Some Cases of the Application of LCC Technique to Maintenance and Material Selection for the Equipment of Coal and Chemical Industry

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Abstract:

It is necessary to make comprehensive balance on price, service life, maintenance fee, efficiency, etc. during anti-resistant material and maintenance time selection as well as the proceeding and decision-making on the equipment of coal and chemical industry. LCC technique is the effective mean for supporting decision-making. This paper describes some cases of successful application of LCC technique in coal and chemical enterprises, which can be taken as the reference for analyzing and making decision on similar issues in LCC technique.

Keywords: LCC technique Coal and chemical equipment Decision-making on maintenance Application

1. Introduction

Coal and chemical enterprises generally covers the technological process like coal blending, coking, gas purification, recovery of gasification product, etc, which include different equipment such as equipment in metallurgy, mining, chemical industry, energy, transportation and many other specialties. Since there are many mediums having strong corrosion, large amount of anti-resistant materials like stainless steel, etc. have been applied in coal and chemical enterprises. Moreover, a lot of investment has been made on anti-corrosion of equipment. Along with the development of iron and steel industry in the recent years, scale of coal and chemical industries has been enlarged, and even one project costs several hundred million RMB. As the scale enlargement, and new material and technology for maintenance gradually coming to light, maintenance expenses have been increased in the same proportion, and the decision-making on maintenance has more and more influence on the operation and even on the survival and development of enterprises. In our production and maintenance practice in the recent years, a certain amount of achievement has been obtained in application of LCC technique in anti-corrosion material and maintenance time selection as well as the proceeding and decision-making on equipment. Now, I would like to introduce several cases to our colleagues for their reference.

2. Some Cases of the Application of LCC method

2.1 Aluminized steel using for horizontal water-tube cooler

Horizontal water-tube primary cooler is the key equipment for gas cooling in the blowing and condensing section. In order to strengthen environment protection, incorporate the tail gas from ammonia decomposition and sulfur recovery in negative pressure gas pipeline before primary gas cooler. Comparing to previous purification process, concentration of H_2S and NH_3 in gas increases so that it raises corrosion strength of primary gas cooler, while the changes of working condition increases the concentration of these corrosive mediums. The primary gas cooler with 8-year service life in the original design has such defect that heat exchange tubes were broken due to corrosion within 3 years that made circulating water polluted for many times and the stable operation of the whole system suffered. The solution of changing cooling tube is adopted for repairing of horizontal water-tube primary cooler. Before execution, a careful study was made on the material selection of heat exchange tubes. From expenses point of view, the maintenance fee is 600,000 RMB per set if using plain carbon steel tube, 1.2 million RMB per set if using aluminized steel and 4.6 million RMB per set when adopting stainless steel. The total expenses for each of 3 coolers would be 1.8/3.6/13.8 million RMB. Based on the economic conditions at that moment, it is hard to bear the expenses of using stainless steel pipe. Therefore, selection would be made on aluminized steel and plain carbon steel. See experimental result on corrosion resistance of the two materials:

1) H_2S corrosion resistance

According to experimental result of large amount of strips overhung at site, corrosion speed of aluminized steel is in the range of 0.007-0.02mm/a, while plain carbon steel is in the range of

0.3-0.6mm/a at H_2S medium in different temperature and concentration.

2) Ammonia corrosion resistance

Aluminized steel in ammonia gas and liquid ammonia in all concentrates has very slow speed in corrosion, 0.015mm/a in average; while average corrosion speed of plain carbon steel is 1.025mm/a.

It can be seen from above mentioned data that aluminized steel has a good corrosion resistance to H_2S and NH_3, and the corrosion resistance in aluminized layer is, at least, 20 times higher than that of plain carbon steel at above mentioned environment. It can be estimated that the service life of a heat exchange tube extends more than 4 years at least due to the protection of an 80-120μm aluminized layer. In case of considering unserviceable loss due to machine stoppage for repair and leakage detection, pollution and corrosion and other factors for other heat exchange equipment in system due to leakage, aluminized steel has a evident advantage. Under the same application condition, unserviceable time mainly refers to the detection of leakage due to corrosion, and different repair time. Therefore, different service life resulted in different accumulated overhaul time. See Table 1 for the comparison of investment and efficiency of adopting different steel.

