The Test Research into the Shock Response Characteristics of Pressure Pipeline System

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ABSTRACT

The pipeline system is distributed widely and there are many supporting points, the shock input has the nature of multiple points, multiple phases, multiple amplitudes and multiple frequencies. Its components and parts are complex and various, and supporting positions, modes, stiffness, damping and the parameters of arrangement positions and the forms of components and parts are complicated and overloaded. In the process of anti-shock design of the pipeline system, it should be considered how to optimize the combination of these factors. In this paper, in order to research and analyze the law of effect of structural parameters on the pipeline system shock response under the action of shock load, a three-dimensional spatial pressured pipeline system is fabricated, which is composed of such components as hangers, elastic supports, Limits, Tees, bending pipes and flanges. By exerting above-mention components individually and changing the parameters of their positions, stiffness and shock loads, researches of pressured pipeline system shock tests are conducted to analyze pipeline system shock response and the law of variation.

INTRODUCTION

The pipeline system is a collective name of pipeline, pump, valve, instrument, control unit and their appurtenances that feed various working substances, which provide power equipments with water, fuel and gas, and are absolutely necessary components for power equipment, ventilation, drainage, cooling, hydraulic control mechanism and other systems. They are widely applied in and playing important parts in various industries such as traffic, petrochemical industry, electric power, construction and nuclear energy, but they also invoke many fateful consequences to production, economy and defense when they are out of service. Therefore, all industries are extensively researching how to guarantee their safe operation.

Under the normal operating conditions, the pipeline system bears various kinds of external force load such as pressure, gravity, vibration, pressure pulsation (water hammer) and thermal expansion. Under some specific conditions, the pipeline system also bears the shock action from equipments and their mounting bases. For designing the pipeline system operating under specific conditions, it should not only conduct normal pipeline system intensity design, stress analysis and fatigue analysis but also conduct pipeline system anti-shock analysis. The pipeline system is distributed widely and supported with many supporting points, and the shock acting force input is characterized by multipoints, multiphases, multiamplitudes and multifrequencies. The pipeline system's components and parts are complex and various; the pipeline system's parameters of arrangement position and modes of supporting position, mode, rigidity, damp, components and parts are complicated and overloaded; these are factors that influence pipeline system shock response. In the process of designing pipeline systems, these factors must be optimized. At present time, under the normal external force load action of pressure, gravity, vibration, pressure pulsation (water hammer) and thermal expansion, the research into the impact rule of pipeline parts, structural parameters, load form on pipeline system response developed rather well, but the research into the impact rule of structural parameters on pipeline system shock response under shock load action developed badly, especially the test research into the structural parameters response rule of the pressure pipeline system is rarely done.

In this paper, authors designed and manufactured a three-dimensional spatial pressure pipeline system tester composed of such parts as cradle, elastic support, limit, three-way pipe, syphon and flange. By exerting cradle, elastic support and limit individually and changing the parameters of position, rigidity and shock load of each part, authors conducted pressure pipeline system shock test research, analyzed the impact of such factors as pipeline parts, structural parameters and shock load on pipeline system shock response, ascertained the characteristics and anti-shock change rules of pipeline system, established the base and course for pipeline system anti-shock optimization design, provided the basis for establishing and demonstrating the nonlinear analysis computation models and methods of the pipeline system shock.

TESTERS

This tester is composed of medium-size shock machine, rigid mounting framework, pipeline system test parts and test system. The rigid mounting framework is specially designed and manufactured according to the carrying capacity of standard medium-size shock test machine and the restrictions on the geometric dimension of test parts, which is convenient for pipeline system tester installation and teardown. To guarantee that the rigid mounting framework is of enough rigidity under the action of shock load, it is made of welded 50mm thick steel plates.

A three-dimensional spatial pipeline system tester is designed and manufactured by reference to the frequency characteristic bounds of certain pressure pipeline system and considered the carrying capacity of medium-size shock machines. To make the test results have definite actual engineering meaning, the materials used in the pipeline tester are the same as the actual engineering materials, and the frequency, internal pressure stress level of the pipeline tester are in accord with the frequency of the actual pipeline. The pipeline system tester is made of Φ57mm seamless stainless steel tubes. The tester includes six 90º elbows, one parallel three-way pipe, two elastic support modes, one elastic cradle, one gap and one lumped mass used to simulate flange and two hammerhead shims. The test pipeline structure is as shown in Figure 2.1. The pipeline system tester is connected to the rigid framework with bolts, and the rigid framework is then connected to the chopping block of the medium-size shock machine with bolts.

