

Main Steam Pipeline Support Hanger Failure and Pipeline Vibration Treatment

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Abstract. There are 19 faults in the main steam pipeline of a power plant, including structural failure, abnormal load bearing, abnormal displacement and other faults. Due to the low horizontal stiffness of the main steam pipe superheater header outlet, the pipe is subjected to periodic pulsation shock and resonates with the fixed frequency of the pipe. The failure of the main steam pipeline support hanger and pipeline vibration seriously affect the safe and stable operation of the unit. Through the calculation of piping stress and pipeline vibration test, a reasonable treatment scheme is formulated to solve the abnormal state of pipeline support and hanger and the pipeline vibration fault. It can provide reference for the maintenance of pipe system support and hanger and pipe vibration control of the same type of unit.

Keywords: Thermal power plant, Pipeline vibration, Support hanger, influence, Control measure.

1. Introduction

As the main energy supply units in our country, the normal operation of thermal power plants is very important for the development of national economy. Pipeline is an important part of power generation equipment, almost all media are transported through the pipeline, the safe operation of pipeline equipment directly affects the benefits of enterprises. The pipe support and hanger bear the steady load (such as the pipe weight) and the transient excitation (such as the relief valve steam discharge) of the pipeline, and at the same time reasonably constrain the displacement of the pipeline and limit the thrust and torque of the pipe end to the boiler and turbine. The working state of the support hanger is an important factor affecting the stress and life of the pipeline, and plays a vital role in the safe operation of the pipeline system. The abnormal state of support and hanger will have a certain adverse effect on the operation safety and equipment life of thermal power plant. Therefore, it is of great significance to study the failure and vibration control of pipeline support and hanger in thermal power plant[1][2].

2. Main steam pipeline support hanger fault

The boiler of Unit #1 of a power plant is WGZ1150/25.4-1 type boiler produced by Wuhan Boiler Co., LTD. The boiler is a supercritical direct current furnace, the swinging burner is arranged in four corners, tangential combustion mode, the burner oscillates to adjust the reheat steam temperature, and controls the superheated steam temperature by water injection and coal-water ratio. The Junker three-compartment rotary air preheater, solid slag extraction, one-time reheat, balanced ventilation, all steel frame, semi-open island arrangement with tight closure. The #1 turbine model is C350-24.2/0.4/566/566, which is produced by Shanghai Turbine Co., LTD. The steam turbine is supercritical, single reheat, single shaft, double cylinder double exhaust, one stage adjusted extraction, condensing steam turbine. According to the pipe system layout diagram 1, the main steam pipe support hangers of Unit 1 were tested. The pipe parameters are shown in Table 1. A total of 19 support hangers were found to have defects.

Table1. Main steam pipe parameters

Design pressure (MPa)	Design temperature (°C)	Piping specification (mm)	Piping material
25.40	576.0	ID235×46; D330×57	A335P91

