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Development of Lifetime Assessment and Rehabilitation Cost Calculation Methods for Overseas ROMM Project

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Abstract

Regarding the implementation of ROMM project (Rehabilitation, Operation, Maintenance & Management), which is one of overseas development projects, it is very important to diagnose the exact current status of aged thermal power plant. However, when people visit the power plant for the purpose of prediagnosis to implement the ROMM project, most target power plants for diagnosis, in general, are under operation. This can be a big interference factor to diagnose the exact current status of power plants. Therefore, in order to solve such interference factor, based on the 30 years of know-how in the field, the present study has developed a regression curve for a simple life time assessment and the calculation of rehabilitation cost that may be used as a reference relatively for the quantitative diagnosis on the status of a relevant power plant even during the operation of the power plant.

Keywords: ROMM (Rehabilitation, Operation, Maintenance & Management), Aged Thermal Power Plant, Rehabilitation Range, Rehabilitation Cost

I. INTRODUCTION

According to the restriction on the emission of carbon dioxide resulted from the Paris Agreement on the Climate Change in December 12, 2015, the construction of new thermal power plants has been suppressed. As for the counter measure for such environmental policy, the movement of rehabilitating the function of aged thermal power plant has been actively emerged throughout the world. Such performance rehabilitation project of aged thermal power plant has been often called as ROMM (Rehabilitation, Operation, Maintenance and Management).

In general, if the design Life time of thermal power plant would be minimum 30 years, the power plants that have been operated for more than 25 years retain the size of 678 GW throughout the world. All those relevant power plants can be considered for the target ROMM project [1].

However, whether to determine the implementation of performance rehabilitation for aged thermal power plants, it is difficult to implement it only by considering the simple political purpose of reducing carbon dioxide without the consideration of economic aspect. Namely, it will be only possible to judge the proceed of ROMM project when the economic assessment should accompany according to the rehabilitation range of aged thermal power plant. In order to overcome such limitation, regression curves have been developed in the present study that calculate the life time during the operation of main components of aged thermal power plants. A cost calculation curve has been also developed according to the capacity of each main equipment, which can be referred to the calculation of rehabilitation cost.

II. NECESSITY OF DEVELOPMENT

One difficult point at the implementation of overseas ROMM project is to calculate the rehabilitation range and the approximate cost according to the range in a short period of time (generally within one week). There exist two limitations due to such difficulty.

The first limitation is the objectivity of rehabilitation range for the equipment deduced from the field. The decision on the rehabilitation range after the diagnosis on the status of field equipment may be much different by the opinion of an individual evaluator. Yet, ultimately, the rehabilitation range can be deduced in any type. However, such deduced rehabilitation range is just the reference involved by the individual evaluator. Therefore, even when the rehabilitation range is deduced, opinions are inevitably divided to determine whether the relevant rehabilitation range is logical or not. Namely, there exists such a problem that there is no quantitative basis for anyone to agree on. Therefore, in order to prepare the quantitative basis for the rehabilitation range, it is necessary to develop the standard for life time assessment during the operation. To overcome such limitation, a regression curve has been developed to calculate the remaining life time of main component in the aged power plant by the number of operation years.

The second limitation is that there is no method to give the initial quotation in the field to the client through the approximate calculation for the replacement cost according to the relevant rehabilitation range within one week even when an exact rehabilitation range can be calculated in the field. In order to overcome such limitation, a regression curve has been developed to calculate the cost by the capacity of each main equipment, which can be referred to the calculation of rehabilitation cost.

Table 2 shows a short summary of a regression curve that calculates the remaining life time during the operation of main components in aged thermal power plant and the development details in relation to the regression curve for the calculation of the cost according to the capacity for each main equipment.

