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Effect of Surface Geometry on Pool Boiling Heat Transfer of Water: A Study by ANSYS

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Abstract: This study explores the impact of the type of heating surface on heat transfer in pool boiling of water, especially the impact of geometric shape on heat transfer efficiency. Through a numerical simulation using CFD techniques in the ANSYS Fluent program. In this study, a two-dimensional model was built to simulate the pool boiling of water in several cases to compare the impact of the geometric shape of the heating surface. Where the first simulation was implemented using a smooth copper surface with constant heat flux $(30\,KW/m^2)$ and then the simulation was repeated several times, changing only the geometric shape of the heating surface without changing the material or dimensions. With the preservation of all parameters of the first simulation, including thermal flux and mesh settings, to maintain the accuracy of the results and obtain a correct comparison. Where the first simulation was amended by the geometrical shape of the heating surface by providing it with different geometric shapes (semicircular, square, trapezoidal), with the preservation of the groove area in the three cases. By comparing the results of different shapes and extracted from ANSYS (heat transfer coefficient, overall heat transfer performance, thermal resistance and Nusselt number), it shows that semicircular grooves increase heat transfer coefficient (HTC) by 42.1%, overall heat transfer performance by 42% and Nusselt number by 35%, and decrease the thermal resistance by 42.4% compared to smooth surface. The heating surface with square grooves increase heat transfer coefficient (HTC) by 66.24%, overall heat transfer performance by 65% and Nusselt number by 50.2%, and decrease the thermal resistance by 66.3% compared to a smooth surface. The heating surface with trapezoidal grooves increases heat transfer coefficient (HTC) by 96.92%, overall heat transfer performance by 95% and Nusselt number by 90.62%, and decrease the thermal resistance by 96.7% compared to a smooth surface.
Therefore, by comparing the results of each geometric shape of the heating surface in each case to the smooth surface, and then compare the results of these different shapes with each other, it was concluded that the best geometric shape of the grooves was a trapezoidal geometry. Which achieves the highest value of heat transfer coefficient (HTC), overall heat transfer performance and Nusselt number, and the lowest value of thermal resistance between the difference in geometric shapes of grooves.

Keywords: water boiling, Nusselt number, pool boiling, heat transfer coefficient, surface type, surface geometry.

1. Introduction

The achievement of the best thermal transmission rate in water pool boiling is essential when designing different thermal systems such as heat exchangers and other of high performance cooling systems [1].
One of the most important factors affecting the efficiency of heat transmission between the heated surface and water is the characteristics of the heating surface. Through which they can be improved and increase heat transfer without having to raise the heating surface temperature or increase the energy consumed, which in turn is considered one of the most important advantages of improving heat transfer through the properties of the heated surface, because it leads to increasing the efficiency of the thermal system without

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increasing costs resulting from energy consumption [2].
Also, by controlling the properties of the heated surface, the process of water pool boiling can be controlled. The most important factors that affect heat transfer are surface roughness [3], wettability [4], type of surface material [5] and the surface geometry through which the heating process takes place.
Geometric analyses of fluid dynamics [6] indicate that changing the geometry of the heating surface in water pool boiling effects on heat transfer, because it changes the contact area between the water and the heating surface.
One of the most important ways to increase the contact area with water is to modify the geometry of the heating surface through protrusion or grooves, which increases the contact area without increasing the size of the system (i.e., while maintaining the same dimensions), which is also considered one of the advantages of this method.
However, the effect of the geometry of these grooves on the effectiveness of heat transfer is not clear, especially when studying and analyzing the pool boiling of water using Computational Fluid Dynamics (CFD) techniques.
Accordingly, the importance of this study lies in highlighting the effect of different geometries of the grooves on the heating surface, effectiveness in transferring heat in pool boiling of water, and the importance of using CFD techniques [7] in obtaining results as close to reality as possible, which saves time and effort compared to implementing practical experiments.
Therefore, this study aims to reach the best geometry for the heating surface grooves, which achieves the highest heat transfer efficiency in pool boiling of water. This is done through two-dimensional simulation using ANSYS, for different geometries of heating surface grooves at the same constant heat flux. This enabled a clear comparison between the different geometries by comparing the average temperature of the heating surface, Nusselt number, thermal conductivity, thermal resistance and heat transfer coefficient (HTC).

2. Previous Studies

Many previous studies have taken the theme of water pool boiling; this topic has received attention due to its importance in several fields, especially in engineering applications such as heat exchangers, cooling systems and others.
The most prominent thing that previous studies in this field addressed is the effect of the characteristics of the heated surface on boiling performance. These studies showed that the surface properties, such as surface roughness, wettability and the geometric shape of the surface, directly affect the characteristics of water pool boiling. The basic purpose of these modifications to the heating surface is to increase the rate of heat transfer, in addition to controlling the bubble size by increasing the number of bubble nucleation sites.
Among these studies have shown the impact of the properties of the heating surface on boiling, especially with regard to heat transfer in pool boiling.
In 2017, Hsu. H. Y et al. conducted a simulation of the effect of the contact angle on the boiling curve, using a two-phase model (VOF). And they reached that:
Hydrophobic surfaces reach the layered boiling stage at a faster rate, but they lower the onset of nucleate boiling (ONB). As for hydrophilic surfaces led to the improvement of the boiling curve and increased CHF [8].
In 2018, Yim. K, Lee. J & Kim. K. J studied the modification of the boiling surface with a hydrophilic layer of TiO_2 and its effect on the nucleate boiling of water compared to a non-hydrophilic layer. They concluded that the presence of the hydrophilic layer increases the heat transfer rate by approximately 64% compared to the non-hydrophilic layer, as the number of nucleation sites and the rate of bubble separation increase [9].
In the same year, Mohammad. N et al studied the impact of the wettability only on the heat transfer rate in water pool boiling, by comparing different wettability properties of silicon super-polished surfaces. The study shows that the surface with higher wettability delayed surface drying and increased the critical heat flux (CHF) relative to surfaces with lower wettability [10].
In 2021Feng.Y et al studied two-dimensional boiling using the Lattice Boltzmann method, by adopting a circular heating surface. They concluded that raising the temperature of the heating surface leads to an

increase in bubble activity and an increase in the number of nucleation centers. And the hydrophobic surface lowers the CHF and leads to faster surface boiling [11].
Thangavelu. N et al conducted an experimental study of boiling performance by comparing CHF and HTC on copper surfaces coated with nano-layers of different roughness and wettability with a smooth copper surface. That was in 2022, and they found out that increasing roughness clearly leads to an increase in CHF and HTC [12].
And in 2024, Li. X et al studied the effect of surfaces with mixed wettability on boiling, that is, surfaces that combine hydrophilic and hydrophobic regions. They find that there are a larger number of hydrophilic areas in the surface, which leads to a reduction in the amount of heat required to reach boiling compared to the hydrophobic surface. It also showed higher values for HTC at the same heat flux [13].
In the same year, Du. J et al analyzed the impact of changing surface roughness and wettability. There by depositing Fe_3O_4 nanoparticles on the heating surface, and that on thermal performance during boiling. They concluded that increasing the roughness and wettability increased the CHF by 52.4% and HTC by 56.2% compared to a smooth surface [14].
Also in the same year, Ali. B. M conducted four experiments to study the effect of the surface nature on heat transfer during boiling by using four different surfaces with varying roughness values. Through these experiments, he concluded that increasing the roughness led to an increase in the CHF by up to 131% and HTC up to 211% compared to a smooth surface [15].
In 2025, Wang. Y et al simulated pool boiling on surfaces designed with micro open channels of different locations and sizes. They found that surfaces equipped with micro channels increase the rate of heat transfer compared to a smooth surface. This is done by increasing the contact area between the heated surface and the water. Moreover, increasing the width of these channels increases the rates of nucleation and bubble, but to a certain extent. Whereas increasing the width of these channels beyond this limit may lead to horizontal adhesion of bubbles [16].
Also in 2025, Li. M et al conducted an experimental study on the effect of mechanical surface modification (polishing, mechanical shear and laser drilling) on heat transfer for refrigerants such as R134a. They found that these mechanical treatments for surfaces can increase the wettability, and it alone increased HTC by 1.87 times and increased CHF by 4.55 times compared to the smooth copper surface.
It shows the above that, and despite the great interest in studying the water pool boiling and the influence one of the surface structures on the boiling process is that most of these studies are experimental, and it was adopted to assess the thermal performance of surfaces and boiling through Critical Heat Flux (CHF) and Heat Transfer Coefficient (HTC) [17].
This made the direct effect of the geometry of the heated surface on the heat transmission in a water pool boiling is not clearly defined. Hence, the importance of this study appears in conducting a two-dimensional simulation of water pool boiling. Which enables studying the effect of the geometric shape of the surface in isolation from other factors, to highlight the importance of this factor and its role in enhancing heat transmission in pool boiling of water and the possibility of investing in controlling the boiling process in thermal systems.

