Experimental Thermal and Fluid Science 35 (2011) 146–153

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Turbine adapted maps for turbocharger engine matching

M. Tancrez [a], J. Galindo [b,*], C. Guardiola [b], P. Fajardo [b], O. Varnier [b]

[a] PSA – Peugeot Citroën, 18 rue des fauvelles, La Garenne-Colombes, France
[b] CMT – Motores Térmicos, Universidad Politécnica de Valencia, Spain

ARTICLE INFO

Article history:
Received 9 January 2010
Received in revised form 18 June 2010
Accepted 6 July 2010

Keywords:
Turbocharger
Turbine characteristic
Matching
Adapted power

ABSTRACT

This paper presents a new representation of the turbine performance maps oriented for turbocharger characterization. The aim of this plot is to provide a more compact and suited form to implement in engine simulation models and to interpolate data from turbocharger test bench.

The new map is based on the use of conservative parameters as turbocharger power and turbine mass flow to describe the turbine performance in all VGT positions. The curves obtained are accurately fitted with quadratic polynomials and simple interpolation techniques give reliable results.

Two turbochargers characterized in an steady flow rig were used for illustrating the representation. After being implemented in a turbocharger submodel, the results obtained with the model have been compared with success against turbine performance evaluated in engine tests cells. A practical application in turbocharger matching is also provided to show how this new map can be directly employed in engine design.

1. Background

Downsizing is a trend in engine development that allows better efficiency and lower emissions based on the increase of power output in reduced displacement engines. In order to achieve this high output it is necessary to increase boosting pressure. In the last decade, variable geometry turbocharger (VGT) technologies have spread to all engine displacements and all segments of the market, and nowadays, new turbocharging technologies are been evaluated such as variable geometry compressors, sequentially turbocharged engines [1,2] or two-stage compressed engines [3].

The right design and coupling of the turbocharging system to the internal combustion engine have capital importance for the correct behavior of the whole engine. More specifically, it is fundamental in the gas exchange process and during the engine transient evolution, and it will influence in an important way the engine specific consumption and pollutant emissions.

The matching of the compressor and turbine to an internal combustion engine is a complicated balance of many design considerations [4,5]. Appropriate turbocharger components must be carefully selected to match a given engine size and to fulfill as optimum as possible the performance required for a wide range of different operating conditions.

Any study of engine matching or system analysis requires certain data of the turbocharger performance. Most turbocharger manufacturers provide compressor and turbine performance maps in the form of lookup tables experimentally obtained in turbocharger test benches. The representation of these data shown in Fig. 1 give the interrelationships between efficiency and pressure ratio, and between mass flow rate and pressure ratio. Rotor speed and VGT turbine position are additional inputs to characterize the turbine in a larger operating range.

From these maps, different approaches can be used to model the performance of the complete system and predict the compressor and turbine behavior: applying a one-dimensional model (1D) derived from basic principles and calibrated with the experimental data, or applying a zero-dimensional (0D) model relying only on experimental data.

The first way is to use a 1D approach which takes into account the fluid and thermodynamic behavior of the exhaust gas in order to compute more in detail the energy conversion. These 1D wave action models are mainly based on the machine geometry interrelating blade tip speed, turbine normalized mass flow, pressure ratio and slip factor (ratio between the tangential velocity of the air leaving the impeller and the impeller tip velocity) [6,7]. They rely on physical principles but include some constants, such as viscous drag or clearance losses, that must be obtained and are not generally available. Furthermore, they are quite time-consuming. This approach is generally avoided in practice to carry out an effective turbocharger matching calculation.

The second way is to use a 0D approach with conventional map interpolation techniques or with 'filling and emptying' models able

* Corresponding author. Address: CMT – Motores Térmicos, Universidad Politécnica de Valencia, Camino de Vera s/n, E-46022 Valencia, Spain. Tel.: +34 963879656; fax: +34 963877659.
E-mail address: galindo@mot.upv.es (J. Galindo).

0894-1777/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2010.07.018