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Heat transfer analysis in a turbocharger turbine: An experimental and computational evaluation

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A R T I C L E I N F O

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This paper presents the performance of a turbocharger under non-adiabatic conditions in order to assess the impact of heat transfer. A commercial turbocharger was installed on a 2.0 l diesel engine and measurements were conducted for a range of engine speeds and loads. The test results enabled to assess the impact of the engine on the temperature distribution of the bodies constituting the turbocharger, quantify the heat fluxes through the turbocharger and evaluate their effects on the deterioration of compressor performance.

A 1-D heat transfer model was also developed and validated against the experimental measurements. The algorithms calculate the heat transferred through the turbocharger by means of lump capacitances. Compressor maps were then generated for a range of speeds and temperatures of the exhaust gases at the inlet to turbine and the efficiency drop associated with heat transfer was quantified. Based on the data generated by the model, a new correlation for the compressor non-adiabatic efficiency was found by means of a multiple regression analysis; the work is based on a statistical description of the different parameters that affect the heat transfer model.

1. Introduction

In the past years there has been increased interest and attention on turbochargers technology driven by engine demand. Turbochargers are widely used in diesel engines; they represent a key enabling technology to achieve highly downsized engines for both compression ignition and spark ignition technology. Extensive research on turbochargers resulted in a significant understanding of their aerodynamic behaviour. In this manner optimization of design procedures has been demonstrated closely coupled with the development of simulation tools. Similar efforts have not been employed on the heat transfer area in turbochargers. Clearly as engine developers try to meet stringent demands, any affordable raise in engine efficiency is highly regarded. The approach of this paper tries to contribute, yet in a simplified manner, to raise the level of the heat transfer analysis. Amongst the main causes that have discouraged efforts on this topic, lack of understanding of the heat effects as well as the high costs associated with testing facilities. Although researchers have shown that heat transfer is not small, the compression and expansion process within turbochargers are still considered to be adiabatic.

Rautenberg et al. [1] and Rautenberg and Krammer [2] investigated the influence of heat transfer from the turbine (hot side) to the compressor (cold side). They found that the heat transferred to the compressor increases the compressor outlet temperature increases the compressor outlet temperature, compared if the compressor was adiabatic. Shaaban and Seume [3] identified the main parameters affecting the deterioration of the compressor efficiency in hot conditions through a theoretical and experimental investigation. The compressor peripheral Mach number was found to be one of the most important parameters affecting the turbocharger non-adiabatic performance. Shaaban [4] also proposed an analytical solution for determining the temperature distribution along the bearing housing taking into account the heat dissipated by free convection to the surroundings, the heat conduction to the bearing housing and the forced convection to the oil. The results of this approach enabled them to determine the exit temperature in the turbine to within ±1.98%. Hagelstein et al. [5] assumed that the heat transferred during the compression and expansion process can be neglected without affecting the global result. Similar to Jung et al. [6], Cormerais et al. [7] proposed a heat transfer model to determine the temperature difference between the exhaust and intake manifold. This model did not need to be fitted with constants but only took into account the convective heat transfer within the bearing housing.

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