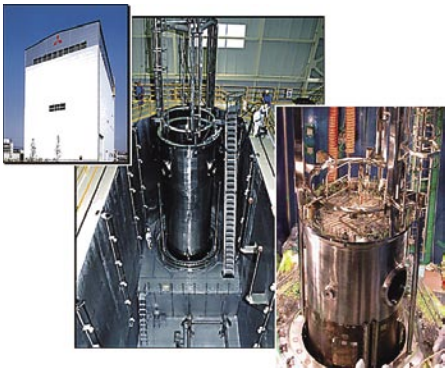

Approach to Long Life Operation and High Capacity Factor of Nuclear Power Plants

JINICHI MIYAGUCHI*1 KAZUYA SEKI*1

The problem of the global environmental load in recent years has increased the advantages of nuclear power plants, and the importance of safe and effective operation of existing nuclear power plants over a long time period. Of the 23 PWR plants currently in operation in Japan, seven have been operated for more than 30 years. Accordingly, it has become extremely important to take measures against aged structures and components in order to ensure the reliability of these plants. Further, in order to improve the operation availability of existing plants, various measures have so far been taken such as reinforcement of preventive maintenance, and shortening the outage duration. For further effective use of the plants, however, the improvement of fuel combustion efficiency by developing high burnup fuel and the improvement of capacity through extended cycle operations have become important.

1. For higher reliability of nuclear power plants

(1) Evaluation of integrity of aged plants

In order to ensure the safety and reliability of a plant, it is important to make an adequate diagnosis of the degradation of the structures and components caused by aging and to carry out appropriate preventive maintenance. From this point of view, a technical evaluation of aging is conducted every 10 years for plants with an operation period exceeding 30 years, in which a comprehensive and cyclopaedical evaluation of the integrity of the plant based on up-to-date knowledge is carried out and a future 10-year maintenance plan is designed based on the results of these evaluations.

The basic concepts in designing the maintenance plan are given in **Fig. 1**. First, an evaluation of the life time of the components currently in use is made on the basis of their current condition and the assumed degradation

