# Experimental Study on Seismic Performance of Spring Vibration Isolation Turbine-generator Foundation

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**Abstract.** The 1:8 modal tests were conducted on 1000MW turbine generator spring vibration isolation foundation. According to the similarity relation conversion, the displacement response and spring deformation of the model were investigated by pseudo-dynamic test. In the pseudo-dynamic tests, 7 degree frequent and rarely earthquake tests were carried out respectively. By experimental results, the foundation has good working performance, and the story drift is under the limit value provided in Code for seismic design of buildings.

## Introduction

The turbine-generator set is the core equipment of the power plant, improvement of technical innovation will bring the improvement of the turbine frame foundation. As a supporting structure of turbine generator, structure of foundation is complex, what influence the safety performance of the dynamic performance and seismic performance of the whole unit is crucial. Shao [1] studied a 1:10 model of the spring vibration isolation turbine-generator foundation, first case in China. The foundation performs well under 7degree rarely earthquake, story drift of the structure is satisfied the limit value provided by Code for seismic design of buildings (GB50011). The pseudo-dynamic test was conducted on 1:8 model of 1251MW turbine-generator foundation, the character of earthquake response is studied [2]. Dynamic characteristic tests were conducted on turbine-generator foundation [3, 4]. Recently, some studies were on the turbine-generator foundation [5, 6]. For a certain turbine-generator unit, its foundation structure is different; the seismic performance is need for the turbine-generator foundation.

## Test Conditions

**Model Fabricating and Test Loading.** The model [7, 8] of turbine foundation scaled 1:8, and the model and materials is same as prototype. The strength grade of concrete is C40. The reinforcement ratio of the model is the same as that of prototype. Model was pouring three times, first pouring is the completion of the bottom and lower column of middle platform, second pouring completed intermediate platform and upper column, then installing the spring vibration isolator, third is the completion of plate casting. According to the similar quality [9, 10] compared with cast iron simulation turbine and related equipment quality, total weight of simulation equipment is 50.22kN. The horizontal load is applied to the hydraulic servo actuator with the load of 500kN and the stroke of 250mm. The actuator is fixed at the reaction wall in one end, and fixed at the model in other end, using ball joint flange. Model of concrete slab fixed in ground by high-strength anchor bolt. The completion of the test model is shown in Fig. 1.

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Figure 1. Experimental model

**Arrangement of Measuring Points.** The high precision displacement sensors (LVDT) were layout on the structure model to control the displacement of the pseudo dynamic test and measurement plate displacement. All columns and joints between column and platform were layout the displacement measuring points. The base plate is also arranged to measure the displacement in order to monitor it.

**Earthquake Input.** The fortification intensity of power plant engineering is seven degrees, the basic design acceleration 0.1g, the earthquake grouping is I, site class IV. According to the design response spectrum provided by seismic design code, the acceleration time history of frequently and rarely earthquake is generated by using triangular series superposition method. Earthquake acceleration time history curves are shown in Fig 2.

