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Experimental Setup for Heat Transfer Analysis on Rectangular Plate by Natural Convection

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ABSTRACT
This paper represents the profiled activity accomplished by natural convection and it has the major broad application in the field of engineering and technology.In natural convection the fluid which surrounds the heat source receives heat radiations as its density decreases by temperature gradient as a result the air becomes less dense and forms its provisions for escape and the process continuously takes place for regular intervals, as the cold fluid is made readily available for heat contact and its geometric figure mainly depends on design, and analysis. Thermal analysis is done on the Rectangular flat plate materials used for the process is made of brass which is an alloy of copper and zinc as the brass is non- ferrous metal with excellent electrical and thermal conductivity as well as good corrosion resistance, ductility and strength the thermal conductivity of brass is 109 (w/mk) by which the brass has the excellent thermal conductivity and is a first choice for heatexchangers.
The design task of rectangular plate can be accomplished in Catia V5R21 software as it is being end up by making its geometrical model and the thermal behavior is studied in ansys 2020 R1 Academic software Fluent database. CFD analysis is to determine the pressure drop, velocity, heat transfer rate and mass flow rate for the rectangular plate. Thermal analysis is to determine the heat flux and temperature distribution along the rectangular plate. Its post processing gives out the study on contours of various parameters and its values. The charts are prepared by plotting the parameters values on Y axis against the Xaxis.
Keywords: Natural convection,Ansys CFD, Thermal Analysis, Rectangular plate, Heat flux, etc..,

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I. INTRODUCTION:

Natural convection is an appliance of heat transfer by which the fluid motion is caused by density differences in the fluid occurred by temperature gradients. Which results in mass movement of fluids, in natural convection, fluid surrounding a heat source receives heat, becomes less dense and rises up. The fluid or air surrounding the source surface moves to replace it. This cooler fluid getsheated and the process becomes unbroken, which results for formation of convection currents, this process transfers heat energy from the bottom of the convective cell tothe top.

Natural convection has attracted a great deal of attention from researchers because of its presence both in nature and engineering applications.

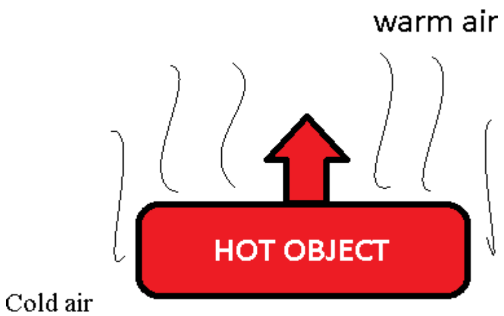


Fig 1: Natural convection heat transfer

In nature, convection cells formed from air raising above sunlight-warmed land or water are a major feature of all weather systems. Convection is also seen in the rising plume of hot air from fire, plate tectonics, oceanic currents (thermohalinecirculation) and sea-wind formation (where upward convection is also modified by Coriolisforces). In engineering applications, convection is commonly visualized in the formation of microstructures during the cooling of molten metals, and fluid flows around shrouded heat-dissipation fins, and solar ponds.

1.1 Literature Review

OronzioManca et.al.,(2015) has carried out an experimental investigation on air natural convection, in a vertical channel asymmetrically heated at uniform heat flux, with downstream unheated parallel extensions, is carried out. Maximum wall temperatures and channel nusselt numbers are correlated to the channel Rayleigh number[1].

Satyaprakashvermaet.al., (2017) conducted experiments on natural convection heat transfer for a rectangular enclosure from the heated triangular array fin has been performed. His present study shows increasing of Ra ($365214 \leq Ra \leq 683826$) and fin height the Nu increases continuously[2].

Thara R et.al.,(2017) Most of the studies on natural convection have been considered constantly whereas velocity and temperature domain, do not change with time, transient one are used a lot. Governing equations are solved using a finite volume approach. Then a configuration of rectangular fins is put in different ways on the surface and heat transfer of natural convection on these surfaces without sliding is studied and finally optimization is investigated[3].

AbimanyuPurusothaman et.al.,(2016) this author proposed is to examine numerically the natural convection heat transfer in a cubical cavity induced by a thermally active plate. Effects of the plate size and its orientation with respect to the gravity vector on the convective heat transfer and the flow structures inside the cavity are studied and highlighted [4].

Loc Ngo, Tunde Bello-Ochende et al. (2015) predicted the Numerical modelling and optimisation of natural convection heat loss suppression in a solar cavity receiver with plate fins and optimized process parameters for the equipment [5].