The testing system includes acceleration sensor, charge amplifier, strain guage, strain guage and data acquisition system. During test, there are total five acceleration sensors and six strain guages installed to measure the shock acceleration and shock strain in key points of pipeline system respectively.

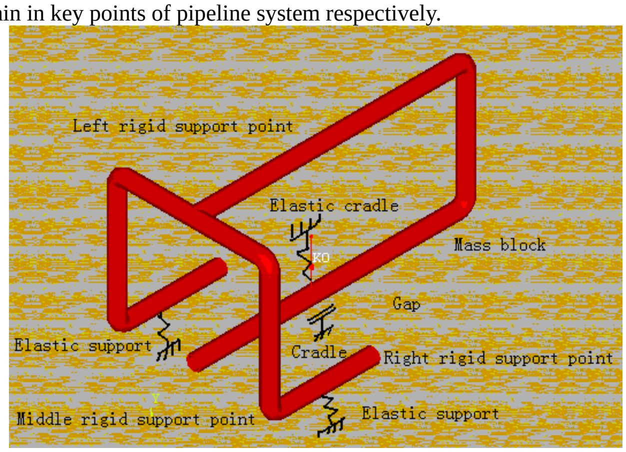

Figure 2.1 Sketch map of pipeline tester model

TEST CONTENTS

During the tests, modal test is firstly conducted to the pipeline system tester, and then vertical and transverse shock tests to the pipeline system tester with medium-size shock test machine. In order to review the repetitiveness of test data, two alike pipeline system testers are manufactured and shock tests are conducted under the same load conditions. According to different boundary conditions (support), internal pressure, bob-weight and shock load devices and so on, the entire shock test is divided into 19 groups: each group for more than 5 times of shock tests with different height of drop hammers. Each group of the first 16 groups of shock tests conducts more than 5 times of shock with different height of drop hammers and control the whole pipeline system within the elastic range; the partial pipeline comes into yield during the last 3 groups of tests. The shock test performance can be seen in Table 2.1. The authors measured the test data such as shock input acceleration stroke of the pipeline system tester, shock acceleration response stroke in key points, shock strain stroke and impact stroke in the gap before and after each shock test. Before each shock test, the hydraulic pressure test is conducted to the pipeline system tester, so as to examine the tightness of the pipeline system; after each shock test, the distortion condition and tightness integrity of the pipeline are examined. The next shock test can only be conducted after the connecting bolts are refastened.

As the shock test-bed is controlled by the open loop, the surface of shock test-bed bears the action of such as the guide bar friction in the process of elevation, shock test repetitiveness is not extremely ideal, but there are following trends as a whole: although the pressure inside the pipeline increases, there is a trend that the shock response of the pipeline system will increase as well; the same pipeline anti-shock performance decreases after exerting elastic cradles in the pipeline system; the pipeline shock stress level under 2mm gap rigidity restraint is evidently higher than that under 1mm gap rigidity restraint, and evidently higher than that with no restraints; after more than 100 times of elastic shocks, the pipeline system can still resist the shock load that is much greater than the design load.

Table 2.1 Shock test performances

Group	Internal pressure (MPa)	Elastic cradle (K, 10^5 N/m)	Gap (δ,mm)	Elastic support type	Hammerhead shim	Weight of simulation mass block (kg)	Shock direction
1	5	—	—	—	—	10	vertical
2	10	—	—	—	—	10	vertical
3	5	1.0	—	—	—	10	vertical
4	5	2.0	—	—	—	10	vertical
5	5	1.0	1.0	—	—	10	vertical
6	5	1.0	2.0	—	—	10	vertical
7	5	1.0	2.0	1	—	10	vertical

8	5	1.0	2.0	2	—	10	vertical
9	5	1.0	2.0	2	δ_1	10	vertical
10	5	1.0	2.0	2	δ_2	10	vertical
11	5	—	—	—	—	10	vertical
12	5	—	—	—	—	20	vertical
13	5	—	1.0	—	—	10	vertical
14	5	—	2.0	—	—	10	vertical
15	5	—	—	—	—	10	transverse
16	5	—	—	—	—	20	transverse
17	13	—	—	—	—	10	vertical
18	13	—	—	—	—	20	vertical
19	10	—	—	—	—	80	vertical

Due to limited space, only the test results under 4 heights of drop hammer of 5 groups of mounting conditions are given in this paper. The maximum strain of the fixed pipeline segment shock under mounting condition 1 can be seen in Figure 3.1; the maximum strain under mounting condition 2 in v 3.2; the maximum strain under mounting condition 3 in Figure 3.3; the maximum strain under mounting condition 4 in Figure 3.4; after the test model is shocked by the first 17 groups of tests, the maximum strain mounting condition 18 see Figure 3.5; after the shock test of the first 18 groups in Table 2.1, the maximum strain under mounting condition 19 mostly exceeds 10000 $\mu\varepsilon$ (exceeds quantity in strain guage), but there appears no much evident plastic distortion in the whole test model pressure boundary integrity and structure.

