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MODELING OF GRINDING PROCESS BY PRINTED CIRCUIT BOARDS RECYCLING

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Abstract: *In the paper we deal with the printed circuit boards recycling problem. We focuse on study of a grinding as an alternative method of conductive ways from plastic board separation as one of stages of the printed circuit board recycling procedure. For this purpose we formulate mathematic model of the grinding process and next we used its analytical solution for its modeling by mathematic software Maple. The obtained results confirm energy intensity of the grinding process.*
Key words: *model, grinding, printed circuit boards, recycling*

1. INTRODUCTION

The printed circuit boards (PCBs) that represent a significant part of electronic waste is potential significant source of material and energy. Therefore possibilities of PCBs reuse are searched in the whole world at present.

Material composition of PCBs is highly heterogeneous. They are made from plastic boards covered by one or more metal layers with moulded electronic components. They can contain not only precious metals (gold, silver and copper), but also a large quantity of other materials as are plastics, ceramics, glass etc. which should be recycled (Janáčová et al., 2007).

Suitability of the above mentioned materials for their reuse strongly depends on economy cost. In our workplace we would like to make antinoise panels based on crushed plastic boards of PCBs sticked by special adhesive mixture. For this purpose, we search energy-saving technological method of the conductive ways from plastic boards separation.

In general, there are many problems by PCB recycling at this time. The mechanical-physical processes are attracting more attention than chemical operations in that condesirable chemical waste water polluted by hazardous chemical substances is produced (Guo, J. et al., 2008), (Tohka, A. & Lehto, 2009). By reason of an effective recycling of precious metals and other valuable raw materials, melting and electrolysis are preferable than mechanical recycling methods. Furthermore, the polluting matters are removed from PCB by melting and electrolysis. On the other hand, the thermic methods seem as most suitable (Janáčová et al., 2009).

In this paper we focuse on study of a grinding as an alternative method of conductive ways from plastic board separation as one of stages of the printed circuit board recycling process. For this purpose we formulate mathematic model of the grinding process and next we used its analytical solution for its modeling by mathematic software Maple.

2. MATHEMATIC DESCRIPTION OF GRINDING PROCESS

In practise, the grinding process can be realized by using of an abrasive belt. The process course depends on many factors.

Geometry sketch of the grinding process you can see in figure 1.

Non-stationary temperature field in PCB and abrasive belt can be described by Fourier-Krchhoff's equations (1), (2) with appropriate initial and boundary conditions (3) – (6) (Lykov, 1967), (Carslaw & Jaeger, 2008) .

$$\frac{\partial t_1(x,\tau)}{\partial \tau} = a_1 \frac{\partial^2 t_1(x,\tau)}{\partial x^2} \qquad \tau > 0, \quad 0 < x < \infty \tag{1}$$

$$\frac{\partial t_2(x,\tau)}{\partial \tau} = a_2 \frac{\partial^2 t_2(x,\tau)}{\partial x^2} \qquad -\infty < x < 0 \tag{2}$$

$$t_1(x,0) = t_2(x,0) = t_p \tag{3}$$

$$t_1(\infty,\tau) = t_2(-\infty,\tau) = t_p \tag{4}$$

$$q + \lambda_1 \frac{\partial t_1(0,\tau)}{\partial x} - \lambda_2 \frac{\partial t_2(0,\tau)}{\partial x} = 0 \tag{5}$$

$$\frac{\partial t_1(\infty,\tau)}{\partial x} = 0\,, \quad \frac{\partial t_2(\infty,\tau)}{\partial x} = 0 \tag{6}$$

Equation (1) represents heat transport in the plastic board. Equation (2) represents heat transport in the abrasive belt. Initial temperature distribution in the belt and in the board is given by equation (3). Final temperature distribution in the belt and in the board is given by equation (4). Heat transport in the touch point of both materials is given by relation (5). Equation (6) determines change of temperature in infinite points of the belt and in the board.

