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# Thickness dependency of CuO Nanocoating layer on thermal performance of HPHE

Aysar Abd Alrazaq Alamery, Hussein Ali Jawad, Zainab Fadhil Mahdi\*

Institute of Laser for Postgraduate Studies, University of Baghdad, Jadriha, P. O. Box 47314 Baghdad, Iraq

## Email address:

Aysar\_Alamery@yahoo.com (A. A. A. Alamery), Hussein@ilps.uobaghdad.edu.iq (H. A. Jawad),

Zainab@ilps.uobaghdad.edu.iq (Z. F. Mahdi)

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**Abstract:** Among the different passive techniques present, surface coating seems to be the most effective one. Copper oxide-based materials are of interest on account of their potential uses in many technological fields. Modeling of the nanocoating on fins in Thermosyphon heat exchangers using ANSYS software is introduced. The temperature distribution was investigated. Seven thicknesses of CuO coating layers are used on fins of HPHE with the aim of improving working system. The enhancement is proportioning with the increment in coat thickness at the evaporator section of transient conditions (-16.95, 3.12, 30.66, 52.68, 70.65, 85.55 and 98.09) for (10, 25, 50, 75, 100, 125 and 150  $\mu\text{m}$ ) thicknesses respectively. From these results, maximum enhancement occurred at 150  $\mu\text{m}$  coat. Coat process of the evaporator fins can give fast response of nanofluid to absorb the latent heat from the outdoor air and vaporize to start the closed cycle working system so the increasing in the energy saving is investigated.

**Keywords:** HVAC, HPHE, ANSYS, Coating Layer Thickness, Copper Oxide, Temperature Distribution

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## 1. Introduction

Due to the human need for energy, a more efficient way of using it is a major challenge in the scientific community. The performance of heat transfer is one of the most important parts of these types of investigation [1]. Heat pipe technology has found increasing applications in enhancing the thermal performance of heat exchangers in microelectronics, energy saving in HVACs [2]. Heat transfer enhancement is an extensive research area, in order to increase the efficiency of energy management. There are several ways to enhance heat transfer characteristics, which can be mainly classified into active and passive techniques. Active techniques rely on external power source, such as electronic or acoustic fields and surface vibration. Most of the active techniques are abstruse and intractable with the surrounding, while passive techniques include surface coating, intrinsic fins, surface roughness and change of nano fluids. The passive techniques help us to overcome the limitations faced by the active techniques [3]. HP is essentially a passive heat transfer device with an extremely high effective thermal conductivity. The two-phase heat transfer mechanism results in heat transfer capabilities from one hundred to several thousand times that of an equivalent piece of copper [4, 5].

Among the different passive techniques present, surface coating seems to be the most effective one. Surface coating can be macro structured micro structured and nanostructured coatings [3]. H.A. Mohammed and K. Narrein. [6] numerically investigated the effects of using different geometrical parameters with the combination of nanofluid on heat transfer and fluid flow characteristics in a helically coiled tube heat exchanger (HCTHE). P.G. Anjankar and R.B. Yarasu. [7] studied the new design and thermal performance of Thermosyphon. W. Srimuanget al. [8] presented the knowledge of two-phase closed Thermosyphon (TPCT) as being used nowadays and the application of TPCT to air to air heat exchanger.

Symbols

HVACs= Heating, Ventilation and Air conditioning systems.

$K$ = Thermal Conductivity ( $\text{W.m}^{-1}\text{K}^{-1}$ )

$C_p$ = Specific Heat ( $\text{J.kg}^{-1}\text{K}^{-1}$ )

$\rho$ = Density ( $\text{kg.m}^{-3}$ )

DBT= Dry bulb temperature

WBT= Wet bulb temperature

$h$  = Convection coefficient.

$\dot{m}$  = mass flow rate of the air into the evaporator or condenser section,  $\text{kg.s}^{-1}$

HPHE = heat pipe heat exchanger  
 HP=heat pipe  
 T = Absolute temperature.

