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Research on Server Installation Direction Based on Newton's Heat Transfer Law

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Abstract: Nowadays, the storage of Seabed Data Center has become a new data storage technology, which has attracted much attention all over the world. Firstly, through the study of Newton's heat transfer law, it is analyzed that the premise of heat dissipation is the temperature difference inside and outside the solid container. On the basis of meeting this condition, the maximum installable quantity caused by the different arrangement of different servers in the container is calculated. The results show that when the server is placed in a horizontal form inside the container, the maximum number of 330 servers of the same type can be placed at the same time, while when it is placed in a vertical manner, the number of servers is only 269. From the comparison of the above conclusions, it can be seen that the horizontal installation method is more suitable for the internal heat dissipation of the server.

1. Introduction

According to statistics, the annual power consumption of global data centers accounts for about 2% of the total power consumption in the world, and the cost of energy consumption accounts for 30%-50% of the whole IT industry. In particular, the energy consumption required for heat dissipation of electronic devices accounts for a large proportion[1]. The construction of big data centers on land needs to occupy a lot of land. When cooling, it needs to consume a lot of electric energy and cooling water resources, and spend a lot of construction costs.

The cooling mode of solid in liquid is mainly convective heat transfer, which can be divided into natural convection and forced convection. It is assumed that the size of the data center set and packing is a cylinder with a diameter of 1m and a length of 12M, which is placed in the air (the cylindrical axis is parallel to the sea level) at the sea depth of 20°C in the South China Sea, in which the heat generation of a single 1U server is 500W (the normal working temperature cannot exceed 80°C), and the height of the 1U server chassis is 44.45mm, With a width of 482.6 mm and a length of 525 mm, it is necessary to evaluate how many servers can be placed in a single container shell[2] (only considering the heat dissipation requirements of the server).

2. Newton's heat transfer law model

The convective heat transfer intensity between the flowing fluid and the solid vessel wall can be calculated quantitatively by Newtonian heat transfer, and the specific formula is as follows:

$$q = h(t_s - T_\infty) \tag{1}$$

Where q is the heat flux density, h is the convective heat transfer coefficient, t_s is the surface temperature of the solid, and T_∞ is the surface temperature of the fluid.

In this question, only the heat dissipation requirements of the server are considered. According to the above formula, in order to realize the heat exchange between fluid and solid, i.e. q > 0, there must be $T_\infty < t_s$. it can be seen from the original text that T_∞ = 20°C. For the heat dissipation temperature of a single server, the given power is 500W, and the temperature can be found between 18 and 25°C by querying the network data, Because a container can accommodate a large number of servers, and the heat dissipation temperature of different servers is superimposed, it must exceed the surrounding seawater temperature, so it is certain that the heat dissipation demand of servers can be met.

For the placement rules of servers, this question compares the horizontal placement with the vertical placement, and determines the more appropriate number and location arrangement structure of servers through the results obtained by different calculation methods. Figure 1 is the style diagram of two server installation modes of cross-section and longitudinal section in cylindrical container, in which the left side is the cross-section of transverse placement and the right side is the cross-section of longitudinal placement.

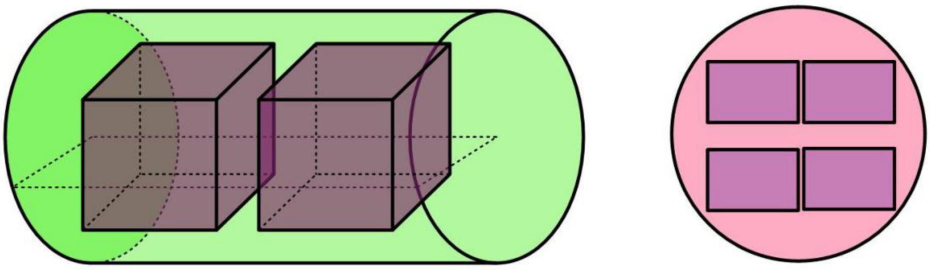

Figure 1: Server installation methods in different directions.

