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Computer Simulations of Natural Convection of Single Phase Nanofluids in Simple Enclosures

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ABSTRACT

Recently, employing nanofluids as heattransfer agent becomes an upward trend and aconsiderable alternative to markedly enhance the heattransfer process. Effective heattransfer during heating and cooling streams is anurgent demand in chemicals, petrochemicals, andpharmaceuticals industries.

Obviously, industry relies on computersimulation as a quick and effective tool to test,monitor, analyze, and modify the individual units (e.g.heat exchangers) and the entire process performanceas well.

In this thesis, the natural convection heat transfer of two nanofluids with different concentrations (0.1, 0.2 and 0.5, vol% of SiC and Al_2O_3 nanoparticles in water) in different enclosures areexamined using CFD analysis. Computer simulations are performed to find the Nusselt number and the heat transfer coefficient for natural convection of nanofluids in horizontal square, annulus and triangular enclosure.

3D modeling is done in Pro/Engineer and analysis is done in Ansys.

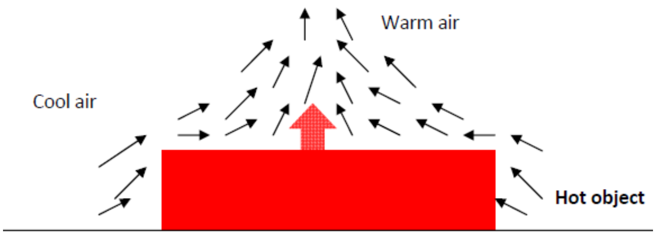
INTRODUCTION

NATURAL CONVECTION

In natural convection, the fluid motion occurs by natural means such as buoyancy. Since the fluid velocity associated with natural convection is relatively low, the heat transfer Coefficient encountered in natural convection is also low.

MECHANISMS OF NATURAL CONVECTION

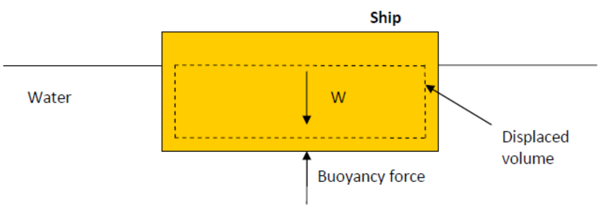
Consider a hot object exposed to cold air. The temperature of the outside of the object will drop (as a result of heat transfer with cold air), and the temperature of adjacent air to the object will rise. Consequently, the object is surrounded with a thin layer of warmer air and heat will be transferred from this layer to the outer layers of air.



Natural Convection heat transfer from a hot body

The temperature of the air adjacent to the hot object is higher, thus its density is lower. Asa result, the heated air rises. This movement is called the natural convection current. Notethat in the absence of this movement, heat transfer would be by conduction only and itsrate would be much lower.

In a gravitational field, there is a net force that pushes a light fluid placed in a heavier fluid upwards.This force is called the buoyancy



Buoyancy force keeps the ship float in water

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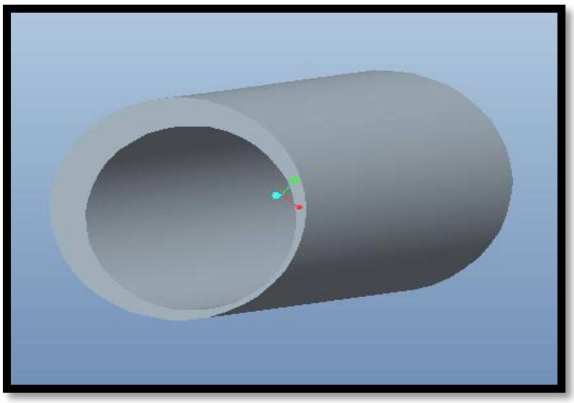
The magnitude of the buoyancy force is the weight of the fluid displaced by the body. Fbuoyancy = ρfluid g Vbodywhere Vbody is the volume of the portion of the body immersed in the fluid. The net forceis:Fnet = W -FbuoyancyFnet = (ρbody-ρfluid) g VbodyNote that the net force is proportional to the *difference in the densities* of the fluid andthe body. This is known as *Archimedes' principle*.We all encounter the feeling of "weight loss" in water which is caused by the buoyancyforce. Other examples are hot balloon rising, and the chimney effect.Note that the buoyancy force needs the gravity field, thus in space (where no gravityexists) the buoyancy effects does not exist.Density is a function of temperature, the variation of density of a fluid with temperatureat constant pressure can be expressed in terms of the volume expansion coefficient β,defined as:It can be shown that for an ideal gasideal gas=1/Twhere *T* is the absolute temperature. Note that the parameter βΔT represents thefraction of volume change of a fluid that corresponds to a temperature change ΔT atconstant pressure.Since the buoyancy force is proportional to the density difference, the larger thetemperature difference between the fluid and the body, the larger the buoyancy force willbe.Whenever two bodies in contact move relative to each other, a friction force develops atthe contact surface inthedirection opposite to that of the motion. Under steady conditions, the air flow rate driven by buoyancy is established by balancing the buoyancyforce with the frictional force.

