Experimental Analysis on Thermal Behaviour of Water Based Nanofluid (AL_2O_3) Using Seperating And Throttling Calorimeter

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Abstract- *In this research work, the experimental analysis is done to check the quality of the steam by using Al_2O_3, water based nanofluid with separating and throttling calorimeter. Since nanofluids are shown the capability of transmitting heat more than the conventional fluids, researchers are interested in quality of the steam which could be useful in many applications.*

The experimental analysis is to determine the dryness fraction of the steam using nanofluid Al_2O_3 with different concentrations 0.1%, 0.2% and 0.3% in separating throttling calorimeter. Results show that the dryness fraction is 0.96 for water based nanofluid (Al_2O_3) with 0.3% concentration as compared with water (dryness fraction 0.83).

Keywords- Al_2O_3 nanofluid, separating throttling calorimeter.

I. INTRODUCTION

Steam quality is the proportion of saturated steam (vapor) in a saturated condensate (liquid) /steam (vapor) mixture. A steam quality is 0 indicates 100 % liquid, (condensate) while a steam quality of 100 indicates 100 % steam. One (1) lb of steam with 95 % steam and 5% percent of liquid entrainment has a steam quality of 0.95. The measurements needed to obtain a steam quality measurement are temperature, pressure, and entrained liquid content.

Steam is the major source for power generation in steam engines or steam turbine. Steam is produced from water by combustion of fuel in a boiler and employed for heating the building in cold weather, in the textile industries for sizing and bleaching, sugar industries, chemical industries etc.

The primary requirements of steam generators or boilers are (I) Water must be contained safely. (ii)The steam must be safely delivered in desired condition as regards its pressure, temperature, quality and required rate. The presence of moisture in steam causes a loss of heat from the feed water temperature to the steam temperature.

Effects of Steam Quality

Low steam quality affects steam system operations in many ways.

- Reduced heat transfer efficiency
- Premature Valve Failure
- Internal Turbine Component Failures

Improving method of quality of steam by using nanofluid

Nanofluid, a simple product of nanotechnology has become a topic of attraction due to its extraordinary heat transfer performance in various areas including cooling, power generation, defense, nuclear, space, microelectronics and biomedical appliances. However, preparation and stabilization of such fluids are indeed a matter of concern for better understanding. For the last decade numerous research and development works have been done in the synthesis

Nanofluids are colloidal suspension of ultra-fine metallic or nonmetallic particles in a given fluids. Despite all other properties, it is well known for its high thermal conductivity and better response as heat transfer medium. Nanofluid can be of two kinds such as metallic nanofluids and nonmetallic nanofluids. Metallic nanofluids are prepared by dispersing nanoparticle made from metals such as aluminum, copper, nickel etc. and nonmetallic nanofluids are made by dispersing nanoparticles of nonmetals i.e. metal oxides, various allotropes of carbon (Grapheme, CNT) etc.Synthesis and stability of nanofluids are the two very primary requirements to study nanofluids. The proper utilization of the potential of nanofluids depends on the preparation and stability of nanofluids.

Steam Quality Measurements

Generally calorimeters are using found out dryness fraction in experimentally. Four types of calorimeters are available for this purpose.

- Tank Calorimeter
- Separating Calorimeter
- Throttling Calorimeter
- Separating and Throttling Calorimeter

Separating and throttling calorimeter

Calorimeter the dryness fraction measured with the help of separating calorimeter is always higher than the actual. This is because of incomplete separation of moisture by mechanical means. If the steam is highly wet (0.6 to 0.9), then its dryness fraction cannot be measured, by throttling calorimeter as it will not become superheated after throttling. Therefore the dryness fraction of highly wet steam is measured accurately by combining in series separating and throttling calorimeter. The arrangement of a separating and throttling calorimeter is shown in figure, where these calorimeters are placed in series. The steam from the sample tube is first passed through the separating calorimeter where major part of the water particles is removed and then it is passed on to throttling calorimeter.

