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Toward Effective Nuclear Power Plant Ageing Management - On the Second Revision of the AESJ Code -

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ABSTRACT

In order to ensure safe and stable Nuclear Power Plant (NPP) operation, effective ageing management (AM) program and implementation of the program is necessary. For this purpose, the “Code on Implementation and Review of Nuclear Power Plant Ageing Management Programs”, which was prepared by the Atomic Energy Society of Japan (AESJ), is used in Japan. The Code has been endorsed and used in the regulation by Japanese regulatory body. Since the first edition was issued in 2007, continuous effort for improvement was made, and the second revision was issued quite recently in 2015.

The Code has the following features;

- Specify ageing management actions according to plant operational years from the early stage of plant operation.
- Utilize “Summary Sheet of Ageing Phenomena”, which has been made based on the results of aging management technical evaluation and the actual operation experience of Nuclear Power Plants (NPPs) in Japan.
- 8 ageing phenomena which should be selected and subject to AM technical evaluation are listed, and the evaluation procedures including the seismic safety evaluation are enacted in the Attachment as a part of the Code.

In the revision, not only new information and data are added reflecting the further operating experience and the latest knowledge including IAEA IGALL, but also the evaluation procedures and “Summary Sheet of Ageing Phenomena” are enriched in terms of seismic effects.

The approach to effective AM program and their implementation are explained and discussed.

KEYWORDS

Ageing Management, Ageing Phenomena, Ageing Mechanisms, Nuclear Power Plant, Seismic Effects

ARTICLE INFORMATION

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1. General Description of Ageing Management (AM) Activities in Japan

Nuclear power plants (NPPs) in Japan have to meet the new requirements formulated by Nuclear Regulation Authority（NRA）for their restarting after the Accident at TEPCO’s Fukushima Daiichi Nuclear Power Station. Various efforts are being conducted particularly for the safety measures. The number of those reactors which are expected for the operation are thought to be about 40 units. The ratio of the NPPs which are over 30 years in plant operation would be about 40%.

For the ageing degradation countermeasure, all structures, systems and components (SSCs) which have safety functions have to be evaluated before the plant operation years of 30 years. This action is called ageing management technical evaluation (AMTE).

For the effective ageing management, the “Code on Implementation and Review of Nuclear Power Plant Ageing Management Programs”, which was prepared by the Atomic Energy Society of Japan (AESJ), is used in Japan. The Code has been endorsed and used in the regulation by Japanese regulatory body. Since the first edition was issued in 2007, continuous efforts for improvement were made. The first revision was made in February 2008, thereby the ageing management was much more harmonized with the maintenance activities. The second revised edition was issued in 2015, reflecting the knowledge learned from the Great East Japan Earthquake. Also in the meantime, the knowledge and information obtained in the AMTE were reflected as the Supplement of the Code, which were issued almost every year.

Here the concept, contents and features of the Code of the second revision were explained and the way towards the continuous improvement is discussed.

2. AESJ Code on Implementation and Review of Nuclear Power Plant Aging Management Programs

2.1. Characteristic Feature of the Code

The Code has various characteristic features, such as the followings since the 2008 edition [1]-[2];

1) Effective ageing management can be continually performed from the early stage of operation. Therefore, ageing management actions are specified in the Code according to the plant operational years, namely, the period from the early stage of plant operation, the intermediate time at every 10 years, and the time when AMTE is needed before the operation of 30 years and following every 10 years.

2) In the early stage of the plant operation, "Summary Sheet of Ageing Phenomena" is utilized for the maintenance management activities. The example of the Sheet is shown in Fig.1 for a pump, by which possible ageing phenomena could be extracted. The database for the Sheet has been established based on the actual operation experience, in particular, by reviewing the final report of AMTE of Nuclear Power Plants (NPPs) in Japan. Through the Summary Sheet of Ageing Phenomena, more harmonized action for maintenance and ageing management activities has become possible from plant commissioning.

3) For the extraction of ageing phenomena which should be subject to AMTE, identification and classification of ageing phenomena were necessary, from the point of the following consideration, namely,

- On degradation modes of each ageing phenomenon,
- On necessary inspections and/or evaluations to monitor the degradation modes,
- On feasibility of trend monitoring.

P01-01 Pump (vertical axial flow turbo pump/seawater/SS)

No.	Issues required to achieve intended functions	Part	Material	Ageing phenomena	Remarks
1	Assurance of pump capacity (head)	Main shaft	SS	Wear	
2		Main shaft	SS	Corrosion (pitting, etc.)	
·		· · ·	· · ·	· · ·	· · ·
13	Maintenance of boundary	Discharge elbow	Cast iron	Corrosion (pitting, etc.)	
14		Discharge pipe	Cast iron	Corrosion (pitting, etc.)	
·		· · ·	· · ·	· · ·	· · ·
23	Support of component	Support plate	SS	(N/A)	
24			SS	(N/A)	
·		· · ·	· · ·	· · ·	· · ·

Fig.1 Schematic diagram of Summary Sheet of Ageing Phenomena

As a result of the consideration, ageing degradations were classified to three modes. The first one ① corresponds to the degradation mode for which planned inspections should be implemented from the early stage of operation. The second one ② is the mode for which continuous inspections should be implemented from the early stage of operation. The last one ③ is the mode for which trend monitoring should be performed at the predetermined timing. For example, IGSCC (Intergranular stress corrosion cracking) and PWSCC (Primary water stress corrosion cracking) were classified to ①, while pipe wall thinning due to FAC (flow accelerated corrosion) was classified to ②. The ageing phenomena classified to the mode ③ were considered to be subject the AMTE.