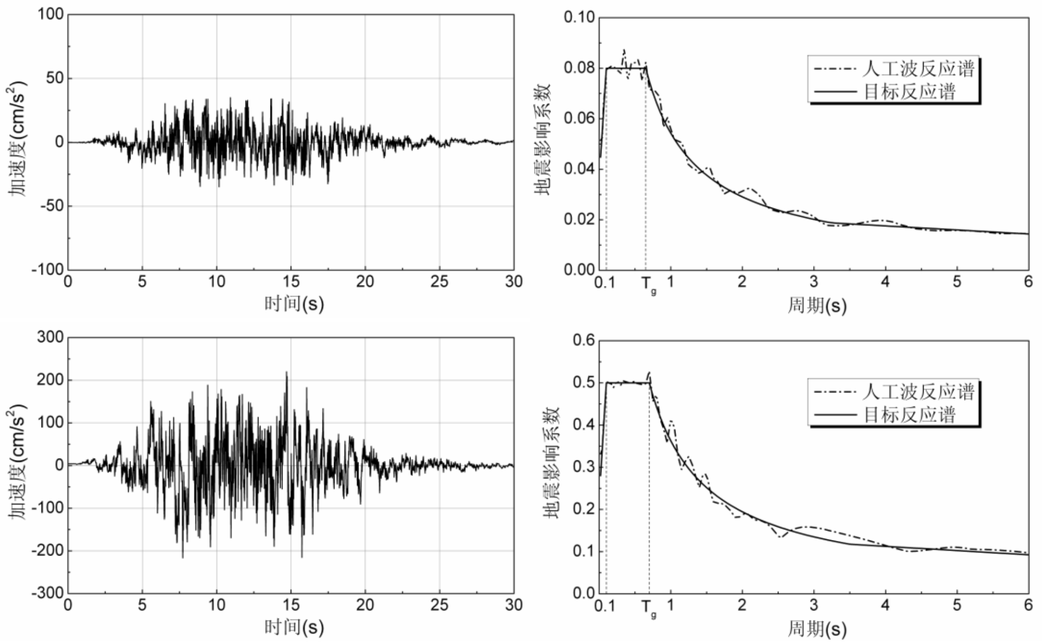


Figure 2. 5%-damped elastic pseudo-acceleration response spectrum matched to the target spectrum according to code GB50011

## Test Results and Analysis

**Crack Development and Distribution.** In the process of rarely earthquake, the development of concrete column crack and the accumulation of final damage are recorded in detail. In rarely earthquake test carried out to the 225th step began to observe the development of cracks in the future every 50 steps. It is the first time to observe the crack location is at the connection of beam-column joints, with the increase of load, the crack extension of a certain moment, in 10.9 seconds, the maximum displacement of the prototype structure, the crack observation instrument read column nodes of the maximum crack width is 0.05mm. Crack at the root of the column is 0.02mm. After the test, the cracks are not obvious. Fig. 3 is the main crack distribution map. Fig.4 and Fig. 5 show the picture of the typical parts of turbine foundation cracks. Under rarely earthquake, the cracks are carried out, and the parts of the cracks are mainly concentrated in the beam column joints, and there are a few cracks in the part of the column. Cracks are mainly distributed in the local area, which extends in a certain range, and does not form through cracks.

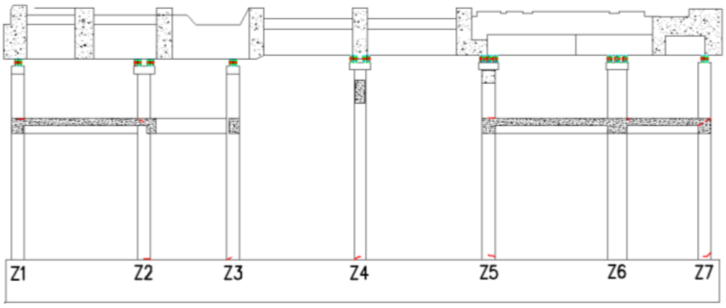


Figure 3. The main crack distribution of turbine foundation



Figure 4. Crack of C3 column root

Figure 5. Crack of joint between C7 Column and middle platform

**Earthquake Response.** Fig. 6 and Fig. 7, respectively, based on the prototype in the case of rarely earthquake, is the displacement response curve. Table 1 lists the maximum value of acceleration, velocity, displacement, restoring force response according to the similarity principle. Based on the prototype, the maximum acceleration response under frequently earthquake and rarely earthquake is 0.287m/s2 and -0.933m/s2, the amplification coefficient of earthquake proof (response when the maximum acceleration, maximum acceleration of earthquake input) is only 0.82; the amplification coefficient in rarely earthquake is only 0.42. The top set of turbine foundation spring vibration isolator, column and separated by a spring plate, the base structure vibration cycle becomes longer, the predominant period of self vibration period of the structure away from the site. Spring the vibration of turbine foundation first-order natural frequency is 0.875Hz, from the response spectrum, earthquake influence coefficient into decline, thereby reducing the earthquake force. When the earthquake occurs, the foundation structure is in the elastic state. In rarely earthquake, from the displacement of foundation structure response can be seen, the response cycle lengthened, because the foundation columns of concrete cracked, foundation stiffness is decreased, the vibration cycle continues to lengthened, the acceleration amplification coefficient becomes small, play on the level of seismic isolation spring damping performance more fully.

