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On thermodynamic consistency of turbulent closures

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Abstract

The problem of the implementation of the second law of thermodynamics for the determination of the thermodynamic consistency of solutions determined by turbulent closures is considered for incompressible fluids. The possibility of the application of the methods of thermodynamics to constraining constitutive laws describing turbulent flow features, but not material behaviour, is discussed. It is shown that the ordinary realizability conditions requiring non-negative values of the averaged squared fluctuations are necessary and sufficient conditions determining the thermodynamic consistency of a process governed by a closure model. Because turbulent closures are not universal, using the second law of thermodynamics to constrain them can impose unnecessary restrictions on the models, when the turbulent entropy is considered as a constitutive quantity. The notion and validity of different forms of the turbulent entropy is discussed. It is found that the form of the turbulent entropy originating from the analogy between the turbulent kinetic energy and absolute temperature contradicts the principle of irreversibility. In a particular case of small temperature fluctuations, the second law yields correct constraints, if the turbulent entropy is assumed not to be a constitutive quantity, but a variable governed by an evolution equation of special form generated by the balance equation for internal energy.

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