3. Theoretical foundations

ANSYS uses numerical methods simulate fluid flow and heat transfer in thermal systems by solving the energy equations, continuity equation, and momentum equation.
In the case of two-phase boiling, bubble formation and heat transfer between the heated surface and the fluids are tracked using a volumetric fluid (VOF)model.
The basic equations that govern this simulation [18]:

$$\frac{\partial \rho}{\partial t} + \nabla(\rho u) = 0 \tag{1}$$

$$\rho\left(\frac{\partial u}{\partial t} + u \cdot \nabla u\right) = -\nabla P + \mu \nabla^2 u + F \tag{2}$$

$$\rho C_P\left(\frac{\partial T}{\partial t} + u \cdot \nabla T\right) = k\nabla^2 T + Q \tag{3}$$

The first equation (1) represents the continuity equation, which expresses the conservation of the fluid mass within the system under study.

Equation two (2) represents the equation of momentum, which expresses the balance of compressive forces, frictional forces, and mass forces acting on the fluid.
The third equation (3) represents the energy equation, which expresses heat transfer and Temperature distribution within the system.
Heat transfer coefficient (HTC) is a physical quantity describing the amount of heat transferred by the surface to the liquid per unit area of the surface per unit temperature difference. The heat transfer coefficient (HTC) is calculated using the following equation [19]:

$$HTC = \frac{Q}{T_{avg} - T_{sat}} \tag{4}$$

The thermal resistance is calculated with the following equation:

$$R_{th} = \frac{\Delta T}{Q} = \frac{1}{HTC} \tag{5}$$

Thermal resistance is the ability of the heating surface to resist the heat flux. The lower the thermal resistance, the better the heat transfer across the surface.
The Nusselt number is used to compare heat transfer performance between different surfaces or thermal systems. The Nusselt number is a dimensionless number that represents the efficiency of heat transfer by convection compared to thermal conduction [20].
The larger the Nusselt number, the greater the effectiveness of convection heat transfer across the surface
The Nusselt number is calculated according to the following equation:

$$Nu = \frac{HTC \cdot L_c}{k} \tag{6}$$

The thermal conductivity is calculated from the following equation:

$$q_x = -k \frac{dT}{dx} \tag{7}$$

Where:
$\frac{dT}{dx}$: thermal gradient in the x direction.
ANSYS tools enable accurate display and analysis of surface temperature distribution, heat transfer coefficient, Nusselt number, thermal resistance, thermal conductivity and nucleation sites, making the comparison of the effect of different heated surface geometries on heat transfer is easier and clearer during pool boiling of water.

4. Research Methodology in ANSYS

This study was performed using thermodynamics (CFD) simulation in ANSYS software to study the through boiling of water using a two-dimensional simulation.
The main objective of this simulation is to compare the effect of surface type on the boiling process, with grooves on the heating surface. Where several models were designed, the first model is a smooth copper surface as a reference case for comparing different designs of heating surface grooves. Where three geometry of grooves were studied (half circular grooves, square grooves and trapezoidal grooves).
To ensure the validity of the results, the model validation was conducted before applying it to the remaining cases studied. For this purpose, the experimental Rohsenow relationship was used at the same thermal condition [21].

$$q'' = \mu_l h_{fg} \left[\frac{g(\rho_l - \rho_v)}{\sigma}\right]^{\frac{1}{2}} \left[\frac{C_{pl}(T_w - T_{sat})}{C_{sf} h_{fg} Pr_l^n}\right]^3 \tag{8}$$

Table 1 Parameters and constants data.

$h_{fg}[J/\text{Kg}]$	$\rho_v[kg/m^3]$	$\sigma[N/m]$	Pr_l	C_{sf}	n
2.26×10^6	0.6	0.0589	1.75	0.013	1.7

Table (1) shows the values of the constants and parameters used in Rohsenow's equation.
The heat flux was calculated from the Rohsenow relationship $q'' = 248031.369\ [W/m^2]$. Then the HTC was calculated from:

$$HTC = \frac{q''}{\Delta T} \quad (9)$$

The result of substitution and calculation in the last equation was $HTC = 13779.5\ [W/m^2K]$. After that, the simulation was carried out under the same thermal conditions as for a smooth surface with constant heat flux, which was calculated from the experimental relationship $q'' = 248031.369\ [W/m^2]$.

Table 2 The model validation.

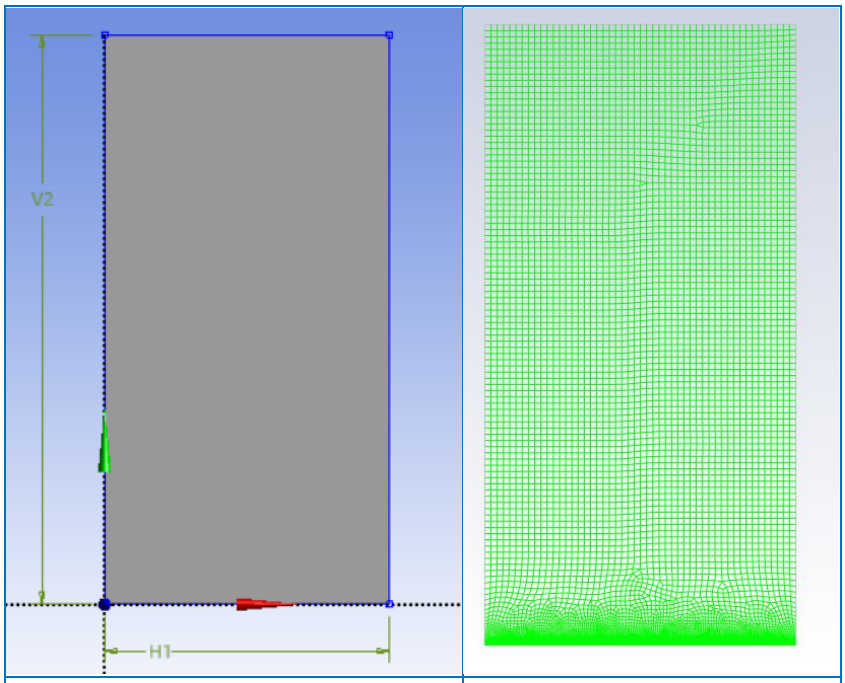
	Empirical correlation	Simulation result	Error
HTC	13779.5	12925.81	6.19

Table (2) shows the simulation result of HTC, comparing it with the calculated value and determining the percentage error.
Based on the study by Freire et al., and since the error is less than 7%, the model is considered valid.
The fluid (water) properties: viscosity, density, specific heat, and thermal conductivity, were determined according to reference values. A Two-phase model was used to monitor bubble nucleation sites and heat transfer between the surface and the fluid, as well as the thermal conductivity and Nusselt number of the heating surface. The VOF model was used with the Lee model for mass transfer; the contact angle was set at $90°$ to show the effect of surface geometry on boiling characteristics. As for the evaporation and condensation frequency coefficients, both were fixed at $0.1[s^{-1}]$.
Where a copper heating surface was adopted with a constant heat flux.
The mesh: An irregular mesh was used with an increasing number of terminating elements and an increasing number of layers in contact with the heated wall, where boiling occurs. The mesh independence was also tested to ensure that the results did not depend on cell size, with the use of smaller cells at the grooves to accurately determine the effect of the geometry of these grooves on heat transfer.

Table 3 Mesh independence test.

Element size $[m]$	Number of elements	Number of nodes	HTC $[W/m^2K]$	Error %
0.005	5484	5684	13034.63	-
0.001	8021	8278	12925.81	0.834
0.0005	16929	17287	12994.92	0.532
0.0003	37607	38089	12886.96	0.831

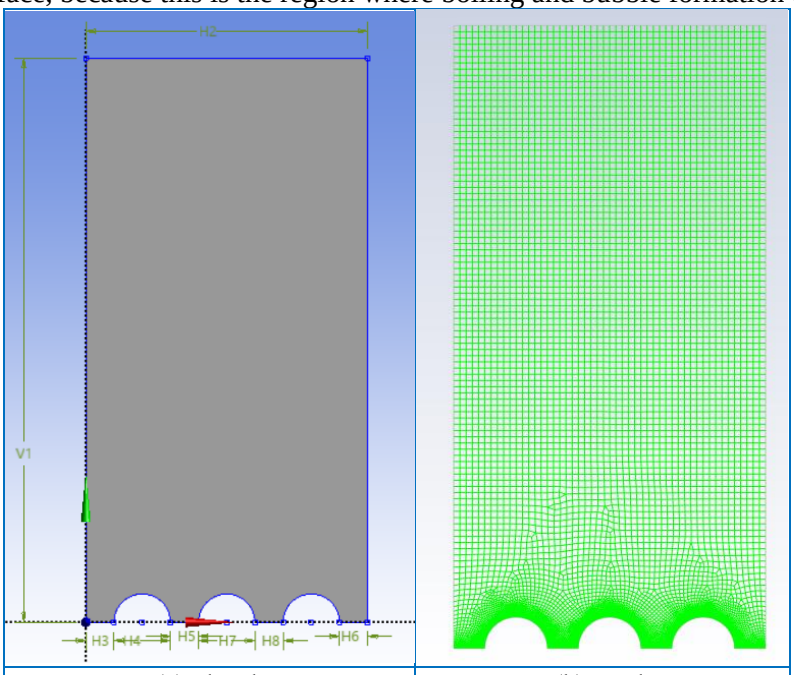
Table (3) presents the mesh independence test by showing the increase in the number of mesh elements versus the change in HTC value, which is considered an essential factor for comparing the different cases in this study. Since the error value was less than 1%, this means that the mesh is independent.
Boundary conditions:
1- The liquid is considered homogeneous and free of initial bubbles, and the initial water temperature was determined to be room temperature.
2- The top, right and left surfaces were identified as the walls of the boiling pool.
3- The lower horizontal surface was identified as the heating surface and had a constant heat flux rate ($30\ KW/m^2$).
4- All surfaces were prevented from slipping.
This simulation focused on: the rate of heat transfer, thermal resistance, thermal conductivity, Nusselt number of heating surface, and the number and distribution of hot spots. Visual and numerical comparisons were made on the results of the boiling process analysis for the different groove shapes of the heating surface as extracted by ANSYS Workbench.



