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Heat Transfer Analysis of Graphene based nano fluids in Heat Exchangers

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Abstract

Graphene-based nanofluids were effectively produced with the addition of 0.05 weight percent, 0.1wt percent, 0.15wt percent, and 0.2 wt percent GNS, respectively. Nanofluids thermal conductivity rises in accordance with an amount of graphene present in the fluid being studied. Furthermore, raising the temperature of the fluid and the quantity of graphene in the fluid will both improve the graphene nanofluids' coefficient of heat transfer. Especially as compared to the nanofluids of other, the nanofluids of graphene-based have notably higher thermal conductivity over the nanofluids of heat transfer coefficients, moreover the impact of this becomes more pronounced as the graphene concentration rises. In heat exchangers the nanofluids' application has shown promise as a method for lowering energy usage while simultaneously improving heat transmission, according to the researchers. This research found that, as a base fluid, when especially in comparison to water, up to twenty seven percent the vertical shell as well as tube heat exchangers heat transfer coefficient has been enhanced while utilizing the nanofluids of graphene or water of about 0.2 weight percent on tube side as hot fluid.

Keywords: Graphene nano sheets, heat exchanger, thermal conductivity, heat transfer coefficient.

1.0 Introduction

It is common in many industries to use heat exchangers, which are devices that exchange heat between different fluids in order to recover waste heat and reduce energy costs. In the industries of wide range have utilized the heat exchangers and may be found in a broad variety of settings. The heat transfer fluids' thermal as well as physical characteristics, for example, have been discovered and studied in addition to making heat exchangers more efficient. The popularity of nanofluids has grown in recent years as a consequence of their improved thermal and flow properties, as a result of which there has been a massive rise in media coverage. The advantages of nanofluids have earned them a reputation as prospective heat transfer fluids that may be used to enhance heat transfer as a consequence of these characteristics. [1-5] A great number of research have been conducted for a great level of understanding the nanofluids heat transfer features in the heat exchangers of various types. In the configurations of a wide variety the heat exchangers were available, including plate heat exchangers, twin pipe heat exchangers, and micro heat exchangers, to name a few examples. In contrast, similar research on shell as well as tube heat exchangers has been lacking at public domain [2-7].

In the context of thermal characteristics, nanofluids are suspensions that may be generated in host fluids by dispersing various nanoparticles with the goal of improving thermal properties [7]. The use of nanofluids has been shown in recent study to increase heat transfer coefficient, thermal conductivity, and stability while simultaneously lowering costs and energy consumption [8-9]. Because of these advantages, In the various heat exchanger types, the nanofluids utilization has increased as a result of the reduced energy consumption associated with them. Because of this, with higher thermal conductivity the suitable nanofluids as well as enhanced heat transfer properties has been an extremely difficult endeavour to far. Because graphene has a higher thermal conductivity than other materials, significant advances in graphene water-based nanofluids have been reported [10, 11]. The empirical findings demonstrate that as the nanofluids heat transfer coefficient as well as thermal conductivity have significantly increased during the last several decades. To gain a nanofluids convective heat transfers greater knowledge numerous investigations has been conducted [11, 12].

During their research on a shell as well as tube heat exchangers thermal performance [13], Shahrul and colleagues used nanofluids containing four different kinds of nanoparticles, including Al2O3, CuO, TiO2, ZnO, and Fe3O4, to study the heat exchanger's thermal performance. According to these findings, Al2O3/water nanofluids have the highest heat transfer coefficient of almost any. [14] Titanium dioxide as well as Al203 are the 2 nanofluids types which have been employed with water as base fluid in a shell as well as tube heat exchanger, as well as the results have been compared to see which one performed better. According to the results of the study, TiO2 nanofluids outperform Al2O3 nanofluids when it comes to heat transfer. [15] Lotfi as well as his associates using a horizontal in shell as well as a tube heat exchanger, an exploratory evaluation of the multi-walled carbon nanotube or water nanofluids' heat transfer capacity was carried out, respectively. As comparing the nanofluids' of MWNT/water to water, the total coefficient of heat transfer (MWNT/water nanofluid) increases, indicating that it is a more efficient heat transfer medium. Albadr and his colleagues are a team of dedicated individuals. Convective heat transfer characteristics were studied for a range of water or Al2O3 nanofluid concentrations used in horizontal shell as well as tube heat exchangers [16] using a variety of Al2O3/water concentrations. These findings lead to just a little amount of increment in heat transfer coefficient. In a study published in Nature

Communications, Ghozatloo et al. [17] looked at the coefficient of convective heat transfer of nanofluids of graphene or water by measuring thermal conductivity in both the shell as well as heat exchangers. As per the findings of the research, As compared to the base fluid, approximately a 35.6 percent of convective heat transfer coefficient is enhanced by utilizing the concentration of 0.1 wt % of graphene nanofluid. When included in a shell as well as tube heat exchanger with graphene oxide nanofluids, exergy analysis had been performed to determine the factors of a different that impacts on the graphene oxide nanofluids thermal efficiency. In turbulent flow as well as in laminar flow it's been noticed that the heat transfer has been improved by the nanofluids of graphene oxide, according to the results of the research. A recent research showed that when used in heat exchangers, graphene/water nanofluids exhibited excellent thermal conductivity and heat transfer characteristics. Present work reports extensive investigation on a wide range of thermal properties at different Nano fluid concentrations.