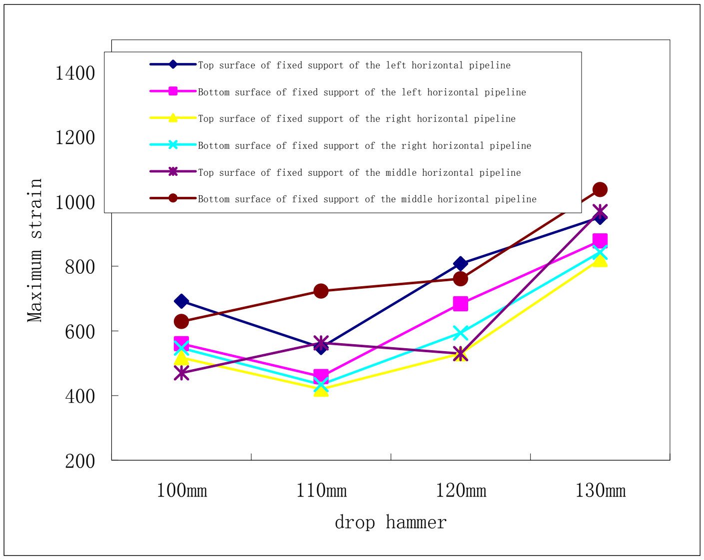

Figure 3.1 Maximum strain under shock on the fixed pipeline segment ($\mu\varepsilon$)

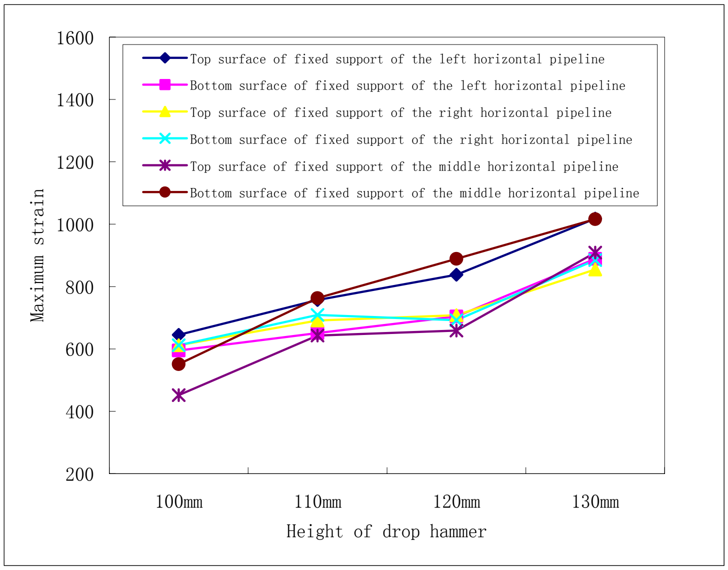

Figure 3.2 Maximum strain under shock on the fixed pipeline segment ($\mu\varepsilon$)

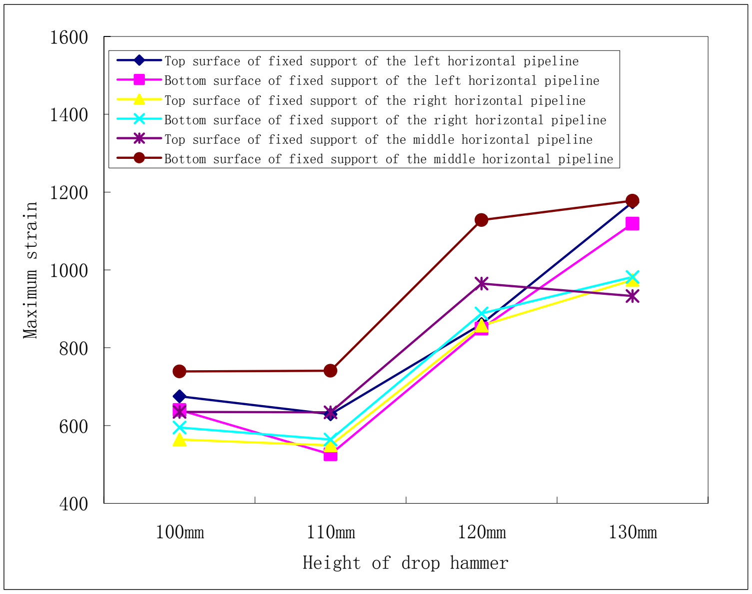

Figure 3.3 Maximum strain under shock on the fixed pipeline segment ($\mu\varepsilon$)

