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A Comparison of the Mechanical Vibration Evaluation Standards of Steam Turbine Generator Foundation

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Abstract. In the paper, the basic design standards (GB50040-96 and ISO10816-2) of various mainstream steam turbine generators at home and abroad were reviewed and their similarities and differences were analyzed in detail. Moreover, the paper also provides the vibration test data on the disturbing points of the foundation and corresponding bearing bracket of three typical 600MW turbine generator units during normal operation so as to search for the relationship between vibration of bearing brackets and vibration of the foundation. The safety coefficient of the chosen foundations using GB50040-96 and ISO10816-2 were also given to compare the severity of each standard. It is hoped to provide designers with accurate grasp of various standards.

1 .Introduction

Due to the complexity of the process, thermal power plants need to use a lot of power machinery and equipment, especially rotary machines. The main body of the power plant is a steam turbine generator set with a speed of 3000r/min which is a large-scale precision rotary machine. Due to the requirements of process layout, the steam turbine generator foundation is a complex space frame structure system. As the capacity of power plant units continues to expand, the vibration requirements are getting higher and higher. Moreover, understanding of vibration on existing steam turbine generator foundation and their interconnection is significant for estimating the foundation vibration in an effective way.

Our country's GB50040-96^[1] (Code for Design of Dynamic Machine Foundation) and ISO10816-2^[2] (Evaluation of machine vibration by measuring on non-rotating parts, part 2: 50MW and above land-mounted large steam turbine generator set) are both important standards for evaluation the dynamic characteristic of steam turbine generator foundation. The former requires the vibration linear displacement of foundation disturbing point in the normal service of steam turbine generator is lower than 20 μ m, but ISO10816-2 uses the root mean square value of vibration linear speed of bearing bracket for evaluation, which is not over 3.8mm/s or 7.5 mm/s. This paper summarizes the GB50040-96 and ISO10816-2 and their applicability by combining with the dynamic testing results of typical 600MW steam turbine generator foundation. Furthermore, the severity of both so as to deepen the comparison and analysis of evaluation standards for steam turbine generator foundation was analyzed.

2 .Applicable standards

There are many standards for evaluation the steam turbine generator foundations home and abroad, for example, our country's Code for Design of Dynamic Machine Foundation [1] (hereafter briefly called



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“GB50040—96”), ISO [2], Germany DIN [3], some manufacturers of steam turbine such as Simens [4], Alston [5] has been also prepared their own enterprise standards. Both GB50040-96 and ISO10816-2 has been widely used for our country’s steam turbine generator foundation design and evaluation, so both are mainly cited for comparison purposes in the paper. GB50040-96 and ISO10816-2 respectively take the foundation disturbing point vibration linear displacement and bearing bracket vibration velocity root mean square value as reference value for their evaluation.

2.1 GB50040-96

GB50040-96 chapter V “steam turbine generator unit and motor foundation” is applicable for the design of foundation for steam turbine set (steam turbine generator, turbine blower) with working speed 3000r/min(and below)and motor (phase modulator and so on), it is the main reference for design of steam turbine generator foundation in our country. Its main characteristic requirements for foundation of unit during operation and startup: within the working RPM (2250-3750rpm), the vibration linear displacement of foundation disturbing point shall be within 20 μ m, and not over 30 μ m during startup (0-2250 rpm). Besides, this standard also specifies the value of disturbing force, and how to calculate the vibration linear displacement and so on. Fig.1 shows the envelop curve of allowable peak value of vibration linear displacement as specified in GB50040-96.

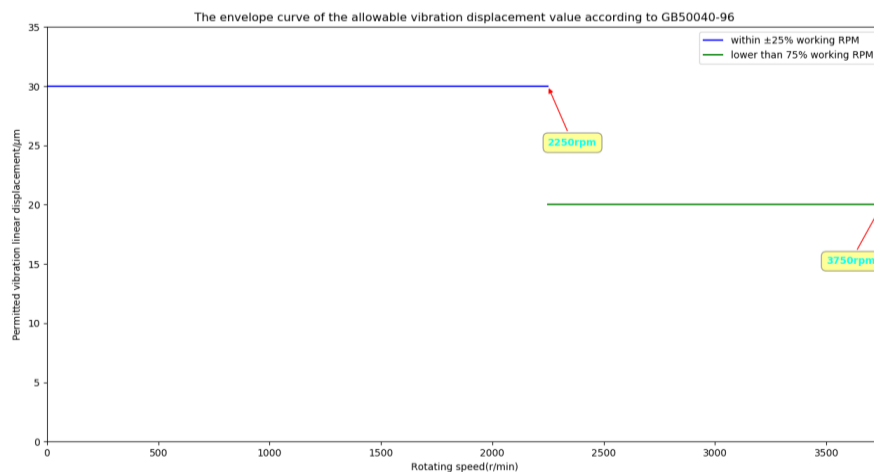


Figure1. The envelope curve of the allowable vibration displacement value according to GB50040-96.

