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Research on Heat Dissipation Design Model Construction and Optimization of Submarine Data Center

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Abstract: In this paper, the heat dissipation optimization of Seabed Data Center is studied, and the packing model and heat dissipation model are established. First of all, the premise of packing without considering the working environment is established. Considering packing only, the maximum number of servers that can be used is 331. Then, the heat dissipation model of heat exchange between data center and seawater is established, and the maximum number of servers is 146. The single size model of fin is established. It is assumed that the maximum size of the container shell does not exceed 1m*1m*12m, and the container is a cylindrical structure with a diameter of 1m, so the required filled fin size is 4 included angles. First of all, the mainstream heat sink needs to be selected, the appropriate heat sink is selected according to its different functions, and the rectangular fin heat dissipation type is selected. Then, the specific shape coefficient of the length, width and height of a single heat sink in the included angle region is studied. Through the study of materials, find a reasonable value range, establish constraints, and solve the maximum number of heat sinks that can accommodate 1448.

1. Introduction

The subsea data center effectively saves energy by exchanging heat with seawater and using seawater flow to dissipate heat for Internet facilities. For subsea data centers, how to store more servers in a limited volume is a key problem in the normal and rapid cooling process of servers in seawater [1]. As China's big data center enters the ocean era, it is necessary to participate in the optimization design of the subsea data center and the development of efficient heat dissipation shell for China's big data construction.

2. Build packing model

2.1 Simplification of data center models

Data center containers are cylinders 1 meter in diameter and 12 meters in length. Simplified model, the cylinder container is cut into multiple rectangular containers.The specific cutting method is to set the longest side of the middle square as the diameter of the section one meter (pink part), and set the remaining part as the largest area of the small rectangle (blue part).

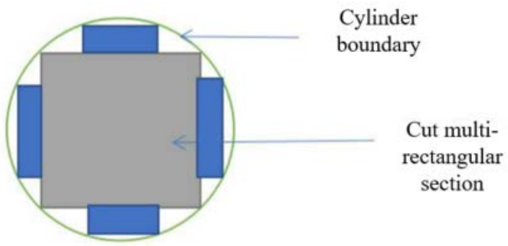

Figure 1: Cross section cutting of data center container

2.2 Build packing model

The number of rectangles parallel to the axis of the cylinder on the cross section parallel to the sea surface is X [2], the number of rectangles perpendicular to the axis of the cylinder on the cross section is Y, the number of rectangles perpendicular to the sea level is Z, and the number of servers is N.

Maximum number of servers:

$$number = \max(n) \tag{1}$$

The sum of all server volumes must be less than or equal to the sum of available space:

$$V_f * n \le V_{sum} \tag{2}$$

The number of servers in each direction does not exceed the size of the container:

$$\{\begin{array}{l} x*44.45/1000 \le X_1 + X_2 \\ y*482.3/1000 \le Y_1 + Y_2 \\ z*525/1000 \le Z \end{array} \tag{3}$$

It was calculated that the container could hold up to 331 neatly stacked servers.

3. Heat dissipation model

3.1 Derivation of heat dissipation formula and optimal heat dissipation orientation

The specific expression of Newton's cooling law is: when there is a temperature difference between the surface of the object and the surrounding area, the heat loss per unit time from the unit area is proportional to the temperature difference, and the proportional coefficient is the heat conductivity:

$$q = h(T_s - T_\infty) \tag{4}$$

Q is the convective heat transfer heat flow density, h is the convective heat transfer coefficient, T_∞ is the surface temperature of the fluid, T_s is the surface temperature of the solid.

Fourier's law is expressed as:

$$Q = -hS\frac{\partial u}{\partial x} \tag{5}$$

Expressed by heat flow density as:

$$q = -h\frac{\partial u}{\partial x} \tag{6}$$

X represents the length from the hottest position inside to the outer surface; The minus sign indicates that heat is transferred in the opposite direction of temperature increase; H denotes thermal conductivity, a fixed value in homogeneous media.

Consider the different visit locations of data center containers, the first is horizontal visit, the second is vertical visit. According to Newton cooling formula, the first cooling formula, cooling area $S_1 = 2\pi r$, the first cooling formula, cooling area $S_2 = L*2r$. Obviously, the second kind of heat dissipation area is larger and heat flow exchange is more obvious. Choose this arrangement with the axis parallel to the sea level and the axis perpendicular to the flow direction of seawater.

3.2 The establishment of heat dissipation attenuation model

For data center containers, servers heat up together. It is assumed that the server is a whole, and the temperature dissipation process of the whole is that the maximum temperature of the container in the data center decreases to the outer shell area, and then the outer shell contacts the seawater to dissipate heat. Ensure that the temperature of the server is lower than 80°C. $T \le 80$: indicates that the temperature of the internal core area of the server is lower than 80°C.