(a) Sketch (b) Mesh

Fig. 1 Smooth surface design in ANSYS Workbench.

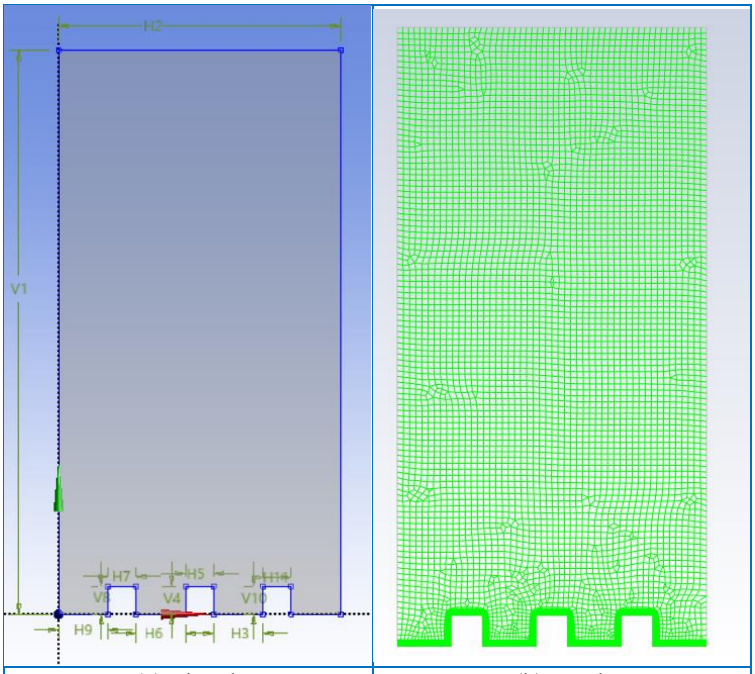
Figure (1-a) illustrates the design of a smooth surface in ANSYS Workbench, from a 2D drawing to a surface creation from the shape's boundaries, in preparation for the next grid generation process.
Figure (1-b) illustrates the design and independence of the smooth surface mesh in ANSYS Workbench. The figure shows the irregular mesh that was generated, with an increasing number of layers and elements near the heated surface, because this is the region where boiling and bubble formation occur.



(a) Sketch (b) Mesh

Fig. 2 Design of half circular grooves for the heating surface in ANSYS Workbench.

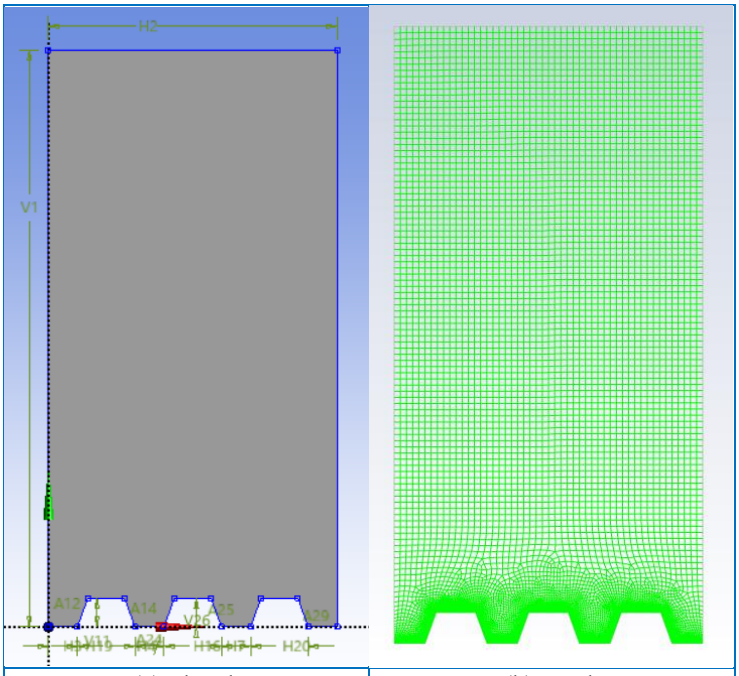
Figure (2-a) illustrates the half circular grooves for the heating surface, which were created in ANSYS Workbench and prepared for a two-dimensional simulation. The figure shows the basic steps for creating the surface, including the initial dimensions and surface generation, before moving on to the mesh generation stage for numerical simulation.
Figure (2-b) shows the mesh in the half circular grooves model in ANSYS Workbench. The figure shows the irregular mesh that was generated, with an increasing number of layers and elements near the heated surface to accurately cover the area where boiling occurs during numerical analysis. The size of the elements around the grooves were also reduced to increase accuracy and clarify their effect on heat transfer during pool boiling of water.



(a) Sketch (b) Mesh

Fig. 3 Design of square grooves for the heating surface in ANSYS Workbench.

Figure (3-a) illustrates the square grooves for the heating surface, which were created in ANSYS Workbench and prepared for a two-dimensional simulation. The figure shows the basic steps for creating the surface, including the initial dimensions and surface generation, before moving on to the mesh generation stage for numerical simulation.
Figure (3-b) shows the mesh in the square grooves model in ANSYS Workbench. The figure shows the irregular mesh that was generated, with an increasing number of layers and elements near the heated surface to accurately cover the area where boiling occurs during numerical analysis. The size of the elements around the grooves was also reduced to increase accuracy and clarify their effect on heat transfer during water pool boiling.



(a) Sketch (b) Mesh

Fig. 4 Design of trapezoidal grooves for the heating surface in ANSYS Workbench.

Figure (4-a) illustrates the trapezoidal grooves for the heating surface, which were created in ANSYS Workbench and prepared for a two-dimensional simulation. The figure shows the basic steps for creating the surface, including the initial dimensions and surface generation, before moving on to the mesh generation stage for numerical simulation.
Figure (4-b) shows the mesh in the trapezoidal grooves model in ANSYS Workbench. The figure shows the irregular mesh that was generated, with an increasing number of layers and elements near the heated surface to accurately cover the area where boiling occurs during numerical analysis. The size of the elements around the grooves was also reduced to increase accuracy and clarify their effect on heat transfer during water pool boiling.

Table 4 Properties of water.

$\rho[Kg/m^3]$	$\mu[kg/ms]$	$C_p[J/KgK]$	$k_{cond}[W/mK]$
1000	1.002	4200	0.606

Table (4) shows the water properties used in simulating the pool boiling of water in ANSYS, including density, viscosity, specific heat, and thermal conductivity.

5. Simulation result

After all these preparations and after performing the simulation in ANSYS, the result of the effect of surface type on heat transmission in water pool boiling are displayed here.
This section will review the results of the two-dimensional simulation implemented for different geometries for surfaces. And comparing the results to determine the effect of the geometric shape of the surface on heat transmission in a water pool boiling. Through presenting the temperature distribution on the surface, Nusselt number, thermal conductivity and Heat Transfer Coefficient (HTC) for the different geometries of the heater surface. And comparing the average values of HTC, thermal resistance and the

maximum temperatures between different geometries for the heater.