We supposed that total heat flow divides equally among q_1 and q_2

$$q_1 = q_2 = 0.5q \tag{7}$$

Under these conditions we obtained analytical solution given by temperature field $t_1(x,\tau)$ in plastic board

$$t_1(x,\tau) = \frac{2q}{\lambda_1}\sqrt{a_1\tau}\left[\frac{e^{-\frac{x^2}{4a_1\tau}}}{\pi} - \frac{x}{2\sqrt{a_1\tau}}\cdot \operatorname{erfc}\left(\frac{x}{2\sqrt{a_1\tau}}\right)\right] \tag{8}$$

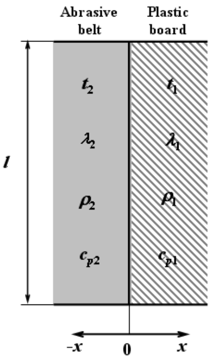

Fig. 1. Geometry sketch of the process

3. MATHEMATIC MODELING OF THE GRINDING PROCESS COURSE

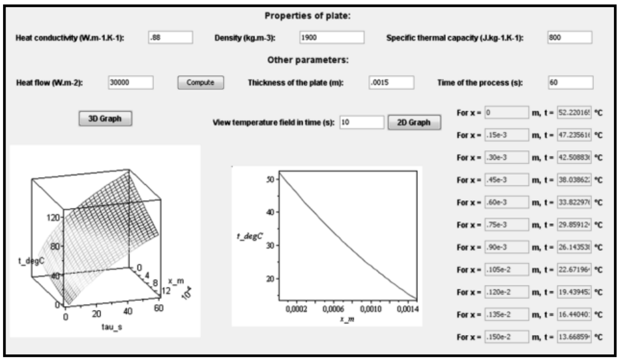

Fig.2. Window of the software application for modeling of grinding process course

For this purpose we programmed special application for calculation and visualization of temperature field $t_1(x,\tau)$ in PCB during grinding by mathematic software Maple (figure 2) (Tocci & Adams, 1996).

4. MAIN RESULTS

Many technological operations of plastic material treatment proceed by temperature above 200 °C.

Quantity of the heat flow generated during the process depends mainly on frequency of the belt rotation, thrust pressure and friction coefficient.

Figure 3 demonstrates grinding process course till temperature 200 °C will be achieved throughout the board. The generated heat flow is 30 kW.m^{-2}. The process time to achieving 200 °C throughout the board for generated heating flow from 10 to 100 kW.m^{-2} is shown in figure 4. In both figures δ = 1 mm, c_p = 800 J.kg^{-1}.K^{-1}, ρ = 1900 kg.m^{-3}.

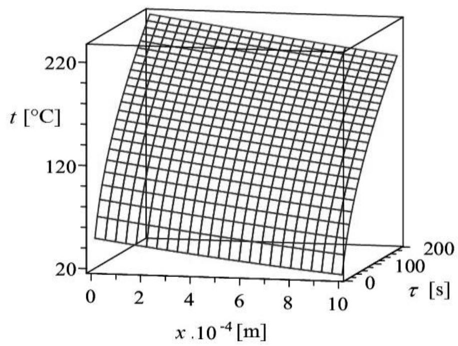

Fig.3. Temperature field in PCB during grinding will be achieved throughout the board

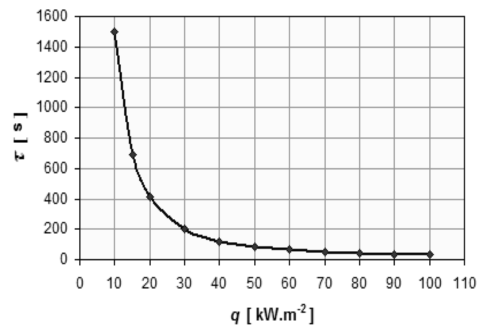

Fig. 4. The process time to achieving 200 °C throughout the board in dependence on the heat flow

5. CONCLUSION

By modeling of the grinding process by mathematic software Maple we determined friction coefficient, thrust pressure and frequency of the belt rotation as major factors that affect generated heat flow. The obtained results confirm energy intensity of the grinding process. In consequence of so much of heat generation during the process, the plastic material can agglomerate with metals, which complicates the process.

6. LIST OF SYMBOLS

a - thermal diffusivity, $a = \lambda/(\rho.c_p)$, [m^2.s^{-1}];
δ - thickness of board, [m];
c_p- specific thermal capacity, [J.kg^{-1}.K^{-1}];
q - heat flow, [W.m^{-2}];
t - temperature, [°C];
x- position coordinate, [m];
λ - thermal conductivity, [W.m^{-1}.K^{-1}];
ρ - density, [kg.m^{-3}];
τ - time, [s].

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