Space-time averaging of turbulent flow equations for permeable media

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Engineering and natural systems of practical relevance can be modelled as a porous structure through which a working fluid permeates. Turbulence models proposed for such heterogeneous media depend on the order of application of time and volume average operators. Two developed methodologies, following the two orders of integration, lead to different governing equations for the statistical quantities. This lecture reviews recently published methodologies to mathematically characterize turbulent transport in porous media. The concept of double-decomposition is discussed and models are classified in terms of the order of application of time and volume averaging operators, among other peculiarities. Thermal non-equilibrium between phases is discussed. For hybrid media, involving both a porous structure and a clear flow region, difficulties arise due to the proper mathematical treatment given at the interface. This lecture discusses mathematical models for such hybrid medium. In addition, macroscopic forms of buoyancy terms are presented for both mean and turbulent fields. Cases reviewed include heat transfer in porous enclosures, cavities partially filled with porous material, moving bed systems, combustion in porous burners and double-diffusion effects in porous media.

References

[1] de Lemos, Marcelo J.S., *Turbulence in Porous Media, 2nd Edition* , Elsevier, Waltham, MA, (2012).