SOME ANALYTICAL INVESTIGATIONS ON A FOUR STROKE DIESEL ENGINE FOR ACHIEVING HIGH SPECIFIC OUTPUT

by

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C E R T I F I C A T E

We are satisfied that the thesis entitled "Some Analytical Investigations on a Four Stroke Diesel Engine for Achieving High Specific Output" presented by Shri Jagdish Kumar Sharma is worthy of consideration for the award of the degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under our guidance and supervision and that the results contained in it have not been submitted in part or full to any other university or institute for award of any degree/diploma.

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A B S T R A C T

The specific output of diesel engines is increasing continually through higher and higher degree of turbocharging. Experimental investigations in the past have indicated the feasibility of achieving very high specific outputs with high boost pressures while controlling the peak pressures to a level determined by the strength of the materials used. To do this, measures like reduction of geometrical compression ratio or use of Atkinson Cycle have been suggested. These measures, when adopted beyond a certain level, result in poor starting and part load characteristics, increased ignition delays and general deterioration of the combustion process. Possible methods to remedy the situation are: use of variable compression ratio, multiple introduction of fuel, and controlling timing and rate of injection etc. Needless to mention that charge cooling is being invariably used to augment the gains of turbocharging at high boost pressures.

The present work aims at investigating through an analytical approach, some of the aspects of high output operation using alternative modes as mentioned above. A brief review of various schemes suggested in the past alongwith the associated problems and proposed remedies has been presented with a view to identify more promising alternatives of achieving high specific output, and to indicate some of the important aspects amenable to an analytical study using cycle

simulation.

To make a generalised analysis possible and to keep it tractable, main emphasis in the present investigation has been laid on the engine proper and the effects of turbocharger matching etc. have been excluded by assuming equal inlet and exhaust pressures under all conditions of operation. However, variation of compressor characteristics, viz. boost pressure ratio and efficiency, with engine load has been incorporated in the analysis in a simplified manner.

Simple semi-empirical models suitable for system-oriented studies have been selected for simulating the basic engine processes. Combustion phase has been represented by single zone model, and to assess thermal loading of major engine components, one-dimensional conduction heat transfer through component walls is assumed. These models could be calibrated with easily obtainable experimental data. Further, the analysis has been developed to include the effect of special measures, viz. variable compression ratio operation, Atkinson Cycle Operation, alternative shapes of rate-of-injection diagrams and pilot injection.

A computer program 'HODE' has been developed by synthesising above models to obtain the performance characteristics of a four stroke diesel engine under altrenative modes relevant to high output operation. While using this program for studying the effect of alternative shapes of rate-of-injection diagrams on high output performance, it was appreciated that a simple fuel injection simulation model would also be useful to identify what combination of fuel injection system parameters resulted in a particular shape of rate-of-injection diagrams. Consequently, a simple computer program 'FINJ' has also been written to predict rate-of-injection diagram from the given geometrical data of fuel injection system.

For calibration of models used for predicting rate of heat transfer, rate of heat release, engine friction, rate-of-injection diagram etc., experimental data has been obtained on two test rigs, viz. Engine rig and fuel-injection rig. Test runs have been conducted on a four stroke, high speed, direct injection, air-cooled, automotive diesel engine under naturally aspirated conditions. The fuel-injection rig has been used to obtain rate-of-injection diagrams at various rack settings and speeds.

The cycle simulation program has been used to conduct a systematic performance analysis of the effectiveness of various alternative measures adopted for achieving higher and higher specific output levels, starting from the naturally aspirated mode, e.g.

(a) Simple supercharging and supercharging with aftercooling when applied to engine having normal compression ratio.

(b) Supercharging and aftercooling with reduction in geometric compression ratio.

(c) Supercharging and aftercooling with reduction in effective compression ratio through the variation of timings of closure of inlet valve (as in Atkinson Cycle).

(d) Supercharging and aftercooling with variable compression ratio operation.

(e) Supercharging and aftercooling with low compression ratio and alternative shapes of rate-of-injection diagrams such as isosceles triangle, trapezoidal, rectangular etc.

(f) Part load performance at low compression ratios using pilot injection.

Full load studies are conducted with certain selected limiting values of peak cylinder pressure (viz. 105 and 135 kgf/cm^2) and air-fuel ratio (18.0) to give the maximum values of BMEP obtainable for a particular mode. The part load studies with alternative modes such as using low compression ratio, variable compression ratio, pilot injection etc. give further insight into the problem areas of high specific output engines and the effectiveness of some of the remedial measures suggested to combat these problems over the complete load range. Typical investigations concerning effect of timing of injection and alternative shapes of rate-of-injection diagrams provide some appreciation of the role of fuel injection characteristics in determining satisfactory engine performance. In addition, a few typical results as obtained from the fuel injection simulation program 'FINJ' have also been given.

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