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Steady and transient mathematical models of steam jets

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Abstract

Exhaust steam into the atmosphere is the most powerful source of noise in the energy, chemical and many other industries. Excess of sanitary industry norms up to 60 dBA at a distance of 15 m from the release point. Knowing processes of steam efflux into the atmosphere allows us to calculate correctly noise levels at a distance from them and to realize measures for noise attenuation. The study of mechanisms of noise generation by jets had begun in the end of 1940s and had been generally related to investigations of air jets and exhaust gas jets of aircrafts. Problems of noise emission by steam jets have been studied insufficiently until recently. The stationary and transient simulation models of the steam jets are discussed. The limitations of a stationary model and the possibility of transient mathematical model of the radiation steam jets are shown. The difference between the simulation results in the stationary and transient models are given. It is shown that the simulation of steam flowing under transient state condition gives the possibility to trace not only regular but also coherent structures and, thereby, to describe processes of noise generation most completely.

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Keywords: Noise; mathematical modeling, steam jet, steady model, transient model.

1. Introduction

Steam outlets in atmosphere are the most powerful noise sources on power engineering, metallurgy, chemical manufacturing and in a number of other manufacturing. Sanitary code exceeding for working zones comes up to 60 dB(A) on a distance of 15 m from a point of outlet and for apartment block territory this exceeding may be within a range of some kilometers [1-2]. For example, in Russia to provide inhabitants by heat (heating, hot-water supply, ventilation) thermal power stations are used, that are built in the immediate vicinity of apartment block territory,

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therefore steam outlets even with atmospheric pressure on a cut of exhaust pipe lead to exceeding of sanitary code on a noise factor on a nearby apartment block territory. Besides that steam outlets pipe are situated on a roof industrial buildings on a level of 30-60 m above ground level, owing to this emitting noise spreads unimpeded in an ambient space in contrast with a noise of sources, situated on the ground which influence reduces due to natural (lay of land) and artificial barriers. High noise intensity, emitting from a height, direct closeness of apartment blocks to industrial territory are the factors of the largest noise influence of steam outlets on environment in comparison with other sources.

Knowledge of steam outlet process allows to define noise levels on some distance and to implement noise abatement arrangements correctly [3-4].

Study generation of noise by jets began at the end of 1940s years and generally was connected with investigation of air jets and exhaust gases jets of aircrafts. Many scientist have studied processes of generation and emitting noise by jet among them are Sir Michael James Lighthill, Munin A.G., Yudin Ye.Ya. and others [5-7]. In [5] introduction in theory of waves in liquid medium is given, analyzed four most important and characteristic types of wave in liquids (acoustic waves, one-dimensional waves in liquids, water waves and internal waves), discussed questions of one-dimensional disturbance propagation, described applications of set forth ideas. In [6,7] given results of theoretical and experimental research of aerodynamic noise and methods of it reduction, a gas jet as a one of the main noise source of an airplane is considered.

Questions of comparison steady and transient mathematical models of steam jets were examined insufficient.

2. Mathematicalmodel

The motion of viscous fluid substance, which the steam flow is, describes by Navier–Stokes equation:

$$\rho\left(\frac{\partial \upsilon_i}{\partial t}+\upsilon_k\frac{\partial \upsilon_i}{\partial x_k}\right)=-\frac{\partial p}{\partial x_i}+\frac{\partial}{\partial x_k}\left(\eta\left(\frac{\partial \upsilon_i}{\partial x_k}+\frac{\partial \upsilon_k}{\partial x_i}-\frac{2}{3}\delta_{i,k}\frac{\partial \upsilon_l}{\partial x_l}\right)\right)+\frac{\partial}{\partial x_i}\left(\zeta\frac{\partial \upsilon_l}{\partial x_l}\right) \quad (1)$$

where η and ζ – viscosity coefficients;

$\upsilon_i, \upsilon_k, \upsilon_l$ – components of velocity vector; $\delta_{i,k}$ – Kronecker delta; ρ – flow density.

To closure this equation needed to interconnect between convective tension and average flow characteristics.

Reynolds formulated the common turbulent flow description methodology, according to which instantaneous values of required functions (velocity, density, pressure, temperature) are the sum of average and pulsating term:

$$f = f' + \overline{f} \quad (2)$$

Study and description of average flow characteristics behavior that fluctuaterelatively gradually in time and space is the more ease task than study of three-dimensional transient and chaotic motion, which the turbulent flow really is.

Many models of turbulence are realized in different software products. Modern turbulence models review applying to flowcomputation given in [8-25].

This paper shows results of steam flow computation using two models: k-ω SST model (Shear Stress Transport) andLES model.This is conditioned by substantiating possibility of computation coherent eddies structures using LES model of turbulence [23], and in [18] shown this model availability.

3. Results of calculations for steady and transient mathematical models

Steam jet exhaust into an atmosphere mathematical modeling results using two models for steam flow (k-ω SST model and LES model) shown in Fig. 1 and Fig. 2. For k-ω SST model computations were carried out in steady mode and for LES model in transient mode.Calculations based on this mathematical models were implemented in software package Ansys Fluent .