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HEAT TRANSFER AUGMENTATION STUDY USING NANO FLUIDS AND SURFACE MODIFICATION

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ABSTRACT

Nano fluids are potential heat transfer fluids with enhanced thermo physical properties and heat transfer performance which can be applied in many devices for better performances (i.e. energy, heat transfer and other performances). In this paper, a comprehensive literature on the applications and effects of nano fluids on heat transfer have been compiled and reviewed. Study reveals that substitution of conventional coolants by nano fluids appears promising. Specific application of nano fluids in, solar water heating, boiling heat transfer cooling, cooling of heat trading gadgets, have been audited and introduced. On near study with the writing accessible, it has been discovered nano fluids have a much higher and firmly temperature-subordinate thermal conductivity at low molecule fixations than traditional liquids. This is considered as one of the key parameters for improved exhibitions for a significant number of the uses of nano fluids. Critical heat flux (CHF) is one such parameter that has required badly designed bargains in the middle of economy and safety in many commercial enterprises identified with thermal frameworks where space and size of heat exchanger is a major requirement. At the point when nano fluids were utilized as a part of boiling heat transfer cooling, strange increment of CHF was accounted for. Therefore, nano particles affidavit on the boiling surface was uncovered to add to CHF upgrade. Research on surface attributes established that three noteworthy qualities influence CHF: wet ability, liquid spread ability and multi-scale geometry. However, few barriers and challenges have been identified in this study and those must be addressed carefully before it can be fully implemented in the industrial applications. Some of the applications were critically analyzed and research gaps for further research have been identified.

Keyword: Nano fluids, Critical Heat Flux, Heat Transfer, Coolants, Surface Modifications.

I. INTRODUCTION

Heat exchangers are an essential part in an assortment of mechanical settings, for example, cooling frameworks, force plants, refineries, and in this way ceaseless endeavor are made to expand their heat transfer efficiencies. In late decades while there has been constant advance in enhancing the execution of heat exchangers by tending to their development and format issues, the poor heat transfer properties of the working liquids utilized as a part of the heat exchangers have still remained an essential execution constraining element for these frameworks. Bringing small solid particles into these cooling liquids appears to expand their abilities since solids have higher heat exchange coefficients than fluids. The advancement of littler particles, of nano-sizes, has beaten the negative hydrodynamic impacts of strong particles in the liquid. Suspension of nano-sized particles in a liquid have been seen to altogether improve heat exchange properties of the liquid while being skilled at neither obstructing nor settling in a heat exchanger application, basic issues connected with suspension of bigger particles. The thought behind improvement of Nanofluids is to utilize them as thermo liquids in heat exchangers for upgrade of heat transfer coefficient and along these lines to minimize the span of heat transfer supplies. Nanofluids help in monitoring heat energy and heat exchanger material. The critical parameters which impact the heat exchange attributes of Nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. The thermo physical properties of Nanofluids also depend on operating temperature of Nanofluids. Hence, the accurate measurement of temperature dependent properties of Nanofluids is essential. Thermo physical properties of Nanofluids are pre requisites for estimation of heat transfer coefficient and the Nusselt number.

Critical heat flux (CHF) has required badly arranged bargains in the middle of economy and security in many businesses identified with thermal frameworks. Late improvement of nanotechnology has empowered blend of nano-sized particles and advancement of new heat exchange liquids with suspended nano-sized particles, i.e., Nanofluids. At the point when Nanofluids were utilized as a part of boiling heat transfer cooling, a typical increment of CHF was accounted for. Along these lines, nanoparticles testimony on the boiling surface was uncovered to add to CHF improvement. Research on surface attributes established that three noteworthy qualities influence CHF: wettability, fluid Spread ability and multi-scale geometry. The misleadingly altered surface with varieties of octagonal miniaturized scale posts, or ZnO nanorods, or both, were organized and concentrated on their execution in improving CHF.

