

On the Establishment of the Analysis and Verification Methods Regarding the Air Ventilation with Very Low Velocity in JEM (KIBO) as the First Manned Space Development in Japan

Ichiro Aoki and Hiroyasu Mizuno
Japan Aerospace Exploration Agency

Sadamu Ito
Mitsubishi Heavy Industries, Ltd. Kobe Shipyard & Machinery Works

This is a work of the Government of Japan

ABSTRACT

Japanese Experiment Module (JEM) called KIBO is the first manned space structure in Japan. Among several high technologies of JEM development, achievement of the air ventilation (AV) under the micro gravity was challenging because the requirements were very difficult to meet. The verification test in the module level under the operation of the flight hardware had a serious problem by the natural convection owing to the heat generation by the flight hardware. The analysis had problems how to verify its own validity because the turbulent flow around diffuser exits in addition to the laminar flowfield where the velocity is extremely small. This paper describes the solution of these problems in the analytical and testing verification points of view. As a result, we found our analysis applied to the AV performance could provide the complicated flowfield in low velocity with the effects of turbulent flow as well as natural convection. Since almost of the region in JEM showed that the velocity met the measured velocity in JPM which is a main element of JEM, we could verify that the analysis method is excellent to predict the AV flowfield in JPM. The scenario for the JEM AV development was successfully established and verified by the JEM development.

1. Introduction

JEM is the first manned space structure in Japan. It needs several representative techniques in each sub-system characteristic of the long term use and the manned space development, major issues of which in ECLSS (Environmental Control and Life Support System), PTCS (Passive Thermal Control System) and ATCS (Active Thermal Control System) are as follows:

- 1) Very small allowable temperature range in the inner structure shell regardless of the complicated thermal interaction among other modules - to be solved in PTCS,
- 2) Design of debris shield replaceable on-orbit with Multi Layer Insulation - in PTCS,
- 3) Preventing corrosion and corruption of fluid components and plumbing (including coolant contamination) for the long duration - in ATCS,
- 4) Safe separation of different two coolants in heat exchangers - in ATCS,
- 5) Low noise requirement in cabin - in ECLSS,
- 6) Low toxic off-gas level in cabin air - in ECLSS,
- 7) Very low velocity AV with the minimum and the maximum limitation - in ECLSS.

Above all, the AV development techniques for JEM were confronted with serious problems to solve such as:

- How to verify the AV performance in the complete configuration in which Japanese two elements, JEM Pressurized Module (JPM) and JEM Logistic Module – Pressurized Section (JLP), are coupled, nevertheless they cannot be coupled each other on the ground,
- How to verify the AV performance for the various operation modes,
- How to establish the test method for required very low velocity flowfield where the natural convection on the ground has to be eliminated

This paper describes the AV achievement in JEM which was the most characteristic of the manned space activity and had problems to solve mentioned above, and includes the scenario of the development, tests, analysis in addition to the result of the verification.

2. Scenario

Scenario for the JEM AV development was adopted in order to solve the problems of a) to c) mentioned in Sec.1 as follows:

- The AV on-orbit operation performance shall be verified by analysis regarding the problems a) and b). This attempt needed the followings;
 - To establish the analysis method which can predict an extremely low velocity flowfield with turbulent flow near the diffuser,
 - To verify the analysis method.
- The AV performance in the representative operation mode shall be verified by the ground test regarding the problem c). This needed the followings;
 - To verify the analysis method which can predict a flowfield generated by the ground test,
 - To establish the ground testing method.

3. Ground Tests for Acquiring Fundamental Technical Data

In the early phase of the development, for the purpose of our fundamental understanding of a complicate flowfield around a diffuser, we investigated performance, noise level, and the velocity distribution map with air entrainment for analysis by using some types of diffuser.

Fig.3-1 shows the pictures of the performance test of the final diffuser model. In the test, the early diffuser model gave an excellent performance but its noise was not low enough to meet the noise requirement in module level. In order to get pressure drop for the appropriate mass flow balance between a Temperature and Humidity Control (THC) fan outlet and each of diffuser outlet as well as to cut down the noise, we changed hole size and hole location of an inner perforated plate (called the punching metal board) and combination of the perforated

plate, straightening vanes and mesh. As a result, the final diffuser model attained 8dB noise reduction even though it was a little inferior in performance to the early diffuser model. The effect of louver angle was also assessed by the ground test and finally 22 degree was selected taken the velocity distribution into consideration. Note that the flight model of the diffuser in JEM can be changed the louver angle manually as the crew prefers.

Fig.3-2 shows the velocity distribution map with air entrainment around the diffuser. The values on the grid points in Fig.3-2 were defined as the measured flow rate at the virtual boundary. The data is essential for providing more precise analysis of the AV on-orbit operation performance.

JAXA ECLSS Test Chamber for the AV investigation which can reduce the natural convection enough is shown in Fig.3-3. It is a full scale model in size, but it simulates only aisle part of the JPM configuration without the Air-Lock (A/L) in the port side. Using it, we carried out the AV performance test in JPM with the diffusers on the module level point of view in the early phase.

The result of the flowfield obtained by the test of AV is given in Fig.3-4. We could find the flowfield was favorable. The result encouraged us to proceed our development but remained a concern on the flowfield in velocity around the A/L which had complicated protrusions into the cabin.



Fig.3-1 Pictures of the performance test of the final diffuser model

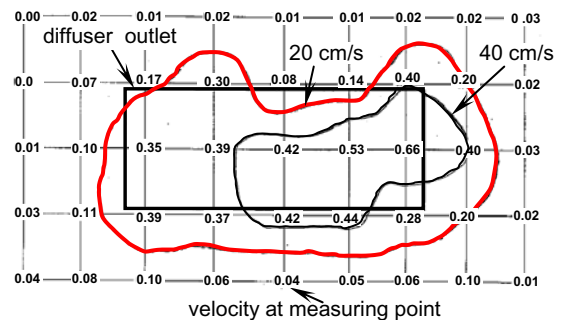


Fig.3-2 Velocity distribution map around the diffuser



Fig.3-3 JAXA ECLSS test chamber (left: outside view, right: inside view)

