Accepted Manuscript

Study on flame-vortex interaction in a spark ignition engine fueled with methane/carbon dioxide gases

Xin Zhang, Tao Wang, Jian Xu, Shizhuo Zheng, Xiaosen Hou

PII: S1743-9671(15)30474-8

DOI: 10.1016/j.joei.2016.09.005

Reference: JOEI 272

To appear in: *Journal of the Energy Institute*

Received Date: 25 December 2015

Revised Date: 20 September 2016

Accepted Date: 26 September 2016

Please cite this article as: X. Zhang, T. Wang, J. Xu, S. Zheng, X. Hou, Study on flame-vortex interaction in a spark ignition engine fueled with methane/carbon dioxide gases, *Journal of the Energy Institute* (2016), doi: 10.1016/j.joei.2016.09.005.

Study on flame-vortex interaction in a spark ignition engine fueled with methane/carbon dioxide gases

Xin Zhang, Tao Wang*, Jian Xu, Shizhuo Zheng, Xiaosen Hou
Department of Power Mechanical Engineering, Beijing Jiaotong University, Beijing 100044, PR China

Abstract

A numerical study on the in-cylinder flame-vortex interaction of gaseous spark ignited engine fueled with methane/carbon dioxide is carried out by means of large-eddy method. Evolution of in-cylinder turbulence in charge phase and flame-vortex interaction during combustion process are analyzed in great detail. It's found out that the large scale coherent structures are transformed into homogeneous small scale vortexes during the intake and compression stroke. The strong vortex cores are generated by interaction between flame and in-cylinder background turbulence. Those generated vortex cores wrinkle flame surface and augment turbulent flame speed. The contra-rotation between the two vortexes of vortex-pair in the unburned area results in the appearance of large scale flame wrinkles, which is because the vortex-pair movement leads to the local entrainment and hence stretch of the flame surface. With the increase of volume fraction of carbon dioxide in the gases, the turbulent flame speed is decreased, the effect of vortex pair on the flame structure is weakened, and the level of the flame wrinkling is decreased correspondingly.

Keywords: IC engine, methane/carbon dioxide, flame-vortex interaction, Large-eddy simulation

1. Introduction

In recent years, the natural gas has been known as the high quality gaseous fuel. However, with the increasingly prominence of the energy crisis, several gaseous fuels such as biogas are becoming the research focus of new alternative energy fuels. The concentration of methane in these fuels is relatively lower and non-hydrocarbon gases are with a higher level in general. The biogas is composed by 40%-60% methane, 40%-60% carbon dioxide [1]. The value of biogas is lower compared with the natural gas. One attractive feature of biogas is that it can be produced close to the consumption points and hence is ideal for decentralized power generation in remote rural areas. The biogas is more suitable for the spark ignited (SI) engine with a high compression ratio because it has an extremely low energy density, low flame velocity and not so wide flammability limits on account of its high carbon dioxide content [2]. The challenges of using these gases as the engine fuel are the lower heat release rate and the unstable combustion, which lead to much lower engine efficiency and higher cyclic variation. The combustion of biogas in engine is much more like a combination of larger portion of EGR and natural gas. Low laminar flame speed is the crucial factor. Therefore, some experimental studies struggled to augment turbulent flame propagation through adding hydrogen in order to improve power output and performance [3][4] However, combustion stability is still a problem there. How to improve the combustion stability of the biogas fueled engine is of great significance for the clean fuel engine development. The inherent factors for combustion stability should be researched.

Based on the research of the SI engine cyclic variation causes and the influence factors, Ramos et al. [5] proposed that small scale turbulent structures and their impact on the mixing process of the reactants lead to the growth of the unstable flame kernel, while the large scale turbulent structures affect the surface area of the flame front. Multi-cycle simulations of IC engines using large-eddy simulation become popular because of huge advancements in parallel computing. Vermorel [6] and

* Corresponding author. Department of Power Mechanical Engineering, Beijing Jiaotong University, Beijing 100044, PR China Tel.: +8601051688404
E-mail address: icetwang@126.com (Tao Wang).