Energy 174 (2019) 1121–1132

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Model of water injection process during closed phase of spark ignition engine

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ARTICLE INFO

Article history:
Received 17 September 2018
Received in revised form
24 January 2019
Accepted 6 March 2019
Available online 9 March 2019

Keywords:
Model thermodynamics
Two zones
Water droplet evaporation
Water injection
Pressure
Mass fraction burned

ABSTRACT

In the continuous quest for increased efficiency and reduced environmental impact in the use of internal combustion engines (ICEs), water injection has historically been one strategy used to achieve these objectives. However, practically all of the investigations carried out in this field are experimental tests in which water is injected into the air or combustible air mixture prior to entering the cylinder. The research presented in this paper demonstrates the results of a thermodynamic model simulation of two zones, which integrates the water injection directly into the combustion chamber. The model allows for prediction of the performance parameters of an ICE that uses water injection, as it adequately interprets the injection process phenomenology during the closed phase and the performances of important operating parameters. The model is validated by comparing its results to those reported by experimental research, using the same proposed water injection methodology and gasoline as fuel. The proposed simulation model offers significant flexibility, as it can be used to simulate different engine geometries, rotation speeds and fuels such as gasoline, ethanol, hydrated ethanol or mixtures thereof, in varying proportions. In addition, it provides a starting point for the implementation of a turbo charge and direct fuel injection model, which would allow the simulation of devices representing the current trend in the use of ECI. The results of the comparison between the experimental and simulated data show maximum error percentages of 11% in the case of BSFC, for different percentages of mass of water injection with respect to the mass of fuel, which shows the promising development of the model.

1. Introduction

Throughout the history of the development of energy conversion by means of combustion, the concept of water injection has emerged frequently. One of the first references using water as an auxiliary technique for combustion control can be traced back to around 1791, in a gas turbine patent [1]. Injecting water into the gases produced by combustion was proposed as a means of protecting the turbine back section. This principle was implemented in initial gas turbine developments [2]. While solid fuels began to be replaced by liquids during the second half of the 19th century, steam was introduced as a means of improving the atomization of these new fuels.

In addition to boilers and turbines, the inclusion of water by means of injection techniques is also associated with the development of internal combustion engines (ICEs). Bertrand Hopkinson used this concept around 1913 in the development of power plants that used water as a cooling agent [1]. Although Hopkinson's idea was not new, at the time, he was the only one who managed to implement it effectively and with success. Not long after World War I, water and methyl-ethyl-water blends were used to increase the performance of Otto cycle engines [3]. However, in 1922, fuel-soluble antiknock agents were discovered and developed. These investigations, along with the high costs and complexity of water storage systems and mixtures with alcohols, discouraged the use of such substances in automobile engines at the time.

Before and during World War II, the development of supercharged engines for airplanes renewed interest in the injection of water and alcohol into the ICE [3]. The strong tendency for detonation and overheating limited overfeeding and implementation of a higher compression ratio at high operational loads. With the use of water/alcohol emulsions, ice formation was avoided and

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https://doi.org/10.1016/j.energy.2019.03.037
0360-5442/