ASME PVP 2016-Awarded Paper

1. Introduction

In 2016, we contributed and presented the paper "FEM Stress Analysis and the Sealing Performance Evaluation of Bolted Pipe Flange Connections with Large Nominal Diameter Subjected to Internal Pressure," which examines the mechanical behavior of flange connections with large nominal diameter, at the Pressure Vessels & Piping Conference (PVP). PVP is a technical divisionof the American Society of Mechanical Engineers (ASME).

ASME's PVP, which consists of 12 committees, holds a professional meeting annually, at which various papers are presented. Among the papers presented, approximately 10 are nominated and receive awards of excellence. Our paper received an award from the Computer Technology & Bolted Joints Technical Committee, one of the 12 committees.

Figure1 shows a picture of the commendation ceremony; Figure2 shows the certificate of commendation given at the ceremony.

This article introduces the paper's contents and the future prospects for basic research regarding this theme.

A Valqua staff member receives a commendation from Mr. Trevor G. Seipp, Honors and Awards Chair (left).

Figure1　Commendation ceremony

Figure2　ASME PVP AWRD

2. Approaches to basic research

Seal engineering is our core technology. Using this technology, we are developing and expanding our services associated with flange working methods to suit the needs of customers' plant operation.

The tightening force of a bolt varies depending on the size of the flange. Therefore, different tools should be used to fasten bolts depending on the flange size. We propose optimal tools that suit the customer's usage environment, and such proposal work is one of our services.

These services have been gradually recognized in the market, and so we began to receive inquiries not only about tool selection but also flange working methods, including optimal fastening procedures, regarding the fastening of flanges with large nominal diameters.

However, more bolts are used in fastening flanges with large nominal diameters, and under such conditions, a marked phenomenon unique to flange tightening, called elastic interaction, occurs. In elastic interaction, axial bolt force, which secures the sealing performance of the gasket, is greatly affected by the tightening force of the neighboring bolts. Therefore, more leakage troubles are known to develop regardless of the gasket's performance. For this reason, basic research is essential in order to propose optimal flange working methods. Based on such research, the mechanical behavior associated with flange connections will be elucidated and bolt tightening methods will be established.

Therefore, we built 24-inch flange connections as shown in Figure 3. The 24-inch flange connection is the largest of the standard flanges. We then conducted stress analyses using the finite element method (FEM) to predict the flange's seal performance. As a result, we established the method and published a paper on it.

Stress analysis using the finite element method (FEM) involves calculating the deformation behavior of a structure based on its mechanical characteristics in order to predict changes.

Figure3　24-inch flange connection

3. ASME PVP 2016-awarded paper

In this study, stress analyses using the finite element method (FEM) were conducted to propose a method to evaluate the sealing performance and develop a bolt-tightening method.

When gaskets are compressed, internal stress develops. Since the sealing performance of a flange connection is considered to be determined by this internal stress, stress analyses using the finite element method (FEM) were conducted to calculate the flange connection's contact pressure when pressure is applied to the internal side of the flange connection through fluid after the gaskets are compressed using bolts. In the analyses, spiral-wound gaskets containing foamed carbon filler (No. 6596V) and joint sheet (No. 6500), and the analysis code ABAQUS were used.

Figure4 is a model of a flange connection under inner pressure (P).

Figure5 shows an FEM model of element decomposition. In the finite element analysis, we took the symmetrical properties into account to divide the model in half in the axial direction and in 1-bolt length in the circumferential direction.

