A Study on the Changes in the Maintenance Environment of Nuclear Power Plants and on Factors that Reduce Maintenance Efficiency

Seok Jin Jung [a,b], Hyun chul Lee [b*]
[a]Korea Hydro & Power, Kyungsangbuk-do, Kyungju-si, Yangbuk-myun, Janghang-ri 283
[b] *The Busan National Univ, Busan-si, Kyumjung-gu, Busandaehakro 63-2*
[*]Corresponding author : hyunchul.lee@pusan.ac.kr

1. Introduction

Since 2011, accidents at Fukushima nuclear power plant in Japan, forgery scandals of quality verification document(QVD), and corruption scandals related to materials have led to a great increase in concerns about the safety of nuclear power plants and in the awareness of the importance on the nuclear power plants. As a result, many measures for preventing the recurrence such confirming the truth of QVD, purchasing procedure changes, and etc. were established and reflected, so that the maintenance environment was dramatically changed like the number of business processes increased, and lots of maintenance workers moved. In addition, the avoidance of the maintenance department also deepened due to increased workloads and responsibilities in the maintenance department. Therefore, this study aims at investigating changes in the maintenance environment of mechanical equipment maintenance sector due to a series of events occurred after 2011 and factors that reduce the maintenance efficiency and at establishing improvement measures for overcoming them.

2. Scopes and Methods

In this study, the number of Corrective Action Program (CAP) issuance was confirmed through Korea Hydro & Nuclear Power Co., Ltd(KHNP)'s operation improvement system to check the change of the maintenance environment, and changes in the number of material contracts through the KHNP report and changes in the number of maintenance days by year through the Enterprise Resource Planning(ERP) of the KHNP were confirmed first. In addition, in order to investigate the factors of efficiency reduction and improvement necessities that are seen from the viewpoints of maintenance workers, the questionnaire contents and items were selected through preliminary interviews with the maintenance workers, and then, it conducted the questionnaire on 176 supervisors of mechanical equipment maintenance working in the mechanical team and 219 workers who belong to partner companies performing the mechanical equipment maintenance in Kori, and then it finally tried to establish alternatives for the improvement through precedent studies.

3. Results

3.1 Change of Maintenance Environment

As administrative steps are strengthened to prevent the recurrence of a series of incidents, workloads and the time and procedures required for handling the tasks increased dramatically. As a result of the questionnaire about the change of workloads compared with three years ago, 93.2% of the supervisors answered that the workloads increased. In the question about the reasons for the increased workloads consisting of multiple answers, more than 75% of supervisors believed that "tightening regulations" and "strengthening the purchasing process" are the main reasons for the increased workloads. In the same questionnaires for workers of partner company, 87% of whole respondents answered that their workloads have increased, and more than 40% said that "the reinforcement of administrative work" and "the enhancement of industrial safety" are reasons for the increase. Overall, the perception of the increase of work is the same, but it has been confirmed that strengthening regulations and business processes put more burden on supervisors. After checking the supervisors' work experiences through the questionnaire, it was found that there was a sudden shift of those people between 2012 and 2014, with 60% or more in 3 years and 20% in 5 years or more. And, as a result of investigating the number of CAP issuance with more than grade 3 in order to confirm the changes in the maintenance environment, it was confirmed that the number of CAP issuance increased by 261% in 2016 compared to 2010, which dramatically increased especially after 2014 [1].

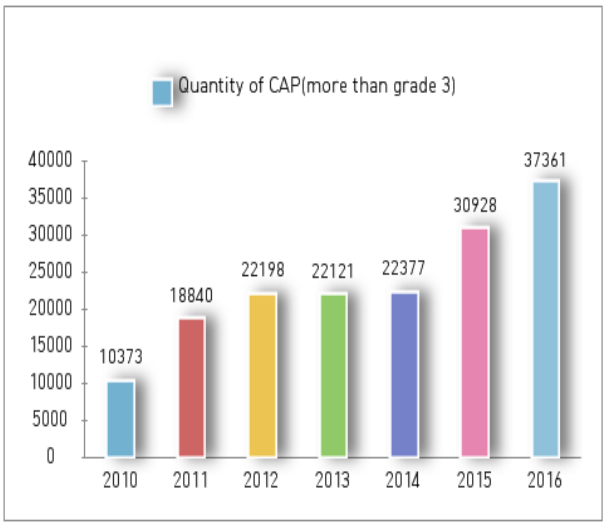

Fig.1 Quantity of CAP(more than grade 3)

