STUDY OF ENHANCEMENT OF HEAT TRANSFER USING UP WASH DELTA WINGLETS IN FIN & TUBE HEAT EXCHANGERS

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STUDY OF ENHANCEMENT OF HEAT TRANSFER USING UP WASH DELTA WINGLETS IN FIN & TUBE HEAT EXCHANGERS

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This is to certify that the thesis entitled ‘Study of enhancement of heat transfer using up-wash delta winglets in fin & tube heat exchangers’, being submitted by Amit Arora to the Indian Institute of Technology, Delhi for the award of degree of Doctor of Philosophy in Mechanical Engineering, is a record of bonafide research work carried out by him under our guidance and supervision. He has fulfilled the requirements for the submission of this thesis, which has attained the standard required for the aforementioned degree of this Institute. The results presented in this thesis have not been submitted in part or full elsewhere for the award of any other degree or diploma.

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FOREMOST, I will always remain grateful to the merciful Almighty who gave me an environment during my stay at IIT Delhi where I learnt a lot beyond just science and engineering, especially under the mentorship of my first supervisor. Words are insufficient for me to express my heartfelt adulation and sincere gratitude to both of my venerable supervisors and respected teachers Professor P.M.V. Subbarao and Professor R. S. Agarwal for their immense knowledge, constant inspiration and encouragement, invaluable guidance, thought provoking discussions and constructive criticism during the whole course of my doctoral investigation.

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Date: Amit Arora
A combined experimental and numerical analysis of passive heat transfer augmentation in traditional inline fin and tube heat exchanger is carried out. Artificially generated longitudinal vortices were used for heat transfer augmentation, which were generated by placing a pair of ‘common upwash’ delta winglets in the downstream of each tube of the heat exchanger. Mindful generation of vortices requires the study of effect of all dominating design parameters to arrive at a favourable configuration of longitudinal vortex generators. A detailed and systematic investigation was carried out to identify the parametric space in which the said delta winglets are effective for heat transfer enhancement. Main endeavour of this work was to create a phenomenological roadmap for the optimization of all key design parameters namely, attack angle, location, and geometry of the said winglets for modifying the flow in a given geometric variant of finned tube heat exchanger. It is found that practically there can be two types of optimization policies for the location of said delta winglets depending upon the application of the heat exchanger. This study guides that upwash delta winglets with an attack angle of $45^\circ$ optimally augments heat transfer in an inline aligned finned tube heat exchanger. And aspect ratio equal to unity is found to be the lower limiting value of thermo-hydraulically optimal geometry for already found optimal locations of the winglets. It is observed that optimally located winglets not only helped in augmenting heat transfer coefficients on the fin surface wetted by the tube wake, but also on the fin surface outside the tube wake. During the study of conventional delta winglets, differential augmentation in the heat transfer was observed on the two sides of a fin which is bound to create thermal stresses along the fin thickness. Such a performance augmentation may affect reliable operation of the heat exchangers, so a novel arrangement of delta winglets is proposed which enables heat transfer enhancement with better mechanical reliability. A comparison of conventional and novel configurations showed that the latter enhances thermal performance of the heat exchanger better than or at par with the former while ensuring better mechanical reliability.

Keywords: Common upwash, longitudinal vortices, vortex generators, aspect ratio.
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<td>O.D.</td>
<td>Outer diameter</td>
</tr>
<tr>
<td>Δp</td>
<td>Pressure drop</td>
</tr>
<tr>
<td>P</td>
<td>Perimeter (wetted)</td>
</tr>
<tr>
<td>P_f</td>
<td>Fin pitch</td>
</tr>
<tr>
<td>P_L</td>
<td>Longitudinal tube pitch</td>
</tr>
<tr>
<td>P_T</td>
<td>Transverse tube pitch</td>
</tr>
<tr>
<td>Q</td>
<td>Heat transfer rate</td>
</tr>
<tr>
<td>r</td>
<td>Radius</td>
</tr>
<tr>
<td>R_h</td>
<td>Thermal resistance</td>
</tr>
<tr>
<td>Re</td>
<td>Reynolds number</td>
</tr>
<tr>
<td>SFF</td>
<td>Scaled Friction factor</td>
</tr>
<tr>
<td>SCF</td>
<td>Scaled Colburn’s factor</td>
</tr>
<tr>
<td>SHF</td>
<td>Scaled Heat flux</td>
</tr>
<tr>
<td>T</td>
<td>Temperature or Thickness</td>
</tr>
<tr>
<td>T_{inf}</td>
<td>Far field inlet air temperature</td>
</tr>
<tr>
<td>ΔT_{LMTD}</td>
<td>Log mean temperature difference</td>
</tr>
<tr>
<td>T_w</td>
<td>Tube wall temperature</td>
</tr>
<tr>
<td>T/C</td>
<td>Thermocouple</td>
</tr>
<tr>
<td>u</td>
<td>Velocity component in X-direction</td>
</tr>
<tr>
<td>U</td>
<td>Overall heat transfer coefficient</td>
</tr>
<tr>
<td>U_{2e}</td>
<td>Far field inlet air velocity</td>
</tr>
</tbody>
</table>
\( v \) Velocity component in Y-direction
\( V \) Velocity
\( \text{VG} \) Vortex generator
\( w \) Velocity component in Z-direction
\( X \) Coordinate in streamwise direction
\( Y \) Coordinate normal to the fin plane
\( Z \) Coordinate in spanwise direction

\( \alpha \) Attack angle of DVG
\( \varepsilon \) Turbulent kinetic energy dissipation rate
\( \rho \) Density
\( \theta^* \) Non-dimensional Excess temperature
\( \mu \) Dynamic viscosity
\( \omega \) Absolute uncertainty

\( \frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z} \) Partial derivatives in respective directions