# CFD Analysis of Shell and Tube Heat Exchanger using Titanium Carbide, Titanium Nitride and Zinc Oxide Nanofluids

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**Abstract: In this paper, analytical investigations are done on the shell and tube heat exchanger, using forced convective heat transfer to determine flow characteristics of nanofluids by varying volume fractions and mixed with water, the nanofluids are Titanium Carbide and Titanium Nitride, Zinc Oxide nanofluids and different volume concentrations (0.02, 0.04, 0.07and 0.15)% flowing under turbulent flow conditions. CFD analysis is done on the heat exchanger by applying the properties of the nanofluid with different volume fractions to obtain temperature distribution, heat transfer coefficient and heat transfer rate. 2D model of the shell and tube heat exchanger will be done in Pro/Engineer and analysis will be done in Ansys.**
**Keywords— Titanium Carbide, Titanium Nitride, Zinc Oxide, CFD Analysis, temperature distribution, heat transfer coefficient and heat transfer rate.**

## I. INTRODUCTION

Heat exchangers are devices in which heat is transfer from one fluid to another. The most commonly used type of heat exchanger is a shell-and-tube heat exchanger. Shell-and-tube heat exchangers are used extensively in engineering applications like power generations, refrigeration and air-conditioning, petrochemical industries etc. These heat exchangers can be designed for almost any capacity. The main purpose in the heat exchanger design is given task for heat transfer measurement to govern the overall cost of the heat exchanger.

### *A. Shell And Tube Heat Exchanger*

A shell and tube heat exchanger is a class of heat exchanger designs. It is the most common type of heat exchanger in oil refineries and other large chemical processes, and is suited for higher-pressure and higher-temperature applications. As its name implies, this type of heat exchanger consists of a shell (a large pressure vessel) with a bundle of tubes inside it. One fluid runs through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. The set of tubes is called a tube bundle, and may be composed by several types of tubes: plain, longitudinally finned, etc.

### *B. Nano fluids*

Nano fluid is nothing but fluid particles which are less than even a micron(nearly 10-9 times smaller) in diameter and highly reactive and efficient material which can be used to increase factor like rate of reaction, thermal conductivity of any metal or material, they are that much reactive and presented four possible methods in nano fluids which may contribute to thermal conduction.

(a) Brownian motion of nano particles.

(b) Liquid layering at the liquid/particle interface.
(c) Ballistic nature of heat transport in nano particles.
(d) Nano particle clustering in nano fluids.
The Brownian motion of nano particles is too slow to transfer heat through a nano fluid. This mechanism works well only when the particle clustering has both the positive and negative effects of thermal conductivity which is obtained indirectly through convection.

*C. Types of nano fluids*

There are different types of nano fluids, basically
$Al_2O_3$ + water
CuO + water
TiO + water
TiC + water
TiN+ water
ZnO+ water
$CH_3CH_2OH$ + water
Out of these we are going to use TiC + water, TiN+ water, ZnO+ water as our nano fluid in heat exchanger.

*D. Properties of Nano Fluid by Changing Volume Fractions*

TABLE 1: TITANIUM CARBIDE NANO FLUID PROPERTIES

| Volume Fraction | Thermal Conductivity (W/m-K) | Specific Heat (J/Kg-K) | Density ($Kg/m^3$) | Viscosity (Poise) |
|---|---|---|---|---|
| 0.02 | 0.644 | 988.314 | 1076.836 | $1.05315\times10^{-3}$ |
| 0.04 | 0.7006 | 1003.4207 | 1155.472 | $1.10033\times10^{-3}$ |
| 0.07 | 0.7838 | 1013.0708 | 1273.426 | $1.178525\times10^{-3}$ |
| 0.15 | 1.04597 | 1098.8511 | 1587.97 | $1.379125\times10^{-3}$ |

