Management of Tightening of Flanged Fasteners at Plants

1. Introduction

Let me express my congratulations on the 90th anniversary of the establishment of Nippon Valqua Industries, Ltd. and on the publication of the 90th anniversary issue. I greatly respect everyone who has supported the sealing industry.

Skills to prevent the fluid within flanged fasteners from leaking are very important for stable and safe plant operation. In addition, high reliability is required in response to the lengthening period of continuous plant operation, environmental problems, and emission regulations regarding leakage. To ensure reliability, it is necessary steadily to build skills and techniques, as shown in Figure1. Especially, regarding sheet gaskets, restrictions on asbestos led to greater use of non-asbestos materials, and so fluororesin sheet gaskets became the norm. So, we needed to take into account the operational behavior of fluororesin sheet gaskets to set the tightening force for them. Robust tightening operation and management for such settings also became important.

This report describes the evaluation of alternative gaskets to asbestos, the results of collaborative studies to clarify the behavior of fluororesin gaskets during operation, and Mitsubishi Chemical Corporation's certification system to ensure proper tightening management.

2. Gasket Selection

Regarding sheet gaskets, asbestos fiber joint-sheet gaskets have mainly been used for their excellent heat resistance, sealing properties, ease of handling, and cost performance.

In 2006, an ordinance amending the Industrial Safety and Health Law Enforcement Ordinance was issued. The ordinance banned the manufacture and use of asbestos and other substances, with an exception for some products. Therefore, asbestos gaskets needed to be replaced with non-asbestos gaskets. As substitutes

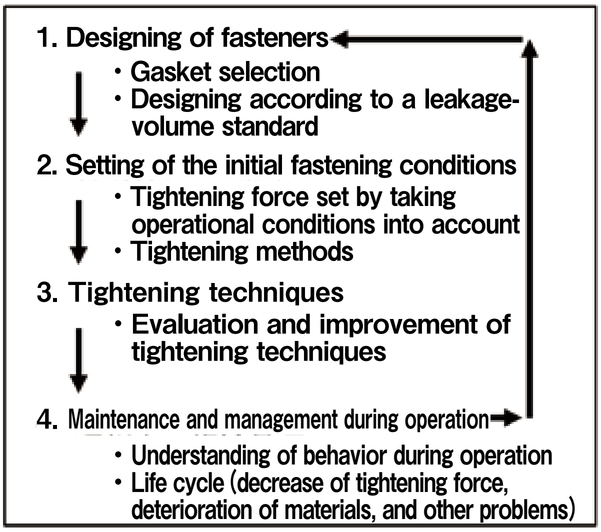

Figure1　Concept of fastener management

for asbestos joint sheets, non-asbestos joint sheets, which contain organic fibers including aramid fibers and inorganic fibers, were considered the primary candidate. However, non-asbestos joint sheets contain non-asbestos fibers, which are stronger than asbestos fibers and have weaker fiber-to-fiber interwinding power than asbestos fibers. In asbestos fiber joint-sheet gaskets, thin and long asbestos fibers themselves were the strength members of a gasket, whereas in a non-asbestos joint sheet, rubber as a binder served as the strength member. Therefore, functional decline due to hardening of the rubber was a concern for gaskets used at temperatures above the heatproof temperature of rubber. To address this concern, we decided to conduct evaluation tests regarding the temperatures of non-asbestos joint sheets.

Figure2 illustrates the test line. We set up test piping in a plant steamline with an inner pressure of 1.3 MPa and a temperature of 190°C and then conducted a 6-month loading test. During the course of the study, no macroscopic external leakage was found. However, in an opening process after the test, cracks developed when a non-asbestos joint-sheet gasket was removed from the surface of a flange sheet as shown in

Figure3. This result showed that non-asbestos joint-sheet gaskets cannot be used for a long time at high temperatures and that additional tightening cannot be applied to those gaskets. So, we concluded that non-asbestos joint-sheet gaskets cannot be a substitute. Also, in this test, other types of gaskets were assembled simultaneously. Foamed-carbon gaskets stuck to the surface of a flange sheet and were not easy to handle, and so we concluded that foamed-carbon gaskets could not be a substitute either. On the other hand, no major macroscopic problems occurred with fluororesin gaskets, making these gaskets the primary candidate.

