Our engagement with improvement of quality in workmanship within a common certification system for flange fastening

1. Introduction

For a stable supply of safe and high-quality product

As part of local community through the operation of petroleum and petrochemical factories, it is essential to appropriately control maintenance of facilities.

The fluids we deal with are diverse, which can be either gas, liquid or solid. Some of them are combustible, flammable or explosive, or toxic to human bodies and environment. Therefore, we must definitely avoid any leakage coming from defects of the flange fastener component.

Meanwhile, there are hundreds of thousands of flange fastener components in the factory. We aim at early detection of defects in our daily check, and we must prevent a leakage disaster in the future with the right control of tightening at flange fastening.

However, in reality, there is a tendency that the number of disasters and accidents "caused by flange fastening" within Japan is increasing. As shown in Table1 and Figure1, the total number of disasters and accidents due to the failure of management control of facilities has been increasing every year. Part of this are disasters and accidents "caused by flange fastening," which count 30% and more of those. They are increasing by number and proportion, and remain high in recent years.

We can suggest that "qualification system" and "industry structure" are the cause of an increase of troubles arising from flange fastening.

Regarding the former, the problem is that there is no official qualification system for flange fastening and we are dependent on technical tradition among operators. For example, all dangerous and important work in the factories including welding, non-destructive checking, crane, scaffolding, and oxygen-deficient operations have official qualification systems and structures in which knowledge and skills are gained systematically including classroom education and practical lectures. On the other hand, flange fastening operation is important, but has no official qualification system. In the current situation, it can be practiced by anyone regardless of their knowledge or skill.

Table1 Number of disasters due to the defects of maintenance control of facilities

year	Poor corrosion management	Caused by flange fastening	Poor inspection management	Poor inspection	Poor vessel management	total
2018	121	95	18	34	13	281
2017	113	93	29	30	7	272
2016	109	102	20	41	10	282
2015	93	60	31	17	21	222
2014	78	55	19	11	16	179
2013	80	56	28	16	20	200
2012	65	59	65	8	11	208
2011	67	66	66	8	20	227

Source : "Summary of accidents related with high pressure gas" by the Ministry of Economy, Trade and Industry

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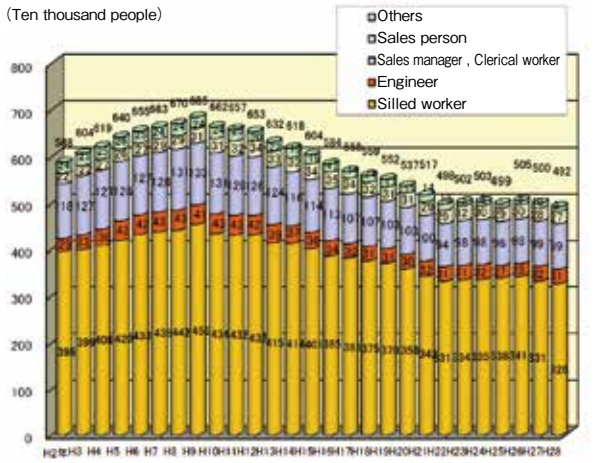
Figure1 Number and proportion of disasters attributed to flange fastening

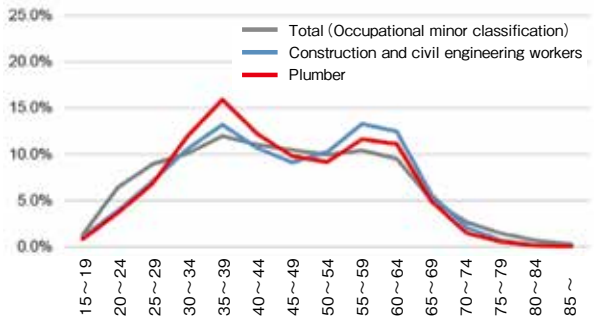
Regarding the latter, the problem is that domestic construction workers are decreasing and aging yearly. As you can see in Figure2, the number of construction workers has decreased by around 30% within the last 20 years. Also, as seen in Figure3, 30% of plumbers are 55 years and older, therefore it is inevitable that those with more experience who we have depended upon for their knowledge and experience will decrease drastically in near future.