2.2 ISO10816-2

ISO10816-2 is a standard for evaluation vibration of machine by measuring the non-rotating parts, the measurement must be done on bearing housing or frame base, especially both mutually perpendicular radial directions of each bearing. Its main requirements for generator unit in operation: general description on evaluation the intensity of vibration on machines. Defining the amplitude of vibration as the root mean square value of maximum vibration velocity taken from each bearing or frame base, the evaluation can be made for four zones of A, B, C, and D, there are different standard values for different zones. The meaning of zones were as followings:

Zone A: newly-operated machine, with vibration usually in this zone;

Zone B: usually the machines with vibration in this zone, suitable for long-term operation without restrictions;

Zone C: it is usually deemed that any machines with vibration in this zone are unsuitable for long-term continuous operation, without any remedies, the working hours of machine shall be limited;

Zone D: vibration within this zone usually cause damage to machine.

The limit values recommended for 50 MW and above land-mounted large steam turbine generator are shown as table 1, newly-operated unit can be evaluated according to bearing bracket vibration linear speed root mean square values at A/B zone boundary.

Tab.1 Recommended value for the critical velocity of steam turbine genetators' bearing brackets

Zone boundary	RPM of shaft/(r/min)	
	1500 or 1800	3000 or 3600
	vibration velocity root mean square value /(mm/s)	
A/B	2.8	3.8
B/C	5.3	7.5
C/D	8.5	11.8

Note: all are values of radial vibration measured at all bearings and axial vibration measured at thrust bearing under rated RPM and stable working situations.

2.3 Applicability

As for applicability of evaluation guidance, the measurement of vibration amplitude of foundation disturbing point specified by GB50040-96 is not easy, for example, the position of disturbing point is uneasily identified, but GB50040-96 is more suitable for foundation design.

The vibration of bearing bracket required by ISO10816-2 is closer to disturbing source, which is more suitable for reflecting the operation situations, however, the puzzle is how to properly appraise the vibration of bearing bracket during foundation design, besides, during modelling and model test, the rigidity of bearing bracket is not easy to simulate accurately, so, ISO10816-2 is almost suitable for all measurement and evaluation.

3 .Foundation Used in The Study

Three similar operating 600MW units were used for dynamic characteristic testing, this kind of unit is comprised of one HP and MP cylinder, two LP cylinders and one generator, manufactured by Shanghai Steam Turbine Co., Ltd and Shanghai Motor Co., Ltd, with shaft operating speed RPM 3000 r/min. The shaft system of this unit consists of HP and MP rotor, LP I rotor, LP II rotor, generator rotor and nine support bearings. The bearing bracket distribution is shown as figure 2, see figure 3 for distribution of corresponding disturbing point on bearing bracket foundation, total eight disturbing points. See table 2 for corresponding relation between bearing bracket and disturbing points.

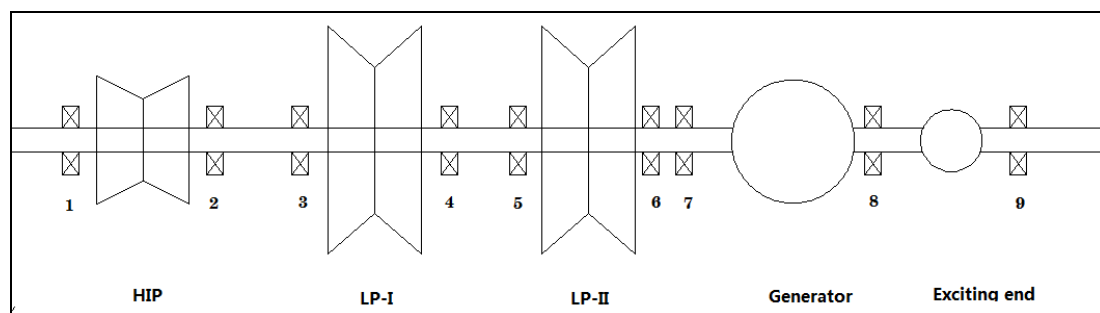


Figure 2. The distribution of bearing bracket of the steam turbine generator.

