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"Analysis of Steel Slab for Unsteady State Heat Conduction by Hermite Aproximation"

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Abstract

This paper presents the ideas on improvement of lumped-parameter model for unsteady state (transient) heat conduction in a slab with temperature-dependent thermal conductivity. The transient temperature depends on various model parameter, they are Biot number, heat source and time. Polynomial Approximation Method (PAM) has been possible to derive a unified relation for the transient thermal behavior of solid (slab and tube) with both internal heat generation and boundary heat flux. In all the cases, a closed form solution is obtained between temperature, Biot number, heat source parameter and time.

A lumped parameter model (steel slab) has been adopted through two point Hermite approximations for integrals. For linearly temperature-dependent thermal conductivity, it is shown by comparison with numerical solution of the original distributed parameter model that the higher order lumped model yields significant improvement of average temperature prediction over the lumped model. For both cooling and heating processes a unified Biot number limit depending on a single dimensionless parameter β is given. The result of the present analysis can be used for conduction slab in heat exchanger and can withstand up to given temperature range.

Key words: *Hermite approximations, PAM, thermal conductivity, lumped model, nonlinear heat conduction, heat conduction, Biot number.*

Introduction

Heat goes from a higher temperature zone to lower temperature zone. Hot articles in a cooler room will be cooled to the room temperature. Colder items in a hotter room will heat up to room temperature.

Heat exchange is the trading of heat because of a temperature contrast with particular systems: conduction, convection, and radiation. Conduction means heat exchange that happens over a static solid or liquid in which a temperature gradient exists. Convection refers to the heat trade that happens over a dynamic liquid in which a temperature slope exists. Radiation intends to the heat exchange between two surfaces at diverse temperatures isolated by a medium straightforward to the electromagnetic waves discharged by the surfaces. Procedure of heat move in every one of the modes is appeared in figure 1.1

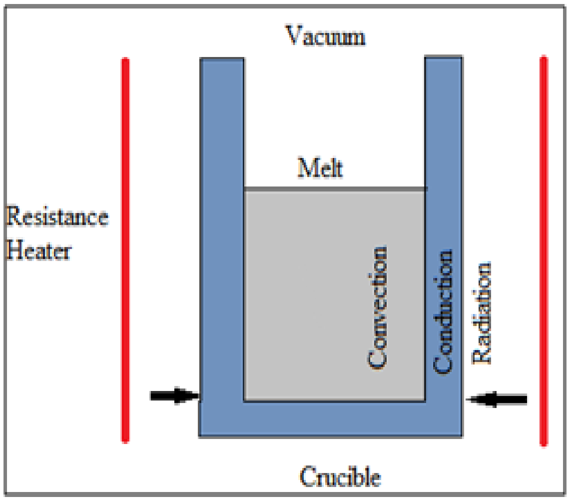

Figure 1: Process of Heat Transfer

A Definition of heat exchange is the transmission of energy starting with one locale then onto the next as an aftereffect of temperature inclination i.e. energy on the move because of temperature contrasts. Heat exchange expands the thermodynamic investigation by examining the basic procedures and methods of heat exchange through the improvement of connection used to calculate its rate. The variation in temperature is represented by the guideline of energy cabby445`` conservation, which expresses that," the total of the stream of energy and heat over the framework, the work done in the framework, and the energy put away and changed over inside of the framework, is zero. Heat move discovers application in numerous critical regions, to be specific configuration of heat and atomic force plants including heat motors, steam generators, condensers and other heat trade types of gear, synergist convertors, heat shields for space vehicles, heaters, electronic supplies and so forth, internal combustion engines, refrigeration and ventilating units, outline of cooling frameworks for electric engines generators and transformers, heating and cooling of liquids and so on in chemical operations, development of dams and structures, minimization of building heat losses utilizing insulation protection procedures, heat treatment of metals, scattering of barometrical pollutants, thermal control of space vehicles.

IMPORTANCE OF HEAT TRANSFER

The study of heat transfer is carried out for the follows purposes:

- To estimate the rates of flow of energy as heat through the boundary of a system under study (both under steady and transient conditions).
- To determine the temperature field under steady and transient conditions Heat transfer problems are encountered which cannot be solved by thermodynamic reasoning alone but require an analysis based on heat transfer principles.

