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Air Purification And Cooling System Using Titanium Dioxide Nanofluid: A Review

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Abstract

By passing the outside polluted air through the honeycomb filter via titanium dioxide nanofluid as well as using the heat transfer properties of titanium dioxide for cooling of this filtered air. The ultraviolet (UV) rays serving as the exciter for the photocatalytic effect which helps the Titanium oxide for the reduction of air pollutants and enhancing the air quality. Atmospheric deposition of pollutants is a major challenge for the environmental governance and management of different depositions could be harmful especially in the air. The main objective is to illustrate the latest achievements in terms of the use of titanium dioxide to neutralize pollutants like NOx, SOx, CO, specks of dust, and aromatic substances. The various concentration of titanium dioxide in the water is checked to see best suitable concentration ranging from 3% to 5% weight concentrations and the particle size of nanometer based on availability and cost, which will range from 40nm to 50 nm. By experimenting with various concentrations of Titanium dioxide in water achieves different results depending upon the external environment. Hence using polluted air as input achieves filtered, clean as well as cooled air.

Keywords— Polluted air ,NO_x, Ultraviolet(UV) rays, Titanium Dioxide,Nanofluid.

I. INTRODUCTION

"Air pollution and its side-effects" is one of the most serious environmental and human health concern. An increase in population, Industrialization, heavy use of vehicles, and burning indisposable substances has led to pollution of air. Air pollution refers to the term of the release of pollutants into the air which stays in the atmosphere for a long duration which is harmful to human health, the environment, and the planet as a whole. Air pollution consists of harmful gases, chemicals that can harm the health of humans, animals, plants, and also is the main reason for global warming. It is the absolute reason behind acid rain and also damages structures. People undergo a wide range of health effects from being exposed to air pollution such as irritation to the skin, or eyes, headaches, dizziness, and queasiness. Long-term effects of air pollution can last for years or lifetime. They can even lead to a person's death. Long-term health effects from Air pollution include skin cancer, heart disease, lung cancer, and respiratory diseases such as emphysema.

There have been many attempts to reduce such emissions. However, there are still emissions polluting the air to a significant level. A process of eliminating these pollutants at the street level once they are emitted is an attractive and interesting air quality management method. Similar to have photosynthesis

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process, photocatalytic compounds such as titanium dioxide (TiO_2) particles can be used to trap and absorb organic and inorganic particles in the air, degrading and depreciating harmful pollutants such as nitrogen oxides (NO_X) and volatile/ Unstable organic compounds (VOC) into CO_2, H_2O, O_2 and harmless inorganic compounds in the presence of UV light or sunlight.

By altering the TiO_2 mixture in nanofluid its Heat transfer capabilities also change accordingly. Hence being an advantage for cooling the air. The ability of a working fluid medium to transfer a large quantity of heat across a small temperature difference enhances the efficiency of energy conversion and improves the design and performance of advanced heat transfer systems.

Here the study deals with the improvement of air quality and its temperature using titanium dioxide as a nanofluid. Various papers studied gave us an idea about how much of Titanium oxide should be mixed with the base fluid for carrying out the reduction of pollutants. The wavelength of UV rays required is also studied which gave the idea of using a UV lamp
having wavelength less than 388nm. As the nanofluid contains titanium dioxide the thermal conductivity of the base fluid also rises which is a useful property in reducing the temperature of the air.

II. LITERATIURE SURVEY

Nobuaki Negishiet. al[1],Studied Performance verification of the photocatalytic solar water purification system. They evaluated a photocatalytic solar water purification system by actual deployment and field tests of the drinking water and determined that the photocatalytic solar water purification system effectively eliminated bacteria which will lead to a reduction in the risk of infectious diseases.

Adawiyah J. Haideret.al[2],Studied Titanium dioxide (TiO_2) in detail with its physical, chemical properties, and features dependent on the crystal phase, size, and shape of particles. By varying the phases of crystalline TiO_2, different bandgaps that rutile TiO_2 of 3.0 eV and anatase TiO_2 of 3.2 eV, determines the photocatalytic performance of TiO_2. Here they explain some applications and theoretical concepts of nanostructure of TiO_2 nanoparticles along with demonstrating electrical, optical, and morphological properties of TiO_2.

