Determination of the size of the coating of a homogeneous material on a hard metal cuboid

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Abstract
To determine the size of the thickness of the coating of the coating of a homogeneous material on to solid metal hard cuboid. 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 problems statement.

Keywords: Coating, thickness, Aspect ratio, gambit

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.

To determine the thickness 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.

Literature Review:- In Today's global economy and competitive manufacturing environment place extreme demands on product performance and product efficiency. In this environment coatings are applied to a diverse range of components and products. Coatings are applied for many reasons including performance characteristics such as corrosion, resilience, wear reduction, lubrication, electrical characteristics, and for aesthetics. The thickness of any coating is important for its impact on a product's performance and technical properties as well as financially in relation to production costs. As there are many different types of coating that can be applied to a range of base materials there are also different physical, chemical, and mechanical methods of measuring the coating thickness. Different test methods are suited for specific measuring applications depending on the material used tier the coating and the substrate. The various test methods offer different levels of accuracy and are suitable for different coating thickness. Test methods can be broadly categorized in destructive and non-destructive measurement. Magnetic induction, eddy current, and X-ray. Wet film measurement of the most commonly used non-destructive coating thickness test methods. Commonly used destructive test methods include coulometric and cross sectioning. There are several steady state 2-D heat conduction problems and solutions, solving techniques given in different technical books and journals such as a Laplace Equation. These equations are solved on the basis of given or available boundary conditions. The concept to determine the thickness of coating material emerged seeing the wide application of coating tools and material in several industrial purposes such as the Carbide tools. There are several methods that we have studied during study to measuring the coating thickness such as Magnetic Gauges, Magnetic and Electromagnetic Induction, Magnetic Pull – Off, Eddy Current Gauges, Ultrasonic Gauges, and Gravimetric, Dry Powder Measurement and Wet Film Measurement. Here are using the Wet Film Measurement Process. In wet film measurement process we paint a metal block by any homogeneous material that is easily available in market. Any hard metal block is painted by the coating material and several heat applications are provided on the block. We use the several boundary conditions to measure the thickness.
In the starting, the varying material coating thickness is hardened by the technique of laser surface hardening process of hard steel that was given by the Woo and Cho in (1997). By following this process the steel remains too tough without any emerging fracture possibility. This process is specially followed for the Carbide and High Speed Steel tools that works at larger temperature. A technique used to find out the thermal conductivity or heat conduction across the interface between thin films or a thin isotropic thermal coating and anisotropic substrates. The 3-ø method is another technique.

A vital role is played by the thin coating on the industrial devices that increase the performance of the metal for a long lasting. The Deposition Process increases the performance of the material by coating. For the Thin Film Deposition the most common method used is Evaporation. In this method, the evaporation of the source material is done in the vacuum. This allows vaporizing particles to travel directly to the target object that is called Substrate, where they condense back to solid state. In macro-scale products such as metalized plastic film and micro fabrication, the Evaporation process is most widely used. For the macro fabrication the Laser Metal Deposition process is most commonly used. Laser Metal Deposition is an additive manufacturing process in which a laser beam forms a melt pool on a metallic substrate or target object, into which powder is fed.