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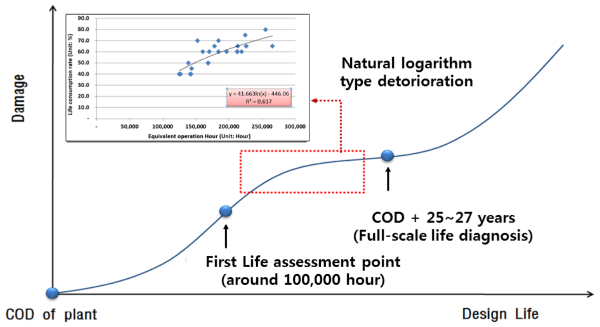
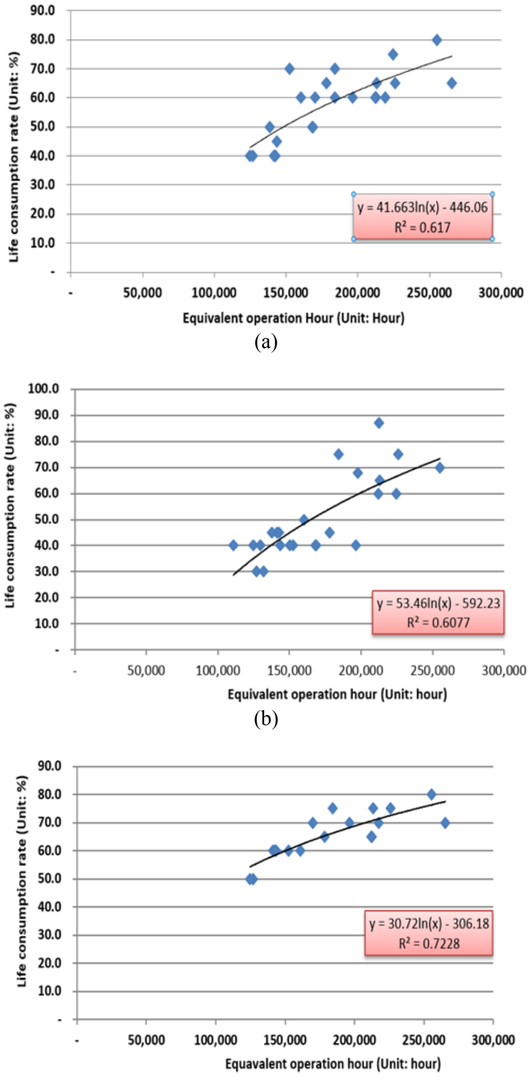


Fig. 1. General lifetime consumption rate curve of power plant equipment.



(a)

(b)

(c)

Fig. 2. Representative calculation examples for lifetime consumption rate according to Operation Hours of Header, Turbine, and Pipe Operation Hour. (a) Subcritical Final Superheater Header. (b) Subcritical High Pressure Turbine Rotor. (c) Subcritical High Temperature Reheater Steam Y-Piece.

Table 1. Status of Thermal Power Plant Operated over 25 Years for Each Region in the World

Region	No. of Power Plant	Capacity (GW)
Asia-Pacific Ocean	185	155
Europe	308	206.7
Middle East & Africa	17	35
North America	419	278.9
Middle & South America	13	2.6
Total	942	678.2

Table 2. Summary of Lifetime Assessment Program & Rehabilitation Cost Assessment Program

Items	Details
Regression curve for Life time Assessment	○ Regression curve of life time consumption rate for main component by operation hour - Target equipment: 44 power equipment including final superheater's header of boiler
Regression curve for Cost Assessment for Rehabilitation	○ Regression curve of cost calculation for each power generation equipment by the capacity of thermal power plant - Target equipment: 7 equipment and components including the heat recovery steam generator

A. Calculation of Regression curve for Simple Life time Assessment

When the first selected replacement range is applied, a regression curve of simple life time assessment is needed to assess the remaining life time and confirm the final replacement range. This regression curve has been created to assess the life time in a simple way without a separate Life time diagnosis for the core equipment of overseas target power plant by converting the life time consumption rate to a regression curve according to the operation hour and the number of start and stops of each component in the machine equipment such as boiler, turbine, piping through the database gathered by classifying the results of life time assessments on 42 power plants implemented in Korea for each capacity, and type. Except, the present simple life time assessment is limited to the high temperature machine equipment.

