Modification and Continue Monitoring of Kartini Reactor Tank Liner for Long Term Safe Operation

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ABSTRACT

This paper discusses an experience on modification of bulk shielding facility (BSF) and monitoring of the Kartini reactor tank liner through in-service inspection (ISI) for long term safe operation. The objective of BSF modification is to prevent future water penetration from BSF to both the thermalizing column and space between the aluminium reactor tank liner and the concrete. Modification of BSF needs to be conducted because leakage from the BSF has entered to the area behind the aluminium tank liner and has saturated the concrete that has potential to corrode the steel reinforcement bar, and subsequently pushing the aluminium bottom tank and causing the swelling. The three swellings on the bottom tank have been continued monitoring through ISI regularly since 2001 up to now to observe and measure the three swellings profile. Result of swellings profile measurement indicated that swelling had grown slowly in size and became relatively stable. Careful analysis and assessment of the root causes of the swelling indicated that swelling do not present a threat to future safe operation of the reactor and Kartini reactor is considered to be in good condition. As an outcome of modification and continue monitoring, Kartini Reactor in Yogyakarta has been already obtained extended operation license for the third period from Nuclear Energy Regulatory Agency of Indonesia (BAPETEN) up to 2020.
Key words: modification, swelling, Kartini reactor, in-service inspection.

1. Introduction

TRIGA Mark II-Kartini Reactor is an open pool reactor with thermal power rating of 100 KWs in Yogyakarta is one of research reactor operated by National Nuclear Energy Agency (BATAN). Kartini reactor went to the critical in 1979, and the first license was obtained for 26 years. Kartini reactor tank liner material is 1050 Aluminium (99.5% pure Al). Tank diameter is 2 m, 6 m in deep, and 6 mm in thickness. The tank liner construction consists of four shells which had been assembled into the reactor pool. In order to establish adequate mechanical strength and get a watertight construction, at each section 300 mm wide “belts”of 5 mm thick Aluminium were fillet welded over the joints in each section [1]. Reactor utilizations are for training, research, and education of students from the university in the nuclear field. Kartini reactor has been already old. In other hand, the reactor must be continued safely in operation due to demand. To have life extension in operation, the condition of reactor tank liner should be known. Therefore, an effective in-service inspection (ISI) to the reactor tank liner has been conducted regularly since 2001 up to now. Results from ISI obtained the three swellings on the bottom tank. Swellings profile measurement such as height and areas of swellings have been conducted through replication technique utilized putty as swelling impression. Root cause analysis of swelling has been performed. Recommendation came from the IAEA expert team to modify the BSF which causes swelling and reactor tank liner should be continue to be monitored through ISI to obtain reactor tank liner condition whether any possible defect or any degradation/deterioration reactor tank liner that have significant impact to the safety.

Hopefully by conducted modification of BSF, water penetration from bulk shielding to both the thermalizing column and space between the aluminium reactor tank liner and the concrete can be stopped. Swellings profile such as high and area will stable or increase in high and area of swellings could be minimized and the safety of reactor for long term safe operation can be assured.

2. In Service Inspection History

Ageing management program of TRIGA Mark II-Kartini Reactor has been implemented through in-service inspection (ISI) of the reactor tank liner. The objectives of ISI are to obtain and evaluate the tank liner condition includes detecting any possible welding defect and determining whether any degradation/deterioration of tank liner that have significant impact to the safety. Reactor tank liner has been chosen as the first priority because of reactor tank liner is the most critical component in the research reactor.

Therefore, an effective ISI to the reactor tank liner has been conducted firstly in 2001 during major shutdown utilized a series of non-destructive testing techniques, such as: visual utilized underwater camera, thickness measurements utilized ultrasonic, hardness measurements utilized in-situ hardness, and surface replication utilized putty.

Visual technique was utilized to assess general condition of the reactor tank liner and other components. Ultrasonic thickness measurements were utilized to obtain the thickness of the reactor tank liner. Hardness measurements were utilized to obtain hardness values of the reactor tank liner material that has bearing to the reactor tank material embrittlement due to neutron, and surface replication technique utilized putty was applied to obtain an impression of any defect on the surface of reactor tank liner. This technique can be used to measure accurately the dimension of defect and the surface profile.

Inspection area of tank liner was conducted to all level of reactor tank liner from the bottom up to the top tank includes circumferential and vertical welds, internal structure, and irradiation facility.