5.1 Simulation results for copper smooth surface

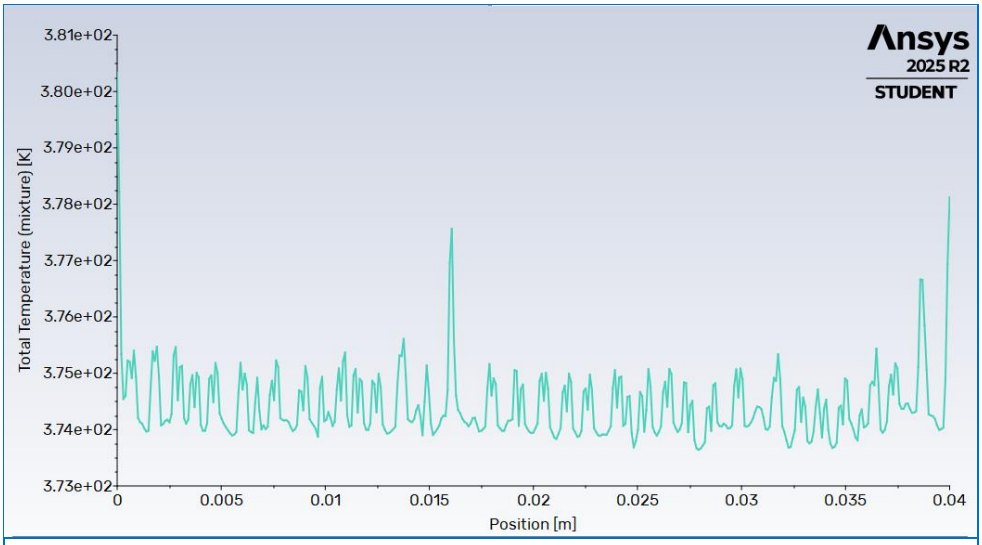


Fig. 5 Total temperature of smooth surface.

Figure (5) shows the total temperature distribution chart according to the location on the smooth heating surface.

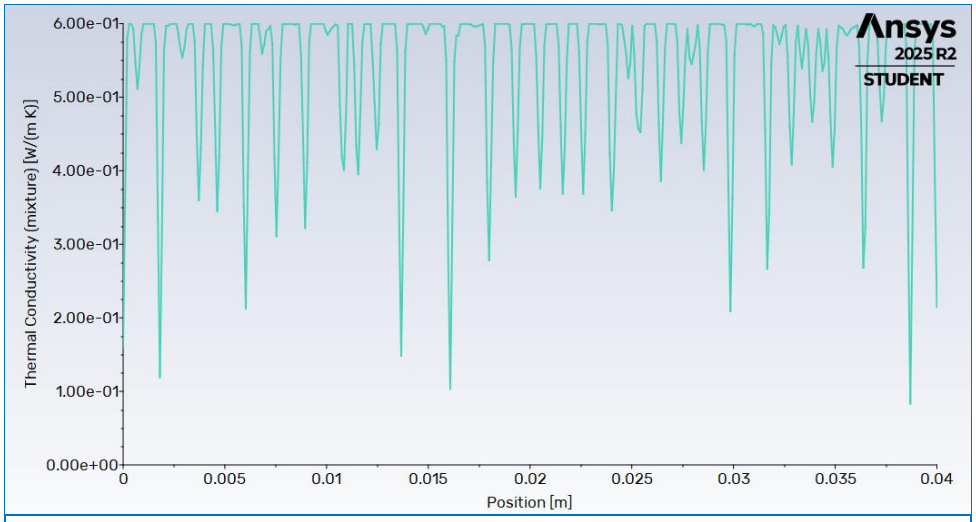


Fig. 6 Overall heat transfer performance of smooth surface.

Figure (6) illustrates the chart of the overall heat transfer performance variation according to the location on the smooth heating surface.

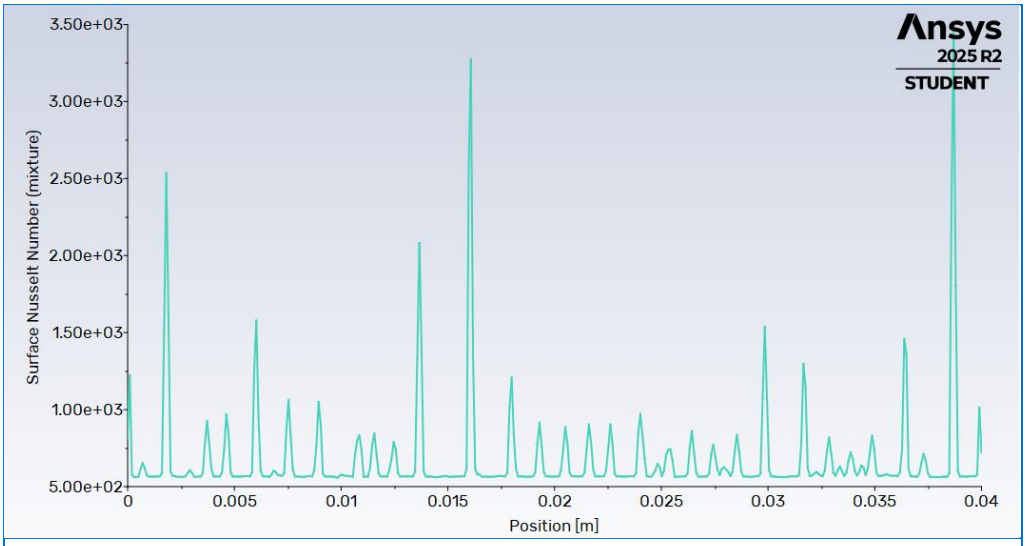


Fig. 7 Surface Nusselt number of smooth surface.

Figure (7) illustrates the chart of Nusselt number variation according to the site on the smooth heating surface.

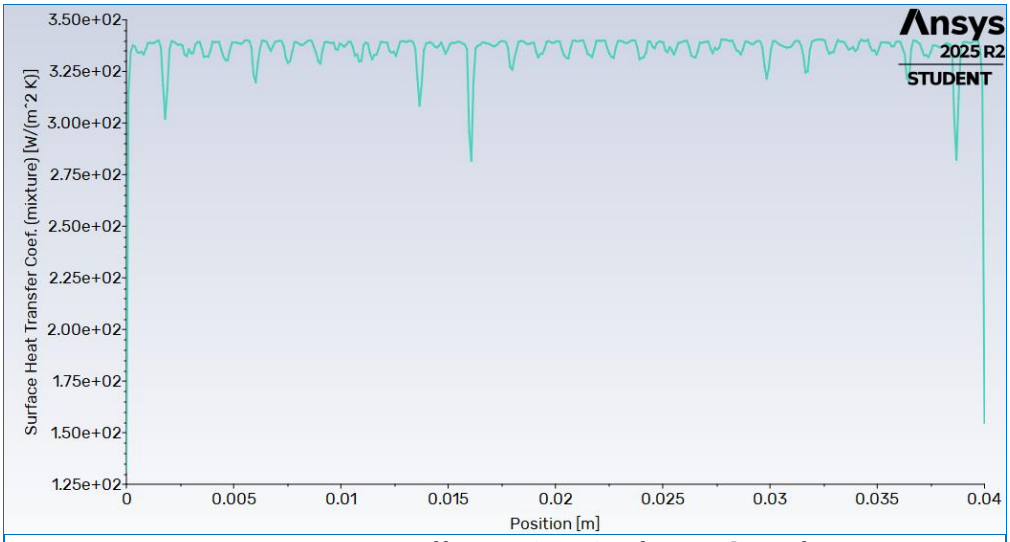


Fig. 8 Heat Transfer Coefficient (HTC) of smooth surface.

Figure (8) shows the chart of the heat transfer coefficient (HTC) variation according to the location on the smooth heating surface.

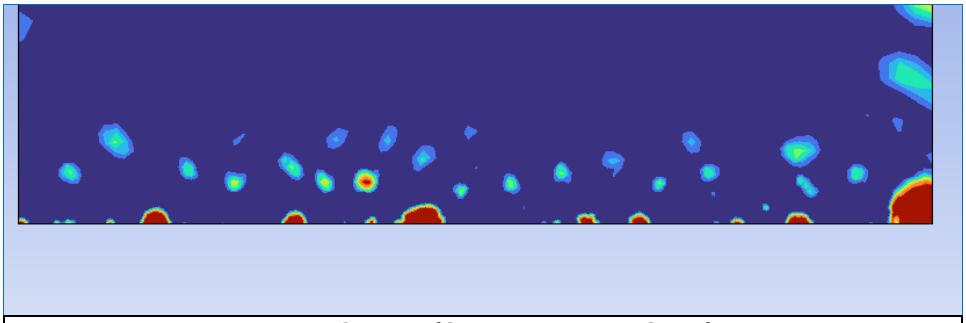


Fig. 9 Distribution of hot spots on smooth surface.

Figure (9) illustrates the distribution of hot spots on a smooth surface.