Siraj Ali Ahmed et. al[3],Studied on Improving car radiator performance by using TiO_2-water nanofluid. In this study usage of TiO_2-water nanofluid's as a coolerin car engine radiator was studied. It was found that the presence of TiO_2 nanoparticle can significantly enhanceradiator's heat transfer rate in a manner dependent on nanoparticlequantity added to the base fluid. Heat transfer coefficient significantlyimproves for 0.2% nanoparticle concentration as comparedto pure water.

Filippo Gandolfo1et.al[4],proposed the Tirex35®. This is a revolutionary paint. The paint is an amalgamation of nitrates produced by the reaction of titanium dioxide with NO_3, with silicates of potassium, high-purity quartziferousinerts and appropriate additives. The result of this shows the efficiency and effectiveness of the formulation is superior than others for road applications. And, effect of direct sunlight on the exposed paint. The aforementioned performance on a surface of 150,000 m^2yields to save around 4,500 ton/year of NOx in terms ofemissions.

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K. Abdul Hamidet. al[5],Studied heat transfer performance of TiO_2nanofluids in2 water–ethylene glycol mixture. The thermal conductivity of TiO_2nanofluids shows enhancements with an increase in concentration and an increase in temperature. While for viscosity, the increase in concentration causes an increase in the viscosity but decreased with the increase of temperature. The heat transfer performance for temperature at 30 °C experienced low en-hancement compared to base fluid when the nanofluidconcentration was less than 1.17%. The heat transfer coefficients of all TiO_2nanofluid concentration for 50 and 70 °C increased with the increase of Reynolds number. As the bulk temperature increases, the enhancement becomes more noticeable for higher concentrations.

Dijy Daviset. al[6],TiO_2 photo catalyst helps to reduce a major portion of NO_2 which is a dangerous pollutant presented in the atmosphere in the presence of UV light. Overall it is concluded that TiO_2 photo catalyst is good for reducing the major amount of NO_2 presented in the atmosphere which is a dangerous gas.

M.Vakiliet.al[7],Experimental study on convective heat transfer of TiO_2nanofluids. In his study, nanofluids with different TiO_2 nanoparticle concentrations were synthesized and measured in different constant heat fluxes for their heat transfer behavior upon flowing through a vertical pipe.It was observed that the enhancement of the nanofluids convective heat transfer coefficient for mixture of water and ethylene glycol as a base fluids is more than the nanofluid of distilled water because the thermal conductivity of mixture of water and ethylene glycol is less than the thermal conductivity of water.

Wang Nanet. al[8],performed an experiment on nano-TiO_2 sol for the effect of purification. Experimental results show that nano-TiO_2 solution degradation could become beneficial oil mist particles and purify oil mist pollution effectively. Solar photoreactor hasbeen demonstrated to be efficient for oil mist by solar photocatalysis with TiO_2sol^n and supported TiO_2 duringtreatment periods of 30~35 min.Various results can be achieved by meticulously altering the composition and amount of reactants in solution.

Th. Maggoset. al[9],Studied Photocatalytic degradation of NO*x*gases usingTiO_2-containing paint An indoor car park was appropriately equipped in order to test the de-polluting efficiency of a TiO_2-containing paint in an indoor pollutedenvironment, under real scale configuration. Depollution tests were performed in an artificially closed area of the parking, which was polluted bya car exhaust during the testing periodThe results presented at the real scale test showed that heterogeneous photocatalysiscould be used as a tool for the improvement of air quality.

Jeanette M.C. Robertson et.al [10],studied the effect of titanium dioxidephotocatalysis and UV radiation for three pathogenic micro organisms. In this study when three common bacterial pathogens, Escherichia coli, Salmonella enterica,serovarEnteritidis and Pseudomonas aeruginosa, were exposed to Titanium dioxide and UVA light. Results showed titanium dioxidephotocatalysis is a more effective technology than UVA irradiation, for disinfection of water contaminated by E. coli and S. enteritidis. Direct UVA irradiation, however, appears to be more effective for removal of Ps. Aeruginosa.

