

Influence of Nanobubble Technology to Enhance Nanoboiling Heat Transfer

Submitted in partial fulfillment of the requirements for the award of
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by

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INSTITUTE OF SCIENCE AND TECHNOLOGY
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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the Bonafide work of R MOHAMED ISMAIL (Reg.No.39150085), M KARPAGAVASAN (Reg. No.39150711), who have done the Project entitled **"Influence of Nanobubble Technology to Enhance Nanoboiling Heat Transfer"** Under our supervision from JULY 2022 to APRIL 2023.

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We R MOHAMED ISMAIL (Reg.No.39150085),M KARPAGAVASAN (Reg. No.39150711)hereby declare that the Project Report entitled“**Influence of Nanobubble Technology to Enhance Nanoboiling Heat Transfer**”.” done by me under the guidance of **Dr. G.SENTHIL KUMAR, ME.,PhD.**,issubmittedinpartialfulfilmentoftherequirementsforthe awardofbachelor ofEngineering inMechanical Engineering.



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ABSTRACT

The primary focus of this experiment is to investigate the behavior of (MWCNT) suspended in clean water during the boiling heat dispersions (transfer process). After using nano boiling to increase the convective heat transfer coefficients of nanoparticles in liquid nanofluids, tests on density, viscosity, and thermal conductivity will be conducted. (MWCNT) of 1g was measured and mixed with water as the nanoparticles to make Nanofluids. Based on the test results, it will be evident that adding (MWCNT) raises the boiling heat transfer coefficients of the base fluids.

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CHAPTER - 1

INTRODUCTION

Recently, there has been interest in modifying heat transfer fluids with nanoparticle additions to enhance their performance. One method for increasing the heat conductivity of mixtures and, consequently, their coefficient of heat transfer in various applications is to disperse or suspend nanoparticles with high heat conductivities in heat transfer fluids are called Nanofluids. The nanoparticle used in this experiment (MWCNT) has a high heat conductivity of $3,000\text{W}/(\text{m}, \text{K})$. Jakob observed how bubbles form and grow using a high-speed camera in 1931. In the early 1970s, the study of boiling heat transfer was further encouraged by the quick rise of industry around the world. The term "Nanofluid" refers to a new form of heat transfer fluid that has been developed and has enhanced thermal characteristics for heat transmission. the little amount of nanosubstance is suspended in base liquids like hydrogen, ethylene glycol, etc. to create Nanofluid.

In order to enhance conductive thermal transferring and other features, such as the frigid point of antifreeze, Hong and Marquis developed a technique to generate stable suspensions of Nanofluids loaded with carbon nanoparticles in traditional thermal transfer fluids.

The invention of the straight method by Choi and Eastman for improving heat conduction of heat transfer fluids like hydrogen, lubricants, and ethylene glycol by dispersing Nanosubstances to these liquids contain very few materials such as Cu, CuO, and Al_2O_3 . Heating the material to be dispersed in a vacuum and then passing a thin layer of liquid close to the heated material creates and disperses nanocrystalline substances in the liquid.

In a different experiment, Witharana looked at the boiling heat transmission capabilities of two different kinds of liquid Nano fluids that were filled with silicon dioxide and gold under barometric pressure in tubular containers. Pressure and boiling heat transfer were recorded in growth and reduction in gold and silicon dioxide Nanofluids, respectively. This contradictory result is not well understood.

In many industrial procedures and applications, including cooling devices, power generation, boilers, cooling of nuclear reactors, and high-power electronic components cooler, boiling heat transfer is employed.

A Nano fluidic composition that improves the transferring of thermal performance is recorded by Phelps & Momota. They also found nanometre-sized phase-changing materials in the thermal transfer fluid to improve heat transfer properties at high temperatures. Methods for preparing such heat transfer fluids based on nanometre-sized phase-changing materials have been reported in patents.

Studies confirm that the effects of Nanofluids while it is used as coolants in the engine have been investigated. Nanomaterial and defoamer mixtures of copper oxide (4.4wt%) and aluminum oxide (4.4wt%) were mixed individually with preprogrammed transmission fluid. Four-wheel drive (4WD) transmission technology used in real-time represented as the experiment's basis. Investigational outcomes show that in identical conditions, the defoaming lubricant has the highest calefaction distribution at the saber clutch & thus the execrable thermal transferring effect, the least temperature variation is seen with copper oxide oil at both top and decreased rates. It has been shown to have the best heating effect.