2.0 Experimental details

2.1 Characterization of graphene and Preparation of nanofluid

Aqueous graphene fluid was created by combining graphene sheets with deionized water as an addition, and the resulting mixture was then mixed together to create the final product. M/s nano shell, based in Bangalore, India, was the first company to manufacture commercially available nano sheets. Figure 1 shows the graphene SEM acquired by the researchers, which is shown in detail. In addition, graphene sheets have a large surface area that may be recognised, as shown in Fig. 1. It is also possible to see that the graphene structure is on the nanoscale in at least one dimension, which is very significant. In preparation for the Raman spectrum stage, a thin layer of graphene was applied to the surface of a polished metal surface. Figure 2 depicts the Raman spectrum of graphene, as well as all of its other characteristics, in more detail.

The presence of covalently bonded oxygen in graphene oxide is responsible for the material's thick structure, as well as sp3 hybridised carbon atoms being displaced somewhat below plus also above the material's initial plane, which are both caused by the presence of covalently bonded oxygen in graphene oxide. When graphene oxide is produced, the XRD pattern may be used to determine the crystallinity structure of the material (Figure 3). 2h 14 10:5 significant diffraction peaks are seen in the sample with D-spacing of 0.8mm and 2h 14 10:5 spacing. The graphene oxide XRD structure is consistent with the structural characteristics of graphene oxide that have been previously described [18-20].