Shinichiro Wakashima et.al.,(2003) Benchmark numerical solutions for a three-dimensional natural convection heat transfer problem in a cubical cavity are presented in this paper. The 3-D cavity has two differentially heated and isothermal vertical walls and also four adiabatic walls. Author proposed benchmark solutions will be useful for checking the performance and accuracy of any numerical methodologies [6].

II. BOUNDARY LAYER OF A FLAT PLATE:

When a viscous fluid flows along a fixed impermeable wall, or past the rigid surface of an immersed body, an essential condition is that the velocity at any point on the wall or other fixed surface is zero.

Consider a flat plate of length L, infinite width, and negligible thickness, that lies in the x – z plane, and whose two edges correspond to x = 0 and x = L. The imposition of this additional constraint causes thin boundary layers, of thickness$\delta(x) \ll$, to form above and below the plate.

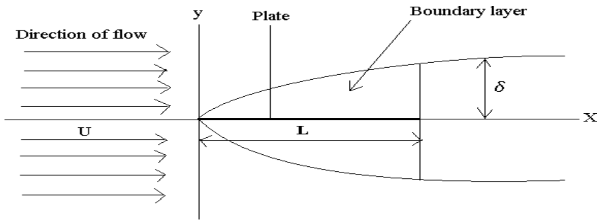


Fig 2: Boundary layer.

III. EXPERIMENTAL SETUP:

Natural Convection Apparatus - a brass plate fitted on a wooden rectangular duct which is open at the top and the bottom an electric heater is provided in the vertical plate, which heats the surface of the plate. Heat is lost from the plate to the surrounding air by natural convection, because the air in contact with the plate gets heated and becomes less dense, causing it to rise. This in turn creates a continuous flow of air upward in the duct. The stylus is used instead of the thermocouple which is capable of transmitting the effect of heat to the recording system the stylus is made to move on the flat plate with a fixed distance there are 4 points to be assumed as moreover 25mm of distance which is the point assumed for thermocoupledistance.

The apparatus consists of a wooden frame structure and the components are embedded with the slots provided on the wooden ply wood as it forms the apparatus setup completely the control panel for the natural convection apparatus is shown in figure.

features:-

- Heat transfer coefficient in natural convection conditions can becalculated.
- Variation of local heat transfer coefficient over the entire length of vertical rectangular plate can bestudied.
- Average value of heat transfer coefficient can be obtained from suitablecorrelation

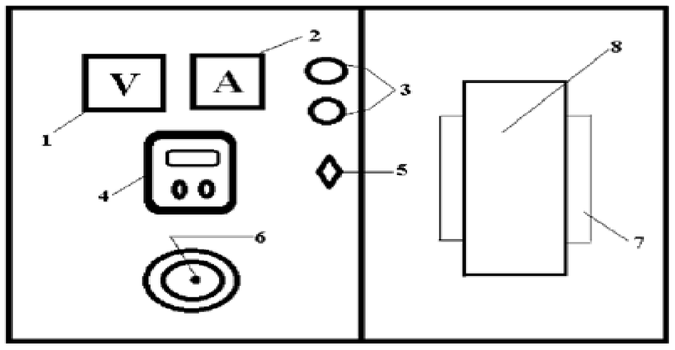


Fig no 3: Line view of Natural convection apparatus

1-Voltmeter, 2-Ammeter, 3-Indicators, 4- Digital temperature indicator, 5-Toggle switch, 6- Dimmer stat 7- heater 8- brass plate.

3.1 **OBSERVATIONTABLE:**

Time	HEAT INPUT			TEMPERATURE OF SURFACE OF THE PLATE					AMBIENT TEMPERATURE
	V	I	V×I	T1	T2	T3	T4	T5	Ta
10 min	50	0.19	9.5	38	37	35	35	34	29
20 min	50	0.19	9.5	36	34	37	34	35	29
30 min	50	0.19	9.5	38	36	35	35	32	29
40 min	50	0.19	9.5	38	38	35	37	35	29
50 min	50	0.19	9.5	40	38	37	39	38	29
60 min	50	0.19	9.5	41	39	36	39	38	30
70 min	50	0.19	9.5	41	39	37	39	39	30
80 min	50	0.19	9.5	42	40	39	40	41	31
90 min	50	0.19	9.5	43	42	39	40	41	32
100min	50	0.19	9.5	43	41	40	40	40	32
110min	50	0.19	9.5	43	41	40	40	40	32

Table1: temperature observation table

The table is noted down until the steady condition values of temperature is obtained by observing the condition's after every 10 minutes of time.
So the system comes to the steady condition after a period of 110 minutes of time the values in the above table is noted at a single power input.