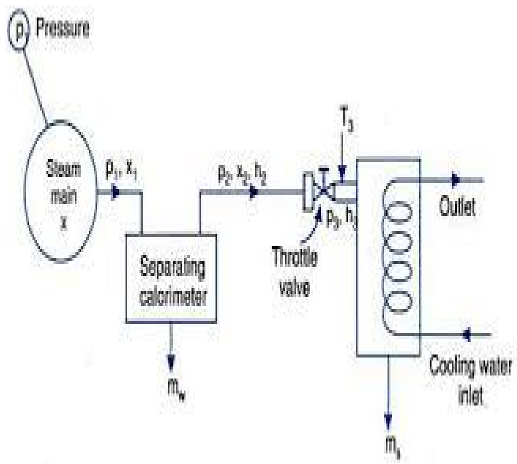


Figure: Separating and Throttling Calorimeter

The steam leaving the throttling valve comes out as superheated steam. The steam coming out of throttling calorimeter is condensed in a condenser and mass of the condensate is recorded. The mass of the water separated in separating calorimeter and the pressure and temperature of the steam leaving the throttle valve are recorded with the help of water manometer and mercury in glass thermometer.

This calorimeter gives very accurate value of the dryness fraction of the steam when it is considerably wet and which cannot be measured accurately by any other method.

II. LITERATURE REVIEW

[1] R.G.Bodkhe, Y. Y. Nandurkar, S. S. Akant, S. L. Bankar.(2014) Proposedin present study the Separating & Throttling Calorimeter set up is developed on thermax diesel fired water tube Boiler in thermal Power Laboratory and experimentation is carried out to determine the quality of steam passing through the steam main. The limitation of our experimentation is the wet steam. The calorimeter results are not applicable to dry and superheated steam. The analytical analysis is also carried out using steam table. The effect of parameters like steam temperature, steam pressure, water outlet temperature of economizer.

[2] Hossein Fatahian, Hesamoddin Salarian **(**2017)The present study investigated the thermal effects of the use of nanoparticles in the fuel-oil and water-based fluids, as well as the numerical simulation of laminar flow of fuel-oil-alumina and the water-alumina nanofluids in a channel. A second order discretization method was used for solving equations and a SIMPLE algorithm was applied for pressure-velocity coupling using Fluent.

[3] Sayantan mukherjee, Somjit paria, (2013),nanofluid, a simple product of nanotechnology has become a topic of attraction due to its extraordinary heat transfer performance in various areas including cooling, power generation, defence, nuclear, space, microelectronics and biomedical appliances. However, preparation and stabilization of such fluids are indeed a matter of concern for better understanding,

[4], Tadjarodi, (2013). The study is the investigation which conducted measurement for nanoparticles suspended in 60 % of ethylene glycol and 40 % of water by volume percentage. Hence, this paper intended to measure thermal conductivity of Al_2O_3 nanofluid using three different mixture ratio solutions of water and ethylene glycol as base solution. The experiment is conducted using 13 nm Aluminium Oxide (Al_2O_3) dispersed in 60:40, 50:50 and 40:60 (water: ethylene glycol) mixture.

[5] Yu and Xie (2012).*The* aim of the study is the investigation of such parameters like sonication time, stabilizer type and suspension *pH* on stability of copper (II) oxide and aluminum (III) oxide water based nanofluids. For the most stable nanofluids particle

[6], Paul et al *(2011).* This method of production is cheaper, because nanopowders are produced on large scale. However, due to large and active surface area nanoparticles tend to agglomerate. Therefore, in order to prepare a stable nanosuspension sonication as well as addition of stabilizer or *pH* adjustment may be required. There are many methods to

determine Nanofluids stability. It may be done visually, by sedimentation tests, centrifugation or UV-VIS analysis. Zeta potential analysis may be also performed.

[7], Zhu et al (2004*).* In the one-step method nanoparticles are synthesized in base fluid mainly by means of chemical methods [*East* in the case of two-step method nanoparticles are firstly prepared in a form of powders by physical or chemical methods, e.g. grinding, laser ablation, sol-gel processing, etc. and then suspended in base fluid.