5.2 Simulation results for a copper heated surface with circular grooves

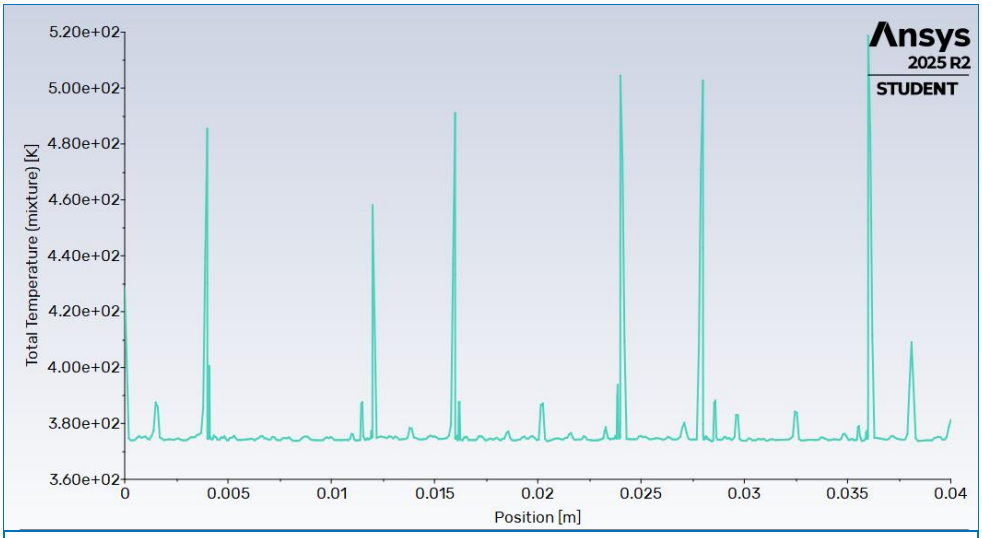


Fig. 10 Total temperature of heated surface with half circular grooves.

Figure (10) shows the chart of total temperature variation according to the sites on the heating surface equipped with half-circular grooves.

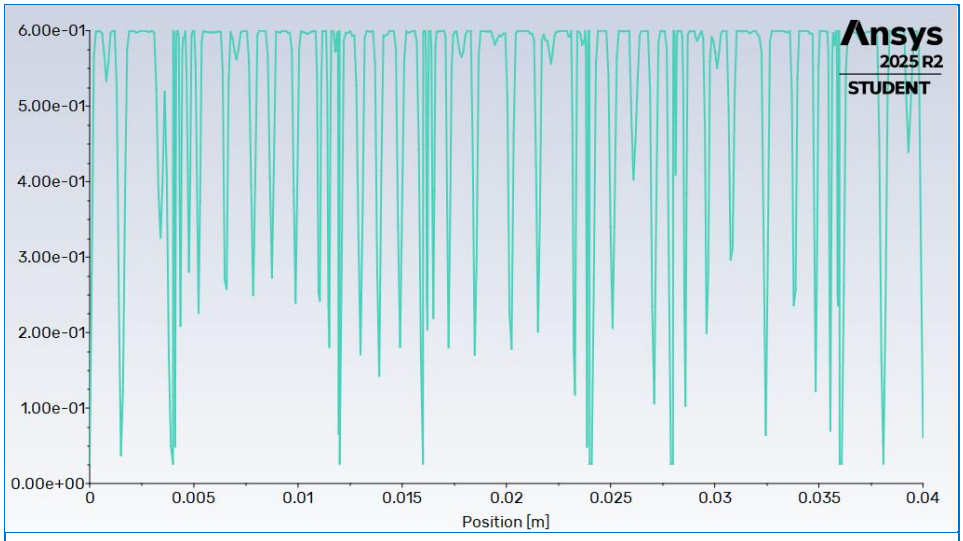


Fig. 11 Overall heat transfer performance of heated surface with half circular grooves.

Figure (11) shows the chart of the overall heat transfer performance variation according to the sites on the heating surface equipped with half-circular grooves.

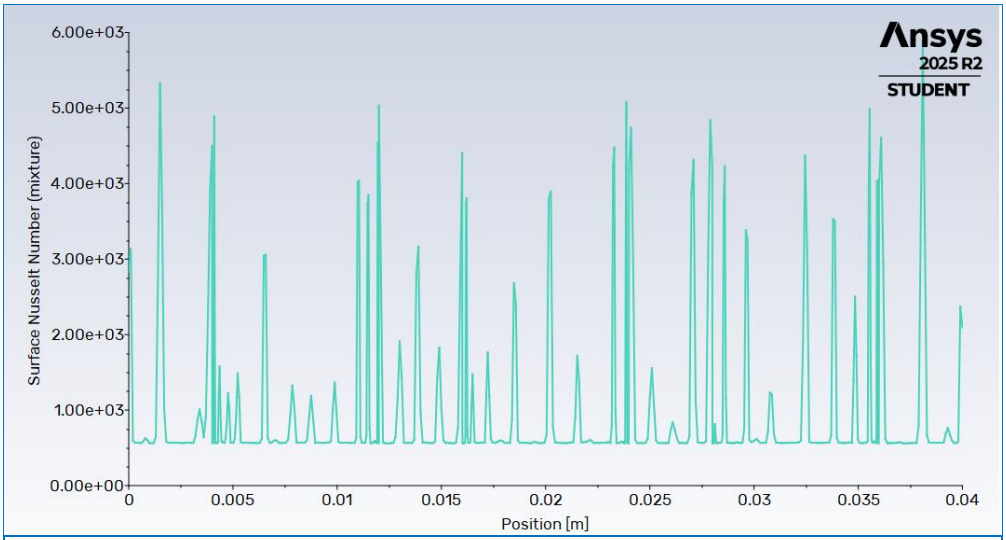


Fig. 12 Nusselt number of heated surface with half circular grooves.

Figure (12) shows the chart of the Nusselt number variation according to the sites on the heating surface equipped with half-circular grooves.

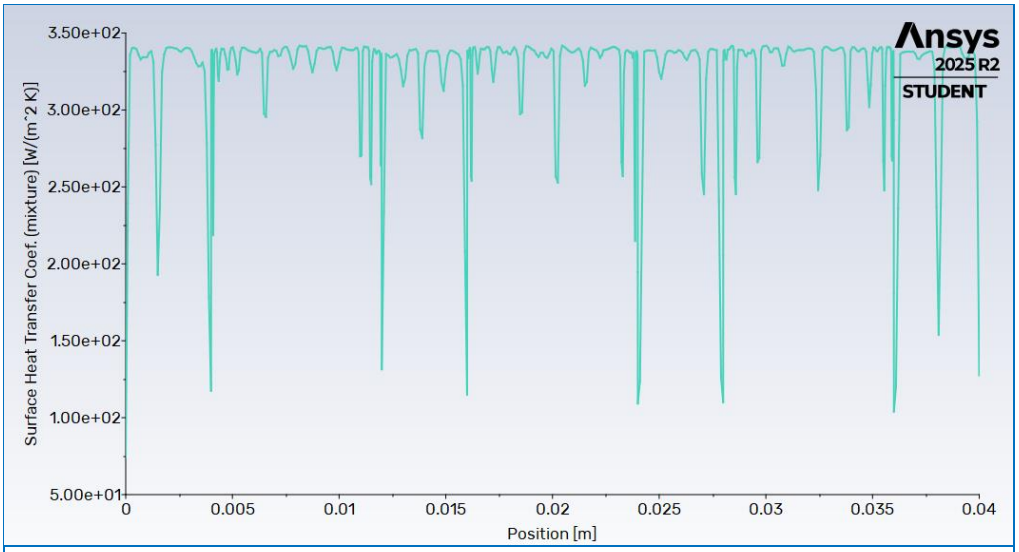


Fig. 13 Heat Transfer Coefficient (HTC) of heated surface with half circular grooves.

Figure (13) shows the chart of the heat transfer coefficient (HTC) variation according to the sites on the heating surface equipped with half-circular grooves.

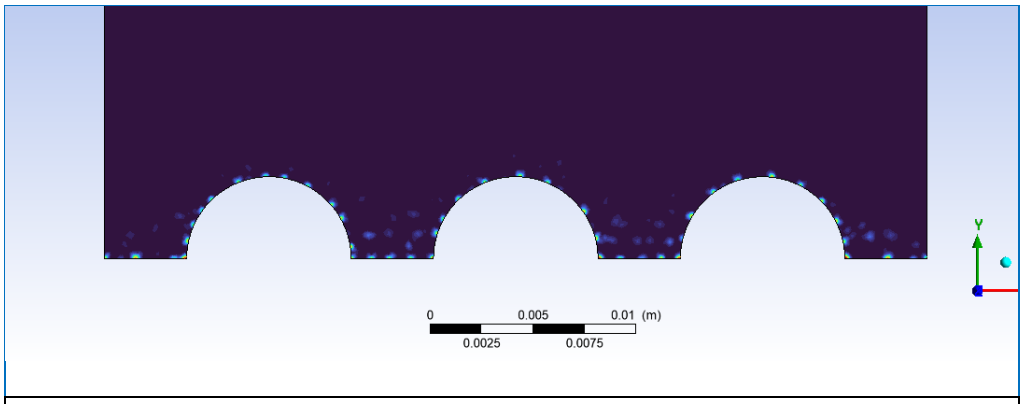


Fig. 14 Distribution of hot spots on heating surface with half circular grooves.

Figure (14) shows the distribution of hot spots on the heating surface equipped with half circular grooves.