HEAT TRANFER MODES

Heat exchange modes are three types: conduction, convection and radiation.

1) Conduction: This is the exchange of heat starting with one piece of substance then onto the next part of same substance, or starting with one substance then onto the next is physical contact with it, without apparent removal of atoms shaping the substance.

In solid, the heat is directed by cross section vibration and transport of free electrons. If there should be an occurrence of gasses, the system of heat conduction is basic. The kinetic energy of a particle is an element of temperature. These atoms are in a constant irregular movement trading energy and moment. If there should arise an occurrence of fluid, the component of heat is closer to that gas. Be that as it may, the atoms are all the more firmly separated and intermolecular power comes into play.

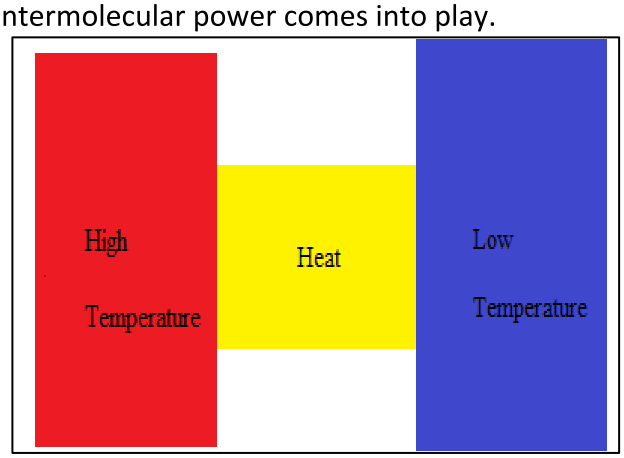

Figure 2: Heat Transfer via Conduction

In conduction process, Fourier's law of heat conduction is an exact law taking into account perception and states as, "the rate of course through a basic homogeneous solid specifically relative to the area of section at right angle to the direction of heat stream, and to change of temperature as for the length of the way of the heat stream". Numerically,

$$Q_{cond} = -kA\frac{dT}{dx} \quad (1)$$

Where A is the cross-sectional area through which the heat is conducting, dT is the temperature different between the two surfaces isolated by a distance dx, and units of conduction are W/m K.

Heat losses in Conduction: The body behaviors heat to whatever the skin is in direct contact with. Conductive heat loss happens when the skin is subjected to either cold air or water; however it is particularly basic in water, as your body loses heat around 25 times speedier in water than in air of the same temperature.

2) Convection: It is the exchange of heat inside of a liquid by mixing of one part of liquid with another. Convection can be either force through for example pushing the stream along the surface or natural/free as that which happens because of buoyancy force.

Natural convection (or free convection): In this the fluid motion is made by the warm fluid itself. The density of liquid decrease as it is warmed. Accordingly, hot fluid is lighter than cool fluid. Warm fluid encompassing hot items rises and is replace by cooler fluid.

Forced convection: It utilizes outside method for delivering fluid motion. Forced convection is the thing that makes a windily, winter day feel much colder than a quiet day with same temperature. The heat loss from your body is expanded because of the consistent renewal of cool air by the wind. Regular wind and fans are the two most normal source of forced convection.

Convection coefficient h is the measure of how successfully a fluid exchanges heat by convection. It is measured in W/m^2K, and is controlled by elements, for example, the fluid density, viscosity, and velocity. Wind blowing at 5 mph has a lower h than wind at the same temperature blowing at 30 mph. The rate of heat exchange from a surface by convection is given by Newton's law of cooling

$$Q_{conv} = -hA(T_{sf} - T_{\infty})(2)$$

Where A is the surface area of the object, T_{sf} is the surface temperature, and T_{∞} is the ambient or fluid temperature.

3) Radiation: Occurs where heat energy is exchanged by electromagnetic phenomenon, of which the light is an especially critical source. It happens between surfaces at different temperature regardless of the possibility that there is no medium between them the length of they face each other. **[18].** The measure of radiation emitted by an item is given by:

$$Q_{emitted} = \varepsilon\sigma.AT^4(3)$$

Where A is the surface area, T is the temperature of the body, σ is a constant called Stefan - Boltzmann constant, equal to 5.67×10^{-8} $W/m^2 K^4$, and ε is a material property called emissivity. Heat losses in radiation. The heat generated from within the body is given-off to the surrounding atmosphere.