Finally from these consideration, eight ageing degradation phenomena necessary for the AMTE are identified. These are as follows;

- Neutron irradiation embrittlement,
- Irradiation assisted stress corrosion cracking (IASCC) including under irradiation creep and irradiation swelling,
- Low cycle fatigue,
- High cycle thermal fatigue (fluctuations in temperature),
- Insulation degradation of electrical /instrumentation equipment,
- Thermal ageing of cast stainless steel,
- Degradation of strength and shielding function of concrete structures,
- Fretting fatigue.

After AMTE implementation, the seismic safety are evaluated considering the degradation phenomena which could affect the safety of the plant. These phenomena are not only the above-mentioned 8 ageing phenomena but also other ageing degradation like flow accelerated corrosion.

For these ageing degradation phenomena, the evaluation procedures are enacted in the Attachment as a part of the Code.

2.2. The Main Revised Points of the 2015 Edition

In principle, the revision has been conducted reflecting not only the latest knowledge which was established after the last edition and expanded operation experience, but also taking into consideration the various changes including the new regulatory requirements and lessons learned from the

•Example ; Pump, Heat Exchanger

No.	necessary function	Location	Material	Ageing degradation phenomena	Seismic Safety		effects
					static	dynamic	
1	ensure capacity and pump head	Main shaft	SUS	wear	／	☆	▼
2				fatigue crack (high cycle)			／
3		Impeller	cast SUS, Cu alloy (cast)	corrosion (cabitation)	／	／	／
4		Impeller Ring	—	(consumables・periodicaly exchange)	／	／	／
5	ensure heat transfer	Heat exchanger tube	Inconell 690 alloy	fatigue crack (fletting fatigue)	★	／	▼
6				crevice SCC			／
7				denting			▼
8				scale adhesion			▼
9		anti-vibration metal fitting	SUS	wear	★	／	▼
10	maintain boundary	coolant outlet/inlet nozzle stub safe end (SUS)	SUS (Inconell overlay)	SCC	★	／	◎
12		manhole (primary side)	low alloy steel (insert plate is SUS)	(not atnticipated)	★	／	／
13		tube plate	low alloy steel (Inconell overlay)	fatigue crack	★	／	◎
14				overlay SCC			▼
15				lower part overlay crack			／
16		gasket	—	(consumables・periodicaly exchange)	★	／	／
17		partition plate	Inconell 600 alloy	SCC	★	／	▼
18			Inconell 690 alloy	SCC			／

From seismic safety point(based on JEAC4601)
•static function— ★:evaluation target、／:non evaluation target
•dynamic function— ★: evaluation target、☆: evaluation target when not rigid、*:cope with general seismic design、／:non evaluation target
•effects— ◎:significant、■:little、▼:depending on the ageing management, ◎ or ■ is judged、／: non evaluation target

Fig.2 Schematic diagram of Summary Sheet of Ageing Phenomena for Seismic

Fukushima Daiichi Nuclear Accident. Main new and/or modified points are as follows [1];

1) One of the most important revised points is seen in the sophistication of seismic safety evaluation relating to ageing. Data and information for seismic evaluation are added in the form of Summary Sheet of Ageing Phenomena for Seismic. The example is shown in Fig.2. Degradation phenomena which could affect the seismic safety are picked out, from not only the above-mentioned 8 ageing phenomena but also other degradation phenomena.

The evaluation procedures are also enacted in the Attachment as a part of the Code. As an example, seismic evaluation method for the local wall thinning of the piping prescribed in the Code is explained next.

2) The effect of local wall thinning on seismic response can be evaluated using either the minimum required thickness piping model or the predicted wall thinning piping model. Because in general seismic response analysis on nuclear power plant requires a lot of time and efforts, the development of simplified and reliable method was essential for the effective ageing management. In the present Code of the 2015 edition, for the seismic response analysis of the thinning piping of the class B and C in terms of the seismic classification, the simplified calculation method which uses the results of sound piping is prescribed. This method is thought to be one of the characteristic point of the present Code.

