Research on acoustic environment optimization design of ship multi-functionnal conference room

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Abstract: In order to optimize the acoustic environment of the multi-functional conference room of the ship, the ODEON software is used for simulation calculation, and the sound absorption performance test of the sound-absorbing material is tested in the impedance tube test system. The reverberation time T30 was used as an evaluation index. A comparative study of different conference room ceiling structures was conducted. The results show that the alumina blanket sound-absorbing material is used as the conference room ceiling structure, the reverberation time of the ship multi-functional conference room is reduced from 1.3s to 0.4s, which achieves better acoustic environment optimization effect.

1. Introduction
With the continuously increasing demands of ship comfortability, the research concerning acoustic performance of ship's space, mainly including noise control in the cabin and acoustic environment optimal design of the using function of cabin, has obtained widespread attention. Currently, the studies focus more on the noise control in the cabin [1-3] and less on the optimal design of acoustic environment in the cabin. Compared with land-based buildings, the ship has its own characteristics in acoustic design, such as smaller inner room, many influencing sound sources and limited usages of acoustic materials, which increases the difficulties of the researches in this domain. As one of the important cabins of the ship, multi-functionnal conference room has its main functions including meetings, speeches and reporting. The excellent interior acoustic environment assists to improve the operational performance of multi-functionnal conference room. Taking the multi-functionnal conference room of one ship as research object, this paper established three-dimensional CAD model, proposed three schemes to optimize acoustic environment, and used ODEON software to calculate and analyze [4-5], which had achieved great results. At present, the optimization of the acoustic environment focuses more on the land-based building [6-7], less on the cabins of the ship. This paper introduced the acoustic technique of land-based building to the acoustics field of cabin, which has significant meaning in improving the acoustic performance of functional cabins, such as military ship and luxury cruise.

2. Research methods
2.1 Research object
With a height of 1.95 meters and an interior volume of 92 square meters (as shown in Figure 1), the meeting room of the cabin studied in this paper belongs to the flattened small space, which has relatively high requirements of reverberation time. With fabric carpet as the floor, the suspended ceiling of meeting room adopts the perforated composite rock wool panel (the perforated side is in the indoor side) and its wallboard all around uses the structure of composite rock wool panel.

2.2 Simulation model
Based on the actual sizes of the meeting room, the three-dimensional CAD model (as shown in Figure 1) was established and the ODEON was introduced for calculation. Source signal P1 was set as the omnidirectional
point sound, the platform of meeting room as coordinate. The sound lines and particles were emitted through the sound source. The Acceptance Point One and Acceptance Point Two were set in the front and back of the meeting room respectively and the model was tested by 3D Investigate Rays sound rays and 3D Billard acoustic particle.

Fig1 The model of marine multi-functional conference room

3. Calculation and analysis

3.1 Calculation and analysis of comparison of the influence of suspended ceiling and wallboard

The acoustic method used in the suspended ceiling and wallboard of the multifunctional meeting room is the key factor to influence the acoustic environment. To compare the influence degree of suspended ceiling and wallboard, the schemes as shown in Table 1 were proposed. The original scheme was to keep the acoustic materials in the meeting room unchanged. Comparison scheme 1 was to keep the materials of suspended ceiling unchanged and adopt the ceramics fiber sound absorbing panel with the thickness of 50mm with the same area of wallboard (48m²). Comparison scheme 2 was to keep the material of wallboard unchanged and replace the suspended ceiling material in 48-square-meter meeting room with the 50-millimeter ceramics fiber sound absorbing panel.

| Scheme          | Wallboard                | Suspended ceiling             |
|-----------------|--------------------------|-------------------------------|
| Original        | composite rock wool panel| perforated composite rock wool panel |
| Comparison 1   | Ceramic fiber sound absorbing panel (replaced 48m²) | perforated composite rock wool panel |
| Comparison 2   | composite rock wool panel | Ceramic fiber sound absorbing panel (replaced 48m²) |

Figure 2(a) is 500Hz reverberation time cloud diagram of multifunctional meeting room with using the original materials. The reverberation time is relatively high and the troubling sound occurs when the meeting room is used. If the acoustical design is not carried out, the communication activities like meeting and video lecture in such a place will be affected easily by the superimposed disturbances of reflection noise in suspended ceiling, thus making the sound quality fuzzy and influencing the understanding of the language of the speaker.

Figure 2(b) is 500Hz reverberation time cloud diagram of the comparison scheme 1, whose reverberation time is reduced to 0.8. The acoustical environment is improved obviously. Figure 2(c) is the 500Hz reverberation time cloud diagram of the comparison scheme 2, whose reverberation time is reduced to 0.6. Its acoustical environment has certain improvement compared with comparison scheme 1. Therefore, the transformation of acoustical material in the multifunctional meeting room could effectively improve its acoustical environment.
When changing the acoustical material in the same area, the improvement of acoustical environment by changing the material of suspended ceiling in the multifunctional conference room is better than that of wallboard.

