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Numerical Analysis of Heat Transfer and Flow structure in a rectangular Channel with Delta Wing Vortex Generators

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ABSTRACT

In this study the augmentation of heat transfer in a rectangular channel with triangular delta wing vortex generators is evaluated . The heat transfer rate get analyzed through CFD software with different attack angles of delta wing and with different aspect ratios of delta wing . At particular Reynolds number , By increasing the attack angle and aspect ratio which kind of effect will produced on heat transfer rate and fluid flow get studied in this project . The attack angles are taken as 10^0, 15^0 and 30^0. Also the aspect ratios are taken as 1, 1.5 and 2 for delta wing. In results , we are going to analyzed velocity vector, counters , pressure distribution and friction factors.

***Keywords*— Heat transfer ,CFD analysis, Delta wing, vortex generator.**

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I. INTRODUCTION

Increasing demands on the performance of heat exchangers used in automotive industry, power systems, , electric circuit in electronic chip cooling, air conditioning and refrigerant applications, ,internal cooling of gas turbine blades and aerospace industry for reasons of compactness, reducing manufacturing cost and higher efficiency lead to use of heat transfer enhancement techniques. Vortex generation has emerged as one promising technique for enhancing air-side convection. In this method, wing like vortex generators (VGs) are punched or mounted on a heat-transfer surface to generate longitudinal vortices.

There are two separate methods for heat exchange augmentation:1) active vortex method and 2) passive vortex method. The active vortex method is used to actively govern the secondary flow and pressure drop so as to meet the required heat transfer rates even at the cost of increased pumping power. There is little use of this method in heat exchangers as the operating cost is very high. A few examples of active vortex method are the use of jets at different angles from the heat transfer surface into the boundary layer, and the generation of a secondary flow through acoustic excitation. Using longitudinal or latitudinal vortex generators for heat exchange augmentation is known as the passive vortex method. Delta wing, rectangular wing, delta winglet, rectangular winglet, trapezoidal delta wing, dimpled surfaces, ribs, and fins all are types of vortex generators.

Vortex generator is a kind of passive heat transfer enhancing device which is attached to the duct walls or fin surfaces and project into the flow at an angle of attack to the flow direction. It can be stamped on or punched out from the fin. Using VGs, the fluid flow can be powerfully disturbed because of the generation of vortex when fluid flows over it. The vortex generator not only disturbs the flow field, disrupts the growth of the boundary layer, but also makes fluid swirl and causes a heavy exchange of core and wall fluid, guiding to the augmentation of heat transfer.

The basic principle of vortex generators (VGs) is to create secondary flow, particularly longitudinal vortices, which disturb the thermal boundary layer developed along the wall and remove the heat from the wall to the core of the flow by means of high-scale turbulence.
In the literature review, The different longitudinal vortex generators such as the delta wing, trapezoidal delta wing and delta winglet pair were numerically studied and compared on the basis of average surface Nusselt number ratio, Friction factor ratio, and Performance Evaluation Parameter to understand the advantages and disadvantages of each using FLUENT. This research involves the numerical analysis of heat exchange enhancement in a rectangular channel using different types of longitudinal vortex generators (LVG) for a laminar flow. He used three different kinds of vortex generators like a delta wing with finite thickness, a trapezoidal delta wing, and a delta winglet pair. [1]

In this literature review, He analyzed a single winglet pair is firstly examined at three angles of attack, 15º, 30º and 45º, followed by multi-pair VGs consisting of a two-pair V-array, a conventional two row configuration and a three-pair V-array and the Reynolds number range based on channel height of 340 to 940. A two-pair V-array deployed at 30^0 attack angle had 12-36 % augmentation in the total heat transfer.[2]

In this literature review, he studied the augmentation of heat transfer in a rectangular channel with triangular vortex generators is evaluated. heat flux are compared with and without vortex generators in the channel at a blade angle of 30° for Reynolds numbers 800, 1200, 1600, and 2000. He concluded that At a particular blade angle, by increasing the Reynolds number the overall performance increases and span wise averaged Nusselt number was found to be greater at particular location for larger Reynolds number [3]

In this literature review, The velocity field and wall heat transfer distributions for internal flows in the presence of longitudinal vortices have been experimentally investigated. A transient method based on temperature measurement with thermo-chromic liquid crystals was used to obtain the heat transfer distribution behind a tetrahedral, full-body vortex generator.[4]

In this literature review, The combined spanwise average Nusselt number was calculated by using computational methods. He proposed new design of wing. At the end of results of the computation are expressed in terms of the compactness achieved by using the proposed design and about 32% reduction in length is possible by the use of delta wing vortex generator at an angle of attack of 26º.[5]

II. PROBLEM DEFINATION & METHODOLOGY

Geometry:
The rectangular channel has cross section dimensions of 25mm × 100 mm. Length of the channel is 900 mm. The delta vortex generators have the dimensions as per the aspect ratios taken like 1, 1.5, 2. The blade angle for the delta vortex generators is taken as 30°, 15^0 & 10^0. The wall material is taken as Aluminium and the fluid flowing is air.

