

Implementation of Micro Nanobubble Technology for Condensation Heat Transfer

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

by

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**DEPARTMENT OF MECHANICAL ENGINEERING
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SATHYABAMA

**INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)**

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of BALAJE S M (Reg.No.39150015), JAYASEELAN (Reg. No.39150052), who have done the Project entitled **"Implementation of Micro Nanobubble Technology for Condensation Heat Transfer"** Under our supervision from JULY 2022 to APRIL 2023.

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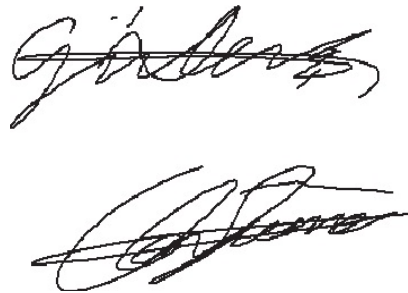
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We BALAJE S M (Reg.No.39150015),JAYASEELAN (Reg. No.39150052), hereby declare that the Project Report entitled“ **Implementation of Micro Nanobubble Technology for Condensation Heat Transfer** done by me under the guidance of **Dr. G.SENTHIL KUMAR, ME.,PhD.** ,is submitted in partial fulfillment of the equirements for the award of bachelor of Engineering in Mechanical Engineering.



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Abstract

This review paper deals with the implementation and investigation of micro-nano bubble technology for condensation heat transfer. Micro-nano bubbles dispersions in aqueous solutions can stay for a substantial time. As an example, 20micron size micro-nano bubbles take daily to rise one meter. Because the inertial force of fluid currents exceeds the buoyant force, any currents within a large vessel would be anticipated to entrain of that kind of micro-nano bubble dispersion. Micro-nano bubbles will vaporize hotter water towards the center of the plume and convert that extra heat of transition to the cold wall, where it will condense the vapors and release latent heat if the condenser is arranged in the micro-nano bubble-assisted airlift configuration.

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CHAPTER 1

INTRODUCTION

Fluids that are synthesized by suspending particles of nano-meter size are nanofluids.

In the most significant sectors, including microelectronics, manufacturing, metrology, etc., fluids have been used to cool components. The common heat transmission fluids, such as water, motor oil, ethylene glycol, etc., exhibit relatively low conductivity performance due to rising thermal loads that need advancements in cooling the new, higher power output devices with quicker speeds and smaller features.

The application of nanobubbles in chemistry, biology, materials science, medicine, and other sectors has been demonstrated by research in countries such as Japan, Brazil, Australia, and others. Over the past 100 years, solid particles, such as microparticles, have been suspended in fluids to increase their heat conductivity.

However, to obtain such an improvement, traditional liquid suspensions of micrometre-sized particles must have large concentrations ($>10\%$) of particles. Fluids containing micrometre-sized particles haven't proven very intriguing for practical applications since they have rheological and stability issues such as sedimentation, erosion, fouling, and pressure loss in flow channels. Nanometer-sized particles that potentially solve these issues can now be created thanks to recent developments in materials science. Because of their special ability to have a wide surface area, they can efficiently transport mass between the liquid and gas phases, which aids in the chemical reaction.

CHAPTER 2

LITERATURE SURVEY

Agarwal A, Ng WJ, Liu Y (2011a) Principle and applications of microbubble and nanobubble technology for water treatment. Nanobubbles(NBs) are very tiny bubbles with an approximate diameter of 10–50 μm and <200 nm.

Wu C, Nasset K, Masliyah J, Xu Z (2012) Generation and characterization of submicron size bubbles. *Adv Colloid Interface Sci*179:123–132 Nano-bubbles are formed when a homogeneous liquid phase undergoes a phase change due to a sudden pressure drop below a critical value known as cavitation. This cavitation is formed by ultrasonic waves in passage or changes in high pressure in running fluid.

