Evaluation of Polyimide Foam Material Applied in Scientific Investigation Ship

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Abstract. Polyimide foams prepared by new technology should be tested each index before application. This article focused on the evaluation of polyimide foam materials which applied in ship. Combined test in typical room and scientific analyzing, we evaluated the polyimide foam comprehensively. In the process of analyzing data which got from the labs which installed polyimide foams one year, we used normalized and standard method for objective evaluation. The result included the advantages and disadvantages of polyimide foams which were very important for popularize of the application in the future.

1. Introduction
Polyimide foam materials are well used in production and manufacturing as the best polymeric because of their outstanding thermal, mechanical and electrical properties [1,2,3]. Due to their excellent chemical and radiation resistance they are also widely used in aerospace, microelectronic, coating and photonic applications.

In foreign countries, the mature technology of polyimide foam was used for battleship and submarine [4,5]. However, the technology of thermal materials in China wasn’t mature enough to application. For example, Northwestern Polytechnical University had prepared Polymethacrylimide foam by using methacrylic acid and acrylonitrile as the main monomers. Harbin Engineering University had prepared Polyimide foam and tested kinds of performance.

Promoting application of polyimide foam needed testing the materials in ship. There wasn’t useful experience on evaluating the performance of materials. Therefore, this article focused attention on how to evaluate the polyimide foam in ship by normalized and standard method.
2. Experimental

2.1. Materials
The polyimide foams used in our experiment were researched by Institute of Advanced Marine Materials which belongs to Harbin Engineering University. They prepared polyimide foams with 3,3',4,4'—Benzophenonetetracarboxylicdianhydride (BTDA); 4,4'-Methylendianiline (MDA); 3,4'-Oxydianiline (3,4'-ODA) and 4,4'-Oxydianiline(4,4'-ODA) so on. In the production of polyimide foams there were some difficulties such as mixing the premonitory liquid, controlling the time of sparkle, evaporation level and the degree of imidization[6]. The specific process concluded.

![Chemical structures of polyimide foams](image)

**Figure 1.** Chemical structures of polyimide foams

2.2. Methods
For evaluating better, we chose typical cabins including labs and centralized control room (showed in fig.2)[7]. Especially, one of two labs was equipped with polyimide foams and another of them without any thermal insulation material for comparison on the scientific investigation ship —“XIANG YANG HONG 06”[8].

![The view of two labs(left) and centralized control room (right).](image)

**Figure 2.** The view of two labs(left) and centralized control room (right).

In the centralized control room, there was a lot of piping with high temperature. We formed tubular polyimide foam integrally which lay the piping. Fixing the polyimide foam with adhesive and nails was easy in two labs. We could prepared the polyimide foam in special shape considering the structure.
Figure 3. The schematic map of laying piping which red expressed piping, yellow expressed polyimide foams, gray expressed silver paper (left) and the actual map of piping after lay(right).

In the two labs we all installed temperature and humidity sensors on the wall and set six points. Point 3 located at the roof and point 2 located on the bottom. At the same time, the rest located all around. In one year, we recorded the data from the sensors and the temperature of six points with infrared thermometer two times one day whatever the ship was under way or not. At the same time we recorded the data using sound meter.

3. Results and discussion
In this article, we applied the professional statistic and analysis software on the base of traditional analysis method, withdraw related data, adopted a land of method to quantify the data, and established corresponding mathematical mod4-5. The mod considered typical environment and scientific analysis. The important of evaluation concluded thermal resistant, absorption of sound, resistance to environment, and improvement of cabin living environment.

3.1. Thermal resistance
The temperature in the two labs was recorded for one year from June to August in 2014 the ship was performing a task on the western Pacific.

Figure 4. Temp. of six points in two labs (star represented the lab without polyimide foam and triangle represented the lab with polyimide foam) from August 3 ~13.

Fig.4 showed that point 3 was warmer than others because it’s at the roof and point 2 was colder than others because it’s on the bottom. By the contrast of two labs, we got qualitative analysis that the polyimide foam showed good adiabatic performance.