With all these situations, it is an urgent necessity to build an education system for flange fastening to secure safety especially for young workers, foreign operators and those working on the spot and to improve operational quality.



Source : "Current situation of construction industry, construction and building workers" by the Ministry of Land, Infrastructure, Transport and Tourism

Figure2　Transition of the number of construction workers



Source : "Detailed sample tabulation of the National Census" by Statistics Bureau of Japan, Ministry of Internal Affairs and Communications

Figure3　Age group distribution of plumbers

Mizushima Refinery of ENEOS Holdings has launched "Mizushima Flange Fastening Committee" together with nearby refineries on April 1, 2019 and built a common certification system for flange fastening in the area, which has been operating with efficiency and effectiveness. Following the education and certifying system of Mizushima, Kawasaki and Negishi Refineries also launched an association of flange fastening in the Keihin Area together with Raiznext Corporation and Valqua, Ltd., to introduce a common certifying system. They have rolled out the common certifying system on a trial basis at the regular repair work (hereinafter, "Regular repair") in the accounting year of 2020 and are advancing its formulation.

Table2　Business establishments composing Mizushima Flange Fastening Committee

・Mizushima Manufacturing Site, Production Control Division, Asahi Kasei Corporation
・Mizushima Factory, Zeon Corporation
・Mizushima Factory, Mitsubishi Gas Chemical Company, Inc. (MGC)
・Okayama Office, Mitsubishi Chemical Corporation (MCC)
・Mizushima Refinery, ENEOS Holdings

In this report, we describe the summary, results and validation of the effect of the certification system for flange fastening introduced on a trial basis at the regular repair conducted in March 2020 at Kawasaki Refinery.

2. Summary of certification system for flange fastening

To improve the quality of flange fastening, what is important are operators' skills who fasten flanges and the knowledge of supervisors who instruct this operation. Therefore, the certification system for flange fastening we created has two educational parts, "practical education (practical skills)" and "knowledge education (classroom learning)," , with unified educational contents, and we realized a system in which we can educate with efficiency by standardizing the level of education.

Also, we issue certificates to approved supervisors and

operators, which allow them to operate flange fastening in other business establishments just by showing them. Overlapped education is not necessary which promotes efficiency.

2-1) Practical education (practical skills)

Practical education aims at learning the behavior of flanges when fastening them and understanding the operators' own abilities. Until now, education was acquiring senses through instructions of supervisors based on their experience. Now we can quantitatively confirm the skill level by having the operators have a real physical experience with the bolting simulator (Figure4). With this simulator, it is possible to evaluate skills quantitatively which used to be evaluated qualitatively. This simulator uses criteria including "enough fastening is given to the gasket," "strength to the fastening shaft of each bolt is even," and "no sign of uneven crush on gaskets."

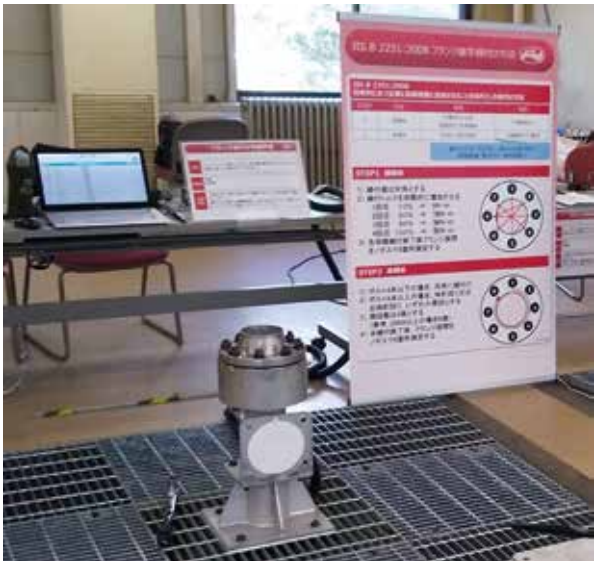


Figure4 Bolting simulator

2-2) Knowledge education (classroom learning)

For knowledge education, we used educational materials created by the Mizushima Flange Fastening Committee, based on HPITR Z110 (Guideline for Flange Fastening Operation Training) issued in September 2018. In addition, we have set up 4 educational levels (Table3) as this committee did, to create an efficient educational system by clarifying the educational contents and participants of education for each level.