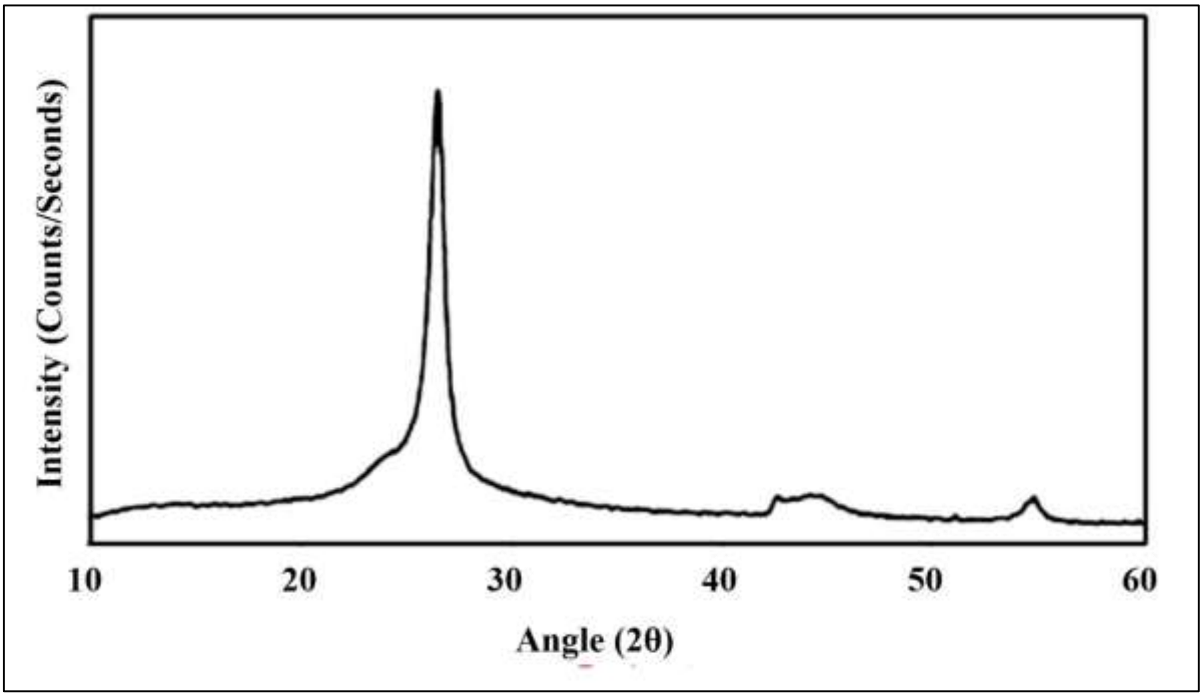

Fig.1.X-ray Diffraction pattern of Graphene nano sheets

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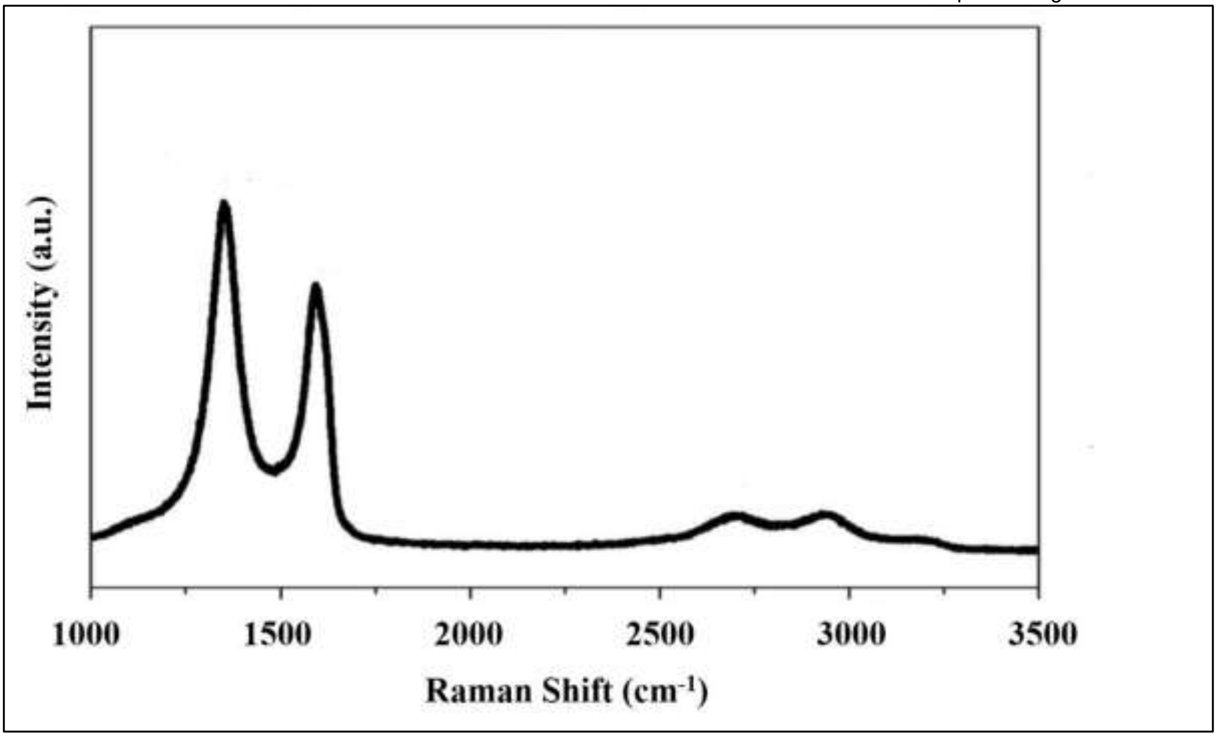