The forced convection facilitates heat transfer in Nanofluids found by Xuan and Li. However, much of this improvement uses nanoparticles. Few convection studies available have been done on oxides. Nanoparticles that moderately increase conductivity while increasing viscosity.

Wang et al. applied three methods to find the viscosity of Nanofluids and no non-Newtonian effects were observed. They found that the Al_2O_3 -water Nano fluid had a 30% higher viscosity compared to pure water with a particle volume concentration of 3%.

Numerous systems and devices may utilize nanofluids. B. Transportation, Electronics cooling, building heating, industrial cooling, pollution reduction, medical systems, nuclear engineering, nuclear system cooling, defense and space, solar absorption, energy storage, magnetic seals, friction reduction, antimicrobial effects, Delivery of Nano drugs, microbial fuel cells, enhancement of microreactors, etc.

Compilation and review of different viscosity properties of Nanofluids by Mahbubul et al. Their experimental findings on the viscosity of Nanofluids confirmed findings from prior research, showing that viscosity rises with rising volume fraction and drops with rising temperature.

CHAPTER – 2

LITERATURE SURVEY

Ali, A. R. I., & Salam, B. (2020, September 5) - This paper points out the previous studies and recent progress in the improvement of heat transfer using Nano fluid. The recent progresses on preparation and enhancement of stability were reviewed. Thermophysical, heat transfer characteristics of Nano fluid and different factors such as particle size, shape, surfactant, temperature, etc. on thermal conductivity were presented. The present study reveals potential applications by utilizing Nano fluid such as heat exchanger, transportation cooling, refrigeration, electronic equipment cooling, transformer oil, industrial cooling, nuclear system, machining operation, solar energy and desalination, defense, etc. Few barriers and challenges were also addressed. Finally, the challenges and further research opportunities were presented.

Ahmad, S. N., Hakeem, S., Alvi, R. A., Farooq, K., Farooq, N., Yasmin, F., & Saeed, S. (2013, June 10) - These MWCNTs were dispersed in epoxy resin (E-51) and their effect on mechanical strength of epoxy nanocomposites was studied. Increase in the mechanical strength of epoxy was observed with the addition of CNTs. The surface characterization was done by using optical microscope and scanning electron microscope (SEM). Mechanical properties were determined by the general tensile strength testing method.

Choi SUS, Eastman JA (2001) - Enhanced heat transfer using Nano fluids this invention is directed to a method of and apparatus for enhancing heat transfer in fluids Such as deionized water. Ethylene glycol, or oil by dispersing nanocrystal line particles of Substances Such as copper, copper oxide, aluminium oxide, or the like in the fluids. Nano crystalline particles are produced and dispersed in the fluid by heating the Substance to be dispersed in a vacuum while passing a thin film of the fluid near the heated Substance. The fluid is cooled to control its vapor pressure

E.N. Ganesh, March (2013) - This paper discusses about all the methods listed above and detail comparisons are listed. We have simulated the single layer and multi-layer Carbon nano tube using nano explorer tool and enumerated its properties for various applications like power storage and medical applications. The simulated properties of CNT would be used for energy storage purpose as well for transmission of electrical energy. Though it is known that CNT's have high aspect ratio, Young's modulus over one terra pascal, Tensile strength of 200 Gigapascal, these properties never remain the same for all the CNT'S. It depends upon the method of preparation, catalyst used etc. So the properties of CNT are studied for specific conditions. Here it is proposed CNT can be modeled for particularly electrical storage purpose. Index Terms – Carbon nanotube, chemical vapour deposition, Plasma enhanced CVD, Multiwall nano tubes.

