CFD ANALYSIS OF RECTANGULAR JET IMPINGEMENT HEAT TRANSFER ON FLAT PLATE USING NANOFLUIDS

K.Siva Satya Mohan  
Asst Professor,  
Department of Mechanical Engineering,  
GRIET, Bachupally, Hyderabad-500090

S.K.Bhatti  
Professor,  
College of Engineering,  
Andhra University, Visakhapatnam, India.

K.P.V.K Varma  
Asst Professor,  
Department of Mechanical Engineering,  
CMR College of Engineering & Technology, Medchal, Hyderabad-501401

ABSTRACT
Jet impingement heat transfer is used in many engineering and industrial Applications. Those include electronic components, Turbine blades, drying paper, Textiles, food, chemicals, tempering of lass and polymer processing. This technique is very attractive and cost effective because it can increase heat flux significantly. The present work investigates the heat transfer and fluid flow effects of Jet Impingement on conducting stationery horizontal jet impinged to vertical plate surface. A directed liquid or gaseous flow released against a surface can efficiently transfer large amounts of thermal energy or mass between the surface and the fluid. A numerical simulation and experimental investigation was performed to analyse the heat transfer performance of a hot fluid in impinging jet on a flat surface. The tests were realized for the following ranges of the governing parameters: the jet diameter is 2cm and the distance of horizontal jet to Vertical plate surface was set to be 1 to 2cm. Three different cases with velocities are considered in this analysis. Turbulent models considered for this analysis are k-ε and k-ω. Two cases are considered and compared in this analysis. They are H/D = 0.5,1. Fluids like Acetylene is compared with γ-Al₂O₃ nano fluid in this analysis. The plate is considered to be stationery. Horizontal Jet with convergent nozzle is impinged to Vertical plate in this analysis. Finally, we found out the heat transfer coefficient and Nusselt number generated on the plate.

Key words- Jet Impingement, Heat transfer, Nusselt number, CFD, Nano fluid

1. INTRODUCTION
Nano fluids are fluids containing nano particles (nanometer sized particles of metals, oxides, carbides, nitrides or nanotubes). Nano fluids exhibit enhanced thermal properties, amongst them. Higher thermal conductivity and heat transfer coefficients compared to the base fluid. It can be used to remove more heat from the engine acts like a coolant. Sparay paining is the latest technology can be used now a days.Impinging jets have received considerable attention due to their inherent characteristics of high rates of heat transfer besides having simple geometry. Various industrial processes involving high heat transfer rates apply impinging jets. Heat transfer rates in case of impinging jets are affected by various parameters like Reynolds’s number, Nozzle plate spacing radial distance from stagnation point, prandtl number, target plate inclination, confinement of the jet, nozzle geometry, curvature of target plate, roughness of the target plate, low scale turbulence intensity, i.e. turbulence intensity at the nozzle exit. Impinging Jets have been used to transfer heat in diverse applications, which include the drying of paper, the cooling of turbine blades and the cooling of a grinding process. Jet Impingement flows can be found in the cooling of hot metal, plastic, glass sheets, electronics, drying paper, fabric and other applications. Jet Impingement is one of the most efficient solutions of cooling hot objects in Industrial processes as it produces a very high heat transfer rate of forced convection. Impingement heat transfer in axisymmetric air jet using thermocouples to measure the temperature with jet positioning is explained in [1].
The development of radially complete results for the liquid film heat transfer with uniform heat flux is explained by [2]. The time averaged and temporal measurements of the heat transfer and fluid flow of an impinging air jet is explained in [3]. Numerical study of multiple circular air jet vertically impinging on a flat plate is explained in [4]. There have been many studies of the heat transfer to or from, an air jet that is impinging on to a surface which is perpendicular to the jet axis. The incentive for these studies is often related to heating and cooling, or drying processes, and the majority are confined to subsonic jets is explained by [5]. Impinging jets have been used to transfer heat in diverse applications, which include the drying of paper, cooling of turbine blades and the cooling of a gridding process, cooling of electronic components explained by [6]. Extensive measurements of the near-field pressure provide solid support for the hypothesis that a feedback mechanism is responsible for the sudden change observed in the pressure fluctuations at the onset of response. The feedback loop consists of downstream-convected structures and upstream-propagating pressure waves generated by Impingement of the coherent structures on the plate explained by [7]. Nano fluids are fluids containing nano particles (nanometer sized particles of metals, oxides, carbides, nitrides or nanotubes). Nano fluids exhibit enhanced thermal properties, amongst them. Higher thermal conductivity and heat transfer coefficients compared to the base fluid. It can be used to remove more heat from the engine acts like a coolant. Sparay painting is the latest technology can be used now a days. Experimental and theoretical studies of the nanofluid thermal conductivity and heat transfer enhancement is explained by [8]. The problem of laminar impingement jet flows of nano fluids has been numerically investigated. Results as obtained for water-Al2O3 mixture, show an enhancement of heat transfer rate due to the presence of nanoparticles in the base fluid explained by [9]. Spray Cooling is a technique for achieving large heat fluxes at low surface temperatures by impinging a liquid in droplet form on heated surface. Heat is removed by droplets spreading across the surface, thus removing heat by evaporation and by an increase in the convective heat transfer coefficient explained by [10]. The problem of laminar impingement jet flows of nanofluids has been numerically investigated by [11].