Fig.2 Raman Spectrum of graphene nano sheets

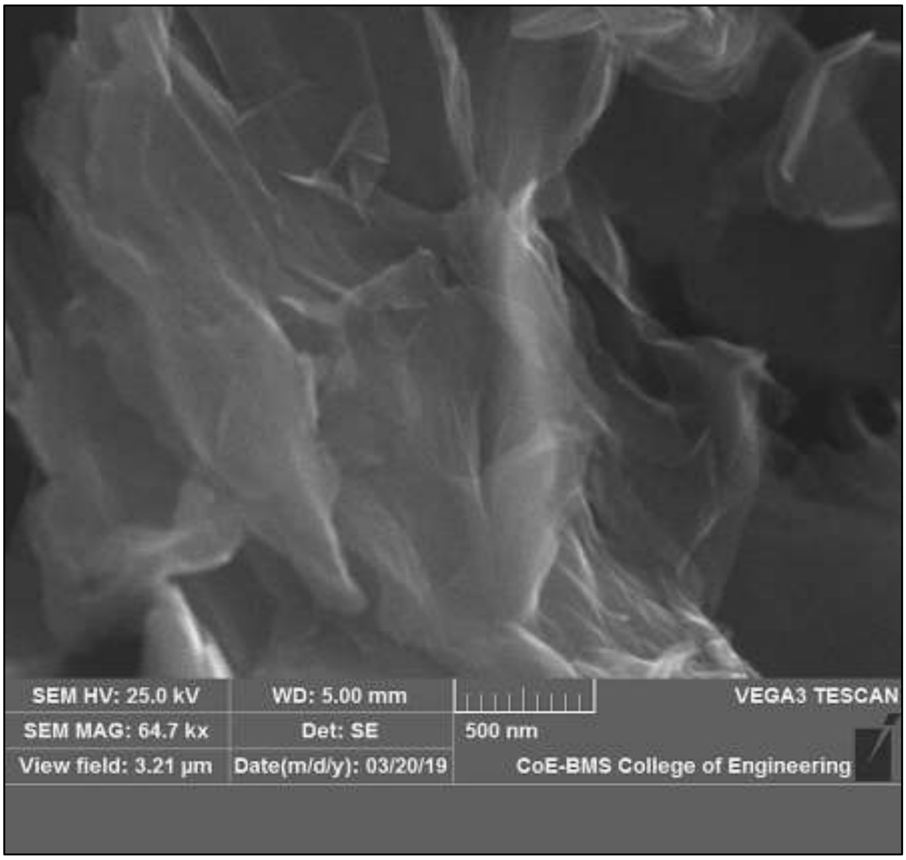

Fig.3 Scanning Electron Micrograph of graphene nano sheets

2.2 Experimental setup

One-metre horizontal circular copper tube with internal and external diameters of 1.07/1.30 cm is used in the experiment, as is a cooling system, a pump, and a tank, among other components. Throughout the test portion to ensure a uniform heat flux, a 2.5/m of resistance of a 7.5m Ni-Cr heater wire had been wrapped in around copper tube. To an adjustable alternating current power supply, had been connected the heater wire. A layer of rock wool thermal insulation was placed around the heater in order to ensure that the heat was distributed evenly throughout the room. Using five (K-type) thermocouples that were evenly spaced apart, we were able to monitor the temperatures of the copper tube's wall surfaces. Additionally, thermocouples implanted into the flow at both heat

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exchanger extremities serve as an additional safety measure. It was necessary to calibrate the system before any experimental measurements could be taken to ensure that they were trustworthy. Several preliminary comparisons were made prior to calibration, including those between experimental findings for the Nu (Nusselt number) as well as 'h' (coefficient of convective heat transfer), as well as between experimental findings for the standard correlations as well as coefficient of convective heat transfer for DI water. The inaccuracy of the system was then measured in order to determine whether or not it was correct. In to the system a 0.5 lit/min of volumetric flow rate had been introduced as well as maintained throughout to achieve laminar flow. When a 20V power source was connected to the copper tube, the tube's outside surface began to heat up dramatically. Based on the modest levels of error discovered during the first tests, the equipment for the laminar flow zone seems to be sufficient for calibration purposes. Because of this, it's possible to assess the nanofluids' heat transfer coefficient by employing a heat exchanger [21-23].

3.0 Results and Discussions

3.1 Thermal conductivity

This property may be utilised to efficiently increase the heat transfer coefficient by using its thermal conductivity properties. A thermal conductivity metre had been used to determine the graphene nanofluids' thermal conductivity in conjunction with three different graphene weight concentrations and temperatures ranging from 10 to 60 degrees Celsius. Thermal conductivity measurements were taken on the samples in the vessel, with the temperature of the samples being controlled using a thermocouple that was contained inside the container. Through the temperature-controlled bath utilization, it had possible to keep up consistency in various nanofluid temperatures throughout the measurement procedure, resulting in trustworthy findings. Thermal equilibrium was achieved by maintaining the temperatures of the samples at the same level for about 30 minutes before the measurements were taken. Three measurements were taken, and then the process was done three more times to get the average thermal conductivity readings. FIGURE 4 depicts how the thermal conductivity of the samples rises first, but subsequently decreases as the concentration of the samples increases. In the presence of graphene at weight percent values of 0.05, 0.1, 0.15, and 0.2, the thermal conductivity of water increased steadily throughout the whole temperature range of testing. Researchers found that nano fluids containing 0.02 weight percent graphene did not have substantially higher thermal conductivity than nano fluids containing 0.15 weight percent graphene or less, according to the findings of the research. In nano fluids, graphene concentrations as low as 0.15 weight percent seem to be sufficient to cause saturation. Due to the decreased stability and threshold for graphene deposition in water as a result of higher concentrations, the conductivity would decrease, resulting in poorer conductivity. According to recent research, the ability of graphene to conduct nanofluids is in direct opposition to its stability.