On the basis of the experimental data find out during the vapor deposition, the optimization is done of the coating variables for achieving the maximum hardness of titanium thin film layers. The optimization of the coating variables for the hardness of industrial tools is based on the Artificial Neural Networks that was given by Yazdi, Khorasani and Faraji in (2011). The surface roughness in CNC lathe is determined and controlled by the Artificial Neural Networks that was given by Karayal in (2009). Chemical vapor deposition was given by Polini, Mantini, Braic, Amar, Ahmad and Taylor in (2006). Optimization of machinery variable by using micro multivariable genetic algorithm. The use of design of experiments to improve the neural network model in order to predict the thickness of the chromium layer in hard chromium plating process was given by Lasheras, Vilan, Neito and Diaz in (2010). Prediction of the thickness of the wire coating extrusion process using Artificial Neural Network. To describe the wire coating thickness the three layer back propagation artificial neural network was used. The Artificial Neural Network is capable of demonstrating the thickness of coating by comparing the experimental data. Integrated Artificial Neural Network – Genetic Algorithm for estimating the minimum value for machinery performance was given by Zain, Haron and Sharif in 2011. Modeling of Electrostatic Fluidized Bed coating process using artificial neural networks. Optimization of a photoresist coating process for photolithography in wafer manufacturing via a radial basis neural network was given by Shie and Yang in 2005. Regression and Artificial Neural Network Models for estimating minimum value of machining performance was given by Zain, Haron, Qasim and Sharif in 2011. Two-dimensional optimization of functionally graded material using mesh analysis and a genetic algorithm. A simulation technique for predicting the coating thickness of the thermal sprayed coatings. In our experiment, to determine the thickness of coating deposited using thermal spray process; we have designed the two dimensional finite difference simulation models. To determine the range of slot die casting, the minimum coating thickness was predicted. A simulation technology is prepared to predict the thickness limit in slot die casting. Detection of defects in thermal barrier coatings by thermography analysis. Thermography plays a vital role in the field of medical sciences. Thermography is a technique used to maintain the early age temperatures of hardening concrete was given by Azenha, Faria and Figueras in 2011. The usage of IR thermography for the temperature measurement inside the automobile cabin was given by Korukcu and Kilic. A review of thermography as a promising non – invasive detection modality for breast tumor was given by Ng in 2009. The throughout study shows that, to determine the thickness of coating material the temperature profile is an important aspect which helps us to achieve the tough task. We have to use the appropriate technique, technology and resources that are beneficiary for our experiment.

**Methodology:** In this problem the hard material block is taken. In this experiment we have taken the steel as hard material. Because it is easily available, 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 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 cuboid, coated with copper on its surface.

![Figure (1) Square steel block](image)

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 center 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.

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

Flow chart diagram of gambit and fluent:-

The flow chart diagram of the data receiving process of Gambit and Fluent is shown in figure(2)

![Flow chart diagram of Gambit and Fluent](image)

To express the temperature profile in four parameters such as mean, standard deviation, skewness and kurtosis; the statistical analysis is carried out. The MATLAB is used for coding to carry out these analyses. This have a set of single data and it will repeat till the new data is collected.
Governing Equation and Boundary wall Condition:-

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:

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

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.

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. The grid is too fine in the middle of the metal block. When we will maximize it on the corners it will see to fine as the seen in the middle.

For the Neural Network Methodology the MATLAB software is used. The input is in the form of four parameters mean, standard deviation, skewness and kurtosis and output is in the form of CoatingThickness.

Result and Discussion:- 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 (5).

From the Gambit software, the optimum range of the start size is taken as the .0025 m for the whole analysis of the block. Now fixing the two parameters the start size and the end
size and keep varying the aspect ratio. For the whole analysis the optimum value of the aspect ratio is taken as 1.5.

The temperature profile variations with the varying aspect ratio are shown in figure (6)

![Temperature profile variation with aspect ratio of inner face.](image)

Figure (6) Temperature profile variation with aspect ratio of inner face.

The maximum temperature variation at the top wall with aspect ratio is shown in figure (7)

![Maximum temperature variation at the top wall with aspect ratio.](image)

Figure (7) The maximum temperature variation at the top wall with aspect ratio of the inner face.

Now at the end fixing the two parameters start size and aspect ratio with varying the end size. The optimum value of the end size is taken as 0.02m throughout the study

With the end size variation, the temperature profile variation for the inner face is shown in figure (8)

![Temperature profile variation with end size of grid.](image)

Figure (8) with end size of grid, the temperature profile variation.

With the variation in end size the maximum temperature profile at the top wall is shown in figure (9)

![Maximum temperature variation at the top wall.](image)

Figure (9) With the end size of the grid the maximum temperature variation at the top wall.
With uniform grid size, the temperature profile variation of the top wall for the outer face is shown in figure (10).

![Temperature profile variation of the top wall for the outer face](image)

Figure (10) With the grid size the temperature profile variation at the top for outer face.

With the uniform grid size, the maximum temperature variation at the top wall for the outer face is shown in figure (11).

![Temperature profile variation at the top wall for outer face](image)

Figure (11) With the variation in grid size, the variation at the maximum temperature at the top wall for inner face.

0.0015 m, the uniform grid size is decided for the outer face; throughout the test.

**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. 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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