Falcaro, P., Ricco, R., Yazdi, A., Imaz, I., Furukawa, S., Maspoch, D., Ameloot, R., Evans, J.D., and Doonan, C.J.(2015) - This review summarizes the developed strategies for the fabrication of nanoparticle/MOF composites for catalyst use, including the strategy using MOFs as host materials to hold and stabilize the guest nanoparticles, the strategy with subsequent MOF growth/assembly around pre-synthesized nanoparticles and the strategy mixing the precursors of NPs and MOFs together, followed by self-assembly process or post-treatment or post-modification. The applications of nanoparticle/MOF composites for CO oxidation, CO₂ conversion, hydrogen production, organic transformations, and degradation of pollutants have been discussed.

Hong H, Marquis FDS (2007) - The process involves the step of dispersing carbon nanoparticles directly into a mixture of a thermal transfer fluid and other additives in the present of surfactants with intermittent ultrasonication. The present invention also relates to the composition of a hydrophilic nanofluid, which comprises carbon nanoparticles, particularly carbon nano tubes, a hydrophilic thermal transfer fluid, and at least one Surfactant. Addition of Surfactants significantly increases the stability of nanoparticle dispersion.

I.M. Mahbubul, R. Saidur, M.A. Amalina, 55 (2012) 874–885. In this paper, different characteristics of viscosity of nanofluids including nanofluid preparation methods, temperature, particle size and shape, and volume fraction effects are thoroughly compiled and reviewed. Furthermore, a precise review on theoretical models/correlations of conventional models related to nanofluid viscosity is presented. The existing experimental results about the nanofluids viscosity show clearly that viscosity augmented accordingly with an increase of volume concentration and decreased with the temperature rise. However, there are some contradictory results on the effects of temperature on viscosity. Moreover, it is shown that particle size has some noteworthy effects over viscosity of nanofluids.

Khan, P., Zhu, W., Huang, F., GAO, W., & Khan, N. A. (2020, June 9) - This paper reviews the important studies on water treatment in the areas of MNBs and discusses their fundamental properties, such as bubble stability (as tiny entities in water solutions), generation methods, and various chemical and physical features. The paper further overviews the current status of MNB application in water treatment processes such as flotation, aeration, and disinfection and its uses in various sectors, including agriculture, aquaculture, medical, and industry. Based on this review, studies regarding MNBs' basic properties, generation, and application are identified and recognized for future research. This study concludes that despite the promising role of MNBs in water-related application, the current status of research has not reached its true potential. Specifically, there is a need to enhance MNB application at a broader scale

Kim, P. Shi, L., Majumdar, A. and McEuen, P. L (2001) - The observed thermal conductivity is more than 3000 W/K m at room temperature, which is 2 orders of magnitude higher than the estimation from previous experiments that used macroscopic mat samples. The temperature dependence of the thermal conductivity of nanotubes exhibits a peak at 320 K due to the onset of umklapp phonon scattering. The measured thermoelectric power shows linear temperature dependence with a value of 80 μ V/K at room temperature.

Momoda LA, Phelps AC, (2002) - Introduction of nanometer sized phase change material into the heat transfer fluid leads to improved, high reversible thermal transport properties at elevated temperatures while ensuring low viscosity of the fluid at sub-freezing temperatures. A method for preparing of the heat transfer fluid with enhanced heat transfer performance, comprising making nanometer sized capsules having the phase change material contained therein and dispersing the capsules into the base heat transfer fluid.

Mitra S, Saha SK, Chakraborty S, Das S (2012) - Experimental results show that cooling rate is enhanced by using nanofluids when compared to water. A one-dimensional finite volume inverse heat transfer model is developed to predict the total heat flux removal rate from the hot steel surface. It is also observed in the present case that the shift from "film boiling" to "transition boiling" regime occurs earlier for nanofluid than that of water jet cooled surface. An order of magnitude analysis shows that the shift may be attributed to the vapor film instability in presence of nanoparticle deposition. However, only marginal variation of critical heat flux (CHF) is observed in case of nanofluid jet when compared to water jet.