Using the status of the procurement of materials, the number of foreign material contracts dropped from 1321 cases in 2008 to 411 cases in 2014, and the number of uncontracted materials at home and abroad surged after 2013, indicating that the timely procurement of materials for the maintenance was not achieved.

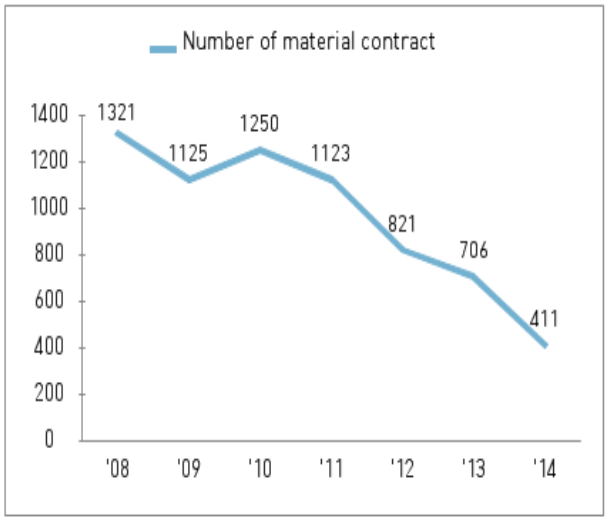

Fig.2 Distribution of mechanical equipment maintenance supervisor's workload

As a result of analyzing a total of 29,896 maintenance order processing days conducted by the mechanical Engineering team since 2010 in order to confirm the change in the period required for maintenance, the required number of days in 2016 was about four times that of 2010 with an average annual increase of 49.9%, indicating the increase in the number of working days due to changes in the maintenance environment [2].

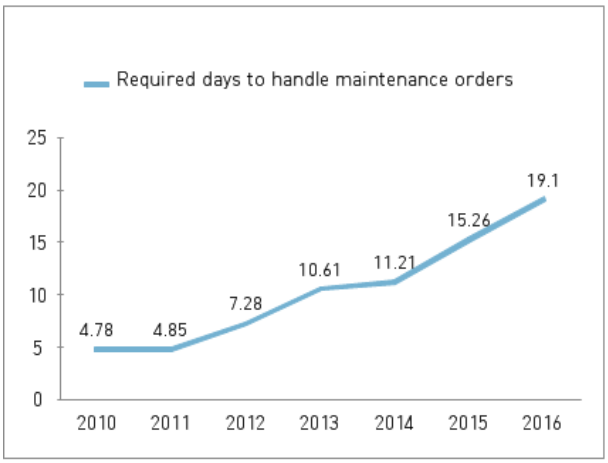

Fig.2 Required days to handle orders for mechanical equipment maintenance

As a result of questioning about the time spent for each job to supervisors, document preparation and administrative tasks were higher than maintenance-related and engineering work, which are the supervisors' proper duties, confirming their ineffective performance of the work.