1.1 Objective and Motivation of work

The issue of cooling has turn into an inexorably discriminating issue in atomic industry and electrical chip cooling. One cooling strategy is boiling heat exchange, which abuses the dormant heat of vaporization amid the fluid to-gas stage change, and is the best approach to cool thermal frameworks running at high temperatures. Be that as it may, boiling heat exchange has an inborn impediment: CHF (critical heat flux). CHF is the greatest heat flux where boiling heat exchange maintains its high cooling effectiveness. At the point when a surface compasses CHF, it gets to be covered with a vapour film, which meddles with contact between the surface and the encompassing fluid, and declines heat exchange productivity. Framework temperature rises, and in the event that it surpasses the points of confinement of its constituent materials, framework disappointment happens. Consequently, every framework joins a security edge by running at heat flux much lower than CHF, yet this methodology decreases the framework's proficiency. This bargain in the middle of safety and effectiveness is a critical issue in industry. Consequently, to ensure an expansive safety edge while amplifying operation locale, there have been various ways to deal with comprehend the component of CHF furthermore to improve CHF point.

The work has been carried out in the chronological order given below:

Introduction and familiarization with the Nano fluids along with the history of its evaluation. Application scope of Nano Fluids in various heat transfer fields because of its favorable properties.

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Impact of various parameters in the heat transfer and their control methodology and variation resulting in the heat transfer augmentation. Study and comparison of the variation in parameters (Wettability, Liquid Spread ability and surface modification) and their impact on heat transfer. Thus deriving a general correlation for the dependency which will be available for ready difference.

1.2 Nanofluid Synthesis

Planning of Nanofluids is the first stride to the exploratory investigations of Nanofluids. The best possible use of the capability of Nanofluids relies on upon the planning of Nanofluids. There are two principle routines to set up a Nanofluids: The single-step planning procedure and the two-stage arrangement process.

The single-step readiness procedure demonstrates the blend of Nanofluids in one-stage. A few single-step systems have been touched base for Nanofluids readiness. Akoh et al. investigated and built up a solitary step direct dissipation technique. In this technique the vaporized metal is dense and after that scattered by deionizer water to deliver Nanofluids. Leverage of blend by one-stage strategy is that Nano-particles agglomeration is minimized. Be that as it may, prime issue is that just low vapour weight liquids are good with such a procedure. One-stage arrangement process (chemical procedure) of Nanofluids is given in the Figure.1

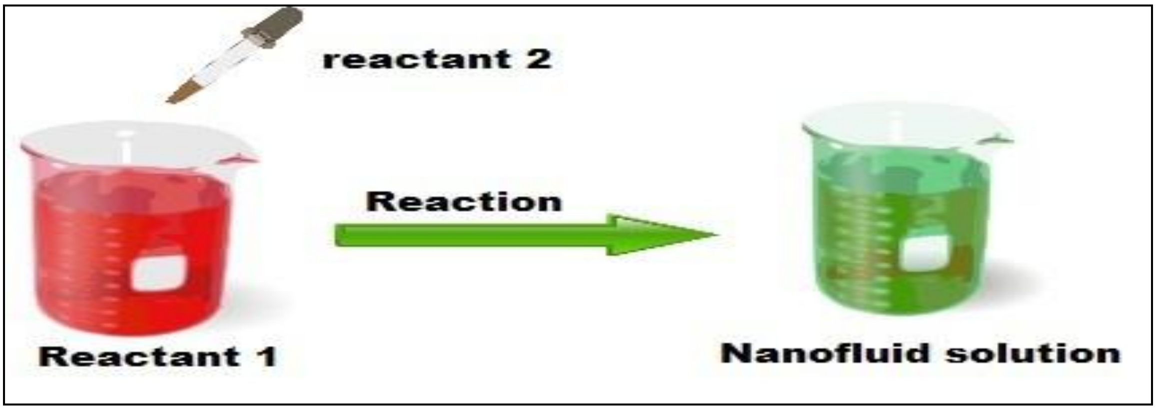

Figure-1- One-step preparation process of Nano-fluids

Two-stage arrangement procedure is broadly utilized as a part of the union of Nanofluids by blending base liquids with industrially accessible Nano powders got from diverse mechanical, physical and substance procedures, for example, processing, crushing, and vapour stage techniques. An ultrasonic vibrator or higher shear blending gadget is for the most part used to blend Nano Powders with host liquids. Incessant utilization of Ultra Sonication blending is obliged to lessen molecule agglomeration. A few writers proposed that two-stage procedure is exceptionally suitable for get ready Nanofluids containing oxide Nano-particles than those containing metallic Nano-particles. Steadiness is a major issue that intrinsically identified with this operation as the powders effectively combine because of solid van-der-wal forces among Nano-particles. Regardless of such weaknesses this procedure is still prominent as the most financial procedure for Nanofluids generation. The most widely recognized two -step strategy is indicated in Figure.2