5.3 Simulation results for a copper heated surface with square grooves

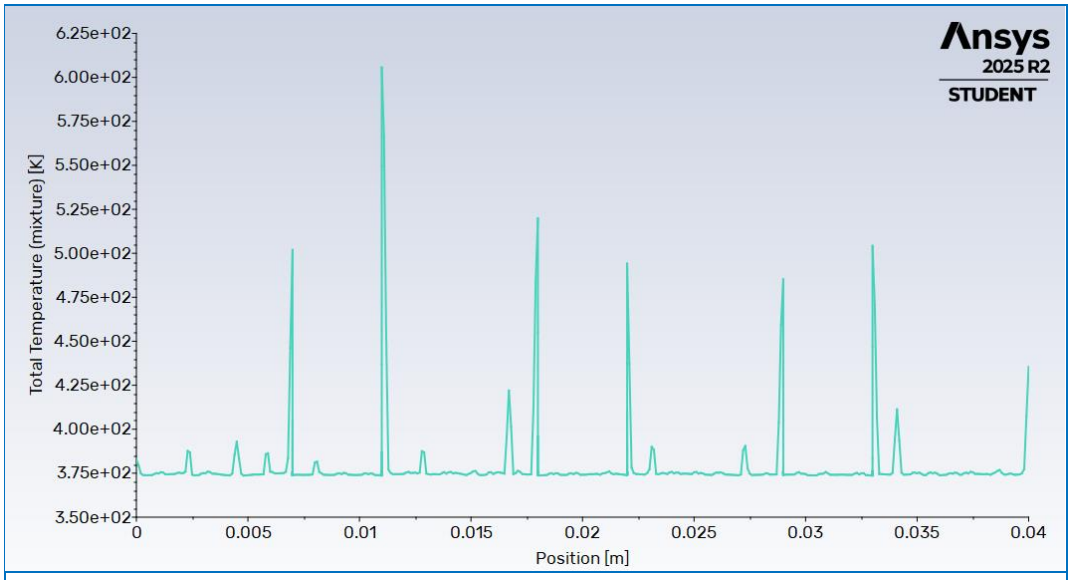


Fig. 15 Total temperature of heated surface with square grooves.

Figure (15) shows the chart of the total temperature variation according to the sites on the heating surface equipped with square grooves.

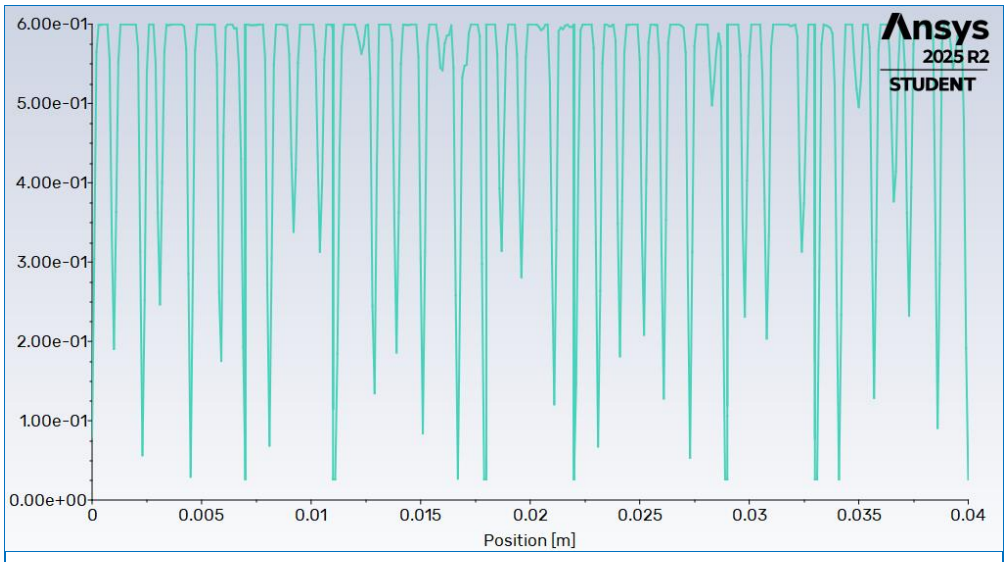


Fig. 16 Overall heat transfer performance of heated surface with square grooves.

Figure (16) shows the chart of the overall heat transfer performance variation according to the sites on the heating surface equipped with square grooves.

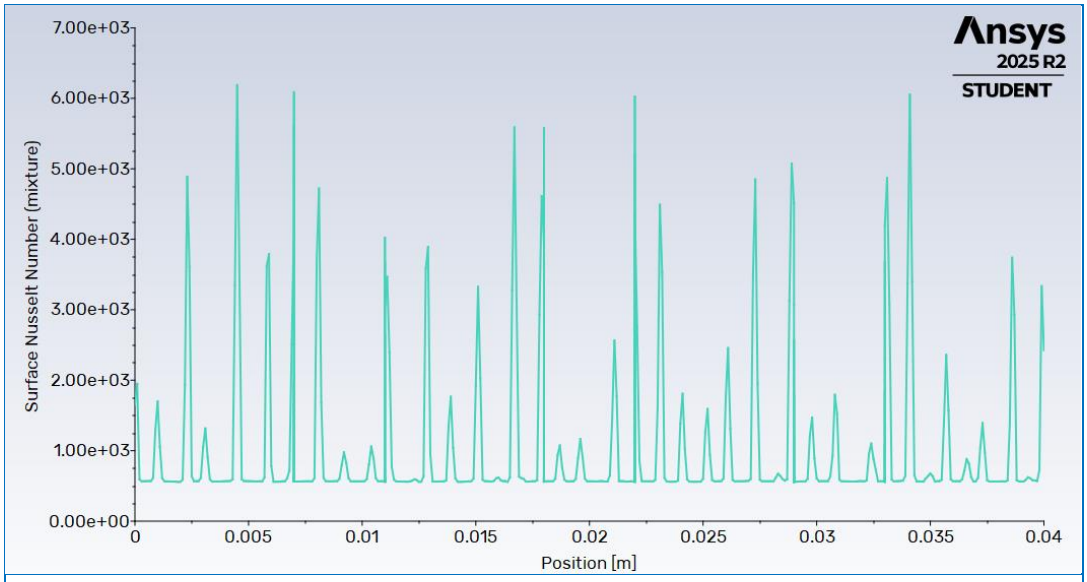


Fig. 17 Nusselt number of heated surface with square grooves.

Figure (17) shows the chart of the Nusselt number variation depending on the sites on the heating surface equipped with square grooves.

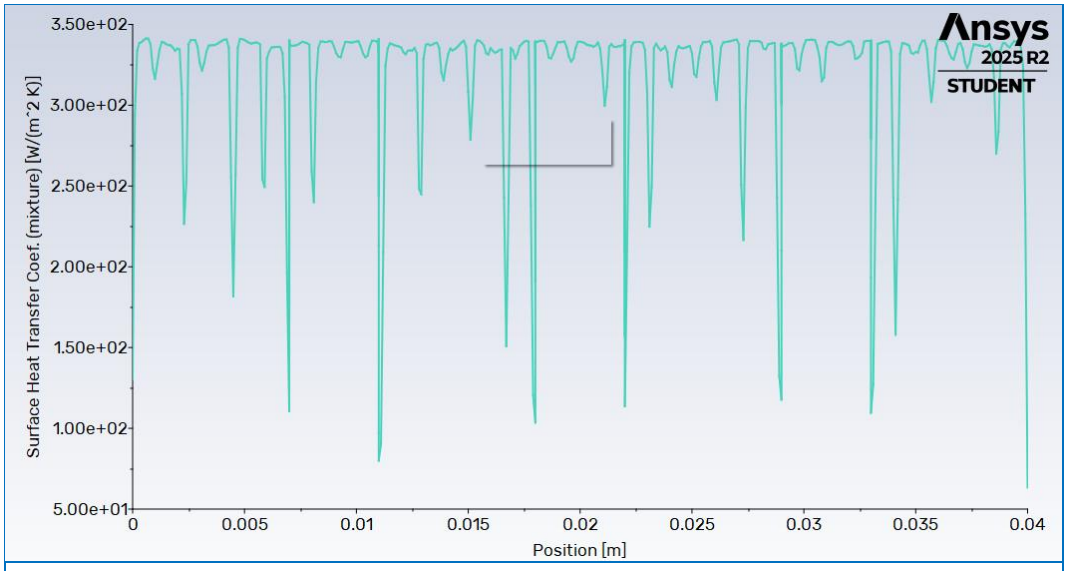


Fig. 18 Heat Transfer Coefficient (HTC) of heated surface with square grooves.

Figure (18) shows the chart of the variation of the heat transfer coefficient (HTC) depending on the sites on the heating surface is equipped with square grooves.