In order to develop the simple regression curve for life time assessment, the results from the life time assessment on total 42 power plants have been converted to database for the components of each equipment from 2001 when the power plant was disassembled to implement the life time assessment to the present time. The regression curve of life time consumption rate has been calculated for the final superheater header and final reheater header of highest temperature and pressure among high temperature headers in the boiler equipment, the main steam curve and the hot reheat steam curve in the high piping equipment, and a rotor, an inner casing, a diaphragm, and high pressure valves (main stop valve and cold reheat stop valve) in the turbine equipment.

At the calculation of the regression curve, it is important to decide the type of regression curve (linear, log). A natural logarithm has been used to draw the regression curve of mater curve in the present study. The reason is as the following. In the Fig. 1, at the starting point of 100 thousand operation hours, the deterioration degree of power generation equipment shows the similar tendency to the natural logarithm. As the target equipment of Life time assessment implemented for the disassembly condition of thermal power plant for the past years had been operated over 100 thousand hours at minimum, the natural logarithm was selected as the function from form for the regression curve.

Fig. 2 shows some examples that calculated the life time consumption rate according to the operation hours of main components with the natural log regression curve. This method was applied to a total of 44 components, of which examples are plotted in Fig. 2. Table 3 shows the detailed results of the

Table 3. Calculation Formula for Life time per component in Power Generation Equipment

Components	Classification	Coal Power [Generation-Subcritical]	Coal Power [Generation-Supercritical]	Combined Cycle
Final Superheater Header	Header	y=41.663ln(x)-446.06	y=44.172ln(x)-469.73	-
	Header R2	0.617	0.762	-
	Stub Tube	y=48.894ln(x)-529.3	y=47.73ln(x)-507.97	y=44.672ln(x)-463.39
	Stub Tube R2	0.6084	0.7785	0.7768
Final Reheater Header	Header	y=39.536ln(x)-420.1	y=33.654ln(x)-347.94	y=35.927ln(x)-362.61
	Header R2	0.594	0.7735	0.783
	Stub Tube	y=41.967ln(x)-445.65	y=35.289ln(x)-362.75	y=34.074ln(x)-337.37
	R2	0.6378	0.7539	0.7955
Rotor	High Pressure	y=53.46ln(x)-592.23	y=38.248ln(x)-407.84	y=23.004ln(x)-222.19
	High Pressure R2	0.6077	0.8789	0.6206
	Intermediate Pressure	y=49.322ln(x)-543.32	y=28.264ln(x)-293.05	y=11.081ln(x)-86.291
	Intermediate Pressure R2	0.648	0.5124	0.303
Inner Casing	High Pressure	y=45.579ln(x)-492.48	y=41.733ln(x)-445.41	y=13.233ln(x)-107.53
	High Pressure R2	0.5469	0.7675	0.7581
	Intermediate Pressure	y=46.719ln(x)-511.88	y=35.3ln(x)-369.05	y=9.8423ln(x)-71.147
	Intermediate Pressure R2	0.7411	0.865	0.4002
Diaphragm	Diaphragm	y=45.222ln(x)-489.77	y=20.695ln(x)-207.25	y=17.98ln(x)-164.77
	R2	0.6579	0.328	0.9319
MSV	MSV	y=36.264ln(x)-378.96	y=50.044ln(x)-543.69	y=6.9868ln(x)-25.577
	R2	0.7252	0.8435	0.5195
CRSV	CRSV	y=31.977ln(x)-327.94	y=44.438ln(x)-477.41	y=6.3924ln(x)-23.036
	R2	0.6236	0.8379	0.8801
Main Steam Pipe	Elbow Pipe	y=34.235ln(x)-353.53	y=49.923ln(x)-542.63	y=55.001ln(x)-608.28
	Elbow Pipe R2	0.6027	0.9407	0.7402
	Y-Piece	y=41.729ln(x)-441.11	y=40.492ln(x)-425.52	y=37.164ln(x)-390.91
	Y-Piece R2	0.5056	0.8183	0.6562
High Temperature Reheater Steam Pipe	Elbow Pipe	y=34.218ln(x)-353.09	y=36.538ln(x)-386.23	y=47.78ln(x)-524.47
	Elbow Pipe R2	0.5958	0.6002	0.7842
	Y-Piece	y=30.72ln(x)-306.18	y=35.919ln(x)-376.01	y=52.754ln(x)-572.26
	Y-Piece R2	0.7228	0.6224	0.9138