PROBLEM DEFINITION

The goal of this study is to discover the gradient temperature and thermal stresses on a conduction slab at different heat flux. The material considered for the analysis are structural steel because, steel is most commonly used engineering material. Our thesis according to literature survey also shows that the mathematical formulation itself not sufficient to get appropriate result and it’s also very expensive. Hence, we are using Finite element analysis (FEA) with the help of Hypermesh software in which we can find the result at every small point of the conduction slab. Other than that, by doing the analysis we can perform number of iteration which is cost effective also.

PROPOSED METHODOLOGY

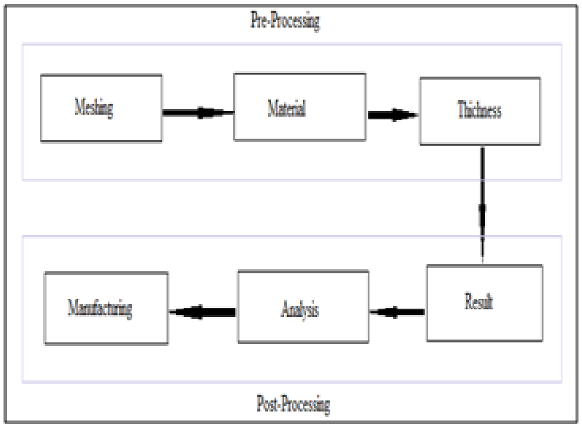

Figure 3: Process Flow Chart

SELECTION OF MATERIAL

We are taking the steel material for the slab by considering it as linear material. In this material we have to assign the properties of material such as Modulus of elasticity or Young Modulus (N/mm^2), Density of Material ($Tons/mm^3$) and Poisson's ratio. Moreover we have to assign thermal conductivity of steel. All the properties of steel material is shown in table 1

Table 1 Steel Material for the slab

Density (rho) $Tons/mm^3$	Modulus of elasticity (E) N/mm^2	Poisson's Ratio	Thermal Conductivity (k) W/m K
7.9 E-9	210000	0.350	0.73

RESULTS AND DISCUSSION

Results: Heat input of different intensity is provided to the conducting heat flux for measuring the maximum and minimum temperature generated in slab. 9 iterations were performed to calculate maximum and minimum temperature of the slab. Starting with 100kW to end up with 500kW, we have performed the iterations.

(i) The figure 4 showing the results of maximum temperature and minimum temperature at 100kW heat flux.

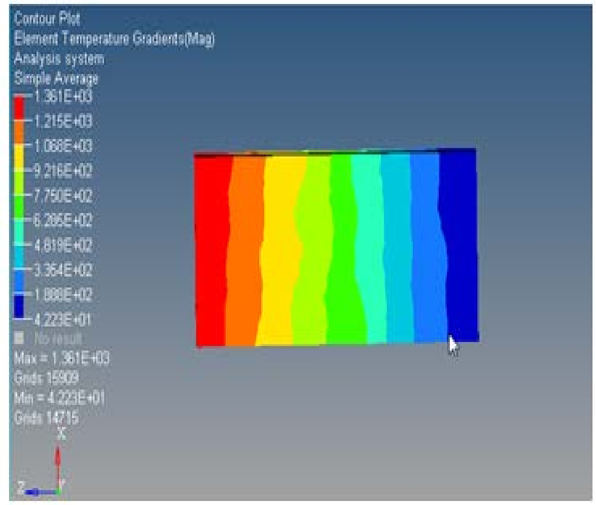

Figure 4: Hyperview panel for post processing

The area which is in red color shows the maximum temperature and the rest of the area which is shown in blue color shows the minimum temperature. Hence Maximum temperature in a steel slab when we have applied the heat of 100 kW is 1361°C and the minimum temperature is 42°C.

(ii) The figure 5 showing the results of maximum temperature and minimum temperature at 150 kW heat flux.