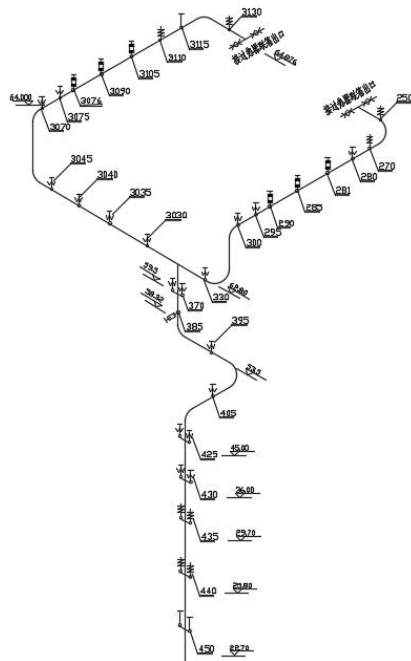


FIG. 1 Layout of pipe hanger

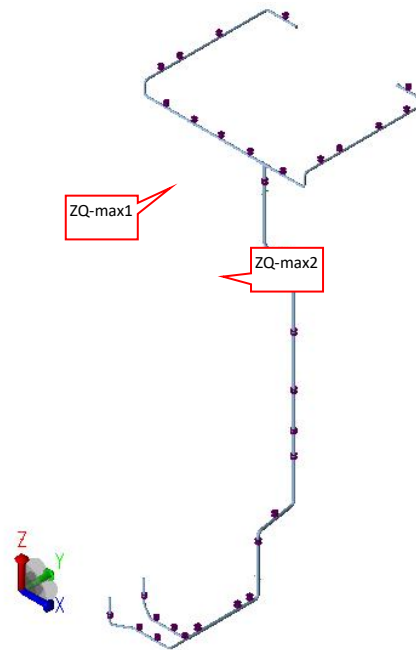


Fig 3 Pipeline calculation model

2.1 Classification of faults

- (1) Structural failure, 4 items, respectively: boom fracture, boom bending deformation, damper oil leakage, etc.
- (2) Abnormal load bearing, 5 items, respectively: constant force hanger stuck, spring hanger overload, spring hanger underload.
- (3) Abnormal displacement, 7 items, respectively: pipe clamp and steel beam collision expansion blocked, boom deviation exceeded, dampers compression extreme limit, dampers will root beam top deformation.
- (4) Other fault problems, 3 items, respectively: pipeline vibration, expansion indicator abnormal.

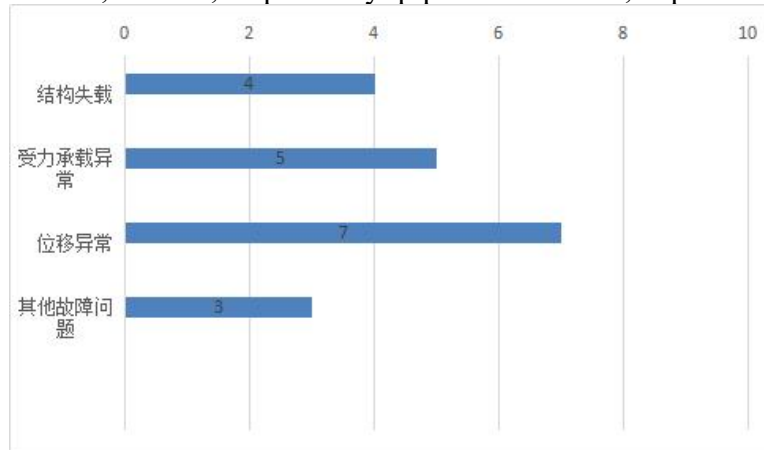


Fig. 2 Defect data of main steam pipeline

3. Pipeline stress analysis and vibration test

On-site inspection found that the main steam pipe of unit #1 was perpendicular to the first bend, and there was an obvious phenomenon of excessive vibration. Pipeline vibration has great influence on the operation of thermal power plant, mainly manifested in pipeline fatigue, leakage, equipment damage, personnel safety and so on. Pipeline vibration will cause fatigue of pipeline structure, aggravate the aging and damage of pipeline, and shorten the service life of equipment. At the same

time, pipeline vibration is also easy to cause pipeline leakage, resulting in energy waste and environmental pollution. In addition, serious pipeline vibration will also pose a threat to the safety of personnel in thermal power plants. Therefore, piping stress and pipeline vibration are evaluated[3].

3.1 Pipeline stress analysis

Under the action of gravity load, displacement load, pressure load and accidental load, the stress of different nature is generated in the whole pipeline or some local areas. The stress of pressure pipeline can be divided into primary stress, secondary stress and peak stress. The stress generated by temporary loads such as gravity load, displacement load, pressure load, accidental load, earthquake load, water impact and safety valve action impact, etc. belongs to primary stress. Pipe due to thermal expansion, cold contraction and other stress due to displacement constraints, temperature difference stress due to the internal and external wall radial temperature gradient or temperature uneven temperature gradient, and pipe and connecting parts have different metal characteristics (linear expansion coefficient is different) thermal stress is a secondary stress. Peak stress is the highest stress value of local stress concentration caused by local sudden change of structure shape and load. The characteristic of peak stress is that the whole structure does not produce any significant deformation, which is the possible source of fatigue failure and brittle fracture[4].

$$\sigma_L = \frac{pd^2}{(D^2 - d^2)} + \frac{0.75iM_A}{W} \leq 1.0[\sigma]^t \tag{1}$$

$$\sigma_E = \frac{iM_C}{W} \leq f \left[1.2[\sigma]^{20} + 0.2[\sigma]^t + ([\sigma]^t - \sigma_L) \right] \tag{2}$$

Formula (1) and formula (2) are the calculation formulas for the primary and secondary stresses of the piping system respectively, where P is the working pressure of the pipeline, d is the inner diameter of the pipeline, D is the outer diameter of the pipeline, i is the stress enhancement coefficient, MA is the resultant moment of continuous load acting on the cross section of the pipe, W is the bending section moment of the pipeline, Mc is the thermal expansion calculated by the elastic modulus of the material at 20°C. $[\sigma]^{20}$ is the resultant torque is the allowable stress of the piping material at 20°C, $[\sigma]^t$ is the allowable stress of the piping material at the design temperature, σ_L is the sum of the axial stress generated by the continuous load, f is the coefficient of stress range reduction, and σ_E is the secondary stress of the piping[5].

