Vibration control technology of reheat steam hot section pipeline of 135MW unit

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Abstract. Based on the on-site cold and hot state inspection of the four pipelines of a 350MW unit in Shandong, combined with the review and calculation of stress, design and installation data, operation and maintenance records and other data, this paper formulates a practical adjustment plan and construction scheme, implements comprehensive adjustment and treatment of the four pipeline supports and hangers, basically restores the normal working state of the supports and hangers and pipelines, and ensures the safe operation of the unit.

1 Introduction

Pipeline vibration is very harmful, which may accelerate the fatigue damage of materials and greatly shorten the service life of materials; It is easy to loosen the valve elements, resulting in control failure or leakage, and even shutdown accidents; It is easy to cause damage to supports and hangers and chain failure reaction [1]. With the rapid development of China's power industry, the unit capacity and parameters of new power plants have been greatly improved, and the changes of working medium parameters in the pipeline and the complexity of thermal system have further exacerbated the vibration of steam and water pipelines in power plants [2]. The harm of vibration to the pipeline is obvious, so the pipeline vibration needs to be controlled [3]. There are mainly the following methods to eliminate the vibration of steam water pipeline: changing the layout of pipeline system, changing the flow state of medium in pipeline, changing the stiffness and damping of pipeline structure [4]. Changing the layout of the pipeline system is generally costly and takes a long time. Changing the medium state in the pipeline often requires changing the operating conditions of the unit. Therefore, generally, the pipeline damping or pipeline structure stiffness will be selected to control the pipeline vibration [5].

2 Pipeline vibration

The #5 unit of a 135MW generator set in Shandong is sg-440 / 13.7m417a boiler manufactured by Shanghai Boiler Works, which was put into operation in 2005 and has operated for about 91000 hours in total. The material of reheat steam hot section pipeline is 10CrMo910, with specifications φ four hundred and six × 14.2mm, design operating temperature 540 ℃, design pressure 2.26mpa.

In recent years, #5 unit reheat steam hot section pipeline has abnormal large amplitude vibration, which endangers the operation safety of the pipeline. Through the comprehensive detection of the vibration state of the #5 unit reheat steam hot section pipeline, the data processing, analysis and diagnosis show that the vibration of the pipeline mainly occurs at the boiler side of the furnace top, showing the basic characteristics of random and non-stationary free vibration, and the maximum vibration occurs on the horizontal pipeline in front of the coal conveying room, in the pipe part of 7 supports and hangers , 19 supports and hangers, 10 supports and hangers At the pipe part of 22 support and hanger , the vibration direction is mainly in the axial direction of the pipe, the vibration frequency is 1.5Hz, and the maximum value of double peak vibration is 2.2mm.

3 Vibration analysis

The vibration fault of reheat pipeline of unit 5 belongs to random vibration caused by steam flow pulsation. The horizontal pipeline outside the coal conveying room is long, and the ability of supports and hangers to restrict the movement of the pipeline in the horizontal direction (including front, rear, left and right) is weak. Small flow pulsation can produce significant pipeline vibration excitation force at the turning elbow of the pipeline. The non-stationary random characteristic of pipeline vibration is that the vibration induced by fluid random disturbance is intertwined with the vibration caused by uncertain intermittent flow pulsation. Whenever there is intermittent pulsation in the flow, it will produce pulse

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force on the pipeline, and the pipeline will produce free vibration under the action of this pulse force. Although the frequency of free vibration is the natural frequency of the pipeline, its motion is constrained when the pipeline vibrates in a large amplitude, resulting in nonlinear vibration, and the vibration frequency deviates from the natural frequency. Therefore, the vibration of reheat pipe is the compound vibration of random forced vibration and nonlinear free vibration.

At present, in the design of reheat pipeline and main steam pipe support and hanger of thermal power unit, the static load of pipeline and steam in the pipe is mainly considered, and the vibration characteristics are not considered. The supports and hangers in the vertical direction of the pipeline restrict the movement in the vertical direction of the pipeline, so the supports and hangers can play a frequency modulation role in the vertical vibration of the pipeline. When the spring of the support and hanger is relaxed, the natural frequency of the pipeline will be reduced. The existence of supports and hangers has certain constraints on the horizontal and axial movement of the pipeline. The longer the suspender, the smaller the motion constraints. In short, the natural frequency of the pipeline system is low, the pipeline is long, there are many elbows, there is a lack of limit device, the suspender of the support and hanger is too long and the stiffness is insufficient, which weakens the constraint on the movement of the pipeline and increases the amplitude of vibration.

4 Measures to reduce pipeline vibration

The static analysis and modal analysis of the pipeline are carried out by using the international general pipeline finite element analysis software CAESAR II, and the load, displacement and natural frequency of the pipeline system under various working conditions are calculated. It is found that the first-order natural frequency of the pipeline system is very low, only 0.221 Hz, which is far lower than the requirement that the first-order natural frequency of the newly designed pipeline shall not be lower than 2.5 Hz specified in the specification. Due to the lack of pipeline stiffness, pressure pulsation and pipeline stiffness, vibration is inevitable. Therefore, it is considered to increase the stiffness of the pipeline and improve the first-order natural frequency of the pipeline system by adding limit devices and hydraulic dampers.

