Technology

Structural analysis in the field of plant engineering

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1. Introduction

Structural analysis is a numerical method that enables quantitative evaluation and analysis based on numerical values of deformation and stress under loads to a structure, as well as vibration characteristics and response during excitation. Because our equipment is often used under high pressure ranging from several MPa to tens of MPa, or low temperature liquefied gases, structural analysis is useful as a means of evaluating safety, ensuring sufficient strength for use in such environments.

Since around 2007, we have used general-purpose structural analysis software, such as Ansys Mechanical, to assist in design[1] and to investigate the causes of defect events that occurred during the operation of equipment.

In this paper, we present some use cases of structural analysis for our plant engineering equipment.

2. Structural analysis in the field of plant engineering

Our plant engineering equipment portfolio includes air separation units that produce oxygen, nitrogen, and argon from air using a cryogenic separation method, alongside space chambers that simulate the cryogenic and high vacuum environment of space on earth for use as experimental equipment for artificial satellites and other devices. Evaluation of strength and vibration characteristics of the equipment is essential, both the design phase and the time of failure occurs. Key evaluation criteria encompass ensuring the equipment's strength to withstand the pressure, cold, and seismic loads, as well as maintaining natural vibration characteristics that avoid resonance with surrounding vibration sources. However, the practicality of fabricating prototypes for equipment is hindered by their unique specifications and the often large or complex nature of their designs. In such cases, structural analysis is an effective evaluation method.

We have conducted over 100 structural analyses on our equipment in the field of plant engineering, and herein present three concrete examples of such analyses.

3. Example of structural analysis

3.1 Example 1 for air separation unit

During an operational test of an air separation unit, the rectifying column experienced an accidental pressure increase. This event raised concerns about potential damage to the distillation plate inside the column. Given the challenges associated with opening the column for inspection, we opted for a stress analysis based evaluation to assess the plate's strength. Figure 1 presents the stress analysis results for the distillation plate. The analysis confirmed that the stress levels in the plate and at its joints, induced by the increased pressure, were within the design's allowable limits, indicating no strength issues. Therefore, based on this analysis, we concluded that opening the column was unnecessary, allowing the operational test to proceed.

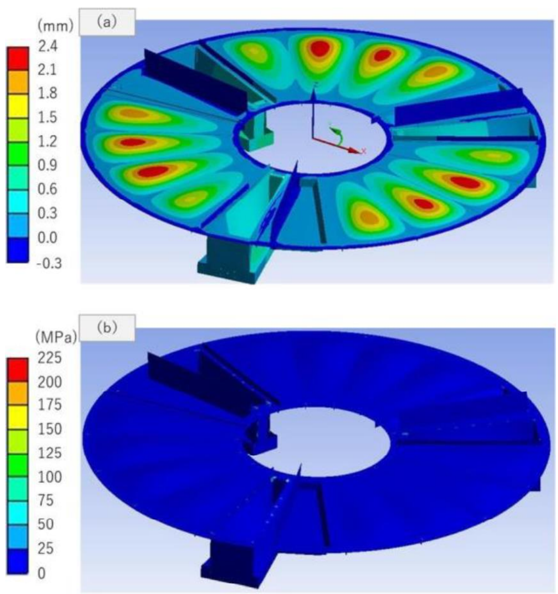

Figure 1 Stress analysis of distillation plate
(a: Deformation distribution,
b: Equivalent stress distribution)

3.2 Example 2 for air separation unit

Multiple compressors are installed in an air separation unit. When the pressure fluctuations generated in the piping due to

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the suction and discharge of fluid by the compressors match the gas column resonance frequency of the gas, large pressure pulsations are generated. Furthermore, if the pressure pulsation matches the natural vibration of the piping, the piping vibrates greatly, and in some cases, the piping is damaged. Therefore, in designing piping, it is necessary to determine the piping route and supporting locations to suppress piping vibration.

Figure 2 presents the results of vibration analysis of the piping connected to a compressor. As shown in Figure 2(a), the original design induced natural vibration in the horizontal direction (x-direction) within the range highlighted in red. Therefore, by changing the piping route and adding supports, we could suppress the natural vibration of the piping as shown in Figure 2(b). The actual piping design adopted this proposed modified piping plan, and no vibration issues were observed.

