DE GRUYTER OPEN

International Conference KNOWLEDGE-BASED ORGANIZATION
Vol. XXII No 3 2016

# MODELING AND SIMULATION OF THERMAL ANALYSIS OF A TEFLON COATED PLATE

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***Abstract**: This paper presents thermal analysis with finite elements for a plate of steel covered on the surface with a thin layer of Teflon. There is the possibility of identification of that part responsible for beginning of the thermal degradation using the vibrational model. The thermal analysis with finite elements made with ANSYS program enables monitoring and determination of plate variation of temperature. This variation of temperature could cause significant changes in guided wave propagation.*

**Keywords: Teflon, thermal analysis, modelling, simulation, ANSYS**

## 1. Introduction

Heat transfer and heat conduction are especially an area where the finite element method is applied successfully.

Problem solving of thermal conduction will be carried out by the finite element method.

Analysis of heat transfer was done using the simulation program ANSYS and finite element modeling and simulation results were compared with the measured values.

Because PTFE shows a high thermal stability and the possibility of usage at temperatures between -150 ºC and 280 ºC, chemical resistance for most corrosive agents [1], very good dielectric properties, remarkable anti adherence without a special preparation of the surface can be mixed with different metallic additives which, in optimal percentages, could enhance properties such as: wear resistance, expansion coefficient, compression resistance, electrical and thermal conductivity.

The Lamb wave method as a diagnosis tool to detect defects in thin plate was applied by Korobov [2].

By adding a complementary layer of PTFE [3], the turnover temperature can be designed for operating at high temperature by variation of the heat flux.

In addition to high temperature operation, it is essential that the static temperature resonance, in high temperature environments is kept [4]. Recently, it has been demonstrated that the acoustic wave devices for surfaces can be thermal compensated at different temperatures by the variation of the acoustic wave propagation direction [5].

The thin layer of PTFE [6] does not expose phase transitions from room temperature to the melting point. Lamb wave resonators with temperature frequency

DOI: 10.1515/kbo-2016-0110

coefficient are experimentally demonstrated [7]. These thermally compensated Lamb wave resonators are exposing a frequency-temperature exponential behaviour with velocity that is temperature dependent.

Lamb wave resonators are made from an interdigital transducer and a metalized surface at the PTFE plate interface. The metalized interface enhances the electromagnetic coupling coefficient due to a strong electric field may be applied between the electrodes and the metallic interface [8].

## 2. The mathematical model of thermal analysis

The first law of thermodynamics states that thermal energy is conserved. Specializing this to a differential control volume [9]:

$$\rho c\left(\frac{\partial T}{\partial t}+\{V\}^T\{L\}T\right)+\{L\}^T\{q\}=\ddot{q} \quad (1)$$

$$\{\mathrm{L}\}=\begin{Bmatrix}\dfrac{\partial}{\partial \mathrm{x}}\\ \dfrac{\partial}{\partial \mathrm{y}}\\ \dfrac{\partial}{\partial z}\end{Bmatrix} \quad (2)$$

$$\{V\}=\begin{Bmatrix}V_x\\ V_y\\ V_z\end{Bmatrix} \quad (3)$$

where, $\rho$ = density, $c$ = specific heat, $T$ = temperature, $t$ = time, $\{\mathrm{V}\}$ = velocity vector, $\{\mathrm{L}\}$ = operator vector, $\{\mathrm{q}\}$ = heat flux vector and $\ddot{q}$ = heat generation rate per unit volume.

It should be realized that the terms {L}T and {L}T{q} may also be interpreted as $\nabla T$ and $\nabla \bullet \{\mathrm{q}\}$, respectively, where $\nabla$ represents the grad operator and $\nabla \bullet$ represents the divergence operator.

Next, Fourier's law is used to relate the heat flux vector to the thermal gradients:

$$\{q\}=-[D]\{L\}T \quad (4)$$

$$[D]=\begin{bmatrix}K_{xx} & 0 & 0\\ 0 & K_{yy} & 0\\ 0 & 0 & k_{zz}\end{bmatrix} \quad (5)$$

where, $[D]$ = conductivity matrix and $\mathrm{K}_{xx}, \mathrm{K}_{yy}, \mathrm{K}_{zz}$ = conductivity in the element x, y, and z directions.

Combining Equation 1 and Equation 4, it results: Este foarte importan

$$\rho c\left(\frac{\partial T}{\partial t}+\{V\}^T\{L\}T\right)=\{L\}^T([D]\{L\}T)+\ddot{q} \quad (6)$$

Expanding Equation 6 to its more familiar form, it will be:

$$\rho c\left(\frac{\partial T}{\partial t}+V_x\frac{\partial T}{\partial x}+V_y\frac{\partial T}{\partial y}+V_z\frac{\partial T}{\partial z}\right)=\ddot{q}$$

$$+\frac{\partial}{\partial x}\left(K_x\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(K_z\frac{\partial T}{\partial z}\right) \quad (7)$$

It will be assumed that all effects are in the global Cartesian system.

Three types of boundary conditions are considered. It is presumed that these cover the entire element.

1. Specified temperatures acting over surface $S_1$, $S_3$:

$$\mathrm{T}+\mathrm{T}^* \quad (8)$$

where, $\mathrm{T}^*$ = specified temperature.

2. Specified heat flows acting over surface $S_2$, $S_4$:

$$\{q\}^T\{\eta\}=-q^* \quad (9)$$

where, $\{\eta\}$ = unit outward normal vector and $q^*$ = specified heat flow.

3. Specified convection surfaces acting over surface $S_5$ (Newton's law of cooling):

$$\{q\}^T\{\eta\}=h_f(T_S-T_B) \quad (10)$$

where, $h_f$ = film coefficient.

Evaluated at $(T_B + T_S)/2$ unless otherwise specified for the element $T_B$ = bulk temperature of the adjacent fluid and $T_S$ = temperature at the surface of the model.

Note that positive specified heat flow is into the boundary (i.e., in the direction opposite of {η}), which accounts for the negative signs in Equation 9 and Equation 10.

Combining Equation 4 with Equation 9 and Equation 10, it results:

$$\{\eta\}^T [D]\{L\}T = q^* \quad (11)$$

$$\{\eta\}^T [D]\{L\}T = h_f (T_B - T) \quad (12)$$

## 3. Meaning of the geometric model

The geometrical model for thermal analysis is made by:

- PTFE insulation;
- Steel plate.

On this plate is applied a Lamb wave resonator.

Lets consider a steel plate (A3) with dimensions of 500 x 200 mm and isolated with a 0,5 mm layer of PTFE (A1, A2, A4 and A5) as shown in figure 1.

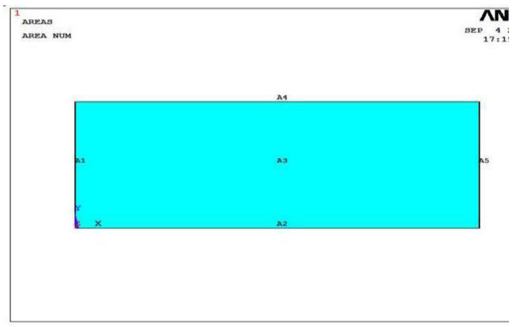


*Figure 1: The steel plate (A3) with dimensions of 500 x 200 mm isolated with a 0,5 mm layer of PTFE (A1, A2, A4 and A5)*

This plate is mashed with 2 mm finite elements as shown in figure 2:

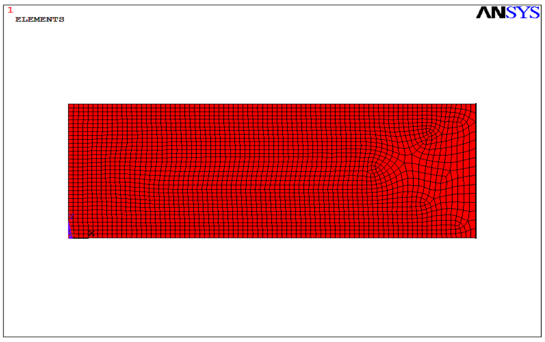


*Figure 2: The plate is meshed with 2 mm finite elements*

The number of nodes and finite elements is shown in figure 3.

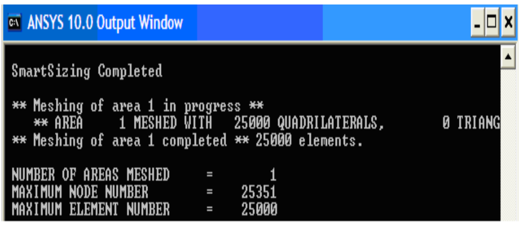


*Figure 3: The number of nodes and finite elements*

## 4. Simulation, numerical results and discussions

On the boundary we applied a charge of 25ºC and on the plate a charge of 280ºC.

The thermal flux on the plate is the integrated temperature flow time in which the mashing had been made.

The thermal flow for the plate is shown in figure 4 and for a quarter of PTFE plate is shown in figure 5a and for a quarter of steel plate is shown in figure 5b.

