An industrial experimental methodology for the unsteady characterization of automotive turbocharger

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Long Abstract

Introduction

To reduce the fuel consumption of automotive internal combustion engines, turbocharger is nowadays a common part under the hood of a car. In order to optimize the turbocharger working points in agreement with the engine conditions, the knowledge of turbocharger's behavior in real exhaust manifold environment has to be improved [1]. Today's common turbocharger test benches work in stabilized conditions [2]. A significant improvement could the ability to recreate a pulsating flow of an engine and to measure the turbocharger's transient parameters such as air velocity, pressure, temperature and mass-flow. Different approaches have been proposed in the literature, each one with its advantages and with its limitations [3] [4] [5]. In this article, the authors deal with development of a new testing methodology, based on the use of an industrial test bench adapted with a particular transient instrumentation for this specific characterization.

1. Bench architecture and instrumentation

The bench architecture is based on an industrial gas stand able to test turbocharger in steady conditions [6]. An add-on to this bench has been developed in order to transform this steady condition into fast transient condition, and so to represent the pulsating behavior of fluid at the inlet of the turbine of an automotive turbocharger. The add-on bench is composed of "n" valves representing the number of cylinder of the engine. Figure 1 represent the all bench and also the position of the instrumentation needed to evaluate the behavior of the turbo charger.

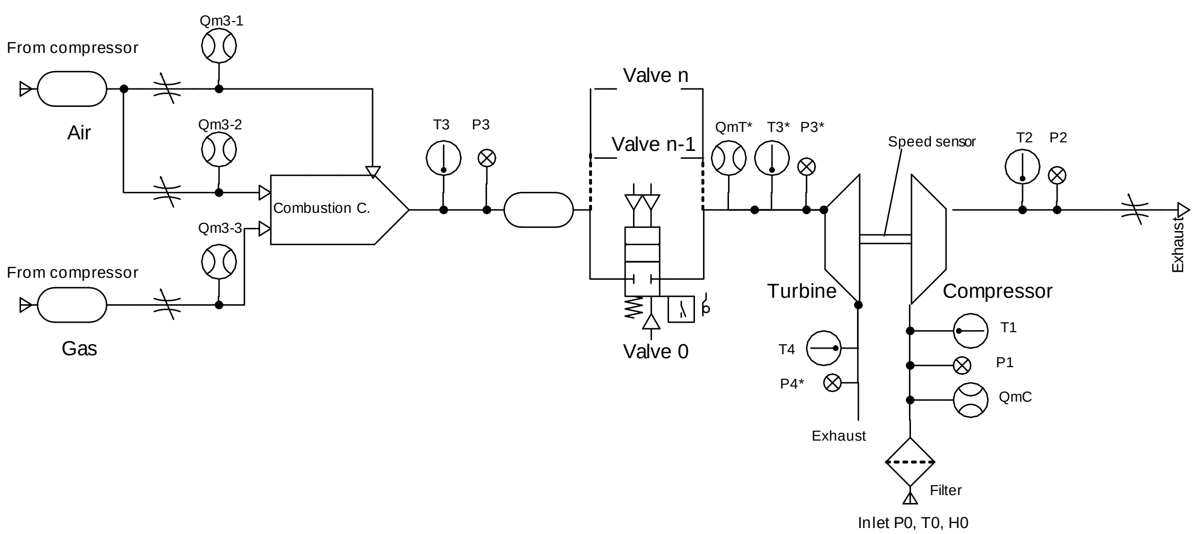

Figure 1. Test bench architecture

In order to evaluate the behavior of the turbocharger in transient conditions, particular methodology for velocity, mass-flow, and temperature measurement have been developed.

A Pitot probe has been designed to be able to measure transient air velocity at the exhaust manifold, between the engine and the turbine wheel, according to acoustics and thermal consideration. Acoustic 3D simulations were used to optimize the geometry of the probe in order to increase its resonance frequency far higher than the harmonics generated by the engine in the exhaust manifold. Static pressure measurements were done on the exhaust line of a turbocharged engine at different levels of load and rotation speeds to evaluate the highest frequency harmonics that have to be taken into account. The Pitot probe was then tested on a bench, and measurements where compared with an acoustic sensor located at the entry of the probe. The data of this experimentation were used to correlate numerical and experimental results with the aim to validate the measurement methodology. An extrapolation of the transient velocity was then used to extrapolate the transient mass flow at the inlet of the turbine.

A transient gas temperature measurement methodology has also been developed using small diameter thermocouples with time compensation models. Different compensations techniques [7] have been tested using one dimensional simulations, which were then correlated to experimental measurements with a specified bench. Transient velocity measurement using the Pitot probe have also been used to compare and validate the compensation techniques.

2. Development and conclusions

In this article, the authors will present the development of a new testing methodology developed via an intense simulation campaign a validated via experimental measurements. The first application to an automotive turbocharger will show the achievable improvement on the turbo charger unsteady efficiency estimation.

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