Chapter 19

Combustion Instability Analysis Using Wavelets in Conventional Diesel Engine

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ABSTRACT

Combustion instability affects the drivability, power, engine performance and efficiency. Elimination of combustion instabilities leads to increase in power for the same fuel economy. Effective controller can reduce combustion instabilities by understanding patterns in the cyclic variations. In this study, cyclic variations of combustion parameters were analyzed in a diesel engine using wavelet analysis. The experiments were conducted at varying loads and compression ratios at 1500 rpm. At steady state condition, cylinder pressure data of 2000 consecutive combustion cycles was measured. Continuous Wavelet Transform was used to capture non-stationary or transient features that might not have been detected using other transforms. Wavelet Power Spectrum (WPS) and Global Wavelet Spectrum were further used to determine the relationship between fluctuations in combustion parameters. Contour Plots were plotted based on WPS for visualizing the intensity and frequency of cyclic Variations. It was found that cyclic variability decreases with increase in engine load and compression ratio.

INTRODUCTION

The internal combustion (IC) engine is the key to the development and existence of modern society. Without the transportation by the millions of personalized vehicles on road and at sea, human society would not have reached the current living standards (in terms of physical facilities). Majority of combustion engines working in vehicle are reciprocating piston engines operating on combustion of fossil fuels. Mainly two types of reciprocating engines (compression ignition and spark ignition) are widely used by automotive industry. Due to economic growth and increase in energy requirement, the number

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of engines (stationary and automotive) are increasing, which leads to higher fuel consumption and emissions. To reduce increasing emissions and meet the stringent emission requirement, efficient combustion control and after treatment technologies are required by industry. To design effective controller, nature and deterministic characteristics of combustion instabilities are needed. Main objective of this chapter is to understand the cycle to cycle variations in combustion using wavelets.

Combustion process in IC Engines are governed by various engine operating conditions and parameters such as engine load, speed, fuel-air properties, flow characteristics of the fuel air mixture in the cylinder, residual gas mixture, intake pressure and temperature etc. High cycle to cycle variations can be observed by even small variation in these factors depending on engine combustion mode. Cycle to cycle variations in combustion leads to undesirable affects on engine efficiency, power, and drivability and also affects the combustion noise (Heywood, 1988). Therefore it is important to characterize and control the cyclic variations in combustion process in IC engines. This chapter is mainly to understand the characteristics of cyclic variations in conventional compression ignition engine and accordingly develop the strategies to control cyclic to cycle variations.

Cycle to cycle variations is higher in spark ignition engine in comparison to compression ignition engines. The flame development and propagation have higher variations due to variations that are always present in the charge motion and flow which influences the flame growth and resulting in large cyclic variation in spark ignition engines (Heywood, 1988). Various researchers have analyzed the cycle to cycle variations in SI engines using statistical and chaotic methods (Ball, Raine, & Stone, 1998; Barton, Kenemuth, Lestz, & Meyer, 1970; Chen & Krieger, 1976; Ozdor, Dulger, & Sher, 1994; Peters & Borman, 1970; Stone, Brown & Beckwith, 1996). However comparatively lower number of published papers are available on cyclic variations in diesel engine. Few researchers (Sagdeo, 1987; Strahle, 1977; Wolschendorf, Dürnholz, & Schmilden, 1991) have shown the relation between combustion randomness and the noise generated by these engines. Cycle to cycle variations in cylinder pressure of diesel engines has been reported in few early studies (Koizuml, Gyakushi, & Takamoto, 1977; Sczomak & Henein, 1979; Wing, 1975). Recently researchers have focused their attention to characterize the cycle to cycle variation in diesel engines due to stringent emission regulation and environmental concerns (Ajoyvalasit & Giacomini, 2003; Boguś & Merkisz, 2005; Macián, Luján, Guardiola, & Perles, 2006; Sen, Longwic, Litak, & Górski, 2008; Sen, Litak, Taccani, & Radu, 2008).

Wavelet transform provides good temporal as well as spectral resolution and therefore wavelets can be employed to estimate the magnitude as well as periodicities of cyclic variations in engines. Sen et al. (2008) demonstrated the use of continuous wavelet transform (CWT) to analyze the cycle to cycle variations at different engine speeds. They found that the cyclic variation decrease with increase in engine speed due to higher piston velocities which makes swirling more effective and enhance the combustion process. Few researchers have also used CWT to investigate the cycle to cycle variations in diesel engines (Ajoyvalasit et al., 2003; Boguś et al., 2005; Macián et al. 2006; Sen et al., 2008). Sen et al (2011) have applied CWT in SI-HCCI engines, which is considered alternative engine combustion mode. Recently Ali et al (2015) in their investigation of cyclic variability of alcohol addition to biodiesel have also made use of CWT. These studies have not explored the effect of compression ratio (CR) on cycle to cycle variations. In present study effect of compression ratio and engine load on cycle to cycle variation is investigated.