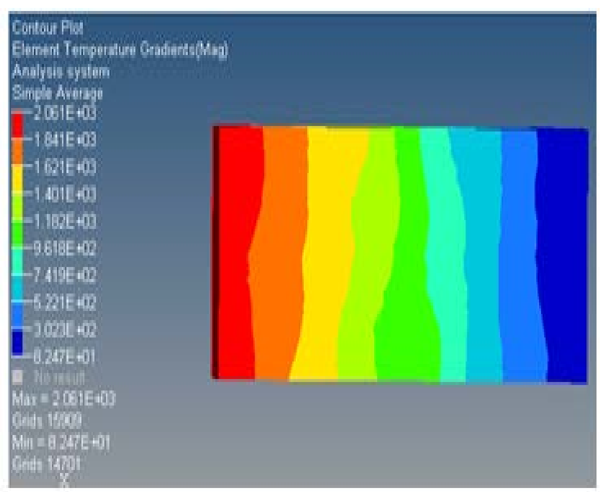

Figure 5: Contour plot of conduction slab at 150 kW

When 150 kW heat is applied then maximum temperature is 2061°C and minimum temperature is 82°C.

(iii) The figure 6 showing the results of maximum temperature and minimum temperature at 200 kW heat flux.

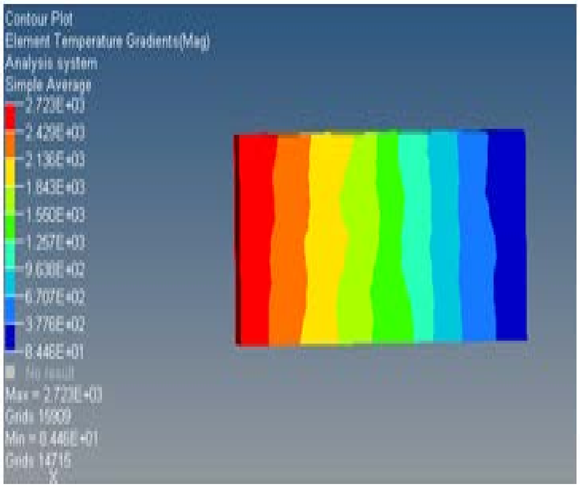

Figure 6: Contour plot of conduction slab at 200 kW

When 200 kW heat is applied then maximum temperature is 2720℃ and minimum temperature is 84℃.

(iv) The figure 7 showing the results of maximum temperature and minimum temperature at 250 kW heat flux

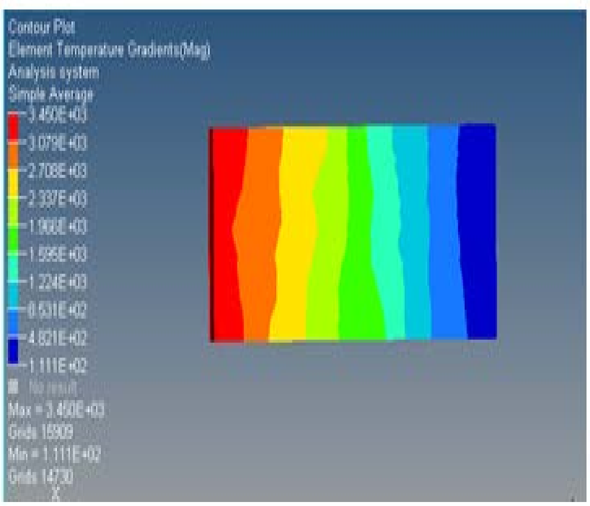

Figure 7: Contour plot of conduction slab at 250 kW

When 250 kW heat is applied then maximum temperature is 3450℃ and minimum temperature is 111℃.

(v) The figure 8 showing the results of maximum temperature and minimum temperature at 300 kW heat flux.

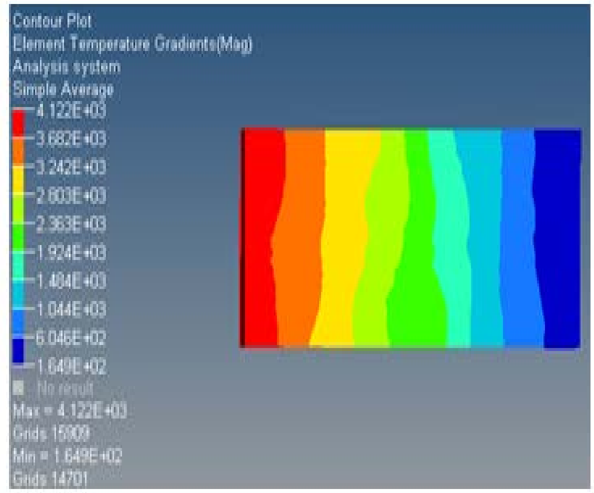

Figure 8: Contour plot of conduction slab at 300 kW

When 300 kW heat is applied then maximum temperature is 4122℃ and minimum temperature is 164℃.