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III. RESEARCH ELABORATIONS

- NO_x Formation: Atmospheric deposition of pollutants is a major challenge for environmental governance. Different depositions of pollutants are harmful primarily on the ground and roads. In particular, in areas where industrial activities are located and significant car traffics occurs, depositions on roads are harmful to all people. The main effects are risks of breathing pathologies and possibly cancer as a long-term outgrowth. Nitrogen dioxide is an irritant pollutant, which at high concentrations may cause swelling of the air airways, In the presence of air during combustion and High-temperature process reaction of Nitrogen and Oxygen causes the formation of NOx molecules. High traffic area zones or in general due to the high usage of vehicles, there is a significant rise in such(NO_x) pollutants [6].NOx gases are formed whenever combustion occurs in the presence of nitrogen and oxygen – e.g. in car engines[11].
- When nitrogen is released during fuel combustion it combines with oxygen atoms to form nitric oxide (NO). This further couples with oxygen to create nitrogen dioxide (NO_2). Nitric oxide is not considered to be dangerous for human health at typical concentrations, on the other hand, nitrogen dioxide is hazardous. Nitrogen dioxide and nitric oxide are referred to together as oxides of nitrogen (NO_x). NO_x gases react to form smog, acid rain as well as has a major part in ozone layer depletion and being central to the formation of particulate matter (PM) and ground-level ozone, both of which are correlated with adverse health effects.
- Application of titanium dioxide- Titanium dioxide as a nanofluid for air purification as well as for air cooling was studied. As there is an increase in air pollution, it has become mandatory to bring it under control. By the use of titanium dioxide as a nanofluid and UV rays helping in the photocatalytic effect, the pollutant in the air can be reduced significantly. The titanium dioxide is well researched for its decontaminating and non-toxicity properties and the killing of various airborne pathogens and germs. Figure 1 describes it in short. By altering the concentration of titanium dioxide in water heat transfer rates can be controlled. Various literature papers study that various particle sizes, as well as the different of titanium dioxide, results in different thermal conductivity properties. There have been many attempts to reduce emissions [2].

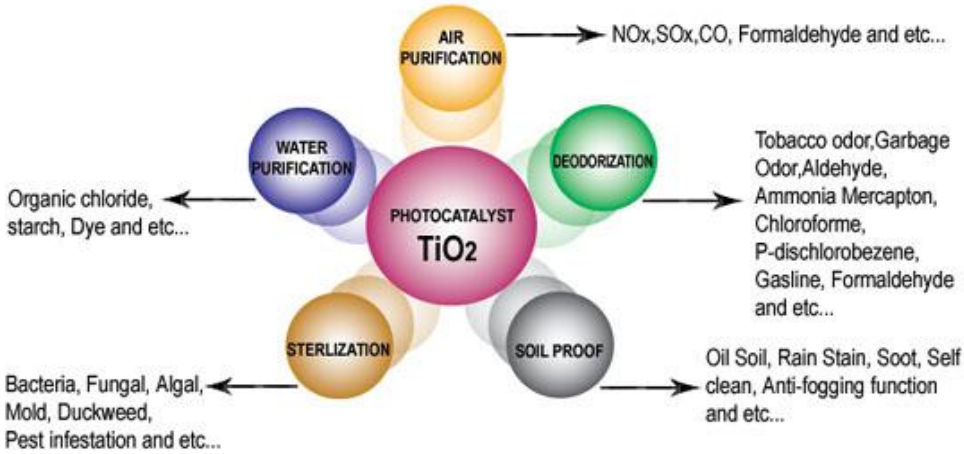

Fig.1Applications of TiO_2 [2]