C.H. Li, G.P. Peterson(2007) - Al_2O_3 and distilled water nanofluids' effective thermal conductivity was assessed using the steady-state approach. Tests were performed for volume fractions ranging from 0.5% to 6.0% at temperatures between 27 and 37 $^{\circ}\text{C}$. The impact of particle size variations on the Al_2O_3 –distilled water nanofluids' effective thermal conductivity was the most important discovery. At a temperature of about 32 $^{\circ}\text{C}$ and a volume percentage of between 2% and 4%, the highest enhancement difference was seen. The enhancement factor for this range of volume fractions for the evaluated temperature range peaked in the experimental data, suggesting that there is an ideal size for various nanoparticle and base fluid combinations.

Fedele, L., Colla, L., & Bobbo, S. (2012) - Water-based nanofluids include titanium oxide (TiO₂) at mass concentrations ranging from 1 to 35%. Their characterization is discussed. First, the stability of the nanofluid is evaluated using measurements of the zeta potential, and the mean nanoparticle sizes are investigated using the dynamic light scattering (DLS) method. The behaviour of viscosity as a function of composition and temperature is then evaluated using a rheometer in the 283 K to 343 K temperature range. In order to understand how temperature and nanoparticle concentration may effect its potential improvement, the thermal conductivity of these nanofluids is also investigated.

Kaufui VW, Omar DL (2010) - This study focuses on showing the wide range of current and future applications using nanofluids, highlighting their enhanced controlled heat transfer properties and the distinct properties that these nanofluids possess that make them suited for such applications. Nanofluids are fluid suspensions of nanoparticles that exhibit notable property enhancements even at low nanoparticle concentrations. It has also been stated that nanofluid acts as a smart fluid with variable heat transmission.

M. Chandrasekar, S. Suresh, A. Chandra Bose(2010) - An Al₂O₃/H₂O nanofluid's thermal conductivity and viscosity are investigated in this study. The distilled water was used to make the nanofluid, and the Al₂O₃ nanoparticles were produced using the microwave-aided chemical precipitation procedure. Al₂O₃/water nanofluids with varying volume contents (0.3–5%) and nominal diameters of 43 nm were used for the study. Testing of nanofluids' viscosity and thermal conductivity reveals that the viscosity increase is noticeably greater than the thermal conductivity increase. Nanofluids become more viscous and thermally conductive as the volume concentration of nanoparticles rises.

Mutuku, W.N. (2016) - This study looks into the cooling properties of a nanofluid made of ethylene glycol (EG) and three different kinds of nanoparticles: copper oxide (CuO), aluminium oxide (Al₂O₃), and titanium dioxide (TiO₂). Due to their improved thermophysical characteristics, nanofluids can be employed in a wide range of mechanical and engineering applications, such as cooling electronics, vehicles, transformers, computers, and electrical equipment. To demonstrate the impacts of the relevant factors on the velocity, temperature, skin friction coefficient, and local Nusselt number, a parametric investigation of the complete flow regime is conducted.

S.K. Das, N. Putra, P. Thiesen, W. RoetzelS.K. Das, N. Putra, P. Thiesen, W. Roetzel (2003) - Nanofluids are regular heat transfer fluids with suspended incredibly small particles of nanoscale size, representing a new level in heat transfer processes. Nanofluids can enhance heat transmission, which is vital for contemporary technology, according to recent studies. The current investigation looks closely at the thermal conductivity of nanofluids made of water as the base fluid and Al₂O₃ or CuO particles as the suspension component. Thermal conductivity is calculated from thermal diffusivity using a temperature oscillation technique. The results demonstrate that enhancing properties increase with temperature, which greatly increases the attraction of nanofluids for high energy density applications compared to previously published normal room temperature data.

Pourfarhang, S, ZeinaliHeris, S, Shokrgozar, M, Kahani, M.," (2015) - We looked at the function of nanofluid in a specific car radiator and how varied volume concentrations affected pressure drop and fluid flow friction. CuO nanoparticles were evenly disseminated to create stable nanofluids using ethylene glycol (EG) and distilled water in a 60/40 ratio as the host fluid. At three distinct inlet fluid temperatures (35, 44, and 54 °C), the radiator's effect of nanofluid concentrations on

pressure drop was assessed. The findings showed that the presence of nanoparticles increased the pressure drop in nanofluid, which was exacerbated by increasing nanoparticle concentration as well as lowering fluid inlet temperature.

