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Pavol TARBAJOVSKÝ[1], Michal PUŠKÁR[2]

Supervisor: Michal PUŠKÁR[2]

STRATEGIE ZASILANIA PALIWEM DLA SILNIKÓW SPALINOWYCH MAJĄCE NA CELU ZMNIEJSZENIE EMISJI

Streszczenie: Silnik spalinowy dwupaliwowy wymaga specjalnych (perfekcyjnych) warunków dla zapłonu mieszanki powietrza, co wpływa na wysoką efektywność spalania. Uzyskanie jednorodnych warunków spalania dla mieszanki powietrze-paliwo w całym cylindrze jest jeszcze trudniejsze. Opracowano wiele koncepcji zapłonu na przestrzeni użytkowania silników spalinowych, ale perfekcyjna mieszanina paliwa i powietrza pozostaje istotnym czynnikiem dla większości najbardziej efektywnych akcji zapłonu. Jest to ciągle realnym inżynierskim wyzwaniem. Opracowano szereg koncepcji przygotowania paliwa, przy czym najbardziej powszechnie stosowanymi są idee: zasilanie dwupaliwowe oraz jednopaliwowe. W artykule zdefiniowano podstawowe zasady obu koncepcji, opisując możliwe kombinacje paliw do praktycznego użycia.

Słowa kluczowe: silnik spalinowy, silnik, spalanie, ECU elektroniczny układ sterowania

INTERNAL COMBUSTION ENGINES FUEL STRATEGIES WITH EMISSION FOOTPRINT ELIMINATION AIM

Summary: Dual-fuel combustion engines need perfect, special conditions for igniting the air mixture, which affects high combustion efficiency. Achieving homogeneous combustion conditions of the air-fuel mixture in the cylinder is even more difficult. Many ignition concepts have been developed over the life of the internal combustion engine, but the perfect mixture of fuel and air is essential for the most efficient ignition, which is a real engineering challenge. Several concepts of fuel preparation have been developed, among the most used are the dual-fuel concept and the single-fuel solution. The article defines the basic principles of both fuel concepts, including possible fuel combinations for practical use.

Keywords: internal combustion engine, engine, combustion, ECU, electronic control unit

[1] Technical University of Kosice, Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering; pavol.tarbajovsky@tuke.sk
[2] Technical University of Kosice, Faculty of Mechanical Engineering, Department of Machine Design and Transport Engineering; michal.puskar@tuke.sk

1. Introduction

The most important aspect of a dual-fuel engine is fuel management. Recently, many types and combinations of low and high reactivity fuels have been explored. When burning in this type of combustion, there are two basic fuel strategies: a dual-fuel strategy and a single-fuel strategy. The dual-fuel strategy is based on mixing two different fuels to create differences in reactivity. However, the dual-fuel strategy requires two tanks in the vehicle to store fuel with different reactivity. From this point of view, a single-fuel strategy is more advantageous for vehicles, as there is no need for a second fuel tank. Different fuel reactivity with a single fuel strategy is achieved by adding additives to the original fuel.

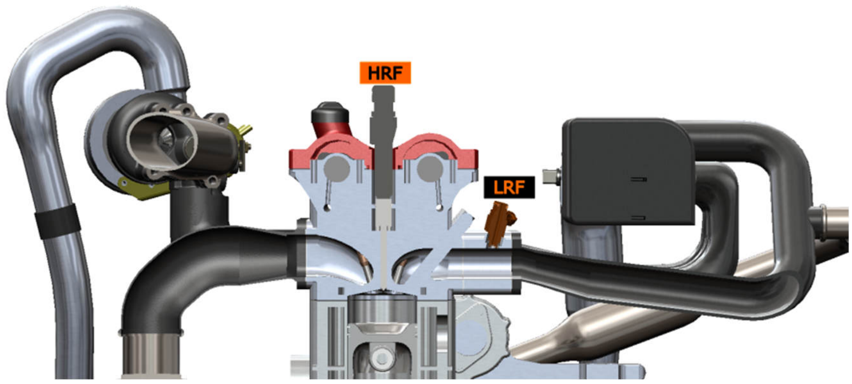

Figure 1. Dual-fuel engine combustion principle

In fig. 1 is a schematic view of the principle of dual-fuel combustion technology, showing where HRF (high reactivity fuel) and LRF (low reactivity fuel) are injected into the combustion process. Low reactivity fuel uses indirect fuel injection that is premixed with air during the intake stroke. HRF (High Reactivity Fuel) is injected into the cylinder by direct injection [1-8].