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- Photocatalysis-Photocatalysis is the process pf acceleration of a photoreaction in the presence of a catalyst here it is UV rays. A *photocatalyst* is a material that absorbs light to bring it to a higher energy level and provides such energy to a reacting substance(NO_x-O_2) to make a chemical reaction occur. The photocatalytic process starts with the absorption of electromagnetic radiation, which excites an electron and moves from the valence band to the conduction band and leaves behind a hole in the valence band. In this process UV light radiations are used by photon energy equal to or greater than TiO_2 band gap energy ($h\nu \geq 3.20$ eV at $\lambda \leq 380$ nm); electron-hole pairs (The charge carrier) are generated. The negatively charged electron moves from the valance band (VB) to the conduction band (CB) leaving behind the positively charged hole. Then, the electron and hole take part in reduction(loss of oxygen atoms)-oxidation(gain of oxygen atoms) reactions with species that are adsorbed on the surface of TiO_2, such as water, hydroxide (OH-) ions, organic compounds, or oxygen. The valence band hole (h+) is highly oxidizing while the conduction band electron (e-) is highly reducing. The charge carrier h+ oxidizes H_2O or OH- ion to the hydroxyl radical (OH•) that is a highly potent, non-selective oxidant. It easily attacks pollutants adsorbed at the surface of titanium dioxide or in aqueous solution degrading them to H_2O and CO_2. On the conduction band (CB) the electron reduces adsorbed oxygen (O_2) species to superoxide (O_2•), then undergoes a series of reactions to give the OH• radical. The reaction of these radicals with an organic substance, environmental pollutants, or harmful microorganisms results in the decomposition of the latter. [2]In a case where the above-discussed processes do not occur, recombination of the charge carriers results, and energy is discharged in the form of heat. This causes a great reduction in TiO_2photocatalysis efficiency. Electron-hole recombination is reaction competing with hole-donor and electron-acceptor electron-transfer reactions. Recombination can occur either in the semiconductor bulk or at the surface resulting in the release of heat [2].
- Nox degradation using TiO_2 – The use of titanium dioxide (TiO_2) to reduce pollutant components is a well-known technique used since last 40 years, needing an ultraviolet light produced by the sun or artificial lighting. Using TiO_2 paint on the road for air purification was studied. The normal and smooth asphalt does not preserve the nanoparticles of TiO_2. Conversely, that allows the reaction on air pollutants producing an air cleaning, reducing specified pollutants for a long time. The above-mentioned performance on a surface of 150,000m 2 yields to save around 4,500 tons/year of NO_x in terms of emissions[4].

  A method of removing pollutants at the street level, once they are emitted to the atmosphere, is an attractive air quality management. Similar to plant photosynthesis, a photocatalytic compound such as titanium dioxide particles can be used to trap and absorb organic and inorganic particles in the air, removing (degrading and mineralizing) harmful pollutants such as nitrogen oxides (NO_X) and volatile organic compounds into CO_2, H_2O and harmless inorganic compounds in the presence of UV light or sunlight. The author performed an experiment in which the author tested two separate concentrations of titanium dioxide in the paint. The experiment was repeated by varying the concentration of TiO_2 contained in the paint. Also, the reaction of TiO_2 under the absence of UV light was tested. To find out the leakage of air from the experimental setup, a leakage test was also conducted. During these tests, it is found that the amount of pollution presented in the box reduces considerably. Also, the results show that the reduction of pollution is more when the amount of TiO_2 presented in the paint increases. Firstly the author painted the setup with 25 % TiO_2 mixed with paint and supplied it with air and UV rays. Results being 49.53% reduction of NO_2. The same setup with 50% TiO_2 resulted in a 52.09% reduction in NO_2[6].