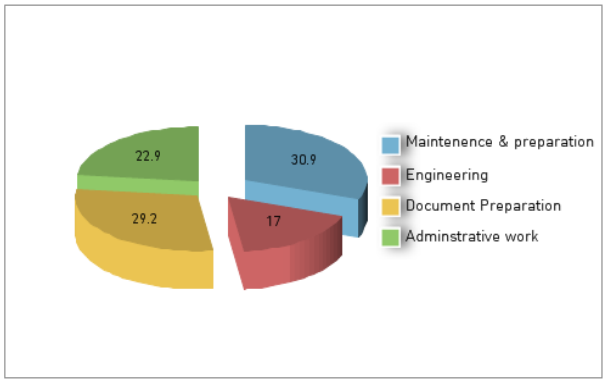

Fig.4 Distribution of mechanical equipment maintenance supervisor's workload

3.2 Recognition of Maintenance Worker about Deterioration in the Efficiency

This study asked for multiple responses to selected factors of reducing maintenance efficiency through pre-interviews to identify them that maintenance workers think. First of all, more than 50% answered that all 14 items are the factors of efficiency reduction in the results of surveys on supervisors. Eight of them achieved a high rate of response more than 90%. On the other hand, in the case of workers belonging to partner companies, there were four items with 50% or less answers, meaning that supervisors were more concerned about work inefficiency rather than workers.

Table I: Factor that reduce the efficiency (supervisor)

Factors that reduce the maintenance efficiency	ratio (%)
Excessive administrative work	98.8
Lack of supervisor's experience	94.3
Inefficient procedure	94.3
Additional work to meet regulatory requirements	94.3
Delay in securing materials due to failure in bidding	92.0
Duplication of process	90.9
Difficulty in securing original producer's materials	90.9
Inefficiency of work assignment	90.0
Excessive review time due to other power plant failure cases	80.7
Reworking due to incorrect design	76.1
Lack of related data such as past maintenance data	72.7
Lack of maintenance workers from parter companies	60.2
Lack of technical skills of workers	59.1
Lack of a sense of ownership and of a sense of duty	53.4

Table Ⅱ: Factor that reduce the efficiency (partner's workers)

Factors that reduce the maintenance efficiency	ratio(%)
Excessive administrative work	82.9
Inefficient procedure	75.3
Additional work to meet regulatory requirements	75.3
Duplication of process	72.6
Lack of maintenance workers from parter companies	70.5
Delay in securing materials due to failure in bidding	61.6
Lack of supervisor's experience	54.8
Excessive review time due to other power plant failure cases	45.9
Lack of related data such as past maintenance data	42.5
Lack of a sense of ownership and of a sense of duty	34.9
Lack of technical skills of workers	34.2

It also surveyed work experience, the number of education participation, and knowledge level in order to confirm work inefficiencies related to capacity for work, it was found that the worker's related career was twice as much as that of the supervisor. In addition, 81.8% of supervisors in the self-evaluation of the level of work-related knowledge evaluated that there is very little work-related knowledge, but only 19.9% of workers answered that way, showing a very big difference between them. And, the number of workers belonging to partner companies participating in education was found to be twice as high. The supervisors' career and knowledge were found to be insufficient, but they did not have educational opportunity to supplement this.

3.3 Recognition of Maintenance Worker about the Improvement Plan

As a result of inquiring 12 items on supervisors' needs for improvement, the average value of 8 items was 4.3 or higher and all 12 items were 3.6 or more, so supervisors thought that a lot of improvement was needed to improve the efficiency. The needs to reduce maintenance work, increase the number of workers in the maintenance department, and establish preferential measures for the maintenance worker were found to be the highest, but among them, it is considered that it is the most helpful to reduce the workload to improve work efficiency.

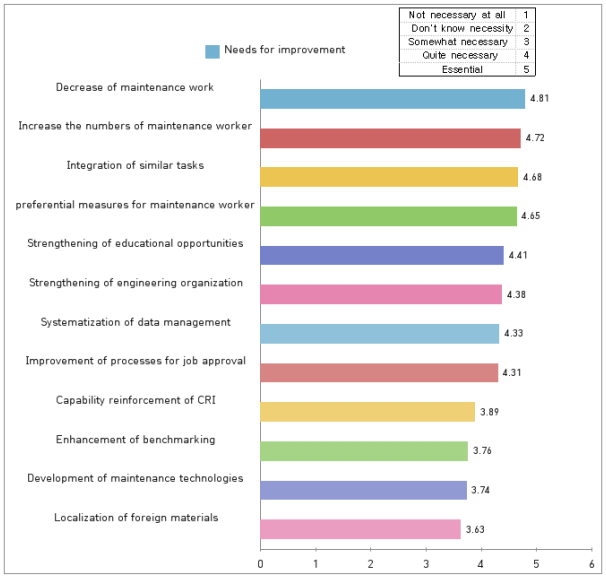

Fig.5 Needs for improvement to increase maintenance efficiency(supervisor's answer)

