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ScienceDirect

Procedia Engineering 206 (2017) 305–311

Procedia Engineering

www.elsevier.com/locate/procedia

International Conference on Industrial Engineering, ICIE 2017

The Numerical Study of Compressed-Air Atomizer for Spark-ignited Jet Fuel Engine

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Abstract

There is increasing interest in the aircraft engine with spark ignition, which is capable of working using jet and diesel fuel. The reason is that the engines with spark ignition have a lower specific weight unlike diesel engines. The working process of the spark ignition engine which can operate on heavy fuels at the compression ratio of a base engine was described in our previous works. The operating cycle of this engine is implemented by the use of a compressed-air atomizer (CAA) in combination with a spray-guided concept. An ignition system has a traditional design and discharge parameters characteristic of gasoline engines. This paper presents a zero-dimensional mathematical model of the processes occurring in a CAA. The model verification is presented.

Keywords: multifuel stratified-charge engines; compressed-air atomizer; jet fuel; spark ignition engine; spray-guided concept.

Nomenclature

CAA	compressed-air atomizer

1. Introduction

The studies, related to the development of engines that can run on different fuels, were always of interest. In recent years this interest is related to "Single Fuel Forward" policy of US Department of Defense. According to this policy, it is recommended to use diesel fuel and jet fuel as the fuels for the US Army (jp-5, jp8) [1,2].

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Peer-review under responsibility of the scientific committee of the International Conference on Industrial Engineering.
10.1016/j.proeng.2017.10.478

Existing multifuel engines have certain shortcomings. The main drawback of the traditional multi-fuel diesel engines is a high specific weight due to the need to use very high compression ratio (17 to 24) [1]. The main disadvantage of multi-fuel engines with spark ignition is a high fuel consumption at high loads when low-octane fuels are used, which is explained by the need of low compression ratio application (around 7.4) [3].

It is reasonable to create a multifuel engine that combines the fuel efficiency of diesel and a low specific weight of an engine with spark ignition. This was managed to perform in the framework of the operating cycle of multifuel stratified-charge engines [4-10]. A long-duration spark discharge was used in these processes for different fuel ignition.

But the ignition in a multifuel stratified-charge engine is desirable to produce by the ignition system, which has a structure and discharge parameters characteristic of engines with spark ignition. Despite the fact that such an ignition was managed to implement in practice (Orbital combustion process is one example of it [11]) to perform the not-knocking combustion it is necessary to reduce the compression ratio relative to the engine variant running on gasoline

The processes of mixing and combustion for a multifuel stratified-charge engine that would solve this problem is being developed on the department of internal combustion engine in Ufa State Aviation Technical University. The operating cycle of this engine is implemented by the use of compressed-air atomizer (CAA) in combination with a spray-guided concept. Diesel fuel, jet fuel, low octane gasoline, and wet ethanol are considered as the fuels which the engine with developed processes should consume. The possibility of ignition and combustion of heavy fuels without detonation was confirmed experimentally in our previous studies [12,13]. However, the issues relating to the processes in the CAA were covered poorly. This paper presents the mathematical model of these processes.

2. Injection system description

Fig. 1a demonstrates the scheme of CAA design. Fuel with a small amount of air enters the CAA working chamber 2, where a preliminary stage of mixing takes place: heating, breaking, mixing and partial vaporization of fuel. The swept volume of CAA makes about 2.5% of an engine swept volume. The CAA piston 1 is driven by an engine crankshaft. When the pressure is sufficient to overcome a nozzle needle spring force, the injection of a fuel-air jet 5 takes place into an engine combustion chamber where a fuel-air mixture is finally formed. The CAA is equipped with the necessary devices for fuel metering. An ignition system has a traditional design and discharge parameters characteristic of gasoline engines.

3. Mathematical model

The conditions of a CAA working chamber are such that the pressure at the end of compression substantially exceeds the critical values of the components included in fuels for automotive internal combustion engines. The volume fractions of a liquid phase and a vapour phase have similar values. Under such conditions, a vapour phase must be considered as a real solution not as an ideal gas mixture (fuel and air). The liquid phase should also be considered as a real air-fuel solution.

Two extreme states of coexisting phases were taken as a basis:

1. The model of thermodynamic equilibrium of heterogeneous systems.
2. There is no heat and mass transfer between phases. The pressures in the phases are equal, there is no slipping of phases.

One of the main areas of vapor-liquid equilibrium mathematical modeling at high pressures is the application of uniform state equations to describe the properties of coexisting equilibrium phases [10,15]. The use of a state equation gives the opportunity to address these challenges on the basis fugacity (f) equality provisions of each mixture component in coexisting phases [15]: