FEM OF THE THERMAL VARIATION AND STRESS DURING METAL DEPOSITION IN RECONDITIONING TECHNOLOGY

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Abstract: The paper presents the finite element modeling of the temperature behavior and stress map during the reconditioning process. This analyze is important to be done because if the temperature of the reconditioned piece is greater than about 200°C structural transformations could appears. On the other hand, important stress appears at this temperatures. These stress, in some conditions can destroy the integrity of the deposed metal layer.

Key words: Reconditioning, temperature, stress, FEM

1. INTRODUCTION

Because of the frictional process, many pieces used in industry are permanent attacked by a wear process. One of the reconditioning technique consists in metal deposition by different methods. One of the methods consists in metal spraying by using an electric arc [1]. Depending on the thickness of the metal that is deposed many layers are applied. In some cases of technological parameters, it is possible that after a specified number of layers, the temperature of the base material increase. This temperature increasing depends on:
- the base material thickness;
- the deposed material thickness;
- the deposition speed;
- the deposed material temperature;
- the geometrical position on the base material, etc.

Generally, the material phase transformation temperature starts from $T = 200^\circ$ C. This temperature has not to be reached because the initial metal characteristics starts to be changed. Because the reconditioning process is very dynamic the temperatures in the working zones varies permanently. The work from this article consist in temperature approximation and stress anlyze in condition of a constrained piece. Because of the temperature increasing up to the about $T = 200^\circ$ C, inside the initial metal piece and deposed this layers inside this structure important stress are appeared. In some working condition, because a part of these stresses that remains inside the piece thin cracks may appeared.

2. FEM OF THE TEMPERATURE BEHAVIOR DURING METAL DEPOSITION

This model [2] consists in a metal plate of a length $L = 100$ mm, high $h = 5$ mm and depth $d = 50$ mm. On the upper surface of the plate thin metal layers of $h_1 = 0.01$ mm, are deposed. One approximation of the model considers that the deposed layer is done very
rapidly at every $t = 0.5$ sec. In these conditions, the modeling will calculate the temperature variation after this period of time. Because each metal drop is in liquid state at the collision with the base plate the temperature of the deposed layer is approximated at $T_{\text{liq}} = 1500^0\text{ C}$. The initial metal plate temperature is considered $T_{\text{sol}}= 20^0\text{ C}$. After the first metal deposition the temperature map is presented in the figure 1. After $t_1 = 0.5$ sec, the deposed layer has the temperature $T_{1\text{layer}} = 50^0\text{ C}$. The temperature at the lower part of the piece has the maximum value $T_{1\text{piece}} = 24^0\text{C}$.

Fig. 1 The piece temperature after the first metal layer deposition

After the second metal layer deposition, the temperature map is presented in the figure 2. In the deposition zone the temperature reached the maximum value $T_{2\text{layer}} = 60^0\text{ C}$. At the lower part of the piece, the temperature increased at the value $T_{2\text{piece}} = 35^0\text{C}$. The temperature map is presented in the figure 2.

Fig. 2 The piece temperature map after the second metal layer deposition

The third metal deposition conduced to an important temperature increasing up to the value $T_{3\text{layer}} = 130^0\text{ C}$ and in the lower part of the piece part the temperature reach the $T_{3\text{piece}} = 61^0\text{ C}$. The figure 3 presents this temperature map and thermal flux vector map.
The forth deposition produced in the upper piece zone a maximum temperature $T_{4\text{layer}} = 132^0$ C and in the lower part a maximum temperature $T_{4\text{piece}} = 91^0$ C.

The fifth and the sixth metal layer deposition are presented in the figure 5. The temperature after two metal depositions reached in the upper zone the temperature $T_{6\text{layer}} = 226^0$ C. The bottom part has the temperature $T_{6\text{piece}} = 124^0$ C. An important temperature increasing is produced after the seventh deposition On the upper zone, in the layers, temperature has a maximal value $T_{7\text{layer}} = 329^0$ C. Immediately, under these layers, the temperatures are greater than $T = 200^0$ C.
In this situation, it is considered that the reconditioning process has to be stopped. Structural transformations are possible and this is not a good thing. The figure 6 presents this situation.

In this step, after the time $t = 2$ sec, temperature starts to decrease and to be relatively uniform in the range $T = 163 - 185^0C$. The figure 7 presents this moment and the thermal flux and thermal gradient.
3. FEM OF THE STRESS AS A RESULT OF PRODUCT HEATING DURING RECONDITIONING PROCESS

Because the working piece, during the reconditioning process, is heated and mechanical fixed, inside the material important stress are developed. Using the finite element method, different types of stress will be presented. In the figure 8, S1, S2, S3 principal stress are presented.

![Fig. 8 S1, S2 and S3 principal stress presentation](image)

The S1 principal stress indicates that the deposed layer is compressed at the maximal value $\sigma_{\text{com}} = 0.1 \times 10^8 \text{N/m}^2$. The value is lower than the Young modulus but is important. The S2 principal stress indicates compression stress in the deposed layer but with different values. The greater value, $\sigma_{\text{com}} = 0.64 \times 10^9 \text{N/m}^2$ is located in the center and the lower value $\sigma_{\text{com}} = 0.1 \times 10^8 \text{N/m}^2$ on the OX axis. The S3 principal stress indicates also compression stress with the maximal value $\sigma_{\text{com}} = 0.1 \times 10^{10} \text{N/m}^2$ on the lower part of the piece. The value is very important, not greater than the elasticity modulus but when the piece will be unclamped only a part of thermal stress will disappear and the piece will be stressed during the working lifetime.

The SX, SY and SZ stress are presented in the figure 9. For the OX axis, compression stress are calculates with the maximal value $\sigma_{\text{com}} = 0.6 \times 10^9 \text{N/m}^2$. The OY stress indicates compression and tensile stress. In this case the working piece and the deposed layer will be subjected to different types of stress that means different solicitations which can produce cracks in the condition of other kind of solicitations. The SZ stress indicates also different tensile and compression stress with a maximal value $\sigma_{\text{com}} = 0.64 \times 10^9 \text{N/m}^2$.

![Fig. 9 SX, SY and SZ stress presentation](image)
Other type of solicitations are presented in the figure 10. These shear stresses are calculated in the plane XOY, YOZ and XOZ. In the first plane, the deposer layer is uniform stressed and the maximal value calculated in the lower part is $\sigma_{\text{com}} = 0.5 \cdot 10^9 \text{ N/m}^2$. The same value, but in tensile sense is also calculated in this case. This alternation tension-compresion can produce small cracks. For the plane YOZ, a uniform stress map is presented on the deposed layer. The maximal value in this situation is $\sigma_{\text{com}} = 0.4 \cdot 10^8 \text{ N/m}^2$. In this plane the stress map is not so important.

![Fig. 10 Shear stress for the planes XOY, YOZ and XOZ](image)

An important discussion has to be done in the case of XOZ shear stress. Here, on the metal deposed layers, two corners are compressed and two corners are supposed to tensile stress. This variation can produce cracks during piece life-time. In this case the maximal tress value is $\sigma_{\text{com}} = \sigma_{\text{tensile}} = 0.5 \cdot 10^9 \text{ N/m}^2$.

4. CONCLUSIONS

The finite element method is very useful in many situations when direct measuring or using sensors is not possible. This method shows its value in the case of temperature approximation or stress calculation in this case of engineering technology. The temperature variation in the case of metal deposition is important and is not every time considered. The article shows that structural modification are possible because the temperature increasing and tells that the FEM should be used before apply this technology. Another problem very important to be study is the possible exfoliation of the metal layers deposed. The thermal stress that are induced by the process in the metal base and deposed layers are important and the temperature come-back do not ensure that stress are eliminated. As it was show, the stress values are very important, below the elasticity modulus but not so far. All the technological steps defined in metal reconditioning steps are to be followed because the stress conditions allow cracks formation and propagation.

5. REFERENCES