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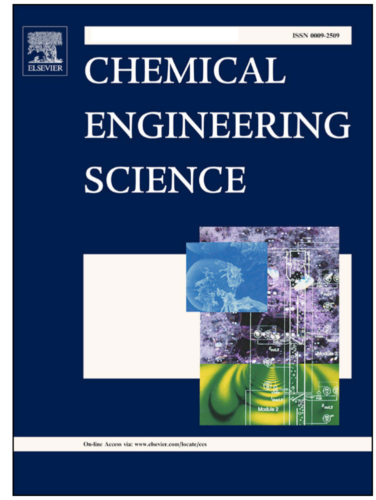

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Multiscale RANS-based modeling of the turbulence decay inside of an automotive catalytic converter

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Abstract

This paper presents a multiscale comprehensive study of the turbulence inside of an automotive monolith using a porous medium approach and a representative group of single channels. A series of RANS simulations of an axisymmetric model of the whole converter and a 3D model of a representative group of single channels is combined to study the turbulence at different scales.Results of simulations are validated against experimental data published in the literature. Good agreement is achieved. Results of simulations reveal that although the continuum porous media model produces good agreement with experimental velocity profiles after the monolith, it does not describe accurately the effects of turbulence inside the monolith. Literature reports that a transition from turbulent to laminar at the beginning of the monolith channels impacts significantly the performance of the whole converter, but, at the same time, it is usually neglected, due the complexity that it adds to the problem. According to the results from the single channels, there is a smooth decay of the turbulence viscosity inside the monolith, that does not appear using the traditional models of porous zones. This decay can be achieved at the converter scale, via the addition of a damping term for the turbulence to the κ-equation of the RANS model.

Keywords: Catalytic converter, monolith, channels, multiscale, turbulence damping, RANS

1 Introduction

Monolith honeycomb reactors are widely used in automotive catalytic converters. As part of the exhaust after treatment system, the monolith is typically a ceramic piece with thousands of channels running in parallel. The surface of the channels is covered by a thin porous layer of oxides (washcoat) that supports the metal catalyst. Monolith reactors were initially developed by the automobile industry to control emissions, but are now widely used in other applications, such as catalytic combustion, oxidation, hydrogenation, dehydrogenation to name a few [1, 2, 3, 4, 5]. Some of the advantages of monolith reactors compared to a packed bed are lower pressure drop, larger external specific surface area and high selectivity, among others [6].

The modeling of the catalytic converter is a multiscale problem that ranges from the molecular to the converter length scale. The smallest scale is the molecular level, where the

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