2 PROBLEM DESCRIPTION

In the present analysis CFD (Gambit and Fluent 6.3.26) software is used. Gambit is used to design the model of the object and Boundary conditions. I took Rectangular jet for my analysis. We draw all the edges of Jet in gambit using edge option by giving x and y coordinates. At the end of jet we keep nozzle for free flow of fluid. I have taken convergent nozzle for my analysis. Draw the rectangular plate with H/D = 0.5, 1 and 1.5. Then we take face option for jet and plate. After that we mesh the edges and faces separately. The purpose of meshing is for free flow of fluid through jet to plate. Then we save the files with an extension of .msh. Fig’s 1-6 shows the Horizontal Jet impingement heat transfer with convergent nozzle on vertical plate with a gap of 1 to 3m. After Geometry and meshing we go to FLUENT to review results. We are considered three turbulent models with upwind scheme in FLUENT. They are Spallart-Almaras, k-ω and k-ε. The wall material is taken to be Copper. The wall properties taken to be fixed. Wall material is taken as Copper.

They are, $h=50 \text{W/m}^2\text{K}$, $Q/V = 15000 \text{W/m}^3$, $Q/A = 15000 \text{W/m}^2$ and $T = 300\text{K}$

CASE-I: H/D = 0.5
WHERE H = JET TO PLATE DISTANCE, D = JET THICKNESS
HORIZONTAL JET WITH STATIONERY & CONVERGENT (Fig.1)
CASE-II: H/D = 1
HORIZONTAL JET WITH STATIONERY & CONVERGENT (Fig.2)

2.2 Boundary Conditions  (Table1)

<table>
<thead>
<tr>
<th>S.No</th>
<th>Edge Type</th>
<th>Type In CFD</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inlet</td>
<td>Pressure inlet</td>
<td>90000KPa</td>
</tr>
<tr>
<td>2</td>
<td>Outlet</td>
<td>Pressure outlet</td>
<td>75000KPa</td>
</tr>
<tr>
<td>3</td>
<td>Wall</td>
<td>WALL</td>
<td>-----</td>
</tr>
</tbody>
</table>

2.3 Thermal Properties

**Acetylene:**

<table>
<thead>
<tr>
<th>Property Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density(kg/m³)</td>
<td>1.07</td>
</tr>
<tr>
<td>Thermal Conductivity(W/mK)</td>
<td>0.0213</td>
</tr>
<tr>
<td>Specific heat(J/kgK)</td>
<td>2167</td>
</tr>
<tr>
<td>Viscosity(kg/ms)</td>
<td>$1 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

**Al₂O₃ Nano Fluid(1%)**

<table>
<thead>
<tr>
<th>Property Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density(kg/m³)</td>
<td>1027</td>
</tr>
<tr>
<td>Thermal Conductivity(W/mK)</td>
<td>0.614</td>
</tr>
<tr>
<td>Specific heat(J/kgK)</td>
<td>4148</td>
</tr>
<tr>
<td>Viscosity(kg/ms)</td>
<td>0.001083</td>
</tr>
</tbody>
</table>