Park KJ, Jung D, Shim SE. (2009) - In this study, pool boiling heat transfer coefficients (HTCs) and critical heat fluxes (CHF) are measured on a smooth square flat copper heater in a pool of pure water with and without carbon nanotubes (CNTs) dispersed at 60°C. Tested aqueous nanofluids are prepared using multi-walled CNTs whose volume concentrations are 0.0001%, 0.001%, 0.01%, and 0.05%. For the dispersion of CNTs, polyvinyl pyrrolidone polymer is used in distilled water. Pool boiling HTCs are taken from 10kW/m² to critical heat flux for all tested fluids. Test results show that the pool boiling HTCs of the aqueous solutions with CNTs are lower than those of pure water in the entire nucleate boiling regime. On the other hand, critical heat flux of the aqueous solution is enhanced greatly showing up to 200% increase at the CNT concentration of 0.001% as compared to that of pure water

Shouguang Yao * and Zecheng Teng (2015) - Base liquids with higher viscosity improve the boiling heat transfer performance of nanofluids. When the base liquid is a multicomponent solution, the relative movement between the different solutions enhances the microscopic movement of the nanoparticles due to the different evaporation order during the boiling process, so that the boiling heat transfer performance is enhanced. Compared with the thermal conductivity of the heated surface, the deposition of the low thermal conductivity nanoparticles reduces the heat dissipation rate of the heated surface and improves the wall superheat.

Shen J, Liburdy JA, Pence DV, Narayanan V 2009 This study investigates the hydrodynamic characteristics of droplet impingement on heated surfaces and compares the effect of surface temperature when using water and a nanofluid on a polished and nanostructured surface. Results are obtained for an impact Reynolds number and Weber number of approximately 1700 and 25, respectively. Three discs are used: polished silicon, nanostructured porous silicon and gold-coated polished silicon. Seven surface temperatures, including single-phase (non-boiling) and two-phase (boiling) conditions, are included. Droplet impact velocity, transient spreading diameter and dynamic contact angle are measured. Results of water and a water-based single-wall carbon-nanotube nanofluid impinging on a polished silicon surface are compared to determine the effects of nanoparticles on impinging dynamics.

Sahebian, S., Zebarjad, S. M., Vahdati Khaki, J., & Lazzeri, A. (June 29) - In the current research, the role of both concentrated nitric acid and ultrasound waves on oxidation of multi-walled carbon nanotubes (MWNTs) was studied. The functionalized MWCNTs were characterized by transmission electron microscopy (TEM), thermogravimetric analyzer, and Fourier transform infrared spectroscopy (FTIR) techniques. It was found that desirable modifications to MWNTs occurred after acid treatment. Carboxylic acid groups were appeared on the side surfaces of MWNTs. FTIR presented the formation of oxygen-containing groups such as C=O and COOH after modification by concentrated nitric acid.

Witharana S, Royal Institute of Technology, Stockholm, Sweden (2003) - The techniques of boiling enhancement have come under rigorous investigation since 1930's while the science of boiling reported in literature itself is bearing an even longer history, running for more than a century of years

Wang, X., Xu, X., and Choi, S. U. S., In this review, different microbubbles compositions and physiochemical properties are discussed in the context of current progress towards developing novel constructs for biomedical applications, with specific emphasis on molecular imaging and targeted drug/gene delivery.

Xuan, Y., and Li, Q., (2003) - Both the convective heat transfer coefficient and friction factor of the sample nanofluids for the turbulent flow are measured, respectively. The effects of such factors as the volume fraction of suspended nanoparticles and the Reynolds number on the heat transfer and flow features are discussed in detail. A new type of convective heat transfer correlation is proposed to correlate experimental data of heat transfer for nanofluids

Xie, H., Lee, H., Youn, W., and Choi, M., (2003) - Treated CNTs were successfully dispersed into polar liquids like distilled water, ethylene glycol without the need of surfactant and into nonpolar fluid like decene with oleylamine as surfactant. We measured the thermal conductivities of these nanotube suspensions using a transient hot wire apparatus. Nanotube suspensions, containing a small amount of CNTs, have substantially higher thermal conductivities than the base fluids, with the enhancement increasing with the volume fraction of CNTs. For the suspensions with the same loading, the enhanced thermal conductivity ratios are reduced with the increasing thermal conductivity of the base fluid. Comparison between the experimental data and the theoretical model indicates that the thermal conductivities of nanotube suspensions seem to be very dependent on the interfacial layer that exists between the nanotube and the liquid

Yang, Y., Zhang, Z. G., Grulke, E. A., Anderson, W. B., & Wu, G. (2005) - The nanoparticles used in this research were graphitic in nature, with aspect ratios significantly different from one ($l/d \approx 0.02$). The graphite nanoparticles increased the static thermal conductivities of the fluid significantly at low weight fraction loadings. However, the experimental heat transfer coefficients showed lower increases than predicted by either the conventional heat transfer correlations for homogeneous fluids, or the correlations developed from the particle suspensions with aspect ratios close to one. New correlations on heat transfer need to be developed for nanofluid systems.