Table3 Levels for knowledge education in the certification system for flange fastening

Education level	Target position	Education item	Education time
Level Ⅳ	Education lecturer	HPI TR Z110 "Manager"compliance	4hr
Level Ⅲ		HPI TR Z110 "Worker"compliance	2hr
Level Ⅱ	Manager	ENEOS standard (classroom lecture + practice training)	1hr
Level Ⅰ	Worker	ENEOS standard (classroom lecture)	5-20min

3. Effect of our engagement

3-1) Summary of system operation

In November 2019, we have conducted education for level III at Kawasaki Refinery (number of participants: 17). Education for Level III is given to be approved as lecturers. We gave classroom education with education content was based on HPI TR Z110 (education time: 2 hours).

Contents of education include "control of fastening gaskets and bolts as fastener parts," "setting up and procedure of fastening load and target torque," "pressure-resistant airtightness test," "opening of fastener part," and "trouble examples."

As practical education (practical skills), we conducted "training on fastening procedure" in accordance with JIS B 2251, using the bolting simulator, following a lecture in advance of practical education regarding interactions of elasticity, causes of uneven fastening and countermeasures for it as warnings on flange fastening, and then evaluated each person's skill (pass/fail).

After this, we launched operation of this system on a trial basis at a regular repair (March 2020) in Kawasaki Refinery. We gave education for level I to all supervisors and operators engaged in flange operations for works on quiet devices (number of participants：411). This education was carried out according to the flow as follows by the lecturers who acquired approval of level III as given above.

The flow of this education starts with collective education (10 to 20 minutes) which explains "behaviors of flanges at diagonal/circling fastening," "importance of

setting up," and "description of interactions of elasticity and uneven fastening". Following this, the skill of each participant was evaluated by using the bolting simulator and judged as pass or fail. We issued certificates to those who passed, which will allow them to do flange fastening operations on sites.

3-2) Findings from hearing of the participants

We received good feedback overall from participants of level III education, including 90% of them replying that it raised their awareness of flange fastening and 80% saying they can apply the contents of lectures at operations on sites. Also, 60% say they found out something new from the contents given to lecturers. Therefore, it was also found effective as an opportunity to learn again.

Seventy percent of participants of level I said that contents of collective education were clear, and 80% replied that the certification method of practical skills was good. We had comments such as, "It was good because changes of axial tension of each bolt at the time of flange fastening were easy to comprehend which made it possible to operate in a short amount of time."

3-3) Findings from analysis of operators' skills

We have analyzed operators' skills, using the bolting simulator. This simulator maintains a log of fastening process which makes it possible to confirm characteristics of operators with fastening (too much fastening, lack of fastening or uneven fastening). For this, we can give appropriate advice on that which leads to improve skills with efficiency.

The result of analysis of operators' skills this time shows that the ratio of too much fastening is higher, about twice, than that of lack of fastening. Furthermore, what we found from analyzing too much fastening, there was a higher proportion of operators that fastened some of the bolts too much rather than generally fastening of bolts too much. We think this is because of difference of axial tensions rising among bolts with operators' postures. Regarding uneven fastening (there is a great variety among surfaces of flanges), we think the set up at the initial stage is important and it is necessary to conduct a proper fastening procedure.

