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Advanced modelling of the CR apparatus, design of innovative injection system architectures and assessment of new strategies for the injected mass control and combustion noise evaluation in diesel engine

By

Zhiru Jin

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Supervisors:
Prof. Alessandro Ferrari

Doctoral Examination Committee:
Prof. Zhijun Wu, Referee, Tongji University
Prof. Antonio Garcia Martinez, Referee, Universitat Politècnica De València
Prof. Tommaso Lucchini, Referee, Politecnico di Milano
Prof. Giacomo Falcucci, Referee, University of Rome "Tor Vergata"

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Abstract

The Common Rail (CR) fuel injection system has been introduced into the market for ages and the investigation has been continuously carried out. CR apparatus enables to achieve high nominal pressure and various injection strategies and it has been considered as a key for the further development of modern diesel engines. The investigation of the CR system has been put forward in different aspects: pressure and injected mass control strategies, innovative system layout and the pollutant emissions improvement, etc.

In this study, the diesel CR system control has been investigated. A previously developed numerical model pertaining to the proportional-integrative-derivative (PID) controller and the pressure control valve of a CR system (electronic, electrical, hydraulic and mechanical aspects were considered) has been validated and optimized. Parametric analyses on the PID controller parameters have been conducted under different working conditions. Moreover, the effect of the accumulator size on the rail pressure time history has been studied when the rail volume is dramatically reduced and it suitable solutions for a fuel injection system without rail have been determined.

With regard to the system layout, an innovative Common Feeding (CF) fuel injection system without rail has been developed for a light duty commercial vehicle diesel engine. In the CF apparatus, an additional delivery chamber is mechanically fit at the high-pressure pump outlet and the rail is removed from the hydraulic circuit. The benefits pertaining to the CF system are the low production costs, the easier engine installation and the prompter dynamic response during transients. Experimental tests have been performed on the test bench with different accumulation volumes integrated at the pump delivery for various injection strategies. In general, the injection performance of the fuel injection system did not vary significantly when the pump delivery changed volume or its shape was modified. In addition, an injection system

numerical model has been developed and validated in order to study the reduced accumulation volumes lined phenomena.

As far as the injected quantity control strategy is concerned, an estimation method of the injected mass based on time-frequency analysis has been proposed for a passenger car CR injection system. The injector inlet pressure time history measured by means of a pressure transducer has been processed with the short time Fourier transform (STFT) technique in order to realize a virtual sensor of the injector needle. The injection temporal length (ITL) has been obtained by identifying the SOI (start of injection) and the EOI (end of injection) of the injection. A correlation between the ITL and injected mass has been determined at different nominal pressures and it has been discovered that it is independent of the fuel tank temperature variation. Therefore, the injected mass can be calculated by means of the above correlation and the estimation of the ITL with the TFA based virtual sensor features an overall accuracy below 2mg.

With regard to the combustion noise modelling, an innovative algorithm based on the time-frequency analysis technique has been developed to calculate an instantaneous combustion noise. The input parameter is the in-cylinder pressure signal, measured on a Euro 5 diesel engine during the combustion process, and the quantitative contribution pertaining to the different combustion phases has been evaluated. The algorithm for the evaluation of the instantaneous combustion noise contribution has been realized through a home-made tool and single and multiple injection strategies have been considered. The time-frequency analysis enables to identify detailed information on the contribution of the various combustion phases and the causality relationship between the injection schedule and combustion noise could be obtained.

Keywords: Common Rail, system control, Common Feeding, time-frequency analysis, injected mass, combustion noise.