Table 2. Stress calculation results of main steam pipeline

Piping name	Stress category	Calculated value(MPa)	Allowable value(MPa)	Calculated /Allowable value	position
Main steam line	Primary stress	40.4	86.9	46.5%	ZQ-max1
	Secondary stress	89.6	252.6	35.5%	ZQ-max2

The pipeline stress calculation software Strat-Prof was used to model and analyze the stress of the pipeline system. The pipeline calculation model is shown in Figure 3, and the calculation results of the main steam pipeline are shown in Table 2. The results show that the stress of the pipeline system can meet the requirements of safe operation of the pipeline, and the stress of the pipeline system is qualified.

3.2 Vibration Test

The vibration mode of the pipeline was observed, and it was found that the pipeline vibration was mainly clearance vibration in Y direction (the direction of boiler and steam engine). The acceleration sensor (1A119E) was used to measure the Y-direction vibration of the pipeline system (see Figure 4). The sensor sensitivity was 10mV/m.s⁻², and the frequency response was as follows: 0.5~12000Hz, the vibration signal was collected by the wireless signal test and analysis system, and the main vibration frequency of the pipeline was measured to be 1.875HZ (see Figure 5).



Fig.4 Pipeline vibration test

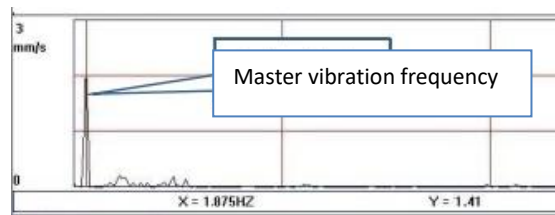


Fig. 5 Y-direction vibration test results

The maximum peak vibration velocity of the pipeline $2\pi fA=65\text{mm/s}$ was calculated according to the Guidelines for Vibration Control of steam Water Pipelines in Thermal Power Plants (DL/T292-2011) [6]. According to Table C.4 of Appendix to DL/T292-2011, when the maximum peak vibration velocity is greater than 34.7mm/s, the vibration state is assessed as unqualified.

4. Pipeline troubleshooting

4.1 Pipeline support and hanger treatment scheme

Based on the calculation of piping stress, this paper analyzes the causes and puts forward the treatment plan for the problems of pipeline support and hanger faults and pipeline vibration:

(1) the fault defects of pipeline support and hanger are generally caused by the installation is not in place during the construction period, the aging performance and quality of hanger are reduced, the weight of pipeline and accessories does not match the design load of lifting point, and the abnormal working conditions of piping. For the structural failure, abnormal load bearing, abnormal displacement and other faults detected, the adjustment plan of the support and hanger of the pipe system shall be formulated according to the cold and hot state inspection results of the support and hanger of the pipe system. The adjustment plan is shown in Table 3. The construction team qualified for pipeline installation shall adjust the construction and conduct cold and hot state inspection of the pipe system again after the adjustment[7].

Table 3. Adjustment scheme of pipeline support and hanger

Fault number	Hanger type	Fault defect condition	Treatment scheme
281、285	damper	Serious oil leakage	Return to factory for repair or replacement
703	Single tie rod spring hanger	The boom is bent out of shape	Change hanger
605	Single tie rod spring hanger	Derrick break	Change hanger
508、820、890	Single tie rod spring hanger	The boom collided with the steel beam	Cut off the part of the steel beam that interferes with the boom
3130、1070、1240	Single tie rod spring hanger	Boom deflection exceeds the limit	Re-mount the derrick, and the deviation Angle of the derrick shall not exceed 4° after the installation
290	damper	Compression extreme limit	Adjust the damper stroke to ensure that the cold and hot indicator of the damper are within a reasonable stroke range
250、270、280、3110、705	Variable force spring hanger, constant force spring hanger	Bearing structure anomaly	Adjust hanger indicator to cold position when cold
/	Expansion indicator	Abnormal state	Return to zero and record the cold state

(2) Pipeline vibration in thermal power plant is a very complicated problem, and the causes of vibration are various. However, in theory, it is caused by the exciting force. When the low-order natural frequency of the pipeline is low, the exciting force frequency is easy to approach the low-order natural frequency of the pipe system and generate resonance. Pipeline vibration will cause fatigue damage of pipelines and accessories, have certain influence on structural welds, endanger pipeline connection equipment, and cause distortion of operation monitoring and measurement signals. The horizontal section of the outlet pipe of the superheater header of the #1 unit is not designed with a y-direction limit. When the steam flow impacts the pipe elbow and the valve element, it is easy to form a periodic pulsating impact on the pipe wall and produce resonance phenomenon with the fixed frequency of the pipe[8].