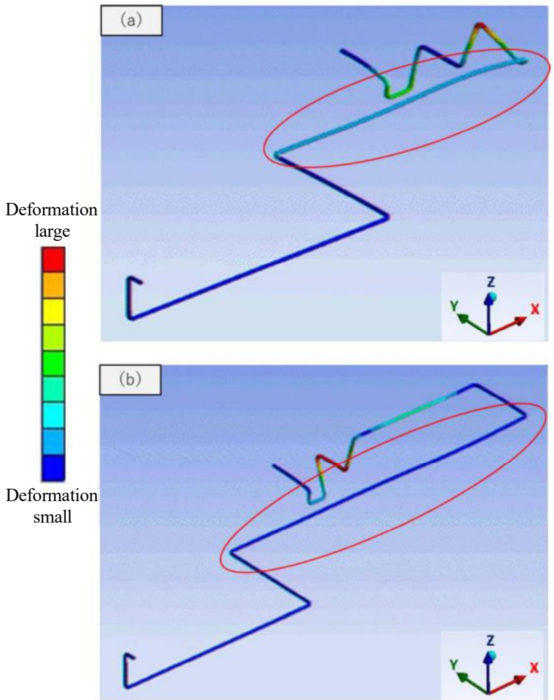

Figure 2 Vibration analysis of piping around compressor
(a: Original plan, b: Modified plan)

3.3 Example for space chamber

In operation of a space chamber, the structure is subjected to mechanical loads due to the vacuum and cryogenic temperatures inside the chamber. In addition, seismic loads are applied in the event of an earthquake. It is crucial to design chamber that is strong enough to withstand these loads so that the chamber itself does not break, and test specimen placed in the chamber is not damaged.

Figure 3 presents the results of stress analysis of the space chamber. Figure 3(a) displays the stress distribution under vacuum condition, while Figure 3(b) visualizes the stress distribution under static horizontal seismic load plus vacuum condition. We confirmed that the stress around the openings, where large stress tends to concentrate, and the stress in the legs, which support the seismic loads, were all within the allowable design values. These analysis results informed our strength evaluations, guiding us to finalize a chamber design with adequate strength to withstand operational loads and seismic loads.

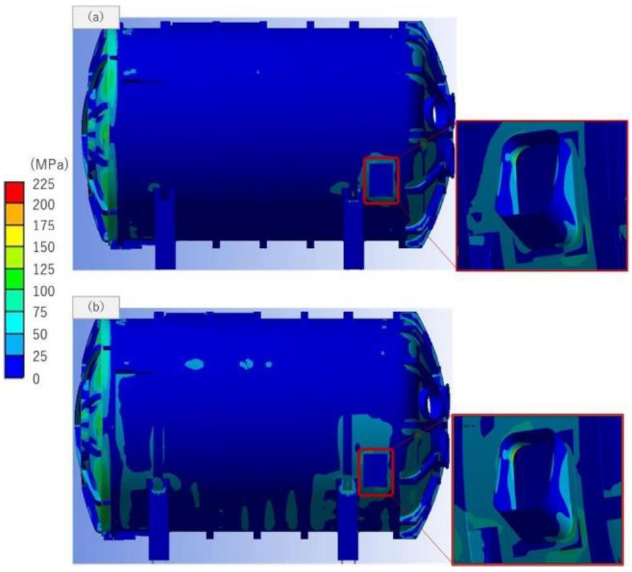

Figure 3 Stress analysis of space chamber
(a: Vacuum, b: Vacuum and static seismic loaded)

4. Conclusion

This paper has showcased various applications of structural analysis for our plant engineering equipment. The equipment has a wide variety of complex structures. By utilizing structural analysis, strength and vibration characteristics of equipment can be evaluated, which are difficult to obtain with actual equipment. This approach enables us to guarantee the safety and reliability of our equipment, ensuring that they can endure the loads they are expected to face.

Reference

1) K. Aiba, J. Muguruma, and O. Iwasaki. Ambient Air Vaporizer of Design Optimization with the Thermal Stress Analysis. Taiyo Nippon Sanso Technical Report No. 34 (2015).