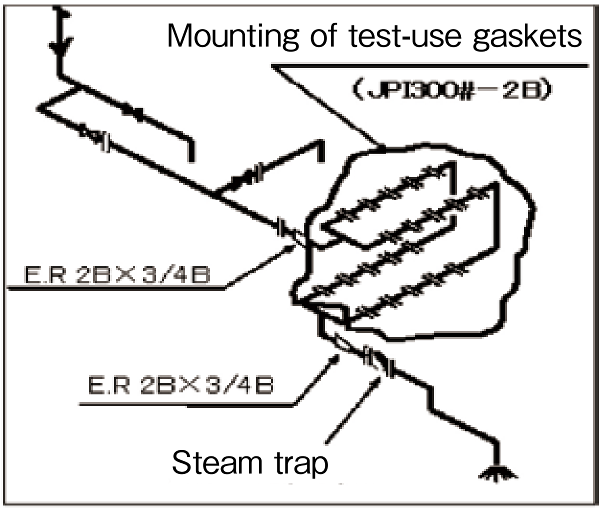

Figure2　Outline of the test line

Figure3　Removed gasket

3. Tests to confirm the behavior of fluororesin gaskets

Fluororesin sheet gaskets had been used as gaskets with excellent chemical resistance before the non-asbestos trend caught on. When fluororesin-specific flow causes a reduction of tightening force, we have applied additional tightening to solve the problem. However, the possibility and timing of additional tightening depend on empirical rules. For proper maintenance and management, we needed to understand the behavior of gaskets and devise proper countermeasures. Therefore, we conducted various tests to understand their behavior.

3-1) Test equipment

Figure4 illustrates the test procedures, and Table 1 shows the test conditions[1]. A strain gauge attached to fastening bolts was used to measure bolt axial tension, and the contact pressure of the gasket was calculated from the contact area with the gasket. Tightening was conducted according to JIS B 2251 (2008) to achieve a gasket contact pressure of 25 MPa[2] (hereafter, bolt tightening was conducted according to the same standard) . No. GF300 gaskets were used.

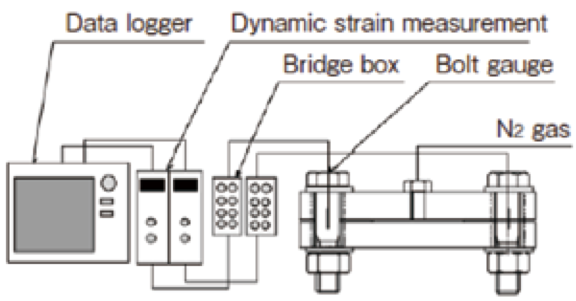

Figure4　Illustration of the stress-mitigation equipment

Table1　Conditions for the stress-mitigation test

Test-use dimension	JIS 10K 50A RF
Test-use temperature	200°C (24-hour cycle)
Gasket	V/NO.GF300
Flange	Material: SS400 Roughness of sealing surface: Rz = 14.4 μm (ave.)
Bolt (loaded with a strain gauge)	Dimensions: M16 × 4 bolts Material: SS400

3-2) Heat cycle-stress mitigation test

Gaskets were heated at 200°C in an electric furnace, and changes of the contact pressure of the gaskets were measured over time. Heating was conducted under the following three conditions: room temperature; continuous heating at a consistent temperature of 200°C; and application of a heat cycle alternating between 200°C and room temperature. In this test, one heat cycle was 24 hours with 2 hours of temperature rise and approximately 3 hours of temperature fall.