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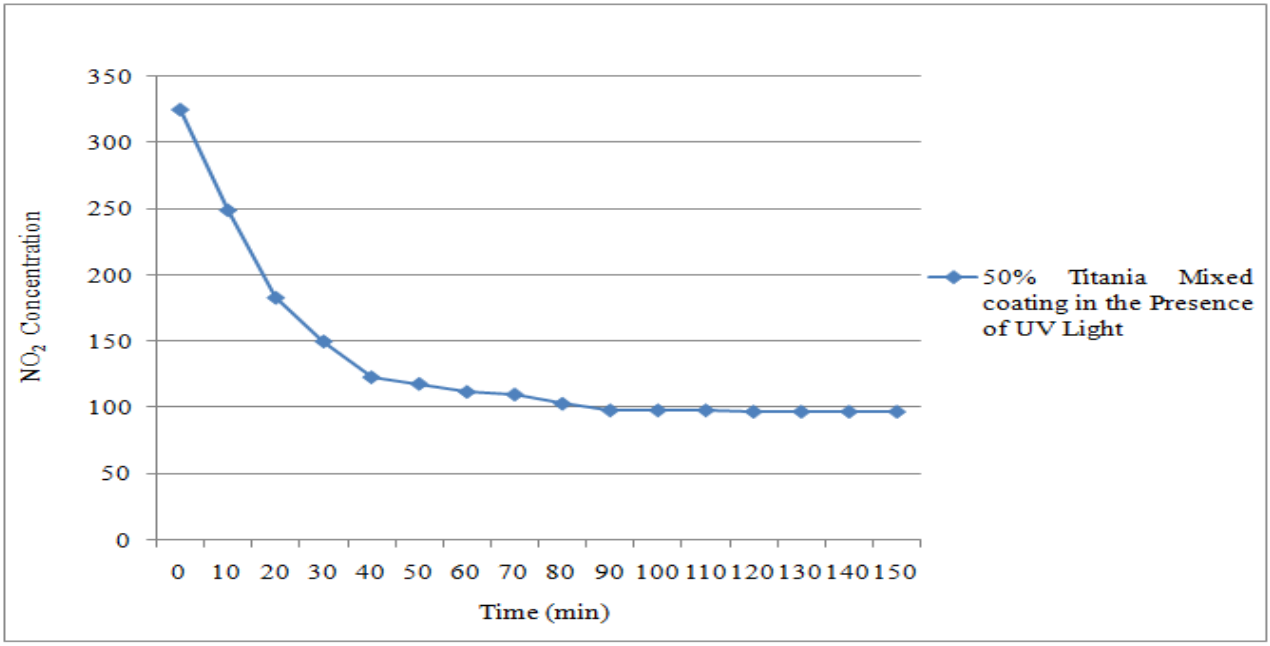

Fig.2Reduction of Concentration of NO_2 when polluted air exposed to 50% of TiO_2 Mixed Paint Coated Tile in the Presence of UV light.[6].

From the Figure2 shows that the reaction of pollutants with titanium dioxide will be faster, as the concentration of titanium dioxide increases. When a photon with an energy of hν exceeds the energy of the bandgap an electron (e-) is promoted from the valence band to the conduction band leaving a hole (h+) behind. In electrically conducting materials, the produced charge carriers are immediately recombined. A portion of semiconductors of this photo-excited electron-hole pairs diffuse to the surface of the catalytic particle and take part in the chemical reaction, along with the adsorbed donor (D) or acceptor (A) molecules. The holes hence have the energy to oxidize donor molecules whereas the conduction band electrons can diminish the suitable electron acceptor.

