Design of Finned Heatsinks Having Minimum Mass

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Abstract – **the model of heat transfer processes in structural elements of heat sinks with finned surfaces is analyzed; the algorithm of optimizing masses of finned heatsinks is developed.**

Keywords - **the thermal regime, the finned radiator, construction optimization, iterative algorithm.**

I. INTRODUCTION

In most cases thermal regime of heat loaded elements in electronic equipment is achieved by using heat-removing devices or forced cooling. Both ways require the cost of materials and influence over the dimensions and weight of radio equipment. Optimization of heat-removing elements of the designs can significantly reduce their weight and dimensions.

One of the most common device is a heat-sink. There are many designs of radiators [1,2], which does not allow to solve the problem of optimizing their dimensions and weight. Investigated only simple structural elements [3], which shows the possibility of reducing the mass of a few times. Optimization of these elements using the integrated mass and size parameters considered in [4]. Optimization procedure in most cases led to an increase in area occupied by the heatsink components on printed circuit boards.

Reducing this area can be a transition to the spatial forms of heat-removing elements from developed surfaces. Examples of such surfaces may be ribbed and pin elements. Because the parameters of these elements affect the processes of heat dissipation by convection and radiation, it is advisable to study the influence of structural elements of radiators on their dimensions and weight.

The purpose of the work is to develop algorithm of design finned heatsinks having minimum weight. To solve this problem it is necessary

– to form the model of heat transfer processes in structural elements of heatsinks with finned surfaces;

– develop an algorithm optimizing masses finned heat sinks.

II. FORMING THE MODELS OF COMPONENTS

Thermal model of finned heat sink is shown in Figure 1, where P -heat flux. Heatsink has equal width Sizes of the another elements differ from each other.

In general case, thermal processes in such structures are described by two-dimensional heat equation. But the practice of heat sink design shows that the relation $l_i >> d_i$ is performed, where l_i and d_i are length and thickness of i -th fin and the base.

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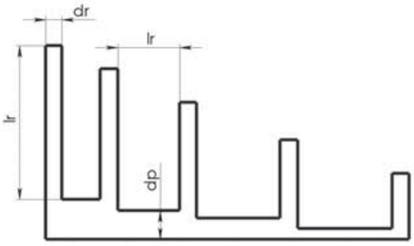

Fig. 1 - Heatsink with finned surfaces

This allows to consider the processes of heat transfer in structural elements as one-dimensional and used to calculate the thermal model in the form of thermally loaded rod with input thermal resistance:

$$R_O = \frac{1}{\lambda bS} \frac{b \cdot ch(bl) + \beta \cdot sh(bl)}{b \cdot sh(bl) + \beta \cdot ch(bl)} \quad (1)$$

Depending on the parameters of heat stress in thermally loaded rod can occur at idling speed, critical and short circuit. Idling $\beta = 0$, and at the end of the rod heat for it. In this case expression (1) is converted to the form:

$$R_P = \frac{1}{\lambda bS} cth(bl), \quad (2)$$

Expressions (1) and (2) are used to calculate the input thermal resistance of finned heatsink, which is formed equivalent transformations of thermal models. At each stage, the input of the next section of the thermal resistance of heat is calculated as a parallel connection of the thermal resistance of the input rib and the next section of foundation:

$$R_H = \frac{R_P \cdot R_O}{R_P + R_O}, \quad (3)$$

where R_P and R_O are input the thermal resistance of the fins and the next section.

III. OPTIMIZING MASS OF HEATSINKS

To minimize mass of heat transfer the objective function is defined as

$$m = \rho L \sum_{i=1}^{n} \left(d_{pi} l_{pi} + d_{ri} l_{ri} \right) \to \min, \quad (4)$$

where ρ is density of the material heat;

L is width of heatsink;

n is number of fins of heatsink.

An optimization problem is solved under the constraint:

$$R \le R_B \quad (5)$$

where R_B is boundary-allowable input thermal resistance of heat sink.

Restriction (4) defines the efficiency of heat, which does not limit the size of elements.

