Identification of the Size or Thickness of the Coating of a Homogeneous Material on a Hard Metal Block

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Abstract— A try to determine the size or the thickness of the coating of the coating of a homogeneous material on to solid metal hard block. Firstly, we will find out the variation in uniform and non- uniform thickness of the material coating through the conduction method of heat transfer that is severely find out or predicted at extremely high temperature. We have selected the hard steel metal block of square shape for the experiment having the different thickness of coating. At the top of the metal block maintaining the constant heat flux and other three sides are maintained at constant temperature. At the top of the metal block, the temperature profile is quite different for the varied uniform and non-uniform thickness of the coating. On the basis of the statistical parameters which are predominantly found with the help of the CFD analysis, is easy to find out the thickness of the coating of homogeneous material. With the help of Finite Volume Method in Two- Dimensional Analysis in fully automatic way, the experimental data is collected for the problem that is being analyzed. A Genetic Algorithm is coded to speed out the performance of the Artificial Neural Network used to decode the problem statement.

Key words: Coating of a Homogeneous Material, Hard Metal Block

I. INTRODUCTION

The selected problem is a steady – state problem. The steady state condition is that in which the temperature within the premises of system does not change with time. The application of steady state heat transfer analysis is to determine the temperature distribution and heat flow in a body. These analysis may be performed at every point within the model, including the surfaces, is independent of time. Same here, the problem we selected is a steady state problem and we have find out the thickness of the material coating with the help of the determination of the temperature profiles at varying length from the boundary conditions. In transportation, especially in airplanes, rockets, warships, marines and sub – marines; there is a wide application of the coated and sub – coated materials having uni or bi blend materials. The application of 2D and 3D analysis is enormously seen in the corporate sector as, the machinery, air- conditioning and fluid flow determination. The surface coating of any material makes it tough and protects it from the corrosion and other harmful reactions, and improves its life with strength. To determine the thickness the of any material coating, we have to know the temperature profile throughout the material block. Thermography is result of above process application. Thermography is widely used in medical science to read out the images of the human body. Thermography is a non- contact images process and there is no transfer of heat into the body. Thermography applications are used in breast oncology, neurology, cardiology, orthopedics, pain management system, veterinary medicine. The application of Thermography is continuously increasing in the modern era, as it also have a vast predominant history.

II. PROBLEM SPECIFICATIONS

In our problem we have taken the hard material block. There are several hard materials that are available in nature in pure or impure form. For example – Quartz, Gypsum, hard coal and Steel etc. In our experiment we have selected the steel as hard material. Because it is easily available, cheap, does not harm to our health have good strength and corrosion properties. It can sustain at high temperature as 1700 degree F. It can be oxidized at elevated temperatures. For coatings many materials are available. According to the International Metal Fusion Corporation the coating materials are Aluminum, Brass, Bronze, Copper, and Lead etc. For experimental setup we have selected the Copper for coating having good properties such as corrosive resistant, high heat and electrical conductivity, easily available, cheap and do not harm to our health as well as to environment. We have taken a hard steel square shaped block, coated with copper on its surface. Steel square block dimensions as well as the dimensions of coating is shown in figure.

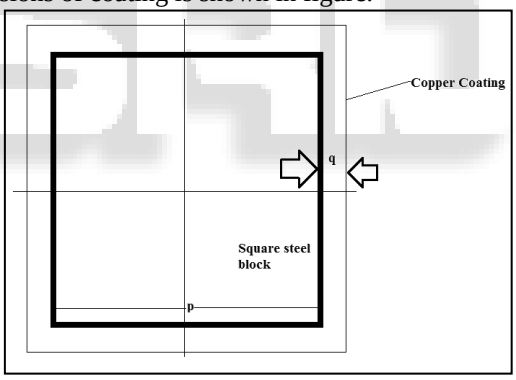

Fig. 1: The schematic representation of square steel block with copper coating.

The each side of the square is represented by ‘p’ and is kept equal to 1.0 m (every side) while the ‘q’ represents the thickness of the copper coatings. Attribute ‘q’ will vary in every case. A two dimensional coordinate system with its origin is set at Centre of the block. X and Y positive axis considered along the right and upper directions, respectively. The left, right and bottom side of the block is maintained at constant temperature. While the top side is maintained with constant heat flux input with boundary wall conditions. With the help of Finite Volume Method, once the geometry accessed the boundary conditions; the temperature profile at the top of the block is determined by generalizing the two dimensional heat equations. Once the temperature distribution is achieved the thickness of coating is easily determined.