## 2. Modeling of Heat Pipe Heat Exchanger

The heat pipe were constructed in ANSYS Preprocessor package [9].The top and bottom layers are represented by the coating, Seven thicknesses of CuO coating layers are used (10, 25, 50, 75, 100,125and 150) on fins in heat pipe were used respectively. These layers thickness are used in coating with the aim of improving the thermal properties of the base metal (aluminum).

## 3. Boundary Conditions

The boundary conditions of the tube is used as temperature distribution along HP which can be obtained by phase change properties from nanofluid in evaporator section to the vapor in the condenser section [10].Boundary conditions of the thermal model were specified as surface loads through ANSYS codes [9,11].Figures(1,2)show counter-flow HPHE for effectiveness ratings and Schematic diagram for the experimental set-up.

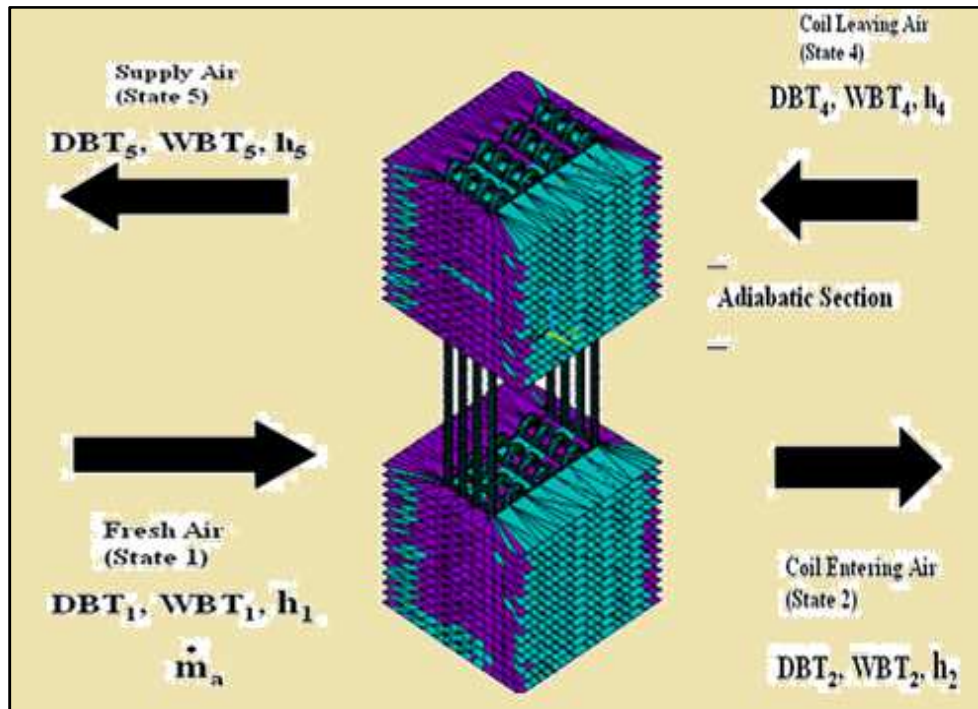


Fig (1). Schematic of the counter-flow HPHE for effectiveness ratings .

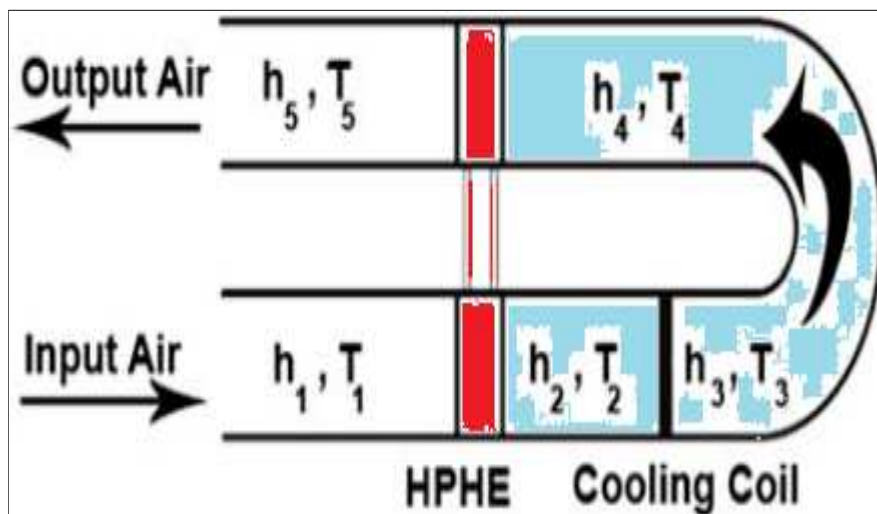


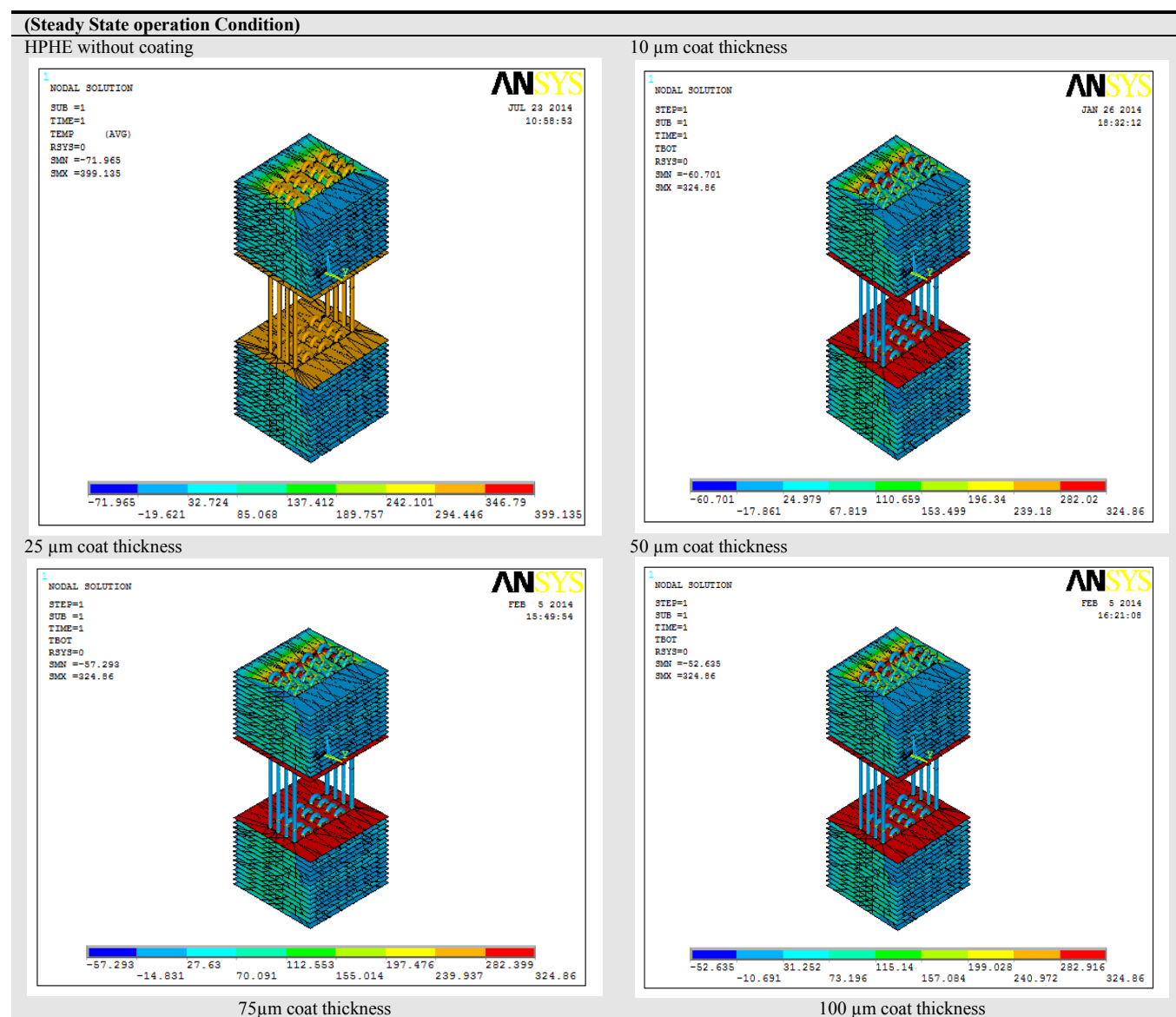
Fig (2). Schematic diagram for the experimental set-up [2].

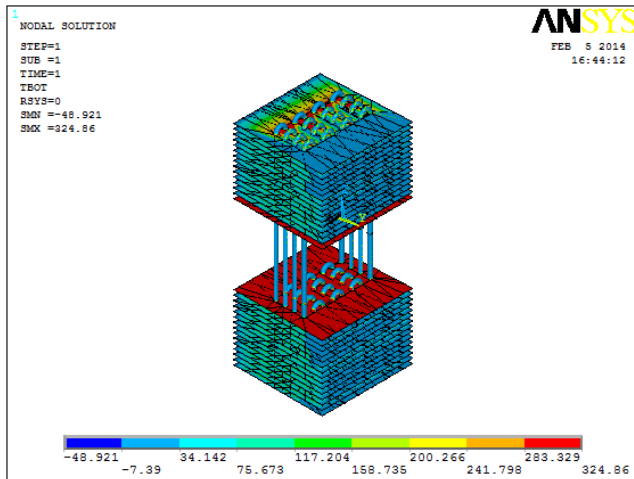
## 4. Results and Discussion

After all the data [Al fins with thickness of 0.4mm and properties ( $K=237 \text{ W.m}^{-1}\text{K}^{-1}$ ,  $C_p=905 \text{ J.kg}^{-1}\text{K}^{-1}$ ,  $\rho=2707 \text{ kg.m}^{-3}$ ), Cu HP with properties ( $K=398 \text{ W.m}^{-1}\text{K}^{-1}$ ,  $C_p=384 \text{ J.kg}^{-1}\text{K}^{-1}$ ,  $\rho=8954 \text{ kg.m}^{-3}$ ) [12], Variation thickness of coat layers, Fixed boundary conditions as mentioned above] were presented. For all tested fins, two fixed positions were taken in evaporator and condenser fins according to the direction of air flow. The results which approach from the ANSYS program after modeling the heat pipe and run the program can show in Table (1). From figures, the response of the system in transient conditions is clear compared with steady state. HPHE works better with the change of the thickness of coat layer as increasing. In the yellow area of this table (125 and 150  $\mu\text{m}$  coat thickness), obvious response of the nanofluid inside HP to absorb large amount of heat from

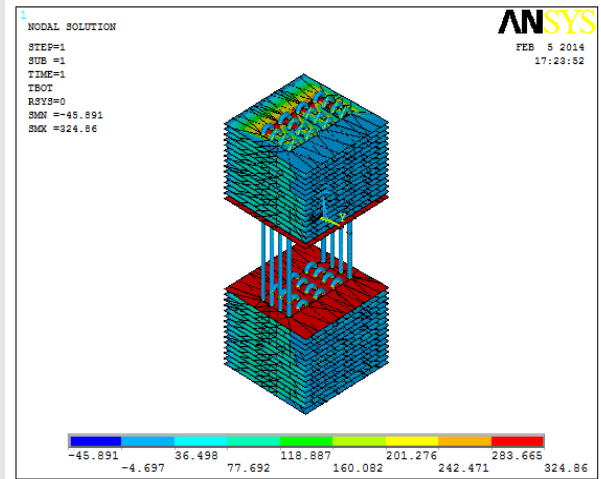
fresh air and vaporizing, the coil entering air temperature decrease which is shown in the nelli color of the fins in the outside of the evaporator section. When the air reaches the inlet side of the condenser section it will be very cold due to the effect of cooling coil and this can be shown in the nelli color of these fins. Nanofluid reaches the condenser section in vaporization state, the heat transfer due to the second law of thermodynamic from the high temperature media to the low temperature media [12]. Very cold air can absorb the heat from the vaporize nanofluid and become warmer which is suitable for the conditioned space. This can be shown in the green color of condenser fins in outside of this section. In conventional systems for this purpose, external energy such as electric energy is used [2]. The evaporator of HPHE functions as the air pre-cooler before cooling coil and the condenser of HPHE functions as the air reheat before electric coil in HVACs.

