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Repair Strategy Optimization for Gas Turbine Based on Equivalent Operating Hour (EOH) Analysis

***Abstract**. It is significant for safe economic operation of gas turbine power plant to rationally arrange repair cycle of gas turbine. This paper firstly sums up key factors influencing gas turbine repair cycle according to operation features of gas turbine, and set gas turbine equivalent operation hour equation with key influencing factors as reference frames and according to equivalent operating hour analytical method (EOH). As to M701F gas-steam combined cycle unit features of Huizhou LNG Power Plant, this paper puts forward gas turbine life evaluation method based on EOH analysis. Finally it brings forward repair strategy optimization scheme according to EOH analysis results.*

***Streszczenie.** W artykule analizuje się czynniki wpływające na częstość napraw turbin gazowych elektrowni. (**Optymalizacja strategii napraw turbin gazowych bazująca na analizie ekwiwalentu godzin pracy EOH**)*

Keywords: Gas Turbine, Repair Strategy, Equivalent Operating Hour
Słowa kluczowe: turbine gazowa, strategia napraw

Introduction

With the rapid development of Chinese gas turbine amount, China has paid out good money to change and repair high temperature parts for foreign gas turbine suppliers every year. Therefore, how to manage gas turbine life well and arrange repair cycle plays a very important part in safe economic operation of gas turbine power plant.

1. Factors Influencing Gas Turbine Repair Cycle

There are various factors influencing gas turbine unit repair plan, among which key factors influencing repair and equipment life is operation method, ignition temperature, fuel type, operation time of gas turbine unit, air quality and water/steam injection level, etc. Thermal mechanical fatigue is key factor influencing unit life of peak-shaving operation.

1.1 Fuel

Presently, Chinese power plants of gas-steam combined cycle unit mainly use natural gas as fuel. Compared with other fuels, natural gas contains less harmful matter, quickest combustion reaction level and relatively smaller influence on heat-channel components. But coagulated liquid hydrocarbon in natural gas is brought in fuel system of gas turbine and can cause life reduction of high temperature smoke-channel components [1].

1.2 Load Change and Service Load

Life of heat-channel components of gas turbine depends on operating temperature, operating load temperature at high load is higher than operating temperature at low load, but life is relatively shortened. If unit operating at low load for a long time has little influence on using life of heat-channel components, life of gas turbine can be prolonged. If peak load operation has greatest influence on heat-channel components, peak load operation for one hour has the equivalent influence on heat-channel components as basic load operation for six hours.

1.3 On-off frequency

Heat-channel components experience extreme change process in periodic change from heating expansion to cooling shrinkage while normal on-off operation of gas turbine. Frequent on-off of gas turbine makes heat-channel components bear heat shock caused by rapid change of fuel temperature, cause heat stress, and will certainly result in fatigue of some heat-channel components and crackle on certain part of stress. In addition, high temperature makes metal material creep deformation, and accordingly reduces using life of heat-channel components.

2. EOH Principle

Accumulated running hours, on-off frequency, load feature, fuel characters, water and steam injection rate, load rate, tripping operation and maintenance level and abnormal operation condition of gas turbine directly influence reliability and using life of hot-end components. Operation life of gas turbine will be greatly influenced for the above reasons in peak load operation method, so we generally use EOH in life evaluation.

Generally, influence of indexes like on-off frequency, load feature, fuel character, water and steam injection rate, load rate, tripping operation and maintenance level and abnormal operation condition on operational reliability can be reflected in equivalent operating hours (EOH) given by manufacturer of gas turbine as the following computing formula:

(1) $$E=Tp+Nw*Ts$$

(2) $$Ne=Nc+Nf+Nj+Nk$$

Among which, E-Equivalent operating hours;

Tp-Actual operating hours;

Nw-Equivalent on-off frequency;

Ts-Equivalent operating hours per on-off operation;

Ne- Equivalent on-off frequency;

Nc-Normal on-off frequency;

Nf-Equivalent on-off frequency under load rejection;

Nj Equivalent on-off frequency under emergency shut down;

Nk-Equivalent on-off frequency while rapid load change;

EOH of hot-end components given by Mitsubishi: EOH is 20 for combustion chamber, changeover sheet, fuel nozzle, and flame tube, rotor and stator blade at first turbine level and ring segment per on-off operation. Load rejection at full load is equivalent to 6 normal on-off operations, and load rejection at 80% load to 5 normal on-off operations. Emergency shutdown at full load is equivalent to 10 normal on-off operations. Due to load change of Mitsubishi gas turbine is taken as procedure, rapid load change will not occur generally [2].

