The modified scheme of microwave for predicting the heat transfer rate

A.N. Yusoff[1], M.A. Salim[1,2,*], I.F. Ahamad[1,2] and G. Omar[1,2]

[1)] Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia
[2)] Centre for Advanced Research on Energy, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

[*]Corresponding e-mail: azli@utem.edu.my

Keywords: modified scheme; microwave; heat transfer rate

ABSTRACT – This paper presents illustration of the scenario for envision the heat transfer rate mechanism by applying simulation and analysis. Simulation and analysis were conducted using fluid flow (fluent) to figure out the flow process of thermal heat distribution occur through a medium. The evaluation was analyzed based on the visualization of temperature and heat distribution, and overall rate of heat transfer in modified scheme of microwave. Based on the results, the rate of heat transfers able to be increased with the aid of other heating tool or equipment and also depend on the material properties. In addition, it also shows the significant enhancement of the performance towards the modification on conventional microwave.

1. INTRODUCTION

The heating process in microwave is speedy and convenient. However, heating process in conventional microwave has a weakness in which the heating process is not uniform and may take some time to heat up the material evenly. In order to increase the conductivity of the conductive ink, heat is significant parameter to trigger the movement of atom particles of the conductive ink substances [1-3]. The materials or substances have highest water content will absorb microwave (electromagnetic wave spectrum) efficiently because microwaves excite more strongly towards liquid particles during heating process [1].

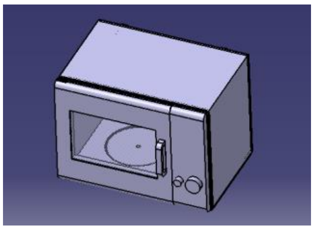
The crucial challenges to improve the uniformization of heat transfer inside cavity of microwave is the modification made to the domestic microwave by adding ultrasonic welder machine and heating rod. Large number of parameters required in the complex multiphysics model, thus the optimization of the input parameters still required to fix the model.

The objective of this study was to study an integrated method to enhance diffusion mechanism in conductive ink and illustrates the desired scenario of process of diffusion mechanism by using simulation and analysis. In this article, the development of the model and simulation and analysis results were elaborated

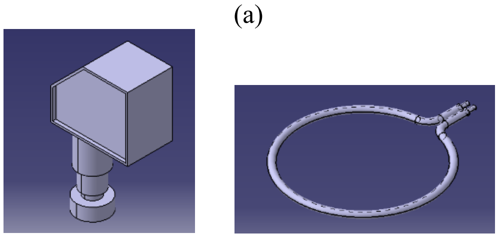
2. RESEARCH METHODOLOGY

2.1 Concept generation

Firstly, a concept of model was developed using two design approach, morphological chart analysis and Pugh method analysis. A finalized concept design model was chosen after evaluates the concepts based on the requirement needed. After that, a concept model was developing in CATIA V5R20 software. Each part of the model was sketched in mechanical part design workbench and assembled in mechanical assembly workbench as shows in Figure 2.1.



(a)

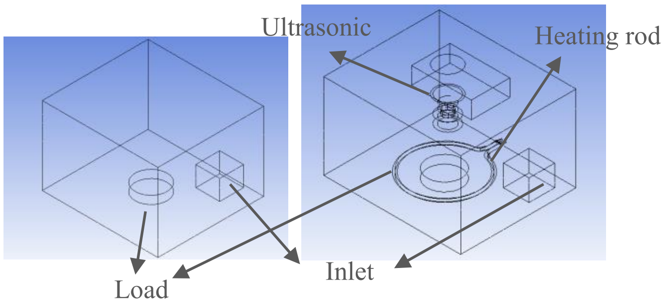


(b) (c)

Figure 2.1 Component of (a) microwave, (b) ultrasonic and (c) heating rod.

2.2 Modelling

The microwave and modified microwave cavity with dimension of 28x24x18 cm were used to simulate the thermal heat distribution. Figure 2.2 shows the configuration for both cavities, where the cylindrical glass sample was located in the center of the cavity.