More detailed re-inspection to the reactor tank especially to the areas of interest on the bottom tank was conducted in 2004 utilized visual, ultrasonic, and replication techniques. To obtain more detail images and profile to allow a better assessment of features, inspection in 2005 up to 2009 were conducted every 6 months. Continue monitoring through comprehensive inspection was conducting up to now regularly to assure the safe operation of reactor due to ageing after long term in operation, utilized visual, ultrasonic and replication techniques.

3. Result and Discussion

Inspection result in 2001 (after 22 years in operation) utilized visual technique indicated that the reactor tank liner has only minor defects such as scratch. Replication of the tank liner defects indicated that the defects observed were a minor nature causes by fabrication process and were not of concern from a safety perspective.

The two swellings features seen on the bottom of the tank observed under thermalizing column indicated as S1 and S2. These swellings could not be examined in more detail due to shortfalls in equipment capability. At that time they were not considered to be a serious issue for future safe operation.

Thickness measurements of the tank wall at various locations were obtained in ranged between of 5.3 mm to 5.5 mm. Hardness values of the reactor tank material were consistent with published data and only minor neutron damaged has occurred. In general, the first inspection result in 2001 revealed that Kartini reactor tank liner was still good and safe condition for continued operation[2].

Result of inspection in 2004 utilized visual technique obtained as same as condition in 2001. The two swellings feature observed under thermalizing column. To obtain the swellings profile, such as height and areas of swellings, replication technique utilized putty was applied. Detailed measurement of the swellings profile can be obtained by measuring the height and area of the swelling replica impression utilized a height meter. In peak of S1 appeared 2 tears and 2 dimples. Lengths of tears were 14 mm and 5 mm approximately, dimple diameters were 2 mm and 3 mm approximately. In peak of S2 appeared 2 tears, they were 10 mm and 2 mm of lengths. Thickness measurement on the swelling areas of S1 and S2 on the bottom tank were obtained to be between of 5.3 mm – 5.5 mm indicated that the metal thickness in the areas of swelling were similar to the reactor tank wall thickness and to the original metal thickness[3].

Inspection results in 2005 were seen that S2 increased both in height and area. The thickness of reactor tank wall at various locations and thickness of swelling areas were still consistent in ranged between of 5.3 mm – 5.5mm[4].
Inspection result in 2007, another swelling feature on the bottom of tank observed under thermal column, indicated as S3. By using the same technique, profile measurement of S3 has been conducted. In S3 were obtained 5 dimples, such as 2 dimples with 2 mm in diameter, 2 dimples with 3 mm in diameter, and 1 dimple with 4 mm in diameter approximately[5].
The cross section of Kartini reactor, swelling locations, and swellings profile are showed in Figures 1 and 2 respectively.

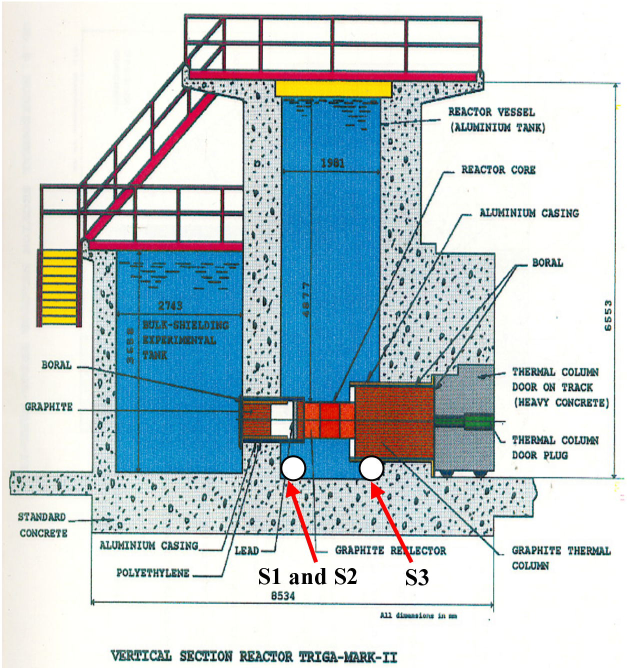

Fig.1. Cross section of Kartini reactor and swelling locations[5]