Through the modal analysis of the pipe system, observe the vibration pattern under the first-order natural frequency, and combined with the actual vibration situation, consider adding the limit in the corresponding direction at the parts prone to vibration. See Table 1 for the added limit device:

Table 1. Table of limit devices and vibration damping devices added to the pipeline

Number	Node	Position	Limit direction	Quantity	Thrust
1	90	Pipe Department of No. 7 support and hanger	Z damper	1 set	/
2	470	Pipe Department of No. 19 support and hanger	Z damper	1 set	/
3	50	Pipe Department of No. 10 support and hanger	Limit in X and Z directions	1 set	6245/-3150N
4	430	Pipe Department of No. 22 support and hanger	Limit in X and Z directions	1 set	-7513/295 N

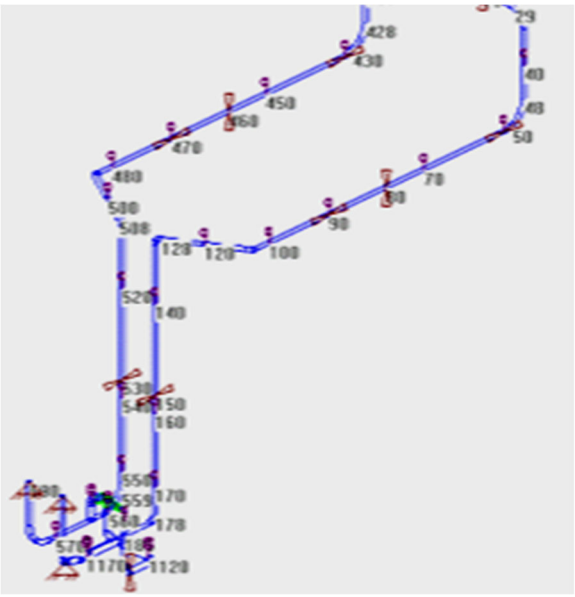

Fig. 1. Three dimensional layout of reheat steam hot section pipeline.

5 Calculation and analysis of pipeline before and after treatment

When adding restraint devices or changing the position, type and load of supports and hangers on the pipeline, it shall be in accordance with DL / T 5366 or ASME B31.1 conduct pipeline stress analysis and ensure that the pipeline stress is qualified [6].

In order to ensure the long-term safe operation of the pipeline, the modeling and joint calculation of the reheat steam hot section pipeline before and after the transformation are carried out by using Caesar II software. The main calculated parameters include primary

stress, secondary stress and displacement. The results show that the stress of the pipeline before and after the transformation is qualified. See Table 2 for stress analysis results:

Table 2. Calculation results of pipe stress.

Stress category	Calculated value/MPa	Allowable value/MPa	Calculated value/Allowable value/%	position
Primary stress before treatment	28.64	44.80	63.9	At supports and hangers 8 and 20
Secondary stress before treatment	84.33	165.83	50.9	At the upper elbow of No. 4 and No. 16 supports and hangers
Primary stress after treatment	27.32	44.80	60.9	At the upper elbow of supports and hangers 11 and 23
Secondary stress after treatment	114.44	166.53	68.7	At the upper elbow of No. 4 and No. 16 supports and hangers

The dynamic analysis of the pipeline is also carried out before and after the transformation. The results show that the first-order natural frequency of the pipeline before the transformation is very low, only 0.221hz. After the transformation, the natural frequency of the furnace top pipeline reaches 2.76hz, which meets the requirements of the regulations that the first-order natural frequency of the newly designed pipeline shall not be less than 2.5hz.

6 Effect after treatment

After the unit runs at full load, the vibration of the reheat steam hot section pipeline after vibration treatment is tested. The results show that the vibration of the reheat steam hot section pipeline is significantly improved after treatment. Under the test load, the maximum vibration value is 0.25mm, about 10% of that before treatment, which meets the requirements of safe operation of the unit.

Table 3. Measurement results before and after vibration treatment of reheat steam hot section pipeline.

Measuring point location	Measurement direction	Double peak maximum value of vibration before treatment	Double peak maximum value of vibration after treatment
No. 7 support and hanger pipe	X	0.55	0.23
	Y	0.67	0.11
	Z	2.02	0.22
No.19 support and hanger pipe	X	0.34	0.21
	Y	0.28	0.13
	Z	1.77	0.20
No. 10 support and hanger pipe	X	0.95	0.24
	Y	0.43	0.15
	Z	2.16	0.25
No.22 support and hanger pipe	X	0.70	0.20
	Y	0.61	0.17
	Z	2.20	0.25

The effect pictures of the pipe section of No.10 support hanger and No.22 support hanger in the Z direction (pipeline axial direction) after installation are shown in Figure 2 and Figure 3. The effect pictures of the pipe section of No.7 support hanger and the axial damper section of No.19 support hanger are shown in Figure 4 and Figure 5.

Fig.2. Site installation drawing of No. 10 support and hanger limit.

Fig. 3. Site installation drawing of No. 22 support and hanger limit.

Fig. 4. Installation drawing of pipe damper of No. 7 support and hanger.

Fig. 5. Installation drawing of pipe damper of No. 19 support and hanger.

7 Conclusion

(1) The long-term large vibration of the pipeline will lead to fatigue damage of the pipeline and accessories and threaten the safe operation of the unit. After installing the limit device and hydraulic damper at the parts easy to cause vibration, the maximum peak vibration velocity of the pipeline system meets the standard requirements, indicating that the vibration treatment effectively suppresses the pipeline vibration.

(2) The stress analysis results of the pipeline in the hot section of reheat steam show that the primary and secondary stresses of the pipeline system meet the standard requirements, and the installation of limit device and hydraulic damper has no impact on the stress of the pipeline system.

(3) Relevant technicians shall regularly check the working conditions of the bearing device, limit device and vibration damping device of the pipeline, and timely analyze and deal with the problems found to ensure the safe and stable operation of the unit.

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