(a) (b)

Figure 2.2 Configuration used in the (a) microwave and (b) modified microwave cavity, where a load with cylindrical shape located in the center of the cavity

2.3 Fluid flow (Fluent) analysis

This study was conducted using fluid flow (fluent) in ANSYS 18.2 software. The steady-state time condition was analyzed by applying energy equation and radiation surface to surface to the models. The modal analysis and function of the ultrasonic welding were neglected during the fluid flow analysis. Air was used which considered as working fluid for the heat exchanger inside the channel. For the boundary conditions, the inlet of the channel known as dielectric made of Alumina material was set 1273.15K and 1173.15K for Nichrome heating rod to a operating temperature. A boundary condition of stainless steel material was set to the wall of outlet with mixed thermal condition and the radiation condition was set up surface to surface to the cavity surface wall. The heat transfer coefficient was assumed to be constant at 50 W/m^{2}K for air, the free stream temperature operating at 300 K and the mass transfer is negligible. Table 2.1 shows the properties of material used for thermal analysis.

Table 2.1 The constant thermal material properties

Material	Density [kg/m^3]	Thermal Conductivity [W/mK]	Specific Heat Capacity [J/kgK]	Emissivity (ε)
Stainless Steel	7700	12	500	0.54-0.63
Nichrome	8400	1130	0.45	0.79
Alumina	3950	25	880	0.8
Glass	2520	0.8	792	0.95

3. RESULTS AND DISCUSSION

3.1 Results of fluid flow analysis

The result calculated in Fluent was remained constant due to the study that examined for constant properties. Figure 3.1 and Figure 3.2 shows the temperature contour which represents the heat transfer process inside cavity of microwave and cavity of modified microwave respectively by iterating of 300 step size with the value of one for the interval.

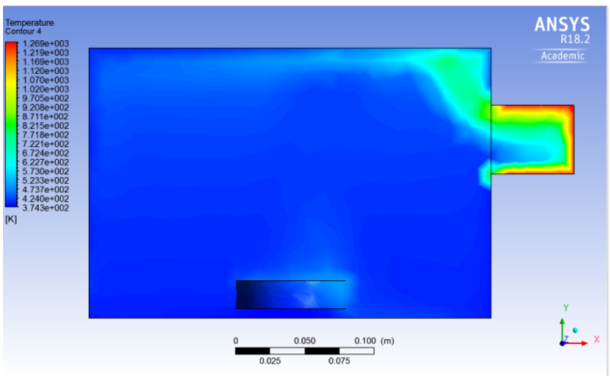


Figure 3.1 Temperature contour xy-plane of the khmicrowave cavity at the end of steady state run

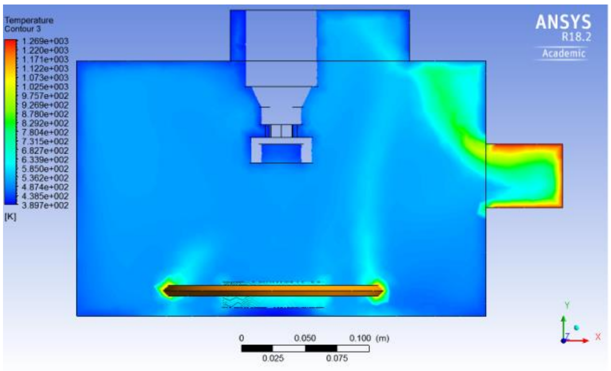


Figure 3.2 Temperature contour xy-plane of the modified microwave cavity at the end of steady state run

Based on the figure above, the heat distribute evenly inside modified microwave cavity and temperature of the cylindrical glass also increases as compared to the heat distributions inside conventional microwave cavity. With the aid of heat from heating rod, the appearance of hot spot which represent light blue up to red colour in the modified microwave cavity is more evenly spread throughout the space.

Table 3.1 The results temperature of cylindrical glass and interior wall of microwave cavity after iteration varies with inlet temperature

Material	Inlet Temperature (K)	Cylindrical glass surface temperature (K)	Interior wall surface temperature (K)
Alumina	1273.15	341.99	362.53
	1373.15	356.04	376.34
	1473.15	373.16	392.02
	1573.15	393.62	409.67
	1673.15	417.62	429.39

Table 3.2 The results temperature of cylindrical glass and interior wall of modified microwave cavity after iteration varies with inlet temperature.