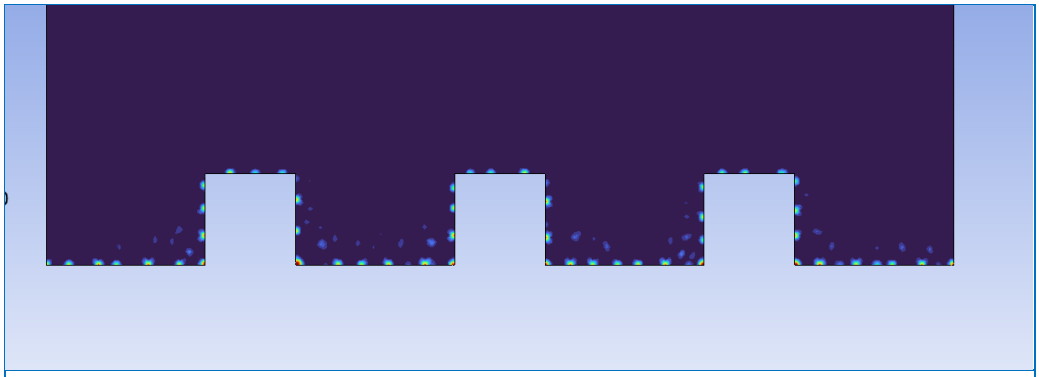


Fig. 19 Distribution of hot spots on heated surface with square grooves.

Figure (19) shows the distribution of hot spots on the heating surface equipped with square grooves.

5.4 Simulation results for a copper heated surface with trapezoidal grooves

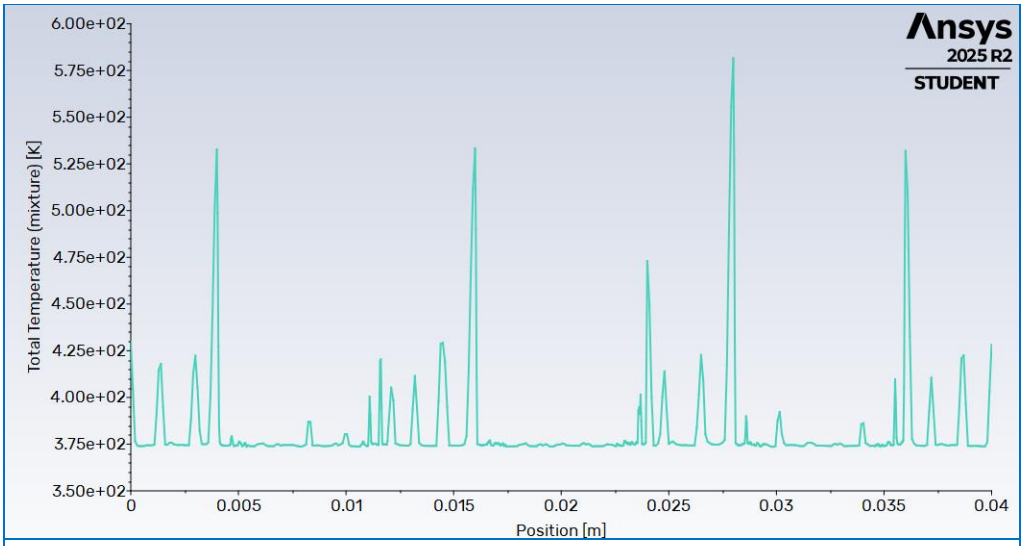


Fig. 20 Total temperature of heated surface with trapezoidal grooves.

Figure (20) shows the chart of the total temperature variation according to the sites on the heating surface equipped with trapezoidal grooves.

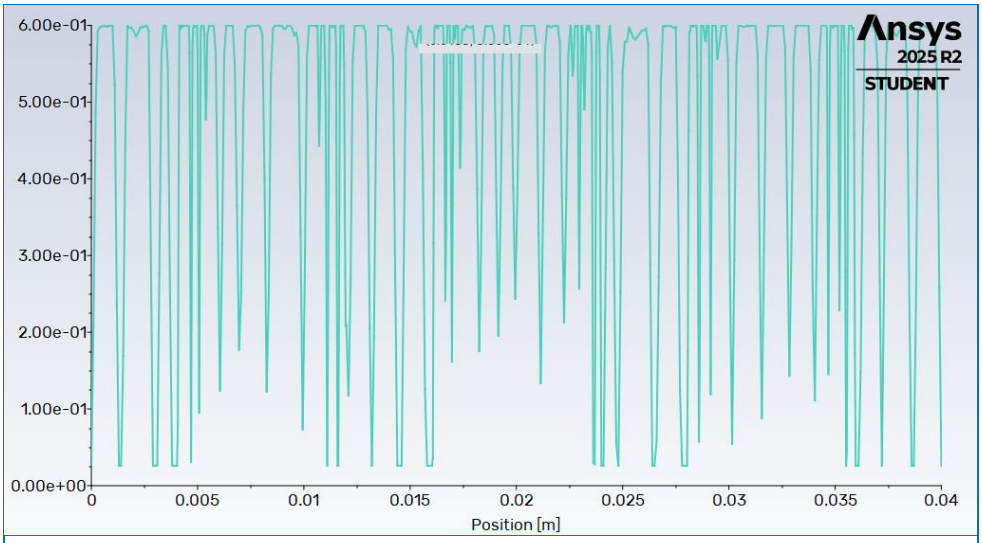


Fig. 21 Overall heat transfer performance of heated surface with trapezoidal grooves.

Figure (21) shows the chart of the overall heat transfer performance variation depending on the sites on the heating surface equipped with trapezoidal grooves.

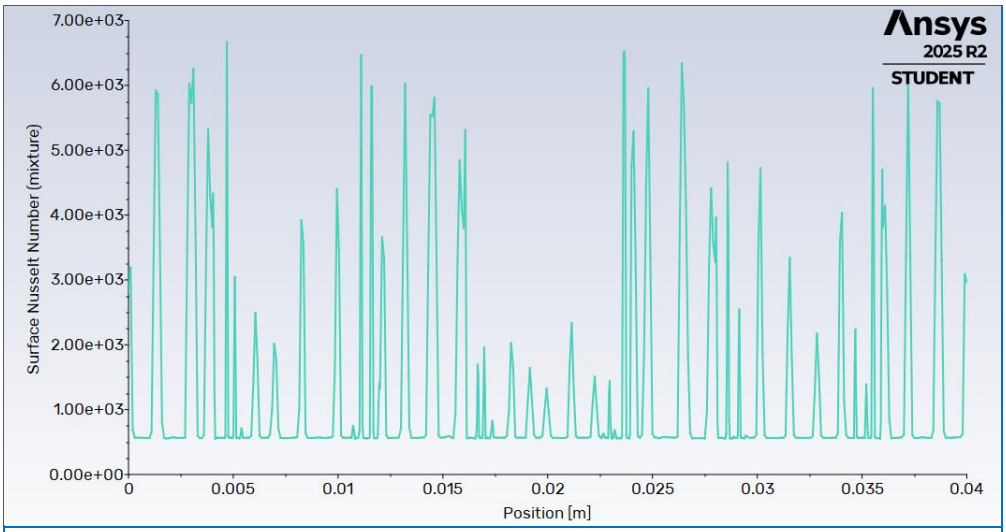


Fig. 22 Nusselt number of heated surface with trapezoidal grooves.

Figure (22) shows the chart of the variation of the Nusselt number according to the sites on the heating surface equipped with trapezoidal grooves.

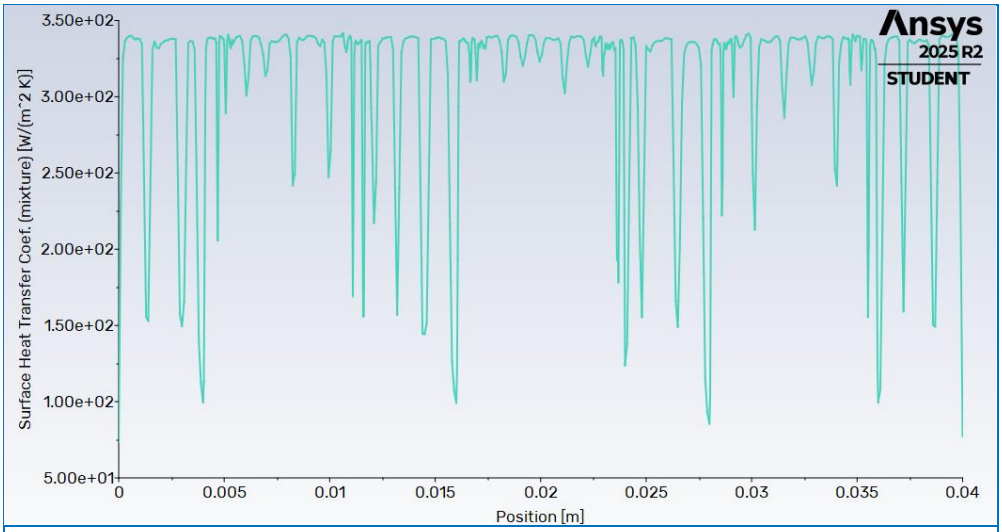


Fig. 23 Heat Transfer Coefficient (HTC) of heated surface with trapezoidal grooves.