y : Life time Consumption rate (unit:%), x : Operation hours (unit: hour)

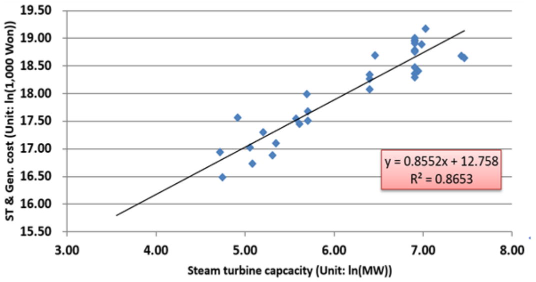


Fig. 3. Examples for cost calculation per capacity of steam turbine and generator.

regression for selected components including ANOVA (Analysis Of Variance) analyses of respective curves and their R2 as an indication of the reliability in the regression curve.

The values of R^2 in a developed formula are distributed between 0.5 and 0.94 except the case of a medium pressure rotor in the combined cycle power generation (R^2=0.303), a medium pressure inner casing in the combined cycle power generation (R^2=0.4002), and a diaphragm in the supercritical power generation (R^2=0.328). If the value is higher than 0.5, the corresponding regression curve is considered to be reliable and significant, so that the developed regression curve can be said to be proper for the simple life time assessment. The details of developed formula are summarized in Table 3.

B. Calculation of Regression curve for Rehabilitation Cost

The procedure developed to estimate the rehabilitation cost consists of two stages. First stage is to collect the cost information for the equipment and materials in thermal power plant and combined cycle power plant with diverse capacities. The second stage is to present the purchase cost collected in the first stage for equipment and materials of diverse power plants with a scatter plot according to the capacity and to verify the cost information by deriving the regression curve. Regarding the cost information for equipment and materials in thermal power plant and combined cycle power plant, the construction experience of 30 years' quantity has been utilized that KEPCO procured. Data have been secured targeting 69 units in total 25 power plants. The cost data have been secured for 34 units in 7 power plants in case of thermal power plant and 35 units in 18 power plants in case of combined cycle power plant, and have been utilized for the basic data to calculate the regression curve.

Fig. 3 shows the example of cost calculation per capacity of steam turbine and generator. Same as in case of program for simple life time assessment, it is important to decide the type (linear, log) of regression curve when a regression curve is calculated. When a regression curve is drawn for the cost calculation formula, a linear regression curve has been selected. As one exception, the natural logarithm has been used for the capacity of steam turbine capacity on the X-axis and the cost for steam turbine and generator on the Y-axis to obtain the linear regression curve for the original data. It is to reflect the gradual decrease in the purchase cost of equipment per each unit capacity as its capacity increases.

For the obtained regression curve, ANOVA analysis has been implemented as shown in Table. 4 (Analysis Of Variance, Residual Analysis). Reviewing the accuracy of regression curve, R2 and p-values are mainly set for the standard. When R2 is 0.5 and higher, the regression curve is considered to be significant. The lower the p-value is, it is considered to be reliable. In case of the cost regression curve according to the capacity of steam turbine and generator, the value of R2 is high enough with 0.8653,