CHAPTER – 3

AIM AND SCOPE

3.1 AIM

To test the influence of Nanobubble technology in Nano boiling. To generate air Nanobubbles in distilled water. To investigate the coefficient of Nanobubble through a Nanoparticle particle tracking analyser

3.2 SCOPE

Biofouling poses considerable technical challenges to agricultural irrigation systems. Controlling biofouling with strong chemical biocides is not only expensive and sometimes ineffective but also contributes to environmental pollution. This study investigated the application of Nanobubbles (NBs) in minimizing biofouling in agricultural irrigation water pipelines.

CHAPTER – 4

MATERIALS AND METHODOLOGY

4.1 GENERATION OF NANOBUBBLES

When water is heated, Nanobubbles frequently develop. Phase changes as a result of an abrupt pressure, cavitation occurs when values fall below a threshold level. Ultrasonic waves or variations in high pressure often cause cavitation in a flowing fluid (hydrodynamic cavitation). Nanobubbles are frequently created using the Venturi-type generator in the hydrodynamic cavitation process. There are three primary components of the Venturi system: input flow, tubular, and tapered output flow.

Gaseous cavitation and vaporous cavitation are two different cavitation types based on the presence of bubbles. Cavitation differs from boiling due to its production process, which is a phenomenon associated directly with pressure falling under a specific critical threshold. There are four types of cavitation methods such as optical, particle, acoustic, and hydrodynamic.

Scaling up, using, and controlling acoustic and hydrodynamic cavitation are simple when using geometrical circumstances and operational characteristics like velocity. One of the most affordable and energy-efficient ways to produce cavitation with basic equipment and minimal maintenance costs is through hydrodynamic cavitation.

When a heated horizontal steel surface is being cooled with a laminar jet, Mitra et al. analysed the boiling heat transfer using MWCNT (multi-walled carbon nanotubes) and water nanofluids. The findings demonstrated that employing Nano fluids improved cooling rates in comparison to water.

Pool boiling heat transfer coefficient (BHTC) measurements by Park et al. Carbon nanotube (CNT)/water nanofluids at critical heat flux on flat, smooth copper heaters. Polyvinylpyrrolidone polymer in water was utilized as a dispersant. The findings demonstrated that his BHTC over the nucleate boiling area was lower for Nanofluids than it was for pure water. Thus, the Nano bubble is generated using a Hydro dynamic cavitation device.

4.2 MULTI-WALLED CARBON NANOTUBES (MWCNT) AS NANOPARTICLE

Hollow nanometre-sized tubes made of graphitic carbon are known as carbon nanotubes (CNTs). Envision a flawless cylinder-shaped roll of graphene formed into a carbon nanotube [17]. A Russian group first created carbon nanotubes in 1952 and published the first transmission electronic microscope (TEM) picture of the tube-like carbon nanotube made from nanometric-sized carbon filaments.

Single-walled carbon nanotubes (SWCNT) and MWCNT are two different forms of carbon nanotubes. A single sheet of graphene may be thought of as a single-walled carbon nanotube, whereas several concentric SWCNTs with various diameters can be thought of as multiple multi-walled carbon nanotubes. The various methods to synthesize the CNT are chemical vapor deposition, arc-discharge, and laser ablation [17], the tremendous strength of multi-walled carbon nanotubes (MWNTs) the following physical, mechanical, and electrical characteristics that garnered many possible applications in industry thorough research.

The hydrodynamic properties of SWCNT Nano fluidic and water droplets impinging on a polished surface were the subject of another report that looked at the impact of surface temperature. Additionally, Shen et al. published on nanostructured surfaces. They discovered that the SWCNT Nano fluid has a greater diffusion width than water

and that nano fluidic or nanostructured surfaces may shorten overall evaporation time by up to 37%.