3D MODELS OF ENCLOSURES

ANNULAS ENCLOSURE



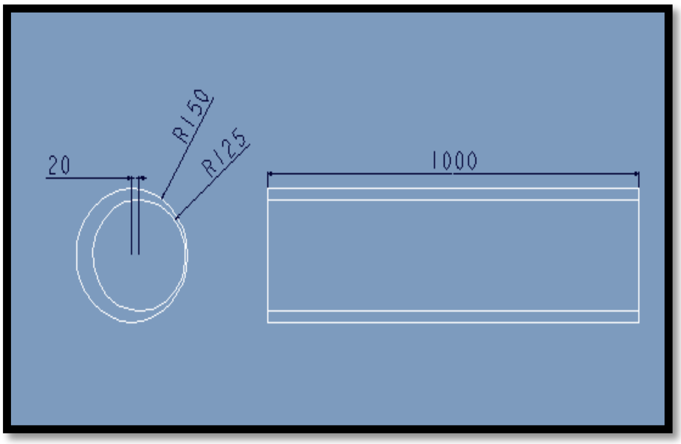


Fig - 3D Model & 2D Drawing of Annulas Enclosure

HORIZONTAL SQUARE ENCLOSURE

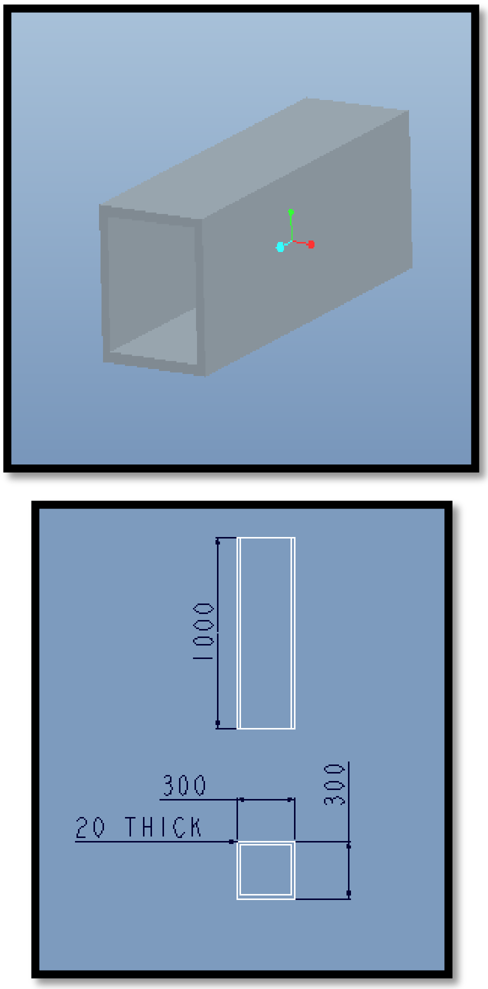


Fig - 3D Model & 2D Drawing of Horizontal Square Enclosure

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TRIANGULAR ENCLOSURE

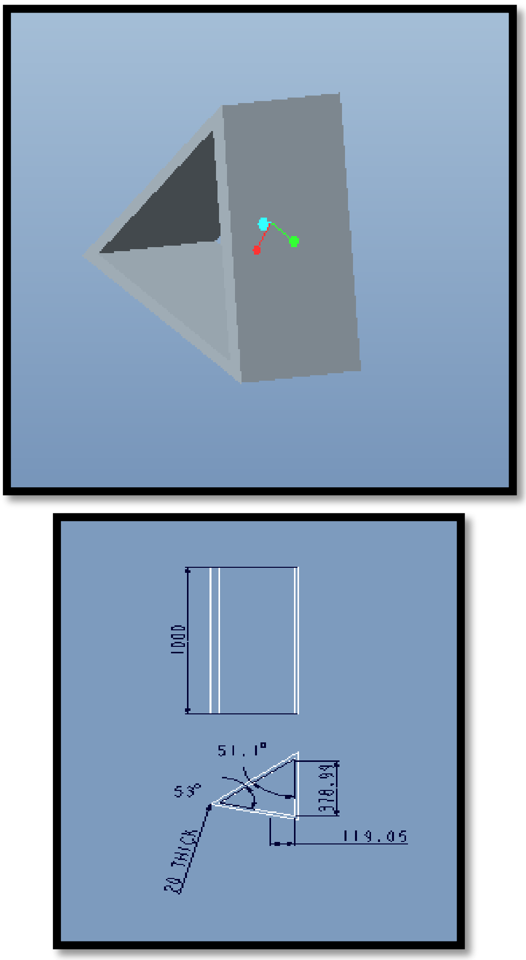


Fig - 3D Model & 2D Drawing of Triangular Enclosure

NOMENCLATURE

ρ_{nf}= Density of nano fluid (Kg/m^3)

ρ_s= Density of solid material (Kg/m^3)

ρ_w = Density of fluid material (water) (kg/m^3)

ϕ = Volume fraction

C_{pw} = Specific heat of fluid material (water) (J/kg-k)

C_{ps} = Specific heat of solid material (J/kg-k)

μ_w = Viscosity of fluid (water) (Kg/m-s)

μ_{nf} = Viscosity of Nano fluid (Kg/m-s)

K_w = Thermal conductivity of fluid material (water) (W/m-k)

