Feasibility Investigation of Next-Generation Fuel Injectors using CFD Analysis

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Abstract Nowadays, the importance of reducing emissions and increasing fuel efficiency has become even more crucial than ever. Some alternative technologies to traditional gasoline and diesel engines have been developed, such as electric vehicles or hydrogen fuel cells, but the transition to these new technologies is slow and expensive, and it is likely that internal combustion engines will be used for a long time to come.

In this context, the development of new technologies that can be used in combination with existing engines structure is critical. The possibility of using alternative fuel sources, such as ammonia or dimethyl ether, is particularly attractive. These fuels have the potential to reduce emissions and increase fuel efficiency, but they require the development of new injectors that can handle their specific properties.

In this research we will not focus on fuel engineering per se, but on the feasibility of a new generation of fuel injectors that can be fitted to existing engines and that can handle these alternative fuel sources. To do this, the use of Computational Fluid Dynamics (CFD) simulations will be critical, as it will allow us to study the interaction between fluid dynamics and the chemical reactions occurring within the injector in an efficient and cost-effective manner.

Keywords Fuel injectors design, Computational Fluid Dynamics, Alternative fuel sources

1 Objectives and Impact

Explain the objectives of the project and the expected impact of the research:

- We need to develop new mechanical components that can handle these alternative fuels.
- CFD simulations are probably the most efficient and cost-effective way to develop new fuel injectors (one of the missing components needed to use alternative fuels in existing engines).
- The impact of this research, in case of positive results in the feasibility study, would be huge. The possibility of using Ammonia for example, would be a game changer in the industry.

2 Background

What's has been done so far regarding the development of innovative fuel injection system.

- Understanding the combustion process in internal combustion engines.
- Optimizing the fuel injection system to improve the combustion process.
- We have always focused on the development of fuel injectors that can handle traditional fuels (gasoline, diesel, etc). They are easy to ignite allowing for an easier design process.
- The use of modern CFD simulations, supported by more powerful computers and experimental data to validate the simulations, may allow us to increase the precision of the modelling and opening the possibility of difficult-to-ignite fuels (such as Ammonia).

3 Research Plan and Methodology

The research plan is divided into three main stages:

1. Feasibility study: supposing that we will be able to design a fuel injector with no constraints, are those alternative fuels feasible to be used in internal combustion engines? What are their characteristics when it comes to ignite them under a controlled environment? → Understand the chemical and physical properties of the alternative fuels and their combustion process.
2. Design and development of the fuel injector: based on the results of the feasibility study, modelling and simulation of diverse fuel injectors designs. → Use CFD simulations to optimize the fuel injector design.
3. Experimental validation: once the simulations are completed, we will build a prototype and test it in a controlled environment. → Compare the experimental results with the simulations. Eventually, rerun CFD simulations to improve the model (and the design).

4 Preliminary Results

A preliminary result would be about a rough estimation of a possible design of the fuel injector.

This implies to have a deep understanding of the chemical and physical properties of the alternative fuels and their combustion process. Given that we don't have such a background in chemistry, nor we have the capability to perform a real CFD simulation, we can only try to replicate the results of the current state of the art just to have a starting point for our research.

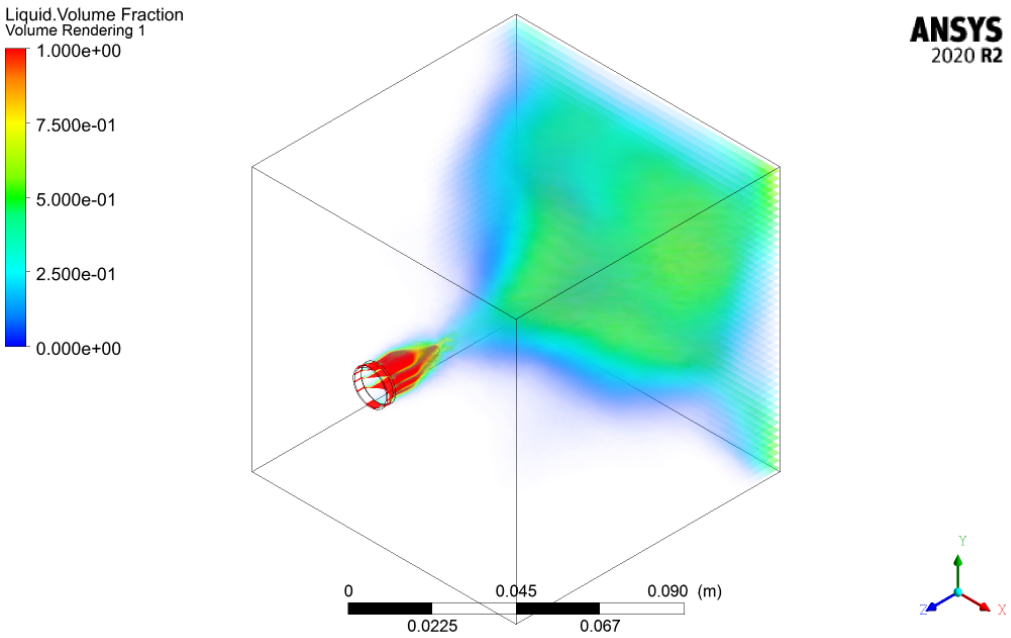

Figure 1: Analysis of a generic fuel injector.

5 Deliverables

The deliverables of this research project are:

- A feasibility study of the use of alternative fuels in current internal combustion engines.
- A new fuel injector design that can handle alternative fuels.
- A set of models and simulations that can be used to optimize the fuel injector design.