Table 1 Comparison of Investment and Efficiency of Adopting Different Kind of Steel

Item	Plain Carbon Steel	Aluminized Steel
Initial investment (10 thousand Yuan)	180	360
Replacement times	1	0
Average service life/y	3	>7
Total investment (counting 8 years as a unit)	>360	360
Benefits	Since aluminized steel is adopted, maintenance times and duration are lowered, therefore, the benefit of using aluminized steel is higher than that of using plain carbon steel.	

Thus, after overall consideration of all kinds of factors, aluminized steel is selected. The application after overhaul is good. It has been used for 6 years without overhaul.

2.2 Selection of titanium tube and 316L stainless steel tube

Corrosion of acid and ammonia steam pipeline is a very big problem for the production of deacidification and ammonia evaporation system, which causes unstable and discontinuous production. At beginning, 1Cr18Ni9Ti stainless steel tube was used and 316L stainless steel tube was adopted afterward. However, the service time was not longer than 2 years for both cases

Working fluid temperature of acid and ammonia steam pipeline is below 200□ and acid and ammonia gas contains rich SO_2(>15%), NH_3(>20%), H_2S and HCN. Since acid and ammonia steam is in straight steaming and blowing, so it contains a large amount of water vapor that forms solution in the inner wall face of pipeline. Part of iron compositions have very high molecular polarizability and adsorption capability with strong corrosion resistance, while the other part of iron composition can form complex with iron, so corrosion is faster.

In respect of stainless steel in austenite, it might form chromium-depleted zone next to grain boundary due to depletion and easy to have intergranular corrosion when slowly passing sensitive temperature zone (450-850□). For 316L, such case is much better than that of 1Cr18Ni9Ti since carbon content is very low. However, corrosion is occurred at welding seam and the entry section close to Klaus furnace and ammonia dissolving furnace and other high temperature zone.

Titanium material has an excellent corrosion resistance. Since there is less resources, so the price is expensive. Recently, titanium and titanium products are widely applied in all kinds of industrial enterprises, whereas a working temperature greater than 350℃is not allowed. It is approved from the application in one coking plant that the service life of this material used in acid and ammonia steam pipeline can reach 8 years which is more than that of 316L stainless steel.

During acid and ammonia steam pipelines in overhaul, we have compared and analyzed the original material of 316L with titanium material by means of LCC technique, see table 2 for the details. It is decided finally to use titanium pipe (Ø219×4mm) instead of original 316L stainless steel pipe (Ø219×10mm).

Table 2 LCC comparison of 316L with titanium material

Item	316L	Titanium Material
Investment (10 thousand Yuan)	114	310
Annual operational maintenance expenditure(10 thousand Yuan)	4.5	0.8
Returns (10 thousand Yuan)	11.5	10.8
Average service lift/yearly	2	7
LCC (counting 14 years as a unit)	1405.2	1288.3

During calculation of service life cycle expenses, we have used minimum common multiple (14Y) of

service life of the two materials as a calculation cycle and assume that bank rate is i=7%:
Stainless steel pipe

LCC1=

$$\sum_{n=1}^{7}114(1+i)^{2n}+\sum_{n=1}^{14}4.5(1+i)^{n}-\sum_{n=1}^{7}11.5(1+i)^{2n-2}$$

＝1405.2 (10 thousand Yuan)

Titanium

LCC2=

$$\sum_{n=1}^{2}310(1+i)^{7n}+\sum_{n=1}^{14}0.8(1+i)^{n}-\sum_{n=1}^{2}10.8(1+i)^{7n-7}$$

＝1288.3

(10 thousand Yuan)

It can be see through analysis that fee for titanium pipe service life cycle is lowered than that of stainless steel pipe. Moreover, you can find that bank rate is very sensitive to this project. If rate is i=10%， LCC1=18.228 million Yuan and LCC2=17.741 million Yuan, both are very close. If bank rate is i=12% ， LCC1=21.725 million Yuan and LCC2=21.947 Yuan, the result is opposite. However, using titanium pipe is very cost-efficient considering the production stoppage loss and requirement of environment protection.

2.3 Decision on replacement of feed water pre-heater

Sub-Economizer (Feed water pre-heater) is mounted between circulation fan and coke dry quenching chamber, which is a horizontal tube heat exchanger in two stages. Bypass pipe is arranged in a space between the inlet and outlet of two-stage heat exchanger so as to keep system to work continuously after heat exchanger is in failure. Its shell pass is the circulating gas before feeding to furnace, and tube pass is the demineralized water from pure water tank. The main function is to cool circulating gas further after being cooled in the boiler so as to reduce energy consumption of circulation fan, and raise water temperature to lower steam consumption for the deaerator as well. The designed service life is 8 years and it has been used for 3 years already.