Because the wall thickness of container and server is not given in this paper, for the convenience of calculation, it is assumed that the thickness is zero and different servers fit closely. For both horizontal and vertical installation, the direction parallel to the sea level and the container axis is defined as the X direction, the direction perpendicular to the X coordinate in the sea level is the Y direction, and the direction perpendicular to the whole sea level is the Z direction. Because the axis of the cylindrical container is parallel to the sea level, it is assumed that there are x servers in the X direction in the defined coordinate system, There are y servers in the Y direction and Z servers in the Z direction. Therefore, for the construction of the objective function, the total number of servers is the largest:

$$F = max(x \cdot y \cdot z) \tag{2}$$

The installable quantities of servers with two different structures are calculated from the transverse section and longitudinal section respectively. The first is the transverse section:

The installation method is server horizontal installation, that is, the length of the server is parallel to the X axis, and the width of the server is parallel to the Y axis. There are the following constraints.

Constraint 1: the sum of the arrangement lengths of all servers cannot exceed the total length of the cylindrical container, that is:

$$x \cdot 525 \leq 12000 \tag{3}$$

Constraint 2: the sum of the arrangement widths of all servers cannot exceed the total width of the cylindrical container, that is:

$$y \cdot 482.6 \leq 1000 \tag{4}$$

Constraint 3: the sum of the arrangement heights of all servers cannot exceed the total height of the cylindrical container, that is:

$$z \cdot 44.45 \leq 1000 \tag{5}$$

Constraint 4: the sum of the volumes of all servers cannot exceed the volume of the cylindrical container, that is:

$$xyz \cdot V_{server} \leq V_{container} \tag{6}$$

For constraint four, it can be understood as the product of the first three constraints. Therefore, through the above understanding and analysis, the objective optimization mathematical model of horizontal installation server is established:

$$\begin{gathered} Target\, \max(x \cdot y \cdot z) \\ \text{s.t.}\begin{cases} x \cdot 525 \leq 12000 \\ y \cdot 482.6 \leq 1000 \\ z \cdot 44.45 \leq 1000 \\ xyz \cdot V_{server} \leq V_{container} \end{cases} \end{gathered} \tag{7}$$

Through calculation, the maximum number of servers installed in X direction, Y direction and Z direction in the transverse section is 22, 2 and 20 respectively. Although the number of servers in different coordinate directions is calculated by this method, a serious problem is ignored: since the structure of the container is a cylinder, the structure of the cylinder shows a tendency that the space inside the cylinder becomes smaller and smaller with the increase of the distance between both sides of the axis, Therefore, solving the number of servers constructed by the above method will inevitably lead to the installation of the server exceeding the maximum internal capacity of the cylindrical container in a certain direction. In order to more accurately obtain the installation number of servers in different sitting directions, the problem content is transformed into solving the volume of the largest cuboid in the cylinder.

How to get the largest cuboid in a cylinder? Firstly, the bottom of the cuboid coincides with the bottom of the cylinder, and the bottom is a square. It is easy to calculate that the area of the square is twice the square of the radius of the bottom of the cylinder, that is, the length of the square is 707mm, and the height of the long cuboid is still the height of the cylinder.

Therefore, data conversion is carried out for the above objective optimization model:

Constraint 1: the arrangement length of all servers cannot exceed the total length of cylindrical containers. This item remains unchanged, that is:

$$x \cdot 525 \leq 12000 \tag{8}$$

Constraint 2: the arrangement width of all servers cannot exceed the total width of the largest box in the cylindrical container, that is:

$$y \cdot 482.6 \leq 707 \tag{9}$$

Constraint 3: the arrangement height of all servers shall not exceed the total height of the largest box in the cylindrical container, i.e.:

$$z \cdot 44.45 \leq 707 \tag{10}$$

Constraint 4: the sum of the volumes of all servers cannot exceed the volume of the cylindrical container, that is:

$$xyz \cdot V_{server} \leq V_{container} \tag{11}$$

Similarly, a new constraint objective equation is established:

$$Target\, \max(x \cdot y \cdot z) \tag{12}$$

$$\text{s.t.}\begin{cases} x \cdot 525 \leq 12000 \\ y \cdot 482.6 \leq 707 \\ z \cdot 44.45 \leq 707 \\ xyz \cdot V_{server} \leq V_{container} \end{cases}$$

According to the calculation, the number of servers installed in X direction, Y direction and Z direction in the transverse section is 22, 1 and 15 respectively, and a total of 330 1U servers can be installed.