2. Low reactivity fuel (LRF)

The initial fuels for advanced combustion technology engines are petroleum-based fuels such as gasoline and diesel. It can be said that gasoline is widespread in the market, which is one of the advantages of gasoline for use as an LRF, as well as the wider use of a dual-fuel engine at the moment when engines with this technology are reliable and ready for operation. There are certain problems with petroleum-based fuels, such as problems with a lack of energy when using them, and also the formation of soot when burning gasoline due to its chemical composition (it contains aromatic substances).
NG is also a non-renewable fossil fuel like gasoline. It is primarily a mixture of methane, but NG also includes ethane, nitrogen, propane, carbon dioxide, etc. Compared to gasoline, NG does not contain aromatics. This property is very important because it can suppress soot formation [4]. The price of natural gas in the market is

lower compared to the price of gasoline, and there are natural gas filling stations in a large number of countries. The octane number of NG is higher than gasoline, which means that NG is suitable for engines with a higher compression ratio and can provide a greater reactivity difference in the cylinder of an internal combustion engine. Compared to gasoline, NG has higher calorific values. Alcoholic fuels (methanol, ethanol, isobutanol) can be substituted for the conventionally used fuel (gasoline), as they are renewable. Alcoholic fuels are characterized by a high octane number, which is very suitable for diesel combustion engines. These fuel types reduce knocking and create a greater reactivity gradient. Higher mass heat capacity is another characteristic of alcoholic fuels. This property has an important cooling effect, which lowers the temperature of the mixture in the cylinder. The formation of NOx is linked to temperature, which means that a reduced temperature of the mixture is suitable for reducing the formation of NOx emissions.

3. High reactivity fuel (HRF)

Diesel and biodiesel can be considered as commonly used fuels with high reactivity. Diesel is a petroleum-based fuel and is non-renewable. Biofuels, which can be considered renewable fuels, are used as an alternative to internal combustion engines. By operating combustion engines on biofuel, it is possible to reduce the greenhouse effect, as well as the dependence on oil imports into countries, together with the emissions that combustion engines produce during operation [6]. Biodiesel is usually considered a compound composed of acidic methyl or ethyl esters obtained from vegetable oils or animal fats with properties suitable for use in diesel engines. Diesel engines fueled with biodiesel showed increased NOx emissions due to oxygen contamination. Biodiesel can be used in a dual-fuel system without modifying the engine, which was also proven by experiments [2]. Biodiesel, used as a high-reactivity fuel, has been shown to be more stable during cycle transitions in a natural gas/biodiesel dual-fuel engine. This stability is ensured by the high cetane number and, as mentioned above, biodiesel is an oxygen-based fuel. Compared to an engine powered by NG/diesel with advanced combustion technology, NG/biodiesel provided an increase in gross thermal efficiency of 1.6%.

4. Single fuel with additives conception

The main purpose of using a single fuel with additives in an internal combustion engine with advanced combustion technology is a single fuel tank in a vehicle. LRF is used in this type of fuel injection. The injection strategy is shown in Fig. 2. To obtain the required reactivity gradient, low reactivity fuel was mixed with additives that increase the cetane number and then directly injected into the combustion chamber as high reactivity fuel. Additives that improve cetane number using a single fuel strategy are DTBP (di-tert-butyl peroxide) [3] and 2-EHN (2-ethylhexyl nitrate). So far, gasoline, ethanol, methanol and isobutanol have been used in this fuel strategy for the engine. DTBP was first used in a dual-fuel engine [4] as a cetane number improver in a high-performance engine to demonstrate a single-fuel strategy. Engine operating loads were at 6 and 9 bar IMEP during the experiments. By using a small amount of DTBP, comparable emissions and thermal efficiency can be achieved with a dual-fuel strategy with a combination of gasoline and diesel.

