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Review of Bolt Preload and Torque for Assembling Threaded Fasteners in Nuclear Power Plant

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1. Introduction

There are numerous threaded fasteners such as bolts, studs, nuts, capscrews and anchor bolts used in nuclear power plants(NPPs). The major applications of threaded fasteners are reactor coolant pressure boundary components, their internals and supports. With the increase of commercial operation period of NPPs, the incidents caused by degradation of threaded fasteners have been occurred. A large number of reported incidents are involved in the pressure boundary and major component supports. The degradation and failure of threaded fasteners is affected by material, preload and torque value at assembly, bolting practice, etc. It is very important to select appropriate bolt preload and decide assembly torque value because torque control using a torque wrench is the most common method in a power plant to assemble a bolted flange connection.

Many researches have been studied to define the proper bolt preload and desired torque value with regard to the integrity of bolted connections including pressure boundary joints by EPRI and other plant industry. But in domestic NPPs, considerably few works are done on the bolted joint assembly in spite of increasing events related with threaded fasters. Therefore we investigated degradation or failure of the threaded fasteners used in NPPs, also examined the codes, standards and technical trends concerning bolt preload and assembly torque in NPPs.

It is the purpose of this study to provide proper technical information for assuring integrity of the threaded fasteners.

2. Investigation of degraded threaded-fasteners

Total of 44 degraded threaded-fastener incidents in class 1 component supports and other safety-related equipment were reported by the American licensees of operating nuclear power plants and the applicants of plants under construction during the period from 1964 to 1982 [1]. General causes were use of improper materials, borated water leakage, out of specification pre-torquing and high sustained tensile stress. Recently, we examined about 350 cases of LER (license Event Report) reported from 1980 to 2005. Figure 1 shows that LER was mainly produced early 1980s but the frequency generally decreased after 1990s. It is thought that lack of attention to installation and maintenance of threaded fasteners results in many incidents in early 1980s.

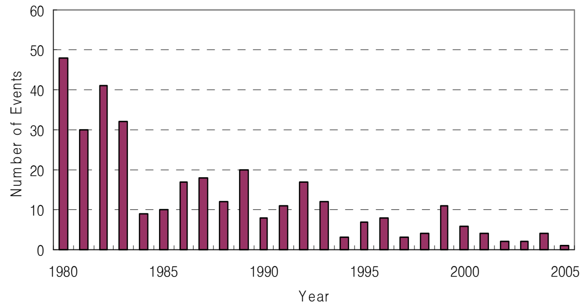

Figure 1. Variation of the number of threaded fastener incidents from the license event report in foreign NPPs.

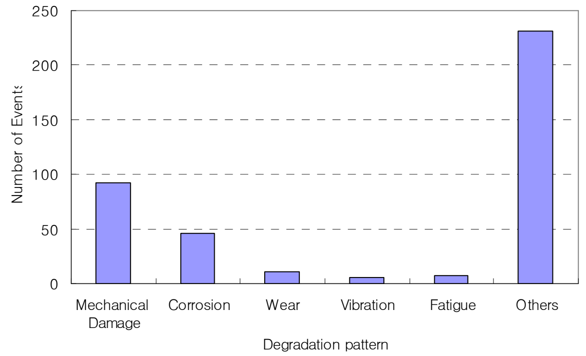

Figure 2. Degradation pattern of threaded fasteners from the license event report in foreign NPPs..

But while continuous works on degradation of threaded fasteners have been studied by EPRI and industry, the number of events considerably decreased. Figure 2 shows that degradation pattern of threaded fasteners from LER. General causes of degradation were mechanical damage, corrosion, wear, vibration, fatigue and mostly other types such as loss and loosening. These degradations of loss and loosening are able to result in leakage of system water and closely associated with bolt preload and torquing.

3. Bolt preload and torque for flanged joints

Bolt preload is the tensile force in the bolts after the bolts have been tensioned by torquing or other suitable methods but before applying pressure, external forces, or moments. Torquing is the most common way to achieve the desired preload and a short form torque/preload equation is generally used to calculate the torque value. This equation is given by $\tau = KDF_p$, where τ is the torque (in-lb), K is the nut Factor, D is the nominal diameter (inches) and F_P is the preload force (lb). This paper describes bolt preload and torque within the common ASME flanged joints because they are closely concerned with the integrity of reactor coolant pressure boundary.