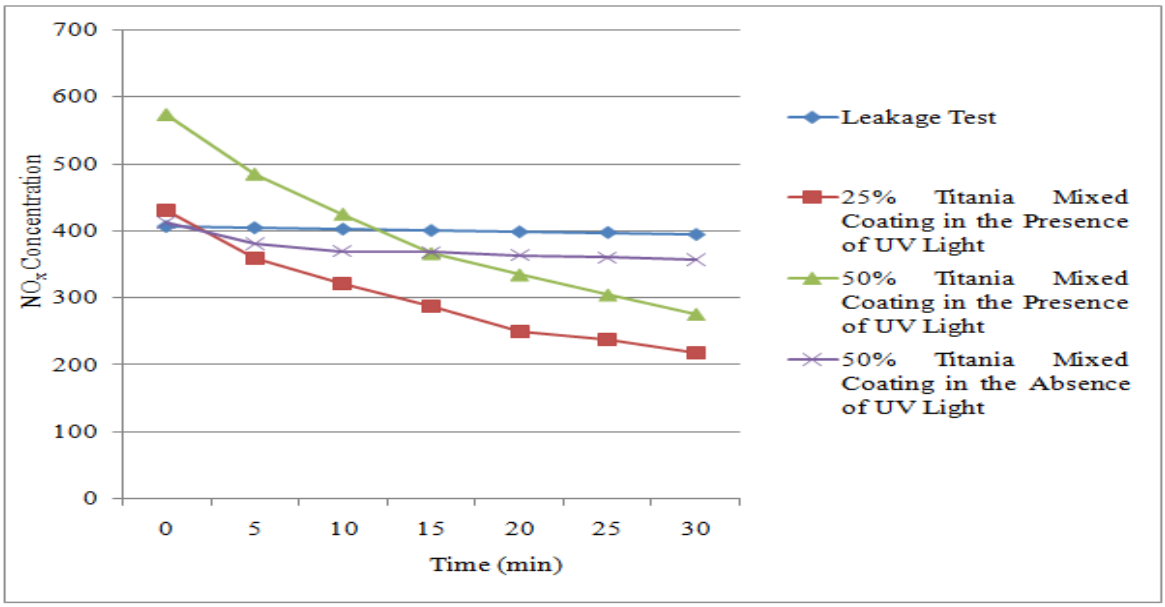

Fig.3 Results of various tests conducted for 30 minutes[6].

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The TiO_2 in the presence of UV light is a good solution for rising air pollution problems. Hence the use of this technique can be useful in considering the targets to be achieved.

$$TiO_2 + h\nu \rightarrow TiO_2 + h^+ + e^- \quad (1)$$

$$H_2O + h^+ \rightarrow \bullet OH + H^+ \quad (2)$$

$$O_2 + e^- \rightarrow \bullet O_2^- \rightarrow \bullet HO_2 \quad (3)$$

$$2\bullet HO_2 \rightarrow O_2 + H_2O_2 \quad (4)$$

$$H_2O_2 + O_2^- \rightarrow \bullet OH + OH^- \quad (5)$$

$$H_2O_2 + e^- \rightarrow \bullet OH + OH^- \quad (6)$$

$$OH^- + h^+ \rightarrow \bullet OH \quad (7)$$

$$\bullet OH + pollutants \rightarrow H_2O + CO_2 \quad (8)$$

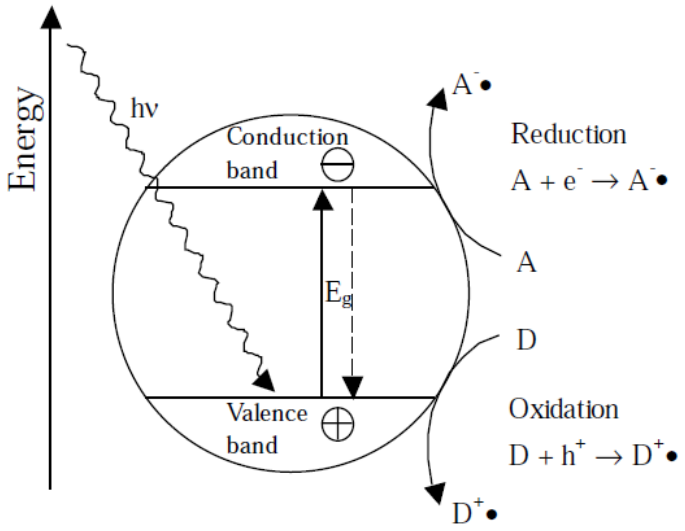

Fig.4Operation of a photochemical excited TiO_2particle[6].

