Application of response surface methodology in optimization of performance and exhaust emissions of secondary butyl alcohol-gasoline blends in SI engine

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Article info

Article history:
Received 21 August 2016
Received in revised form 30 November 2016
Accepted 1 December 2016
Available online 16 December 2016

Keywords:
2-Butanol
Performance
Emissions
RSM

Abstract

Producing an optimal balance between engine performance and exhaust emissions has always been one of the main challenges in automotive technology. This paper examines the use of RSM (response surface methodology) to optimize the engine performance, and exhaust emissions of a spark-ignition (SI) engine which operates with 2-butanol–gasoline blends of 5%, 10%, and 15% called GBu5, GBu10, and GBu15. In the experiments, the engine ran at various speeds for each test fuel and 13 different conditions were constructed. The optimization of the independent variables was performed by means of a statistical tool known as DoE (design of experiments). The desirability approach by RSM was employed with the aim of minimizing emissions and maximizing of performance parameters. Based on the RSM model, performance characteristics revealed that increments of 2-butanol in the blended fuels lead to increasing trends of brake power, brake mean effective pressure and brake thermal efficiency. Nonetheless, marginal higher brake specific fuel consumption was observed. Furthermore, the RSM model suggests that the presence of 2-butanol exhibits a decreasing trend of nitrogen oxides, carbon monoxides, and unburnt hydrocarbon, however, a higher trend was observed for carbon dioxides exhaust emissions. It was established from the study that the GBu15 blend with an engine speed of 3205 rpm was found to be optimal to provide the best performance and emissions characteristics as compared to the other tested blends.

1. Introduction

Energy shortage of fossilized fuel, as well as its adverse environmental impact are given due attention globally. Owing to the unsustainable nature of fossilized fuel, its rapid depletion and overdependence must be addressed immediately [1–3]. Moreover, the utilization of these conventional energy resources, mainly in transportation areas, has led to major environmental side effects [4,5]. This trend of energy consumption is envisaged to continue in the near future [6]. The emission of greenhouse gases (GHG) namely carbon dioxide (CO2), nitrogen oxides (NOx), carbon monoxides (CO), and unburned hydrocarbon (HC) are of interest as it affects the earth’s climate change [7]. As the utilization of fossilized fuel is deemed to be the primary contributor of the aforementioned GHG, the research community as a whole are continuously investigating on the search for cleaner alternative fuels such as alcohol, bio-diesel, and vegetable-oil [8–10]. These alternative energies are fundamentally environmental-friendly; however, they are still required to be evaluated in terms of engine performance and emission characteristics [11].

Transportation is one of the leading causes of environmental problems in almost every part of the world [12,13]. Furthermore, it is expected that the number of vehicles, especially cars, and light trucks, are to increase to up to 1.3 billion by 2030 and to over 2 billion vehicles by 2050 [14]. In order to facilitate the effort for a better environmental condition throughout the world, the European Union (EU) have pledged that by the year 2020, 20% and 10%, of its transportation fuels and energy supply, respectively must be replaced by renewable resources [15]. For spark-ignition (SI) engines, alcohol is considered one of the feasible solutions for fuel substitution [16]. This is because the presence of excess oxygen in alcohol allows gasoline fuels to produce better engine combustion