Analysis of emission footprint for fuel mixtures with renewable component

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ABSTRACT

Introduction: Fossil fuels, which are the main contributors to climate change and global warming, currently have a significantly negative impact on the environment. Fuels with a renewable component can serve as an alternative for the transportation sector in reducing the emission footprint. Among such fuels is bioethanol, which is environmentally friendly and renewable. However, it is essential to continuously conduct research in this field and develop blends of new sustainable fuels.

Material and methods: As part of the study, the emission footprint was analyzed using a test vehicle and experimental fuel blends created by mixing two types of fuels. ELF's E85 fuel stands out in this segment, providing optimal knock resistance and excellent fuel reactivity due to its exceptional Research Octane Number (RON). This fuel allows for optimized ignition timing and enhances the generated performance. The second experimental fuel, unleaded gasoline (UG), complies with the valid European standards EN 228 and is commonly available at fuel stations. The bioethanol content in the blend varied at 50%, 30%, 10%, and 5%. As an experimental model, a motorcycle with a 4-stroke engine and a displacement of 125 cm^3 was used. The engine was tested in an acoustically isolated chamber equipped with a ram air fan supplying air for cooling and engine intake. The chamber also had an exhaust gas extractor to remove emissions from the room. Inside the chamber, there is a Dynojet i250 device capable of transmitting a maximum power of 373 kW. The standby equipment also includes sensors for ambient air temperature, pressure, and humidity. The engine speed measurement is derived from the impulses sent by the Engine Control Unit (ECU) to the ignition coil of the cylinder, with a resolution of 1 rpm. According to the manufacturer, the accuracy of other parameters related to the chassis dynamometer are as follows: timing accuracy of 1 ms; drum speed accuracy of 1/100 mph; rotational speed accuracy of 1/10 rpm. The accuracy of the torque can be estimated at 0.2% of the full torque range, meaning ±2 Nm during steady-state tests conducted using an electric dynamometer. For the emission analysis of the experimental motorcycle, the following driving cycles were used: European type-approval driving cycle (ECE and EUDC). ECE and EUDC consist of urban (ECE) and extra-urban segments (EUDC). The urban segment is divided into two phases: ECE1 (cold-start testing) and ECE2 (testing at normal operating temperature). The complete test begins with four repetitions of the ECE cycle. ECE is an urban driving cycle, also known as UDC. It was designed to represent urban driving conditions, such as those in Paris or Rome. It is characterized by low vehicle speed, low engine load, and low exhaust gas temperature. The Extra Urban Driving Cycle (EUDC) segment was added after the fourth ECE cycle to account for more aggressive driving patterns at high speeds. The maximum speed of the EUDC cycle is 120 km/h. An alternative EUDC cycle was also defined for low-performance vehicles with a maximum speed limited to 90 km/h. Power, torque, and emissions served as metrics used to measure the performance of fuel blends.

Results and discussion: The obtained results provide a comprehensive view of the output power generated at different speeds and fuel combinations. When using a 50:50 blend (E85:UG), more than 6 kW of power was produced at 7500 revolutions per minute. Due to the reduction in biofuel content, the parameters subsequently decreased. A higher concentration of unleaded gasoline (UG) was used, stabilizing the power parameters. The investigation shows that E85 biofuel significantly enhances performance due to its superior chemical composition, containing more oxygen than pure gasoline. Combustion is more efficient. In terms of the emission footprint, compared to pure gasoline, the increasing content of bioethanol reduces carbon dioxide (CO_2) production. Engine revolutions have a fundamental impact on the amount of emitted CO_2.
In terms of NOx production, flame combustion temperature, oxygen concentration, and combustion duration are crucial factors. Based on the experimental results, it is shown that NOx levels are lower in the range of 500 to 3000 rpm, followed by an increase in NOx content after 3000 rpm. All blends of bioethanol and gasoline emit less NOx than regular gasoline.

Conclusions: Considering the types of fuels and engines adapted for their combustion, the most promising fuels or their components are those that will serve as substitutes for conventional fuels. Biohydrocarbons, bioethanol, and biofuel, therefore, have the greatest potential for development. Maximum effort should also be made in the handling of a significant amount of waste biomass. The use of practically any type of biomass as a raw material for biofuel production contributes to a reduction in greenhouse gas emissions compared to conventional fuels. On the other hand, synthetic fuels also have potential for the future.

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