Turbulence kinetic energy for an axisymmetric steam jet

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Abstract

Jet noise prediction using acoustic analogy based models require the numerical evaluation of a tensor product of the propagator for the Linearized Euler equations (LEE) and the Reynolds stress auto-covariance tensor. This latter term is approximated using symmetry properties of the turbulence. This process essentially boils down to obtaining a representation of the tensor involving a sum of certain of its components each of which are multiplied by an irreducible product of basic invariants formed by appropriate permutations of the tensor suffixes such that they possess the same tensorial structure as the original. Obtaining this statistical information is an expensive task of either performing multiple experiment campaigns or running high-fidelity numerical simulations (typically in the form of Large-Eddy Simulations, LES). Low-order models of the acoustic spectrum assume that the amplitude of the correlation functions are proportional to the turbulence kinetic energy (TKE). This assumptions works well when the TKE is scaled with a fixed pre-factor representing the change in magnitude of the individual correlations (see Karabasov *et al.*[1]).

The aim of this work is to assess how the structure of TKE distribution changes when the flow is 100% water vapour (cold steam) or various fractions thereof and compare this to a simulation of pure air. While this is a relatively straightforward task in terms of Computational Fluid Dynamics (CFD) simulation, the importance of this cannot be understated since it shows (in a very simple way) whether the addition of water vapour in the jet will ultimately cause an decrease or increase in radiated sound. The former is favorable for jet noise control purposes. To fix ideas, we have considered various round jets at an acoustic Mach number of $Ma = U_J/c_\infty = 0.5$ for a convergent nozzle of inner diameter 58 mm and exit diameter of 17 mm. This particular configuration was chosen because it has the same mass flux (i.e. the same exit area) as the $8:1$ rectangular jet used in experiments conducted at NASA and for which there is extensive data available. The jet static temperature ratio for both the air and steam cases is $\mathrm{TR} = T_J/T_\infty = 1.05$. Figure 1 shows profiles of the normalized TKE computed using $\mathrm{STARCCM+}$ for the pure steam jet is approximately $\times 1.5$ that of the air jet.

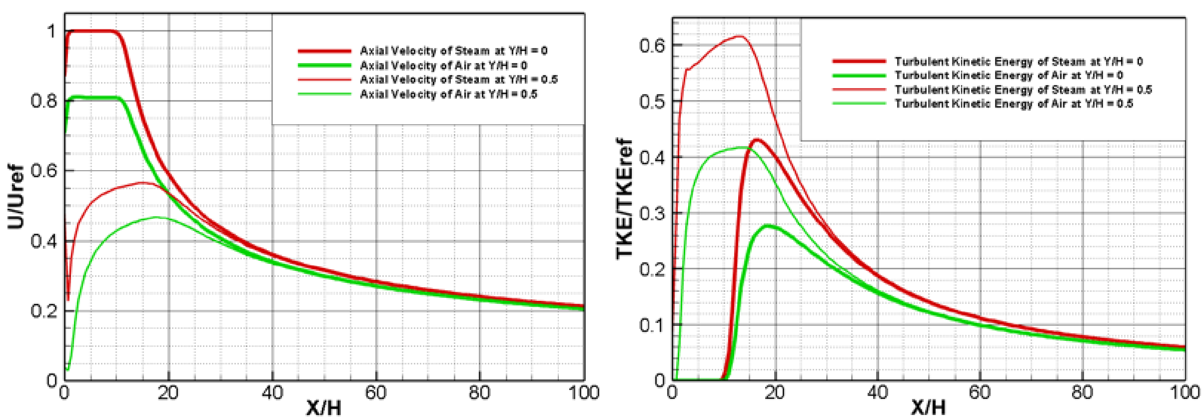

Figure 1: Normalized TKE using STAR-CCM+ as solver and $k - \varepsilon$ realizable turbulence model)

[1] Karabasov S. A., Afsar, M.Z. and others *AIAA J.*, vol. 48, 2010