TABLE 2: TITANIUM NITRIDE NANO FLUID PROPERTIES

| Volume Fraction | Thermal Conductivity (W/m-K) | Specific Heat (J/Kg-K) | Density ($Kg/m^3$) | Viscosity (Poise) |
|---|---|---|---|---|
| 0.02 | 0.6447 | 3835.55316 | 1083.036 | $1.05315\times10^{-3}$ |
| 0.04 | 0.69182 | 3539.4391 | 1167.872 | $1.10033\times10^{-3}$ |
| 0.07 | 0.7671 | 3168.005 | 1325.072 | $1.178525\times10^{-3}$ |
| 0.15 | 1.00057 | 2460.2749 | 1744.272 | $1.379125\times10^{-3}$ |

TABLE 3: ZINC OXIDE NANO FLUID PROPERTIES

| Volume Fraction | Thermal Conductivity (W/m-K) | Specific Heat (J/Kg-K) | Density ($Kg/m^3$) | Viscosity (Poise) |
|---|---|---|---|---|
| 0.02 | 25.32 | 3798.58 | 1091.736 | $1.05315\times10^{-3}$ |
| 0.04 | 27.52 | 3475.68 | 2175.27 | $1.10033\times10^{-3}$ |
| 0.07 | 31.868 | 3076.77 | 1325.576 | $1.178525\times10^{-3}$ |
| 0.15 | 54.091 | 2334.98 | 2550.97 | $1.379125\times10^{-3}$ |

## II. LITERATURE REVIEW

A brief review of the work carried by various researchers on shell and tube heat exchangers by using various nano fluids is presented following. Prof. Alpesh Mehta et al. [29] have studied the improvement in performance of STHE with Using of Nanofluids. Jaafar Albadr et al. [30] have reported an experimental study on the forced convective heat transfer and flow characteristics of a nanofluid consisting of water and different volume concentrations of Al2O3 nanofluid (0.3–2)% flowing in a horizontal shell and tube heat exchanger counter flow under turbulent flow conditions are investigated. S.Gh. Etemad et al. [31] have reported that the heat transfer characteristics of nanofluid enhance significantly with increasing higher overall heat transfer coefficient, convective heat transfer coefficient and Nusselt number respectively. Tuckerman and Pease [9] are the first to introduce this idea by using micro channel heat sink (MCHS) as a source for cooling of electronic devices in the year 1981. They experimentally narrated the MCHS capability and claimed that they were able to dissipate heat flux at a rate of 790 W/cm2. They showed that the convective heat transfer of single phase flows could be improved by decreasing the width of the heat sink channels and increasing wetted area by the heat transfer fluid. The experimental and analytical studies by Wang et al. [10], Lee et al. [11], Wang et al. [12] and Koo and Kleinstreuer [13] showed that nanofluid have a higher thermal conductivity than that of pure fluids and therefore has great affinity for heat transfer enhancement.

Li and Xuan [14], Xuan and Li [15] and Pak and Cho [16] experimentally showed the convection heat transfer and pressure dropping for nano fluid tube flows. Their results show that heat transfer coefficient was greatly incremented and it depends upon factors like Reynolds number, particle size and shape, and particle volume fraction. They also found that nano particles did not cause an extra pressure drop. Another scientist named Donsheng and Yulog [17] studied practically the convective heat transfer of nanofluid made up of ã-Al2O3- water, flowing through a tube made up of copper in the laminar flow region and showed a considerable enhancement of convective heat transfer using the nanofluids. The enhancement was particularly significant in the entrance region as it was higher than that obtained solely due to the enhancement on thermal conduction. Seok and Choi [18] investigated numerically the cooling performance of micro channel heat sink with nanofluids. They showed that the cooling performance of a MCHS with water based nanofluids containing diamond (1% volume fraction and 2 nm) at the fixed pumping power of 2.25 W is enhanced by about 10% compared with that of a MCHS with water.

