FORCED CONVECTION HEAT TRANSFER ANALYSIS OF ZIG-ZAG CHANNEL

Suneel Sharma[1],Vardan Singh[2]

[1] *M.Tech student, Vidyapeeth institute of Science and Technology, Bhopal*
[2] *HOD, Mech Dept., Vidyapeeth institute of Science and Technology, Bhopal*

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Abstract: As things are compacting now a days so it is necessary that our heat transfer equipment's has to reduce in size without decreasing their effectiveness.in this regard in micro channels if we implant zig zag channel for fluid flow ,it increases area of heat transfer in increasing effective length.an experiments were performed on a zigzag plate to find relation of convective heat transfer and nusselt no.

Introduction:

The major advantages of Zig-Zag channels includes, increased surface area for heat flow, better flow mixing at curved portion consequences in better distribution of heat, and effective cooling . In normal heat flow as in straight channel same molecule remains in contact with the surface throughout the flow causes poor heat transfer, but in wavy or zig-zag channel, due to the phenomenon known as boundary layer regeneration fluid particle from free layer gets chance to come in contact with the surface which enhances the heat transfer characteristics. But its disadvantage is that it causes pressure drop. But the value of effectiveness of channel is greater than one which shows that heat transfer enhancement is more as compared to pressure drop.

In Zigzag channel as compared to straight channel the effective channel length (Le) for heat transfer increases, which allows the fluid to take more heat from the surface, which increases the fluid outlet temperature (for given temperature slope and fluid inlet temperature) and hence increases the convective heat transfer coefficient.

Physical significance of Dimensionless Numbers

- For Forced convectionh=f(V,ρ,u,K,Cp,Lc)

1. Reynold's Number , Re= $\frac{inertia\ force}{viscous\ force} = \frac{\rho VL}{u}$
2. Prandlt's Number, Pr = $\frac{Kinematic\ Viscosity(v)}{thermal\ diffusivity(\alpha)} = \frac{uCp}{K}$
3. Nusselt's Number , Nu= $\frac{heat\ transfer\ rate\ by\ convection}{heat\ transfer\ rate\ by\ conduction} = \frac{hL}{K}$
4. Stanton's Number , $St = Nu/RePr$

- For natural convection h=f(gβΔT,ρ,u,K,Cp,Lc)

1. Grashof's Number , Gr= $\frac{Buoyancy\ Force\ X\ inertia\ force}{eviscous\ force^2} = \frac{g\beta\Delta T\rho^2L^3}{u^2}$
2. Prandlt's Number, Pr = $\frac{Kinematic\ Viscosity(v)}{thermal\ diffusivity(\alpha)} = \frac{uCp}{K}$

5. Nusselt's Number , Nu= $\frac{heat\ transfer\ rate\ by\ convection}{heat\ transfer\ rate\ by\ conduction} = \frac{hL}{K}$

6. Rayleigh's Number , $Ra = GrPr$

EQUATION OF CHANNELS

1) Straight Channel:-

$$y = 0$$

2) Zig –Zag Channel:-

$$y = A\,\frac{8}{\pi^2}\left[\sin\left[\frac{2\pi}{\lambda}x\right] - \frac{1}{9}\sin 3\left[\frac{2\pi}{\lambda}x\right] + \frac{1}{25}\sin 5\left[\frac{2\pi}{\lambda}x\right] - - - - -\right]$$

EFFECTIVE LENGTH OF HEAT TRANSFER (Le):-

$$Le = \int_0^L \sqrt{\left[\frac{dy}{dx}\right]^2 + 1}\ dx$$

Basic Trapezoidal rule is used for integration,

EXPERIMENT

In this experiment, various thermal properties of channel is determined by varying flow rates as well as power input to the heater. Basic boundary condition used in the experiment is constant heat flux from the heater source.

Basically the heat loss by the channels is taken up by the fluid flowing over it, and by measuring surface an fluid temperature we can determine various thermal properties which includes, convective heat transfer coefficient, nusselt number, Reynolds number, friction factor etc.

Time for filling 500 ml (in sec)	**Voltage (In Volts)**	**Current(in amperes)**	**T1(temperature at heat inlet of rod)(in ^oC)**	**T1(temperature at heat outlet of rod)(in ^oC)**	**T3(temperature at water inlet)(in ^oC)**	**T4(temperature at water outlet)(in ^oC)**
100	100	0.4	37	35	26.5	27.2
50	100	0.4	36	34	26.4	27
100	150	0.5	42	37	26.5	27.6
50	150	0.5	46	37	26.5	27.7
100	200	0.65	69	47	26.6	28.2
50	200	0.65	67	46	26.6	29.2

Calculation

1. Qsupp=V*I
2. Mass flow rate=$\rho * Q$
3. Qout =m*cp*(T4-T3)
4. $Ts = T1 - 1.4 * (T1 - T2)$

$5Tmf = \frac{T3+T4}{2}$

6. $h = \frac{Qout}{(TS - Tmf)*A}$
7. $Re = \frac{\rho * V * Dh}{U}$
8. Nu= $\frac{h*dh}{k}$

RESULT;

Q SUPP	m(kg/s)	Qout	Tmf	Ts	h	Re	Nu
40	0.005	14.6545	26.85	34.2	**912.081**	111.481	0.14374
40	0.006	15.0732	26.7	33.2	**1060.82**	222.963	0.16719
75	0.003	13.8171	27.05	35	**795.059**	111.481	0.1253
75	0.006	30.1464	27.1	33.4	**2188.99**	222.963	0.34499
124	0.003	20.0976	27.4	38.2	**851.276**	111.481	0.13416
124	0.006	65.3172	27.9	37.6	**3080.39**	222.963	0.48547

Conclusion

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1. Experimentally we have seen that as flow rate increases value of coefficient of convective heat transfer also increases, and also higher value of heat input shows better heat transfer characteristics.
2. Within tolerable limit of experimental error as discussed above, we can conclude from experimental results, cfd analysis that zig-zag channel show better heat transfer characteristics as compared to straight channel due to
3. Increased surface area for heat flow,
4. Boundary layer regeneration fluid particle from free layer gets chance to come in contact with the surface which enhances the heat transfer characteristics
5. It creates secondary flow, vortex and turbulence results in better flow mixing, distribution of heat, and effective cooling.
6. In Zigzag channel as compared to straight channel the effective channel length (Le) for heat transfer increases, which allows the fluid to take more heat from the surface, which increases the fluid outlet temperature (for given temperature slope and fluid inlet temperature) and hence increases the convective heat transfer coefficient.

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