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S.U.S. Choi (1995) - They contend that a whole new class of heat transfer fluids might be produced by floating metallic nanoparticles in conventional heat transfer fluids. Since they are anticipated to have higher thermal conductivities than the heat transfer fluids now in use, the resulting nanofluids offer the greatest potential to enhance heat transmission. The results of a theoretical study on copper nanophase materials' thermal conductivity in nanofluids are provided, along with an assessment of the fluids' potential benefits. One of these benefits—which has been demonstrated—will be a considerable reduction in the power required to pump heat exchangers.

Timofeeva, E.V., Yu, W., France, D.M., Singh, D., Routbort, J.L. (2011) - It is explained how the viscosity, thermal conductivity, and cooling efficiency of nanofluids are affected at the nanoscale. Because of the extraordinarily high surface-to-volume ratio in nanofluids, a nanoparticle suspension is thought of as a three-phase system consisting of the solid phase (nanoparticles), the liquid phase (fluid medium), and the interfacial phase. A thorough analysis of numerous parameters in the multivariable nanofluid systems was produced because of using the systems engineering method to nanofluid design. Engineering nanofluids with the appropriate set of attributes is made possible by the relative significance of nanofluid parameters for heat transfer examined in this article.

Zhu, D., Li, X., Wang, N., Wang, X., Gao, J., Li, H., (2009) - In this study, Al_2O_3 - H_2O nanofluids were synthesized, and their dispersion behaviours and thermal conductivity in water were investigated under different pH values and different (SDBS) concentrations. The zeta potential and particle size of the particles were measured and the (DLVO) theory was used to calculate attractive and repulsive potentials. The thermal conductivity was measured by a hot disk thermal constants analyser. The results showed that the stability and thermal conductivity enhancements of Al_2O_3 - H_2O nanofluids are highly dependent on pH values and different SDBS dispersant concentrations of nano-suspensions. The Al_2O_3 - H_2O nanofluids with an ounce of Al_2O_3 have noticeably higher thermal conductivity than the base fluid without nanoparticles, for Al_2O_3 nanoparticles at a weight fraction of (0.15wt%), thermal conductivity was enhanced by up to 10.1

Kaufui VW, Omar DL (2010) - This study focuses on showing the wide range of current and future applications using nanofluids, highlighting their enhanced controlled heat transfer properties and the distinct properties that these nanofluids possess that make them suited for such applications. Nanofluids are fluid suspensions of nanoparticles that exhibit notable property enhancements even at low nanoparticle concentrations. It has also been stated that nanofluid acts as a smart fluid with variable heat transmission.

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CHAPTER 3

AIM AND SCOPE

3.1 Aim

The aim of the present investigation is to study the properties and behaviour of the nanofluids in this we can able to investigate their thermal properties, density, and viscosity these investigations can be used in the field of science. The nanofluids are prepared with different nanoparticles and mixtures of base fluids along with surfactant to form stable nanofluids these fluids can be tested and used for cooling applications.

3.2 Scope

Future applications for this research include the use of nanofluid coolants in heat-exchangers, generators, electronics, vehicle cooling, computer cooling, and cooling in the chip manufacturing industry. A recent study shows that micro-nano bubbled mixtures exhibits higher thermal conductivity, and by combining a variety of base fluids, surfactants, nanoparticles, and mixtures, we can create a better coolant for a variety of industries.

CHAPTER 4

EXPERIMENTAL OR MATERIALS AND METHODS

4.1 Generation of Nano-Bubble

4.1.1 Dispersed air method

In the most significant sectors, including microelectronics, manufacturing, metrology, etc., fluids have been used to cool components. The common heat transmission fluids, such as water, motor oil, ethylene glycol, etc., exhibit relatively low transmission performance due to rising thermal loads that need advancements in cooling the new, higher power output devices with quicker speeds and smaller features.

By rapidly rotating the impeller, the mechanical approach reduces the gas to the micro nano degree. The two types of the jet technique are self-priming and air compressor injection types. In the former, air is injected into the suction chamber using a compressor, and gasoline and liquid are combined before being blasted fast to create micro-nano bubbles in the turbulence between the fuel and liquid. In order to create a negative pressure environment inside the suction chamber and let air into the chamber, the self-priming type primarily uses a high-speed jet.