The above research mainly focuses on the installation mode of transverse section. The calculation method of server installation quantity for longitudinal section is analyzed below.

There are also four theoretical constraints:

Constraint 1: the arrangement length of all servers cannot exceed the total length of cylindrical containers, that is:

$$x \cdot 44.45 \leq 12000 \tag{13}$$

Constraint 2: the arrangement width of all servers cannot exceed the total width of cylindrical containers, that is:

$$y \cdot 525 \leq 1000 \tag{14}$$

Constraint 3: the arrangement height of all servers cannot exceed the total height of cylindrical containers, that is:

$$z \cdot 482.6 \leq 1000 \tag{15}$$

Constraint 4: the sum of the volumes of all servers cannot exceed the volume of the cylindrical container, that is:

$$xyz \cdot V_{server} \leq V_{container} \tag{16}$$

For constraint four, it can be understood as the product of the first three constraints. Therefore, through the above understanding and analysis, the objective optimization mathematical model of horizontal installation server is established:

$$\begin{gathered} Target \max(x \cdot y \cdot z) \\ \text{s.t.}\begin{cases} x \cdot 44.45 \leq 12000 \\ y \cdot 525 \leq 1000 \\ z \cdot 482.6 \leq 1000 \\ xyz \cdot V_{server} \leq V_{container} \end{cases} \end{gathered} \tag{17}$$

It can be seen from the above research content of transverse section that this method has certain calculation defects. Therefore, the calculation method of internal maximum cuboid is also used to determine the number of servers in different coordinate directions, including:

Constraint 1: the arrangement length of all servers cannot exceed the total length of cylindrical containers. This item remains unchanged, that is:

$$x \cdot 44.45 \leq 12000 \tag{18}$$

Constraint 2: the arrangement width of all servers cannot exceed the total width of cylindrical containers, that is:

$$y \cdot 525 \leq 707 \tag{19}$$

Constraint 3: the arrangement height of all servers cannot exceed the total height of cylindrical containers, that is:

$$z \cdot 482.6 \leq 707 \tag{20}$$

Constraint 4: the sum of the volumes of all servers cannot exceed the volume of the cylindrical container, that is:

$$xyz \cdot V_{server} \leq V_{container} \tag{21}$$

Similarly, a new constraint objective equation is established:

$$Target \max(x \cdot y \cdot z)$$
$$\text{s.t.}\begin{cases} x \cdot 44.45 \leq 12000 \\ y \cdot 525 \leq 707 \\ z \cdot 482.6 \leq 707 \\ xyz \cdot V_{server} \leq V_{container} \end{cases} \tag{22}$$

Through calculation, the number of servers installed in the X direction, Y direction and Z direction in the longitudinal section is 269, 1 and 11 respectively. In total, 269 1U servers can be installed.

Therefore, the numerical conclusion is obtained by comparing the number of servers in the horizontal section with that in the vertical section. The number of servers that can be installed in the horizontal section is 330, and the number of servers that can be installed in the latter is 269. Compared with the latter, the number of servers in the former is 23% more, and the heat dissipation temperature can also be seen from the initial calculation formula, it has been improved to a great extent.

3. Model evaluation

On the basis of simply considering that the heat dissipation meets the requirements, the calculation and analysis of the two server arrangement modes are carried out, and the result data are fully compared. The whole problem-solving idea is clear, and there is data comparison, which makes the result more reliable.

However, considering the heat dissipation of each server and whether the work is overloaded, there is a little deviation from the actual results.

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