Joescon and Issam [19] performed experiments to explore the micro channel cooling benefits of Al2O3-water nanofluid. They found that the high thermal conductivity of nano particles enhance the single phase heat transfer coefficient especially for laminar flow. Higher heat transfer coefficient was achieved mostly in the entrance region of the micro channels and the enhancement was weaker in the fully developed region, providing that nano particles have an appreciable effect on thermal boundary layer development. It was also observed that higher concentrations also produced greater sensitivity to heat flux. Mushtaq et al. [20] investigated the effect of channels geometry (the size and shape of channels) on performance of counter flow micro channel heat exchanger and used liquid water as a cooling fluid. They found that the effectiveness of heat exchanger and pressure drop were increased by decreasing the size of channels and claimed depending on the application of which type of heat exchanger is used.

Mushtaq I. Hasan [21] numerically investigated the performance of counter flow micro channel heat exchanger with MEPCM suspension as a cooling fluid. He fund that using MEPCM suspension lead to improve thermal performance of CFMCHE but also lead to extra increase in pressure drop and resulting in decreasing the overall performance with using suspension as a cooling medium. For modeling, Nano fluid is treated as a single-phase type fluid. This assumption can be used since the particles are ultra fine and they are easily fluidized [14]and[15]. Also, the particle volume fraction in nano fluid is usually low. Under such conditions the governing equations for the nano fluid flow and heat transfer are simplified and local fluid and particles are in thermal equilibrium. Schematic structure of the studied counter flow micro channel heat exchanger with square channels. Due to the geometrical and thermal symmetry between hot and cold channels rows, an individual heat exchanger unit consisting of two channels containing hot and cold fluids and a separating wall is considered as a model figure to represent the complete counter flow micro channel heat exchanger since it gives an adequate indication about the performance and the heat is transferred from hot to cold fluid through a thick wall medium separating both fluids.

### *A. Research Gap & Problem Description*

In the thesis, the shell and tube heat exchanger is taken in the water with various temperatures. In this thesis, along with water, TiC, TiN AND ZnO nanofluids at different volume fractions (0.02, 0.04, 0.07 and 0.15) of the shell and tube heat exchanger is analyzed for heat transfer properties, temperature, pressure, velocity and mass flow rates in CFD analysis. Modeling is done in Pro/Engineer, Thermal analysis and CFD analysis is done in

Ansys. The boundary conditions for thermal analysis is temperatures, for CFD analysis is pressure, velocity and temperature

## III. CFD ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER

Here we have done CFD analysis by showing below flow chart fig 1. This shows that different nano fluids with various volume fractions are used to obtain the results are Temperature distribution, Heat transfer coefficient and heat transfer rate.

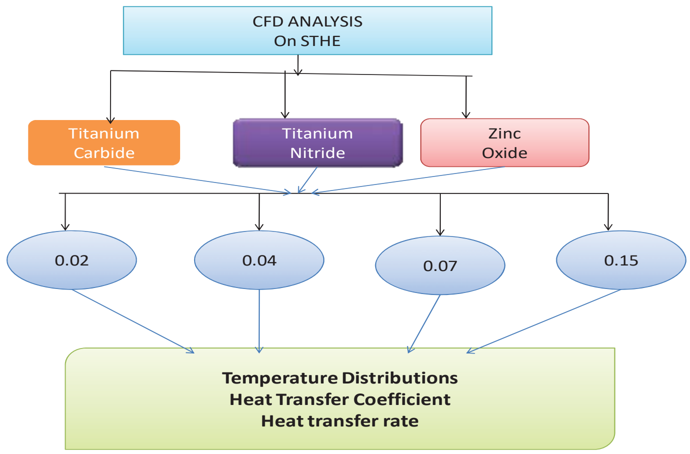


Fig.1 Flow Chart for CFD Analysis

The effect temperature distribution in fig 2, fig 3, fig 4 and Heat transfer coefficient fig 5, fig 6 fig 7 and heat transfer rate in shell and tube heat exchangers is observed in CFD analysis by using Ti C, Ti N and Zn O with volume fractions of 0.02, 0.04, 0.07 and 0.15 are shown in below.

