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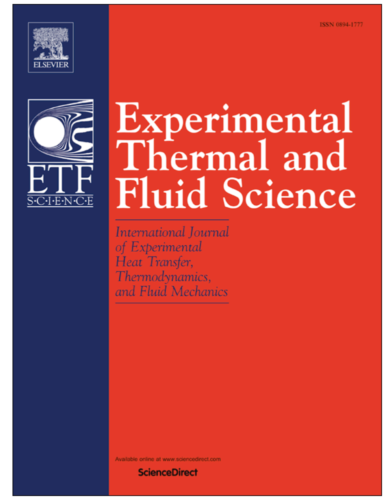

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On the influence of inlet elbow radius on recirculating backflow, whoosh noise and efficiency in turbocharger compressors

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Abstract

While the influence of inlet geometry on turbocharger compressor behaviour has usually been investigated in terms of performance, surge margin and efficiency, data is scarce regarding the impact of the inlet flow field onto the noise emission. In many applications where tight packaging is required, a 90º elbow is placed just upstream of the compressor inducer. This can create a distortion of the incoming flow that affects the turbocharger operation; a distortion that is related to the radius of the elbow. In this experimental investigation three 90º elbow inlets are tested, measuring the in-duct sound intensity through acoustic beamforming, the spectral signature of the noise, and the distortion of the high temperature backflow typical of partially stalled conditions by means of thermocouple arrays. Results show that a tighter elbow radius not only impacts efficiency but also increases inlet noise at conditions close to surge. Spectral analysis shows that this increase is mainly produced in the form of a medium frequency broadband noise usually known as 'whoosh' in the literature. On the other hand, effect on the outlet is less noticeable. Measurements of the recirculated backflow distortion in terms of circumferential skewness show good correlation with whoosh noise increase, indicating that flow distortion caused by tighter elbows at marginal surge conditions facilitates the transmission of whoosh noise oscillations to the inlet duct, worsening the acoustic behaviour of the system.

Keywords: Automotive, Acoustics, Optimization, Turbomachinery, Internal Combustion Engine, NVH

1. Introduction

Due to increased pressure to lower harmful emissions and increase fuel efficiency, turbocharging has become commonplace in internal combustion engines from all market segments. Previously restricted to higher performance vehicles, nowadays even smaller automotive engines are equipped with these systems. Moreover, in these applications it is typical that the turbocharger compressor operates at points closer to its deep surge limit, where partially stalled conditions are already in place [1, 2].

Different geometric variations of the inlet line near the impeller have been proposed [3–6] in order to mitigate the negative effect of the flow instabilities due to the partial stall and enlarge the air mass flow rate that can be used without risking deep surge conditions.

While studies mainly aimed at obtaining a more stable flow to delay deep surge onset and to keep compressor thermodynamic efficiency even at low air mass flow conditions, the impact of these geometric solutions in the generated and transmitted compressor noise is not often considered.

The acoustic emission of the compressor can be detrimental not only because it contributes to the overall noise created by the engine and thus to the acoustic contamination caused by thermal vehicles, but also because as a very high speed flow machine, its acoustic signature in terms of frequency content differs significantly from that of the reciprocating thermal engine itself.

At operating conditions where the 'blowing' noises of the compressor overpower the deeper, lower frequency combustion noise of the engine, the customer may perceive the engine acoustic response as unpleasant or even faulty, since subjective perception of noise quality is not only tied to overall levels but also frequency content [7, 8].

Among the inlet geometries found in automotive turbochargers, it is common [9] to find a 90º elbow just upstream of the compressor inducer, since tight packaging requirements inside the engine compartment often require the turbocharger to be placed at a side of the engine block.

This particular geometry has been studied in previous research works, both from numerical and experimental standpoints [10, 11]. While they have demonstrated influence on the surge margin and the efficiency of the compressor [12], literature is scarce on the consequences of 90º elbow inlets regarding the acoustic output of centrifugal compressors.

In this experimental investigation, three 90º elbow compressor inlet geometries with different radii are tested in a turbocharger test bench fitted with both piezoelectric pressure sensor arrays to perform in-duct acoustic intensimetry and with thermocouple arrays to characterize the behaviour of the compressor backflow at unstable conditions, thereby allowing the establishment of correlations between the flow field and the acoustic emission.

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