**Al₂O₃ Nano Fluid(4%)**

<table>
<thead>
<tr>
<th>Property Name</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density(kg/m³)</td>
<td>1113</td>
</tr>
<tr>
<td>Thermal Conductivity(W/mK)</td>
<td>0.667</td>
</tr>
<tr>
<td>Specific heat(J/kgK)</td>
<td>4046</td>
</tr>
<tr>
<td>Viscosity(kg/ms)</td>
<td>0.001486</td>
</tr>
</tbody>
</table>
2.4 Turbulent models considered in our analysis:

In our analysis the fluid is turbulent in nature. So we have to consider turbulent models in Fluent software. They are

a) k-ε model  
b) k-ω model

where k is turbulent kinetic energy and ε is eddy viscosity, ω is angular velocity

5 RESULTS AND DISCUSSION:

RESULTS OF HORIZONTAL JET H/D=0.5  k-ε  ACETYLENE

Fig 1.5.1 wall heat transfer coefficient vs Surface  
Fig 1.5.2 Nusselt number vs Surface of the plate
RESULTS OF HORIZONTAL JET H/D=0.5  \text{k-\omega}  ACETYLENE

Fig 1.5.3 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.4 Nusselt number vs Surface of the plate

RESULTS OF HORIZONTAL JET H/D=0.5  \text{k-\epsilon}  1\%\gamma-Al_2O_3  CONVERGENT

Fig 1.5.5 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.6 Nusselt number vs Surface of the plate

RESULTS OF HORIZONTAL JET H/D=0.5  \text{k-\omega}  1\%\gamma-Al_2O_3
RESULTS OF HORIZONTAL JET H/D=0.5  k-ε 4%γ-Al₂O₃

Fig 1.5.7 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.8 Nusselt number vs Surface of the plate

RESULTS OF HORIZONTAL JET H/D=0.5  k- ω  4%γ-Al₂O₃

Fig 1.5.9 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.10 Nusselt number vs Surface of the plate
RESULTS OF HORIZONTAL JET H/D=1 k-o ACETYLENE

Fig 1.5.11 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.12 Nusselt number vs Surface of the plate

Fig 1.5.13 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.14 Nusselt number vs Surface of the plate
RESULTS OF HORIZONTAL JET H/D=1 \( k-\omega \) ACETYLENE

Fig 1.5.15 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.16 Nusselt number vs Surface of the plate

RESULTS OF HORIZONTAL JET H/D=1 \( k-\epsilon \gamma-Al_2O_3\)

Fig 1.5.17 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.18 Nusselt number vs Surface of the plate

RESULTS OF HORIZONTAL JET H/D=1 \( k-\epsilon 4\%\gamma-Al_2O_3\) GAS-

Fig 1.5.19 wall heat transfer coefficient vs Surface of the plate

Fig 1.5.20 Nusselt number vs Surface of the plate
RESULTS OF HORIZONTAL JET  H/D=1 k-ω 4%γ-Al₂O₃

Fig 1.5.21 wall heat transfer coefficient vs Surface
Fig 1.5.22 Nusselt number vs Surface of the plate
From Fig 1.5.1-1.5.21 it is observed that Acetylene gas has more heat transfer rate than nano fluid.

1.8 CONCLUSIONS/RECOMMENDATIONS

- At  H/D = 0.5, Acetylene gas has more values of surface heat transfer coefficient and Nusselt number compared with Nanofluid at k-ω turbulent model.
- At H/D = 1, Acetylene gas has more values of surface heat transfer coefficient and Nusselt number compared with nano fluid at k-ω turbulent model.

- Also Acetylene gas is preferred than other fluids for better heat transfer rate.
- k-ω turbulent model is assumed to be the best model used for better heat transfer calculation.
- It is to recommend that as the distance between Jet and plate increases we can get more transfer rate
- Finally it is concluded that nano fluid exhibits more heat transfer characteristics than base fluid(water) and less than Acetylene gas.
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