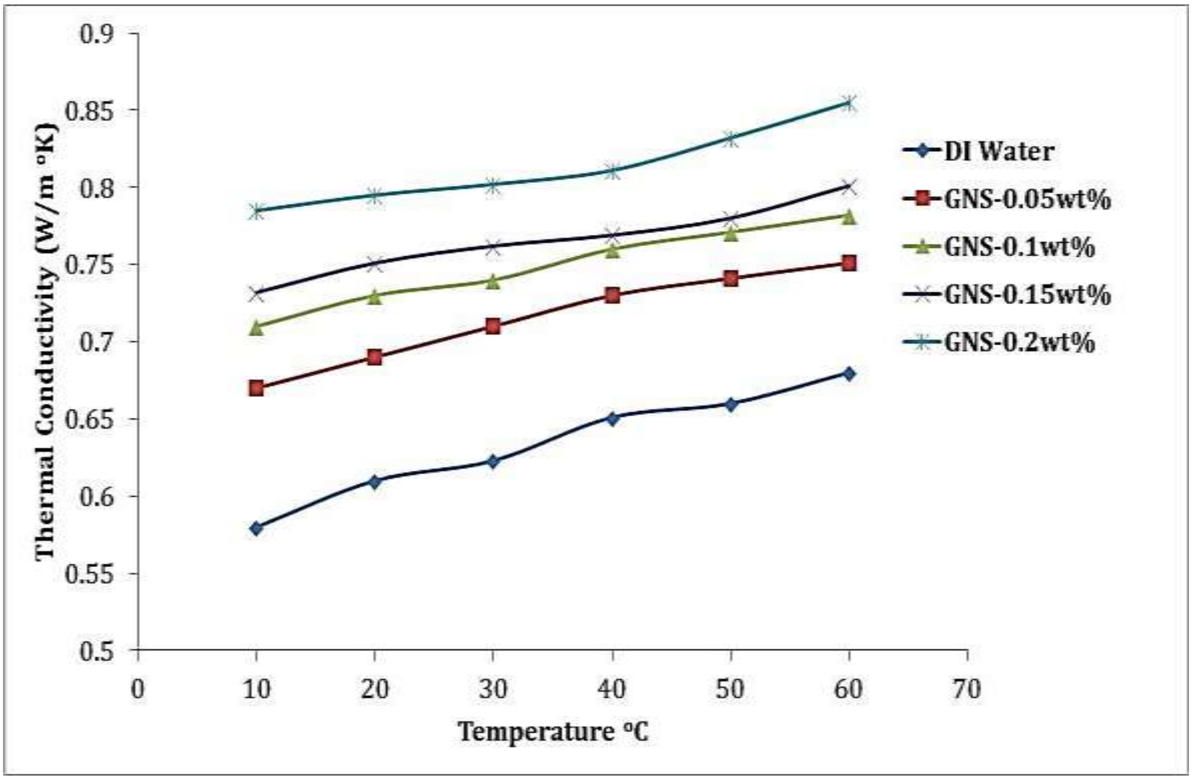

Fig.4 Effect of graphene concentration on thermal conductivity of nano fluids at different temperature

3.2 Heat transfer coefficient

Have determined the coefficient of heat transfer by evaluating the fluid temperature and thermocouple recording of the inner wall temperature's examination part using the evaluation of the temperature of fluid. Compared to water the graphene nanofluids have a viscosity of very high, at Reynolds number of constants they require a flow rate of very higher to ensure laminar flow. Whenever heat exchanger is operating within the mode of laminar flow, altering volumetric flow rate of heat exchangers as a result of the input, a constant is produced of Reynolds' number for both graphene as well as water nanofluids when the heat exchanger is operating in the turbulent flow domain. During the laminar flow generation, the coefficient of heat transfer, which's defined by the distance between the output as well as input of the heat exchangers, is taken into consideration. Because the Reynolds number remained constant, it should have been possible to test a local heat transfer coefficient at various tube levels, but this was not the case. The Reynolds number should be chosen in such a way that it falls within the acceptable range of errors for the experimental setup. Five different methods are available for measuring the coefficient of heat transfer depends within the heat exchanger on the location of the sensor and how much heat is transferred. Graphene nanofluids' as well as water's heat transfer coefficients are shown in Figure 5 in comparison to one another.

When a heat exchanger is pushed away from a source of energy, the local coefficient of heat transfer decreases exponentially despite the fact that the temperature gradient and the heat exchanger's coefficient of heat transmission ought to be low. For this reason, since the temperature gradient across the heat exchanger's thermal boundary layer is so small when it first begins to operate, both its thermal coefficient of transfer and its thermal resistance both increases. The expansion of the border layer in a heat exchanger results in an increase in heat resistance while simultaneously decreasing the coefficient of heat transfer. Despite the fact that a boundary layer seems to be forming across the heat exchanger, the exponential development rate appears to be higher at the heat exchanger's initial stages than it is later in the heat exchanger. The consequence is that the initial half of heat exchanger performs a large portion of the heat transfer activity. The conductivity function has been utilized to figure out the coefficient of heat transfer; samples with greater graphene concentrations had a lower heat transfer coefficient than other samples. While data indicate that it does not always decline, the tendency is that it is on the increase. Please keep in mind that the use of circulation mixing methods may help to reduce the amount of graphene that settles in water over time, which is beneficial. Although all other factors remain constant, the quantity of heat supplied to the pipe wall may be adjusted. In this case, it is necessary to repeat all of the previous calculations. The results of the calculations, which were carried out at temperature of fluid differing from 20^{o} Ce to thirty degrees Celsius to forty degrees Celsius, are shown in figures 6, 7, and 8.