3.2 Specimen calculation:$h_{exp} and h_{theoritical}$observation table:

(Duck) T_s= T_∞	$h$exp =(q/A×(T_S−$T\infty$))	$h_{theoritical}$
36	4.65×10^{-3}	7.28×10^{-3}
35	5.69×10^{-3}	8.16×10^{-3}
35	6.03×10^{-3}	8.65×10^{-3}
37	6.38×10^{-3}	8.96×10^{-3}
39	5.93×10^{-3}	8.45×10^{-3}
39	6.32×10^{-3}	8.94×10^{-3}

39	7.12×10^{-3}	9.13×10^{-3}
40	7.45×10^{-3}	9.63×10^{-3}
41	7.49×10^{-3}	9.70×10^{-3}
41	7.49×10^{-3}	9.70×10^{-3}

Table no 7.3: experimental and theoritical values of h

*The experimental and theoritical values of heat transfer coefficient is compared in the above table and the variations are being observed.

IV. PROBLEM DESCRIPTION

The objective of this project is to make a 3D model of the rectangular plate and study the CFD and thermal behavior of the plates by performing the finite element analysis.3D modeling software (Catia) was used for designing and analysis software (ANSYS) was used for CFD and thermal analysis. The methodology followed in the project is as follows:

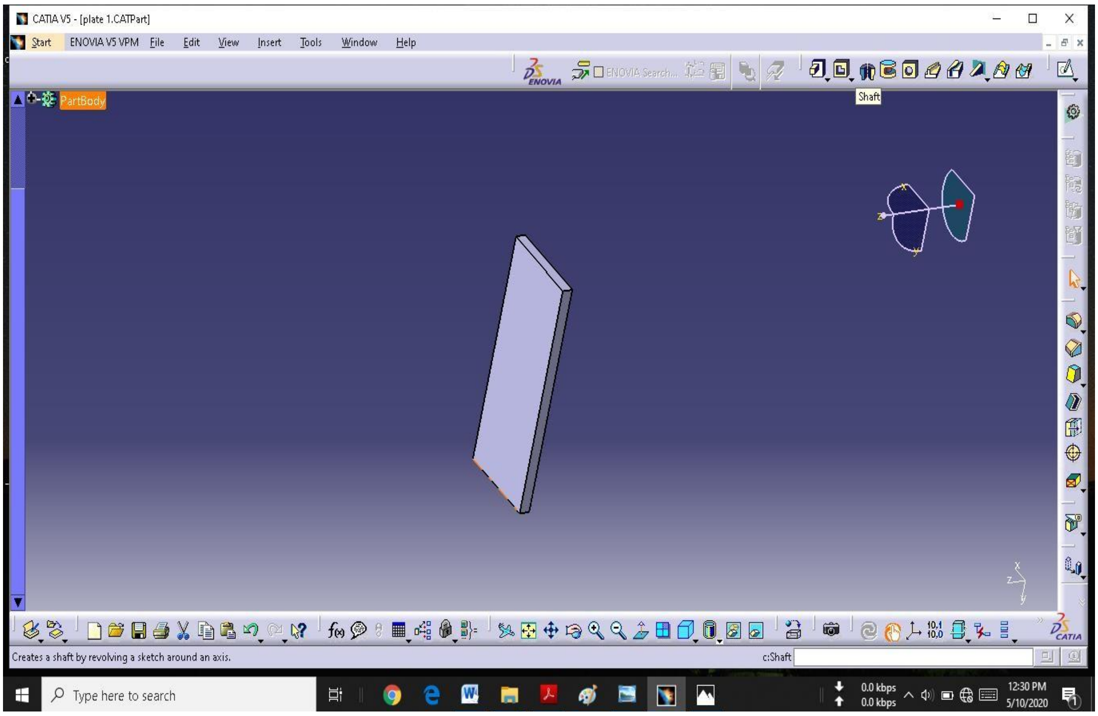


Fig 4: Catia designed model

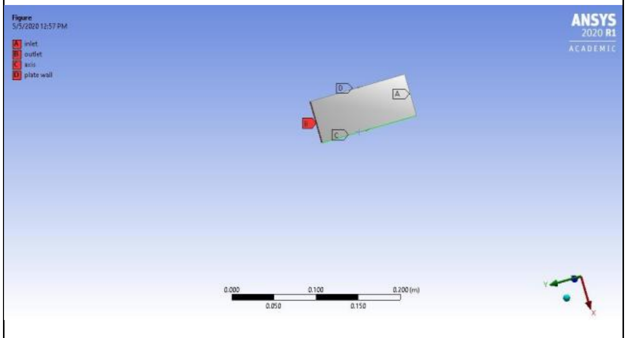
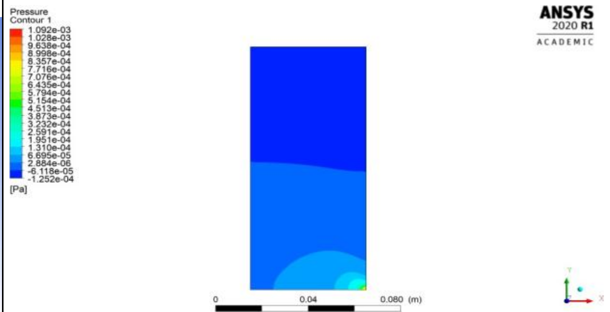
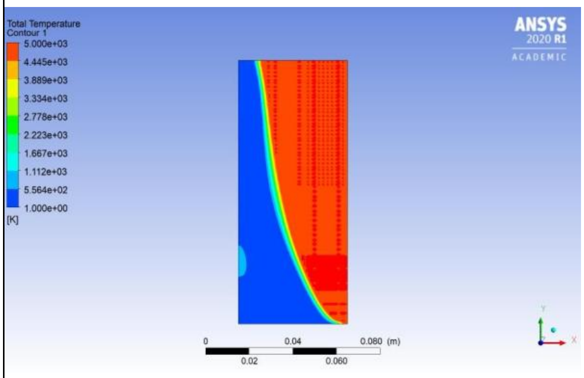
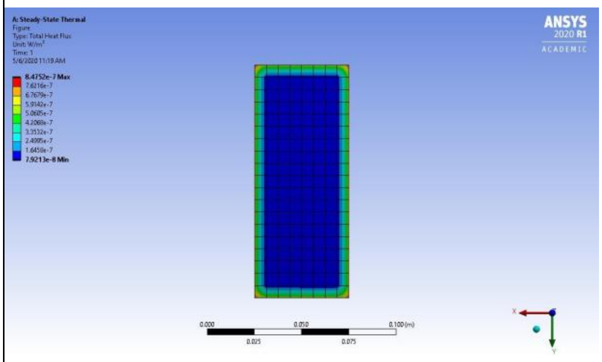
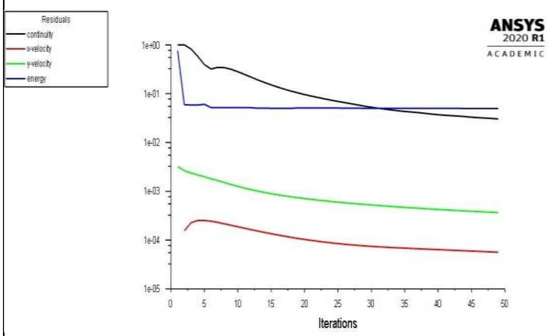
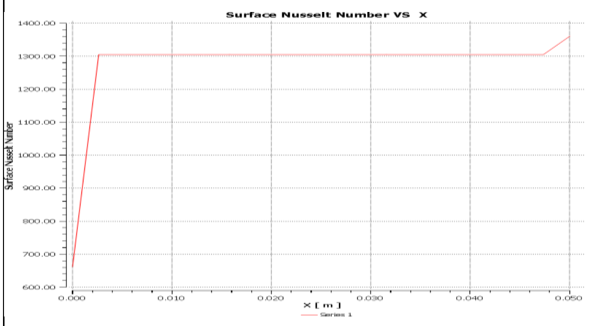
V. RESULTS

5.1 THERMAL ANALYSIS OF FLATPLATE

Material used: Brass Material properties:
Thermal conductivity 109 W/m-k Density : 8.79 g/cc
Melting point : 900-950º c

Ansys (Workbench) — fluid flow fluent—version 2020R1

To generate the meshing, there are two methods one is automatic mesh generation and the other is with required size meshing. In this we used auto meshing with mediummeshing.
Here presented below various cfd analysis figures like boundary conditions, pressure contour, temp contour, wall heat flux contour and various graphs.