(vi) The figure 9 showing the results of maximum temperature and minimum temperature at 350 kW heat flux.

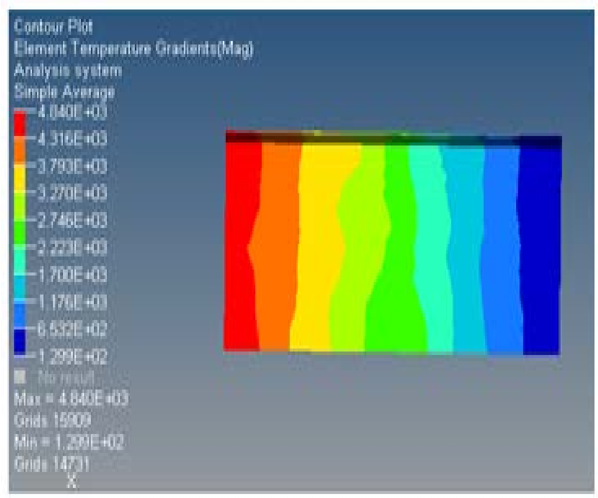

Figure 9: Contour plot of conduction slab at 350 kW

When 350 kW heat is applied then maximum temperature is 4840℃ and minimum temperature is 129℃.

(vii) The figure 10 showing the results of maximum temperature and minimum temperature at 400 kW heat flux.

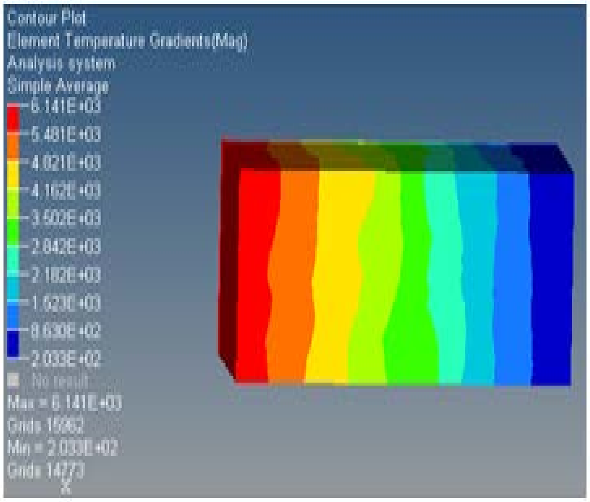

Figure 10: Contour plot of conduction slab at 400 kW

When 400 kW heat is applied then maximum temperature is 5445°C and minimum temperature is 168°C.

(viii) The figure 11 showing the results of maximum temperature and minimum temperature at 450 kW heat flux.

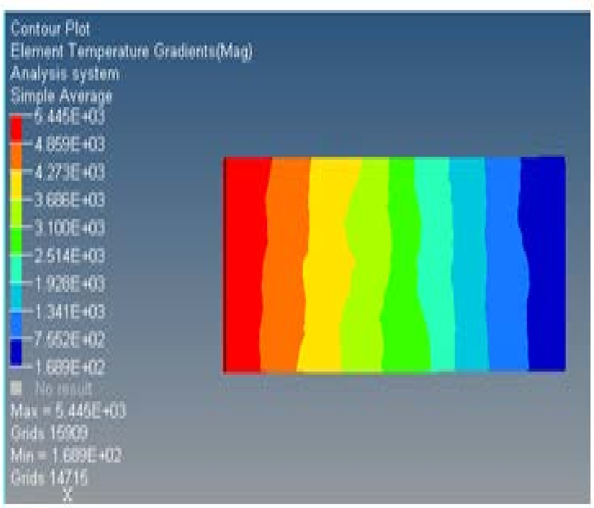

Figure 11: Contour plot of conduction slab at 450 kW

When 450 kW heat is applied then maximum temperature is 6141°C and minimum temperature is 203°C.

(ix) The figure 12 showing the results of maximum temperature and minimum temperature at 500 kW heat flux.