Figure5 shows the test results. The rate of contact pressure reduction with temperature load was more reduced than that at room temperature. In the heat-cycle case, a great reduction in contact pressure during the temperature-fall period was confirmed. Although the contact pressure of the gaskets increased during re-heating, it did not reach the contact pressure before temperature reduction. After periodic maintenance and before the start of operation, airtight tests are conducted. When the fall in temperature greatly reduces the contact pressure, countermeasures to restore the contact pressure should be taken to confirm the absence of leakage and then to prepare for the start of operation. Also, in areas where frequent heat cycles develop, the contact pressure of gaskets decreases gradually, so the same countermeasure to restore the contact pressure should be taken.

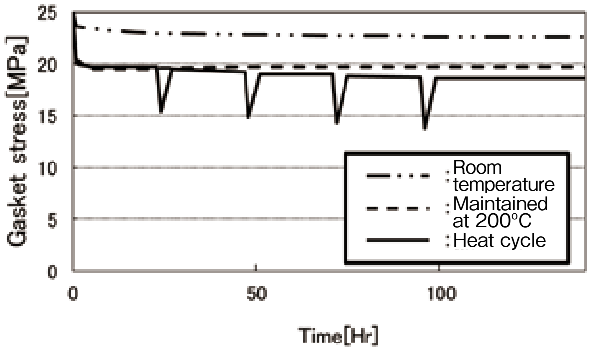

Figure5　Results from the heat cycle-stress mitigation test

3-3) Confirmation of the effects of additional tightening

Usually, as a countermeasure against reduced contact pressure, additional tightening is applied. Regarding the timing of performing this additional tightening, the following two conditions are taken: application at high temperatures after the start of operation; and application at room temperature during operational suspension for periodic maintenance and other reasons.

Figure6 shows the test results. Additional tightening increased the residual contact pressure, and the effects of contact-pressure retention were confirmed. Regarding the timing, additional tightening at higher temperatures resulted in greater residual contact pressure than at room temperature. Since the stiffness of gaskets decreased at high temperatures, tightening was conducted while flowing, which resulted in weaker flow after additional tightening. Such weakening was supposed to reduce stress mitigation. In the case of additional tightening under decreased stiffness, crushing strength is also expected to decrease, so the tightening force must be carefully considered. Although additional tightening at room temperature resulted in weaker effects than that at high temperatures, it is considered an adequate countermeasure in pre-operation airtight tests.