Table 4. ANOVA Analysis Result for Steam Turbine and Generator

	Degree of Freedom	Square Sum	Square Average	F Ratio	Significant F	
Regression	1	16.5567	16.5567	192.6793	1.35118E-14	
Residual	30	2.5779	0.0859	-	-	
Total	31	19.1346	-	-	-	
	Coefficient	Std. Dev.	t Statistics	p-Value	Low 95%	High 95%
Y intercept	12.7579	0.3871	32.9584	4.03326E-25	11.9674	13.5485
X1	0.8552	0.0616	13.8809	1.35118E-14	0.7294	0.9810

Table 5. Cost Calculation Formula for Each Equipment in combined cycle Thermal Power Plant and Summary of ANOVA Analysis Result

(Cost Unit: 1,000 KRW, Capacity Unit: MW)

Name of Equip.	Calculation Formula	ANOVA		
		R2	p-Value	
			Y Intercept	X Coefficient
HRSG	Cost=exp(0.8045×Ln(ST Capacity)+13.126)	0.7965	4.64E-13	1.46E-06
ST	Cost=0.6943×[exp(0.8552×ln(ST Capacity)+12.758)]	0.8653	4.00E-25	1.35E-14
ST-Gen.	Cost=0.3056×[exp(0.8552×ln(ST Capacity)+12.758)]	0.8653	4.00E-25	1.35E-14
GT	Cost=0.8419×[exp(0.661×ln(GT Capacity)+14.511)]	0.8391	2.57E-14	6.32E-07
ST-Gen.	Cost=0.1580×[exp(0.661×ln(GT Capacity)+14.511)]	0.8391	2.57E-14	6.32E-07
Auxiliary	Cost=exp(0.5232×ln(Power Plant Entire Capacity)+14.057)	0.6168	6.74E-11	0.0005
I&C	Cost=exp(0.1457×ln(Power Plant Entire Capacity)+14.84)	0.4618	7.37E-06	0.4354

Table 6. Summary of Verification Result for Simple Lifetime Calculation Formula per Each component in Power Generation Equipment

Type of Power Generation	Error Range for Real Value	No. of Verification Target	No. of Excessive Error	Excessive Error Rate(%)
Coal Power Generation -Subcritical	-1.23～40.9%	14	1	7.1
Coal Power Generation -Supercritical	-17.1～5.7%	15	2	13.3
Combined Cycle Power Generation	-15.0～27.5%	14	3	21.4

※ Consider it as the excessive number of error if the error rate exceeds ±15% compared to the real value.

X coefficient value of linear formula and p-value of Y intercept also are very low so that the corresponding regression curve is very reliable.

Repeating the above process, a cost calculation formula has been obtained as in Table 5 according to the capacity of each equipment that consists of combined cycle power plant. Both R2 values and p-values of calculation formula have been displayed for each equipment. Except the case of I&C (Instrument & Control), R2 shows the values between 0.6168 and 0.7965, and p-values show very low numerical values.

This shows a very strong connection between capacity and cost of equipment. This means that it is possible to identify the purchase cost of corresponding power plant simply and approximately when it is available to know what capacity the power plant has.

If it is desirable to know the cost for detail component that consists of steam turbine, it is available to obtain the detail cost for each component of steam turbine by (1) substituting the capacity in the calculated steam turbine formula, and (2) multiplying the price rate of component in general steam turbine. When the list of components for rehabilitation target is decided by referring to the cost for each component obtained by the above process, it is available to calculate the entire rehabilitation cost. One precaution is that the cost of the above calculation formula is the price standard as of January 1, 2015.

III. VALIDATION OF THE METHOD

A. Result of Verifications of Regression Curves for Simple Lifetime Assessment

Table 6 shows the organized result of verifications for each type of power generation, and Tables 7, 8 and 9 show detail results. The verification method is to compare the result of Lifetime assessment after the past disassembly ("Y" coal fired power plant unit 1, "H" coal fired power plant unit 5, "I" combined cycle power plant unit 7) with the result obtained from the simple life time regression curve. It has been confirmed that the simple life time assessment calculated in the present study could be used for the reference data within the corresponding error even under the impossible restricted condition for the inspection through disassembly as the error rate for each type of power generation was distributed in subcritical coal power generation (-1.2% ~ 40.9%), supercritical coal power generation (-17.1% ~ 5.7%), and combined cycle power generation (-15.0% ~ 27.5%).