K_s = Thermal conductivity of solid material (W/m-k)

DENSITY OF NANO FLUID

$$\rho_{nf}= \phi\times\rho_s + [(1-\phi) \times \rho_w]$$

SPECIFIC HEAT OF NANO FLUID

$$C_{pnf} = \frac{\phi\times\rho s\times Cps+(1-\phi)(\rho w\times Cpw)}{\phi\times\rho s+(1-\phi)\times\rho w}$$

VISCOSITY OF NANO FLUID

$$\mu_{nf} =\mu_w\ (1+2.5\phi)$$

THERMAL CONDUCTIVITY OF NANO FLUID

$$K_{nf} = \frac{Ks+2Kw+2(Ks-Kw)(1+\beta)^3\times\phi}{Ks+2Kw-(Ks-Kw)(1+\beta)^3\times\phi}\times k_w$$

β=0.1 taken from journal

SILICON CARBIDE NANO FLUID PROPERTIES

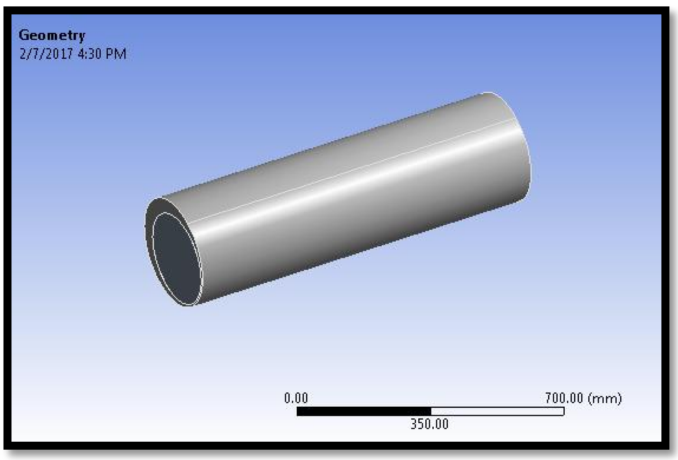
Volume fraction	Thermal Conductivity(W/m-k)	Specific Heat(J/kg-k)	Density(kg/m^3)	Viscosity(kg/m-s)
0.1	1.02577	1797.43	1129.98	0.120125
0.2	1.9198544	3684.33072	1361.58	0.14415
0.5	4.4777896	3685.78	2056.38	0.216225