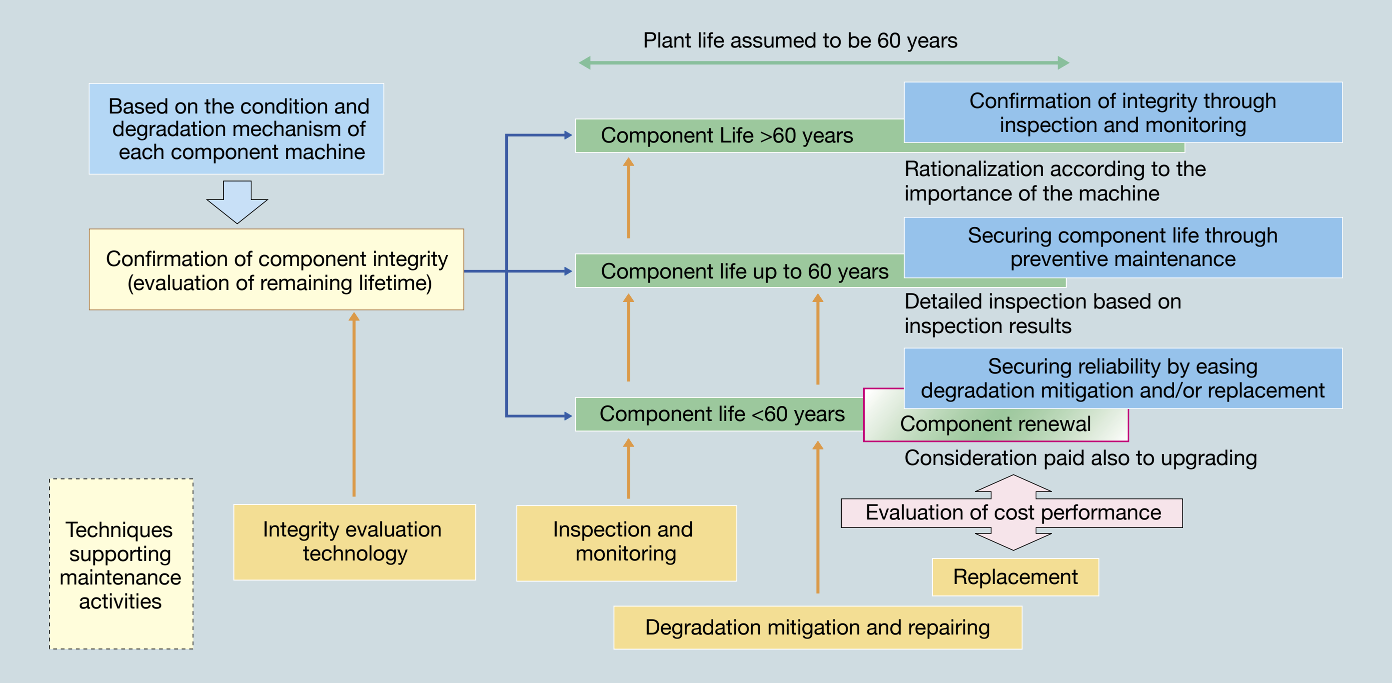

Fig. 1 Concept of countermeasures against aging

*1 Kobe Shipyard & Machinery Works

mechanism. According to the results of evaluation, the structures and components are broadly divided into the following three categories.

(a) Components found to have a sufficiently long life of over 60 years have their reliability confirmed through inspection or monitoring their condition while continuing a basic and normal maintenance program.

(b) Components found to have a life time up to 60 years are suitable for the dedicated preventive maintenance program such as degradation mitigation and/or repair in addition to inspection and monitoring their condition.

(c) Components found to have a life time of less than 60 years are candidates for replacement in addition to the degradation mitigation and/or repairs.

In taking measures against aging structures and components, it is important to choose appropriate measures from the maintenance menu based on the component condition, and for this it becomes necessary to provide the basic maintenance techniques in a timely manner such as evaluation and analysis, inspection and monitoring, degradation mitigation and repair, and replacement.

(2) Maintenance techniques contributing to the safety and reliability of the plant

These individual maintenance techniques are actually used in maintenance activities in nuclear power plants, for example, high-speed and high-accuracy inspection equipment for non-destructive testing of components and pipes, and repair equipment that removes detected defects and carries out welding using reliable material by automatic remote-control, and are effectively utilized in preventive maintenance to prevent accidents.

In order to ensure the high-level safety and reliability of nuclear power plants, it is necessary to achieve high-quality preventive maintenance, which is not only for aging issues. To this end the high-level integration of the three technical fields of maintenance engineering development and manufacturing and on-site field work is extremely important, and Mitsubishi Heavy Industries, Ltd. (MHI) has the advantage of comprehensive technical knowledge.

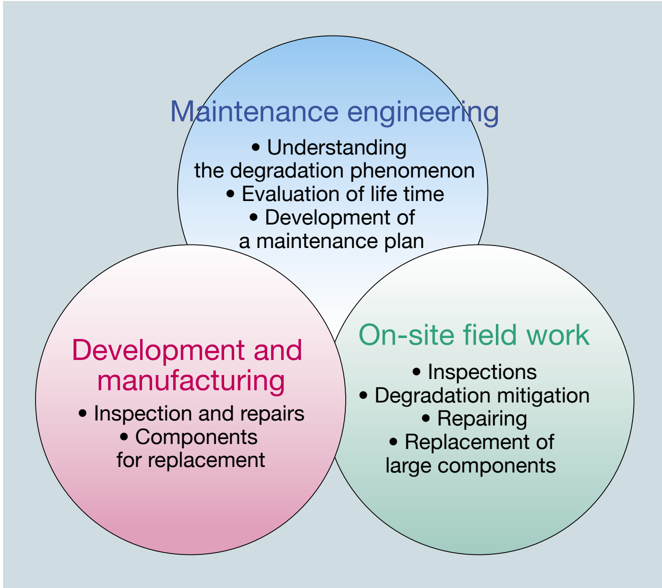

Fig. 2 Three techniques supporting high-grade maintenance

2. Improvement of capacity through optimized maintenance program

The nuclear power plants in Japan are currently shut down every 13 months to undergo periodical inspections.

