Modeling of temperature fields inside two layers board copper – plastic materials during treatment

Dagmar JANÁČOVÁ, Hana CHARVÁTOVÁ,
Karel KOLOMAZNÍK, Vladimír VAŠEK
Department of Automatic Control
Faculty of Applied Informatics, *Faculty of Technology Zlin
Tomas Bata University in Zlin
Nad Stráněmi 4511, 760 05 Zlín
CZECH REPUBLIC
janacova@fai.utb.cz, http://web.fai.utb.cz

Abstract: - We are dealing with the possibility of electronic waste separation by the temperature effect. It gives a possible direction how to solve the problem of electronic waste growth not only in Czech Republic, but also throughout the world. Further, we are dealing with a heat transfer inside the printed circuit boards (PCBs). With the usage of the utilized experience from detail references background research and various software simulators we achieved the maximum analysis of the problem. The solving, which resulted from the calculations. The development of new criteria for PCBs recycling has opened new possibilities of treatment for used materials.

Key-Words: - Electronic waste, printed circuit boards (PCBs), recycling, separation, heat transfer.

1 Introduction

The electronic waste is the fastest growing kind of waste at present. Worldwide it forms up to 5% of weight of solid domestic waste now, almost as plastic packages. In the countries of European Union, where families annually product about 8 millions of tons of electronic waste, its dimension grows in the rate of 3 till 5% per year, fast three times faster than total waste dimension. The developing countries even suppose that their electronic waste production will treble by the year 2010. Experts estimate that European Union will have to face up to almost 11 millions of tons of electronic waste in keeping of electronic sale. Ten years later will the annual production rise almost up to 14 millions tons. It is needful to add next 3 millions of tons of electronic waste coming from organizations and firms [1].

According to the last informations roughly one milliard of personal computers are used at present. Independent analytic company Gartner supposes that number of personal computers will be doubled in following six years [2].

According to this study the computer sale worldwide grows in 12% per year. In the growth calculation is necessary to count on old models depreciations. As the study presents, this year will be replaced roughly 180 millions of PCs which will make 16% of all used systems. The fifth of them will be totally liquidated then and the rest should be used for other purposes, eventually will go to less advanced countries.

It is supposed that in the Czech Republic there are in service about five millions personal computers [3]. It means that by average life expectancy of 4 years is discarded about fifty thousand personal computers, what means, by average weight of PC 12 kg, 600 tons of recycled material. This fact will get worse in the process because the number of people is going up and the product consumption as well, whereas the usage time of the products is rapidly cut down. Apparently the most valuable raw material which is possible to get from electronic waste, especially from PCBs, are precious metals [4,5].

The work is simply oriented at the separation way of PCBs (printed circuit boards) by the temperature influence on the basis of the different linear thermal expansion and tenseness in the stress link of the metal way and plastic material.

Printed circuits create together with electronic components basis of all electronic units. The material difference and also its difficult recycling is given by presence of great of electronic component ammount [6]. The boards themselfs contain the ammount of dangerous materials but also precious metals, e. g. silver, gold, platinum and palladium (printed connectors, pins).

Appropriate material for printed circuit boards is laminated insulator-laminate. It is material on the basis of resin and paper with adequate absorption of

moisture, middle fortress and good electric characters. In the field of computer technics and industry electronics are mainly used primary materials on the basis of glass fabric and epoxy.
Before the recycling of printed circuit boards it is necessary to remove all the electronic components [8].

There are several methods which are the most known: ***Mechanic removing – grinding***

This method is appropriate for selective separation of only some important components (diodes, semicoductor triodes, resistors….). It is implemented by the mechanic removing of pins from appropriate components by grinding.
A grinding process sounds like acceptable from the point of view of ecology.The grinding process can be realized by using of an abrasive belt. In consequence of so much of heat generation during the process, the plastic material can agglomerate with metals, which complicate the process. Therefore it is necessary an optimal time course of grinding to find. For this purpose we deal with the mathematic model of temperature course in PCB during the grinding process

2. Modeling of temperature field in PCBs during a grinding process

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

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

$$t_1(x,0) = t_2(x,0) = t_p \qquad (3)$$

$$t_1(\infty,\tau) = t_2(-\infty,\tau) = t_p \qquad (4)$$

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

$$\frac{\partial t_1(\infty,\tau)}{\partial x} = 0 \qquad \frac{\partial t_2(\infty,\tau)}{\partial x} = 0 \qquad (6a,b)$$

$$q_1 = q_2 = 0.5q \qquad (7)$$

After solution of this model is given by temperature field t1(x,t) in plastic board [14]:

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

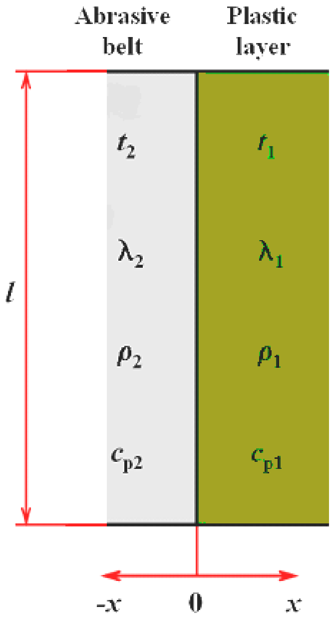

Figure 1: Model of grinding process

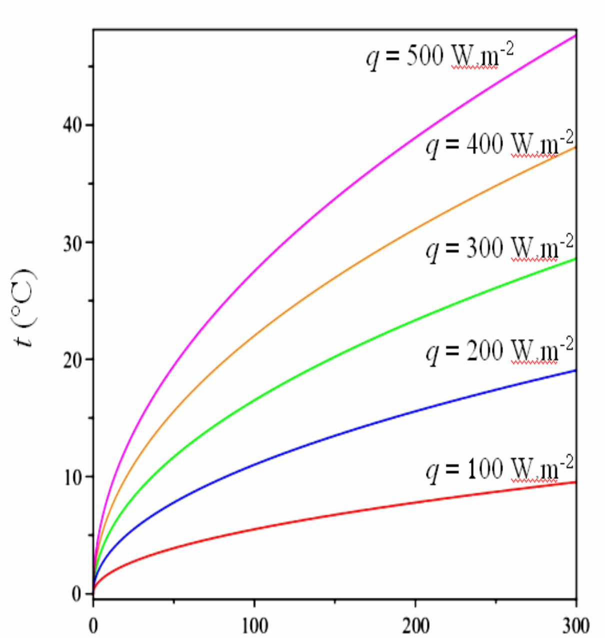

Figure 2: Dependence of time course of grinding on quantity of supply heat for a =5.8·10-6 m^2.s^{-1} [11]

Mathematic model of non–stationary temperature field of two layers folder

For describing heating process of two layers folder we used following mathematic model:

$$\frac{\partial t_1}{\partial \tau}(x,\tau) = a_1 \frac{\partial^2 t_1}{\partial x^2}(x,\tau), \quad \tau > 0, 0 < x < b \qquad (9)$$

$$\frac{\partial t_2}{\partial \tau}(x,\tau) = a_2 \frac{\partial^2 t_2}{\partial x^2}(x,\tau), \quad \tau > 0,\ b < x < \infty \qquad (10)$$

$$t_1(x,0) = t_2(x,0) = t_p \qquad (11)$$

$$t_1(b,\tau) = t_2(b,\tau) \qquad (12)$$

$$t_1(0,\tau) = t_o \qquad (13)$$

$$\frac{\delta t_2}{\delta x}(\infty,\tau) = 0 \qquad (14)$$

$$\lambda_1 \frac{\delta t_1}{\delta x}(+b) = \lambda_2 \frac{\delta t_2}{\delta x}(-b) \qquad (15)$$

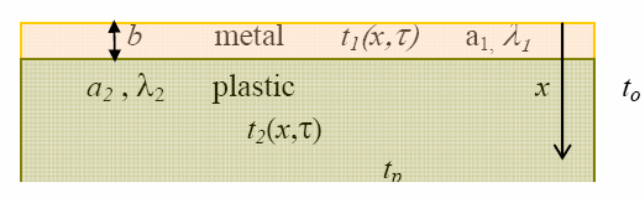

Figure 3: Mathematic model of non - stationary temperature field for two sheet folder

After solving we obtained an accordance with A. B.Lykov [12]

$$\frac{t_1 - t_p}{t_o} = erfc\left(\frac{x}{2\sqrt{a_1\tau}}\right) - h\sum_{n=1}^{\infty} h^{n-1}\left[erfc\left(\frac{2n-x}{2\sqrt{a_1\tau}}\right) - erfc\left(\frac{2nb+x}{2\sqrt{a_1\tau}}\right)\right] \qquad (16)$$

$$\frac{t_2 - t_p}{t_o} = \frac{2K_\varepsilon}{1+K_\varepsilon}\sum_{n=1}^{\infty} h^{n-1} erfc\left(\frac{x-b+(2n-1)\sqrt{K_a}b}{2\sqrt{a_2\tau}}\right) \qquad (17)$$

where

$$h = \frac{1-K_\varepsilon}{1+K_\varepsilon} \qquad (18)$$

$$K_a = \frac{a_1}{a_2} \qquad (19)$$

$$K_\varepsilon = \sqrt{\frac{\lambda_1 c_{p1}\rho_1}{\lambda_2 c_{p2}\rho_2}} \qquad (20)$$

