

Support information

SA. Model of the curing oven

The model of this curing oven may be seen the reference [1]. The finite difference method, a common modelling method for complex thermal processes, is used to model the curing process. The two-dimensional surface of the lead frame is discretized into many small zones by uniform intervals Δx and Δy , as shown in Figure S1. The coordinate of the zone (i, j) is $(x_i, y_j, 0)$. Each zone is assumed to have a uniform temperature, heat flux, radiative property. Since the lead frame is thin enough, axial thermal gradient may be neglected.

The heat transfer model of every zone may be described as

$$m_{i,j}c \frac{dT_{i,j}(t)}{dt} = q_{i,j}^d + q_{i,j}^r + q_{i,j}^e + q_{i,j}^{wall} + q_{i,j}^{dist} \quad (i=1, \dots, n; j=1, \dots, p) \quad (S1)$$

Where

$T_{i,j}(t)$ — the temperature of the (i, j) zone at time t ;

c and $m_{i,j}$ —the specific heat coefficient and mass of the (i, j) zone, respectively;

$q_{i,j}^d$, $q_{i,j}^r$ and $q_{i,j}^e$ —heat flow rates coming into the (i, j) zone via conduction, radiation from heater block and convection from air respectively

$q_{i,j}^{wall}$ and $q_{i,j}^{dist}$ —unknown heat from the chamber wall and disturbance respectively

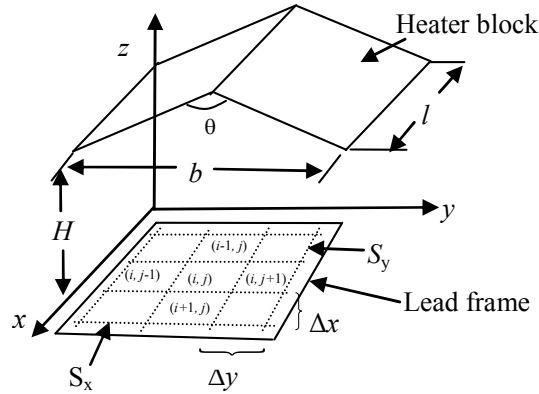


Figure S1: Geometric explanation

According to Fourier's rule of heat conduction, heat conduction across a surface is expressed as

$$q_{i,j}^d = kS_x \left(\frac{T_{i+1,j}(t) + T_{i-1,j}(t) - 2T_{i,j}(t)}{\Delta x} \right) + kS_y \left(\frac{T_{i,j+1}(t) + T_{i,j-1}(t) - 2T_{i,j}(t)}{\Delta y} \right) \quad (S2)$$

where k denotes thermal conductivity, S_x and S_y are the cross-sectional area of every zone.

The radiative heat of a zone is

$$q_{i,j}^r = \varepsilon S_{i,j} \{F_{i,j}(d)u(t) - \sigma T_{i,j}^4(t)\} \quad (S3)$$

Where

ε and σ —the emissivity of the lead frame and Boltzmann constant, respectively;

u —the control variable that offers power to heaters;

$F_{i,j}(d)$ —the view factor from the (i, j) zone to the heater block, it is a function of design variables $d=[\theta, l, b, H]$, where θ, l, b are curve angle, length and breadth of the heater block respectively and H is distance between the LF and the heater block;

The view factor $F_{i,j}(d)$ is expressed as

$$F_{i,j}(d) = F(x_i, y_j, 0) + F(x_i, b - y_j, 0) \quad (S4)$$

where b and $(x_i, y_j, 0)$ are the breadth of heater block and the coordinate of the zone (i, j) respectively, and the function $F(x, y, 0)$ can be derived according to the definition of view factor and Stokes' theorem and expressed as

$$F(x, y, 0) = F_1 + F_2 + F_3 + F_4$$

with

$$\begin{aligned} F_1 &= \frac{\frac{b}{2} - y}{2\pi \sqrt{(\frac{b}{2} - y)^2 + (H + \frac{b}{2} \text{ctg}(\frac{\theta}{2}))^2}} \left(\text{atan} \frac{l - x}{\sqrt{(\frac{b}{2} - y)^2 + (H + \frac{b}{2} \text{ctg}(\frac{\theta}{2}))^2}} + \text{atan} \frac{x}{\sqrt{(\frac{b}{2} - y)^2 + (H + \frac{b}{2} \text{ctg}(\frac{\theta}{2}))^2}} \right) \\ F_2 &= \frac{y}{2\pi \sqrt{y^2 + H^2}} \left(\text{atan} \frac{l - x}{\sqrt{y^2 + H^2}} + \text{atan} \frac{x}{\sqrt{y^2 + H^2}} \right) \\ F_3 &= -\frac{l - x}{2\pi \sqrt{\eta^2 + (l - x)^2 + (l - x)^2 (tg\theta)^2}} \times \left(\text{atan} \left(\frac{(-y)(1 + (tg\theta)^2) + \eta \times tg\theta}{\sqrt{\eta^2 + (l - x)^2 + (l - x)^2 (tg\theta)^2}} \right) \right. \\ &\quad \left. - \text{atan} \left(\frac{(\frac{b}{2} - y)(1 + (tg\theta)^2) + \eta \times tg\theta}{\sqrt{\eta^2 + (l - x)^2 + (l - x)^2 (tg\theta)^2}} \right) \right) \\ F_4 &= \frac{x}{2\pi \sqrt{\eta^2 + x^2 + x^2 (tg\theta)^2}} \times \left(\text{atan} \left(\frac{(\frac{b}{2} - y)(1 + (tg\theta)^2) + \eta \times tg\theta}{\sqrt{\eta^2 + x^2 + x^2 (tg\theta)^2}} \right) - \text{atan} \left(\frac{(-y)(1 + (tg\theta)^2) + \eta \times tg\theta}{\sqrt{\eta^2 + x^2 + x^2 (tg\theta)^2}} \right) \right) \\ \eta &= -y \text{ctg} \frac{\theta}{2} - H \end{aligned}$$

Since the heat convection has a small effect compared with the other heat flux, it can be regarded as a disturbance. Define

$$\hat{w}_{i,j}(t) = \frac{1}{m_{i,j}c} (q_{i,j}^e + q_{i,j}^{wall} + q_{i,j}^{dist}) \quad (S5)$$

As a result, the heat transfer model (S1) may be rewritten as

$$\begin{aligned} \frac{dT_{i,j}(t)}{dt} = & \frac{kS_x}{m_{i,j}c} \left(\frac{T_{i+1,j}(t) + T_{i-1,j}(t) - 2T_{i,j}(t)}{\Delta x} \right) + \frac{kS_y}{m_{i,j}c} \left(\frac{T_{i,j+1}(t) + T_{i,j-1}(t) - 2T_{i,j}(t)}{\Delta y} \right) \\ & + \frac{\varepsilon S_{i,j}}{m_{i,j}c} \left\{ F_{i,j}(d)u(t) - \sigma T_{i,j}^4(t) \right\} + \hat{w}_{i,j}(t) \end{aligned} \quad (S6)$$

SB. Training and Testing samples of input u

SB.1 Training input

377.469561068062445	735472195426	85.5222134250340	382.566415961190	714.874603850722
241.834943117463	0	163.008853958344	556.583107664582	240.498914701160
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0	964.308017864370	404.159533433228	428.468412725915	40.7355888387698
469.509649932928	448.836783615611	107.076296095646	649.586367883267	1075.84078331050
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SB.2 Test input 1

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SB.3 Test input 2

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