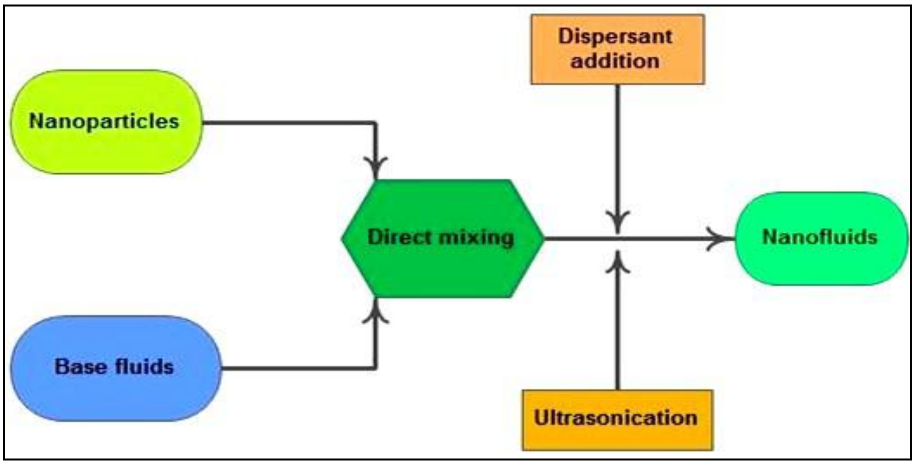

Figure-2- Two-step preparation process of Nano-fluids

II. HEAT TRANSFER AUGMENTATION: NANO FLUIDS APPLICATION

The efficiency and effectiveness of a cooling (Heat Transfer) systems is of great importance and focus in present scenario of technological advancements. One such cooling technique is boiling heat transfer; its standard includes the extraction of inactive heat of vaporization amid the fluid to-gas stage change, and is the best approach to cool thermal frameworks running at high temperatures. Notwithstanding, boiling heat transfer has an inalienable limit: **CHF (Critical heat flux).** CHF is the most extreme heat flux at which boiling heat transfer is managed at its highest cooling productivity. At the point when a surface methodologies its CHF, it gets on covered with a vapour film, which meddles the contact of the surface with the encompassing fluid, and consequently declines heat transfer effectiveness. Presently keeping in mind the end goal to accomplish higher heat transfer the framework temperature is expanded, and in the event that it surpasses the points of confinement of its constituent materials, framework disappointment happens. Consequently, every framework is compelled to fuse a safety edge by running at heat flux much lower than its CHF; however this constrained impulse influences the framework proficiency severely. This bargain in the middle of security and effectiveness is a vital issue in industry. Consequently, to guarantee a vast safety edge while working with developing operation locale, there is a vast scope get in deep for understanding the mechanism of CHF and exploring various ways to enhance CHF and thus the heat transfer rate.

2.1Approaches to CHF Enhancement

We have understood the role and importance of CHF in heat transfer efficiency in any thermal system. Literature is available suggesting various methods for CHF enhancement and most of them are either implemented or having some practical constraints while going for implementation. In this work the main focus is given to the methods of heat transfer enhancement by changing conditions of the heat exchange surface. The surface modification methods include either by oxidation, scratching, sanding, cleaning, machining and appending outside materials to the surface. The principle target is to accomplish an upgraded surface harshness to offer turbulence to the heat exchange liquid. Surface change has fundamentally two parameters to control surface qualities: surface science and geometry. Wettability is a term utilized as a part of the writing for the inclination of the liquid to come in contact and wet the surface to get the powerful heat transfer contact area.