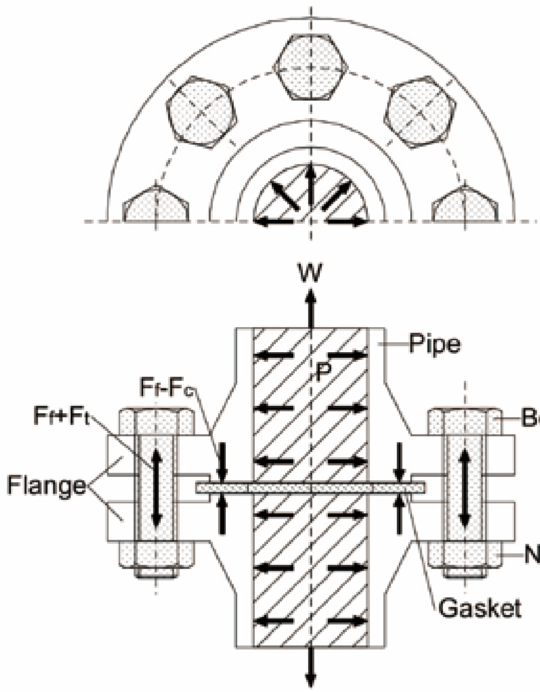

Figure4　FEM model of a flange connection

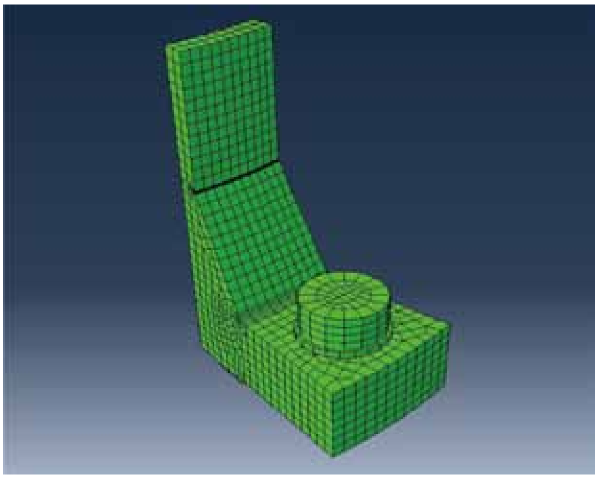

Figure5 FEM model

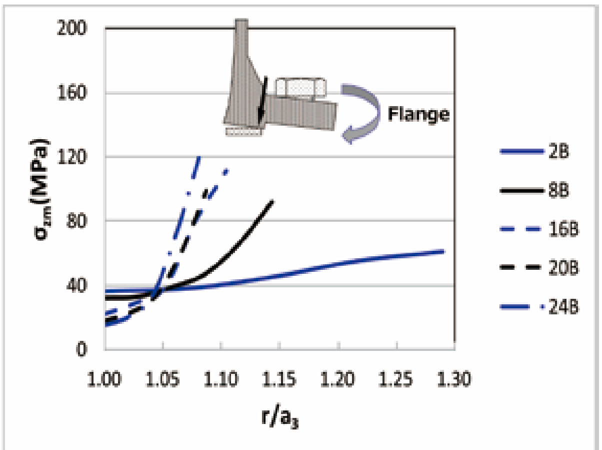

Figure6 contact gasket stress distribution of the spiral-wound gasket in the radial direction

Figure6 shows the contact gasket stress distribution of a spiral-wound gasket in the radial direction. The horizontal axis indicates dimensionless numbers. The number was calculated by dividing the length between the center and the pressure point in the radial direction by the gasket's internal diameter. On the assumption that two flanges were tightened in parallel with each other, this study was conducted under the condition that the contact gasket stress does not change much in the circumferential direction, but only in the radial direction.

This figure indicates the trend that the larger the flange, the greater the contact pressure on the side of the gasket's outside diameter. This trend indicates that, after bolt tightening, the application of pressure through fluid generates rotation which deforms flanges in the circumferential direction.

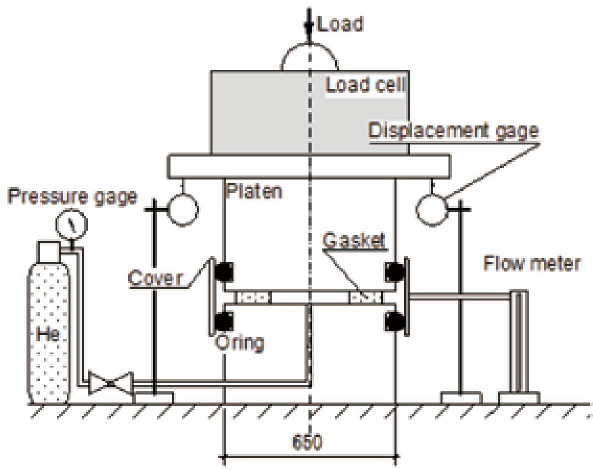

Figure7 Outline illustration of the test equipment stipulated by JIS B 2490

The basic leakage amount of the gasket was calculated according to JIS B 2490.