Such cases exist that the subcritical coal power generation shows large 40.9% error rate and the combined cycle power generation 27.5%. Yet this is just a singular point which may exist in statistics, and it cannot be considered to be a significant case. This can be easily checked in Table 6. Namely, if a case is checked in Table 7 through 9 that show more than ±15% error rate than the real values, the error rates are just 7.1% in case of the subcritical coal power generation, 13.3% in case of supercritical coal power generation, and 21.4% in case of combined cycle power generation, so that their reliability shows the higher result in average.

B. Result of Verification of Regression Curves for Cost Assessment

Utilizing formulas explained in the previous clauses, Table 10 shows the result of summary that calculated the purchase details of equipment and materials in the 1,000 MW coal fired power plant.

The results obtained previously have gone through the

Table 7. Result of Verification of Simple Lifetime Calculation Formula for Each Component of Power Generation Equipment (Subcritical Coal Fired)

Components	Classification	Calculation Formula (%)	Real Values (%)	Error Rate (%)	Power plant that uses real values
Final S/H Header	Header	64.9	60.0	8.1	○ "Y" Coal Fired Power Plant Unit 1 - Year of Precision Diagnosis: 2001 - Equivalent Operation Hour: 211,893 hrs
	Stub Tube	70.3	70.0	0.4	
Final R/H Header	Header	64.8	60.0	8.0	
	Stub Tube	69.0	65.0	6.2	
Rotor	HP	63.4	45.0	40.8	
	IP	61.6	60.0	2.7	
Inner Casing	HP	66.5	60.0	10.8	
	IP	-	-	-	
Diaphragm		64.8	60.0	8.0	
MSV		65.8	65.0	1.2	
CRSV		64.2	65.0	-1.2	
MSP	Elbow	66.3	65.0	2.0	
	Y-Piece	70.6	65.0	8.6	
High Temp. R/H Steam	Elbow	66.6	65.0	2.5	
	Y-Piece	70.6	65.0	8.6	

Table 8. Simple Lifetime Calculation Formula for Each Component in Power Generation Equipment (Supercritical Coal Power Generation)

Components	Classification	Calculation Formula (%)	Real Values (%)	Error Rate (%)	Power plant that uses real values
Final S/H Header	Header	46.5	52.0	-10.6	○ "H" Coal Fired Power Plant Unit 5 - Year of Precision Diagnosis: 2013 - Equivalent Operation Hour: 118,986 hrs
	Stub Tube	49.8	58.0	-14.1	
Final R/H Header	Header	45.4	52.0	-12.7	
	Stub Tube	49.7	58.0	-14.3	
Rotor	HP	39.2	40.0	-2.0	
	IP	37.3	45.0	-17.1	
Inner Casing	HP	42.3	40.0	5.7	
	IP	43.5	50.0	-13.0	
Diaphragm		34.6	40.0	-13.5	
MSV		41.2	45.0	-8.4	
CRSV		41.9	50.0	-16.2	
MSP	Elbow	40.8	40.0	2.0	
	Y-Piece	47.7	50.0	-4.6	
High Temp. R/H Steam	Elbow	40.8	45.0	-9.3	
	Y-Piece	43.8	45.0	-2.7	

Table 9. Simple Lifetime Calculation Formula for Each component in Power Generation Equipment (Combined Cycle)

