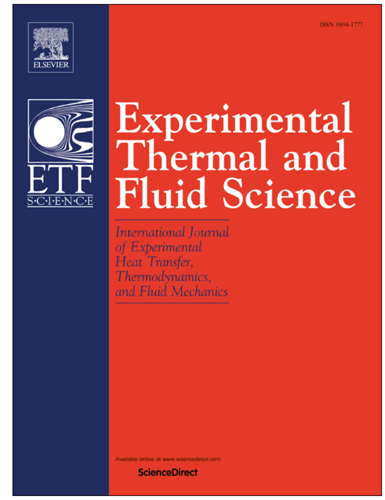


# Local flow measurements in a turbocharger compressor inlet

A.J. Torregrosa, A. Broatch, X. Margot, J. García-Tíscar, Y. Narvekar, R. Cheung

PII: S0894-1777(17)30203-0
DOI: http://dx.doi.org/10.1016/j.expthermflusci.2017.07.007
Reference: ETF 9149

To appear in: *Experimental Thermal and Fluid Science*

Received Date: 7 December 2016
Revised Date: 2 June 2017
Accepted Date: 14 July 2017

# Local flow measurements in a turbocharger compressor inlet

A. J. Torregrosa[a], A. Broatch[a], X. Margot[a], J. García-Tíscar[a,*], Y. Narvekar[b], R. Cheung[b]

[a]CMT – Motores Térmicos, Universitat Politècnica de València, Camino de Vera, 46022 Valencia, Spain
[b]Jaguar Land Rover Limited, Abbey Road, Whitley, Coventry CV3 4LF, UK

**Abstract**

This paper describes an experimental study carried out with the objective of characterizing flow instabilities in turbocharger compressors, specially the distribution of the high-temperature compressed backflow that appears upstream of the impeller at marginal surge conditions. The inlet of a test compressor was fitted with linear and circumferential thermocouple arrays in order to measure the temperature distribution caused by this backflow, whose independence of duct wall temperature was validated through thermographic imaging. Miniaturized pressure probes at the inducer and diffuser showed how pressure spectra varied during the different operating conditions. In-duct acoustic intensity was measured in both the inlet and the outlet to investigate the correlation between a known super-synchronous broadband issue known as whoosh noise and the backflow behaviour as characterized by local pressure and temperature. Analysis of the results points to inlet whoosh noise being boosted by this reversed flow but not caused by it, the source probably being located at or downstream of the compressor impeller.

*Keywords:* Aeroacoustics, Noise, NVH, Automotive, Whoosh, Surge

## 1. Introduction

As pressure grows on automotive internal combustion engines to meet ever increasing efficiency and sustainability requirements, engine manufacturers are resorting to further downsizing, with three-cylinder engines quickly replacing four-cylinder engines in many market segments.

Such a high reduction in the displacement due to environmental and efficiency concerns, implies the necessity of more aggressive turbocharging strategies in order to keep the engine power output at the value demanded by the vehicle [1]. These increased turbocharging requirements, together with strict packaging restrictions, have led to small turbocharger compressors operating at more demanding conditions, away from their stable operating points and closer to their surge limit [2].

Thoroughly studied for almost a century [3], deep surge is a destructive condition caused by airflow completely detaching from the compressor impeller blades, so that the compressed air reverses its direction and flows back from the diffuser to the inlet duct of the compressor. There, the momentum associated with the incoming fresh air motion forces the high temperature, reversed flow back into the compressor, and the detachment and reversing cycle starts again. This self-sustained cyclic phenomenon creates extreme pressure gradients that can compromise the structural integrity of the compressor. Hence, it is very important to avoid reaching such extreme operating conditions.

Different deep surge mitigation strategies have been proposed, either based on the modification of the inlet line and the compressor inducer [4, 5], or by introducing swirling [6] or pulsations [7] into the flow. These have been successful in delaying the onset of deep surge, thus expanding the useful air flow range of the compressor.

However, deep surge does not usually happen all of a sudden, especially in centrifugal compressors [3]. Before conditions become so critical that flow completely separates from the blades, partial detachments along the external edges of the blades begin to occur, leading to high temperature flow reversing along the periphery of the inducer and into the first portion of the inlet line.

Since turbocharger compressors keep decreasing in size to fit to smaller engines, their rotating speed further increases, while the minimum mass flow demanded by the engines keeps decreasing. As a result, operation in these partially stalled conditions is becoming increasingly common.

While the effect of partial blade stall on compressor performance and efficiency is well known (specially in axial flow compressors) since at least the 1950s [8, 9], pressure disturbances caused by these "marginal surge" conditions have also been linked to increased noise generation in the turbocharging system. These Noise, Vibration and Harshness (NVH) issues are specially challenging in the development of modern downsized engines [10].

Regarding noise issues, not only an increase in the overall acoustic level is adversely perceived by the end-user, but also the subjective perception of noise quality is influenced by the frequency content of the acoustical emission. High speed tur-

*Corresponding author. Tel.: +34 963 877 650,
email: jorgarti@mot.upv.es