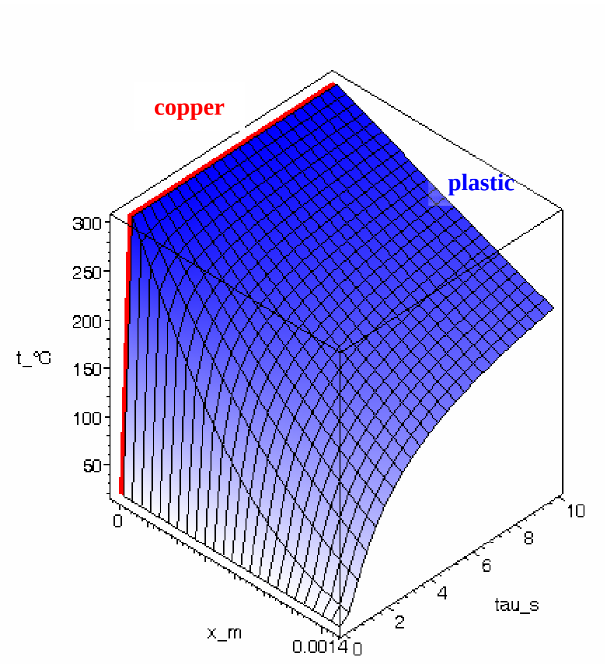

Figure 4: The non-stationary temperature field for two sheet folder

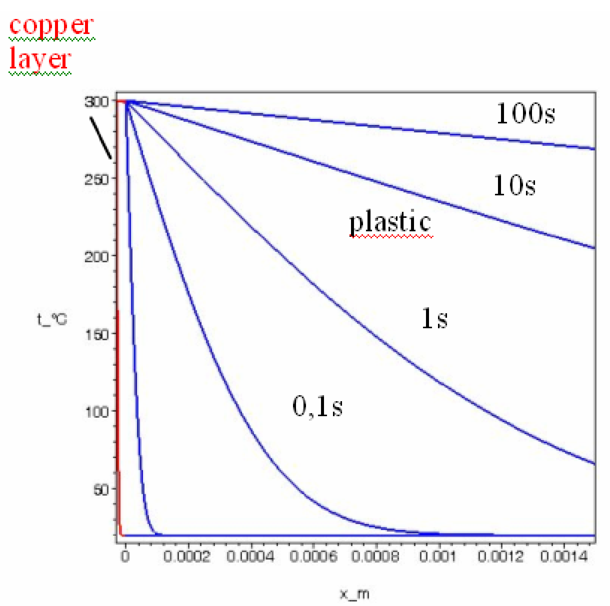

Figure 5: The temperature course for variable times (0; 0,01; 0,1; 1; 10; 100s) of heating in the two sheet folder

4. Conclusion

We implemented the production study of PCBs (printed circuit boards) to be able to choose the right way of separation.

We formulated mathematic models of temperature course in PCBs during a grinding process and matehematic model for describing of temperature fields into two layers board. The obtained results can be used for finding of the effective and environmental friendly recycling method of electronic waste.

List of symbols:

Symbol	Meaning	Unit
a	temperature conductivity, $a = \lambda/(\rho.c_p)$	$[m^2.s^{-1}]$
c_p	specific thermal capacity	$[J.kg^{-1}.K^{-1}]$
l	length of the ground surface	[m]
q	heat flow	$[W.m^{-2}]$
t	temperature	[°C]
x	position coordinate	[m]
λ	heat conductivity	$[W.m^{-1}.K^{-1}]$
ρ	density	$[kg.m^{-3}]$
τ	time	[s]

References:

[1]Božek, F., Urban, R., Zemánek, Z.: Recyklace, 2002. p. 202 . ISBN 80-238-9919-8

[2]ČSÚ, Available: http://www.czso.cz/, Last revision: February 2009

[3]Evropská Unie, , Available: http://www.kurzy.cz/ , Last revision: February 2009

[4]ComputerWorld, Available: http://computerworld.cz/ Last revision: February 2009

[5]Recycling, Available: http://ekologie.xf.cz, Last revision: May 2007

[6]Krištofová, D.: Kovy a životní prostředí, Ediční středisko VŠB – TU Ostrava, 2005

[7]Dekompozice a utilizace vysloužilé domotechniky, Technický týdeník 25/2000

[8]Téma měsíce, Odpadové fórum 9/2005

[9]Šuba, O., Jurčiová, J.: On Design of Plastic Cylindrical Shells of Wastewater Treatment Systems. In: The 13th Int. Conf. on Problems of Material Engineering, Mechanics and Design 2008, August 25-28, 2008, Slovakia, ISBN 978-80-969728-2-1

[10]Sýkorová, L. Šuba, O.: The Transient Temperature Field Simulation of Laser Cutting. In: 12th International Research/Expert Conference „Trends in the Development of Machinery and Associated Technology" TMT 2008, 26. – 30. August 2008, p. 73-76, Istanbul, Turkey, ISBN 9958-617-30-7

[11]Copper. TU in Liberec.. Available: http://www.kmt.vslib.cz/, Last revision: May 2007

[12]Lykov, A., B.: "Teoria teploprovodnosti", p.369, Vyssaja škola, Moskva, 1967

[13]Charvátová, H., Fialka, M., Janáčová, D.: Optimization of pelt deliming process, AV ČR, Topical Problems of Fluid Mechanics 2008, Praha, 2008, 51-54, ISBN-ISSN 978-80-87012-09-3

[14]Charvátová, H., Janáčová, D., Fialka, M., Kolomazník, K.: Modeling of Temperature Field in Printed Circuit Boards during a Grinding Process, Zakopane, Proceedings of 10th International Carpathian Control Conference, Poland, 2009

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