Boundary conditions: A: inlet, B: outlet, C:axis, D:side plate wall 	Pressure: Max value 9.638e-04— Min value 1.252e-04 
Fig 5: Boundary conditions of rectangular flat plate	Fig 6: Pressure contour
Total temperature: Max value 5.00e+03—Min value 1.00e+00 	Wall heat flux: Max value 8.475e-7—Min value 7.921e-7 
Fig 7: Total temperature contour	Fig 8: Wall heat flux contour
Iterations: 50 iterations 	*Surface Nusselt's Number:* 
Fig 9: Iterations	Fig 10: Surface Nusselt number vs X Graph

Heat flux vsX:	*Surface Heat Transfer Coefficient vs X:*

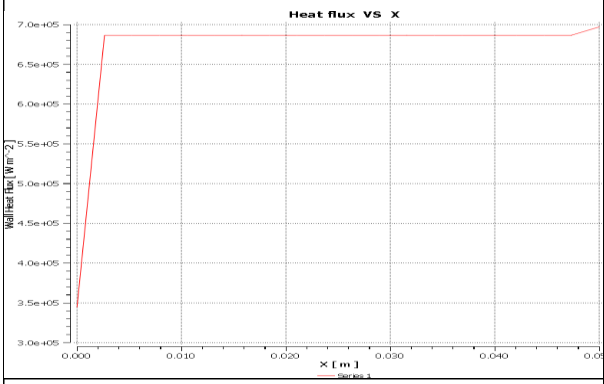
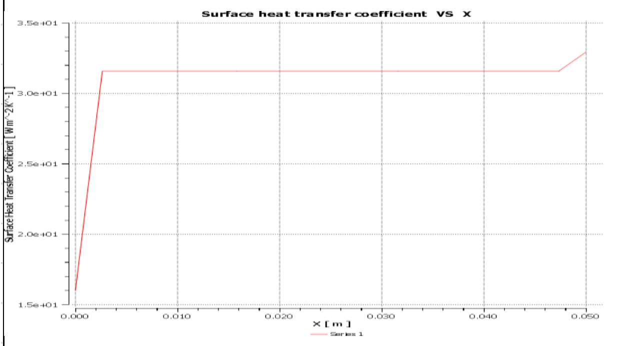

	

Fig 11: Heat flux vs X Graph	Fig 12: Surface Heat Transfer Coefficient vsX Graph

5.2 CFD analysis results table:

Reynolds number	Nusslet's number	Pressure (pa)	Velocity (m/s)	Mass flow rate (kg/s)	Heat transfer coefficient (w/m2-k)	Heat transfer rate (W)
2×10^5	3.2×10^2	2.326*e*+03	2.60*e* +02	180.1799	3.69e+02	360359.9
		1.963 *e*+01	2.44*e* +02	11820.615	3.39e+02	236412.3
		3.326 *e*+02	5.01*e* +02	17819.265	3.29e+02	356385.3
		3.962 *e*+02	3.40*e* +02	36849.16	4.26e+02	736983.2

Table 3: CFD analysis table

5.3 Thermal analysis results:

Material	Temperature K (0^0C)	Heatflux (W/mm²)
Brass	335.2	0.13101
Brass	335.6	0.15530
Brass	335.8	0.17160
Brass	335.9	0.18320

Table 4: Thermal analysis results table

VI. CONCLUSION

The presented paper view on heat transfer by natural convection have been viewed on many aspects of theoretical and practical and its analysis makes the picture bright the experiment on flat brass plate is conducted by close observation by keenly observing the temperature variations till the steady values of the table is obtained as the aim of the experimental setup is to find out the theoretical and experimental heat transfer coefficient by using the necessary formulae's and observations the mean difference between the theoretical and experimental values of h depends on temperature geometry and other thermo-physical factors like viscosity, thermal conductivity etc. and is independent of time, the 3d cad model is prepared for the importing the designed data into ansys by presenting the relation between the Reynolds number and Nusselt number and the heat flux data finally concludes the presented input data above Reynolds (Re), Grashof (Gr), and Rayleigh numbers (Ra), have been investigated. So the plate is fixed to the experimental board so the fixed values are supposed to be obtains as well as The above notations are increasing with the increase of inclination angles. So placing the plate with maximum inclination is better since the heat transfer rates are increasing. So it can be concluded that by increasing inclination the plate's yields betterresults.

The heat transfer rates by using flat rectangular plate are analyzed using thermal analysis. The material which is taken as brass By observing the CFD analysis results, the pressures, velocity, nusselt's Number, Reynolds number contours gives out the proper graph indications as the plotted values vs the x axis are increasing with increase of inclination angles. So placing the plate vertical with a heating source at the bottom gives the better since the heat transfer rates are increasing. By observing the thermal analysis results, the heat transfer rates are almost similar for the flat rectangular plate. This data obtained from the analysis forms a reference basis for comparing the experimental values for different variables with the same input and boundary conditions. As the above part is being analyzed in ansys which gives out the picture or its thermal deform along its different contours and flow rates the minimum and maximum wall heat flux is found.

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