Components	Classification	Calculation Formula (%)	Real Values (%)	Error Rate (%)	Power plant that uses real values
Final S/H Header	Header	-	-	-	○ "I" Combined Cycle Power Plant Unit 7 - Year of Precision Diagnosis: 2013 - Equivalent Operation Hour: 193,935 hrs - Except, 110,126 hr is applied to the stub tube of final superheater header.
	Stub Tube	51.0	40.0	27.5	
Final R/H Header	Header	74.8	88.0	-15.0	
	Stub Tube	77.5	88.0	-11.9	
Rotor	HP	57.9	53.0	9.2	
	IP	48.6	47.0	3.4	
Inner Casing	HP	53.6	55.0	-2.5	
	IP	48.7	50.0	-2.6	
Diaphragm		48.7	55.0	-11.5	
MSV		58.5	50.0	17.0	
CRSV		54.8	50.0	9.6	
MSP	Elbow	61.4	50.0	22.8	
	Y-Piece	61.6	60.0	2.7	
High Temp. R/H Steam	Elbow	57.3	50.0	14.6	
	Y-Piece	70.0	70.0	0.0	

process to compare and verify with the data provided by professional companies in relation to the field of power generation. The points for precaution in the comparison process are 1) the large fluctuation of the cost for power generation equipment on behalf of the situation of a continent or a relevant country where a corresponding power plant is built, and 2) the assumption that each company in cost calculation makes internally. Out of such two reasons, when the purchase cost (Korean Won, KRW) per each capacity of unit installation would be actually estimated for a new construction of power plant with the same capacity, most estimated prices between companies show much difference. Therefore, the comparison and verification in the present clause has been implemented for the purpose of a simple comparison to deduce whether the cost calculation formula developed in the present study deduces proper value rather than to judge whether the calculated cost by a certain company would be correct absolutely.

The following shows the method to calculate the standard value of coal power. In case of "B" coal fired power plant unit 7 (500 MW) and unit 8 (500 MW), total construction cost was 1 trillion 250 billion KRW as of June 2009 [2]. Converting the relevant amount to the value of January 2015, it becomes 1.3 trillion 33.8 billion KRW. In general, in case of coal fired power plant, the cost for equipment and materials occupies 40～50% of entire construction cost so that after setting 45.0% its medium value as the standard value, this 45.0% is multiplied by 13 trillion 33.8 billion KRW, and 600 billion 21 hundred million KRW has been set for the cost for the equipment and materials required at

Table 10. Calculation Result of Purchase Cost for Equipment and Materials in 1,000 MW Coal Fired Power Plant

(Cost Unit: 1,000 KRW)

Names of Equipment	Calculation Formula	Cost
Boiler	Cost=274,024×(ST Capacity/1,018)^0.72	270,527,278
ST	Cost=0.6944×[exp(0.8552×Ln(ST Capacity)+12.758)]	88,699,281
Generator	Cost=0.3056×[exp(0.8552×Ln(ST Capacity)+12.758)]	39,041,334
Auxiliary	Cost=CA × (Total Capacity of Power Plant/1,018)^b	261,070,301
	Total	659,338,194

* a and b are original values of 43 auxiliary equipment

Table 11. Calculation Result of Purchase Cost for Equipment and Materials in 504 MW Combined Cycle Power Plant (GT:321 MW, ST:183 MW)

(Cost Unit:1,000 KRW)

Names of Equipment	Calculation Formula	Cost
HRSG	Cost=exp(0.8045×ln(ST Capacity)+13.126)	33,165,861
ST	Cost=0.6943×[exp(0.8552×ln(ST Capacity)+12.758)]	20,757,176
Generator(ST)	Cost=0.3056×[exp(0.8552×ln(ST Capacity)+12.758)]	9,136,352
GT	Cost=0.8419×[exp(0.661×ln(GT Capacity)+14.511)]	76,581,149
Generator(GT)	Cost=0.1580×[exp(0.661×ln(GT Capacity)+14.511)]	14,378,140
Auxiliary	Cost=exp(0.5232×ln(Total Capacity of Power Plant)+14.057)	33,020,922
I&C	Cost=exp(0.1457×ln(Total Capacity of Power Plant)+14.84)	6,897,223
	Total	193,936,823

the construction of relevant coal thermal power plant [3].