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Generally contact edge was measured for assessing surface energy and transparently expressed as level of wettability, which is discovered corresponding to CHF. For controlling surface science, there are different systems including oxidation, carving, UV illumination are clarified in the written works demonstrating observable CHF upgrade with higher wettability. One more approach towards the same is by expanding surface roughness however the outcomes and conclusions are not generally in accordance with the support, so the value of expanding surface harshness to improve CHF is farfetched. In any case, it has been found that changing the harshness of the surface, influences surface attributes, similar to contact angle to some degree. Another way to deal with improve CHF is surface machining. Research on this methodology has yielded with conflicting results. A few reports indicated increment of CHF and some demonstrated no impact. In spite of the fact that numerous studies demonstrated that expanded thickness of nucleation locales may improve heat transfer improvement in the nucleate boiling area, yet it can't promise CHF upgrade. One other methodology is to connect remote materials to the surface. Sometimes, the remote materials are predominantly made out of wicking material which instigates fine inflow of the cooling fluid to the boiling region. In different cases, the remote material is a permeable layer made out of particles of various sizes and materials, which is expected to influence hydrodynamics or to instigate capillary inflow of fluid. As of late, some examination gatherings created fake structures which has multiple of these methodologies.

2.1.1CHF Enhancement with Nanofluids

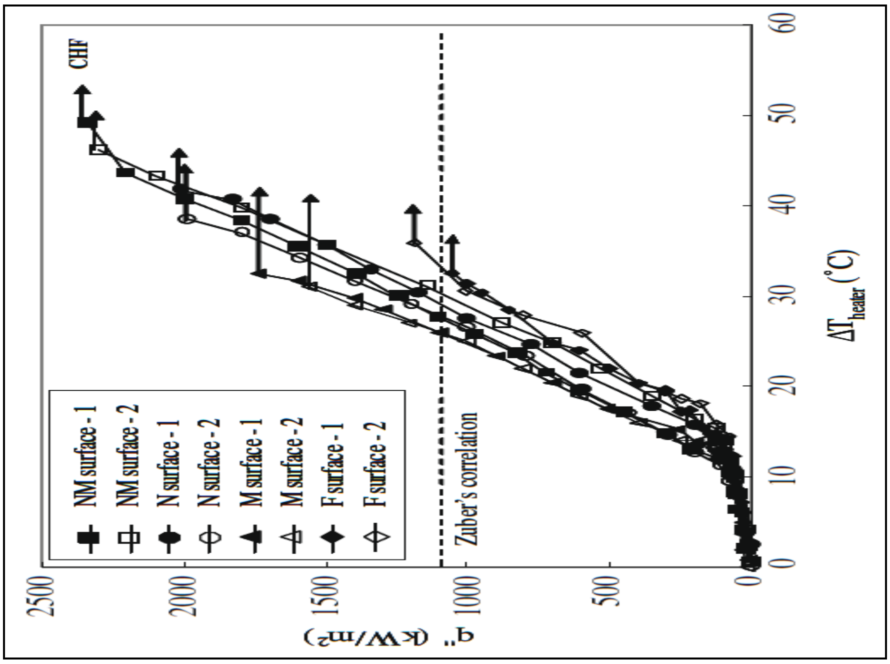
Nanotechnology has made it conceivable to deliver numerous sorts of nano-scaled particles known as Nano particles. Materials downscaled to nano-size are found to groups predominant properties (counting mechanical, optical, electrical, and warm) than what they were having at their traditional size. History of nano liquid is not very old; it is right around a late field investigated with tremendous extension in all the fields. In 1995, Choi presented the idea of Nanofluids: ". . . another class of nanotechnology-based heat transfer fluids built by scattering and steadily suspending nanoparticles with average length scales on the request of 10 nm in conventional heat exchange fluids". Numerous analysts in their work have used the extraordinary properties of Nanofluids. One investigation that is important in the heat transfer field is a typical CHF upgrade with Nanofluids. Numerous exploration papers have guaranteed that they have reported 2–3-fold upgrade in CHF when a little measure of alumina nanoparticles was suspended in water. Other resulting studies additionally reported comparable results with different nanoparticles. By delivering the same or higher CHF improvement with a nanoparticles-covered wire heater in unadulterated water contrasted with Nanofluids (Fig. 1), the specialists watched that CHF improvement is singularly subject to nanoparticles affidavit on the boiling surface. It is likewise recommended that the harshness, wettability and slender wicking add to postponing CHF phenomena and this proposition was later affirmed tentatively. One more essential parameter started to be narrow wicking. It was seen that quick and wide fluid spreading on nanoparticles-covered wire surfaces. In the wake of representing the narrow wicking impact, the remaining impacts which couldn't be clarified by wettability turned out to be clear. Therefore, it was inferred that wettability and fluid Spread ability (fine wicking) are both vital parameters that add to CHF increment in nanoparticles-covered surfaces. The impacts of roughness on CHF improvement were not demonstrating a dependable and certain pattern and subsequently not effectively decided. The surface has an extremely intricate and fractal geometry with miniaturized scale and nano scales in progressive surface geology (Fig. 2). Since it is realized that surface unpleasantness can control the level of wettability, the wettability (besides, fluid Spread ability) of nanoparticles-covered surfaces more likely than not been opened up by its unpredictable geometry. Thus, it can be said that the nanoparticles-covered surface is a sort of all around altered surface with enhanced discriminating surface attributes which may have real impacts on CHF upgrade.