CFD ANALYSIS OF SIMPLE ENCLOSURES BY USING NANO FLUIDS

ANNULUS ENCLOSURE

FLUID – SILICON CARBIDE

VOLUME FRACTION - 0.1



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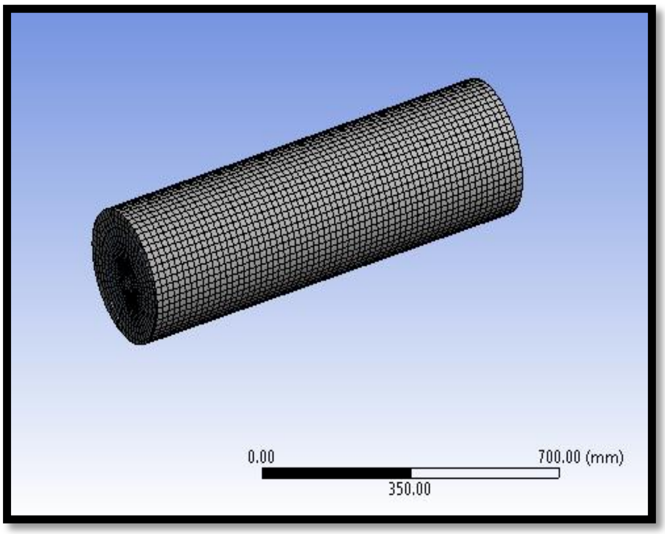
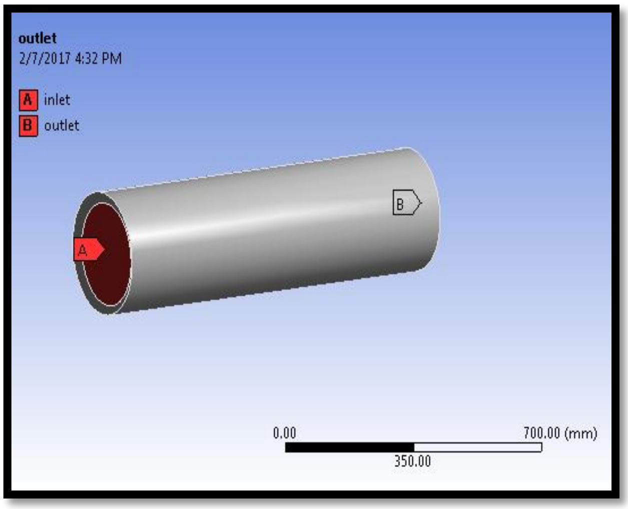
Imported model



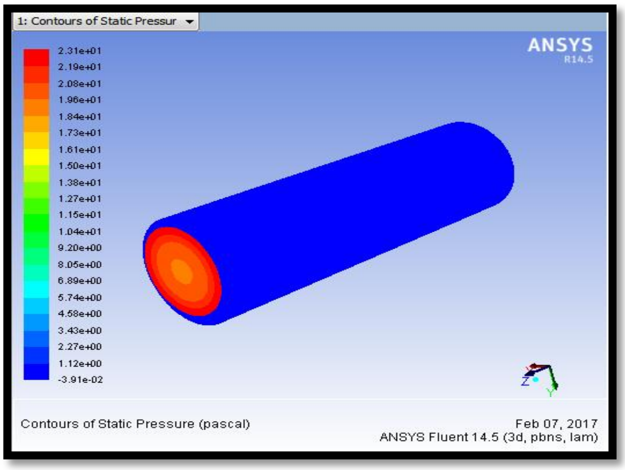
Meshed model



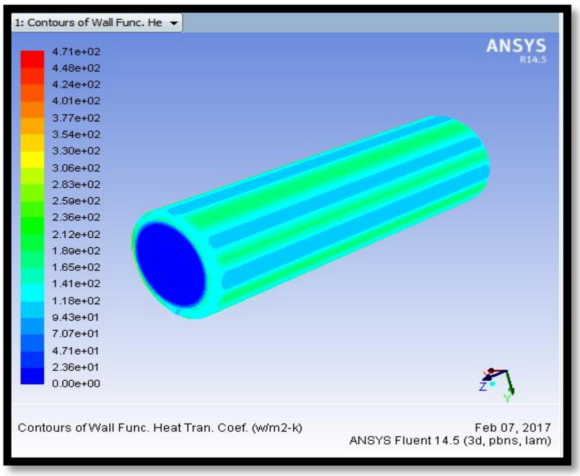
Thermal conductivity - 0.75w/m-k
Specific heat - 3142.33 J/kg-k
Density - 1282.38kg/m^3
Viscosity - 0.00125kg/m-s

BOUNDARY CONDITIONS

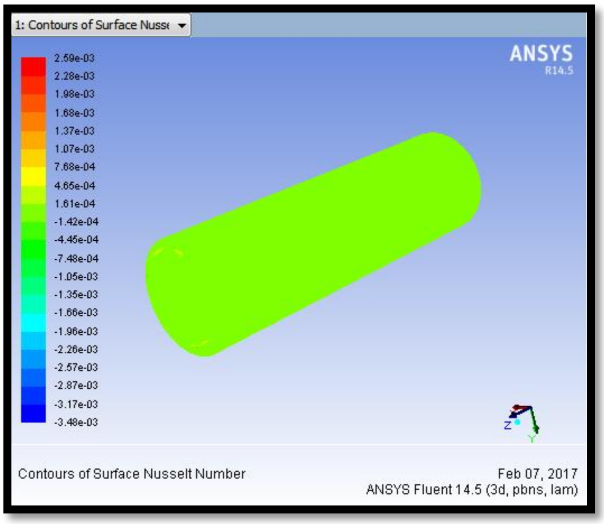
inlet temperatures(t)	303K
inlet pressure(p)	101325 Pa
inlet velocity(v)	0.1524m/s