### *A. Temperature Distribution along STHE using Ti C*

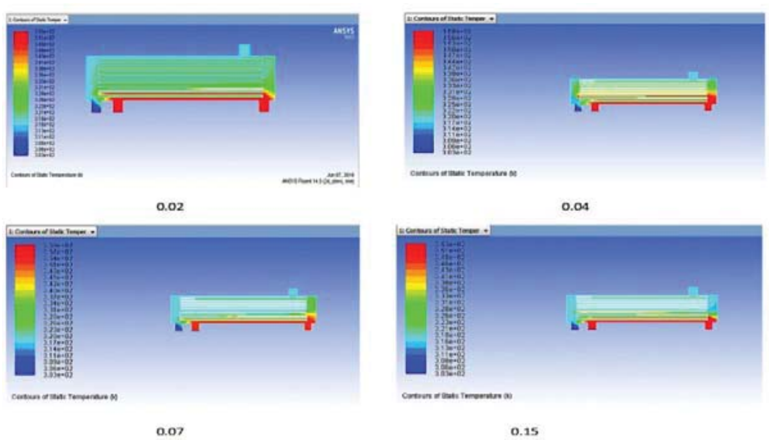


Fig..2 Temperature distribution of Titanium Carbide nanofluid at various volume fractions

### *B. Temperature Distribution along STHE using Ti N*

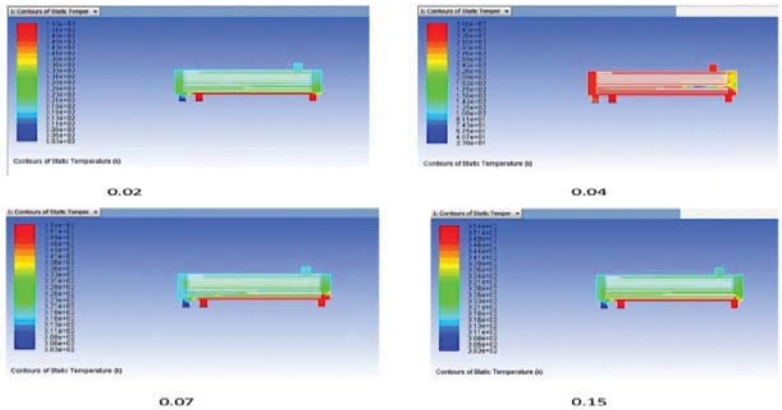


Fig..3 Temperature distribution of Titanium Nitride nanofluid at various volume fractions

### *C. Temperature Distribution along STHE using Zn O*

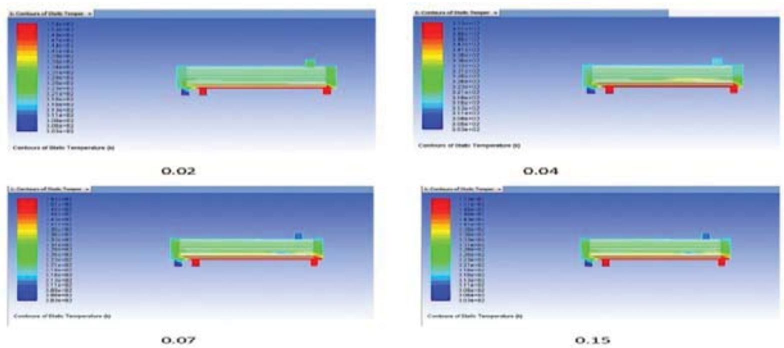


Fig. 4 Temperature distribution of Zinc oxide nanofluid at various volume fractions

