Proper Orthogonal Decomposition Analysis of Cross Sectional Fuel Spray Data

Santosh Tirunagari*, Tuomo Hulkkonen, Ville Vuorinen, Ossi Kaario, Martti Larmi
Aalto University, School of Engineering, Espoo, Finland
(santosh.tirunagari, tuomo.hulkkonen, ville.vuorinen, ossi.kaario, martti.larmi)@aalto.fi

Abstract

In the present study, we analyse laser sheet spray imaging data using Proper Orthogonal Decomposition (POD). The analysis sheds light into the spray structures including spray-vortex interaction. The analysis of these structures is essential in understanding the fundamentals of spray characteristics. We study the influence of injection pressure on spray formation. Two different cases are considered corresponding to 450 bar, and 1000 bar injection pressures. The POD analysis reveals that the spray images can be decomposed into a set of orthogonal basis functions which provide more insight to the structures seen by bare eye. The effect of injection pressure is coherently explained with the POD modes. In particular, with the increase in pressure, might lead to better mixing in sprays. Furthermore, the sensitivity analysis of the POD modes reveals that the present conclusions are independent of the number of spray images for considered ensembles.

Introduction

Mixing of fuel droplets and air in diesel engines determines the quality of mixture. Thereby spray formation has a strong impact on emissions and efficiency in a particular engine. Hence the study of the spray formation is of great importance. To gain a deeper understanding on combustion process and mixing of fuel droplets and air, machine-learning methods can be utilised. Such a field include, Proper Orthogonal Decomposition (POD), a linear data transformation method. The POD modes can be considered to be energetically the optimal decomposition for the flow. Only a few POD modes are required to capture the large scale structures in sprays. In order to study about the inter connections among POD modes, POD mode coefficients can be utilized. The relationship between the two modes is the scatter plot of the two POD mode coefficients. The circular distribution in the scatter plot reveals strong connection between the two POD modes [1].

Results and Discussions

The spray images for different injection pressures corresponding to 450 bar and 1000 bar of pressure is decomposed into set of orthogonal basis functions using POD, called POD modes. From Figure 1, 450 bar pressure clearly has more energy when compared to 1000 bar pressure. The presence of high energy is related to the presence of large scaled structures. These large scaled structures in the POD modes reveal poor mixing.

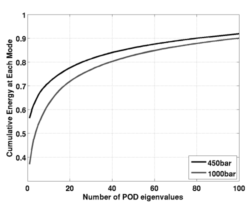

Figure 1. Cumulative energies.

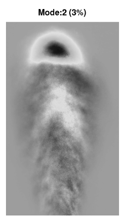

Figure 2. pressure = 450 bar.

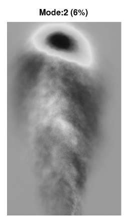

Figure 3. pressure = 1000 bar.

From Figure 2 and Figure 3, POD mode 2 reveals a coherent structure with greater intensity fluctuations near the tip region of the spray for both the injection pressures. This phenomenon is due to the spray to spray variations. A tilt in the tip penetration is observed for 1000 bar injection pressure. This possibly indicates a swirl caused in the spray. The Comparison of the two injection pressures is presented in the full paper.

References

[1] Meyer, K.E. and Pedersen, J.M. and Ozcan, O. A turbulent jet in crossflow analysed with proper orthogonal decomposition. Journal of Fluid Mechanics, 583 , pp 199-227 doi:10.1017/S0022112007006143

*Corresponding author: santosh.tirunagari@aalto.fi