Pressure



Heat Transfer Co Efficient



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Nusselt Number

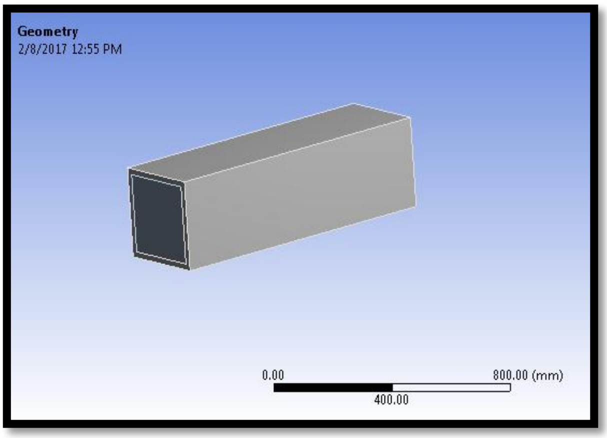
Heat Transfer Rate

Total Heat Transfer Rate	(w)
contact_region-src	0
contact_region-trg	0
inlet	73252.688
outlet	-73253.336
wall-12	0
wall-13	0
wall-4	-0.00061918149
wall-4-shadow	0.00083802867
wall-solid	0
Net	-0.64821865

Mass Flow Rate

Mass Flow Rate	(kg/s)
contact_region-src	0
contact_region-trg	0
inlet	8.4310484
interior-fluid	528.67706
interior-solid	6.8429129e-10
outlet	-8.4312506
wall-12	0
wall-13	0
wall-4	0
wall-4-shadow	0
wall-solid	0
Net	-0.00020217896

HORIZONTAL SQUARE ENCLOSURE
FLUID- SILICON CARBIDE
VOLUME FRACTION 0.1



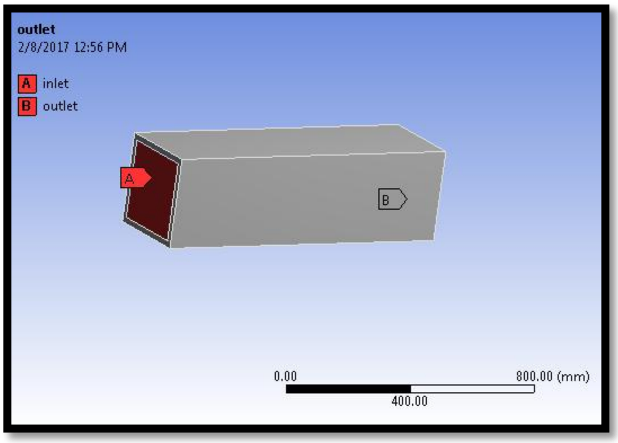
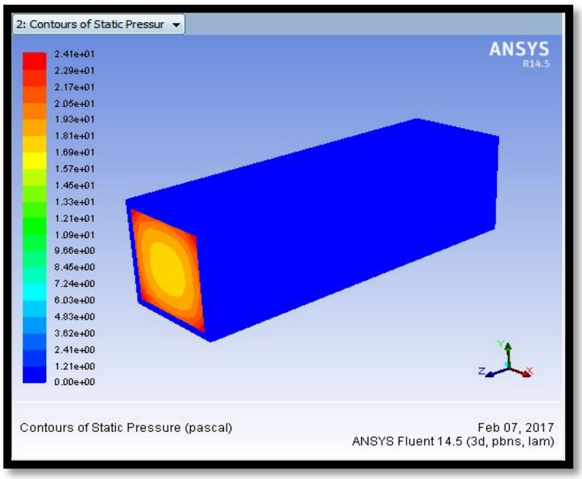
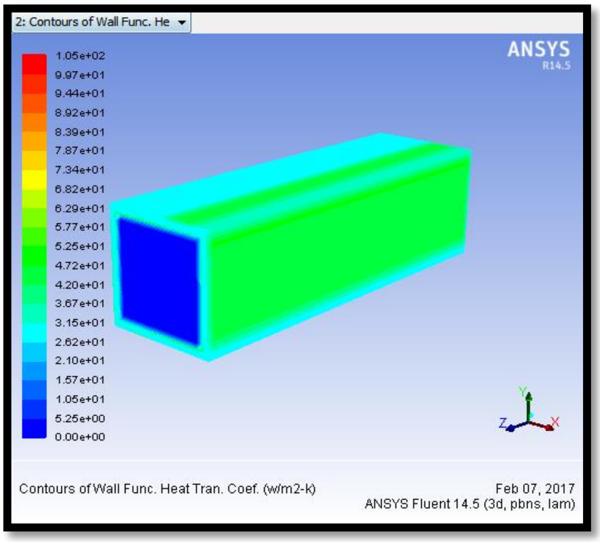


