Development and application of online load measurement system for hanger and support

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Abstract. It was difficult to monitor the load and evaluate the performance of the hanger and support of power plant. The online load measurement system for hanger and support was developed and some experiments had been carried out. Compared with the offline bench performance testing machine, the experimental results showed that the average measurement error of the online measurement system was less than 1%. It can effectively measure the performance parameters of the hanger, conveniently and reliably monitor the real-time load of the hanger, which is important for the safe operation of the hanger and the steam/water pipeline in the power plant.

1. Introduction
The hanger and support device can bear the weight of the steam/water pipeline and medium in the power plant, at the same time restrain the displacement and control the vibration of the pipeline [1-2]. Therefore, the performance of hanger and support will directly affect the service life and safe operation of the pipeline system [3-4]. The design, manufacture, installation and operation of the hanger and support may affect its working performance. The design and manufacturing quality of the hanger and support is guaranteed by the factory quality inspection, but its working performance of the hanger will change during the installation and operation [5-6]. For the hanger and support in service, the power plant generally adopts a fixed period of on-site visual inspection to check its status [7]. There is no load indicating device for rigid hanger and support, so it is impossible to determine the real-time load on site. Although the load can be roughly pushed back through the displacement scale by the spring hanger displacement display device, it cannot be accurately measured. Therefore, the on-site inspection is highly dependent on the personal experience of the engineers and technicians. Wan Yu [8] et al. studied the use of benchtop performance testing machine to test the performance of the in-service hanger, but this requires offline testing after the hangers are removed from the system, which makes it impossible to conduct rapid measurement of the hanger, and it is impossible to evaluate the real-time status of the hanger in the system. Liu Ming [9] et al. studied the performance monitoring of the hanger and support through online indirect test method, but accuracy of this method is too low and requires post-processing of data, so it cannot achieve real-time measurement in the field. For this reason, a set of load measurement system for hanger and support is designed and integrated, which can quickly measure the real-time stress and performance indexes of various in-service hanger and support.
2. Principle and composition of online load measurement system

2.1. Principle of online load measurement for hanger and support

As shown in Figure 1, the auxiliary support hanger is installed in balance with the support hanger to test, the stress sensor and displacement sensor are installed on the auxiliary hanger and the hanger. The sensor is wired to the data acquisition device, and the data acquisition device is wirelessly connected to the terminal. Through the data processing software on the terminal processing device, all data are recorded, processed and stored in real time. Firstly, start the lifting device of the auxiliary hanger to gradually transfer the load of the hanger to the auxiliary hanger system, the sensor will obtain the real-time load change of the hanger to be tested. When the load on the hanger to be tested is completely transferred to the auxiliary hanger, the load on the hanger to be tested will not change any more. At this time, the measured stress of the auxiliary hanger is the real-time load of the original hanger during operation.

By the method, the hanger to be measured needn’t be disassembled, and the parameters of the hanger can be measured through one load unloading and loading process, so the measurement method has the advantages of real-time and online measurement.

![Figure 1. Schematic diagram of load measurement system for hanger.](image1)

![Figure 2. YSJ-1-F bow strain sensor.](image2)
2.2. Composition of hanger load online measurement system

YSJ-1-F bow strain sensor (as shown in Figure 2) produced by ZEMIC is selected for the cylindrical structure of hanger suspender. It collects strain analog signals through a full bridge circuit composed of four resistance strain gauges installed on the sensor. The sensor is suitable for the field strain detection of steel structure components. It is installed on the surface of the cylindrical suspender structure with special clamps, which avoids the tedious process of pasting strain gauge on site and the influence of high temperature on the adhesion and fixation. The data output is stable and reliable, and it is convenient for the test of small deformation in the node area of the structure [10].

A set of auxiliary measuring device is built through the integrated chain lifting device, force sensor and displacement sensor. In order to adapt to different load sizes, force sensors with ranges of 1t, 3t and 10t are selected. The sensors are connected with the lifting chain through hooks and lifting rings, and the displacement load curve can be recorded at the same time of applying tension.

The wireless data acquisition device (as shown in Figure 3) adopts a four-channel acquisition system supporting various bridge forms, each channel adopts an independent 24bits ADC, with a high signal-to-noise ratio, and each channel keeps synchronous acquisition. The instrument has built-in large capacity rechargeable battery, which can work continuously for more than eight hours to solve the problem of power supply on site; at the same time, it supports external DC power supply (battery, solar cell) in the range of 9-36V for long-term monitoring.

![Figure 3. Photo of hanger and support load online measurement system.](image)

In order to deal with the complex field situation, the data acquisition system adopts WiFi wireless transmission protocol; the mobile terminal receives and processes the collected data. Compared with the traditional wired data transmission mode, the wireless transmission mode can reduce the construction difficulty and system cost without considering the installation of the transmission cable, which is suitable for the field where the power supply or the personnel is difficult to reach.