3-4) Review of effect of education on comprehensive airtightness test

At the very final phase of a regular repair, we conduct a comprehensive airtightness test by bringing in nitrogen within the system for the purpose of confirming soundness of open parts including devices and plumbing flanges, and the whole equipment. To be precise, we conduct a soap bubble test to check leakage of nitrogen at the open parts including each flange after bringing in nitrogen and pressure rising. If leakage is detected, more flange fastening is carried out. If leakage cannot be halted despite of that, we decrease the pressure of nitrogen in the system and conduct the pressure rising test again upon re-opening flanges, maintaining surfaces of gaskets and exchanging gaskets.

To validate the effect of education, we inspect "number of re-rising pressure system caused by flange fastening" and compare it with the results of re-rising pressure at the last regular repair in 2016. As shown in Table4, we halved the number of re-rising pressure system compared to the last results and lowered the risk of increase of the number of operations and extension of the procedure, and a certain level of educational effect was recognized.

Table4 Survey on number of re-rising pressure system caused by flange fastening

Comprehensive airtightness test number of strains	Number of re-boosting systems		2020 regular maintenance Number of points (Reference value)
	2020 regular maintenance	2016 regular maintenance (Same scale as last time)	
307	6	11	4520

Next, regarding leaked flanges (14 flanges within 6 systems) which were the main cause of re-rising pressure, we show in Table5 the findings from our survey on the specifications of flanges and gaskets, reasons of leakage and layout of the scene. We found out the main reasons of leakage as the following two:

- Cleaning of surfaces of gaskets failed as the plumbing layout did not allow secure clearance between flanges when they were open.
- Fastening layout was not good as there were obstacles, which led to uneven fastening.

Table5 Detailed investigation of the flange responsible for re-pressurization

System No.	Size (B)	Class (pound)	Working pressure (MPa)	Cause of flange leakage	Flange orientation	Tightening layout	Clearance between flanges
1	11/2	300	3.35	One-sided tightening	Vertical	Defective	Have clearance
	18	–	3.35	Improper cleaning of the gasket surface	Beside	Defective	Have clearance
	11/2	300	3.35	One-sided tightening	Vertical	Defective	Have clearance
	18	–	3.35	Improper cleaning of the gasket surface	Beside	Defective	Have clearance
	6	600	3.35	RJT poor rubbing	Beside	Good	No clearance
2	18	–	2.3	Deterioration due to aging of the gasket surface	Vertical	Good	Have clearance
3	6	300	1.48	Improper cleaning of the gasket surface	Beside	Good	No clearance
	6	300	1.48	Improper cleaning of the gasket surface	Beside	Good	No clearance
	8	300	1.48	Improper cleaning of the gasket surface	Beside	Good	No clearance
4	6	150	0.42	Improper cleaning of the gasket surface	Vertical	Good	No clearance
	12	150	0.42	Improper cleaning of the gasket surface	Vertical	Defective	No clearance
	11/2	150	0.42	One-sided tightening	Vertical	Defective	No clearance
5	18	150	1.08	Improper cleaning of the gasket surface	Vertical	Defective	No clearance
6	1	300	0.35	One-sided tightening	Beside	Defective	Have clearance

As measures for these, we will continue engagement towards eliminating re-rising pressure tests by reviewing the operation manuals and education contents so that we can carry out the right operation.

4. Summary and overview for the future

4-1) Summary

- Certification system for flange fastening allows us to standardize education and we do not need overlapped education for users and operators.
- We can evaluate skills quantitatively by using the bolting simulator, and with logs of fastening process, we can give right instructions to operators.
- We had good feedback from the participants through a hearing regarding system operation (level III, level I). They say "contents of lecture were clear," "awareness with flange fastening was raised," and "(what we learned) are applicable at operation scenes."
- We decreased the number of re-rising pressure systems at the comprehensive airtightness test, compared to the previous (2016) regular repair.

4-2) Overview for the future

ENEOS Holdings is planning to systematize education by introducing the certification for flange fastening as well as bolting simulator in all its refineries from now on. Although it is possible to establish a certification system that is shared within the country and not just for a single company alone and can operate effectively for the convenience of operators, there are many agendas including unified maintenance of skill data of operators and controllers.

We will continue collaborating on this to completely eliminate troubles caused by flange fastening in the future in Japan.

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