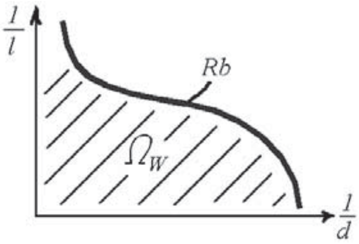

Figure 2 - Forming operability domain

To limit the numerical values the parameters of the thermal line in the calculations are mapped into the area of inverse values:

$$d_{pi} = \frac{1}{x_{1i}}; l_{pi} = \frac{1}{x_{2i}}; d_{ri} = \frac{1}{x_{3i}}; l_{ri} = \frac{1}{x_{4i}}; i = \left(\overline{1...n}\right),$$

This mapping transforms operability domain to the form is shown at Fig. 2, where Ω_W is operability domain. In this case the objective function is converted to the form:

$$m = \rho L \sum_{i=1}^{n} \left(\frac{1}{x_{1i}} \frac{1}{x_{2i}} + \frac{1}{x_{3i}} \frac{1}{x_{4i}} \right) \to \max. \quad (6)$$

The boundary of operability domain is formed by using expressions (1) has a point of inflection, which may hinder the convergence of iterative optimization algorithms. To improve the convergence the output function model is used

$$R(X) = \sum_{i=1}^{n} \sum_{j=1}^{4} c_{ij} x_{ij}^2 , \quad (7)$$

The coefficients of the model are determined from the condition of coinciding tangent to function (1) and tangent to ellipsoid (7). The equation of the tangent to boundary function is formed as linear model:

$$R(X) = a_0 + \sum_{i=1}^{n} \sum_{j=1}^{4} a_{ij} x_{ij} , \quad (8)$$

Comparison of equations of tangents to the functions (1) and (7) yields an expression for the coefficients of the boundary function (7) in the form:

$$c_{ij} = \frac{R_B}{R_B - a_0} \frac{a_{ij}}{x_{bij}} .$$

The optimal parameters of the thermal line is determined by the method of Lagrange multipliers, which leads to the relations:

$$x_{1i} = \frac{1}{\sqrt[4]{2\lambda}} \sqrt[8]{\frac{c_{2i}}{c_{1i}^3}}; \quad x_{2i} = \frac{1}{\sqrt[4]{2\lambda}} \sqrt[8]{\frac{c_{1i}}{c_{2i}^3}} \quad (9)$$

$$x_{3i} = \frac{1}{\sqrt[4]{2\lambda}} \sqrt[8]{\frac{c_{4i}}{c_{3i}^3}}; \quad x_{2i} = \frac{1}{\sqrt[4]{2\lambda}} \sqrt[8]{\frac{c_{3i}}{c_{4i}^3}} \quad (10)$$

To calculate the heatsink having minimum weight initial data are thermal resistance R_B, coefficient of thermal conductivity λ and width of the heat L and number of fins n.

Since the values of the coefficients in expressions (9) and (10) depend on the position of a boundary point, then to define the optimum size the iterative algorithm is used.

IV. HEATSINKS HAVING MINIMUM MASS

Optimization of the mass was carried out for the heat sink is shown in Fig. . The material is -an aluminum alloy Ad2. Power is $P = 10$ W, ambient is $t_c = 40^0 C$, permissible input thermal resistance is $R_B = 2$ K/W. In the algorithm the dependence of heat transfer coefficients of the intercostals distances is considered [3]. The dependence of the mass of heatsink on the number of fins. The results of calculations are shown at Fig. 3.

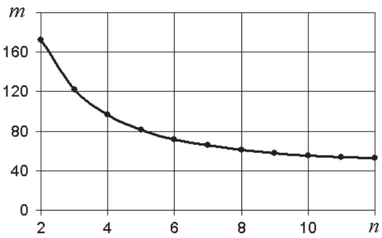

Figure 3. - Dependence of the mass of heatsink on the number of fins

The figure shows that the optimization can significantly reduce the mass of heat. The greatest change in mass is carried out with increasing the number of fins $n = 6$, that can reduce a lot of heat in 2,5 times. In comparing with plate the mass of heatsink is reduced by 4 times. A further increase in the number of fins can reduce the mass of heat up to 25%.

Optimization leads to heatsink having the thickness of the base varies from 10mm to 2mm. The thickness of the fins varies from 1,6 mm to 0,4 mm. The height of fins at the end of heatsink decreases to 30%.

V. CONCLUSION

The developed algorithm allows to design heatsinks having minimum weight by changing the parameters of structural elements. The mass of heatsink can be decrease in several times in comparing with plate heatsink. The mass of heatsink having standard sizes is reduced in 10 percents. The algorithm allows to take into account structural constraints and the form of heat sinks at the design stage.

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