Fig – Inlet and Outlet



Pressure



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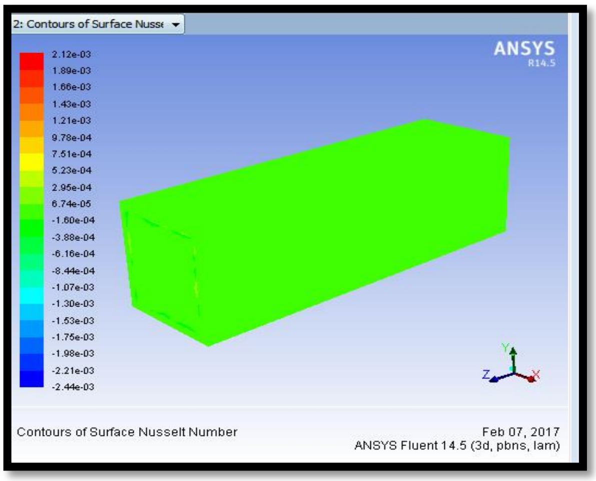
Heat Transfer Co Efficient



Nusselt Number

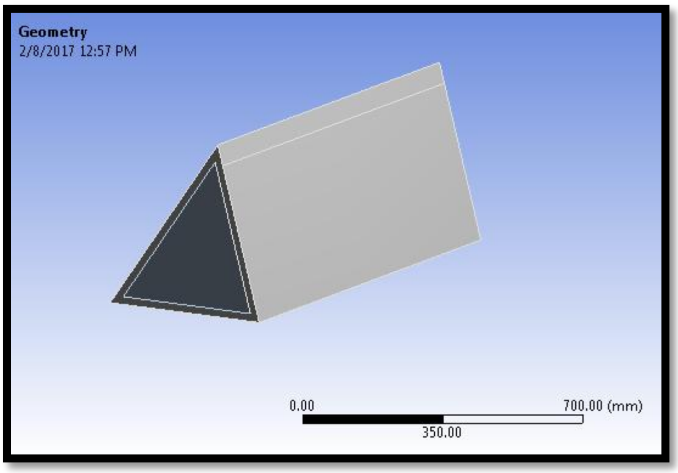
Heat Transfer Rate

Total Heat Transfer Rate	(w)
contact_region-src	0
contact_region-trg	0
inlet	101145.45
outlet	-101147.2
wall-12	0
wall-13	0
wall-7	-0.00078287727
wall-7-shadow	-0.00070731324
wall-solid	0
Net	-1.7514902

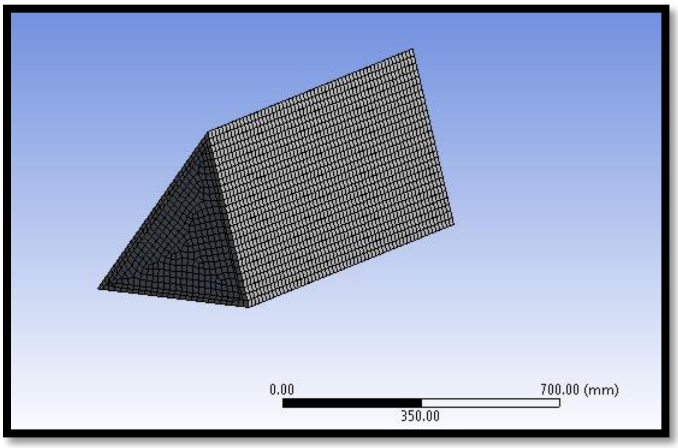
Mass Flow Rate

Mass Flow Rate	(kg/s)
contact_region-src	0
contact_region-trg	0
inlet	11.641347
interior-fluid	721.78082
interior-solid	8.5813863e-09
outlet	-11.641155
wall-12	0
wall-13	0
wall-7	0
wall-7-shadow	0
wall-solid	0
Net	0.00019168854