The method first assumes the degraded configuration by use of, for instance, the minimum required thickness piping model shown in Fig.3. Then, the primary stress of the wall thinning piping is calculated based on either the wall thickness or floor response spectrum by comparing the result of degraded piping with that of sound piping. For this purpose, we use such ratios like section modulus, stress factor and response acceleration ratios. For adopting to the Code, careful attention had to be paid so as to the make the evaluation conservative. Hence, the selection of the evaluation points or the correction of floor response spectrum configuration, etc. are important, and these are also prescribed in the Code.

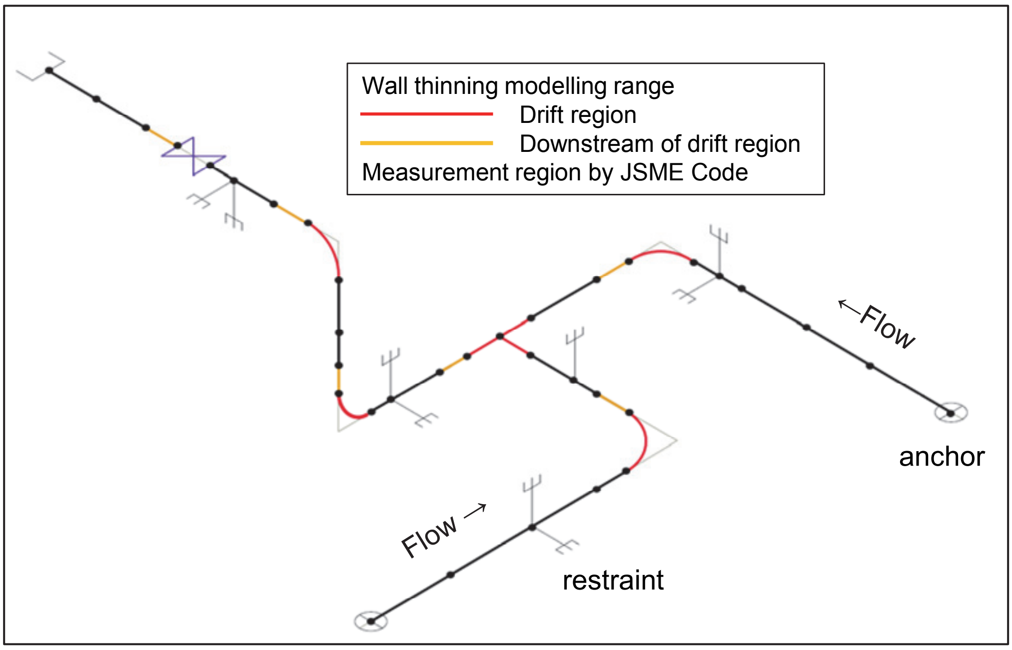

Fig.3 Example of the minimum required wall thickness piping model

3) For the plant which is stopped for a long time, ageing evaluation has also become possible taking account the reason that caused the prolonged stop as well as the plant condition in the meantime.

4) Evaluation on the tsunami-resistant safety from the point of ageing for cold shutdown plants is

incorporated to the 2015 edition. This corresponds to the new regulatory requirements after the Fukushima Daiichi Nuclear Accident.

5) The knowledge from the IAEA IGALL (International Generic Ageing Lesson Learned) [3] was also reviewed whether there existed any domestic plant issue. As a result, ageing phenomena relating to wear, boric acid corrosion, tensioning force relaxation of the tendon, etc. are reflected in the revision.

6) Other points revised are like the followings:
- Target evaluation period for AMTE is changed to have more flexibility, not necessarily fixed to 60 years considering the various plant specific situation.
- Reflecting the latest version of various civil codes and standards, including evaluation guides which were prepared based on the results of national projects,
- Evaluation procedure on the assessment of ageing management measures which was made at previous AMTE is prescribed in the Code. The verification is considered important to confirm whether there is a gap between the prediction and actual ageing progression.

3. Future Direction and Conclusion

The continuous improvement reflecting the latest knowledge of both domestic and overseas, taking every surrounding circumstance relating to plant safety into consideration, steady accumulation of operating experiences and ensuring the path for the feedback of new knowledge to standards and codes, etc. should be the key to effective and useful AMP and hence that is our philosophy to improve the Code. Industry-academic-government cooperation as well as international cooperation and/or international contribution will continue to be essentially important [4].

From the technical point of view, the lessons learned from the Fukushima Daiichi Nuclear Accident are reflected in the revised Code as stated in the Section 2.2. If further facts are made clear as the investigation proceeds, proper revision will also be made accordingly.

Technical development would also take place rapidly in the future in such area as inspection technology. For example, many innovative technologies are proposed in the area of wall thinning detection, because wall thinning phenomenon requires the technologies about nondestructive sensing and anti-corrosion measures. It should be the role of code engineer to incorporate the new method which is important to safety to code and standard timely.

On the other hand, further efforts have to be made especially in the area of stakeholder communication. For example, extending the plant operation over 40 years should require the understanding of local residents. The role of the academic society should become even more important, and hence it is also our policy to make a clear explanation of the Code at every opportunity. The communication would also contribute to the continuous improvement.

Acknowledgement

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