2.1.2 CHF enhancement with surface modification

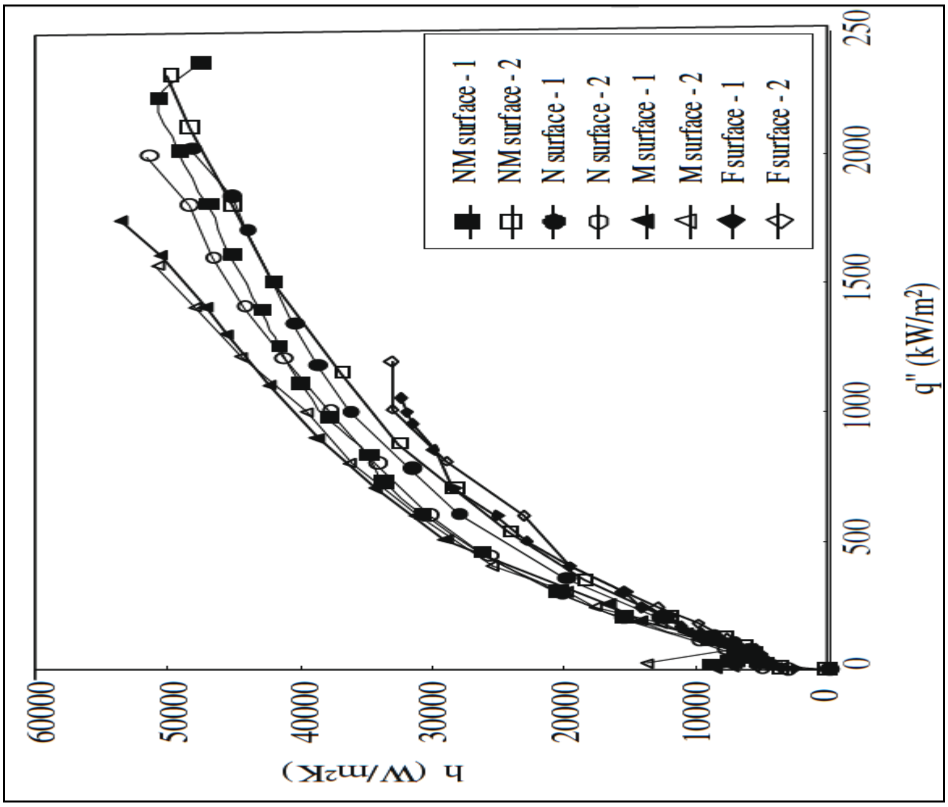
From the above study, it was watched that CHF improvement has two vital realities. The primary is that wettability and fluid Spread ability are basic surface parameters which may upgrade CHF. The second is that multiscaled surface structure increases the qualities of these surface parameters. Despite the fact that nanoparticles-covered surfaces demonstrate these helpful qualities furthermore nano-liquid pool boiling additionally can be utilized as another surface covering system, nano-liquid pool boiling procedures and nanoparticles-covered surfaces have natural points of confinement in useful uses and genuine applications, in light of the fact that they are hard to control and are subject to characteristic phenomena. In this way, the specialists chose to make counterfeit surfaces which have the qualities of wettability, fluid Spread ability, and multi-scaled geometry, to affirm their commitments to CHF and to focus the ideal states of these attributes. As a first test Seolte et. al manufactured four straightforward and essential simulated surfaces utilizing the microelectromechanical systems (MEMS) procedure and the outcomes got were thought about as far as their CHF exhibitions.