According to the results, the local coefficient of heat transmission seems to rise when the temperature and concentration are raised. It is recommended that the concentration of graphene be increased in order to improve heat transfer coefficients. As seen in the two figures, the distance between the 40°C and 30°C curves is slightly more than the distance between the 30°C and 40°C curves. The distance between the 40°C and 30°C curves is somewhat greater than the distance between the 30°C and 40°C curves. This is due to the fact that the 40°C and 30°C curves are a little closer together. It is found that when the material's temperature rises, on local coefficient of heat transfer the positive impact of graphene becomes more pronounced. Increased temperature of the fluid has an effect on dispersion of a previously decreased local heat transfer coefficient, to put it another way. Therefore, when the temperature is enhanced, the coefficient of heat transfer declined exponentially, as well as the thickness of the heat barrier layer decreased in proportion to the increase in intake temperature. Heat transfer was accelerated as a result of the little resistance it provided during the process. According to the researchers, this was caused by the heat exchanger's higher average wall temperature, which elevates the fluids mean temperature while running it through and decreases efficiency.

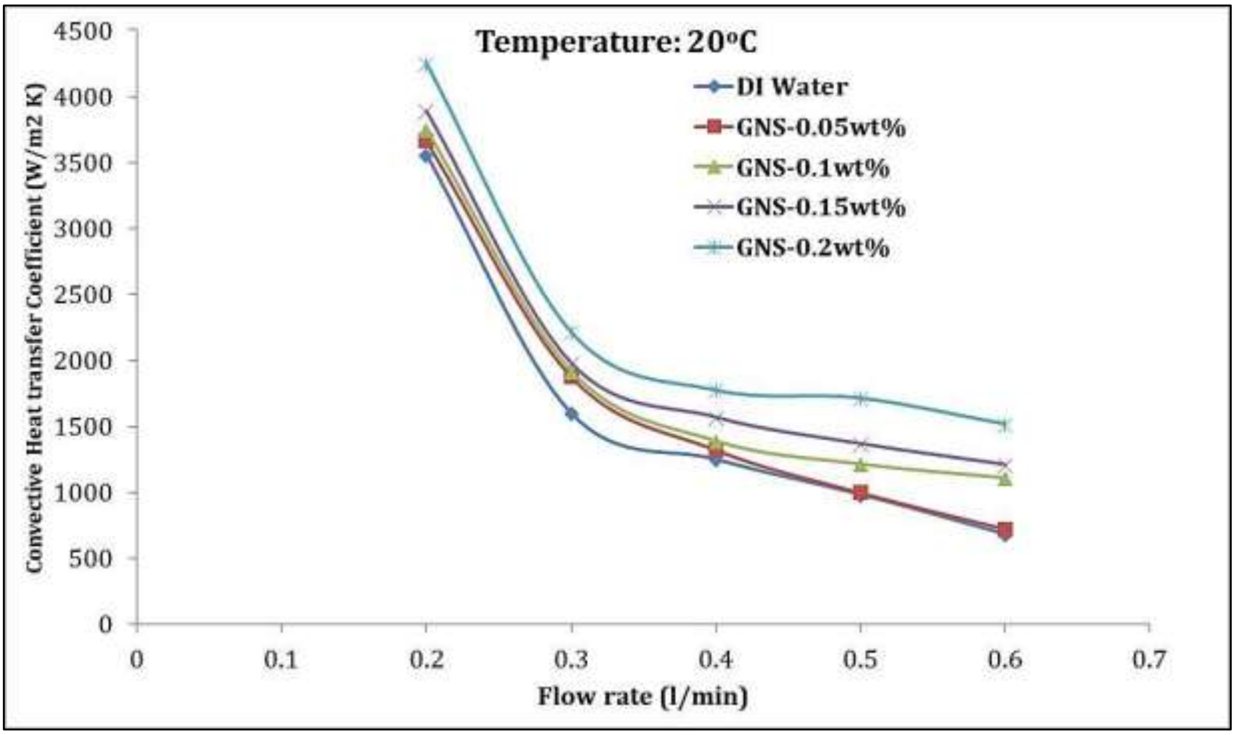

Fig.5 Effect of flow rate on heat transfer coefficient at a temperature of 20^{o}C

The utilization of temperature in combination with other variables was employed just to determine the nanofluid graphene's local coefficient of heat transfer in various areas of heat exchanger under conditions of fixed Reynolds numbers and constant concentration. Researchers discovered that the water concentration in graphene nanosheets was 0.15 percent by weight, as per their

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findings. Have measured the convective coefficients of heat transfer in 3 various temperatures as well as with three variety of Reynolds numbers to see which was the most efficient. According to the graph, increasing temperatures are associated with a rise in the material's coefficient of heat transfer which's that is being heated. An extensive number of variables may be responsible for this improvement. In order to enhance thermal conductivity, it is necessary to raise amplitude and frequency of Brownian motion particles as the temperature of the material increases.