[8],*Choi and Eastman*, *(1995)*, it is a rather new idea proposed in 1990's, connected with development of nanotechnology In the case of Nanofluids, satisfying improvement of thermal properties is achieved for much smaller particles concentration. Additionally, they are more stable and can be stored without recirculation. Nanofluids may be prepared either by one-step or two-step method.
[9] Eastman (1997), a 40% increase in thermal conductivity was found in the Cu oil-based nanofluids with 0.3% volume concentration, while the Al_2O_3 water-based Nanofluids exhibited a 29% enhancement thermal conductivity of for the 5%volume concentration nanofluids

[10] Masuda,(1990)introducing suspended nanometre sized particles to the research field and found out that nanometre size particles have higher stability when suspended in conventional fluid than micrometer and millimetre size particles.

[11] Maxwell, *(1881)*proposed model for thermal conductivity enhancement suspensions .However, application of micro- and larger particles is connected with many disadvantages, e.g. high concentrations of solid phase are needed to achieve satisfying enhancement of thermal properties. Moreover, they are not stable and require continuous recirculation. Additionally, due to high solid content they cause abrasion of installation parts. These problems may be reduced by application of nanofluids. Nanofluids are the suspensions of nanoparticles (i.e. particles smaller than100 nm) in base fluids.

[12] Tadjarodi et al. which conducted measurement for nanoparticles suspended in 60 % of ethylene glycol and 40 % of water by volume percentage. Hence, this paper intended to measure thermal conductivity of Al_2O_3 nanofluid using three different mixture ratio solutions of water and ethylene glycol as base solution. The experiment is conducted using 13 nm Aluminium Oxide (Al_2O_3) dispersed in 60:40, 50:50 and 40:60 (water: ethylene glycol) mixture, base solution. The temperature is varied between 30 to 70 ^{0}C using KD2 Pro Therm.

[13] N. A. Usria, W. H. Zamia*, Rizal man Magmata, K. Abdul Hamida, G. Najafib. In the base paper is the ability of nanofluids that exhibits enhanced thermal performance is acknowledged by researchers through studies since decades ago. However, the observation of thermal properties for nanofluids in water and ethylene glycol based is not fully explored yet. Hence, this paper presents the thermal conductivity of water and ethylene glycol (EG) based Al2O3 nanofluid. The 13 nm sized Al_2O_3 nanoparticles were dispersed into three different volume ratio of water: EG such as 40:60, 50:50 and 60:40 using a two-step method.

III. EXPERIMENTAL SETUP

Throttling and separating calorimeters are used to measure the dryness fraction of steam .if on the other hand the steam is very wet, and then a separating calorimeters used. When the dryness fraction of the steam is somewhere in between then a combined setup of throttling and separating calorimeter is used. And these calorimeters are used increasing the quality of steam by using different variations of nanofluid.

Requirement of materials

- Water (base fluid).
- Distilled water.
- (Al_2O_3+water) concentrations as 0.1%, 0. 2% & 0. 3%.

Preparation of nanofluid

In this work to prepare the nanofluid with desired concentration, nanoparticles were equivalently dispersed into water. The characteristics of nanofluids are governed by not only the type and size of the nanoparticles but also their dispersion status in the pure water. Nanofluids were prepared by two processes: Single step preparation method and Two step Preparation method.

Two step preparation method

To prepare nanofluid, the number of researchers developed two-step techniques in this method the nanoparticle first produced in dry powder form by physical or chemical methods, e.g., grinding, milling and vapor phase method, etc. The nanoparticles were purchased from NANO WINGS PRIVATE LIMITED the details are given in table 3.2.1.

Properties of nanoparticles

Parameter	NANO ALUMINA(Al_2O_3)
Appearance	White powder
Crystallite size	10-20nm
Purity	99%
Bulk density	0.2-0.4/cm³

This method mostly used in synthesizing nanofluid by mixing base fluids. For large scale production, this method is very economical because of synthesizing techniques widely used in the industries and the schematic diagram of this method for preparation of nanofluid is clearly. Most of researchers suggest that the two step method is more suitable because of the synthesis of nanofluid having oxide nanoparticles in comparison with metallic nanoparticles.

The Al_2O_3 nanofluid used in the present paper are prepared by using two step method. The powder nanoparticles are purchased from nano wings pvt ltd with 99.8 % purity. The density value of Al_2O_3 nanoparticle provided by the manufacturer is 3883kg/m3.The base fluid is prepared using water following designated ratio based by volume percentage which are 0.1:99.9, 0.2:99.8 and 0.3:99.7.

