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Experiment Number (9)

Free and forced convection

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Abstract:

There are three modes for heat transfer: convection, conduction, and radiation. The convection heat transfer plays an important role in many industrial applications. The convection heat transfer is usually subdivided into free and forced convection. In the forced convection, the fluid is blown or pumped past the heated surface using a pump or a fan, while in the natural (or free) convection, fluid flow is naturally achieved by buoyancy effects, i.e., density variation in the fluid. The aim of this technical report is to comparing free and forced convection for different surfaces, determination of heat transfer coefficient (h), for free and forced convection in different geometries and comparison of heat transfer surface efficiency.

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Results:

Table (1): Reference temperatures

T_1 (°c)	T_2 (°c)	T_3 (°c)
24.9	25.2	25.2

Free convection

Table (2): raw data for free convection (pinned surface)

power (w)	T_2 (Surface T_s (°c))	T_1 (Duct inlet (ambient) T_{in} (°c))	Difference T_s - T_{in} (°c)
20.1	63.3	26.7	36.6

Forced convection

Table (3): raw data for forced convection (power = 20 w)

Air velocity (m/s)	T_2 (Surface T_s (°c))	T_1 (Duct inlet (ambient) T_{in} (°c))	Difference T_s - T_{in} (°c)
1.1	52.5	26.3	26.2
1.6	48	26.3	21.7
2	44.6	26.3	18.3
2.5	41.7	26.2	15.5
3	40.4	26.3	14.1

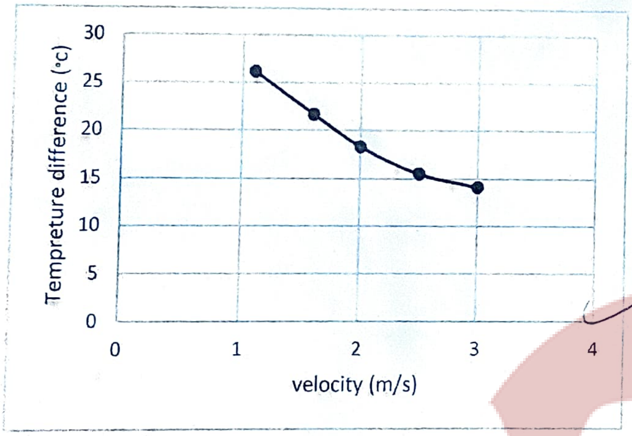

Figure (1): Air velocity vs. temperature difference (V vs. (T_s - T_{in}))

Heat transfer coefficient

Table (4): properties of convection (power = 20 w)

Duct transverse probe position (mm)	T_1 Ambient temperature (probe) T_{in} (°c)	T_2 Heat transfer surface temperature T_s (°c)	T_3 Duct transverse probe T_p (°c)	Difference T_s-T_{in} (°c)	Difference T_p-T_{in} (°c)
0	26.7	39.7	27.9	13	1.2
1	26.7	39.6	27.9	12.9	1.2
2	26.8	39.6	27.9	12.8	1.1
3	26.7	39.5	27.6	12.8	0.9
4	26.7	39.4	27.4	12.7	0.7
5	26.7	39.4	27.2	12.7	0.5
6	26.6	39.4	27.0	12.8	0.4
7	26.6	39.4	27.9	12.8	1.3
8	26.5	39.3	27.9	12.8	1.4

Table (5): average temperature (power = 20 w)

T_{in} (°c)	T_s (°c)	T_p (°c)	T_s-T_{in}(°c)	T_p-T_{in}(°c)
26.7	39.5	27.6	12.8	0.97

Logarithmic mean temperature difference T_m= 53.76 C

heat coefficient h_c=13.77 W/m^2 K

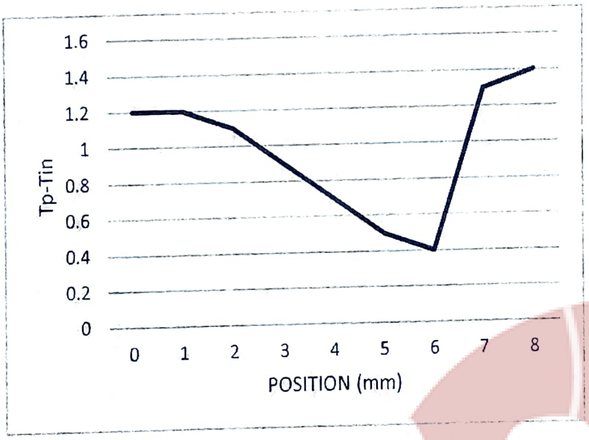

Figure (2): position vs. (T_P-T_{in})

Discussion

Pinned surface was used since its surface area more that the flat plate or finned plate results to more efficient transfer heat.

In free convection the heated air moves naturally when buoyant force effecting on it is greater than the gravity force, that happen when the heated air density decrease, and that takes a lot of time.

On the other hand, there is air moving the heated air in force convection, as you can see in figure 1 as the air velocity increases the temperature different between inlet and surface temperature decreases, which means the air temperature didn't rise that much while moving through the pins resulting to higher driving force and higher efficiency for transferring heat.

The pins temperature decrease moving far from the base which means the heat transfer also decreases.

The heat coefficient calculated in this experiment h_c=13.7 W/m^2 K is in the forced convection range

Conclusion:

- The rate of heat transfer in forced convection is higher which can be controlled by external equipment.
- The system with forced convection has a higher overall heat transfer coefficient than free convection
- Extended surfaces enhanced rate of heat transfer , pin surface shows higher heat transfer than other surfaces

references

1-https://mechcontent.com/free-convection-vs-forced-convection/ 24/8/2022

calculations

Sample of calculation

For free convection:

$Difference(T_s - T_{in}) = 63.3 - 26.7 = 36.6°C$

For force convection:

$Difference(T_s - T_{in}) = 50.5 - 26.3 = 26.2°C$

For Heat transfer coefficient:

$Difference(T_s - T_{in}) = 39.7 - 26.7 = 13°C$

$Difference(T_p - T_{in}) = 27.9 - 26.7 = 1.2°C$

$T_m = (T_{out} - T_{in})/\log((T_s - T_{in})/(Ts - T_{out})) = (0.97-26.7)/\log((39.5-26.7)/(39.5-0.97)) = 53.76$ C

$hc = Q/(A_s * T_m) = 20/(0.27*53.76) = 13.77$ W/m^2 K