**Table (1.a).** Results approach from the ANSYS program after modeling the heat pipe. (Steady State operation Condition)

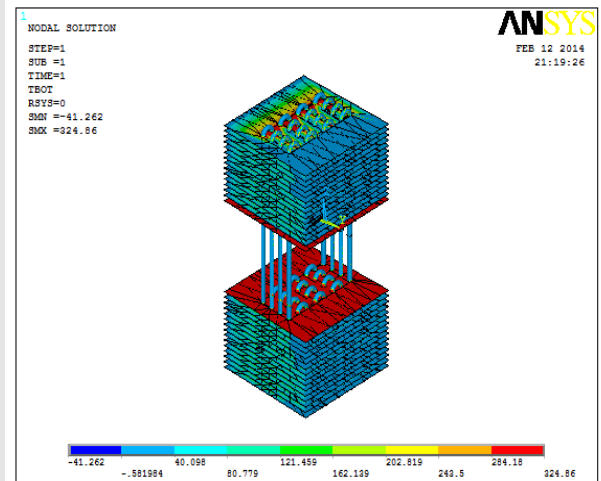
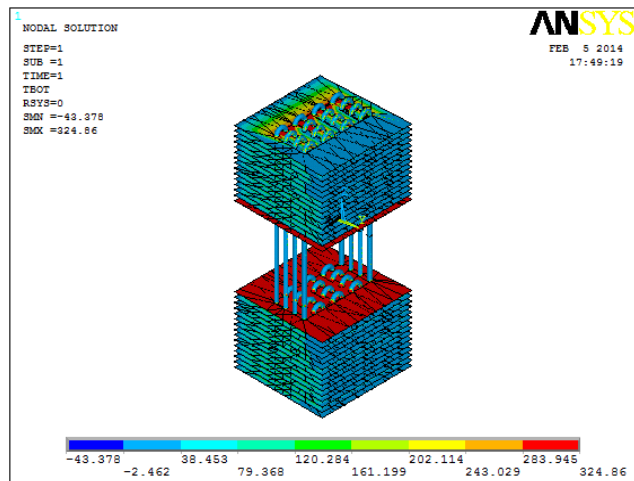