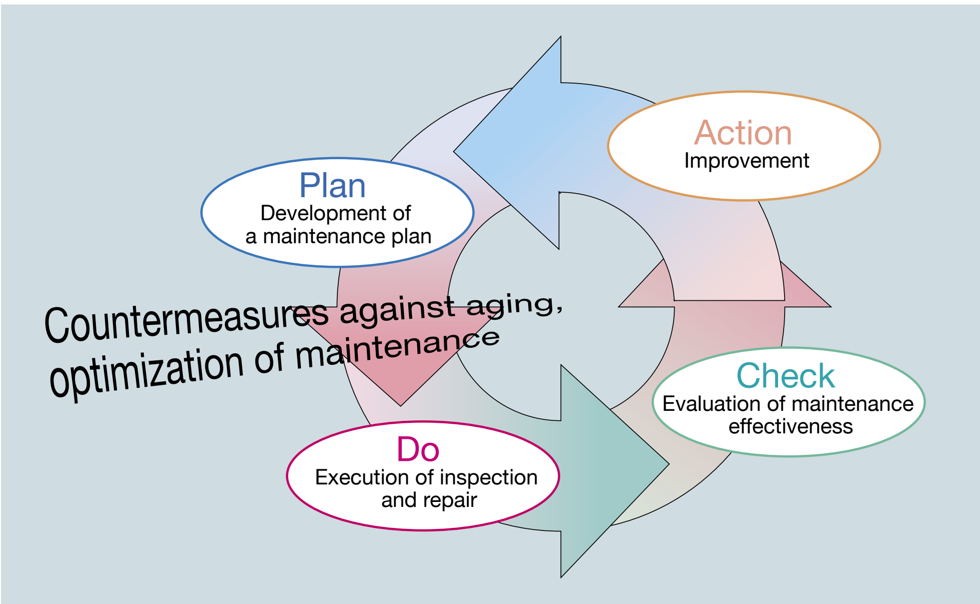

Fig. 3 Maintenance PDCA

However, the capability of extended cycle operation, which improves capacity by extending the shutdown intervals, has been discussed in consideration of overseas experiences.

Of course, safe and reliable operation is fundamental to extending the operation cycle, so that is necessary to evaluate the reliability of the structures and components based on maintenance experience and the latest knowledge and, if needed, to promote optimization by reviewing the specifications and interval of individual activities. In this case, it is necessary from the safety point of view to carry out maintenance based on the importance of the structures and components. Further, in order to increase the effectiveness of maintenance activities, it is important to continuously review them according to their results (performance), i.e. to make effective use of the PDCA (plan, do, check, action) cycle in everyday maintenance activities.

From these points of view, utilities are currently promoting integrating their maintenance activities cyclopaedically and systematically. And as a plant supplier MHI is providing full support by employing its comprehensive technical knowledge.

3. Improvement of fuel efficiency

Since the number of reloaded fuel assemblies is increased when extended cycle operations are carried out under the same burnup limit, i.e. under the same uranium enrichment level, the fuel combustion efficiency deteriorates. Hence, efforts are being made to achieve higher discharge burnup by increasing the uranium enrichment in order to improve the fuel combustion efficiency. Higher burnup fuel generates more energy and requires less replacement fuel assemblies and therefore brings enhanced fuel combustion efficiency.

The maximum burnup of a fuel assembly for PWR fuel has been improved from 39 GWd/t to 48 GWd/t, and currently fuel assemblies of 55 GWd/t are gradually being introduced in Japanese PWR plants. To further improve fuel efficiency, MHI is striving to develop advanced fuel with a burnup level of more than 60 GWd/t.

One of the problems involving high burnup fuel is the increased corrosion of the outside of the fuel cladding tube caused by prolonged use of fuel in the core. The PWR fuel cladding tubes are conventionally made of Zircalloy-4. Since the enhanced corrosion resistance of the cladding tube is indispensable for high burnup, new cladding with changed alloying elements has been developed. MHI have developed MDA (Mitsubishi developed alloy) cladding tubes for high burnup fuel. Step 2 (55 GWd/t) fuel adopts MDA cladding as well as ZIRLO™ cladding developed by Westinghouse Electric Corporation.