Schematic diagram of acquisition system as shown in Figure 4, the functions of each module of acquisition system are as follows:

- Strain/load sensors: conversion from non-electrical to electrical signal
- Signal conditioning/amplification: the weak electrical signal is processed and amplified to improve the accuracy of measurement
- A/D conversion module: converts analog signals into digital signals for further processing by CPU
- CPU control module: the core part of the hardware system, coordinates the work of all modules
- WIFI data transmission module: provides the channel to collect data for the system software
- App software module: Based on Java language development on Android system platform, send instructions to CPU control module
- Power management module: responsible for power on or off and charging
- Lithium battery power supply module: supply power to all modules of the system
When the load measurement system of support hanger is used for measurement, the hardware connection shall be carried out first, the measurement system app shall be opened when the hardware equipment is turned on. The app communicates with the acquisition device through mobile WiFi, controls the work of the acquisition device, displays and stores data.

3. Comparison between traditional and online measurement system

3.1. Traditional measurement system of hanger and support load

The traditional measurement system of hanger and support load relies on a bench type performance testing machine fixed in the laboratory. The system consists of a test bench, a connecting and fixing device, a force sensor, a displacement sensor, an industrial computer and corresponding control software (as shown in Figure 5). Before the test, disassemble the support or hanger from the power plant pipeline and transport it to the laboratory. Use the connection device installs the hanger vertically on the test bench. The angle between the connecting rod and the plumb line should less than 4° [11-12]. Start the test system, tension hanger, and sensor output hanger load change, when attain the maximum stroke of hanger, release the hanger rod, then change the output load with the decrease of tension, hanger back to the initial state, record the load displacement curve during loading and unloading, and finally get the performance index of hanger.

3.2. Comparison between the results of traditional and online measurement system

3.2.1. Error analysis of measurement results. The hangers used in power plants are mainly divided into rigid hangers and spring hangers (spring hangers include variable force spring hangers and constant force spring hangers). Because of its complex structure and the natural relaxation of the spring after a long time of work, the spring hangers are more likely to have operational failure than the
stable rigid hangers [13]. Therefore, two constant force spring hangers and a variable force spring hanger which have been running more than 60000 hours are selected to contrast test. The performance of each hanger is tested by traditional test system and online test system respectively to compare the measurement results of the two systems.

Using the online measurement system and the traditional measurement system to test the performance of the spring hanger, both of them can meet the test requirements of the standard [14] for the initial load deviation, constancy and displacement. The load displacement curves of the three spring hangers are shown in Figure 6, Figure 7 and Figure 8.

![Figure 6](image6.png)

**Figure 6.** Experimental results of constant force spring hanger A.

![Figure 7](image7.png)

**Figure 7.** Experimental results of constant force spring hanger B.

Based on the measurement results of bench performance testing machine (the traditional measurement error is 0.2%), the error analysis of online measurement is carried out. The results show that the average relative errors of the three hangers measured by the online measurement system are 0.693%, 0.674% and 0.718% respectively, and the maximum relative errors are 1.27%, 1.18% and 1.01% respectively (as shown in Figure 9, Figure 10 and Figure 11). The test results show that if the traditional measurement system is replaced by the online measurement system, the measurement relative error is about 1%.
Figure 8. Test results of variable force spring hanger.

Figure 9. Error analysis of constant force spring hanger A.

Figure 10. Error analysis of constant force spring hanger B.
3.2.2. Comparison of traditional and online measurement system. It can be seen from Table 1 that the traditional hanger measurement system has the characteristics of high measurement accuracy, large weight and large installation area. For the hanger in service, it should be disassembled and transported to the laboratory for testing. It is unable to measure the real stress state of the hanger in work, which is only applicable to the factory inspection. The online measurement system of hanger has the characteristics of small volume, small weight, portable and online analysis and storage, which is especially suitable for the measurement of hanger which is on active service or not convenient to disassemble. In addition, the output load of hanger and support of power units participating in deep peak load regulation or flexible operation will change more frequently and violently [15]. The online measurement system can be installed on the supports and hangers for real-time load monitoring, providing basic data for safety monitoring and life assessment of the pipeline hanger and support system.

Compare the index of online measurement system with that of traditional measurement system, as shown in Table 1.

Table 1. Comparison table of online measurement system and traditional measurement system.

| Index of comparison | On line measurement system | Traditional measurement system |
|---------------------|----------------------------|-------------------------------|
| System weight       | ≤5kg                       | 5~10t                         |
| Average measurement error | <1%                     | 0.2%                          |
| Types of measurement indicators | Initial deviation, constancy and displacement | Initial deviation, constancy and displacement |
| System characteristics | Portable, real-time measurement | Fixed, offline measurement |

4. Conclusions
An online measurement system of hanger and support load was designed and tested. The experimental results showed that the average relative error of online measurement system was less than 1%. The online measurement system has the following advantages:
(1) The online measurement system is especially suitable for the measurement of hanger which is in work or not convenient for disassembly.
(2) For the pipelines of peak load regulating units with more frequent and violent load changes of supports and hangers, the online measurement system can be installed on the hangers for long-term real-time load monitoring, which provides the basic data for safety monitoring and life assessment of the hanger and support system.

In summary, the online measurement system of support and hanger load has the advantages of accurate online measurement, stable and reliable system, convenient installation and disassembly, so it has a good application prospect.

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