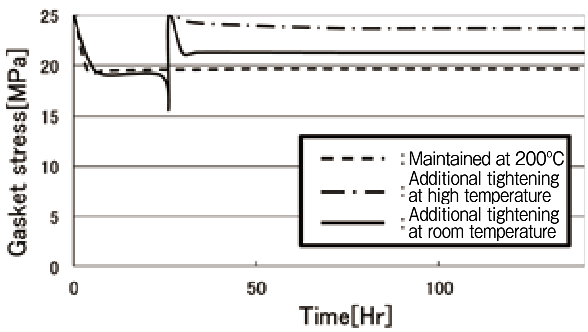

Figure6　Results of verification testing of additional tightening

4. In-house certification system

Ideally, a flanged fastener's behavior is clarified, tightening is quantitatively managed for all procedures, and tightening is performed in a controlled manner. However, due to limitations of managing tools, measurement cost, and limited work period, we select the target. So, most flanged fasteners are tightened based on the operator's skills and experience. In the past, assembling while misunderstanding a gasket's specifications, inadequate tightening, and uneven clamping caused malfunctions. To address these problems, Mitsubishi Chemical Corporation introduced and is utilizing a certification system for chief gasket operators. Table 2 shows the contents of the certification training. Chief gasket operators who have passed the test instruct, mentor, and supervise operators and conduct the final confirmation of assembling operations. In this way, they have responsibility for gasket assembling. Gasket-assembling cannot be conducted without the presence of a chief gasket operator. To date, approximately 3000 operators have been certified as chief gasket operators. This system appears to be effective for preventing malfunctions. All certification training sessions are provided in a classroom, which is expected to enhance knowledge, but skills are also acquired through on-site experience. Nonetheless, only on-site experience causes the problem that although operators understand differences in tightening conditions occurring when bolt axial tension is reduced by elastic interaction and when a different tightening attitude is applied, the timing and mechanism of the effects of bolt axial tension and torque cannot be visualized numerically and other measures remained as a problem. Therefore, part of our mobile training system was introduced in the Mizushima Plant and a practice training session was held for operators. Figure7 shows a picture of the practice training session. The training session includes the following four contents: evaluation of flange-tightening skills, torque-sensing training, understanding the importance of bolt maintenance, and recognition of crushing-prone gaskets. A total of 43 operators including new employees who had no on-site experience and skilled operators who had 30 years of experience participated in the training. Regarding their post-training impression, "understood very well" and "understood" accounted for over 90%. In addition, the training received good feedback including "visualization of changes in bolt axial tension made the training easy to understand". So, the training appeared to be very effective. We are now studying how to utilize the mobile training system and incorporate it into our certification system. In Mizushima's case, the number of trainees was 40. Therefore, we need to study the curriculum contents and training using multiple training devices to enable hundreds of trainees to participate during periodic maintenance.

Table2 Contents of the training session

1. Responsibilities of a gasket operator
2. Training to prevent mistakes in gasket mounting
   - Gasket types and their handling
   - Pressure rating and flange specifications
   - Bolt specifications at each plant
   - Points to confirm regarding core tightening and uneven clamping
   - Tightening methods (circling tightening)
   - Inspection and record submission
3. Handling of asbestos gaskets
4. Previous trouble cases
5. Verification testing

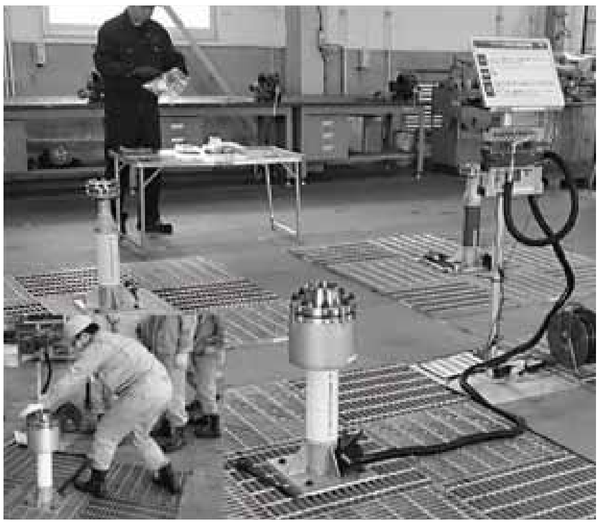

Figure7 Training session

5. Conclusion

Due to the retirement of old skilled operators and the trend of younger operators to leave work, there has been a declining number of operators specialized in flange-tightening operation and a decrease in the level of techniques and skills. A system for conducting proper tightening management without depending on skilled workers is necessary. For example, sealing-operation management systems enable automatic tightening tools to conduct tightening according to programmed procedures, enabling even novices to systematically apply tightening force at a predetermined torque value.

This report introduced our education and certification systems, as well as training sessions utilizing our mobile training system. Through such training media, we will strive to maintain the levels of our operators' skills. We will also introduce new systems in the pursuit of more reliable leakage-prevention technologies.

6. Reference

1) Hajime Nonogaki, Masayuki Yamabe, Riichi Morimoto. Stress-Mitigation Characteristics of Gasket Fasteners, *Piping Engineering*, Vol. 52, No. 7, p. 28; 2010

2) JIS B 2251 "Flange Joint Assembly Guidelines", (2008)

Riichi Morimoto

Mitsubishi Chemical Corporation
Mizushima Plant
Mechanical Group 2
Maintenance and Engineering Department