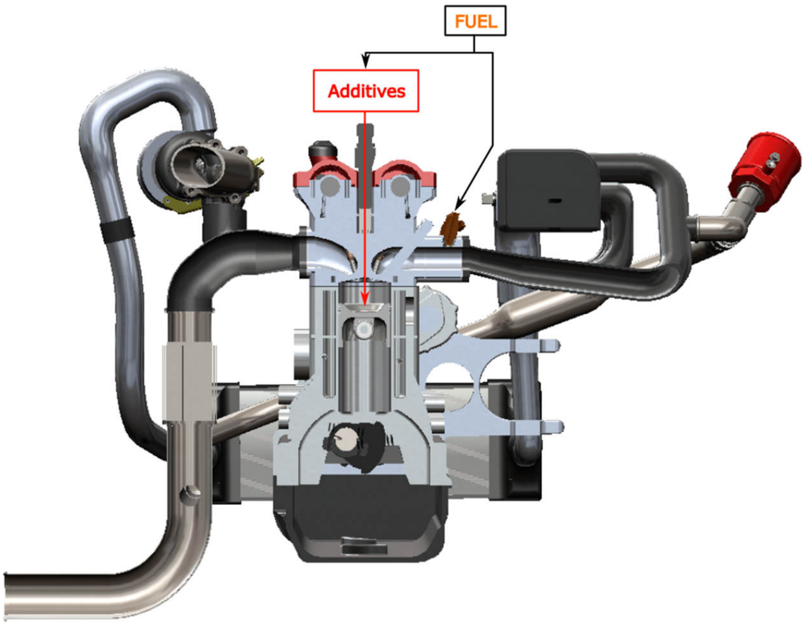

Figure 2. Single fuel strategy with additives

5. Conclusion

Engines with different advanced fuel strategies can be the future of internal combustion engines because they have low emissions of NO, CO, UHC and PM.
Different fuel combinations were mentioned in the text, for example petrol and diesel, petrol and biodiesel or n-butanol/biodiesel. These combinations can be used to achieve the highest reactivity gradient, optimize engine performance and reduce emissions. An interesting concept is also the use of one fuel with additives that are suitable for use in an engine with advanced combustion technology. The overall combustion control is then influenced by many factors such as fuel ratio, EGR rate or compression ratio. The reduction of NOx and soot emissions is mainly achieved by increasing the LRF ratios, which show the importance of the fuel ratio.

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REFERENCES

1. ABD ALLA G., SOLIMAN H., BADR O., ABD RABBO M.,: Effect of injection timing on the performance of a dual fuel engine. Energy Conversion and Management, 2002, 43, 269-277.
2. SAHOO B., SAHOO N., SAHA, U.: Effect of engine parameters and type of gaseous fuel on the performance of dual-fuel gas diesel engines—A critical review. Renewable and Sustainable Energy Reviews, 2009, 13, 1151-1184.
3. AGARWAL A., SINGH A., MAURYA R.: Evolution, challenges and path forward for low temperature combustion engines. Progress in Energy and Combustion Science, 2017, 61, 1-56.
4. PACHIANNAN T., ZHONG W., RAJKUMAR S., HE Z., LENG X., WANG, Q.: A literature review of fuel effects on performance and emission characteristics of low-temperature combustion strategies. Applied Energy, 2019, 251, 113380.
5. MANIGANDAN S., GUNASEKAR P., DEVIPRIYA J., NITHYA, S.: Emission and injection characteristics of corn biodiesel blends in diesel engine. Fuel, 235, 2019, 723-735.
6. CHEN H., SU X., HE J., XIE, B., Investigation on combustion and emission characteristics of a common rail diesel engine fueled with diesel/n-pentanol/methanol blends. Energy, 167, 2019, 297-311.
7. Van NIEKERK A., DREW B., LARSEN N., KAY, P.: Influence of blends of diesel and renewable fuels on compression ignition engine emissions over transient engine conditions. Applied Energy, 255, 2019, 113890.
8. ETIM A., MUSONGE P., ELOKA-EBOKA A.: Effectiveness of biogenic waste-derived heterogeneous catalysts and feedstock hybridization techniques in biodiesel production. Biofuels, Bioproducts and Biorefining, 14, 2020, 620-649.