Vertical shell as well as tube heat exchanger's convective coefficient heat transfer has been estimated via a series of tests conducted in a counter-current flow environment. It was first discovered that the convective coefficient of heat transfer might be calculated in terms of water-to-water heat transfer. The tube side water had been heated to the following temperatures by the heating system: 20, 30, 40, and 42 degrees Celsius, respectively. In order to calculate the convective coefficient of heat transfer, several tube side fluid flow rates were investigated. The flow rates of hot water have been investigated at a variety of different rates. The heat transfer coefficient is affected by the flow rate of tube side and is investigated in depth in this paper. As the rate of heat flow rises, so does the convective heat transfer rate, as shown in figure below. There seems to be a greater impact of the input temperature's hot fluid on tube side flow rates when the tube side flow rates are higher on the tube side flow rates. For the heat exchanger of water or graphene nanofluid the overall convective heat transfer coefficient had been explored in this research for the first time in detail. In the other side of the tube, heated nanofluids such as water or graphene are injected into the tube by being pushed into it from the other side of the tube. As shown in Figures 5, 6, and 7, the effect of altering GNS on total coefficient of heat transfer (in percent) depending on rate of flow change of either water or graphene nanofluids (in percent) can be shown (0.05, 0.1, 0.15 and 0.2). Total, the findings show that the overall coefficient of heat transfer direct proportional rise to the pace at which the nanofluid is injected into the system. According to the results of the research, high flow rates of tube side had a somewhat greater impact on GNS concentration than low flow rates of tube side. Using nanofluids boosts the total convective coefficient of heat transfer, resulting in greater temperatures being reached. When compared to water, it has been discovered showed that especially when it comes to thermal conductivity the nanofluids' of water or graphene heat transfer performance is enhanced, [18]. It's possibly that this's what's causing the total coefficient of heat transfer coefficient to rise.