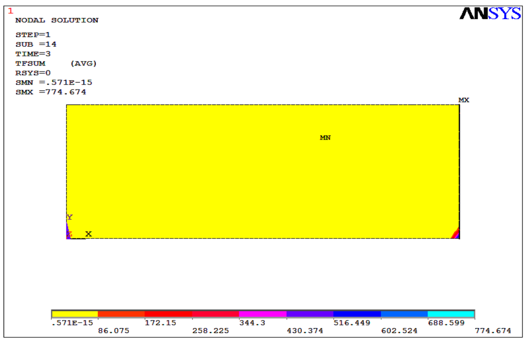


Figure 4: The thermal flow for the plate

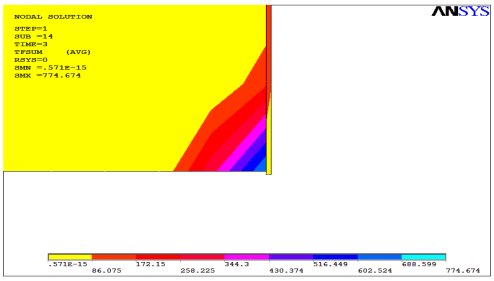


*Figure 5a: The thermal flow for a quarter of PTFE plate*

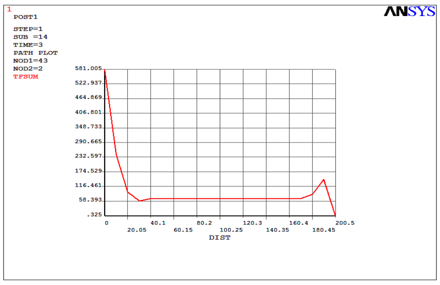


*Figure 7a: The thermal flux variation for the PTFE plate*

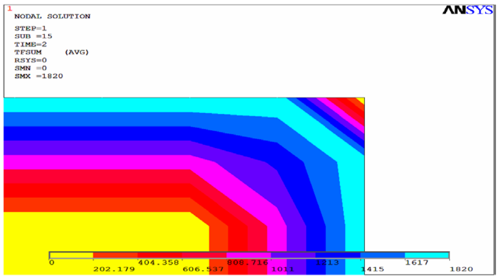


*Figure 5b: The thermal flow for a quarter of steel plate*

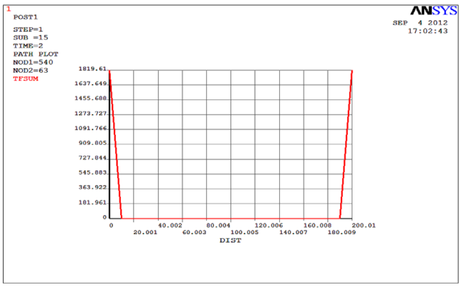


*Figure 7b: The thermal flux variation for the steel plate*

The simulation was made in ANSYS (Qnod4mode55) [10] for 0,150, 280 ºC, with the thermal conductivity of 1,22 and 1,44 for steel and 0,28 for PTFE.

Modified temperature plate is shown in the figure 6.a bellow and the heat plate graphic in figure 6b.

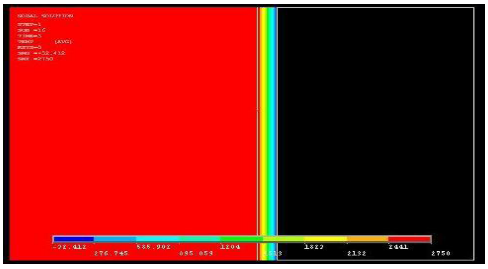

*Figure 6a: The domain of the temperature*

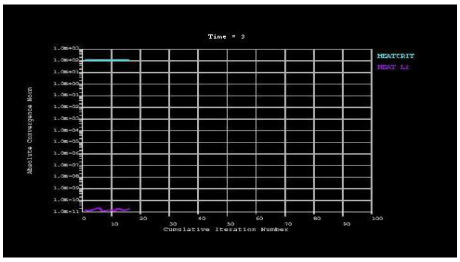

*Figure 6b: The heat plate graphic*

The thermal flow variation for the PTFE plate is shown in figure 7a and for the steel plate is shown in figure 7b.

The thermal flow has a more significant thermal variation in the PTFE layer.

The velocity regularly varies on the plate and on the margins it has a sudden variation because the PTFE layer is isolating and the heat is transmitted under 180$^{o}$C.

Thermal variations which occur in the two cases can lead to significant changes in guided wave propagation.

## 5. Conclusions

The isolation of the plate with PTFE layer is an optimal solution because this can be additivated with different ingredients, such as: glass, ceramics, carbon/graphite, bronze, salts and metallic oxides which in optimal percentage can improve such properties as resistance to wear, thermal and electrical conductivity, the coefficient of dilatation, hardness and resistance to compression.

**Acknowledgements**

The work has been funded by the Sectorial Operational Program Human Resources Development 2007-2013 of the Ministry of European Funds, through the Financial Agreement POSDRU/ 159/ 1.5/S/132395.

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