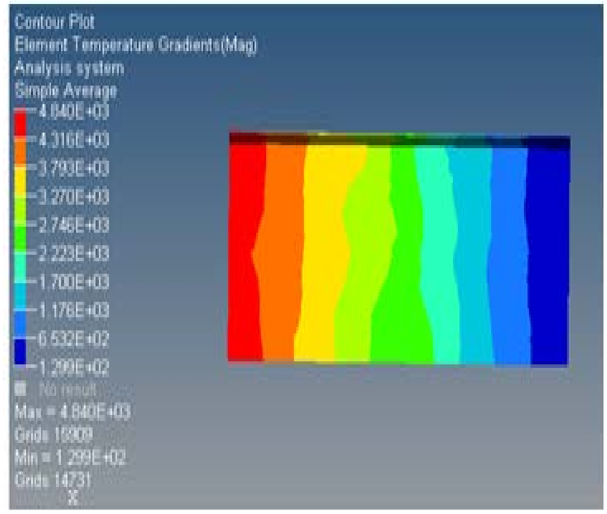

Figure 12: Contour plot of conduction slab at 500 kW

When 500 kW heat is applied then maximum temperature is 6900°C and minimum temperature is 222°C.

Table 2 Result analysis of heat conduction in a slab and corresponding temperature obtained

Heat load (Q) (kW)	Maximum Temperature (°C)	Minimum Temperature (°C)
100	1361	42
150	2061	82
200	2720	84
250	3450	111
300	4122	164
350	4840	166
400	5445	168
450	6141	203
500	6900	222

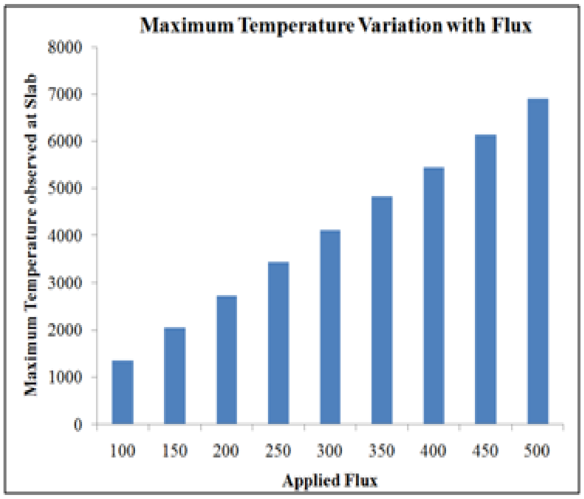

Figure 13: Amount of heat provided to the conduction slab maximum temperature obtained from it (Results Comparison)

Line demonstrates the measures of warmth given to the warmth flux, and at given distinctive warmth stack the greatest temperature and least temperature variety in section. The load applied between 100 to 500 kW and temperature variety between 0 to 8000^{0}C.

Discussion: When we provided Heat input of different intensity to the conducting heat flux for calculating the maximum and minimum temperature generated in slab. The 9(nine) iterations were performed to calculate maximum and minimum temperature of the slab. The heat flux is applied between 100 kW to 500 kW. In the first iteration, 100 kW heat flux is provided at the one end of slab area, then the higher temperature 1361 ^{0}C is generated and its dropdowns to lower temperature 42 ^{0}C at second end of the slab. Hence we found different phase of heat conduction at contour plot, red color shows higher temperature and green color at lower temperature. Similarly other eight iteration were found in contour plot for different heat fluxes thus maximum and minimum temperature generated. In this analysis the solid slab of steel material properties for the heat exchanger is being analyze, which is use in power plant to generate the electricity. The solid slab of steel material run error free between 100 kW and 500 kW load it means that this solid slab of steel (dimensions 200*100*100) can be usable anywhere between these heat load. The main objective of this analysis is to selecting right engineering materials to manufacturing of engineering devices using for different industries. In the past the selection or right engineering material by theoretical method is too difficult due to long numerical calculations. This takes more time and gives errors during material property selection, due to this issue the breakdown of engineering devices is found in large amount. Early, to solving this type of problems the Finite Element Method has been developed. In this method the selection of right engineering materials is easily done and gives error free numerical calculations in less time than other methods. Hence our analysis done for solid steel slab for heat exchanger device, the analyses solid slab can be work between 100 kW to 500 kW of heat load. This can be use in power plant industries or any other manufacturing/production industries for given load variations.

