Load Specification and Seismic Analysis for ITER Tritium SDS

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1. Introduction

Korea is supposed to design, fabricate, deliver and install the ITER tritium storage and delivery system (SDS) [1]. SDS is one of the major components of the tritium plant. It includes the fuel storage and delivery systems and the tritium loading station. The tritium loading station serves for receiving tritium from external facilities and supplying tritium to the fuel delivery system. Prior to unloading, calorimetric determinations of the amount of tritium contained in the tritium shipping containers are carried out. The storage system is composed of metal hydride beds to ensure safe storage of tritium inventories.

To evaluate the integrity of SDS, load specifications and analyses for dominant load case should be conducted. This study includes a load specification and a structural analysis for SDS. For the load specification, every single load possible to occur in SDS was generated [2]. Load combinations were made based on the characteristics of each single load and incident/accident scenarios. This structural analysis includes the modal analysis and the seismic analysis for the tritium SDS glove box. The dynamic characteristics of the glove box are obtained through the modal analysis. The seismic response results are calculated for the floor response spectra given.

2. Load Specifications for SDS

The object of system load specification aims at the loads on the SDS. For clearer specification, the SDS was divided into three parts. And the load specifications were performed for each of those parts. Three divided parts are:

(1) Glove boxes (GBs) and the structures located in the glove box
(2) Getter beds (primary vessel, outer jacket, etc.)
(3) Room where pipes and cables are installed

The heating and cooling processes are iterated in getter beds. The getter beds can have many kinds of applied loads. Even though the beds are installed on the inside of the glove box, it is necessary to separate beds from the SDS and to specify the loads applied to beds. Many pipes and cables are installed in the room where the GBs are located. The behavior of these pipes and cables under the seismic load and fire load should be deliberately evaluated. Therefore, the room is divided as the third part of the SDS.

In this study, only load specification for glove box is included for the limitation of paper quantity. The glove box is currently in the conceptual design stage. There are 12 beds, vacuum pump, vertical tank and other equipment in each glove box, which is composed of H beam, box beam, channel beam, plate, polycarbonate window and gloves. This glove box is 6m long, 1.6m wide and 2.5m high [3]. Fig. 1 shows the glove box configuration. There are many kinds of loads applied to a glove box. The derived single load is as follows:

(1) Weight: Gravity (dead weight). Mass and centre of gravity assessment required.
(2) Forces: Electromagnetic Loads (probably negligible), Nuclear Heat Loads (probably negligible)
(3) Pressure Loads: Pressure applied to the inside of GB, The pressure in the glove box is very small. The magnitude is next to negative pressure of 4 torr, which is about 0.001 atm. So, it is negligible.
(4) Thermal Loads: Thermal load when the glove box is in the steady state. The steady state would be better to be interpreted as a thermal cyclic load since the processes of tritium loading and unloading are iterated periodically.
(5) Test Loads: Test pressure, Loads applied when manipulate or assemble GB structure
(6) Dynamic Loads: Loads from start-up or shut-down (negligible), Vibration or resonance with pump (negligible, since frequencies do not match.)
(7) Detrimental Effects: erosion, corrosion, transport-ation, storage, erection and cyclic fatigue, Loads induced by these situations are probably negligible. However, thermal cyclic load in beds should be considered for fatigue and creep if the number of occurrences and temperature is high.
(8) Assembly and RH Loads: Lifting load, The glove box consists of two parts, which is the left and the right part of GB. For installation of it, two parts shall be handled separately. For the installation of GB, wheels are scheduled to be installed under the GB for easy transporting. And lugs are scheduled to be installed on the top of GB for lifting. The wheels and lugs shall have affordability for the couple of times of GB weight with regard to the margin.
(9) Incident/Accident Loads:
① Thermal loads – These loads occur when the cooling process become malfunctioned after the heating process in the getter beds. These thermal loads would be defined as a load occurring in the beds. And it is evaluated as an interface load between GB and BED. Thermal stress added to structural stress later.

② Seismic loads (Acceleration Loads) – They occur due to the seismic events happen. There are SL-1 and SL-2 based on the magnitude of the seismic acceleration.
③ Seismic events: SL-1 (10 load cycles), SL-2 (cat. IV)
④ Fire following an earthquake: It is within the design basis for ITER.