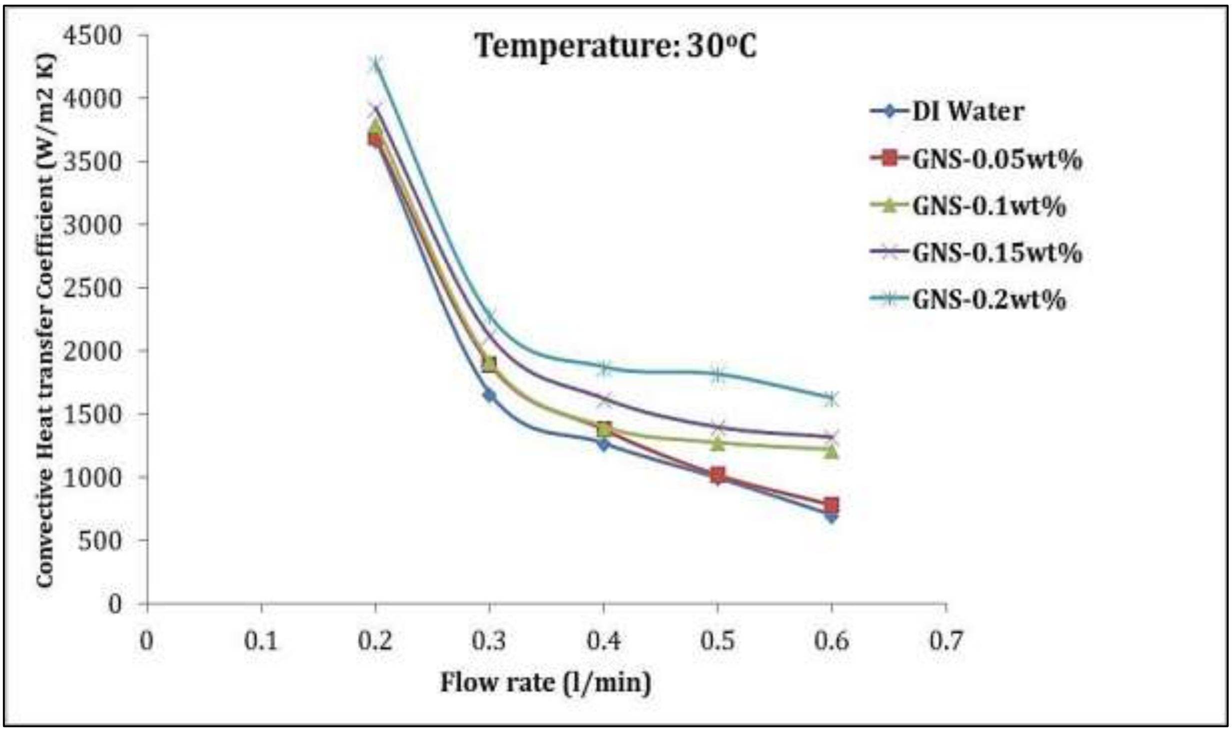

Fig.6 Effect of flow rate on heat transfer coefficient at a temperature of 30°C

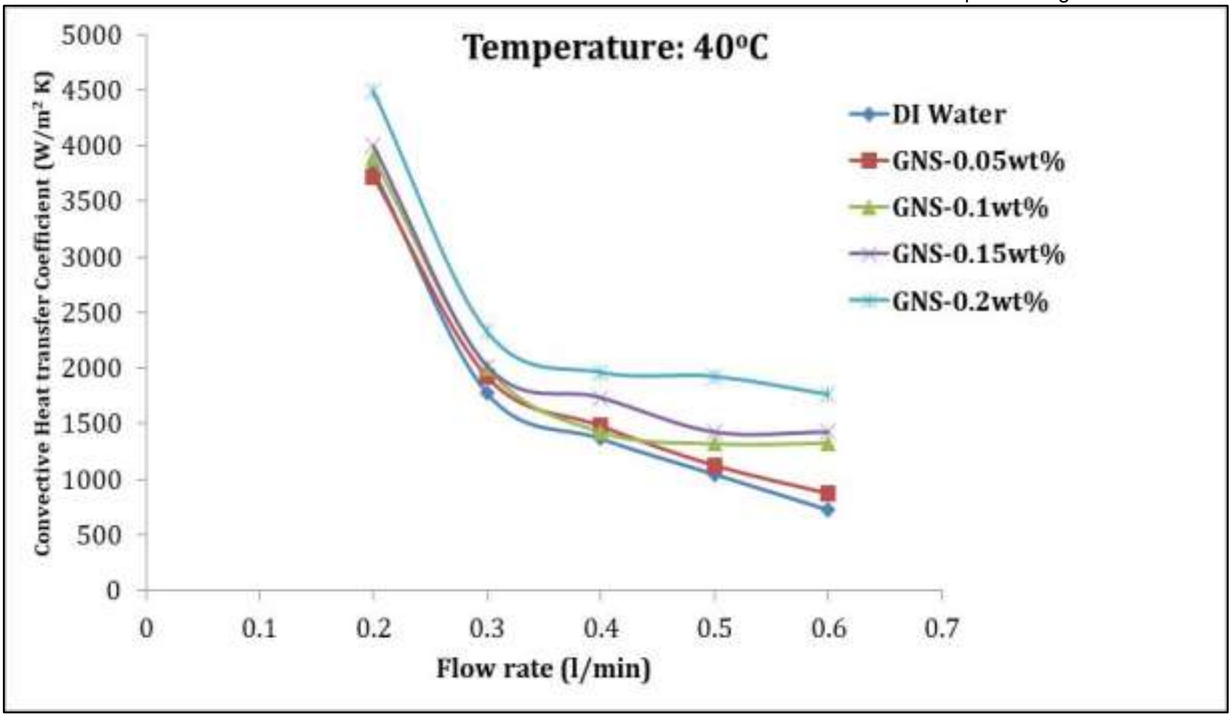

Fig.7 Effect of flow rate on heat transfer coefficient at a temperature of 40ºC

4.0 Conclusions

GNS was used to successfully generate graphene-based nano fluids at concentrations of 0.05wt percent, 0.1wt percent, 0.15wt percent, and 0.2wt percent in the final product. The thermal conductivity of a fluid rises in direct proportion to the quantity of graphene in the fluid, and vice versa. Furthermore, the graphene nanofluids' heat transfer coefficient also increases as the graphene concentration as well as temperature of the fluid increase, the heat transfer coefficient of graphene nanofluids increases as well. It has been shown that when compared to the nanofluids' heat transfer coefficient the graphene based nanofluids' is substantially higher, as well as therefore this impact grows in proportion to the amount of graphene present. As a method for reducing energy consumption while increasing heat transfer, in heat exchangers the nanofluids' application has shown considerable potential. This research found that, as a base fluid, when especially in comparison to water, up to twenty seven percent the vertical shell as well as tube heat exchangers heat transfer coefficient has been enhanced while utilizing the nanofluids' of graphene or water of about 0.2 weight percent on tube side as hot fluid

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