

# Habilitation Thesis

## Extended Abstract

*Investigating the influence of some parameters upon the energetic performance of the internal combustion engine:  
the role of compression and expansion ratios, valve actuation, turbocharging and fuels.*

by

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## ABSTRACT

*Road mobility* is the engine of economic development and is one of the fundamental aspects of social cohesion because it allows everyone the freedom of movement, along with the advantages inherent to it: easy access to various jobs, to public services, vacations/leisure etc.

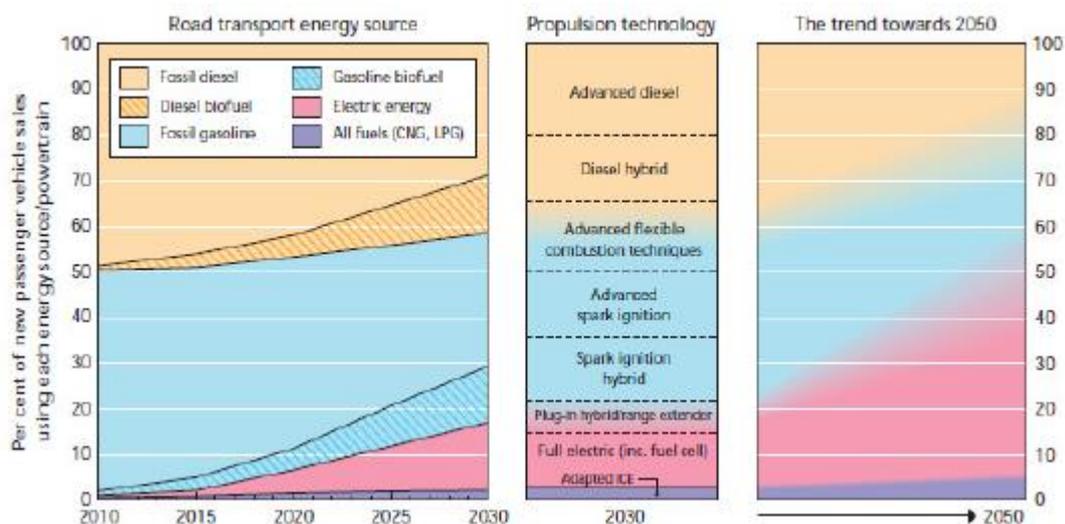
Even though it still represents the most spread energy source in the field of road mobility, the internal combustion engine (ICE) faces environmental issues.

Therefore, now more than ever, the need to strike a balance between natural increase of road mobility and environmental protection is obvious. Thus, the concept of *sustainable mobility* was born, which is, at present, the biggest challenge of the automotive industry.

If we define *sustainability* as being the feature that allows an activity (in this case, mobility) to take place without exhausting the available resources and damaging the environment, therefore, without compromising the ability of future generations to meet their needs, then the usefulness of concerns for reducing the automobile impact on the environment is obvious.

However, the significant progress of the ICE in the last decade has failed to "off" concerns about long-term effects on the environment. The discussions about a future less rich in fossil fuels have led to the industrial orientation towards electrification of the automotive industry. The paradox is that the fundamental advantage of the automobile (*freedom of movement*) is affected: mobility is reduced to the battery autonomy period. Therefore, regarding the electric propulsion: *low environmental impact but strongly affected freedom of movement*.

Consequently, according to ERTRAC<sup>1</sup>, the near future of road mobility (by 2050) most probably means a mix between different energy sources: advanced spark and compression ignition engines (SIE, CIE) powered vehicles using conventional and alternative fuels, battery electric vehicles (BEV), hybrid electric vehicles (HEV), plug-in HEV (PHEV), fuel cell EV (FCEV).



**Fig. 1.** The evolution of passenger road transport energy source and propulsion technology<sup>1</sup>

<sup>1</sup> ERTRAC, *Research and Innovation Roadmaps*, 2011. [http://www.ertrac.org/pictures/downloadmanager/6/50/ertrac-researchinnovation-roadmaps\\_60.pdf](http://www.ertrac.org/pictures/downloadmanager/6/50/ertrac-researchinnovation-roadmaps_60.pdf)

Coming back to the ICE, it is clear enough it still has a future (especially for long distances), thus, sustainable mobility passes through drastic improvement of ICE's energetic performance (i.e., overall energy efficiency).

