STUDIES ON SIMULATION OF FUEL INJECTION, COMBUSTION, AND GAS EXCHANGE PROCESSES IN A DIESEL ENGINE

Thesis submitted to the
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ABSTRACT

The present work was aimed at the development of detailed simulation models for fuel injection, combustion and gas exchange processes in a direct injection turbocharged engine. The need for this work was particularly felt by the author's organisation (Indian Railways) while embarking upon a project to develop a highly rated locomotive engine. An exhaustive review of the available simulation techniques concerning various processes has been presented to put into perspective the current state of development as also to chalk out the strategy for the present investigation.

With a view to appreciate the effect of various assumptions and also to arrive at a suitable method of solution, two versions of the fuel injection model, viz., FINJ1 and FINJ2 were developed. In FINJ1, the aim was to keep the model relatively simple for general application. In this model, the equations of unsteady flow in the high pressure pipe have been solved by using the explicit finite difference method (Knight's scheme). The boundary equations at the pump and nozzle ends have been solved by using the Newton-Raphson and iterative methods. An attempt to calibrate and validate the model has been made with the help of test data obtained by the author as well as with information from other sources. After ascertaining the validity of model, detailed parametric studies were undertaken to predict the influence of important fuel injection parameters on the performance of the injection

system. The model includes the analysis of both pintle and orifice type nozzle. In model FINJ2, an attempt has been made to refine the analysis with a view to appreciate the effect of various assumptions and also to develop alternative methods of solution. In addition to the method of characteristics, Lax-Wendroff two step and Leap-Frog schemes have been used to solve the unsteady flow equations. The boundary equations have been solved by using the iterative and Newton-Raphson methods. A limited effort was also made to assess the suitability of other methods like Predictor-Corrector and Runge-Kutta methods for solving the boundary equations. This model also takes into consideration the effect of variation of bulk modulus and density of fuel oil, convective terms in the unsteady flow equations, and the variation of pressure in the feed chamber.

For combustion calculations, the aim was to develop firstly a simple combustion model which could be used for general performance calculations and subsequently a more detailed model to enable appreciation of actual combustion process effects. Also, it was envisaged that the model should be capable of being extended for predicting emissions. Based on the burning laws proposed by Whitehouse and Way, two models, viz., single zone and two zone, have been developed. The two zone model is suitable for a quiescent type combustion chamber as the effect of swirl has been neglected.

The two zone model has been used to investigate the effect of a few relevant parameters like injection timings, duration of

injection, number of orifice holes etc. Also, the predicted results of the two zone model have been compared with those of the single zone model.

The gas exchange model has been formulated for a single cylinder engine with a straight exhaust pipe. In this model, both the method of characteristics and Leap-Frog finite difference schemes have been used to solve the unsteady flow equations. While using the method of characteristics, the unsteady flow equations have been solved in terms of A and U instead of the Reimann variables. The various boundaries investigated include gradually opening valve, closed end, open end and nozzle. The boundary equations have been solved by using both the iterative and Newton-Raphson methods. For validation of the models, a single cylinder tractor engine was used to measure the transient pressures in the cylinder and exhaust pipe.

An overall cycle calculation program to predict the performance of the locomotive engine has been synthesised. In this program simple analytical functions have been used to represent the characteristics of compressor and turbine. The above program has been used to study some aspects of the existing and uprated versions of the turbocharged locomotive engine.

CERTIFICATE

This is to certify that the thesis entitled 'Studies on Simulation of Fuel Injection, Combustion and Gas Exchange Processes in a Diesel Engine' being submitted by Krishan Kumar to the Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy in Mechanical Engineering, is a record of bonafide research work carried out by him. He has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has reached the requisite standard.

The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for any degree or diploma.

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CONTENTS

CONTENTS (CONTD.)

CONTENTS (CONTD.)

CONTENTS (CONTD.)

CONTENTS (CONTD.)

CONTENTS (CONTD.)