3.1 ASME B16.20

ANSI B16.20 [2] specifies that a bolt stress of 30 ksi should compress most gaskets to within about 0.011 inches of full metal-to-metal compression. For NPS 1/2, NPS 3/4, and NPS 1 gaskets in Classes 150 through 600, lower 25 ksi bolt stress should compress the gaskets to within about 0.011 inches of full compression.

3.2 ASME B&PV Code

ASME Code Sec.III, Appendix XI [3] specifies the minimum required bolt load for gasket seating against the internal design pressure. ASME Code Sec.III, Appendix XII states that preload stresses higher than the Code-specified minimum can be used to achieve leak free performance. Appendix XII approved the use of simple wrenching without verifying the actual bolt stress and the probable bolt stress is given by $S = 45000 / \sqrt{d}$, where S is the bolt stress and d is the nominal diameter of the bolt.

3.3 EPRI recommendations

EPRI NP-5067 [4] recommends several different levels of preload depending on the application. Preload to 40% of the material yield strength for gasketed pressure boundary joints, which have not given trouble and/or, are in “routine service”, preload to 70% are experienced “low preload” problems in the past, and preload to 85% are consistent “trouble-makers” in the past and require the maximum safe preload. It contains several torque tables with stress of 15 ksi and 30 ksi but the stress level is too low to use in NPPs. But this report provides useful torque computation worksheet for application.

EPRI NP-5769 [5] provides recommended torque values acceptable for all steel bolt studs with 70 ksi minimum yield strength used for flanged joints with gaskets to provide 30 ksi or 45 ksi of bolt preload stress. 0.17 of nut factor and root area of the fastener are used for calculating torque value

EPRI TR-104213 [6] provides torque required to develop 40%, 70% and 85% of yield strength for various materials. The values given in the tables are based on a nut factor of 0.2 and the root area of the fastener. This report describes that torque tables should specify flange facing, pressure rating, bolt material and gasket type. Accordingly, it provides the torque tables for desired gasket stress developed by Callaway Nuclear Plant.

EPRI TR-111472 [7] containing recent information for assembling bolted connection suggests that a stress of 52.5 ksi is optimum bolt preload stress for all ASME flanged joints with bolting having a yield strength equal to or greater than that of A193 Grade B7 through experiment and analysis. Recommended torque table based on standard industry tables is provided with following modifications; it is based on a nut factor of 0.16 and it includes a column for 52.5 ksi bolt stress besides of 30, 45, 60 ksi, latest bolt stress area (tensile stress area) values instead of thread root area values.

3.4 Domestic NPPs

The procedure of assembling flanged joint in domestic NPPs is performed in accordance with the guidance of EPRI NP-5769. Bolt preload of 45 ksi is used for KEPIC MN flange and 30 ksi for Non-KEPIC MN flange. Torque table in NP-5769 is also used for assembling flanged joint.

4. Conclusion

The incidents of degraded threaded fasteners in NPPs were investigated in this study. As a result of case study, the incidents have increased with the increase of operating period of plants in domestic NPPs. The major degradations were mechanical damage and loosening related with bolting. The results show that it is very important to assemble with appropriate bolt preload and torquing.

This study reviewed the previous researches on the bolt preload and torque. The ideas of proper bolt preload and torque values have been updated by continuous experiments. These results are exceedingly useful for NPPs to develop their own torque values. We have to conduct adequate evaluation of our present assembling method of flanged joint. Also We need to develop own procedure suitable for our NPPs.

REFERENCES

[1] U.S. Nuclear Regulatory Commission, NUREG-0943, Threaded-Fastener Experience in Nuclear Power Plants, 1983

[2] ASME, ASME B16.20, Metallic Gaskets for Pipe Flanges -Ring Joint, Spiral Wound, and Jacketed, 1993

[3] ASME, ASME B&PV Sec.III., Rules for Construction of Nuclear Power Plant Components, 1998

[4] EPRI, NP-5067, Good Bolting Practices - A Reference Manual for Nuclear Power Plant Maintenance Personnel, 1987

[5] EPRI, NP-5769, Degradation and Failure of Bolting in Nuclear Power Plants, 1988

[6] EPRI, TR-104213, Bolted Joint Maintenance & Applications Guide, 1995

[7] EPRI, TR-111472, Assembling Bolted Connections Using Spiral-Wound Gaskets, 1999