**(Steady State operation Condition)**

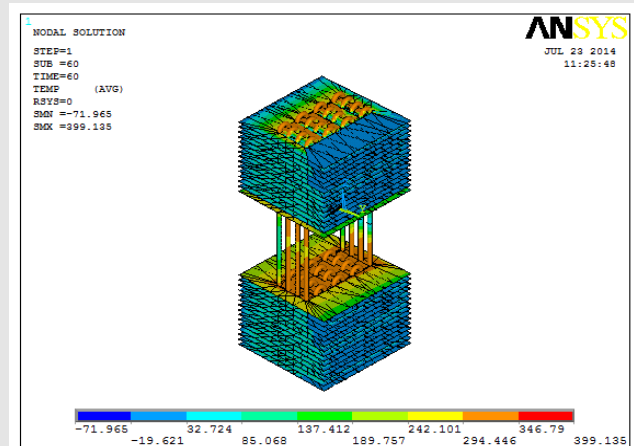
125 µm coat thickness



150 µm coat thickness

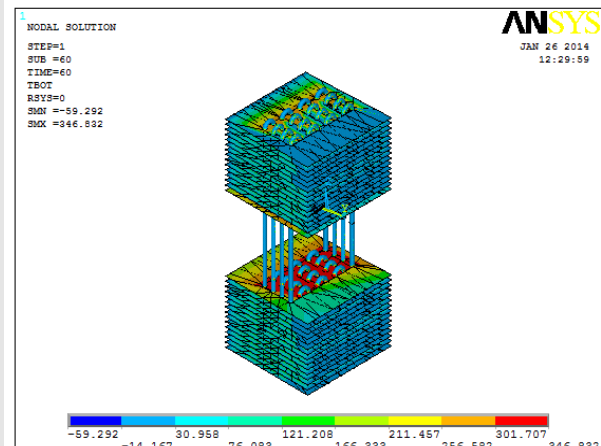
*Table (1.b). Results approach from the ANSYS program after modeling the heat pipe. (Transient operation Condition)***(Transient operation Condition)**