Figure 4.1 Micro Bubble generator

4.1.2 Dissolved gas release

Increasing and reducing pressure is the basic mechanism for releasing dissolved gases. The gas is first dissolved in the liquid by providing a particular pressure, and then, when that pressure is reduced, the gas is expelled in microscopic form. This technology-based moulded foam has reached the application stage.

4.1.3 Electrolysis

By electrifying the water, the electrolysis method specifically produces microbubbles on each electrode. However, this approach has drawbacks, such as high energy use, electrode consumption during electrolysis, and a lack of electrolysis-generated bubbles. Conventional techniques include the ultrasonic method, high temperature method, chemical method, etc., comparable to the first three methods mentioned.

4.2 Imaging

4.2.1 Atomic force Microscope

An AFM scans a specimen surface using a cantilever and a pointed probe. At one end of the cantilever beam, there is a piezoelectric displacement actuator that is controlled by AFM. The opposing end of the cantilevered houses the probe tip that contacts the surface. When the probe is in close contact to the surface, surface interactions cause the probe to feel an attractive or repulsive force, which places a bending moment on the cantilever. The cantilever deflects in reaction to this moment, and the deflection is measured by a laser beam that is reflected from a mirror on the cantilever's reverse side onto a split photodiode.

The differential output (difference in responses of the top and lower parts) of the split photodiode is used to measure the cantilever deflection. In comparison to the thickness and length of the cantilever, the deflections are incredibly modest. As a result, the deflection and probe displacement are directly connected.

In contact mode, a repulsive reaction occurs when the tip physically touches the surface. The other extreme, known as the non-contact mode, is when the tip makes long-distance surface force interactions with the surface.

While oscillating probe is taken closer, the contacts between the probe and the surface transition from long-range tugging to mild repulsion. As a result, the amplitude (& phase) of the cantilevered oscillation changes. The point intermittently hits the surface of a typical induced 100 nm frequency oscillation and momentarily extends into the repulsion zone close to the surface. Intermittent contact mode is utilized to measure nanoparticle size because it can photograph soft surfaces or particles that are only marginally adhering to a surface.

4.2.2 Transmission Electron Microscopy: Standard Operating Mode

TEM, also known as amplitude imaging or diffraction contrast imaging, uses a small percentage of the electrons that pass through the material to create the final, highly magnified image. A tiny objective aperture is set at the rear focal plane of the objective

lens, preventing the majority of scattered (or diffracted) electrons from entering the picture. When an incident electron beam meets the advanced diffraction requirement, electron diffraction patterns (EDP) are utilised for crystalline materials. Under such diffraction contrast circumstances, many typical structural flaws have a highly distinctive look. If the EDP is initially calibrated with known materials, it is also possible to calculate the distances and angles between crystal lattice planes. Furthermore, the availability of crystalline substrates or supports might offer a useful way to conveniently orient the sample during observation. The thickness homogeneity of the different layers may be easily verified, and they are each plainly apparent. Finally, it should be mentioned that electron microscopists may face significant difficulties while preparing such complicated samples for TEM inspection. Due to significant variations in thinning rates, it is frequently challenging to produce samples that are concurrently electron transparent throughout the full area of interest. There are several places where the standard procedure created to get ready electron transmissive samples is described.

4.2.3 Dynamic Light Scattering

Dynamic light scattering deals with intensity variations over time brought on by the movement of macromolecules and macromolecular complexes. Due to the necessity for spatial and time ("temporal") coherence, light must be released from the source as a continuous wave rather than in brief bursts. Lasers are better suited for static light scattering due to their high intensity, collimation, and monochromaticity. The ionic strength of aqueous solvents should be high enough to suppress charge results. The necessary loading concentrations will mostly depend on the size of the scattered light and the output from the laser, which must be measured after clarification, similar to static light scattering.

It is often used to study nanoparticles. Calculating the dimensions of proteins, nanogold, latex, and colloidal are a few examples. The method is often used in standards for microspheres and can be utilized to quantify particles smaller than a nanometer. Additionally, dynamic light scattering may be used to study complex fluids like concentrated mixtures.