CONCLUSION

In this research work solid slab (Dimensions 200×100×100) of steel AISI1018 or steel AISI material for heat conduction is taken which is used in heat-exchanger. In the above research heat flow pattern in a steel conduction plate is analyzed. Nine iterations are performed with different heat source and measured corresponding temperature at different element zone. On the basis of analysis we can assure that one can use this kind of conduction slab in heat exchanger and can withstand up to given temperature range.

REFERENCES

1. Rajendra P. Patil, Dr. Atul Patil, Pro. T.A. Koli, “Analysis of Steady State Heat conduction in Different Composite Wall”, International Journal of Innovative Research in Science, Vol. 4, Issue 7 July 2015.
2. N Ravindra babu, Dr. C Natarajan, “Temperature Distribution in Concrete Slabs Exposed to Elevated Temperature”,

International Journal of Engineering Science Invention, 2319-6734, Vol. 3, Issue 31 March 2014, PP. 35-43.

3. Amechi Joseph Ujam and Chinagorom Ajike, "Analysis of Heat Flow in a Slab Using the Finite Element Model", IOSR Journal of Engineering, Vol-2, Issue 10 Oct. 2012, PP.59-65.
4. Sharanjeet Dhawan, Sheo Kumar, "A Comparative study of Numerical Techniques For 2D Transient Heat Conduction Equation Using Finite Element Method", International Journal of Research and Review in Applied Science, 2073-7366, Vol. 1, 1Oct. 2009.
5. Malte Estorf, "Thermal Frequency-Response Characteristic of a Solid slab", Vatten fall Europe Nuclear Energy GmbH, Über seering 12, 22297 Hamburg, Germany, Revised August 2009.
6. B. Kundu, D. Bhanja, "Performance and Optimization Analysis of a Constructal T-shaped Fin Subjected to Variable Thermal Conductivity and Convective Heat Transfer Coefficient", International Journal of Heat and Mass Transfer, Volume53, Issues 1-3, 15 January 2010, pages 254-267.
7. P. Kettil, N-E. Wiberg, "Adaptive 3D finite element analysis in structural design",568 (2001).
8. E. Rank, A. Düster, "Dimensional Adaptivity Using the P-version of the Finite Element Method", 114 (2000).
9. D. Kelly, T. Cao, "Point-wise Estimates for the Finite Element Method in Engineering: a Super-convergent and Local Approach", 578 (2001).
10. Douglass, John G.; Young, Marvin; Washington State Energy Office, "An Analysis of Predicted vs. Monitored Space Heat Energy use in 120 Homes", 2010 T 23:59:59.000Z.
11. Mikhail Mikhailov, Gianni Comini, S. Del Giudice, G.P. Runchi, "Determination of Thermal Wave Distributions by the Finite Element Method", 03/1977; 20(3): 195–200 DOI: 10.1016/0017-9310(77)90205-8.
12. Gergely Friedl, Miklos Kuczmann, "Edge Finite Element Method in case of High Frequency Simulation", 2014.
13. Antony S. H. Lowe, Thomas Morel, "A New Generation of Tools for Accurate Thermo-Mechanical Finite Element Analyses of Engine Component", 1992-02-01.
14. F. Alhama, A. Campo, "Electric Network Representation of the Unsteady Cooling of a Lumped body by Nonlinear Heat Transfer Modes", J. Heat Transf. 124 (2002) 988–992.
15. J. Su, R.M. Cotta, "Improved Lumped Parameter Formulation for Simplified LWR Thermo-hydraulic Analysis", Ann. Nucl. Energy 28 (2001) 1019–1031.
16. O. Balima, Y. Favennec, D. Petit, "Model Reduction for Heat Conduction With Radiative Boundary Conditions Using the Modal Identification Method", Numer. Heat Transf. Part B Fund. 52 (2) (2007) 107–130.
17. P.E. Ergatis, P.G. Massouros, G.C. Athanasouli, G.P. Massouros, "Time-dependent Heat Transfer Coefficient of a Wall", Int. J. Energy Res. 27 (2003) 795–811.
18. Chris long and Naser Sayma, " Heat Transfer", Ventus Publishing APS ISBN (2009) 978-87-7681-432-8.
19. A. G. Ostrogoraky, "Transient Heat Conduction in Sphere", Heat Mass Transfer, 44,(2008), 1557-15.