The treatment of pipeline vibration is mainly solved by eliminating the exciting force and improving the vibration characteristics of pipeline system. Once the pipeline layout form is established, the pipeline structure and pipe wall thickness are difficult to change, and the operating parameters are difficult to adjust, and it is generally difficult to eliminate the exciting force. Improving the vibration characteristics of pipe system and increasing the stiffness of pipe system can effectively avoid the excitation frequency and eliminate the vibration phenomenon. According to the existing layout conditions on site, 1a and 1b dampers are designed to be installed at the downward position of the pipe elbow (as shown in Figure 6) to improve the pipe damping without affecting the free expansion of the pipe system, which can effectively solve the pipeline vibration phenomenon.

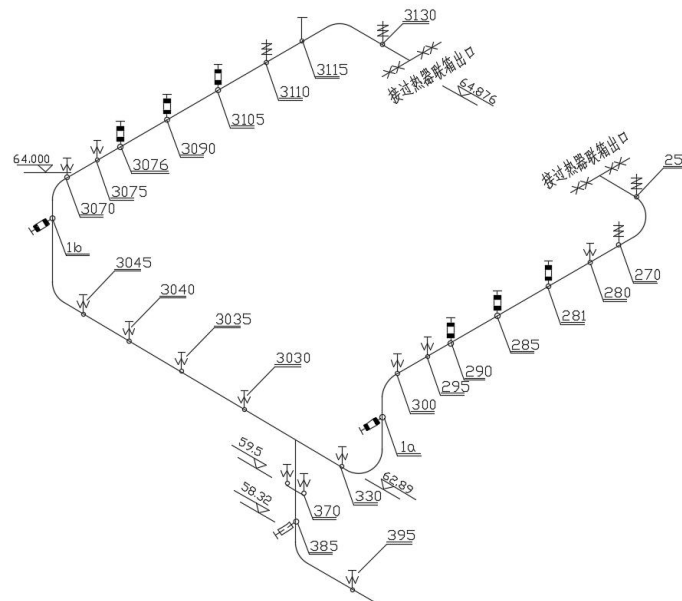


Fig 6. Installation diagram of pipe damper

4.2 Evaluation of governance effect

(1) After treatment according to the treatment plan, the main steam piping support hangers were checked in cold state before hoisting and hot state after starting, and it was found that the status of all support hangers were consistent with the design value, and the hangers were in normal state.

(2) After the installation of 1a and 1b hydraulic dampers, the vibration acceleration of piping was re-measured, and the vibration measurement results are shown in Table 4. The maximum peak vibration velocity of the pipeline was calculated according to the Guidelines for Vibration Control of steam Water Pipelines in Thermal Power Plants (DL/T292-2011), and $2\pi fA=10.5\text{mm/s}$. According to Table C.4 of Appendix to DL/T292-2011, when the maximum peak vibration velocity is less than 21.3mm/s , the vibration state was evaluated as excellent. It shows that the vibration control scheme is scientific and reasonable.

Table 4. Measurement results of pipeline vibration

	Master frequency (Hz)	Peak displacement (mm)	Maximum peak velocity(mm/s)	Vibrational state
Before treatment	1.875	5.52	65	Out of standard
After treatment	3.528	0.47	10.5	Up to standard

5. Summary and suggestions

(1) Site inspection found that there were 19 faults in the main steam pipeline, including: structural failure, abnormal load bearing, abnormal displacement, and other faults. Due to the low horizontal stiffness of the main steam pipeline superheater header outlet, the excitation load resonates with the fixed frequency of the pipeline after the periodic pulsation impact. The failure and vibration of the main steam pipeline support hanger seriously affect the safe and stable operation of the unit. The abnormal state of the pipeline support hanger and the pipeline vibration fault are solved by making a reasonable treatment plan.

(2) The pipeline support hanger is not installed in place so that the pipeline stiffness is lower than the design requirements, which increases the coupling of the pipeline to the medium disturbance;

(3) In the daily maintenance should strengthen the macroscopic inspection of the pipeline and support hanger, especially when the pipeline vibration, should be timely treatment.

(4) When selecting the location of the vibration reduction point, it is necessary to consider the thermal displacement of the pipeline, and set the shock absorption device in the place where the displacement is small. The vibration reduction plan can be implemented only after the stress check calculation of the pipe system.

(5) In strict accordance with the relevant standards, the four major pipelines with large thermal displacement are regularly rolled to carry out comprehensive inspection, mechanical calculation and analysis, adjustment and other work.

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