Large surface areas, high mobility, and low particle momentum are desirable characteristics that make nanoparticles suitable candidates for suspension in liquids. In terms of increasing conductivity, you can move from copper to MWCNTs, which are 20,000 times more conductive than motor oil at room temperature. By Asael et al., the thermal conductivity of multi-walled CNTs was measured. MWCNTs with an average length and diameter of around 40 μ m and 130nm respectively had a thermal conductivity of 34% at 0.6 percent volume, while double-walled CNTs had a thermal conductivity of 8% at 1% volume water suspension.

4.3 PROPERTIES OF MWCNT

4.3.1 Mechanical properties

Carbon nanotubes are made from graphene sheets, and a graphene layer's C-C bond is probably the strongest chemical bond ever seen in nature. The steel can endure 5GPa of stress, but CNTs can tolerate an exceptionally high 130GPa (gigapascals). SWCNTs and MWCNTs were examined for tensile strength, which was discovered to be 13-52GPa and 63GPa, respectively. A single layer of MWCNTs has tensile strength that is 100 times greater than that of steel. CNTs are pliable and can endure tension. Young's modulus can be used to calculate elasticity experimentally. Young's modulus for SWCNTs was 2.8-3.6TPa (Tera pascal) and 1.7-2.4TPa for MWCNTs, according to Lourie and Wagner (1998).

4.3.2 Thermal properties

Due to their geometrical structure carbon nanotubes are good at thermal conductivity. According to theory, CNTs have a thermal conductivity of 6600W/m K, which is higher than diamond (3320W/m K) or graphite (>2000W/m K). Over 3000 W/m K of thermal conductivity has been measured for bulk samples of individual MWCNTs.

The estimated thermal conductivity of MWCNTs with a common diameter of 15nm and a length of 30 μ m suspended in water, ethylene glycol, and decene by Xie et al. The ethylene glycol and water suspensions had practical groups that included oxygen but no surfactant. Oleylamine was used as a surfactant to help in the suspension of those in decene. It was shown that there was more improvement for the same extent percentage within the fluid with lower thermal conductivity. Decene was found to have the greatest increase in thermal conductivity, which was 20 percent for a CNT content of 1%. Additionally, it was shown to be increasing linearly with the extent percent.

4.4 APPLICATIONS OF CARBON NANOPARTICLES

4.4.1 Energy storage

Electrodes made of graphite, carbon fibre, and carbonaceous materials are often utilized in batteries, fuel cells, and other electrochemical applications. The smooth surface topology, ideal surface specificity, and compact size of nanotubes make them a viable option for energy storage.

4.4.2 Hydrogen storage

Hydrogen has an advantage over other energy sources in that water is produced during burning. According to a capillary effect theory, carbon nanotubes may carry gas or a liquid in their inner cores. 6.5% of the weight of hydrogen must be stored as a minimum for hydrogen fuel cells. According to reports, utilizing gas phase adsorption, multi-walled carbon nanotubes (MWNTs) were able to reach and occasionally even surpass this level.

CHAPTER – 5

RESULT AND DISCUSSION

5.1 RESULT AND DISCUSSION

The thermal conductivities of these nanofluids have been investigated. The experimental results show that the addition of nanotubes into a fluid lead to a substantial enhancement of thermal conductivity. The thermal conductivity enhancement increases with the increase in nanotube loading but is reduced with the thermal conductivity increase of the base fluid. Heat transfer fluid before and after the influence of Nano bubbles generation. As compared with the inlet temperature, the hot fluid outlet temperature with Nano bubbles generation was found to be higher this indicates the difference in the cold air as heat transfer fluid before and after the influence of Nano bubbles generation. As compared with the inlet temperature, the cold fluid outlet temperature with Nano bubbles generation was found to be higher.

CHAPTER – 6

CONCLUSION

6.1 CONCLUSION

The Nano bubble is generated by hydrodynamic cavitation. Boiling of the given nanoparticle is taken as a Sample and the following tests are done to observe the changes occurring around the Sample, tests like viscosity, density, zeta potential, dynamic light scattering, as well as thermal conductivity are done to record the properties of a taken sample.

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