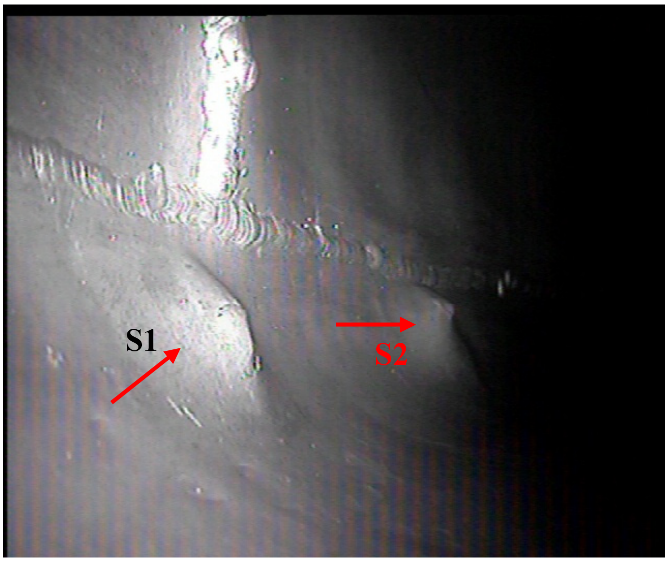

Fig.2. Swellings profile of S1 and S2[5]

3.1. Root cause analysis

Root cause analysis of swelling problem has been performed in comprehensive by IAEA expert team during the time of inspection. Probable root cause of swelling is the seal of cover plate in BSF has deteriorated and allowed water in BSF entered both the thermalizing column and space between the aluminium reactor tank liner and the concrete. The water also saturated the concrete and has potential to corrode the steel reinforcement close to the surface of the concrete. It is believed that water leakage from the BSF has entered the area behind the aluminium tank liner and has saturated the concrete, and also believed the carbon steel reinforcement bar that were located close to the inner surface of the concrete pool backing has corroded. The expanding corrosion product (rust) has force the layer of concrete covering the steel reinforcement and subsequently pushing the aluminium bottom tank inwards and causing the swelling [6,7].

Under coordination of the IAEA expert team, in August 2007 the sealing plate cover the thermalizing column was removed and approximately 200 liters of water was drained from the thermalizing column. The first 200 mm thick layer of graphite was removed to allow examination of the aluminium behind the boral layer separating the graphite and thermalizing column. Examination the condition inside of the thermalizing column indicates that uniform corrosion has occurred on the inside of the thermalizing column. The painted surface of BSF concrete wall contained crack that have allowed water penetration[7].

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3.2. Remedial action

The IAEA expert team recommended to modify BSF, such as surface area of the BSF concrete should be lined with aluminium to prevent future water penetration[6].

In March 2008 a remedial action such as modification of BSF has been conducted to remove the conditions that are causing swelling. The BSF was dried and then half of BSF area which contacted to the thermalizing column was lined with aluminium supplied by local company to prevent future water penetration to the concrete. Modification activity of BSF are shown in Figures 3. Figures 4 and 5 are showing BSF before modification (before remedial action) and BSF after modification, respectively.

Fig.3. Modification activity of BSF[8]

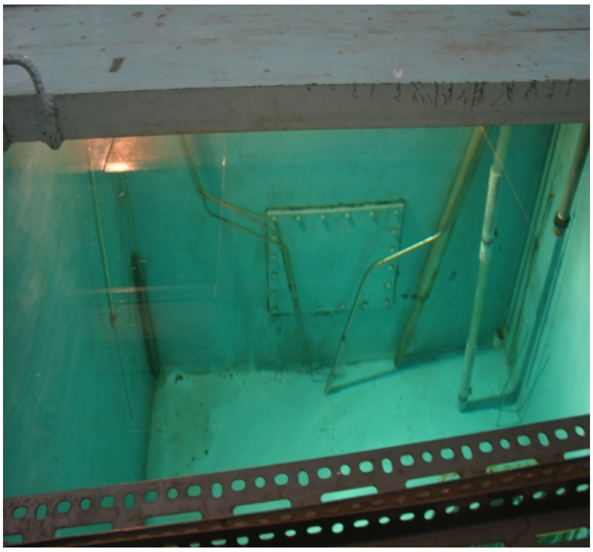


Fig.4. BSF before modification[9]

Fig.5. BSF after modification[9]

3.3. Safety assessment of the modification

The BSF function is as interem storage pool of spent fuel as well as irradiation facilities in Kartini TRIGA Reactor. Related to the BSF modification, the safety assessment is necessary as re-licensing requirement from the Nuclear Energy Regulatory Agency of Indonesia (BAPETEN), and as part of the safety analysis reports document. The safety assessment was done related to the design of modification, criticality, thermal hydraulic, radiation, and seismic aspects of the spent fuels which are in the BSF modified[10]. Spent fuels are located in the BSF using aluminium bracket as well as TRIGA fuel storage rack standards. For analysis assumptions, the maximum loading number of spent fuel in the BSF modified are 77 spent fuels and the maximum burn up is 50%.

