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Colloidal Clusters 宇宙実験供試体の開発

Equipment Development for Colloidal Clusters Experiment

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1. Introduction

Colloidal Clusters Experiment was selected as one of the Feasibility Studies for 'Kibo' Utilization in December 2015. This is one of scientific experiments, which was proposed by Prof. Yamanaka at the Nagoya City University. The main aim of experiment is to investigate appropriate conditions for obtaining tetrahedral clusters efficiently. The Feasibility Study was ended in December 2017 and the proposal was authorized to prepare the flight experiment. The System Definition Review (SDR) was held in June 2018. A launch was planned to use SpaceX CRS-19 (SpX-19) at the SDR. The Preliminary Design Review (PDR) was held in March 2018. The Critical Design Review (CDR) and Post Qualification Test Review (PQR) was finished in August 2019. The Pre-Shipment Review (PSR) was completed in September 2019 and then the equipment was handed over. Samples were directly transported to the Johnson Space Center by refrigerated delivery service.

A period of equipment development from conceptual design to shipment is about 15 months. This is relatively short in the discipline of physical sciences as compared with the past equipment development. The development cost is also relatively low. The shorter development period and the lower cost are quite essential in future experiments in scientific utilization. Therefore, we describe important points for equipment development.

2. Roles of Team Members

Every organization has appropriate roles. JAXA designed the equipment, inspected and tested the equipment, prepared Safety Assessment Report (SAR) and several documents, and held necessary review boards. JAMSS selected the best UV LED unit (commercial off-the-shelf, COTS), provided many documents, and strongly supported to make a utilization requirement. JSF supported to carry out ground-based experiments at NCU, assisted preparation of colloidal dispersion samples, and transported flight samples to the Johnson Space Center. AES carried out clinostat experiments, provided sample bags, assisted sample preparation, and finalized flight sample bags. NCU determined sample compositions, carried out ground-based experiments, and provided flight samples including fine particle synthesis.

3. Equipment Design

3.1 Requirements

Several important requirements exist, for example, structure fracture control, materials compatibility, electromagnetic compatibility, electrical, electronic and electromechanical (EEE) compatibility, and so on. In addition, samples should be prepared by considering toxic safety and structural robustness. These requirements should be qualified by inspection,

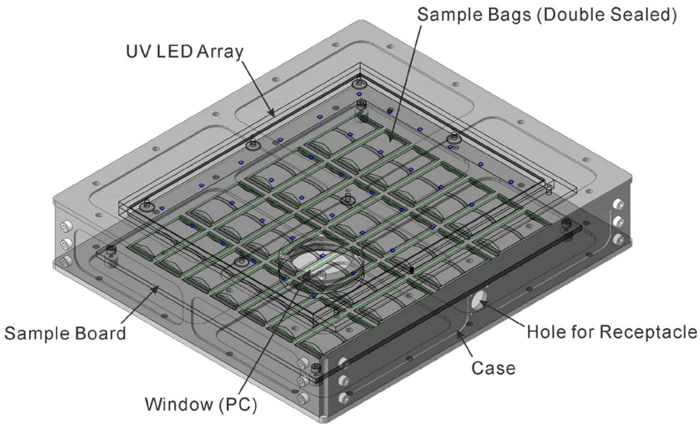


Fig. 1 Final Design of Equipment for Colloidal Clusters Experiment

analyses, or tests. Many documents are also required.

3.2 Equipment Design

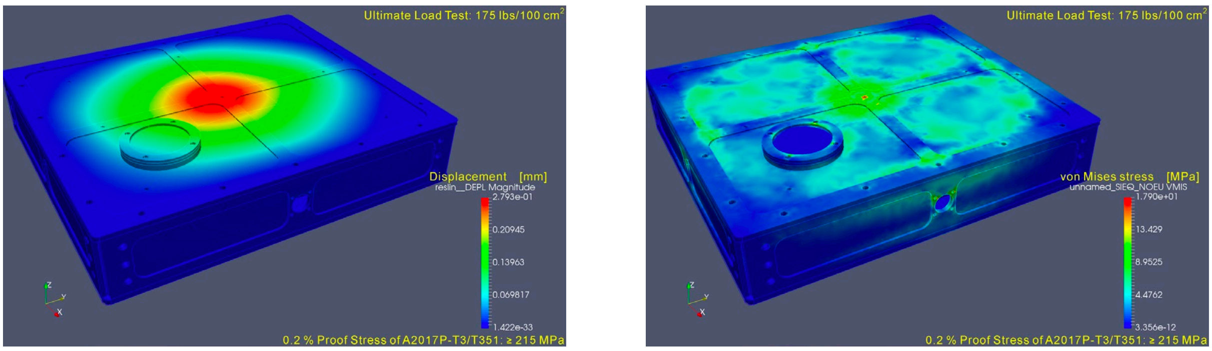
The draft design of equipment should be drawn first. The draft design must satisfy experimental requirements. This is the most important point. After finishing the draft design, then the draft design is improved so that other requirements as mentioned previously can be satisfied. The final design for the colloidal clusters experiment is shown in **Fig. 1**. The equipment is mainly made of heat-treated duralumin due to high strength. 28 sample bags are stored inside the equipment. The sample bag is enclosed in double from the toxic hazard level (THL) of 1, which is determined by NASA. At the end of experiment, ultraviolet light is irradiated to the sample bags to make the samples gelate.

