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Exergetic analysis of a spark ignition engine fuelled with ethanol

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ABSTRACT

Exergetic analysis consists in the evaluation of the exergetic balance on experimental data. When applied to an internal combustion engine, exergetic analysis can identify sources of inefficiency and potentialities for utilizing exergy that would be rejected. To perform this analysis, experimental data were acquired for different operating conditions of a spark-ignition engine by using gasohol and hydrous ethanol as fuels. With these data, an exergetic analysis was carried out by evaluating the effects of engine operating parameters on associated irreversibilities. Afterwards, a comparison between the exergetic analyses of hydrous ethanol and gasohol was presented. Finally, first and second law efficiencies were evaluated as functions of engine speed, engine load and air–fuel ratio. Exergy distributions of hydrous ethanol at different conditions and the accounts of exergy losses during engine operations were also evaluated.

1. Introduction

Although the concept of available work, known as technical working capacity, was already developed, Zoran Rant proposed the term 'exergy' to describe it in 1956 [1]. Exergy is defined as the maximum amount of theoretical useful work, which can be obtained when a system comes to thermodynamic equilibrium with its surroundings. Exergy destruction or irreversibilities are accompanied by entropy generation [2–5]. The principal objective of an exergetic analysis is to conceptualize the optimal design for a system [6].

Numerous researchers applied exergetic analysis in order to study Diesel cycles. Subsequently, Lior and Rudy [7] carried out a theoretical exergy analysis for Otto cycles by considering octane as fuel. They suggested ways for minimization of exergy losses in order to improve efficiency. Soon afterwards, researchers applied the concept of exergy analysis for different fuels on spark-ignition engines. Gallo and Milanez [8] executed an exergetic analysis for gasoline and ethanol fuelled engines by using heat release rate model and simulation. The comparative analysis revealed that ethanol fuel has higher combustion efficiency than gasoline. Rakopoulos [9] presented a detailed analysis of exergy losses in the spark-ignition engine as function of compression ratio, ignition time and equivalence ratio. Alasfour [10] carried out an exergy analysis of the spark-ignition engine by using a butanol–gasoline blend. Caton [11] provided a detailed analytical analysis of exergy destruction due to combustion irreversibilities for the combustion of octane. He summarized the effects of pressure, temperature and equivalence ratio on exergy destruction. Hosoz et al. [12] presented an exergetic analysis of a multi-cylinder spark-ignition engine for gasoline fuels of different research octane numbers (RON) by varying engine torque and speed. They concluded that fuels with higher octane ratings for the given range of octane numbers have lower exergetic efficiency. Design and operating parameters have considerable effects on exergy balance during engine operations [13,14]. The exergetic analysis based on simulation presented by Sezer et al. [15] showed that oxygenated fuels have fewer exergy losses than that of isooctane. The exergetic analyses presented by Caton [16,17] for engine operation simulated with different fuels showed similar results. Recently, Kiani et al. [18] used bioethanol–gasoline blends to investigate the effects of inlet charge temperature and spark advance on total exergy of spark-ignition engines.

Ethanol has a long history of being used as an alternative fuel in Brazil [19]. The Brazilian government promoted the production and usage of ethanol as fuel during oil crises in order to achieve energy independence. Consequently, ethanol fuelled cars began to replace the gasoline fuelled cars. This trend was reversed during 1980s due to the fluctuations in supply and demand of ethanol fuel [20]. The flex-fuel vehicles (FFVs) were introduced in 2003 which are capable of running on blends with any proportions of commercially available fuels (i.e., hydrous ethanol and gasohol). Today, FFVs make up the largest share of light duty vehicles in Brazil [21]. The automotive manufacturers are looking for new ways to optimize the efficiency of internal combustion engines while reducing the pollutant emissions. The first law of

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