It is commonly used to analyze nanoparticles. Examples include determining nanogold size, protein size, latex size, and colloid size. In general, the technique is best used for submicron particles and can be used to measure particle with sizes less than a nanometer. In this size regime (microns to nanometers) and for the purposes of size measurement (but not thermodynamics) the distinction between a molecule (such as a protein or macromolecule) and a particle (such as nanogold) and even a second liquid phase (such as in an emulsion) becomes blurred. Dynamic light scattering can also be used as a probe of complex fluids such as concentrated solutions.

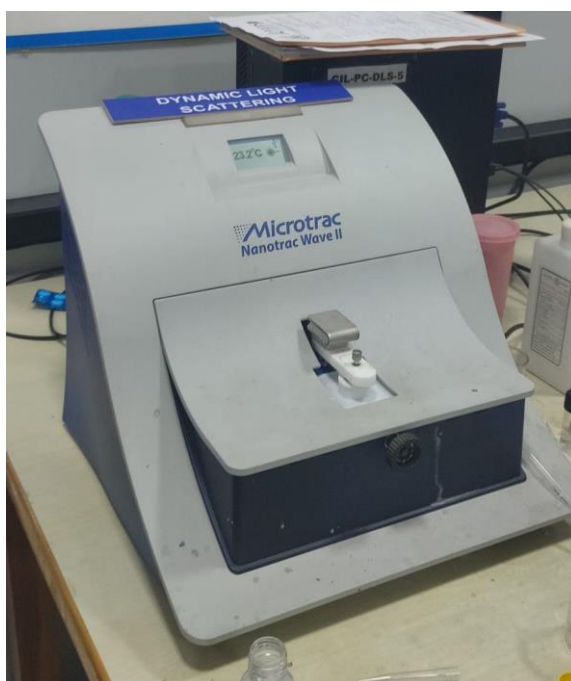


Figure 4.2 Dynamic light scattering

4.3 Materials used

4.3.1 Titanium Oxide

Titania has been used for a variety of thermal applications, including solar thermal energy production, heat storage, heat transfer, photoprotection, heat relief, and more. Bulk titania, titania nanoparticles, titania-based nanofluids, and titania nanoparticle enhanced phase change heat storage materials have all been used to use titania in the thermal

applications. Additionally, titanium has been mixed with other nanoparticles to create hybrid nanofluids with controllable thermal and optical properties.

Increased TiO₂ content improved the thermal conductivity. The rationale is that a typical solid-liquid combination has a higher thermal conductivity because solid particles have a greater thermal conductivity. As the concentration of nanoparticles rises, more solid particles must have been present, which will result in more Brownian motion and higher thermal conductivity. As nanoparticle concentration rises, the likelihood of particle collision increases, resulting in a quicker rate of energy transfer. The clumping of nanoparticles in the base fluids may potentially be connected to this situation. As heat transfer happens at the particle-liquid interface where heat transfer occurs in solid-fluid suspension, an increase in the interfacial area may result in more efficient heat transfer. The thermal conductivity will be significantly increased as a result of this clustering.

4.3.2 Copper Oxide

Due to their high thermal conductivity compared to metallic oxides, copper oxides have also been examined. In order to create cupric oxide nanofluids, copper (II) acetylacetonate, the precursor, underwent thermal decomposition at a temperature of 705°C, yielding a combination of copper oxide and copper nanoparticles. Since that time, several techniques have been employed to create copper oxide nanoparticles and create nanofluids utilising them.

Sol-gel, wet chemical reduction, sonochemical reduction, thermal breakdown of copper oxalate, plasma decomposition of cupric hydroxide, microwave irradiation, and other pyrolysis processes are some of the techniques used to create CuO nanoparticles. Here, we describe the chemical reduction processing of copper acetate using NaOH to produce needle-shaped CuO particles. It is also stated how response time affects morphology. Any thermal management program that uses convective heat transfer must be able to anticipate the flow and transfer of heat using data on viscosity and thermal conductivity.