To complete the equipment design, knowledge of structural engineering, material engineering, electromagnetic engineering, electric and electronic engineering, and other disciplines are required. Some examples are described in the following subsections.

3.3 Structure Fracture Control

The equipment must not be destroyed under several specific conditions with an enough margin of safety. The conditions are as follows; (i) crew kick load [1)] of 125 lbs/10×10 cm^2 as limited load (LMT) and of 175 lbs/10×10 cm^2 as ultimate load (ULT), (ii) sudden decompression from normal pressure to vacuum and sudden pressurization from vacuum to normal pressure, (iii) launch acceleration, and (iv) metal fatigue. A simulation model is made by use of VectorWorks and is exported to IGES format files. Then IGES format files are imported into FreeCAD and are exported to brep format files. Finally, brep format files are imported to Salome-Meca. Salome-Meca is open source software for structural analysis, which has been developed by eDF, the most major electric power company in France.

The typical simulation result in the ULT case is shown in **Fig. 2**. In this case, the displacement is about 0.28 mm at maximum, which is negligibly small, and the von Mises stress is about 17.9 MPa, which is much smaller than the proof



(a) Displacement (b) Von Mises Stress

Fig. 2 Results of Stress Analysis in ULT by Crew Kick Load stress of duralumin A2017P-T3/T351 of 215 MPa. The equipment also has enough margin of safety under the other conditions. Thus, it is verified that the equipment has enough strength against the structure fracture.

3.4 Materials Compatibility

Used materials must have suitable properties for the ISS, that is, flammability, toxicity (offgassing), odor, thermal vacuum stability (TVS), fluid system compatibility (FSC), stress corrosion cracking (SCC), and corrosion. These parameters are evaluated and summarized in Materials Identification and Usage List (MIUL). For example, duralumin parts must have anticorrosive anode oxide coating to prevent corrosion. Dissimilar metal contact has possibility of galvanic corrosion. The equipment, however, is not soaked into water (air environment). Therefore, the galvanic corrosion is negligibly small for an expected experiment period. Actually, the galvanic corrosion is not recognized for more than 6 months in the atmosphere though bolts and screw inserts made of stainless steel is attached on duralumin plates. The SCC is also not recognized for more than 6 months on the ground since the stress is much smaller than the fatigue limit. As a result, the corrosion, galvanic corrosion, and SCC are negligibly small for an expected experiment period.

3.5 Electromagnetic Compatibility

There are two approaches to investigate the electromagnetic compatibility, that is, EMC tests and analysis. In the case of colloidal clusters experiment, the EMC analysis was applied. Radiated emission (RE), conducted emission (CE), susceptibility to radiated emission (RS), and susceptibility to conducted emission are analyzed. The former two items mean interference given to the other equipment, while the latter two items mean interference taken from the other equipment. All four items are important for experiment success but especially the former two may have a bigger impact on the development. In the colloidal clusters experiment, all four EMC items are acceptable from the analysis due to no electromagnetic generation source.

3.6 EEE Compatibility

EEE components must satisfy several requirements, that is, enough margins for electric stress (derating), temperature stress, mechanical stress, radiation stress, and expected lifespan. In the colloidal clusters experiment, these requirements are satisfied with enough margins.

4. Conclusions

Although many requirements exist for flight equipment, we successfully developed the equipment for colloidal clusters experiment by gathering ability of all members. The team was very functional and collaborative. As a result, the developed equipment was launched and operated on orbit as planned. The essence of equipment development is described in this paper. The lower cost is also achieved. The Grant-in-Aid for Scientific Research (A) is enough for equipment development and operation on orbit.

References

1) International Space Station Flight Crew Integration Standard, SSP 50005.