III. METHODOLOGY FOLLOWED FOR UNDERSTANDING THE IMPACT OF VARIOUS PARAMETERS ON CHF

There are two common graphs available, First one showing the variation of heat flux with heater temperature difference (q'' Vs $\Delta_{Theater}$) shown in graph 4.1



Graph.4.1 Boiling curves of the four test surfaces. (The origin points of arrows are the CHF points of each test sample.)



Graph 4.2 Graph showing the variation of Heat transfer coefficient (h) vs. heat flux (q'') for the four test surfaces.

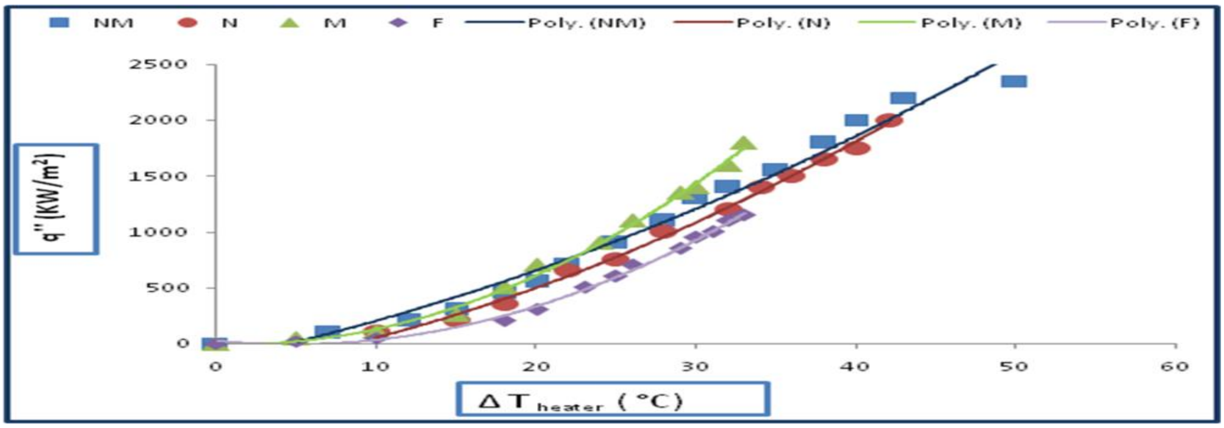
IV.RESULT AND CONCLUSIONS

The study carried out and summarized above is significant one in identifying the extent of contribution of various mysterious parameters in enhancing critical heat flux and thus pushing the limits of heat transfer to a higher values. Heat transfer enhancement directly or indirectly modifies the systems efficiency along with maintaining the high safety margins