3. Life Evaluation for Gas Turbine of Huizhou LNG Power Plant

Huizhou LNG Power Plant mainly as variable load plant of Guangdong Power Grid presently uses two-shift operation starting in the morning and stopping in the night and takes part in grid routine AGC peak load operation. Unit frequent on-off operation and rising or falling power will try stress life of unit hot-end components (combustion chamber and turbine rotor and stator blade). Therefore, scientifically life evaluation of unit primary device and auxiliary equipment will offer important scientific reference for unit operation repair.

3.1 Life Evaluation for M701F Gas Turbine

1. EOH Computation:

Life evaluation for gas turbine of Huizhou LNG Power Plant adopts EOH:

EOH (1) or EOH (2) = (AOH+A×E) × F

Among which: EOH (1)-EOH of first heat components (shell of combustion chamber, changeover portion, crossfirer, fuel nozzle, rotor and stator blade at first turbine level and ring segment);

EOH (2)-EOH of second heat components (rotor and stator blade at second, third or fourth turbine level and ring segment);

AOH-Actual operating hours;

E-Normal off Equivalent Frequency under load rejection, tripping and rapid load change;

A-Equivalent Hours for Normal Off (h/time), refers to Table 1. Fuel nozzle is dry low NOx type in Table 1;

F-Fuel factor, fuel of Huizhou Power Plant is natural gas, namely F is 1.0.

3.2 Life of Heat-Channel Components

Life of heat-channel components of Mitsubishi Heavy Industries refers to Table 2 presently.(Here is Table. 2)

Note: * indicates that life value is changed with fuel type and air purity; we can compute allowable on-off frequency as per A=10h/time.

3.3Inspection Time Interval of Heat Components (EOH)

Inspection time interval of heat components recommended by Mitsubishi Heavy Industries refers to Table 3 presently.

Table 3 Inspection Time Interval of Heat Components

Periodic Repair Interval Frequency	First	Second	Third	Fourth	Fifth	Sixth
EOH/h or On-Off Frequency	8000 /300	16000 /600	24000/900	32000/1200	40000/1500	48000/1800
Burner	♦	♦	♦	♦	♦	♦
Turbine		⊙		⊙		⊙
Overhaul						♣
Predicted Time/Day	10	16	10	16	10	36

Note: ♦ refers to repair cycle of burner; ⊙ refers to repair cycle of turbine; ♣ refers to overhaul cycle of gas turbine.

Table 4 Repair Interval Computed According to Equivalent On-Off Frequency

2006-10	2008-04	2009-10	2011-04
commissioning and Running	First Check for Combustion Chamber	First Check for Heat Channel	Second Check for Combustion Chamber
2012-10	2014-04	2015-10	
Second Check for Heat Channel	Third Check for Combustion Chamber	Overhaul	

4 Repair Strategy Optimization Analysis for Huizhou M701F Gas Turbine

4.1 Repair Cycle Optimization Analysis for Gas Turbine

Presently, unit annual operating hours of Huizhou Power Plant is about 4,000 hours, and annual on-off frequency is about 240. According to 1# unit repair condition offered by power plant presently, annual equivalent on-off frequency is 240. Starting from August 2006, 1# unit repair interval refers to Table 4:

4.2 Prediction for Primary Changeover Parts

Due to Huizhou Power Plant adopts two-shit operation model, its on-off frequency can meet repair time demands rather than equivalent operating hours. We can conclude theory data of primary changeover parts to repair and change within one overhaul cycle of 1# unit by taking on-off frequency as repair reference (Table 5).

We can get heat-channel primary changeover parts to match according to Table 5, and equipments to scrap within one overhaul cycle are as follows: flame tube, changeover portion, crossfirer, fuel nozzle, turbine rotor blade at first and second level, turbine stator blade at first, second and third level and spilt ring at first and second level. Generally, we shall prepare a complete set of combustion chamber parts and parts to scrap and certainly purchase within one overhaul cycle before first check for combustion chamber. Part fee for one gas turbine is about RMB 0.2 billion Yuan according to market price within one overhaul cycle. Expensive part fee heavily influence unit operation cost, so allocation optimization of part amount is a key sector for reducing repair cost of gas turbine power plant and improving economic benefits of power plant.