The flow in the channel is with 5% turbulent intensity and enters the channel with uniform constant velocity across the cross section. The backflow turbulent intensity at outlet is also taken as 5%. The velocity of air is taken around 8 m/s to 10 m/s.

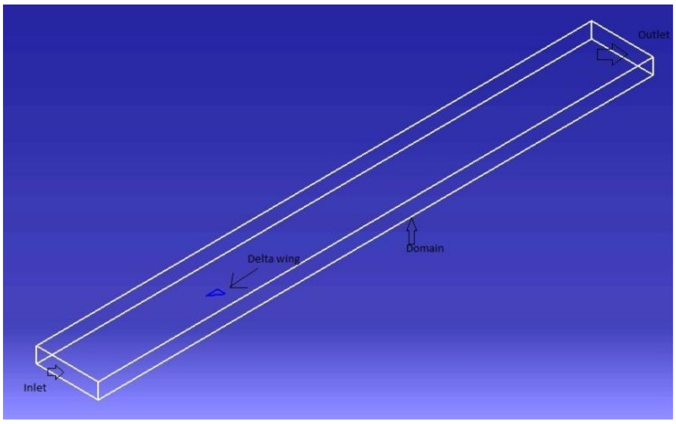

Fig no 1 Geometry of the domain with delta win

Table I

Sizes of Delta with respect to Aspect Ratio			
Sr. No.	**Aspect Ratio(ʌ)=2b/c (for Delta wings)**	**Delta Size**	
		Base (b)mm	**Height(c) mm**
1	1	12.8	25.6
2	1.5	19	25.4
3	2	12	12

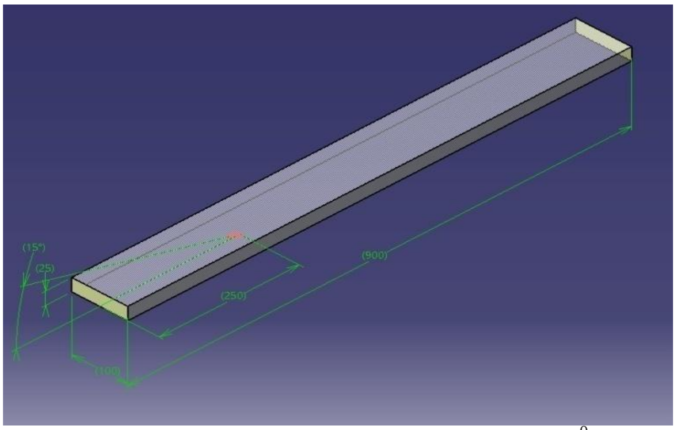

Fig no 2 Geometry of domain with delta wing at 15^0 attack angle

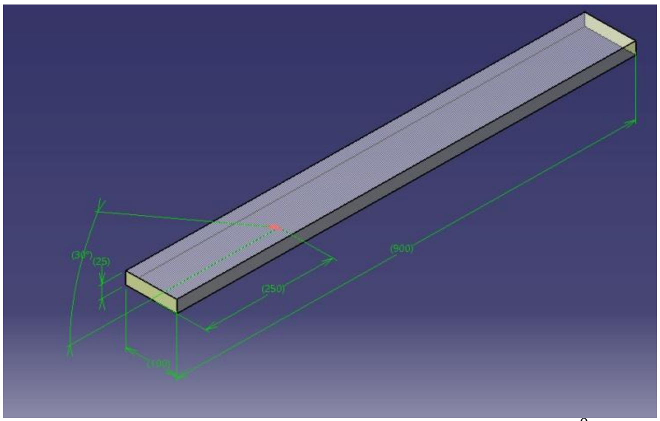

Fig no 3 Geometry of domain with delta wing at 30^0 attack angle

III.FLUENTSETUP

a Fluent Setup :