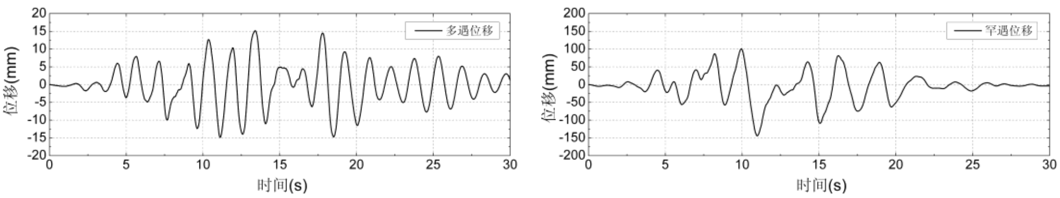


Figure 6. Time-history displacement of bedplate in frequently and rarely earthquake

Table 1. Earthquake response of foundation

| | Displacement[mm] | Acceleration[m/s$^2$] | Velocity[m/s] | Restoring force[kN] |
|---|---|---|---|---|
| Frequently | 15.21 | 0.287 | -0.072 | 2105.00 |
| Rarely | 144.34 | -0.933 | -0.430 | 6551.00 |

**Hysteresis Curve.** The restoring-force displacement curve is shown in Fig.8. It can be seen from the chart, in the earthquake, the restoring force displacement curve structure of the linear relationship between the restoring force and displacement, the basic symmetric sliding direction, surrounded by the hysteresis loop area is very small. In the course of load and reciprocating action, the stiffness degradation is not obvious, and the structure is in the elastic state. The rarely earthquake, with the increase of the load, the slope of the curve decreases as the load increases, the structure of tension, hysteresis curve area increased and the structure performance good energy dissipation capacity, hysteresis loop area is surrounded by more big earthquake. When the load is about -4000kN, the slope of the restoring force displacement curve decreases, and the structural stiffness appears a certain degree of degradation, but there is no obvious plastic deformation.

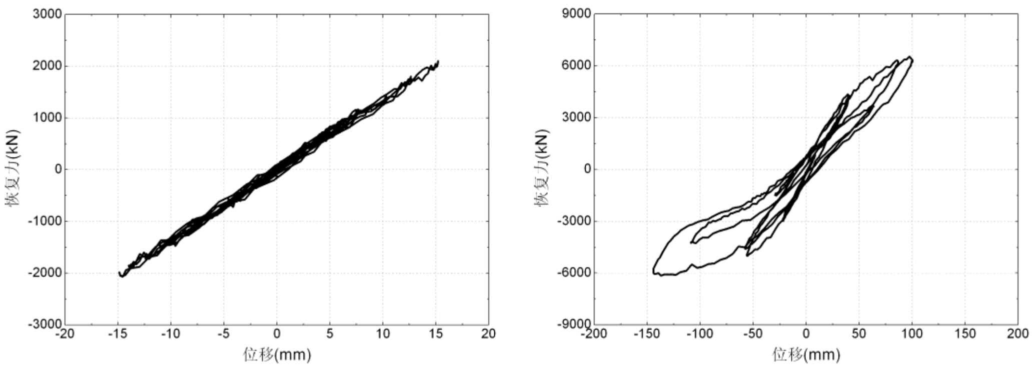


Figure 8. Hysteretic curve in frequently earthquake and rarely earthquake

## Conclusions

In this paper, the pseudo-dynamic seismic test of the vibration isolation foundation of the turbine-generator of a thermal power plant under 7 degree earthquake is conducted to study the seismic performance of the vibration isolation foundation under the horizontal earthquake. Under the action of rarely earthquakes, the foundation has good working performance. The restoring force - displacement curve of the structure under the action of frequent earthquakes is basically linear. Under the action of rare earthquakes, the energy dissipation capacity of the structure is better.

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