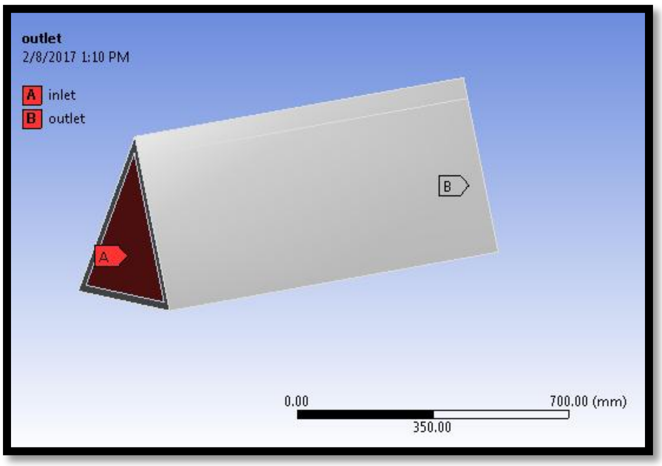
TRIANGULAR ENCLOSURE
FLUID – SILICON CARBIDE
VOLUME FRACTION 0.1



Imported model



Meshed model



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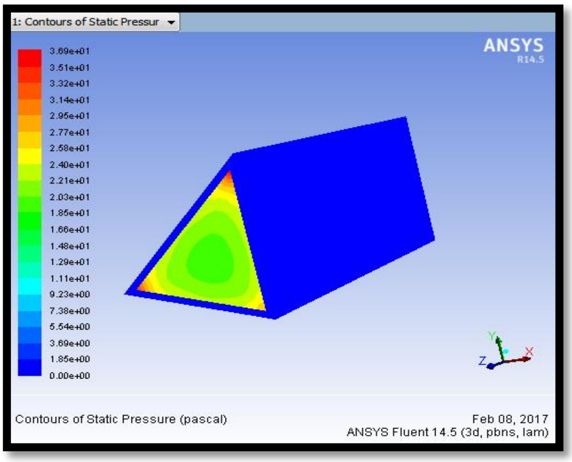
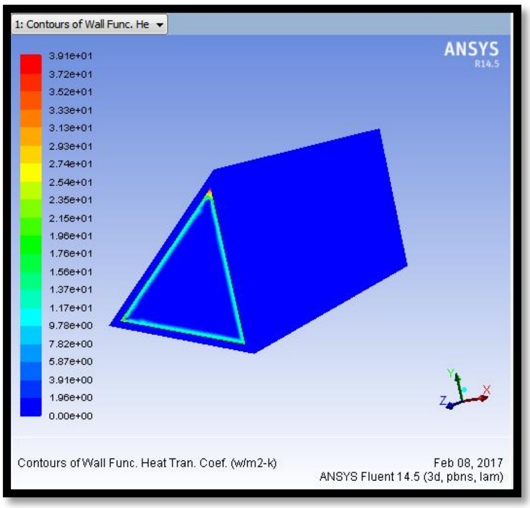
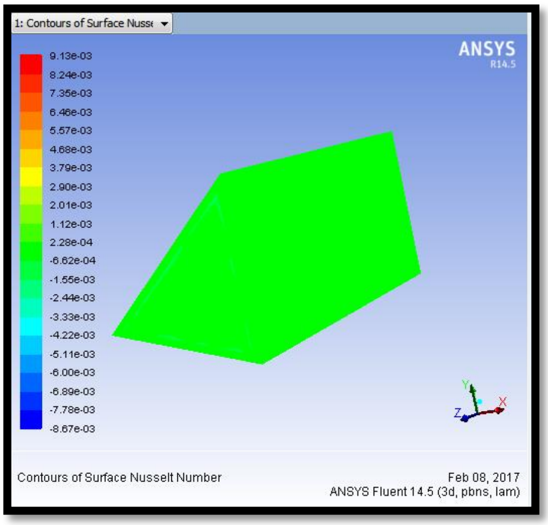


Pressure



Heat Transfer Co Efficient



Nusselt Number

Heat Transfer Rate

```
      Total Heat Transfer Rate                  (w)
---------------------------- --------------------
         contact_region-src                    0
         contact_region-trg                    0
                      inlet            108323.22
                     outlet           -108321.34
                    wall-12                    0
                    wall-13                    0
                     wall-7         -0.061507016
              wall-7-shadow        -0.0052960888
                 wall-solid                    0
           ---------------- --------------------
                        Net            1.8081969
```

Mass Flow Rate

```
         Mass Flow Rate                (kg/s)
-------------------- --------------------
  contact_region-src                    0
  contact_region-trg                    0
               inlet            12.467514
      interior-fluid            718.83331
      interior-solid                    0
              outlet             -12.4674
             wall-12                    0
             wall-13                    0
              wall-7                    0
       wall-7-shadow                    0
          wall-solid                    0
    ---------------- --------------------
                 Net        0.00011444092
```