4.3 Operation Condition Optimization

1. Avoid tripping at full load as much as possible

Equivalent on-off frequency of gas turbine tripping at full load is 10 times of normal stop operation. We can conclude from the above EOH computing formula: influence on life of first heat-channel components is equivalent to life of normal operation for 200h; influence o life of second heat-channel components is equivalent to life of normal operation for 100h.

2. Avoid load rejection at full load as much as possible

Equivalent on-off frequency of gas turbine with load rejection at full load is 6 times of normal stop operation. We can conclude from the above EOH computing formula: influence on life of first heat-channel components is equivalent to life of normal operation for 120h; influence o life of second heat-channel components is equivalent to life of normal operation for 60h.

3. Prolong unit operation hours and reduce unit normal on-off frequency as much as possible

Equivalent operating hours for one normal on-off operation is 20h for first heat-channel components; and 10h for second heat-channel components. So we shall make the turbine operating for a longer time every time it turns on, try to reduce damage on high temperature parts from overtemperature and frequency alternating thermal stress, prolong high temperature parts life and improve economic benefits of power plant [4].

REFERENCES

1. F.J. Li,, X.D. Deng . Thermal Power Generation, 9, 89-91(2009).
2. W.Q. Gong ,Q.G. Wang. Power Technology, Vol.19 (8): 28-30.(2010)
3. Y. Hao, A.B. Meng , X.G. Peng . Power System Engineering, 25 (4): 36-38(2009).
4. D. Mao, Y.S. Zhu. Gas Turbine Technology, 24 (3): 53-57(2010)

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Table 1 Equivalent Hours for Normal Off of Each Heat Components (A)

Heat Component	Combustion Chamber	Changeover Portion	Fuel Nozzle	Cross firer	Turbine Rotor Blade				Turbine Stator Blade				Blade Ring			
					1st.	2nd	3rd	4th	1st.	2nd	3rd	4th	1st.	2nd	3rd	4th
A (h/time)	20	20	20	20	20	10	10	10	20	10	10	10	20	10	10	10

Table 2 Life List of Heat-Channel Components of Gas Turbine

Part Name		EOH Type	EOH	On-Off Frequency	Equivalent EOH Per On-Off Operation
Shell of Combustion Chamber, Changeover Portion, Crossfirer		EOH (1)	24000	1600	15
Fuel Nozzle		EOH (1)	50000	1800	27.8
Turbine Rotor Blade	First	EOH (1)	50000	1800	27.8
	Second	EOH (2)	50000	*	
	Third	EOH (2)	80000	*	
	Fourth	EOH (2)	100000	*	
Turbine Stator Blade	First	EOH (1)	50000	1800	27.8
	Second and Third	EOH (2)	50000	*	
	Fourth	EOH (2)	100000	*	
Ring Segment	First	EOH (1)	50000	1800	
	Second	EOH (2)	50000	*	
	Third	EOH (2)	80000	*	
	Fourth	EOH (2)	100000	*	

Table 5 Primary Changeover Parts to Repair and Change of 1# Unit

Parts	2008-04	2009-10	2011-04	2012-10	2014-04	2015-10
Flame Tube, Changeover Portion, Crossfirer	(Minor) Repair	(Partial) Repair	(Minor) Repair	(Partial) Repair	Scrap	(Overhaul) Repair
Fuel Nozzle	(Minor) Repair	(Partial) Repair	(Minor) Repair	(Partial) Repair	(Partial) Repair	Scrap
Turbine Rotor Blade at First and Second Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	Scrap
Turbine Rotor Blade at Third Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	(Overhaul) Repair
Turbine Rotor Blade at Fourth level		(Partial) Repair		(Partial) Repair	(Partial) Repair	(Overhaul) Repair
Turbine Stator Blade at First, Second and Third Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	Scrap
Turbine Stator Blade at Fourth Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	(Overhaul) Repair
Turbine Rotor Blade at Fourth Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	(Overhaul) Repair
Split Ring at First and Second Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	Scrap
Split Ring at Third Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	(Overhaul) Repair
Split Ring at Fourth Level		(Partial) Repair		(Partial) Repair	(Partial) Repair	(Overhaul) Repair