Figure7 illustrates an outline of the test equipment stipulated by JIS B 2490.

Figure8 shows the results from a test conducted according to JIS B 2490; the bold line indicates the basic leakage amount of the gasket, which was calculated as the leakage amount plotted against the gasket's contact pressure on unloading.

This basic leakage amount of the gasket was compared with the leakage amount obtained by an experiment, in which the leakage amount of the flange connection was calculated based on the average contact-pressure pattern of the gasket shown in Figure6.

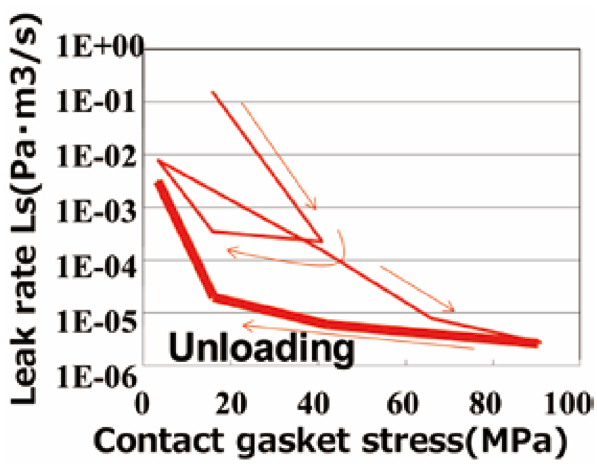

Figure8 Measurements of basic leakage amount of spiral-wound gaskets

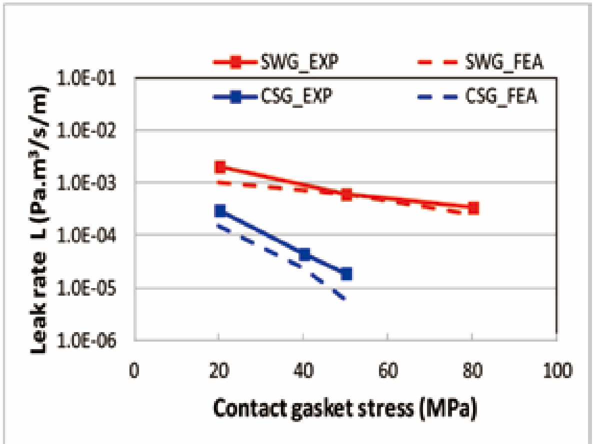

Figure9 Comparison of the results from the experiment with the analysis results

Figure9 compares the results from the experiment with the analysis results.

The red line represents the spiral-wound gasket and the blue line represents the joint sheet; both gaskets had less leakage when the gaskets' contact pressure increased. The experimental and analysis results matched closely, indicating the validity of the analytical method.

With this analytical method, it is possible to predict the leakage amount of a flange connection. Also, the results indicate that setting a higher initial tightening force of the bolts is effective for reducing the leakage amount.

4. Future prospects

Currently, we are studying how to apply these results to our proposal services regarding flange working methods, and are now introducing these services. In the long run, we believe that application of the results of this basic research will allow us to evaluate and analyze working methods, which are difficult for customers, and then propose the optimal working methods.

Receiving an award for this paper showed that our study is highly evaluated in the United States, where sealing technology is actively studied. This high evaluation not only raises the brand profile of Valqua but also verifies our evaluation methods and working methods regarding flange connections. We received an inquiry regarding tightening methods for flanges with large nominal diameters from a major U.S. oil company soon after presenting this paper, indicating strong interest in this theme. This quick reaction indicates that even major oil companies have problems regarding tightening methods for flanges with large nominal diameters and wish to collaborate with companies which possess advanced sealing technology. Cooperation with major oil companies might be achieved by strengthening Valqua's technological foundation using the results of this study.

5. Conclusion

In this study, an ideal flange connection was established as an ideal model, assuming the flange and bolts had no scratches and the gasket was tightened uniformly.

However, in actual working conditions, we cannot fasten such ideal flanges; for example, gaskets are compressed unevenly. In future, we aim to determine the effects of such uneven fastening on the sealing performance of flange connections, and to establish solutions to on-site problems.

In addition, since the thermal burden and external force can affect actual piping, we intend to take these effects into account in further studies.

Akira Muramatsu
H&S BUSINESS GROUP