III. METHODOLOGY

Due to the heat conduction through the top wall by the constant heat flux, so the heat travels in remain three sides of the block. Now with the help of two - dimensional heat equation the temperature profile will find out in the whole block. At the top of the wall the temperature will vary for different kinds of thickness of several materials. To solve the transportation problem of heat conduction the two software's are commonly used named as Gambit and Fluent. Gambit is used for making the geometry and for meshing it while the Fluent is used for numerical calculation purpose using Finite Volume Method.

A different temperature profile is seeing at the top of the wall for different types of material coatings and it is quite different for the copper coating. Along the top wall the reading of temperature or temperature distribution values is carried at regular interval at different length throughout the solid square shaped steel block. As per the uniform and non – uniform thickness of coating the variety of temperature values is collected. And this data is collected with the help of CFD software such as Gambit and Fluent. The Neural Network is guided by the training data and the experimental data is used to check the determination capability of the developed technology and methodology. The Gambit is used to define and simplifying the problem and the experimental data is used in mesh file. After receiving the processed mesh file from the Gambit and giving input to the Fluent itself to reach the destination temperature profile at the top of the block wall, and solve the 2D heat conduction problem. The one complete set of data is collected in this first process. To get a large variety of data for the block wall simultaneously from the Gambit and Fluent. If we do this process manually, it is too tough to achieve the task; it is time taken and hard process.

A. Governing Equation and Boundary Wall Conditions

The governing equation of 2D heat conduction process to find out the thickness of the coating is given as that is with no heat generation-

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial y}\right)=0 \qquad (1)$$

The wall boundary conditions are used for bottom, left and right side and top side of the square block. At the wall, boundaries the no – slip and no – penetration condition is applied and the u=0, v=0. Now at the top of the wall constant heat flux is maintained while at the bottom, left and right side the constant temperature is maintained.

B. Grid Size

The grid pattern is employed as the triangular grid is applied and the value starts from .0025 m, aspect ratio 1.5 and end size is 0.02m; for the inner face. For the outer face the grid size is .0015 m.

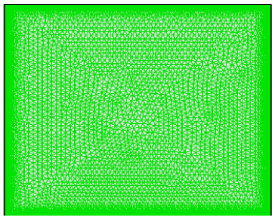

Fig. 2: The schematic representation of the grids for the particular thickness.

IV. RESULTS AND DISCUSSION

In this the Grid Independence Test is mentioned in the first step that is in the form of different temperature profile graphs. Results are available for uniform and non – uniform coating thickness.

A. Grid Independence Test

Finite Volume Method generated the temperature profile at the top of the wall, numerically. In the Grid Independence Test, the pave type triangular grid is selected. The grid size being varied while the other parameters are fixed as the thickness of coating and size of block. According, to the mesh file a temperature profile is generated at the top wall; for every grid size. The parametric study of the three parameters as start size, aspect ratio and end size is proceed for selecting the grid size. Now keep the aspect ratio and end size fixed and there is variation in the start size. For the inner face, the start grid size varied with temperature profiles is shown in figure.

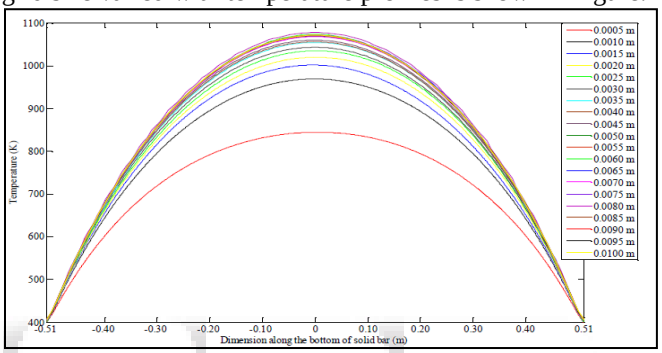

Fig. 3: For inner face, the start grid size with varying temperature profile.