For further analysis of the adiabatic performance, we processed a large number of thermal data. Due to the bottom weren’t laying polyimide in both, we discarded point 2, meanwhile, point 1,4,5,6 were
around the lab with impact of different light levels, we focused on the comparison between point 3 which on the roof.

We used the mod to process the data with average of two days at the same time. From fig.5(a) we got the messages that the overall data were warmer than 28°C due to the ship was in the tropics and after discarded some singular values, the lab with polyimide foam were colder than the other about 4.8°C.

![Temperature Comparison](image)

**Figure 5.** Contrast of temperature between two labs(square represented the lab without polyimide foam and triangle represented the lab with polyimide foam), (a) showed from July to August in Summer , (b) showed from October to November in Autumn and (c) showed from January to February in Winter.

In Autumn, the total temperature changed from 10°C to 20°C, when the environment temperature was higher than 15°C, the temperature of the lab with polyimide foam was a little lower than the other. When the environment temperature was lower than 15°C, the temperature of the lab with polyimide foam was a little higher than the other.

In Winter, the total temperature changed from -5°C to 5°C, by analyzing the data we got that the lab with polyimide foam was warmer than the other about 4°C.

For further quantitative analysis the performance of polyimide foam, we fitted the temperature difference using Fourier function [9]. The fitted curve proved that polyimide foam performed better in worse environment. We got same result using the significance test formula [10].
Figure 6. The curve of temperature in two labs(left) and contrast of the fitted curve and experiment curve of the temperature difference between the two labs.

3.2. Noisy resistance

The level of noise in the main engine room was highest on the ship due to turbine in it. In our experiment, the data was always higher than 70dB. Whatever, the crew was on duty in the main engine room. It’s bad for health when stayed in the main engine room more than 6 hours.

There were obvious differences between temperature and noise data. Fig.7 showed that the noise out the room was about from 80 to 90dB when the engine was working and in the room with polyimide foam resisting the noise, the data waved from 60 to 70dB.

Figure 7. Contrast of the noise between in and out the main engine room(square represented out the room, triangle represented in the room).Half of the experiment days were on work and the other were out work.

When the engine was out work, the noise out of the room was down to 60dB and in the room polyimide foam made the data down to 50dB. The polyimide foam performed good noisy resistant.

3.3. Poor environment resistance

Traditional materials were contaminated by oil and gas easily in special environment easily. Considering the disadvantage, we focused on the polyimide foam changing in the special environment.

After a year of test, the polyimide foam still maintained good outlook and performance no matter poor environment or normal.

3.4. Friendly to environment

People needed working long time in typical rooms, for example monitoring the instrument and analysis of the sample got from the sea so on. Therefore, it’s very important that the materials had pungent smell or not.
Investigation by people on ship showed that polyimide foam had performed well without pungent smell and toxicity.

3.5. Advantages after reducing weight

We chose typical rooms in the performance of materials testing. When we calculated the number of reducing weight after laying polyimide foam, we chose appropriate mod.

![Figure 8. The profile of the testing ship in mod.](image)

According to the lowed density than traditional materials, the ship would reduce weight about 88.3t if laying polyimide foam all. After reducing weight, the ship would reduce the consumption of fuel and enhance the ability of endurance.

4. Conclusion

We could summarize the characteristics of polyimide foam by analyzing the actual data and the result of mod.

1. Polyimide foams were easy to fixed, shaped and lay in ship.
2. With good thermal resistance and noisy resistance, polyimide foams could maintain the room in better temperature and noise than outside.
3. With good oil resistance and acid resistance, polyimide foams could keep performance in extreme environment.
4. Without pungent smell and toxicity, polyimide foams showed friendly to environment.
5. With lower density than traditional materials, polyimide foams showed strong competitive power considering consumption of fuel.

In conclusion, polyimide foams had many advantages as a new kind of thermal resistance material. Polyimide foams will play an important role in flame retardant, thermal resistance, noisy resistance, reducing weight and so on. They are suitable for popularizing in ship.

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