Thermal properties of Al_2O_3 water based nanofluid

Water based nanofluids ofAl_2O_3 was characterized regarding its later use in heat transfer applications. Well dispersed nanofluids were prepared at three different volume fractions (0.1% v., 0.2% v., 0.3% v.) and for each one the experimental measurements were carried an out at three different temperatures.

Thermal Conductivity Measurement

There are several technique have been adapted to measure thermal conductivity of nanofluid such as transient hot-wire method (THW), steady-state parallel-plate method and cylindrical cell method. This paper utilized thermal constant analyzer technique to measure thermal conductivity of Al_2O_3 nanoparticles dispersed in different base ratio water (0.1:99.9, 0.2:99.8 and 0.3:99.7). The measurement is conducted under controlled temperature ranging from 30 to 70 ^{0}C using a Memmert water bath. And specific heat and density values of nanofluid (Al_2O_3) were measured by using these formulas.

$$Cp_{nf} = \{(1-\varphi)(\rho C_p)_f + \varphi(\rho C_p)_p\}/ \rho_n$$

$$\rho_{nf} = (1-\varphi)\rho_f + \varphi\rho_p$$

Table: Properties of Al_2O_3 water based nanofluid.

	Concentration (volume percentage of Al_2O_3)	Density (kg/m³)	Specific heat (J/kgK)	Thermal conductivity (W/mK)
Water	0	998	4182	0.597
Distilled water	0	998	4182	0.6
Water +Al_2O_3	0.1	1027.018	4012.33	0.614
	0.2	1055.83	3931.47	0.63
	0.3	1084.65	3816.17	0.648

Experimental procedure

The unit mainly consists of a separating calorimeter which has steel tube lagged with asbestos rope. the steam from the main line is sample d out over a period of time through the sample tube from main line is sampled out over a period of time through the sampling tube and control valve .the pressure of the steam inside the separating calorimeter is indicated by a pressure gauge provided. The steam impinges on a perforated cup inside the separating calorimeter which separates the suspended water particles from the steam and due to gravity water is collected at the bottom. The amount of water separated from the steam can be found out from the water level indicator.

Figure: separating and throttling calorimeter

Table: observations:

	Concentration (volume percentage of Al_2O_3)	Pressure inside the separating calorimeter (P1)kg/cm^2)	Pressure inside the throttling calorimeter (P2)kg/cm^2	Temperature of the steam at the inlet (T_1) °C	Temperature of the steam after throttling (T_2) °C	Volume of water collected from the separating calorimeter (w) ml	Volume of condensed water collected from the condenser (ws) ml
Water	0	0.79	0.712	96.405	90.33	100	20
Distill water	0	0.79	0.7354	96.405	91.01	98	17
Water + Al_2O_3	0.1	0.79	0.74	96.405	91.43	91	16
	0.2	0.79	0.761	96.405	92.16	89	15
	0.3	0.79	0.78	96.405	92.83	86	15

MODEL FORMULAS

Dryness fraction for separating calorimeter

$X_1 = W_S / W_S + W$

Dryness fraction for throttling calorimeter

$X_2 = H_2 + C_p (T_2 - T_s) - H_1 / L_1$

Actual dryness fraction $X = X_1 \times X_2$

Enthalpy for combined throttling calorimeter $h = h_f + X (h_{fg})$

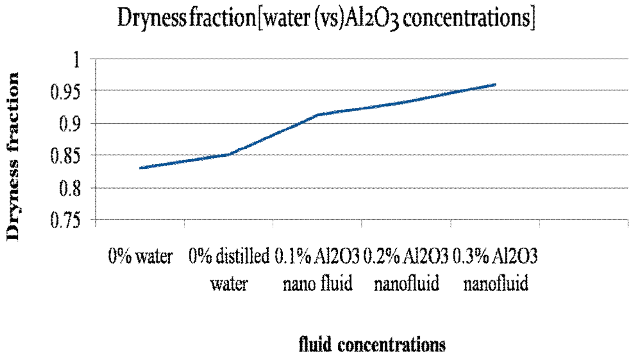
Entropy for combined throttling calorimeter $s = s_f + X (s_{fg})$