Based on the derived single load and characteristics of this load, load combination was generated and load categorization was made for SDS.

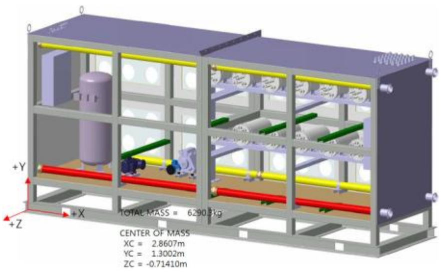

Fig. 1. Configuration of the glove box

3. Seismic Analysis of Glove Box in SDS

Various loads can be generated in the glove box during in-service, such as thermal, mechanical and seismic loads. This study presents the seismic analysis of the glove box. The purpose of the analysis is to ensure that the strength of the glove box is adequate for the seismic load. The tritium SDS glove box is a kind of a structure. The design code applicable to the seismic analysis of the glove box is not defined yet [4]. So in this study the stress results obtained from the seismic analysis of the glove box is compared with the allowable stress of the ASME Code [5]. Material properties data used in these analyses are obtained from the reference [6].

The Block Lanczos method [7] is used for the mode extraction. The modal analysis results of the glove box are summarized in Table I. The first and second frequencies have about 14Hz, which correspond to modes at beds and bed supports. These frequencies are lightly under the high energy upper bound of the FRS (Floor Response Spectrum) of the vertical direction. The strength of the sub-cross channel beams supporting the bed supporting beams is contributed to the results.

The maximum stresses at glove box for the seismic event are calculated by using floor response spectrum analysis with ANSYS computer code [8]. The maximum stresses are compared with the allowable stresses of the ASME Code [5]. All calculated values satisfy their allowable limits. However, the fundamental frequency of about 14Hz is close to the high energy band of the given seismic floor response spectrum, so the strengthening way of the support center beam of beds is recommended for design improvement in future. Fig. 3 shows the cross section change of center beams. The 1st mode shape in the revised design is represented in Fig. 3. The first frequency is over 20Hz.

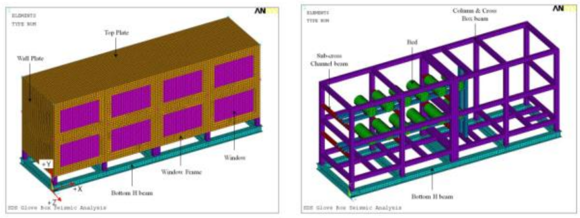

Fig. 2. Glove box FE model using ANSYS. The SHELL181 element is used for the frame structure, plate, beds and bed supports. The MASS21 element is used for the vertical tank, vacuum pump, bed accessories and other accessories.

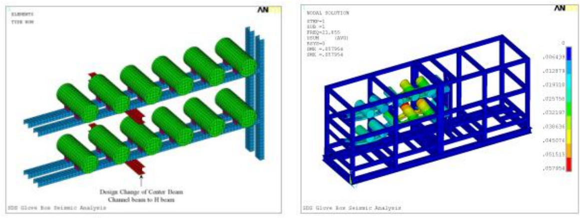

Fig. 3. Design change of center beam and 1st mode shape change by this design change

Table I: Modal Analysis Results of Glove Box

Mode No.	Freq. (Hz)	Mode shape	Mode No.	Freq. (Hz)	Mode shape
1	14.1	Beds(1st)	8	26.0	Global Mode(1st)
2	14.2	Beds(2nd)	9	31.7	Beds(4th)
3	21.9	Lower Beds(3rd)	10	33.2	Beds(5th)
4	22.1	Upper Beds(3rd)	11	37.1	Global Mode(2nd)
5	22.8	Top plate(1st)	12	38.3	Beds(6th)
6	22.8	Top plate(2st)	13	39.2	Global Mode(3rd)
7	22.8	Top plate(3rd)	14	39.6	Beds(7th)

4. Conclusions

To evaluate of the structural integrity of the glove box, system load specification and structural analysis were conducted. Every single load for SDS was derived. Load combination and load categorization was generated. The modal analysis and seismic response analysis were performed and results were discussed.

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