4.3.3 Magnesium Oxide

In comparison to ethylene glycol-based nanofluids comprising oxide nanoparticles and low viscosity, MgO nanofluids exhibit greater thermal conductivity. These characteristics make MgO-EG nanofluids particularly intriguing in terms of potential applications.

Magnesium oxide nanoparticles are often found to range in size from 5 to 100 nm and to have a specific surface area of 25 to 50 m²/g. Despite having a very tiny size, these metal oxide nanoparticles have melting and boiling points that are much higher than those of their bulk material, namely 2852°C and 3600°C, respectively. Due to its new features crystal structure, easy stoichiometry, strong ionic character, and structural flaws on the surface, magnesium oxide nanoparticles are in high demand.

It is well known that magnesium oxide has a halite or cubic structure, empirically denoted by the formula MgO, and a lattice arrangement of Mg²⁺ and O²⁻ ions, which interact by ionic bonding. Magnesium oxide nanoparticles were discovered to be very marginally soluble in water with a percentage of 0.0086 g/100 ml at a temperature of 20 °C, which is one of the most significant physical features of these metal oxide nanoparticles. These nanoparticles and the products made from them ought to possess qualities including hardness, dust resistance, high-strength fire resistance, abrasion resistance, and thermal insulation.

CHAPTER 5

RESULTS AND DISCUSSION

So far , we have sent out prepared samples of nano particle and nano bubbled water mixture for various tests, which are as follows:

1. Atomic forced microscopy (AFM) – To determine the sizes of particles and micro and nano bubbles in the sample prepared
2. Dynamic Light Scattering (DLS) – To find the size ranges and distribution of micro-nano bubbles in the samples prepared
3. Thermal conductivity- To determine the thermal conductivity of the mixtures at various temperature conditions
4. Viscosity – To determine the viscosity to ensure the industrial transmission applications
5. Density – To determined the density of the samples prepared

The results of Dynamic light scattering for the micro bubbled water are below

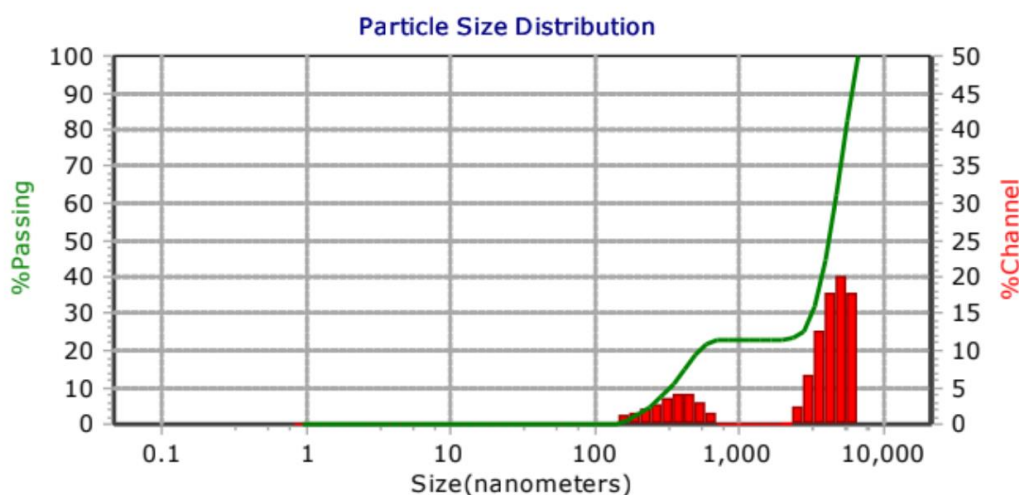


Figure 5.1 Graphical representation of Particle size distribution of the sample prepared

CHAPTER 6

CONCLUSION

Conclusion

Comparison research was carried out employing suspensions of magnesium oxide, copper oxide and aluminum oxide in nano bubbled water. Dispersed air method is used to prepare micro nano bubbled water. Such prepared water is used as base fluid to prepare the nanoparticle suspension. Considering the other research papers, it's stated that the prepared suspension have thermal properties which can be used in various cooling applications, which might give many positive impacts in the processes.

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