The security of the server is considered in the container of the data center. The gas is used as the heat dissipation medium. While the server as the source of heat, the boxing model assumes that the server as a whole is a uniformly distributed whole. Therefore, the distribution of internal temperature considered is that the core area of the middle axis has the highest temperature and gradually decreases towards the shell.

Let T1 be the temperature of the gas part of the container. The heat emitted by the air in the container is the heat transmitted from the server to the air in the container

$$Q_1(i) = cm\left(T_1(i+1) - T_1(i)\right) \tag{7}$$

$T_1(i+1) - T_1(i)$ the temperature change in the gas from the ith second to the i+1 second.

i seconds of heat from the container:

$$Q_1(i) = \frac{c\rho V\left(T_1(i+1) - T_1(i)\right)}{\Delta t} \tag{8}$$

By Fourier's law, the heat that the container emits to the gas from the server's hot zone at the beginning of the next unit time:

$$\Phi_1(i+1) = \frac{\left[T_0(i) - T_1(i)\right]Sh_2}{d} \tag{9}$$

h is the convective heat transfer coefficient of the gas in the container; d=0.5L is the thickness of the gas from the center of the axis to the edge of the container

The amount of heat emitted by seawater in unit time (1 second)

$$Q(n) = \Delta TSh_1 = (T_{appear} - T_0)Sh_1 \tag{10}$$

ΔT is the temperature difference between the gas in the container and sea water in unit time; S is the surface area of container;h1 is the convective heat transfer coefficient of seawater at 20°C.

The empirical correlation equation of convective heat transfer coefficient H is:

$$h = kNu = k\,\mathrm{Re}^{0.8}\,\mathrm{Pr}^{0.3} \tag{11}$$

Re is the Reynolds number, Pr is plant criterion. The thermal conductivity is about 0.6 W /(m* K) and many other seawater thermal properties.

3.3 Differential cooling of time

The difference of time can be obtained at the time when unit time is equal to 0, t0=20 .At the second moment, as the server generates power consumption, according to The Fourier law and Newton's law of cooling, we can conclude that the temperature T must change, so there is a temperature difference between the container temperature and the ocean temperature, and there is a cause at the second moment part of the heat consumed by the temperature difference forms a difference equation:

$$\begin{gathered} T_1(i+1) = \frac{Q_1}{hs} + T_1(i) \\ Q_{i+1} = \left(T_1(i+1) - T_0\right) sh \end{gathered} \tag{12}$$

Given the minimum and maximum value of the number of servers, the number of servers within this range can be traversed through the traversal algorithm to find the number of qualified values from the beginning of power generation to stability of the temperature does not exceed 80 degrees Celsius, the maximum value of which is the maximum number of servers required for this problem is 146.

4. Optimization of structure and quantity of heat sink

Re-design the structure on the container shell to allow the container to obtain the maximum heat dissipation effect. The heat transfer equation is $Q = KA\Delta t$. For the forced circulation air cooler, the heat transfer coefficient can be obviously improved by taking effective measures to reduce the heat transfer resistance of the air side or controlling the liquid supply by means of selective liquid supply on the refrigerant side or using high efficiency heat transfer tube. In addition, increasing the flow velocity of the fluid can increase the heat transfer coefficient, but the flow resistance also increases accordingly. Therefore, there is a certain limit to enhance the heat transfer coefficient K by increasing the flow velocity of the fluid.

Assume that the height, thickness and distance of the fin structure currently selected are respectively height, width, distance. The rectangular fin structure is chosen as the fin base model, which simplifies the process of solving the surface area.

Generally speaking, the width of the fin should not be too large, sometimes the width of the fin structure is given, and here it takes 1.6mm. The value of space ranges from 3.5mm to 10mm. Thickness width is 0.9 mm to 4.2 mm.

$$\text{s.t.Maxf} = fin\_n \tag{13}$$

$$\begin{cases} \alpha = \arccos\left(\dfrac{d}{2\times(R+h)}\right) \\ l = R\left(\dfrac{\pi}{2} - 2\alpha\right)\pi \\ \text{fin\_n} \times width + space \times \left(fin\_n - 1\right) \le l \\ 20 \le \text{height} \le 50 \\ 0.9 \le width \le 4.2 \\ 3.5 \le \text{space} \le 10 \end{cases} \tag{14}$$

When the height of the fin structure, thickness and spacing of 20 mm, 0.9 mm and 3.5 mm respectively, to be able to get to a maximum of can loading quantity, namely 362.9, also known as an integer, therefore, a quarter of a round container can load 362 fin structure, so the whole container can load 1448 specifications of the fin.

5. Conclusion

This paper establishes the packing model and heat dissipation model, traverses the number of 1 to 331 servers, and solves the maximum number of servers. Then the single size model of the fin is established, and the rectangular fin heat dissipation type is selected. In the included angle region, the specific shape coefficient of the length, width and height of a single heat sink. Through the study of materials, find a reasonable value range, establish constraints, and solve the maximum number of heat sinks that can accommodate 1448.

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