In order to comply with the higher burnup fuels, MHI has developed M-MDA™ (modified MDA) alloy by adjusting the alloying elements. M-MDA™ exceeds MDA in corrosion resistance, while its other mechanical characteristics remain equivalent to those of conventional alloys such as MDA and Zircalloy-4. In order to confirm the performance of M-MDA™, an irradiation test was conducted in a PWR plant in Spain, with the fuel rod burnup reaching a level of 70 GWd/t or more. As is clear from the maximum cladding oxide thickness in **Fig. 4**, the thickness of corrosion of the M-MDA™-SR cladding was found to be much less than that of MDA[1] (SR: stress-relief annealed, RX: recrystalized annealed). **Figure 5** shows fuel rod growth by irradiation, indicating higher dimensional stability than the conventional material.[1] MHI plans to continue development to comply with higher burnup levels by confirming its performance through post irradiation examinations.

MHI is also engaged in a joint development with the Japanese PWR industry on J-Alloy™, a binary alloy of Zr-Nb for cladding tubes, which has excellent corrosion resistance, with irradiation tests being conducted in the PWR plant in Spain.

These claddings are planned to be adopted appropriately according to the operating conditions such as the start of operations, the burnup level, and the linear power density.

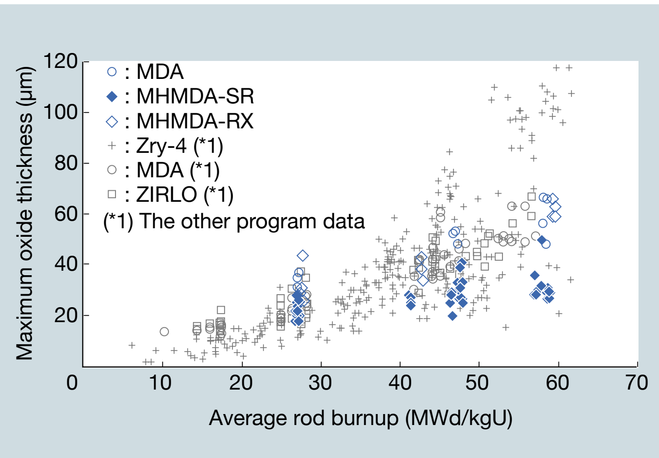

Fig. 4 Cladding corrosion

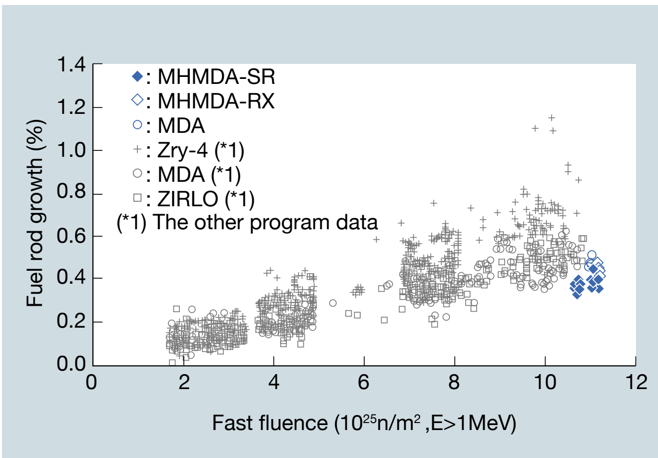

Fig. 5 Fuel rod growth

4. Conclusion

Amidst mounting concerns over the global environmental load, the safe and effective operation of existing nuclear power plants has become an important challenge from the viewpoint of arresting global warming.

MHI is determined to maintain efforts to promote the reliability of individual structures and components by using state-of-the-art technology, and to ensure the safety and reliability of existing nuclear power plants, and also to enhance their effectiveness, by utilizing comprehensive maintenance technology.

Reference

1. S. Watanabe, et al., Proc. 2007 International LWR Fuel Performance Meeting, San Francisco, October (2007)


Jinichi Miyaguchi


Kazuya Seki