Material	Inlet Temperature (K)	Cylindrical glass surface temperature (K)	Interior wall surface temperature (K)
Alumina	1273.15	516.47	451.07
	1373.15	528.20	457.74
	1473.15	541.51	468.36
	1573.15	558.46	479.29
	1673.15	575.73	491.16

The results of temperature of the cylindrical glass and the interior wall surface of microwave and modified microwave cavity obtained as refer to the Tables 3.1 and 3.2, repectively. From the result, temperature gained in modified microwave was slightly higher as compare to the temperature gained in conventional microwave.

Table 3.3 Total heat transfer rate varies with inlet temperature of conventional microwave

Inlet temperature (K)	Total heat transfer rate (w)
1273.15	72.16
1373.15	97.63
1473.15	129.30
1573.15	168.11
1673.15	215.06

Table 3.4 Total heat transfer rate varies with inlet temperature of modified microwave

Inlet temperature (K)	Total heat transfer rate (w)
1273.15	79.95
1373.15	106.10
1473.15	139.66
1573.15	178.45
1673.15	226.37

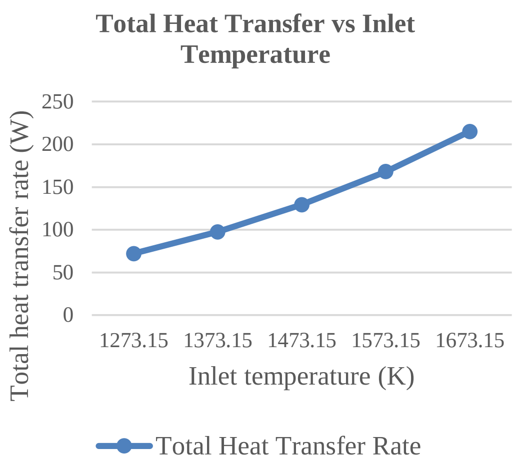


Figure 3.3 Graph of total heat transfer rate versus inlet temperature for conventional microwave

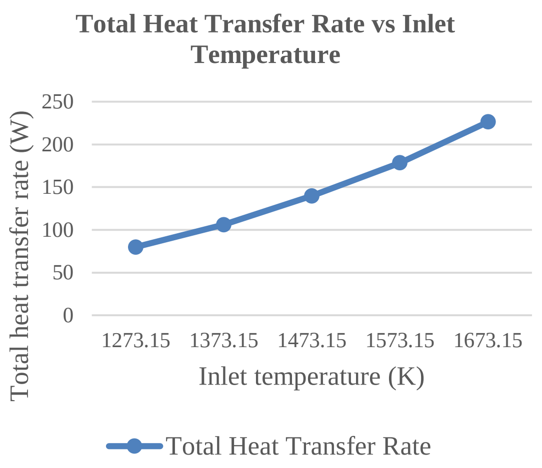


Figure 3.4 shows graph of total heat transfer rate versus inlet temperature for modified microwave

Graph shows in the Figures 3.3 and 3.4 show the results obtained for the total heat transfer rate for both cavities which tabulated in table 4 and table 5. There were marginly different of the value from the results gained after analysis run. From the observation, the value of total heat transfer rate in the cavity of modified microwave was larger than cavity area in microwave. This is because of the additional heat aid from the heating rod placed in the modified microwave that help to accelerate the heat absorbtion by a cylindrical glass. Therefore, the cylindrical glass more quickly absorbs the heat in the modified microwave than the cylindrical glass in the ordinary microwave that relies solely on heat from the dielectric.

4. SUMMARY

This study was carried out to design modified microwave and illustrate the scenario of heat transfer behaviour throughout cavity area in order to enhance the conductivity of silver nanoparticles ink. The morphological and Pugh method selection analysis were used as a tool to represent and combine ideas to produce finalized concept design. After that, a model developed in CATIA was used to simulate and analyze thermal conductivity by observing temperature distribution from the inlet to the area inside the cavity of modified microwave by comparing results of heat transfer rate with conventional microwave.

The heat transfer rate of modified microwave was slightly higher than the conventional microwave, thus this can be conclude that the heat distribute inside modified microwave cavity faster and this will help to increase the absorbtion of the heat by the sample and improve the conductivity of the ink. However, the analysis must be further study to analyze and compare the electromagnetic field distribution with different materials of dielectric properties and combine together the modal analysis of the ultrasonic horn with fluid flow analysis inside a modified microwave.

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