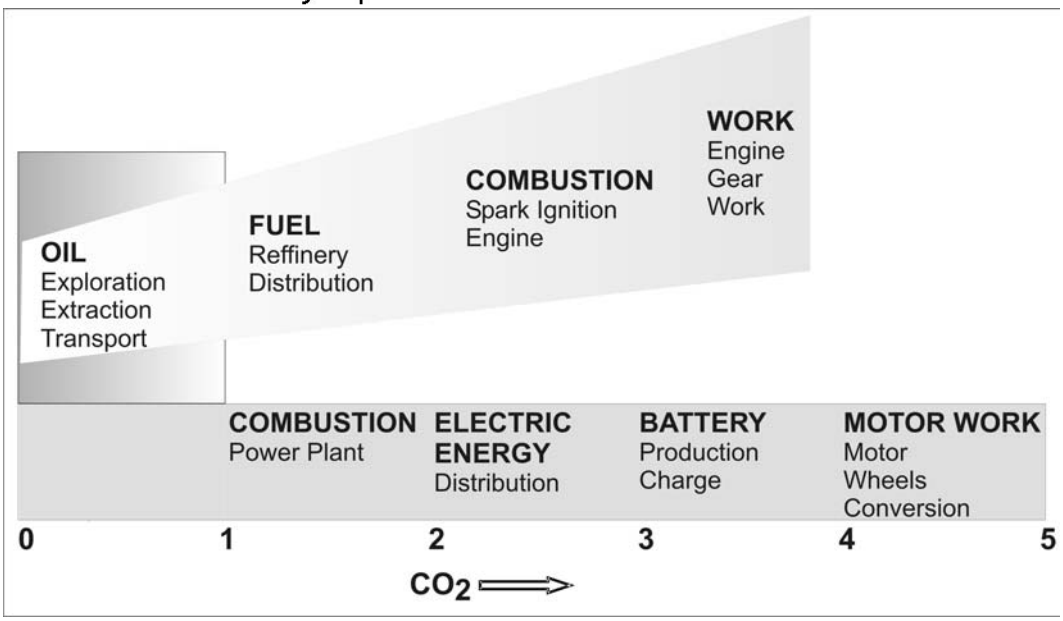

Fig. 2 Comparison of CO_2 emission chain between electric propulsion and propulsion by spark ignition engine

For example the fuel cell as converter of hydrogen energy in electric current for motor propulsion is generally considered as a clean and efficient alternative for the future. But the hydrogen is only insignificantly produced by electrolyze, the present technology is practically based on hydrocarbons (stream reforming or cracking of methane), implicating a well-defined CO_2 emission. Furthermore, the storage of hydrogen at temperatures under 20 K requires an expensive technology. In addition, the efficiency advantages of fuel cell versus internal combustion engine are demonstrated only at relatively low power and for steady conditions – at a price, which is out of competition.

Such a concept becomes a challenge in creating alternative chains. Following examples – which are schematically represented in Fig. 3 – are significant for comparison:

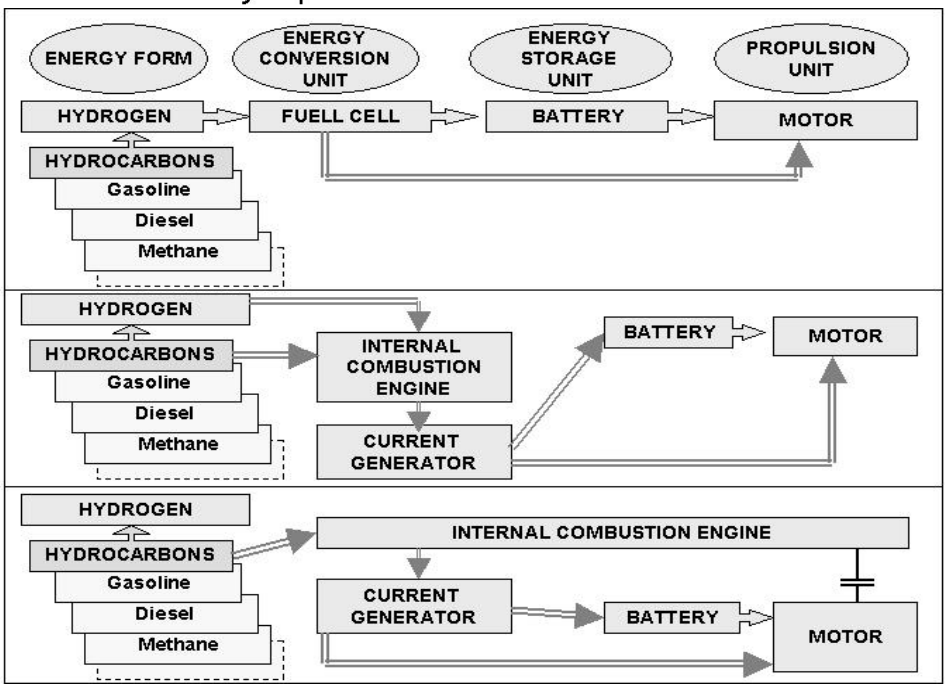

Fig. 3 Alternative propulsion chains from energy form to propulsion unit – examples

- direct use of methane in a spark ignition engine optimized for the use at constant load and speed, functioning as current generator with propulsion by electric motor
- use of hydrogen instead of methane in the same configuration
- fuel cell powered by gasoline – electric motor
- internal combustion engine powered by conventional fuels, methane or hydrogen working partially as a current generator and additionally as propulsion unit, together with an electric motor
- internal combustion engine powered by a certain conventional or alternative fuel as propulsion unit, fuel cell working with the same stored fuel as current generator onboard for the auxiliary modules and – depending on necessities – for partial motor propulsion.

The optimum configuration can be deducted for a specific application with extension possibilities, in base on following criteria: power-to-weight, power-to-volume, torque characteristic, acceleration behavior, specific consumption of energy, specific emission, availability of planned energy form, technical complexity, costs, safety, regional service capabilities.

Evidently, in every module of such configuration – from energy source to propulsion unit – the most adaptable form to a specific propulsion chain is required.