HPHE without coating



25 µm coat thickness

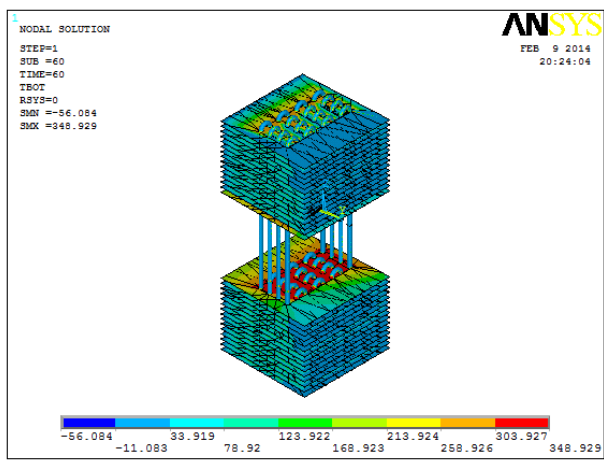
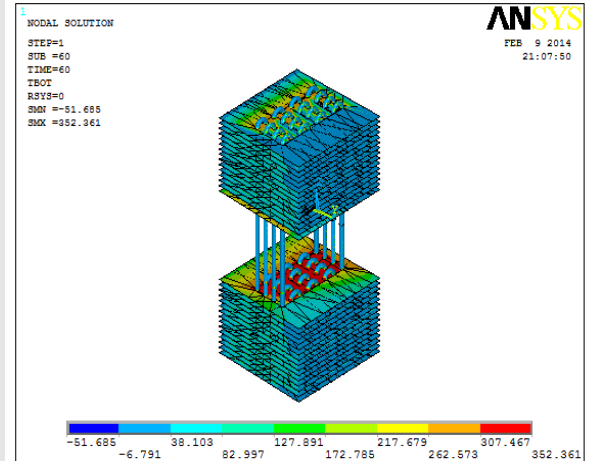
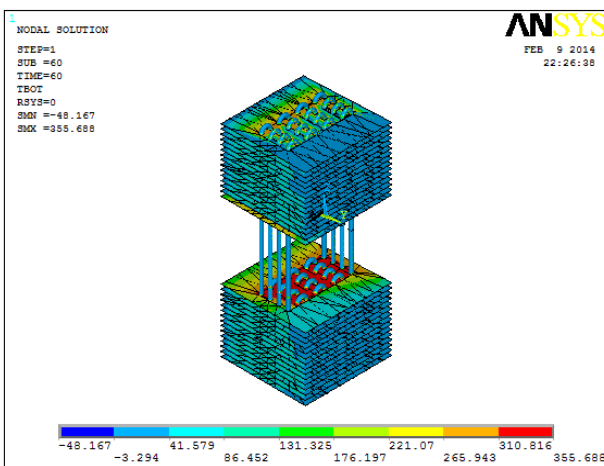
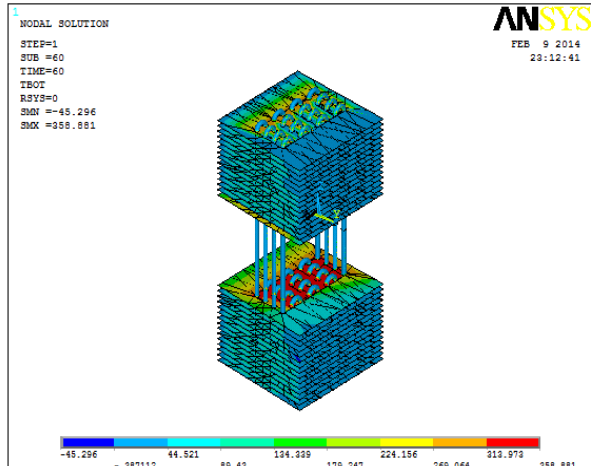
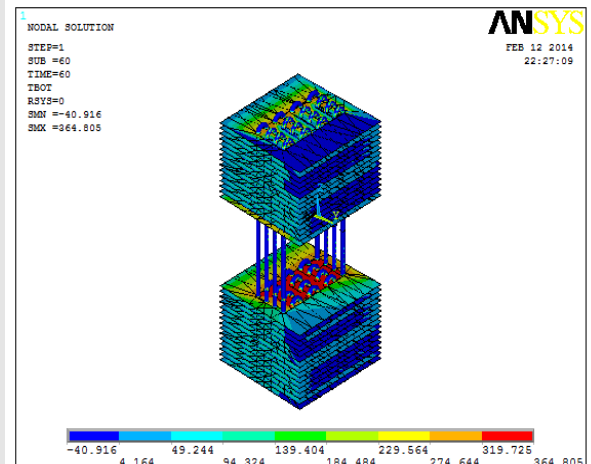
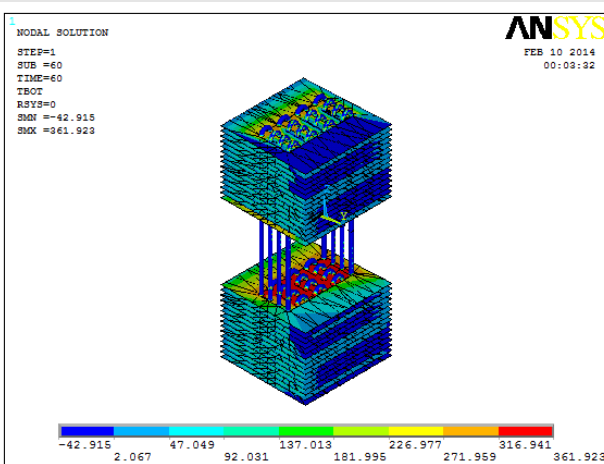
10 µm coat thickness