As mentioned by ERTRAC<sup>1</sup>, *“the improvement potential for fuel consumption of advanced ICEs is still significant and continued improvements in regulated emissions performance and low overall cost are still feasible. For these reasons, advanced ICEs and powertrains will be important for meeting future consumer and regulatory demands over the near- and medium-term and they will be the pacesetter technology for alternatives like hybrid and battery electric vehicles. As such, they will be an important contributor to achieving ERTRAC's grand societal challenge for decarbonization of transport.”*

This being the current context, this report aims to present the influence of some parameters upon the energetic performance of the ICE. For instance, *the role of compression and expansion ratios, valve actuation, turbocharging and fuels upon the energetic performance will be discussed*. Certainly, this report is not an exhaustive work on this subject. The author has only attempted to enable a clear tracking of some scientific achievements that he contributed to. The structure of this work is an arbitrary one, as the subjects included here were not necessarily conducted in chronologic order. They were rather treated in parallel over the time.

Since he obtained his PhD in 2003 with a thesis on variable compression ratio (VCR), the author has continued to work on the improvement of energetic performance of ICE as it is briefly presented below.

Nuanced understanding of compression and expansion ratios is really the basis of thermodynamic improvement. The author's preoccupations on this subject led to an original quantification of real compression ratio that could be applied to any given SIE.

Then, giving variabilities to the valve actuation makes the SIE more fuel efficient. An original variable valve actuation (VVA) initially developed by Professor Vasile Hara at University of Pitești was undertaken by the author who brought a significant scientific contribution by succeeding to control it in the absence of the conventional throttle butterfly (i.e., *throttle-less operation*). The existence of such an operational VVA engine prototype enabled the move to the in-cylinder flow field estimation through CFD (Computational Fluid Dynamics) numerical simulations. This was performed under the frame of a joint doctoral thesis of Mr. Victor Iorga-Simăn between University of Pitești and Le Cnam de Paris (2008 – 2012), the author of this report having the role of co-lead. Thus, a scientific cooperation started in 2015 with Renault France (Dr. Stéphane Guilain) and AVL France (Dr. Wolfgang Schwarz), which allowed to further advance in the numerical simulation of unsteady in-cylinder flow in a VVT (Variable Valve Timing) engine, aiming also to correlate CFD data with PIV (Particle Image Velocimetry).

Since engine overcharging is a key factor for increasing specific performance of ICE, thanks to the good scientific cooperation with Professor Georges Descombes and Dr. Pierre Podevin from Cnam Paris, the author was drawn into a work aiming to investigate the performance at low speeds of the small centrifugal compressors from the turbocharging system. At that time, the involvement of the author was possible thanks to 3 post-doctorate stages at Cnam Paris where the whole experimental investigation happened.

Another subject thoroughly investigated by the author and his colleague Dr. Rodica Niculescu was the use of biodiesel blends in CIE and its impact on the cold starting performance of the engine. A major drawback associated with the use of biodiesel, however, is its poor cold flow properties, which have a direct influence on the cold starting performance of the engine. Since diesel engine behavior

at negative temperatures is an important quality criterion of the engine's operation, one goal of this paper is to assess the starting performance at  $-20^{\circ}\text{C}$  of a common automotive CIE, fueled with different blends of fossil diesel fuel and biodiesel. The study was possible thanks to the good technical cooperation of the author with Renault Technologie Roumanie (Mr. Marin Gheorghe, Mr. Xavier Roumat, Mr. Adrian Ivan).

*The brief synopsis of the above outlines how the author of this report has had a positive trajectory in his research involvement: from the PhD research, through added value to research projects led by other scientists, to developing projects on his own.*

Each of the four chapters of the research activity starts with an overview underlining the concerns that motivated the studies and drawing the scientific context to which the major results are related. Then the author provides detailed information about them.

As a conclusion, the last chapter of the research activity depicts the works that the author intends to lead and/or to contribute to in the coming years. These orientations are deeply influenced by the author's past successful and failed studies described in the first four chapters. In the same time, they are driven not only by the author's own scientific preoccupations/intuitions/curiosity but also by the ones of other close colleagues to whom the author relates on scientific subjects. In fact, as in all other fields, team work with its associated debates is what makes the research truly interesting and stimulating.

**Keywords:** efficiency, compression ratio, expansion ratio, variable valve actuation, in-cylinder flow velocities, CFD simulation, turbocharging, biodiesel, Di-Ethyl-Ether