### *D. Heat Transfer Coefficient along the STHE using Ti C*

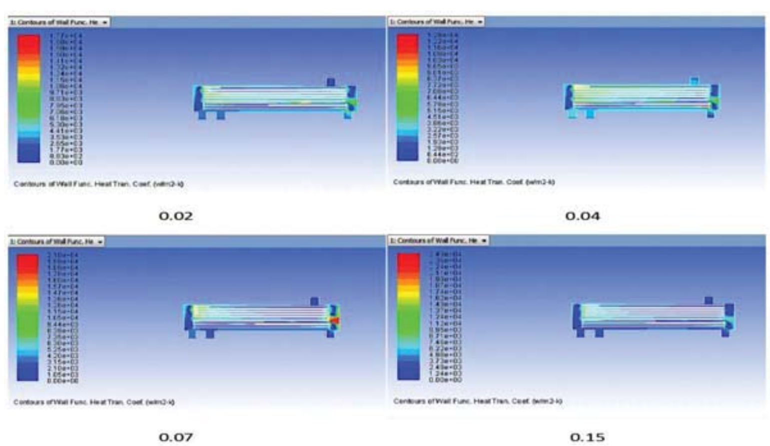


Fig. 5 Heat transfer Coefficient of Titanium Carbide nanofluid at various volume fractions

### *E. Heat Transfer Coefficient along the STHE using Ti N*

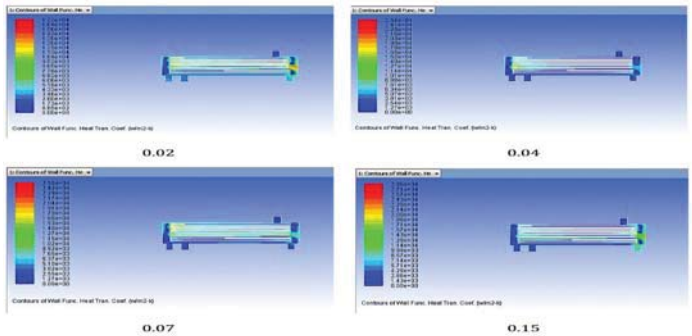


Fig 6 Heat transfer Coefficient of Titanium Nitride nanofluid at various volume fractions

*F. Heat Transfer Coefficient along the STHE using Zn O*

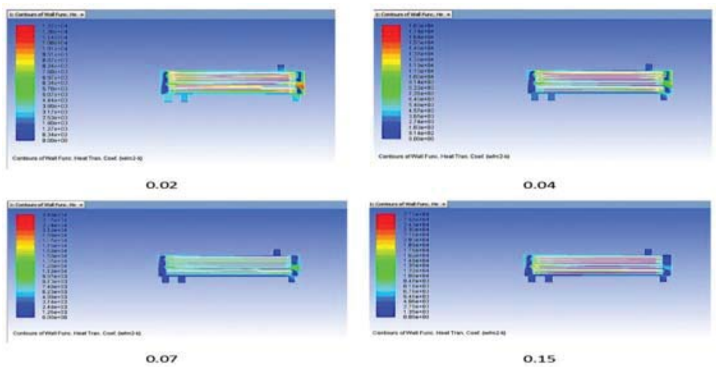


Fig. 7 Heat transfer Coefficient of Zinc oxide nanofluid at various volume fractions

## IV. RESULTS AND DISCUSSIONS

We are using Titanium Carbide, Titanium Nitride and Zinc oxide nanofluids with varying volume fractions of 0.02, 0.04, 0.07 and 0.15 with base fluid water. We are going to analysis heat transfer coefficient and maximum temperature and total heat transfer rate by using CFD analysis. After the analysis we are deciding that the maximum heat transfer coefficient and maximum heat transfer rate is achieved in 0.15 volume fraction where using Titanium Nitride. And also we have observed that heat transfer coefficient is gradually increases when increasing the volume fractions of nano fluids during CFD Analysis.