The method to calculate the standard value of combined cycle power plant can be described as follows. In case of "I" combined cycle power plant (503 MW), as of April 2004, the construction cost was total 2 trillion 63.2 billion KRW. When the relevant amount is converted to the value of January 2015, it becomes 3 trillion 7.4 billion KRW [4]. In general, in case of combined cycle power plant, the cost for equipment and materials occupies 56.5% of entire construction cost so that 1 trillion 73.6 billion 9 million KRW that is 56.5% of 3 trillion 7.4 billion KRW was set for the cost for equipment and materials required at the construction of combined cycle thermal power plant [5].

From the verification results for the validity of fire power and combined cycle power plant, if comparing the actual purchase cost of main equipment as in Table 12, it can be known that the error is ±10.0%. In order to judge the level of relevant error rate objectively, AACE (Association for the Advancement of Cost Engineering) international table as in Table 13 has been utilized. The corresponding table shows the final goal, method and precision of cost calculation and the required cost according to the progress stage if any arbitrary project would be proceeded. Such classification is not quantitative, but just conceptual classification. It may correspond to "Class 4" if the error rate is substituted to Table 13 based on the corresponding table. The purpose of developing a regression curves for cost assessment at the promotion of present study happened to correspond to "Class 5" which was used to be utilized for the valid investigation at the earliest stage of implementing ROMM project. In case of the developed calculation formula, it may have achieved the satisfactory surpassing result that was the initially scheduled goal.

Table 12. Verification Result of Validity in the Calculation Result of Purchase Cost for Power Generation Equipment

(Cost Unit:1,000 KRW)

Types	Capacity (MW)	Calculated Cost	Standard Cost	Error	Standard Value Source
Coal Power	1,000	6593.4	6002.1	-9.9%	The Electric Power Economy [2]
Combined Cycle	503	1939.4	1736.9	11.7%	Monthly of Electrical Technology & Info. [4]

Table 13. Generic Cost Estimate Classification Matrix

	Primary Characteristic	Secondary Characteristic			
Estimate Class	Level of Projection Definition	End Usage	Methodology	Expected Accuracy Range [a]	Preparation Effort [b]
Class5	0%~2%	Screening or Feasibility	Stochastic or Judgment	4~20	1
Class4	1%~15%	Concept Study or Feasibility	Primarily Stochastic	3~12	2~4
Class3	10%~40%	Budget, Authorization, or Control	Mixed, but Primarily Stochastic	2~6	3~10
Class2	30%~70%	Control or Bid/Tender	Primarily Deterministic	1~3	5~20
Class1	50%~100%	Check Estimate or Bid/Tender	Deterministic	1	10~100

[a] If the range index value of "1" represents +10/-5%, then an index value of 10 represents +100/-50%

[b] If the cost index value of "1" represents 0.005% of project costs, then an index value of 100 represents 0.5%

IV. CONCLUSION

In the present paper, a calculation formula for the simple life time assessment and the development process, result and verification process of calculation formula for rehabilitation cost have been examined for the rehabilitation project of aged thermal power plant.

In the area of the calculation formula for the simple life time assessment, in order for the life time assessment under a condition of non-disassembly of main components that consist of the power plant, a formula for cost calculation has been developed that can calculate the life time consumption rate according to the operation hour. From the verification result, the result of life time assessment under the actual disassembly condition and the case when it exceeds ±15%, show 7.1% in subcritical coal fired power plant, 13.3% in super critical coal fired power plant, and 21.4% in combined cycle power plant, so that it is expected to utilize it for the quantitative criterion to compare and verify the rehabilitation range for each equipment calculated at the ROMM diagnosis.

From the result of developing the calculation formula for the rehabilitation cost, it was available to deduce a cost for equipment and materials per equipment capacity. Its precision showed the distribution between –9.9% and 11.7%. Reflecting on AACE Table, the calculation formula for cost corresponds to "Class 4", which showed the satisfactory result that had exceeded "Class 5" which was used to be utilized for the validity investigation at the earliest stage of implementing ROMM project.

It is expected to utilize the calculation formula for a simple Life time assessment and the calculation formula for rehabilitation cost developed in such a way for a tool to enhance the competitiveness regarding future ROMM project.

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