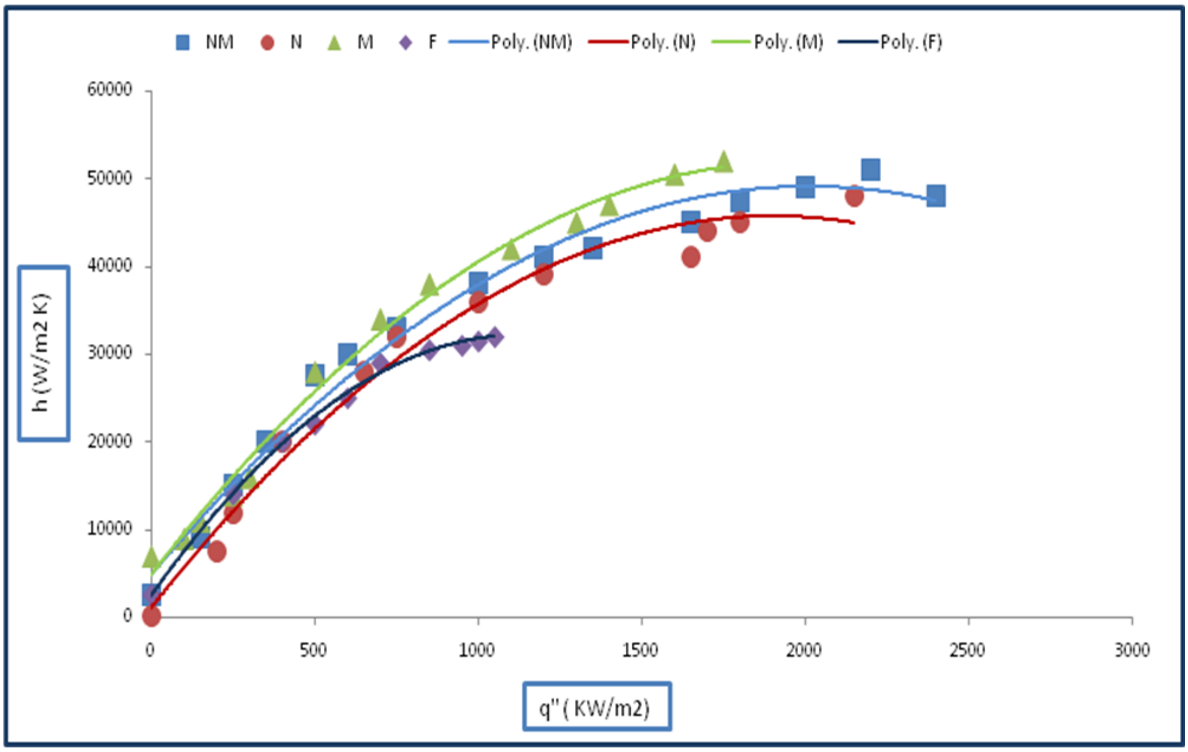
Some of the outcomes and general discussions are mentioned below for an overall brief of the work and its scope.

1. Boiling heat exchange is a promising heat scattering strategy for frameworks working under thermally basic conditions. Discriminating heat flux is a standout amongst the most noteworthy configuration criteria for boiling heat exchange and is likewise a vital calculates economy and security.
2. After improvement of nanotechnology, endeavours were made to apply it to thermal engineering.
3. The CHF improving execution of nano-liquid was uncovered to be an after-effect of nanoparticles testimony on bubbling surfaces. From there on, parts of wettability and fluid Spread ability were proposed as essential donors to this marvel.
4. Wettability and fluid spreading impact was demonstrated as CHF upgrade contrast between F surface and N, NM surface. Fluid spreading impact was demonstrated as CHF improvement contrast between N surface and NM surface. Furthermore, multi-scaled geometry impact was demonstrated as contrast between fluid spreading qualities of N and NM surface and by implication influenced CHF upgrade.

5. From this examination, we gauged the impacts of wettability, fluid Spread ability and geometry on CHF. Extra investigations furthermore, examination of surface attributes and different surface- adjustment routines are needed for ideal condition
6. Various studies have managed test and hypothetical ways to deal with improve CHF. These incorporate changing surface science and geometry.
7. Here utilized MEMS to create counterfeit surfaces and assess how their wettability, Spread ability and surface geometry influence CHF. The multi-scaled surface with higher wettability and Spread ability delivered more (107%) in CHF improvement than the different surfaces.
8. The correlations obtained for details behavioural study of each surface on CHF.



Graph 3. q'' Vs ΔT for F, M, N, NM Surface



Graph 4. h Vs q'' for F, M, N, NM surface

V. LIMITATIONS

The limitations or shortcoming in the work that are still to be overcome or information which cannot be obtained from this work is that the surface modification needs a very high level of accuracy and are tough to achieve that so the error due to this is considered as negligible. However the impact of surface roughness is still one mysterious parameter which to be explored further. Also the common correlation explaining the behavior of all the surfaces and their deviation with the actual value is not done in this work.

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