Figure (23) shows the chart of the heat transfer coefficient (HTC) variation depending on the sites on the heating surface equipped with trapezoidal grooves.

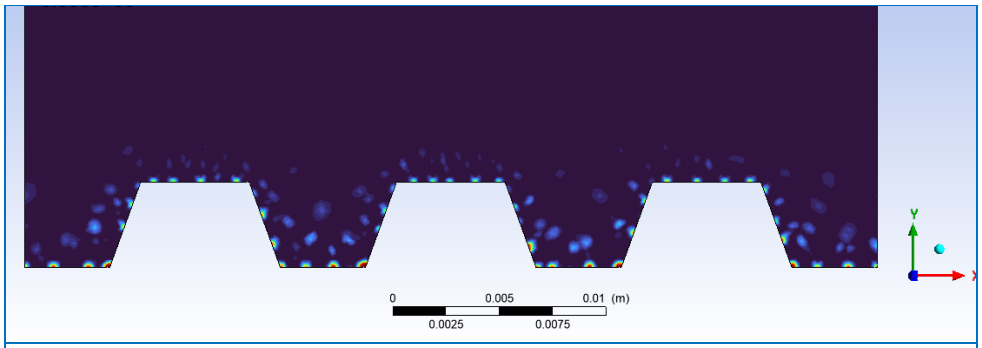


Fig. 24 Distribution of hot spots on heated surface with trapezoidal grooves.

Figure (24) shows the distribution of hot spots on the heating surface equipped with trapezoidal grooves. It was demonstrated by comparing the results of numerical simulations of water pool boiling at several geometries of the heating surface obtained from ANSYS, that only changes the geometry of the heating surface without changing its roughness or wettability clearly affects heat transfer, thereby changing the contact area between the heating surface and the water due to the change of surface geometry.
The results showed that changing the geometry of the heated surface leads to a change in the average surface temperature, thermal conductivity, heat transfer coefficient and Nusselt number, in addition to different number and distribution of nucleation sites, which in turn affects the boiling process.
Therefore, these results confirm that the geometry of the heated surface plays an essential role in improving the pool boiling process of water.

6. Analysis of results

The results from 2D simulations of water pool boiling for different heating surface geometries in ANSYS Fluent were analyzed.
It has been shown from figures (9-14-19-24) that the number of hot spots on surfaces with grooves was greater compared to the smooth surface. And when comparing the number of hot spots in the different shapes of the heating surface grooves, it was found that the trapezoidal grooves have the highest number of hot spots, as shown in figure (24), compared to the square and semicircular grooves. While the surface

containing square grooves had fewer hot spots, as shown in figure (19), than the trapezoidal grooves, but more than the semicircular grooves. While the smooth surface showed the least number of hot spots, as shown in the figure (9).
As the number of hot spots increases, the rate of bubble generation and indicates greater efficiency of heat transfer and higher efficiency of the boiling process.
And after examining the charts of the simulation results, the average values of these results were extracted for each case and presented in a table, to facilitate comparison between different shapes of heated surface grooves and determine the best shape to improve the heat transfer rate.

Table 5 Numerical simulation results.

Surface geometry	HTC $[W/m^2K]$	R_{th} $[K/W]$	k $[W/mK]$	Nu number
Smooth surface	272.8	0.00366	382.3	682.3
Semicircular grooves	387.6	0.00257	542.4	925.1
Square grooves	453.5	0.0022	630.5	1024.8
Trapezoidal grooves	537.2	0.00186	745.7	1300.6

Table (5) shows the average numerical values of the thermal properties extracted from ANSYS. The table shows the average values for heat transfer coefficient (HTC), thermal resistance, overall heat transfer performance (k), and Nusselt number for several forms of heating surface.
These values show that the trapezoidal shape of heating surface grooves show higher heat transfer coefficient, as well as the highest value for the Nusselt number and overall heat transfer performance. It also showed the lowest value for thermal resistance. As it increases the contact surface with water, it increases the Nusselt number. It also increases the number of bubble formation centers, and thus reduces the thickness of the vapor layer in contact with the heating surface. This increases the number of bubbles and facilitates their separation from the surface, which in turn leads to reducing thermal resistance and obtaining the best efficiency of the thermal process.

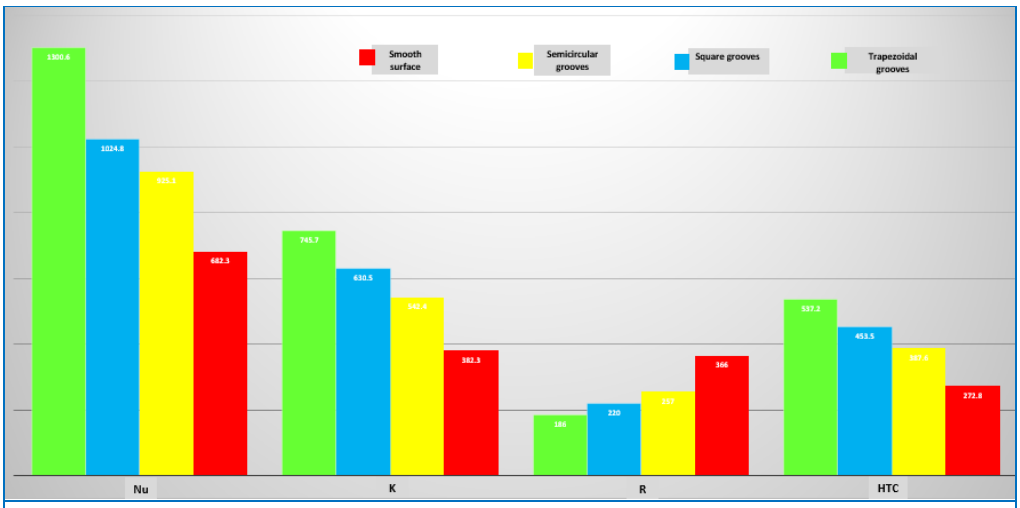


Fig. 25 The differences in thermal characteristics between studied cases.

7. Conclusions

This study gains its importance from utilizing CFD techniques in ANSYS software to improve the water pool boiling. By two-dimensional simulation, which significantly reduces time and effort. It also requires fewer computer capabilities compared to 3D simulation. Forever, this study has highlighted a simple method to improve heat transfer and thermal system efficiency, by modifying the geometry of the heat

exchange surface.

1- Simulating the boiling process using CFD techniques in the ANSYS program showed that the geometric shape of the heating surface greatly affects the rate of heat transfer.
2- By examining and monitoring the heating surface during the boiling, it was found that changing the geometric shape leads to a change in the number of hot spots that, in turn, affect the intensity and frequency of the bubbles.
3- The results showed that the square grooves of the heating surface led to an increase in the heat transfer coefficient (HTC) by 66.24%, Nusselt number by 50.2%, and overall heat transfer performance by 65%. The thermal resistance decreased by 66.3% compared to the smooth surface.
4- The semicircular grooves increased the heat transfer coefficient by 42.1%, the Nusselt number by 35% and overall heat transfer performance by 42%. While the thermal resistance decreased by 42.4% compared to the smooth surface.
5- The results showed that the best shape of heating surface grooves is a trapezoidal shape, which increased the heat transfer coefficient by 96.92%, Nusselt number by 90.62% and overall heat transfer performance by 95%. The presence of trapezoidal grooves in the heating surface led to an increase in thermal resistance by 96.7% compared to the smooth surface.
6- The best percentage of improvement in the Nusselt number of 96.92%, which was trapezoidal, indicates greater efficiency in heat transfer and faster reaching of the nuclear boiling of water. In addition to the significant savings in energy required for boiling, compared to lower values in other cases of surface geometry.
7- These results show that it is possible to exploit the geometry of the heating surface to control the characteristics of the boiling process.
8- These results can form the basis for subsequent research, including performing simulations on surfaces containing grooves of complex shapes, the impact of the depth of grooves on heat transfer, study different surface materials, the experimental verification of the results and apply supported technologies such as three-dimensional simulation.

Nomenclature

h_{fg}	Latent heat of vaporization $[W/m^2]$
L_c	Characteristic length of the surface $[m]$
q_x	The heat flux is in the x direction $[K/m]$
σ	Surface tension $[N/m]$
Pr	Prantdl number [-]
C_{sf}	Constant depends on the surface type [-]
n	Constant depends on the fluid type [-]
ρ	Fluid density $[Kg/m^3]$
u	Fluid velocity $[m/s]$
P	Pressure [Pa]
C_p	Specific heat capacity $[J/KgK]$

μ	Viscosity $[Pa \cdot s]$
T	Temperature [K]
Q	Heat flux $[W/m^2]$
k	Thermal conductivity coefficient $[W/mK]$
ΔT	Temperature difference $[K]$

Subscripts

v	Vapor
l	Liquid
avg	Average
th	Thermal
sat	Saturation

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