TABLE 4: CFD ANALYSIS RESULTS

| Type of Nano Fluid | Volume Fraction | Heat Transfer Coefficient ($W/m^2k$) | Max Temp (K) | Total Heat Transfer Rate (W) |
|---|---|---|---|---|
| Titanium Carbide | 0.02 | 17700.00 | 353.00 | 10870920.00 |
| | 0.04 | 12900.00 | 358.00 | 10871004.00 |
| | 0.07 | 21000.00 | 359.00 | 10871065.00 |
| | 0.15 | 24900.00 | 353.00 | 10870875.00 |
| Titanium Nitride | 0.02 | 17300.00 | 353.00 | 10870875.00 |
| | 0.04 | 25400.00 | 360.00 | 10870997.00 |
| | 0.07 | 25500.00 | 354.00 | 10871076.00 |
| | 0.15 | 28600.00 | 354.00 | 10871082.00 |
| Zinc Oxide | 0.02 | 12700.00 | 354.00 | 10870960.00 |
| | 0.04 | 18100.00 | 353.00 | 10870915.00 |
| | 0.07 | 24900.00 | 353.00 | 10870869.00 |
| | 0.15 | 27070.00 | 354.00 | 10871032.00 |

The above table 4 is extracted from CFD analysis results for shell and tube heat exchanger. In CFD Analysis results are clearly indicating that the Titanium Nitride nano fluid is better in heat transfer coefficient and heat transfer rate at volume fraction of 0.15 comparing to titanium carbide and Zinc oxide nanofluids. Because of titanium nitride nanofluids consist of better thermal properties like thermal conductivity, specific heat is more than titanium carbide and zinc oxide. The Comparison of Heat transfer coefficient between three nano fluids at different volume fractions shown in Fig 8 and Fig 9, Fig. 10 shows that Comparison of maximum temperature and Total Heat transfer rate between three nano fluids at different volume fractions in CFD Analysis.

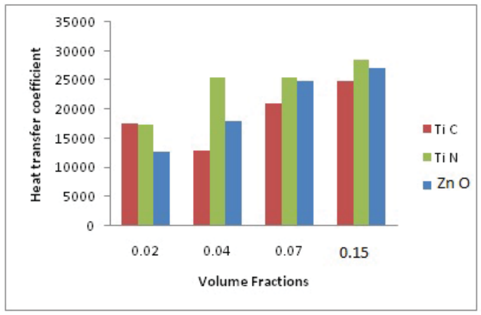


Fig. 8 Comparison of Heat transfer coefficient between three nano fluids at different volume fractions

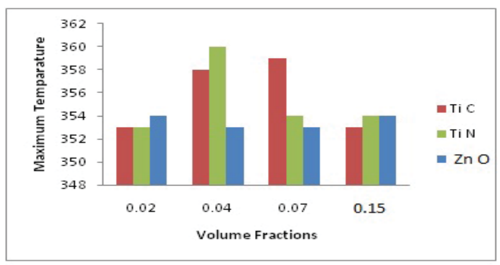


Fig. 9 Comparison Maximum temperature between three nano fluids at different volume fractions

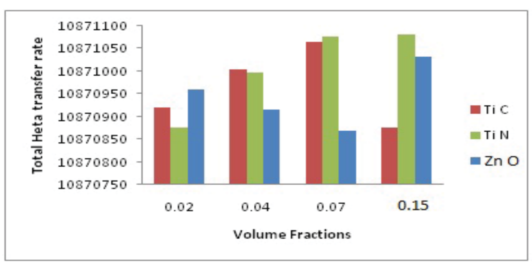


Fig. 10 Comparison of Total Heat transfer rate between three nano fluids at different volume fractions

## V. CONCLUSION

In this paper, analytical investigations are done on the shell and tube heat exchanger, using forced convective heat transfer to determine flow characteristics of nanofluids by varying volume fractions and mixed with water, the nanofluids are Titanium Carbide and Titanium Nitride, Zinc Oxide nanofluids and different volume concentrations (0.02,0.04,0.07and 0.15)% flowing under turbulent flow conditions. By observing the CFD analysis results, heat transfer coefficient and heat transfer rates are increasing by increasing the volume fractions. The values are more when Titanium Nitride is used than other two fluids.

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