FLUENT 14.5 was used for CFD analysis in this study. The mesh files created in ANSYS Workbench called ICEM CFD and imported in fluent. The Fluent model is setup to allow energy equation in a Realizable *k*-Ű model with enhanced wall treatment. The fluid which is used in this study is air with a constant density of 1.225 kg/m3, dynamic viscosity of 1.7894 * 10-5 kg/m.s, the constant pressure specific heat of 4182 J/Kg-K, and thermal conductivity of 0.0314 W/m.K. The operating condition on the interior of the channel is fluid . the boundary conditions are tabulated in Table II are applied on the rectangular channel including the inlet and outlet channel. A temperature of 373K is applied on the bottom surface of the rectangular channel and all the surface of the vortex generator. The inlet has been given an inlet temperature of 300 K and a specific velocity of air at inlet is between 8 m/s to 10 m/s and with respect to that particular Reynolds number was calculated. The outlet was set at ambient condition. The walls of the whole channel, as well as surfaces of the vortex generator, have been given the no slip boundary condition. A second order upwind discretization method has been used for energy and momentum. Convergence is based on the absolute criteria of continuity, *x* velocity, *y* velocity and *z* velocity being equal to 10-3 and energy equal to 10-6. This means that the solution will converge once the residuals reach the above mentioned mark. The model is computed from the inlet surface and 1000 iterations were given for the solution to converge. The flow is with turbulent intensity of 5 % . and the flow is turbulent and the velocity of the flow is calculated as,

$$Re = \frac{\rho V H_d}{\mu},$$

where, Re = Reynolds number, (dimensionless)
ρ = density of the fluid, (kg/m3)
V = mean velocity of fluid flow, (m/s)
Hd = characteristic length or hydraulic diameter, (m)
μ = dynamic viscosity of the fluid, (kg / (m·s))

The hydraulic diameter is taken as

$$H_d = \frac{4 * \text{Area of the rectangular cross section}}{\text{Perimeter of the rectangular cross section}}$$

$$H_d = \frac{4 * B * H}{2(B + H)}$$

So the hydraulic diameter Hd = 0.04 m

The heat transfer coefficient is used to calculate the convective heat transfer

$$h = \frac{Q}{A \cdot \Delta T}$$

where, Q = heat transfer capacity, (W)
A = heat transfer surface area, (m2)
ΔT = log mean temperature difference, (K)

The continuity equation in a non-dimensional form for a steady state flow is given by

$$\frac{\partial u^*}{\partial x^*} + \frac{\partial v^*}{\partial y^*} + \frac{\partial w^*}{\partial z^*} = 0$$

The momentum equation in a non-dimensional form for a steady state flow is given by,

$$u^*\frac{\partial u^*}{\partial x^*} + v^*\frac{\partial u^*}{\partial y^*} + w^*\frac{\partial u^*}{\partial z^*} + \frac{\partial P^*}{\partial x^*} = \frac{1}{Re}\left(\frac{\partial^2 u^*}{\partial x^{*2}} + \frac{\partial^2 u^*}{\partial y^{*2}} + \frac{\partial^2 u^*}{\partial z^{*2}}\right)$$

$$u^*\frac{\partial v^*}{\partial x^*} + v^*\frac{\partial v^*}{\partial y^*} + w^*\frac{\partial v^*}{\partial z^*} + \frac{\partial P^*}{\partial y^*} = \frac{1}{Re}\left(\frac{\partial^2 v^*}{\partial x^{*2}} + \frac{\partial^2 v^*}{\partial y^{*2}} + \frac{\partial^2 v^*}{\partial z^{*2}}\right)$$

$$u^*\frac{\partial w^*}{\partial x^*} + v^*\frac{\partial w^*}{\partial y^*} + w^*\frac{\partial w^*}{\partial z^*} + \frac{\partial P^*}{\partial z^*} = \frac{1}{Re}\left(\frac{\partial^2 w^*}{\partial x^{*2}} + \frac{\partial^2 w^*}{\partial y^{*2}} + \frac{\partial^2 w^*}{\partial z^{*2}}\right)$$

The energy equation in a non-dimensional form for a steady state flow is given by

$$\frac{\partial(u^*T^*)}{\partial x^*} + \frac{\partial(v^*T^*)}{\partial y^*} + \frac{\partial(w^*T^*)}{\partial z^*} = \frac{1}{Re\,Pr}\left[\frac{\partial^2 T^*}{\partial x^{*2}} + \frac{\partial^2 T^*}{\partial y^{*2}} + \frac{\partial^2 T^*}{\partial z^{*2}}\right]$$

The computational domain uses following boundary conditions. Table III shows the boundary conditions assigned

TABLE II BOUNDARY CONDITIONS.

Zone	Assigned Boundary Type
Inlet	Velocity Inlet, Inlet fluid temperature = 300K
Outlet	Pressure Outlet, 0 Pa gauge
Bottom wall	Wall (No Slip), Constant Temperature = 373 K
Top wall	Wall (No Slip), Constant Heat Flux = 0 W/m2
Side walls	Wall (No Slip), Constant

	Heat Flux = 0 W/m2
Vortex Generators	Wall (No Slip), Constant Temperature = 373 K

Results and Discussion :In previous study [5]. The enhancement in heat transfer by delta wing was done in various methods. In our proposed work , we are going to find out enhancement in heat transfer by delta wing attached to flat rectangular plate .The numerical study is carried out in CFD by taking different aspect ratios and different attack angles. We are going to compare our results with Existing Experimental results.

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