B. Prediction of Coating Thickness

To determine the thickness of the coating of solid metal block, the Neural Network is trained by the training data. The Neural Network performance is optimized by the coded Genetic Algorithm. Then, the comparison between determined thickness and original thickness is made. The performance of the Neural Network is tested with set of test data.

C. Thickness varying on Top Side (Keeping fixed the other sides)

Following the same procedure the comparison is made between the thickness during the simulation and the predicted thickness for each individual test case is shown in figure.

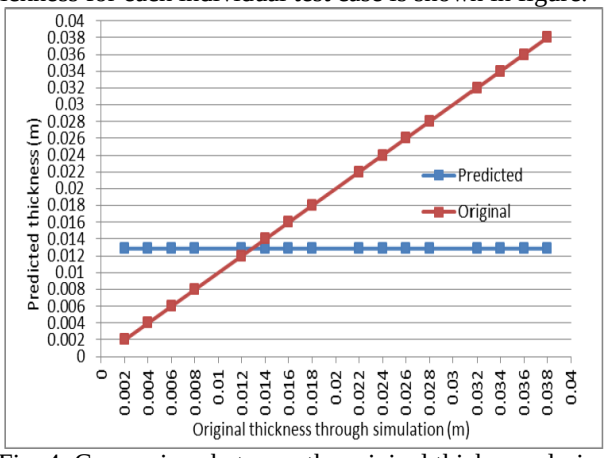

Fig. 4: Comparison between the original thickness during simulation and predicted thickness.

The two sets of comparison between the temperature profile with original thickness and predicted thickness that is shown in figure, by using the optimum sets of Neural Network parameters.

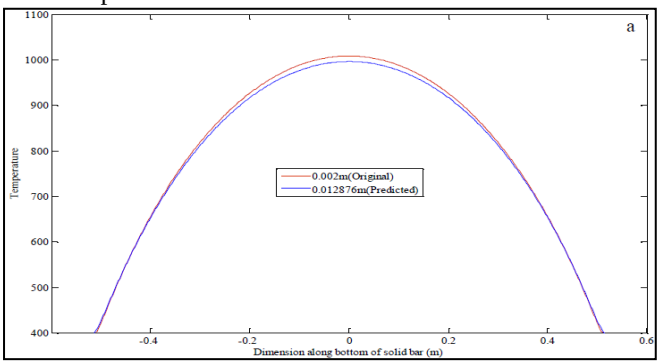

Fig. 5: Type one comparison between the thickness during the simulation and predicted thickness

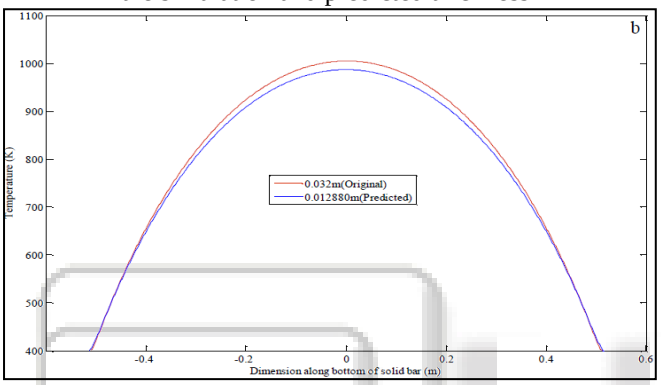

Fig. 6: Type two comparisons between the thickness during simulation and the predicting thickness through the developed methodology.

V. CONCLUSION

By using the developed methodology the determination of the coating thickness by using the conduction analysis by using the programming language C and the analysis software Fluent and Gambit. The performance of developed methodology is measured to determine the uniform and non- uniform thickness of coating material on a homogeneous solid body of steel from some known temperature elsewhere in the block at the top of the wall Gambit and Fluent software that works in fully automated way is used to determine the thickness of several coating thickness, numerically. Statistical parameters of temperature profile have been extracted using the MATLAB to build the training and test data. To determine the thickness of the coating the Feed- Neural- Network is used with the back propagation algorithm. The neural Network has been designed in the C language using the LINUX operating system. A Genetic Algorithm has also been designed in C language in LINUX operating system to optimize the performance of the Neural Network parameters. By analyzing the temperature profile the top wall for different coating thickness, it can be concluded that the temperature profile the top wall is very much affected by the thickness of the coating. It can be said the developed methodology may be applied for the other prediction problems through the conduction analysis.

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