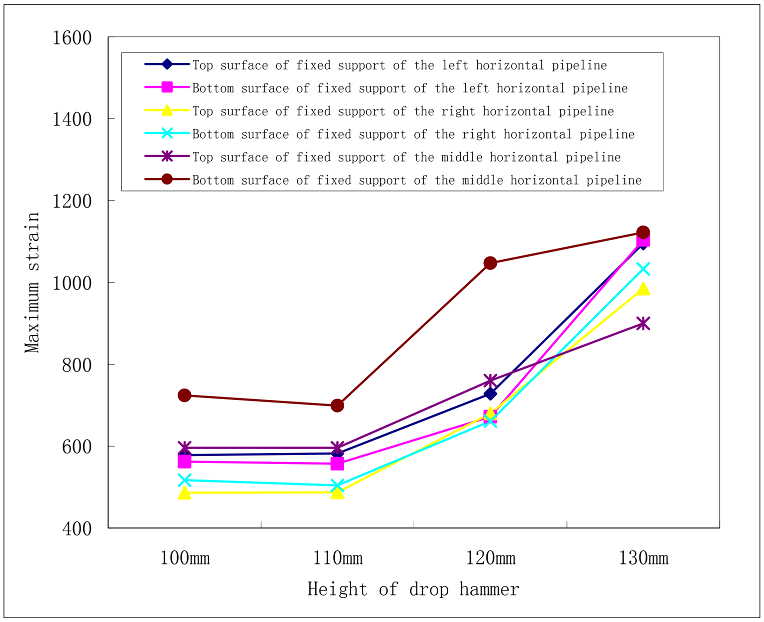

Figure 3.4 Maximum strain under shock on the fixed pipeline segment ($\mu\varepsilon$)

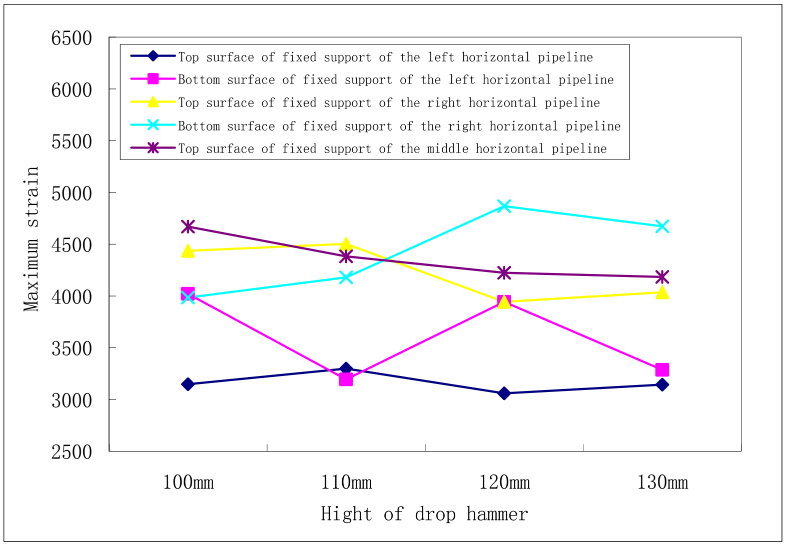

Figure 3.5 Maximum strain under shock on the fixed pipeline segment ($\mu\varepsilon$)

CONCLUSIONS

By a great amount of test measurement and test data analysis, it can be concluded as following:

a. The shock response of the pipeline system is directly related to the shock load and internal pressure, and the change law of shock response presents monotony.

b. Making the best use of elastic components such as elastic support and elastic cradle is conducive to ameliorate the shock response of pipeline system, but the shock response of the pipeline system and rigidity variation of components is of no monotony. Therefore, the elastic components of the pipeline system should be reasonably selected and optimally arranged.

c. The shock response in the lumped mass of the pipeline system is evidently more violent than in the free tubules, so it needs to pay much more attention.

d. It is found during testing the test pipeline system that the shock response increases under the same shock after increasing the internal pressure. By analysis, it is considered that may be caused by the coupling action of the fluid inside the pipeline and the fluid fixation of the pipeline system.

e. By 19 groups of shock tests (more than 5 times for each group) to the tested pipeline system, the shock test load and computational nominal stress of the last group is higher than 2000Mpa, but there appears no visible plastic distortion in the boundary integrity of the pipeline system and the integral structure. This phenomenon means that it may be too conservative in safety margin of present engineering pressure pipeline system design, and this certainly needs a mass of test data to carry on further research and analysis.

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