RESULT TABLES

ANNULUS ENCLOSURE

Material	Volume fraction	Pressure (Pa)	Heat transfer coefficient (W/m^2-k)	Nusselt number	Heat transfer rate(W)	Mass flow rate(Kg/s)
Sic	0.1	2.31e+01	4.71e+02	2.59e-03	-0.64821865	-0.00020217896
	0.2	2.77e+01	8.82e+02	2.81e-03	-5.8901059	-0.00023365021
	0.5	4.17e+01	2.06e+03	3.08e-03	-6.2803987	-0.00031471252
Al_2O_3	0.1	4.01e-01	3.59e+02	3.66e-03	0.094213103	3.8146973e-6
	0.2	4.82e-01	4.60e+02	3.68e-03	1.610192	1.7166138e-05
	0.5	6.83e-01	9.77e+02	3.95e-03	2.1562943	4.1007996e-05

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HORIZONTAL SQUARE ENCLOSURE

Material	Volume fraction	Pressure (Pa)	Heat transfer coefficient (W/m²-k)	Nusselt number	Heat transfer rate(W)	Mass flow rate(Kg/s)
Sic	0.1	2.41e+01	1.05e+02	2.12e-03	-1.7514902	0.00019168854
	0.2	2.18e+02	4.98e+02	2.12e-03	-7.2031256	-0.00032615662
	0.5	4.88e+02	6.99e+02	3.72e-03	-40.031336	-0.00052833557
Al_2O_3	0.1	4.15e-01	3.78e+02	3.41e-03	1.3313311	1.9073486e-06
	0.2	4.99e-01	4.85e+02	3.62e-03	6.7021713	3.6239624e-05
	0.5	7.07e-01	1.03e+03	4.47e-03	8.4210931	-4.0054321e-05

TRIANGULAR ENCLOSURE

Material	Volume fraction	Pressure (Pa)	Heat transfer coefficient (W/m²-k)	Nusselt number	Heat transfer rate(W)	Mass flow rate(kg/s)
Sic	0.1	3.69e+01	3.91e+01	9.13e-03	1.8081969	0.00011444092
	0.2	3.38e+02	5.8e+01	9.88e-03	-1.9386105	-0.00012207031
	0.5	7.60e+02	2.78e+02	1.58e-02	-2.1967844	-0.0001964591
Al_2O_3	0.1	6.39e-01	2.12e+02	7.93e-03	0.054099457	1.9073486e-05
	0.2	7.65e-01	2.71e+02	9.21e-03	-0.27699082	4.3869019e-05
	0.5	1.09e+00	5.77e+02	1.10e-02	1.8649901	4.9591064e-05

CONCLUSION

Computer simulations are performed to find the Nusselt number and the heat transfer coefficient for natural convection of nano fluids in horizontal square, annulus and triangular enclosure. The output values considered for comparison are pressure, heat transfer coefficient, heat transfer rate, nusselt number and mass flow rate.

By observing the results, the heat transfer coefficient, Nusselt number and heat transfer rate are increasing by increasing the volume fractions. By comparing the results between different enclosures, the heat transfer coefficient, Nusselt number and heat transfer rate are more when horizontal square enclosure is taken when SiC is used. By comparing the results between fluids, the values are better for Al_2O_3 than SiC.
So it can be concluded that using horizontal square enclosure and fluid SiC is better.

REFERENCES

[1] RajKumarBodakuntla, RajuRaoPeralaand Srinivasulu P, IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 8, August 2016 ISSN (Online) 2348 – 7968 | Impact Factor (2015) - 4.332.

[2] Mohamed H. Shedid, Proceedings of the International Conference on Heat Transfer and Fluid FlowPrague, Czech Republic, August 11-12, 2014Paper No. 206.

[3] M. A., A. Karimipour, Jorfian, A. Darisavi S.N. Kazi ,M.Goodarzi, H. Bohlooli, S. Gharehkhani.

[4]ArashKarimipour, Mohammad HemmatEsfe, Mohammad Reza Safaei,DavoodToghraieSemiromi, SaeedJafari, S.N. Kazi, Physic A 402 (2014) 150–168.

[5] G.S. Aglietti, and C. Schwingshackl, School of Engineering Sciences, Aeronautics and Astronautics, University of Southampton, UK.

[6] Joseph E. Blanks, William R. Saunders, Chairman Harry H. Robertshaw Douglas J. Nelson February 7, 1997 Blacksburg, Virginia.

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