![Fig2](image)

Reverberation time cloud of marine multi-functional conference room (500Hz)

### 3.2 Experimental analysis of suspended ceiling material in multifunctional conference room of cabin

The acoustical material of suspended ceiling has a larger influence on the acoustical environment of the multifunctional conference room in cabin so that it is important to select the suitable acoustical material of suspended ceiling. Alumina blanket, ceramics fiber and pinhole aluminum sheet are the sound-absorbing materials that meet the using requirements of cabin. To study the influence of suspended ceiling structure with different sound-absorbing materials on the multifunctional meeting room, the sound absorption test of these three materials was carried out.

The sound absorption test was finished in the impedance tube test system, whose test objects were alumina blanket sound-absorbing material with the thickness of 50mm, ceramics fiber sound-absorbing material with the thickness of 50mm as well as 1.3 pinhole aluminium sheet sound-absorbing material with 50 cavity. Figure 3 is the comparison of sound absorbing coefficients of these materials. From Figure 3, it is found that the sound absorbing coefficients of 50-millimeter alumina blanket and 50-millimeter ceramics fiber increase with the increasing of frequency, the peak value of sound absorbing coefficient occurs in the area of high frequency and the sound absorbing coefficient of alumina blanket is higher than that of ceramics fiber at most frequencies. The sound absorbing coefficients of 1.3 pinhole aluminium sheet sound-absorbing material with 50 cavity increase and then decrease as the frequencies increase and its peak value occurs in the area whose frequency is 1600Hz.

![Fig3](image)

Sound absorption coefficient of different materials

### 3.3 Optimal computation

Based on the analyzed results of the following simulations and tests, three optimization schemes to improve
acoustical environment in the multifunctional meeting room in the cabin were proposed. Under the premise of keeping the original materials of suspended ceiling and wallboard unchanged, the methods of three optimization schemes are to use 50-millimeter alumina blanket, 50-millimeter ceramics fiber and 1.3 pinhole aluminium sheet with 50 cavity respectively to replace the original material of suspended ceiling in meeting room. After obtaining the test results, the ODEON was adopted for calculation and analysis. Table 2 lists all the comparison data of reverberation time of the original scheme and three optimization schemes. Figure 4(a), Figure 3(b) and Figure 3(c) are the 500Hz reverberation time cloud diagram of the optimization scheme 1, 2 and 3 respectively. Combining figures and tables, it is seen that after changing three materials above, the inner acoustical environment of the multinational meeting room is improved obviously. When adopting ceiling structure of alumina blanket sound absorbing material, the reverberation time at front rows reaches 0.41, while the reverberation time at back rows reaches 0.42. When using ceiling structure of ceramics fiber, the reverberation time at front rows reaches 0.51 and the reverberation time at back rows reaches 0.53. For ceiling structure of pinhole aluminium sheet, the reverberation time at front rows reaches 0.55 and the reverberation time at back rows reaches 0.56. From the comparisons of three kinds of materials, it is seen that the average reverberation time in the meeting room is shortest when using ceiling structure of alumina blanket sound absorbing material, which could effectively improve speech intelligibility of the multifunctional meeting room in cabin and audience's intelligibility to the content. Therefore, the ceiling structure of alumina blanket sound absorbing material is suitable for this multifunctional conference room.

Tab 2  Reverberation time comparison table for different materials

| Scheme       | Acoustic method                                | Reverberation time $T_{30}$ (500Hz) |
|--------------|------------------------------------------------|------------------------------------|
|              |                                               | front rows | back rows                |
| Original     | 50mm perforated composite rock wool panel     | 1.28       | 1.27                     |
| Optimal 1    | 50mm alumina blanket                          | 0.41       | 0.42                     |
| Optimal 2    | 50mm ceramics fiber panel                     | 0.51       | 0.53                     |
| Optimal 3    | 1.3mm pinhole aluminium sheet with 50 cavity  | 0.55       | 0.56                     |

(a) 50mm alumina blanket  (b) 50mm ceramics fiber panel  (c) 1.3mm pinhole aluminium sheet with 50 cavity

Fig4  Reverberation time cloud of three ceiling materials(500Hz)

4. Conclusions
With the multifunctional conference room as research object, we simulated and calculated the reverberation time by using ODEON and conducted performance tests of sound absorption by using impedance tube test system. Additionally, we also studied the optimization design of the acoustic environment in the multifunctional meeting room. The conclusions are made as follows:

1) The reform of the acoustic practice in the multifunctional meeting room could effectively improve the acoustical environment and the improvement of acoustical environment by changing acoustic material in ceiling is better than that in wallboard.

2) The sound absorbing coefficients of 50-millimeter alumina blanket and 50-millimeter ceramics fiber increase with the increasing of frequency, the peak value of sound absorbing coefficient occurs in the area of high frequency. The sound absorbing coefficients of 1.3 pinhole aluminium sheet sound-absorbing material with 50 cavity increase and then decrease as the frequencies increase and its peak value occurs in the area whose frequency is 1600Hz.
3) Using alumina blanket, ceramics fiber and pinhole aluminium sheet with cavity in suspended ceiling could effectively improve the acoustical environment in multifunctional meeting room of cabin. The suspended ceiling structure of alumina blanket sound-absorbing material makes the reverberation time of front rows reach 0.41 and the reverberation time of back rows reach 0.42, which is more suitable for this multifunctional meeting room.

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