50 µm coat thickness



## (Transient operation Condition)

75  $\mu$ m coat thickness100  $\mu$ m coat thickness125  $\mu$ m coat thickness150  $\mu$ m coat thickness

The temperatures distribution in two positions for each fin in bottom and top of each evaporator and condenser sections for steady and transient operation conditions are listed in table (2).

After calculations of the percentages of thermal performance enhancement with nanocoating layers by using the equation  $((\text{Without Nanocoat}-\text{With Nanocoat})/(\text{Without$

Nanocoat))\*100. The results were arranged in Table (3). As observed from the values the using of nanocoat were successful in the evaporator section especially in transient case of operation. The best results occurred at the evaporator section of transient conditions especially in 150  $\mu$ m thickness coat.

**Table (2).** Temperatures distribution results which approach from running ANSYS program after the modeling heat pipe with all operation conditions.

Steady state conditions of operation								
Positions/Sec32	Al pure	Coat layer thickness(μm)						
		10	25	50	75	100	125	150
1	-14.2	-17.86	-14.83	-10.69	-7.39	-4.69	-2.46	-0.58
2	-14.2	-17.86	-14.83	-10.69	-7.39	-4.69	-2.46	-0.58
Positions/Sec4								
1	321.35	323.47	323.36	323.47	323.35	323.47	323.039	323.36
2	323.57	323.68	323.68	323.68	323.68	323.68	323.679	323.68
Positions/Sec3								
1	297.96	297.98	297.98	297.98	297.98	297.98	297.976	297.98
2	297.96	297.98	297.98	297.98	297.98	297.98	297.976	297.98
Positions/Sec31								
1	287.07	260.39	260.54	260.77	260.98	261.16	261.326	261.48
2	287.07	260.39	260.54	260.77	260.98	261.16	261.326	261.48
Transient conditions of operation								
Positions	Al pure	Coat layer thickness(μm)						
		10	25	50	75	100	125	150
Sec32								
1	-14.2	-16.608	-13.757	-9.846	-6.719	-4.17	-2.051	-0.27
2	-14.2	-16.608	-13.757	-9.846	-6.719	-4.17	-2.051	-0.27
Sec4								
1	260.14	68.173	61.431	52.383	45.335	39.72	27.908	16.98
2	302.96	253.95	253.09	285.7	217.75	217.03	213.472	248.86
Sec3								
1	279.87	276.01	274.22	270.87	267.19	263.27	294.095	289.61
2	279.87	276.01	274.22	270.87	267.19	263.27	294.095	289.61
Sec31								
1	287.07	260.44	258.93	260.79	260.98	269.06	261.324	261.47
2	287.07	260.44	258.93	260.79	260.98	269.06	261.324	261.47

**Table (3).** Percentages of thermal performance enhancement with different CuO Coating layers thickness

Evaporator (steady state)							Evaporator (Transient)						
Coat layer thickness( $\mu\text{m}$ )							Coat layer thickness( $\mu\text{m}$ )						
10	25	50	75	100	125	150	10	25	50	75	100	125	150
Bottom of Evap.(Sec32)							Bottom of Evap.(Sec32)						
-25.78	-4.44	24.71	47.96	66.93	82.66	95.92	-16.95	3.12	30.66	52.68	70.65	85.55	98.09
-25.78	-4.44	24.71	47.96	66.92	82.66	95.92	-16.95	3.12	30.66	52.68	70.65	85.55	98.09
Top of Evap.(Sec4)							Top of Evap.(Sec4)						
-0.66	-0.63	#VALUE!	-0.63	-0.66	-0.53	-0.63	73.79	76.38	79.86	82.57	84.73	89.27	93.47
-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	16.18	16.46	5.69	28.12	28.36	29.54	17.86
Condenser (steady state)							Condenser (Transient)						
Coat layer thickness( $\mu\text{m}$ )							Coat layer thickness( $\mu\text{m}$ )						
10	25	50	75	100	125	150	10	25	50	75	100	125	150
Bottom of Cond.(Sec3)							Bottom of Cond.(Sec3)						
-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	1.38	1.38	3.22	4.53	5.93	-5.08	-3.48
-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	1.38	1.38	3.22	4.53	5.93	-5.08	-3.48
Top of cond.(Sec31)							Top of cond.(Sec31)						
9.29	9.24	9.16	9.09	9.03	8.97	8.91	9.28	9.80	9.15	9.09	6.27	8.97	8.92
9.29	9.249	9.169	9.09	9.03	8.97	8.91	9.28	9.80	9.15	9.09	6.27	8.97	8.92

## 5. Conclusions

One of the most advanced methods to improve the thermal conductivity of heat pipes is coat the fins by nonomaterial. The recent advances in the field of micro and nanotechnology have led to the development of efficient methods for heat transfer enhancement using nano-fins which are expected to give unique heat transfer potential and more

efficient than the existing techniques. The effect of coating thickness layer on temperatures distribution on the fins was investigated. The best enhancement occurred at the evaporator section in transient conditions (-16.95, 3.12, 30.66, 52.68, 70.65, 85.55 and 98.09) for (10, 25, 50, 75, 100, 125 and 150  $\mu\text{m}$ ) thicknesses respectively. The maximum enhancement occurred at 150  $\mu\text{m}$  thickness coat. Coat process of the evaporator fins can give fast response of nanofluid inside HP to absorb the latent heat from the outdoor air and

vaporize to start the closed cycle for working the system so the increment in the energy saving is investigated which is the more important in HVACs.

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