In research on Decreasing the Nox gas by using titanium dioxide containing paint for car parking was done. An indoor car parking was suitably equipped to test the de-polluting efficiency of a titanium dioxide containing paint in an indoor polluted environment, under real scale configuration. The pollution tests were performed in a closed area of the parking, which was polluted by keeping the car in ideal(engine is turned on) car exhaust during the testing period. The ceiling surface of the car park was covered with paint containing white acrylic titanium dioxide. The closed area was supplied with car exhaust gases. As soon as the system reached a steady-state, the UV lamps were turned on for 5h. The difference between the final and the initial steady-state concentration indicates the removal of the pollutants due to both the photocatalytic paint and car emission reduction. Results showed significant photocatalytic oxidation of NOx gases [9].

- Heat transfer properties- Among the various semiconductors Titanium dioxide in the form of anatase has attracted wide interest, due to its strong oxidizing power under UV irradiation, its chemical stability, and the absence of toxicity. The development of innovative materials that can

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be easily applied on facades, with both de-soiling and de-polluting properties, would be a significant step towards the improvement of air quality. The use of titanium dioxide photocatalyst in combination with cementitious and other construction materials has shown a favorable synergetic effect in the removal of air pollutants. The most recent developments in nanotechnology have led to improvements in the original uses of nanofluids in car motor cooling. In the present study, enhancement of car engine radiator by titanium dioxide-water nanofluid as a coolant of car engine radiator was investigated experimentally. To determine the effect of titanium dioxide-water nanofluid on the radiator's performance, experiments were performed with pure water and titanium dioxide-water nanofluid separately and results were compared with other studies on the vehicle engine system. The main objective was to check the aspects of heat transfer of the titanium dioxide-water nanofluid as a substitution to the customary coolant system. For this purpose, experiments were carried out using a titanium dioxide nanofluid with 0.1, 0.2, and 0.3 % volume concentrations with flow rates of 0.097 and 0.68 m^3/hr in the laminarow region, where Reynolds number ranged from 560 to 1650. The results show that the friction factor decreases when the Reynolds number and the volume concentration are increased. Moreover, titanium dioxide-water nanofluid with 0.2 % concentration can enhance the effectiveness of car radiator by 47 % as compared to 0.1 and 0.3 % concentrations and pure water as a coolant. Finally, the average heat transfer coefficient was directly affected by the increase in Reynolds number and volume concentration fraction of the nanofluid. In the current study, the usage of TiO_2-water nanofluid's as a cooler in a car engine radiator was studied. Based on the experimental results, TiO_2-water nanofluid offers better overall performance than base fluid. The overall heat transfer coefficient of TiO_2nanofluids in an automobile radiator was experimentally measured as a function of concentration and temperature. It was found that the presence of TiO_2 nanoparticle can significantly enhance the radiator's heat transfer rate in a manner dependent on nanoparticle quantity added to the base fluid. The heat transfer coefficient significantly improves for 0.2% nanoparticle concentration as compared to pure water. This is because TiO_2's greater thermal conductivity, aspect ratio, lower specific gravity, thermal resistance, and larger specific area as compared to pure water.Use of titanium dioxide as a nanofluid for air purification as well as for air cooling was studied, As there is an increase in air pollution, it has become mandatory to bring it under control. By the use of titanium dioxide as a nanofluid and UV rays help in the photocatalytic effect, the pollutant in the air can be reduced significantly. By altering the concentration of titanium dioxide in water heat transfer rates can be controlled. This experiment will use outside polluted air as input and by the photocatalytic effect these pollutants can be subtracted and pure oxygen-rich air is cooled due to heat transfer properties of the nanofluid. Hence achieved purified and cooled air[6].

IV. CONCLUSION

Use of titanium dioxide as a nanofluid for air purification as well as for air cooling was studied, As there is an increase in air pollution, it has become mandatory to bring it under control. By the application of titanium dioxide as a nanofluid and UV rays helping in the photocatalytic effect, the pollutant in the air can be reduced significantly. By altering the concentration of titanium dioxide in water heat transfer rates can be controlled. This experiment will use outside polluted air by the photocatalytic effect these pollutants can be subtracted and pure oxygen-rich air is cooled due to heat transfer properties of the nanofluid. Hence purified and cool air is achievable.

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