The modification programs are related to the schedule of modification, safety analysis, and quality assurance program documents[11]. After verification, modification of the BSF has been accepted by the Nuclear Energy Regulatory Agency of Indonesia (BAPETEN).

3.4. Continue monitoring

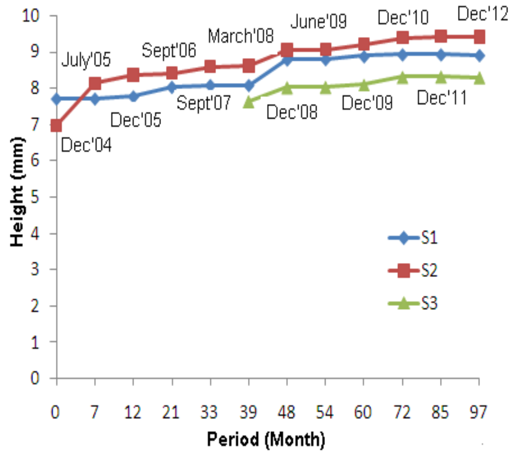
Continue monitoring the condition of the three swellings such as S1, S2, and S3 through ISI of Kartini reactor tank liner was conducting especially concentrated to the area of swelling in year 2008 up to now (December 2012). Aim of continue monitoring is to obtain images and swelling profile from time to time and to allow a better assessment of these features.

Inspection results during this period obtained that the thickness of reactor tank wall at various locations and thickness of swelling areas were still consistent in ranged between of 5.3 mm – 5.5 mm.

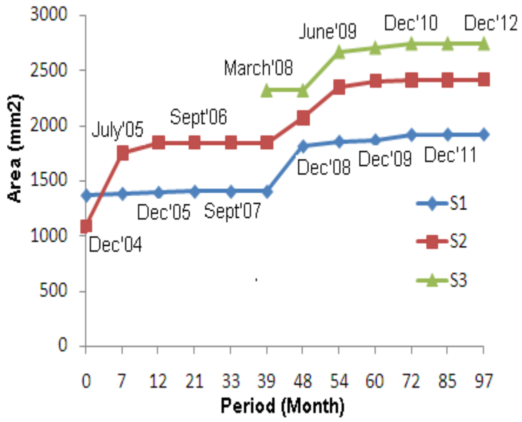
Lengths of the two tears in peak of S1 were 14 mm and 5 mm approximately, and diameters of the two dimples were 2 mm and 3 mm approximately.

Lengths of the two tears in peak of S2 were 10 mm and 2 mm approximately. In S3 were obtained 5 dimples, such as 2 dimples with 2 mm in diameter, 2 dimples with 3 mm in diameter, and 1 dimple with 4 mm in diameter approximately[12].

Figures 6(a) and figure 6(b) are showing the graph of swelling height and areas of S1, S2, and S3 as a function of time measured from December 2004 up to December 2012 respectively[12].



(a)



(b)

Fig. 6. The graph of swelling S1, S2, and S3, (a) height in mm and (b) area in mm^2[12]

Data in the Figure 6 shows that the swelling height and area had grown slowly in size and became relatively stable from year 2009. Taking into account the remaining thickness of the aluminium at the swelling location could not be accounted by the formation of corrosion products from aluminium due to the low"pilling-bedworth ratio" for aluminium. The occurrence of the swelling as an ageing consequence.

Also for ageing aspects, there was conducted the continous monitoring of the BSF modified by visual test included on ageing management and maintenance programs.

4. Conclusion

The three swellings on the bottom of the Kartini reactor tank as an ageing consequence of the reactor after more than 26 years in operation. Modification of BSF to remove the conditions that are causing swelling has been conducted. Continue monitoring through ISI of the Kartini reactor tank liner was conducting up to now to obtain the reactor tank condition and it also to ensure that the Kartini reactor tank is in good condition and safe for continues operation. Swelling have been monitored one a year. All data obtained from inspection results are very usefull in obtain new operation license from Nuclear Energy Regulatory Agency of Indonesia (BAPETEN).

As an outcome of BSF modification and continue monitoring through ISI of reactor tank liner since 2001 up to now, TRIGA Mark II-Kartini reactor has been obtained plant life extension already or extended operation license from Nuclear Energy Regulatory Agency of Indonesia (BAPETEN) for the third period until 2020.

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