Evaluation of local and continuous approaches during the hydrodynamic description accounting for turbulence in a packed bed presenting a low tube-particle diameter ratio.

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Highlights

- We evaluate the hydrodynamics accounting or not for turbulence in packed bed presenting a low tube to particle diameter ratio.
- Two hydrodynamics approaches, local and continuous ones, are evaluated.
- The continuous approach accounting for turbulence is not yet able to describe velocity profiles.

1. Introduction

Packed bed reactors (Figure 1) with low tube-particle diameter ratios (d_t/d_p) have mainly been used for carrying out selective oxidations. Nowadays, there is no a model totally accepted to describe the observed behavior in this type of reactors [1]. This has essentially been related to a lack of describing hydrodynamics and its effect on heat transport [1, 2]. This research is aimed at evaluating the role of turbulence on describing hydrodynamics in a packed bed presenting a low tube-to-particle diameter ratio. Main results will be used to describe heat transfer in this type of systems in future investigations. It is worth stressing; we are interested on developing a turbulence model considering the packed bed as a pseudo continuous system because of the practicality to model the aforementioned industrial catalytic reactors. [1-2]

2. Methods

Table 1 shows operating and geometrical conditions from the packed beds to be modeled in this research. The models used to describe hydrodynamics make use of Reynolds Average Navier-Stokes (RANS) equations coupled to turbulence equations, namely k-ε or k-ω. These models are evaluated considering two scenarios. In the first one, the packed bed is modeled locally by means of computational fluid dynamics (local approach) and, in the second one, the packed bed is modeled considering it as a pseudo-continuous medium (continuous approach), thus, Darcy and Forchheimer equations are added to those turbulence models in order to account for solid-fluid interaction due to viscous and inertial forces, respectively. [3]

Table 1: Reactor configuration and operating conditions

Reactor	**Value**	**Units**
Length	2.6	m
Diameter	0.025	m
Relation d_t/d_p	3.048, 5.1	-
Air density	1.293	kg/m^3
Inlet Air flow rate.	4.004	m^3/h
Reynolds number	618, 702, 1050, 1405	
Packing		
Diameter	0.0082	m

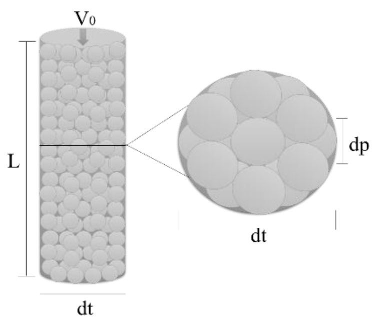

Figure 1: Packed bed system.

3. Results

Figure 2 displays a comparison of velocity profiles predicted using different model approaches. Figure (a) compares model predictions by using the RANS and the Navier-Stokes (NS) models coupled to Darcy and Forchheimer terms under the continuous approach. Figure (b) compares model predictions given by the NS equations following the continuous approach and the kappa-epsilon turbulence model following the local approach. Figure (c) compares model predictions given by the NS equations following the continuous approach and the RANS model coupled to kappa-omega equations following the local approach. Figure (d) displays the prediction of a RANS model estimating the turbulence viscosity rather than estimating it by using k-ε or k-ω equations. In this last Figure, predictions are compared with observations. In this regard, main contribution in this work indicates that the continuous approach can describe observations when turbulent viscosity is estimated rather than evaluated with the turbulence models: k-ε or k-ω. An attractive result in terms of computation times when this hydrodynamic is coupled to heat and mass transport models for the studied systems.

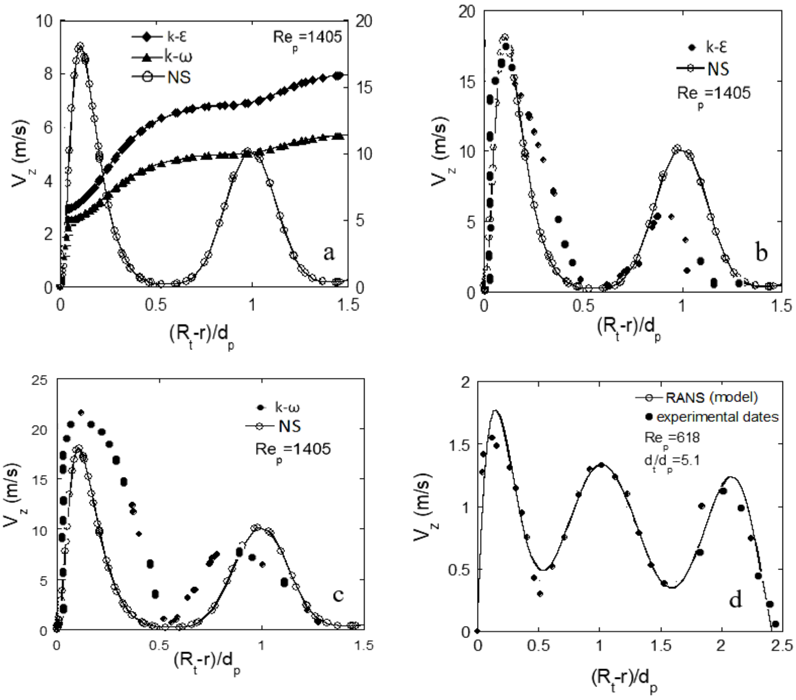

Figure 2, Velocity prediction following different models and approaches,

4. Conclusions

Due to the high computational times, in the modeling of catalytic reactors hydrodynamic models should consider the system as pseudo-continuous., however this class of models ignores the effect of turbulence. These models, accounting for turbulence, based on the continuous approach are not able to properly describe observations or predictions by means of the local approximation.

Based on the results obtained in this work, it is suggested that the hydrodynamic description following a continuous approach by RANS equations but estimating the turbulent viscosity rather than determining it by turbulence models such as the kappa-epsilon or kappa-omega is an approach that describes properly observations or predictions obtained by the local approach.

References

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Keywords

Hydrodynamics; turbulence; Navier-Stokes equations (NS); RANS equations