It was also surveyed that the need for the integration of similar tasks and the elimination of unnecessary tasks, the strengthening of educational opportunities for maintenance supervisor, and ensuring the internal stability of engineering organization was also high. The questionnaire results for education on of workers belonging to partner companies, maintenance skills, and etc. and four times of personnel-related improvement needs also showed a high value around 4.0. Overall, the maintenance workers were sympathetic to the opinion that a lot of improvements were needed in the current maintenance environment.

3.4 Alternative Idea Presentation

Changes to the methods of predictive maintenance should be reviewed first. KHNP's predictive maintenance is Time Base Maintenance(TBM) based on the recommendation of the original manufacturer and on maintenance experience, and concerns over excess maintenance and reduced reliability due to missed maintenance time are constantly being raised as a problem. It is necessary to change the maintenance strategy to Condition Base Maintenance(CBM) which confirms signs of failure and carries out maintenance in a timely manner. In order to obtain more device information, technology development for the diagnosis of conditions should be done, and at the same time, additional measurement devices must be installed in order to acquire more equipment operation data [3]. The introduction of the RCM technique, which is applied to complex industrial facilities such as aircraft and power plants, can be an alternative [4]. Another option is improving technology. Maintenance technology development is a factor to improve maintenance efficiency, selected by both mechanical maintenance supervisors and of workers belonging to partner companies. It is necessary to develop technologies that are essential for equipment maintenance and inspection in nuclear power plants, but which have not been developed yet, through the R & D projects of SMEs. The R & D projects are to develop new technologies that can be applied to the power plants jointly by KHNP and SMEs through the agreement, which needs to be revitalized as it is steadily decreasing from 29 cases in 2006 to 2 cases in 2014. R & D tasks can be used not only for technology development, but also as a localization method for foreign materials which are continuously problematic in supply. However, it seems that a strategy must be established in parallel to maximize performance through continuous management from the selection of tasks to development and utilization [5]. It is also a good idea to recruit excellent engineers retired from domestic and overseas related companies and arrange them to each regional office and then allow them to perform technical support roles. In fact, excellent designers with experience in design companies have been hired and performing technical support in the headquarter and each management office since 2014, which contributes greatly to finding design errors that design companies did not find. It is also necessary to conclude a technical agreement with a typical equipment manufacturer so that technical backup of deficient data and equipment can be promptly provided. The contract with Westinghouse is a good example. It is also necessary to unify preparation documents for work. The most factors to reduce maintenance efficiency chosen by supervisors and of workers belonging to partner companies are excessive administrative works and inefficient procedures, and more than 80% of the respondents answered that they are the most factors of reducing the efficiency. And, obtaining an approval for more than 10 documents such as a fire work plan before work is becoming a major factor in job delays and an increase of workload. It is necessary to minimize unnecessary administrative factors by unifying the work order system to prepare each administrative document and obtain its approval. In addition to this, it is also necessary to revitalize common educations for business place and conduct customized job training for each career in order to secure stable materials and strengthen employee capacity through the method of confirming authenticity immediately after issuing documentary evidences for materials.

4. Conclusions

Due to the Fukushima nuclear plant accident and the QVD forgery scandals occurred after 2011, there have been rapid changes in the maintenance environment like the number of work process increased in the field of mechanical equipment maintenance for nuclear power plants and lots of maintenance workers moved. There is a great concern about the surge in maintenance workloads of workers, and this study confirmed that the actual required days for work order is rapidly increasing every year. Also, the maintenance workers are very aware of the inefficiency of maintenance work and are demanding many alternatives to improve it. First, the current maintenance environment and the seriousness of the maintenance worker's perception should be admitted, and then MAN-POWER improvement in the company should be done promptly through the improvement of maintenance methods confirmed through previous studies and the technology development by the activation of the R & D projects of SMEs, and the utilization of retired excellent engineers and the education reinforcement.

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