Unsteady Interaction of Turbocharger Compressor with IC Engine

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INTRODUCTION

Growing global concern pertaining to climate change has meant that engine development has become more focused on engine emissions. A method of reducing the emissions of an internal combustion (IC) engine is to use smaller engines but recover power lost due to reduction in size by using a turbocharger or supercharger.

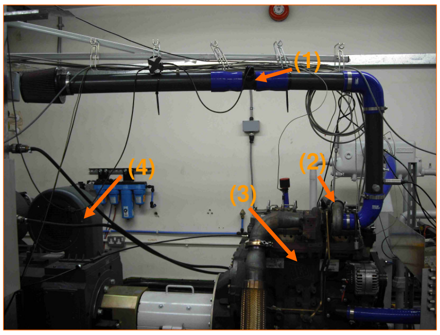
To ensure that a turbocharger is appropriate for a given engine it has to be matched correctly. This process is called turbocharger matching. Turbocharger matching ensures that the compressor is providing sufficient air to the engine over a wide range of operating conditions.

Currently compressors are mapped by carrying out controlled experiments which put limits on its applicability to real world situations

EXPERIMENTAL SETUP

The operating conditions of the compressor were analysed on a state of the art test bed. This test bed uses a 4 cylinder 4.4L diesel engine and is equipped with a high speed data acquisition system to examine the flow characteristics. A sampling frequency of 69444Hz was used to ensure that all time dependant phenomena could be analysed.

The mass flow of air was measured using a hot film mass flow meter was placed in the flow upstream of the compressor.



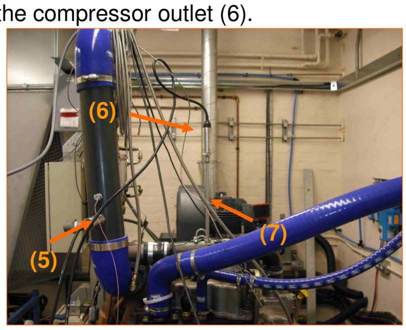
Left: Picture shows engine test facility. The labels (1), (2), (3) and (4) show the orientation of the air mass flow meter, the compressor, engine and dynamometer respectively.

The dynamometer is capable of handling a maximum torque of 500Nm and maximum speed of 5000rpm. This means that the test facility is ideally suited for testing on low to medium capacity engines.

Pressure measurement across the compressor is an essential parameter when determining the operating conditions of compressor and engine. The setup is equipped with highly sensitive pressure transducers were used with an accuracy of 0.04%.

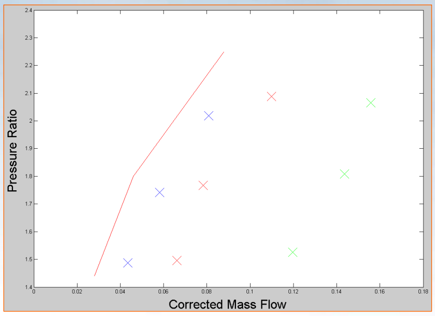
Below: The pressure transducers were mounted on the compressor inlet (5) and at the compressor outlet (6).

The compressor outlet reaches temperatures of 130⁰C. The pressure transducers, however, are only rated to 80⁰C. To ensure that the pressure transducers are not damaged a stand off pipe is used (7).



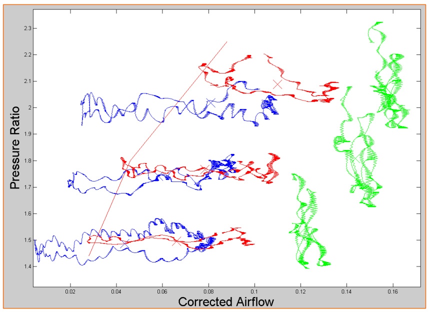
Nine steady engine states were measured. The engine speed and torque were set to ensure that three operating points were measured at three different pressure ratios.

RESULTS



Left: Typical points of compressor performance. Red line is the surge line, to the left of this line the compressor goes into surge. Surge is an unstable operating condition observed at low mass flows and can cause severe damage and hence is undesirable

The points are averages over several cycles of the pressure ratio and corrected mass flow measured on the engine test rig described below.

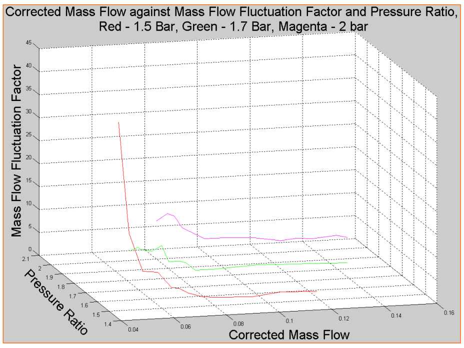


Left: When the instantaneous flows are measured using the high speed data acquisition it was shown that the flows had very large fluctuations of both pressure ratio and mass flow.

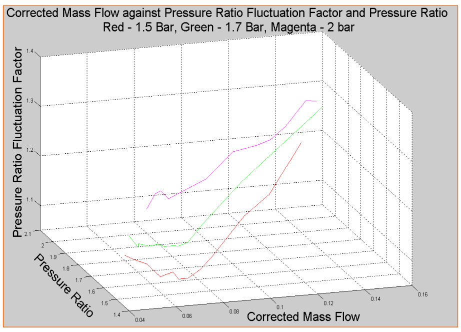
These flows are shown to fluctuate to such a large degree that they cross the surge line even when the average point is well within the heart of the map.

Right: To quantify the mass flow fluctuation a ratio of m_{max}/m_{min} was used. This ratio was then plotted on the graph against both average pressure ratio and average corrected mass flow.

The Results showed that the mass flow fluctuation were increase as the average mass flow rate decreases.



Right: To quantify the pressure ratio fluctuation the difference between maximum and minimum pressure ratio was used. This range was then investigated on the graph against both average pressure ratio and average corrected mass flow.



The Results showed that the pressure ratio fluctuation reduced with decreasing mass flow to a minimum. Beyond which the pressure ratio fluctuation increases again.

CONCLUSION

Unsteady interaction with compressor and IC engine has been investigated

The flows were shown to have large fluctuations which were caused by the unsteady interaction of a roto-dynamic machine (Turbocharger Compressor) and with a reciprocating machine (IC engine) .

The Relationship between pressure fluctuation and mass flow have shown that the pressure fluctuations are minimum at a give mass flow rate. This minimum has been observed in the heart region of the compressor map, but near to the surge line. This indicates a possibility of using pressure ratio fluctuations as a measure to determine the onset of compressor surge.