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Research on the Durability of Subsea Container Materials Based on AHP

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Abstract: On Jan. 10, 2021, the first submarine data module built by Beijing Hailanxin Data Technology Co, Ltd. and China Shipbuilding Group Guangdong Shipbuilding International Co., Ltd. was unveiled in Zhuhai Gaolan Port, marking the fact that China's big data center has entered the ocean era. For submarine data centers, it is a very challenging problem to store more servers in a limited volume and ensure the normal and fast heat dissipation to seawater during the work of servers.

For the container to select the appropriate material, this document uses the AHP (hierarchical analysis), a total of four dimensions, first using the yield strength of the material as a judgment of the material's material compression resistance[1]. At the same time, seawater itself is a strong corrosive medium, the selected materials need to have a certain degree of corrosion resistance, this paper according to the given topic attachment materials[10], a total of 1 to 8 levels. The higher the level, the better its corrosion resistance. Then we need to improve the heat dissipation effect [5]. This paper, according to the relevant information [8], selected the thermal conductivity[7] of the material as the basis for judging the heat dissipation effect of the material, and finally, it also needs these costs. In this paper, according to the material on the futures trading site in recent days, the price of the material, weights, and other related calculations are carried out to select beryllium copper as the material.

1. Question Restatement

Deeper seawater has a lower temperature, which can achieve a better heat dissipation effect. At the same time, the increased pressure will put higher requirements on the pressure resistance capacity of the container shell; it is worth noting that seawater itself is a strong corrosive medium. All kinds of metal structures in direct contact with seawater are inevitably corroded by seawater. We need to select suitable materials and seabed depths to optimize the design, further improve the heat dissipation effect[9], reduce the cost as much as possible, and increase the service life[2].

2. Model Assumptions

Assume that the server is a cuboid with a height of 44.45 mm, a width of 482.6 mm, and a length of 525 mm.

It is assumed that there is no extreme weather, such as typhoons, hurricanes, etc.

It is assumed that the metal texture is uniform and the heat conduction rate is average.

It is assumed that the pressure of seawater does not deform the container.

Table 1: Symbol Description

Symbol	Content
λ_{max}	Eigenvalues
CI	Consistency indicator
CR	Concordance ratio
ω_i	weight vector
RI	Mean Stochastic Consistency Indicator

3. Problem analysis

Solve the problem of choosing the right material. Because seawater has greater pressure, which has a higher requirement for the container shell pressure resistance, this paper chose the yield strength of the material as a judgment of the material's pressure resistance. At the same time, seawater itself is a strong corrosive medium. The selected material needs to have a certain degree of corrosion resistance. This paper, according to the given topic attachment materials, has a total of 1 to 8 levels. The higher the level, the better its corrosion resistance[4].

Then it is necessary to improve the heat dissipation effect. According to the relevant information, the thermal conductivity of the material is selected as the basis for judging the heat dissipation effect of the material, and finally, the cost needs to be reduced. This article uses the price of the material on the futures trading website as the price of the material[6].

There are a total of four dimensions, and this paper uses the AHP method to perform related calculations such as weights. Finally, beryllium copper was selected.

4. Model Building and Solving

AHP component evaluation system

Build a Hierarchical Model [3].

The decision-making problem is decomposed into three levels. The top level is the target level, which is to select the most suitable key indicators for evaluating the impact of materials on corrosion resistance, thermal conductivity, price, and compressive resistance; the bottom level is the program level, that is, two influence factors, P1 and P2; the middle layer is the standard layer, including four indicators: corrosion resistance C1, thermal conductivity C2, price C3, and compression resistance C4, as shown in Figure 1:

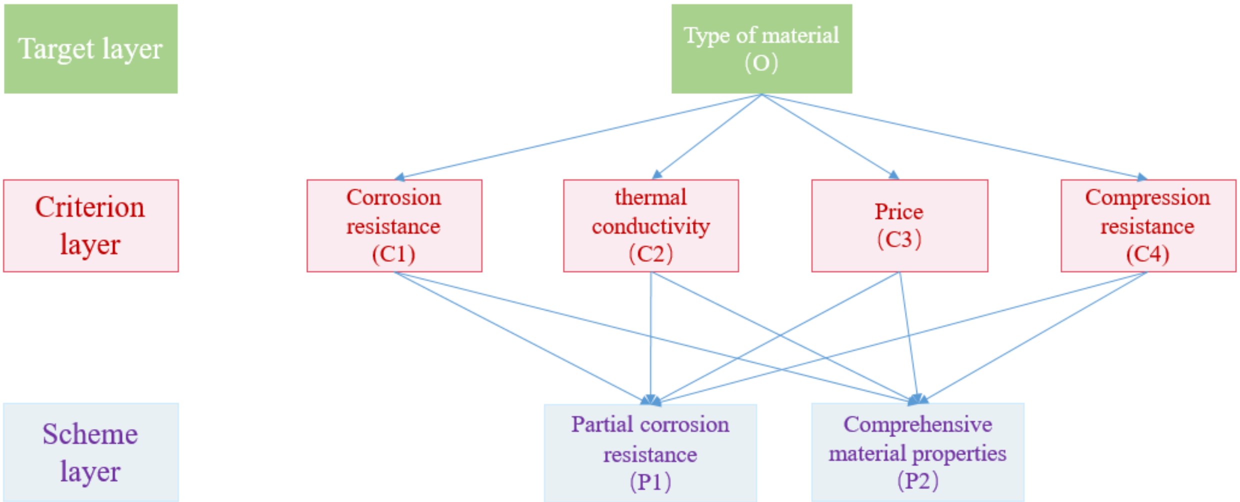

Figure 1: Hierarchy

Construct the judgment matrix, O-C; compare the four elements, C1, C2, C3, and C4 in the reference layer C in pairs to obtain the pairwise comparison matrix, Table 2 and Table 3:

Table 2: Comparison matrix

Index	C1	C2	C3	C4
C1	1.0000	0.3300	0.7000	1.0000
C2	3.0303	1.0000	4.0000	6.0000
C3	1.4286	0.2500	1.0000	2.0000
C4	1.0000	0.1667	0.5000	1.0000

Table 3: Material Grading (Partial) [10]

Material	Corrosion resistance	Thermal conductivity	Price	Compression resistance	Score
Aluminum alloy 5052	4	138	18000	31	379.8211
Aluminum alloy 7075	4	130	20000	73	425.3861
Copper	5	401	68000	50	1349.719
Beryllium copper	5	100	59000	170	1099.31
Red brass	3	90	60000	49	1064.706
Aluminum bronze	3	40	43000	49	756.5625
High silicon bronze	3	100	45000	52	820.2013
90-10 cupronickel	3	60	55000	57	969.7161
70-30 cupronickel	3	60	56000	79	994.8201
Cast aluminum bronze	5	110	57000	46	1023.391
Inconel 625	3	100	15500	201	384.4693
Nickel-chromium stainless steel	3	17	20000	40	357.8722
Ductile Iron	2	80	17500	85	363.7432
1040 steel	2	70	15500	86	325.8764
1080 steel	2	75	14500	142	332.9928
hy-=80 steel	2	80	14500	90	315.5532
hy-100 steel	2	85	15500	93	335.8236
low alloy high strength steel	2	90	20000	50	396.972
Aged steel	2	80	10000	300	320.6232
Pure titanium	7	15	23000	90	426.5681

Material	Corrosion resistance	Thermal conductivity	Price	Compression resistance	Score
Titanium 6	7	50	13000	155	301.3689
303 stainless steel	1	27	1500	75	66.90818
304 stainless steel	1	27	2000	75	75.25818
302 stainless steel	1	27	2000	75	75.25818
316 stainless steel	1	27	2000	38	61.12418
17-4 ph stainless steel	1	27	2500	180	123.7182
410 stainless steel	1	27	2500	143	109.5842

Find the eigenvalue of O-C to allow $\lambda_{max} = 4.0671$, and the weight vector $\omega_i =（0.1367, 0.5760, 0.1813, 0.1060）^T$ formula $CI = \frac{\lambda_{max} - n}{n-1}$, so according to $CR = \frac{CI}{RI}$, calculate to get Table 4.

Table 4: Correlation calculation

largest characteristic root	CI value	RI value	CR value
4.0671	0.0224	0.89	0.0251

Pass the consistency check.

Thus, the weights of the corresponding indicators are obtained in Table 5:

Table 5: Index Weight

Index	Weights
Corrosion resistance	0.1367
Thermal conductivity	0.5760
Price	0.1813
Compression resistance	0.1060

In summary:

Beryllium copper can be selected as the material of the container.

Beryllium copper is an alloy with good mechanical, physical, and chemical properties. After quenching and tempering, it has high strength, elasticity, wear resistance, fatigue resistance, and heat resistance. At the same time, beryllium copper also has high electrical conductivity. High thermal conductivity, cold resistance, non-magnetic, no sparks on impact, easy to weld and braze, excellent corrosion resistance in atmosphere, fresh water, and seawater. The corrosion resistance rate of beryllium copper alloy in seawater: (1.1-1.4)×10-2mm/year. Corrosion depth: (10.9-13.8)×10-3mm/year. Because it retains its strength and elongation after corrosion, it can be kept in seawater for more than 40 years, making it an indispensable material for submarine cable repeater construction. In a sulfuric acid medium, in sulfuric acid with a concentration of less than 80% (room temperature), the annual corrosion depth is 0.0012-0.1175mm, and the corrosion is slightly accelerated when the concentration is greater than 80%.

5. Model evaluation

5.1 Advantages of the model

See the results clearly and intuitively.

Built on rigorous mathematical concepts.

The analysis of the problem is comprehensive, taking into account various situations.

The physical concept is clear, has strong applicability and flexibility, and can not only deal with complex geometric shapes in mechanical analysis, arbitrary boundary conditions, and heterogeneous anisotropic materials.

5.2 Disadvantages of the model

If the amount of data is too small, there may be errors.

There should not be too many decision-making layers for evaluation. If there are too many, the weight vector will increase, and the difference between the judgment matrix and the consensus matrix may be very large.

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