Sub-Economizer cools circulating gas from 180℃ to 115℃～130℃. If outlet gas temperature at the Sub-Economizer is too high, it can cause temperature-rise of coke discharging and make circulation cooling gas increase. The inlet water temperature of Sub-Economizer is controlled in a range of 60～90℃, and outlet water temperature in a range of 100℃～120℃. Temperature difference is kept over 40℃ and average flow is 70t/h.

3 months before annual overhaul in 2006, leakage had been occurred in the upper section of Sub-Economizer due to the process reason, and 12 heat exchanging tubes had been blocked through temporary repair. During repair, we found that other heat exchanging tubes in the upper section had corrosion in different degree that should be treated in annual repair time. Three solutions have been put forward through discussion. Solution one: blind the heat exchanging tube that can't be used further for over one year in our anticipation. Such work needs 4 days, which belongs to simple repair, keeps existing heat exchanging capacity basically, and waits for treatment together with coke dry quenching chamber in annual overhaul (55-days overhaul time); Solution 2: purchase spare parts and change whole section of heat exchanger that needs 7 days; Solution 3: remove it for tube replacement during annual overhaul that requires 45 days. Since the given annual overhaul time is ≤28, solution 3 was rejected during pre-selection. Select the best one from other two solutions with cost-efficiency decision model.

The advantage of solution one is less repair fee. However, energy-saving benefit is reduced since heat exchange capacity is lowered. The advantage of solution 2 is that heat exchange capacity is recovered and energy-saving benefit is available, but the initial investment is increased evidently. See table 3 for the details of cost-efficiency analysis of the two solutions.

Table 3 Table of Cost-Efficiency Decision
Unit: ten thousand yuan RMB

Cost-Efficiency Item	Solution One	Solution Two	Remarks
Maintenance/replacement fee in this annual overhaul C1	1.5	100	Single set of equipment costs 960,000 RMB.
Abandonment loss in this annual overhaul L1	0.7	50	Revaluation - salvage value of rejected part
Maintenance/ replacement fee in this annual overhaul C2	62	1	
Abandonment loss in ensuing year L2	23.8	0	Revaluation - salvage value of rejected part
Benefit from steam saving B1	0	103.5	

Electric power saving due to the reduction of circulation air B2	0	13	
Other expenses and benefits	A=B	A=B	
Present value of the converted benefit B	-81.6	-43.1	Without consideration of same benefit in A and B

Where:
1) Benefit of steam saving is calculated as per following procedure.
Heat exchange capacity in solution two is strong, and outlet water temperature is 20□ higher than that of solution one. Therefore, the saved steam power ≈ water-absorbed energy =4.18kJ/kg□×70000kg/h×20□=5.86×106GJ/h.
Based on the calculation of 23 Yuan per GJ heat energy, the annual benefit of heat energy recovered from steam is B1=5.86GJ/h×23 Yuan /GJ×320d/y×24h/d=1.035 million Yuan/y.
2) Calculation of power-saving benefit
Heat exchanging capacity of solution two is strong and outlet water temperature is lower than that of solution one. Power of re-circulating blower is reduced. Power energy can be saved for 130,000 Yuan/y as per estimation of differential value of electric power meter.
3)Calculation of present value of the converted benefit
Assume interest rate is 3%, the present value of converted benefit B is calculated as per (B2+B1-L2-C2)/1.08-L1-C1, and negative value represents maintenance investment. Obviously, solution B is better than solution A based on the maximum criterion of benefit, which shows that recovery of heat exchanging capacity is more important than saving maintenance cost. In this issue, we didn’t calculate absolute expenses and benefits of the two solutions, but only compare the different expenses of the two. When you calculate benefits, take solution one as reference. This strategy has simplified the analysis. However, there is no influence to the conclusion.

3. Conclusion and problem

Based on the technical analysis, application of LCC technique can rapidly and effectively make maintenance decision so as to make maintenance more practical and economical.
The more technical analysis you made, the more convenient you use LCC technique. Both are in mutual supplement.
In respect to the new material and new technology without reference, risks should be fully considered and certain safety factors be kept when making decision, although they can be tested and compared in the similar environment or applied under the similar condition for technical analyzing basis.

References:

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