IV. RESULTS AND DISCUSSION

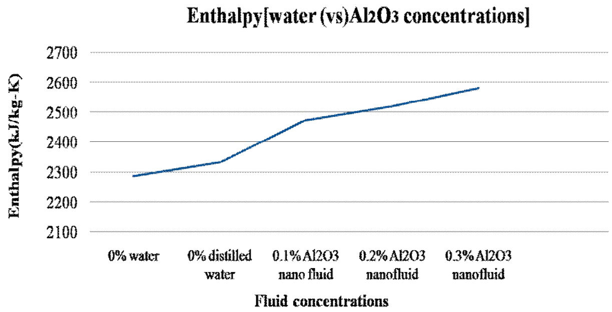
The experimental results obtained show reasonable variation in the dryness fraction as expected. And another results obtained reasonable variations in the enthalpy, entropy, and thermal conductivity as expected.

Base fluid with Al_2O_3 Concentration in percentage (%) » &Properties	Water (0%)	Distilled water (0%)	Water +Al_2O_3 (0.1%)	Water+ Al_2O_3 (0.2%)	Water+ Al_2O_3 (0.3%)
Dryness fraction	0.83	0.85	0.912	0.933	0.96
Enthalpy in kJ/kg	2285.05	2330.38	2470.9	2518.49	2579.69
Entropy in kJ/kg K	6.405	6.526	6.919	7.03	7.19
Thermal conductivity in W/mK	0.597	0.6	0.614	0.63	0.648

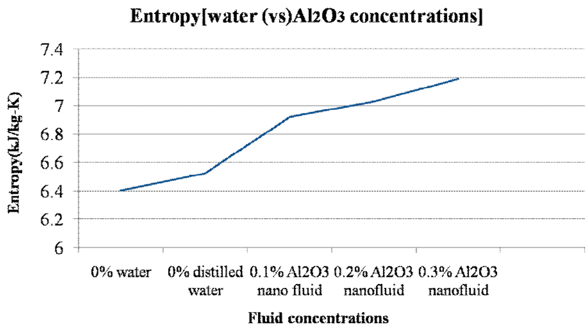
Graph:Dryness fraction along the fluid concentrations.



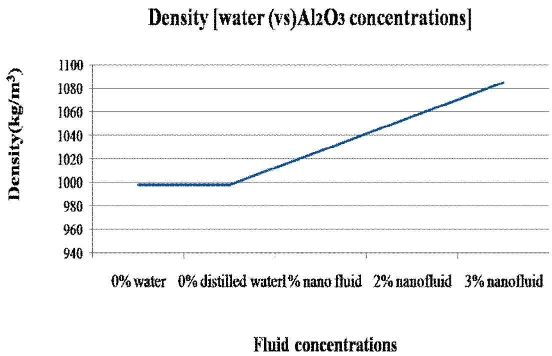
Graph: Enthalpy along the fluid Concentrations.



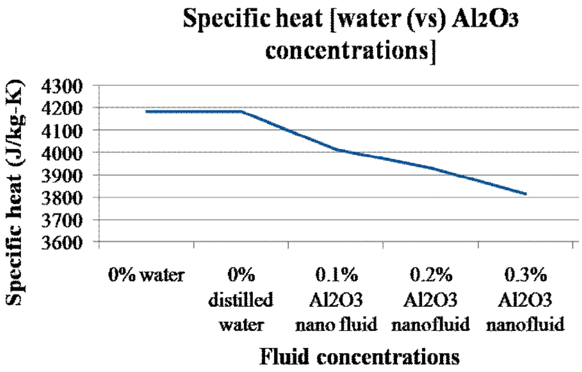
Graph: Entropy along the fluid Concentrations.



Graph: Density along the fluid Concentrations



Graph:Specific heat along the fluid Concentrations.



V. CONCLUSIONS

From the observations and calculations, it is observed that, thermal conductivity, dryness fraction and specific heat values are for water based nanofluid Al_2O_3 are increasing with concentration.

In the expansion process of the turbine, it is necessary to maintain the quality of the steam as dry, as to prevent from the corrosion effects. Nanofluid of 3% of (Al_2O_3+water) gives the better thermal properties comparing with water.

Finally it is concluded that by using nanofluids, we can maintain better quality of the steam in steam turbines

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