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Flow Field and Heat Transfer in an impingement Synthetic Jet: Application of Different Turbulence Models

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Abstract
In the present paper, capabilities of three different turbulence models, namely Abid low Reynolds number $k-\varepsilon$, $SST\ /k-\omega$ and v^2-f, for simulation of unsteady flow field and heat transfer of a three-dimensional impinging synthetic jet on a constant temperature copper surface at Re of 2100, frequency of 80 Hz and impinging distance of $\mathrm{H/D}=3$ are investigated. For more accurate simulation of a synthetic jet diaphragm, the dynamic mesh approach is employed. The problem is solved under assumptions of incompressible flow, symmetric and temperature dependent properties. The PISO algorithm is used for coupling continuity and momentum equations. Present results demonstrate that the v^2-f turbulence model provides the best prediction accuracy amongst the turbulence models in all areas of hot surface. In addition, in center of hot surface, the $SST\ /k-\omega$ turbulence model displays more accurate results than the low Re $k-\varepsilon$ turbulence model.

Keywords: impinging synthetic jet, turbulence modeling, heat transfer, dynamic mesh, oscillatory flow

Introduction

By vibration of a diaphragm, synthetic jets produce an unsteady flow. Different applications of synthetic jet such as flow control, mixing enhancement, vectoring and spot cooling of electronic boards cause to publish many papers about it. These types of jets use the environment fluid as the working fluid and create vortex dipole by changing of volume of cavity. In an experimental study, Campbell [1] has showed that synthetic jet can influence on cooling of processor of a laptop. In a certain amplitude and frequency, it is found that utilization of synthetic jet can cause 22% reduction of processor temperature in comparison of free convection. Pavlova and Amitay [2] have investigated effects of distance of surface to orifice, Re and jet formation frequency on heat transfer of an impinging synthetic jet experimentally. They have found that at high oscillation frequencies heat is removed better than low oscillation frequencies for small distance while low frequencies are better for lager distance. McGuinn et al. [3] have studied effects of heat transfer on a constant temperature surface experimentally. They have concluded that increase of Reynolds number has a direct influence on heat transfer. Also, they have found that in the range of distances under investigation, by increasing distance of hot surface to orifice, the heat transfer coefficient is increased. In another experimental study, Vukasinovic and Glezer [4] have confirmed that maximum of heat removal is not in the stagnation point; rather it is in a distance about half of orifice radius. They have also concluded that by decreasing of distance of orifice to surface and increasing of frequency, the heat transfer coefficient is increased. Persoons et al. [5] have studied an impingement synthetic jet for a constant distance of surface to orifice and uniform heat flux in large ranges of stroke length and Reynolds numbers. They have extracted a relation between Nusselt and Reynolds numbers for each stroke length. Bazdidi- Tehrani et al. [6] have examined different turbulence models for an axisymmetric impingement synthetic jet on a constant heat flux surface. They have reported that the $SST\ /k-\omega$ turbulence model is relatively more accurate than the standard $k-\varepsilon$ and low Reynolds number $k-\varepsilon$ models and it gives a more reliable set of results concerning heat transfer caused by a synthetic jet. Lee et al. [7] have investigated the interaction between a synthetic jet and cross flow in a micro-channel in two different frequencies and amplitudes, numerically and experimentally. They have reported that usage of a synthetic jet increases mixing and heat transfer. Bazdidi-Tehrani et al. [8] have simulated effects of frequency and distance of surface to orifice on one constant Re number, numerically. They have found that at lower frequencies, mean Nu number increases with increase of frequency and for higher frequencies, Nu decreases with increasing of frequency.

Although various experimental studies have been carried out regarding the impingement synthetic jets, numerical simulations have received less attention. In addition, in the limited existing numerical simulations, effects of the synthetic jet actuator have been neglected by researchers and instead an inlet boundary condition at the inlet of orifice is used. The objective of this paper is the investigation and analysis of capabilities of three different turbulence models, accurate comparison of results with the available experimental data and simulation of synthetic jet actuator via the dynamic mesh approach in a three- dimensional impinging synthetic jet.