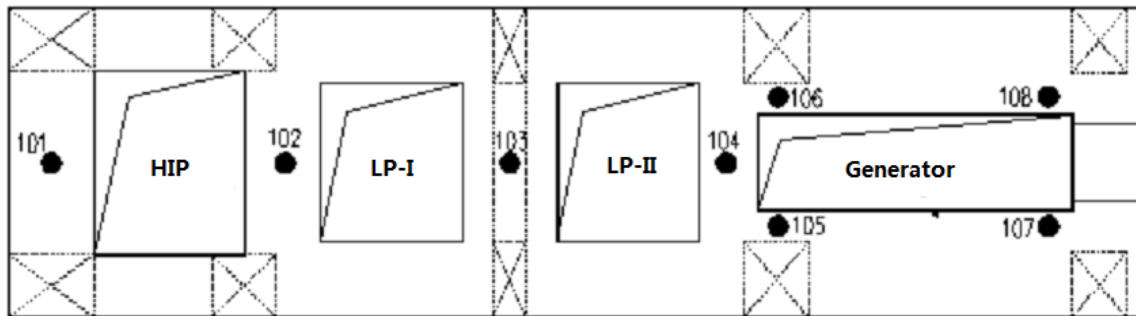


Figure 3. The distribution of disturbing points of the steam turbine generator.

Table 2. The mapping relationship between the bearing brackets and the disturbing points.

Bearing bracket No.	1#	2#	3#	4#	5#	6#	7#	8#
Corresponding disturbing points	#01	#02	#02	#03	#03	#04	#05,06	#07,08

4. Test Method

By measuring the vibration linear displacement and linear speed root mean square values at foundation disturbing point and bearing bracket under full load of generator unit, you can get all dynamic characteristic data of unit and foundation. During measuring, directly arrange the sensors on the corresponding points of foundation, any acquired signals shall be transferred into signal collector to get the maximum peak speed and root mean square value by analyzing and calculation, you can also get the vibration linear displacement by integration of speed signal, see figure 4 for testing process flow. Testing items include:

1. In normal service conditions of unit, measure the vibration of foundation and get the vibration linear displacement at disturbing point ;
2. In normal working conditions of unit, measure the vibration of bearing bracket and get the speed root mean square value of bearing bracket.

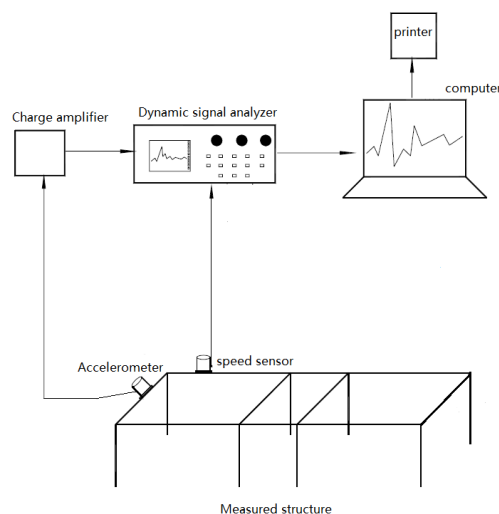


Figure 4. The flowchart of the vibration testing.

5. Comparison

The evaluation of ISO10816-2 adopts four zones of A, B, C, and D, wherein:

Zone A: newly-operated machine, with vibration usually in this zone;

Zone B: usually the machines with vibration in this zone, suitable for long-term operation without restrictions;

Zone C: it is usually deemed that any machines with vibration in this zone are unsuitable for long-term continuous operation, without any remedies, the working hours of machine shall be limited; under shaft RMP 3000 or 3600 r/min, recommended the A/B zone boundary value is 3.8 mm/s, and that of B/C zone is 7.5 mm/s. Combining with dynamic characteristic test results of typical 600 MW unit, the evaluation for severity of ISO10816-2 (including recommended A/B zone boundary values, B/C zone boundary values) and GB50040-96 is as below.

5.1 Test Results

Under normal service of steam turbine, collect the speed signals from respective disturbing points on bearing bracket and foundation of three same types of unit. Calculate and get the vibration velocity root mean square value of bearing bracket and vibration linear displacement at corresponding disturbing points of foundation, figure 5 shows the spatial distribution of vibration velocity root mean square values of bearing bracket and disturbing point vibration linear displacement values of foundation on B unit. Seen from above tables: the vibration velocity root mean square value of bearing bracket and linear displacement values at corresponding disturbing point of foundation are discrete, no obvious law of distribution

The positions of foundation disturbing points are, indeed, uneasy to identify, and rigidity of foundation is not uniform, so the measured vibration amplitude values are quite different, shown as figure 6, partial disturbing points have higher vibration amplitude, but some of others are lower vibration amplitude. Relative to foundation disturbing point, the bearing bracket is closer to the disturbing source of vibration, in theory, it shall be more capable to reflect the operation of unit. However, the vibration of bearing bracket is relatively complicated, this involves not only steam turbine structure and operation, but also the foundation itself, which can't be simply specified as a rigid body, the vibration of bearing bracket is inevitably under the affection of foundation, so the spatial distribution of speed root mean square value of bearing bracket is uneven.

Generally speaking, higher the vibration of bearing bracket, higher the vibration of foundation at corresponding disturbing point. This trend reflects on the diagram, however, the spatial variation trend of vibration on different positions of bearing bracket is not completely corresponding to the disturbing points, for uneven spatial distribution of foundation rigidity.

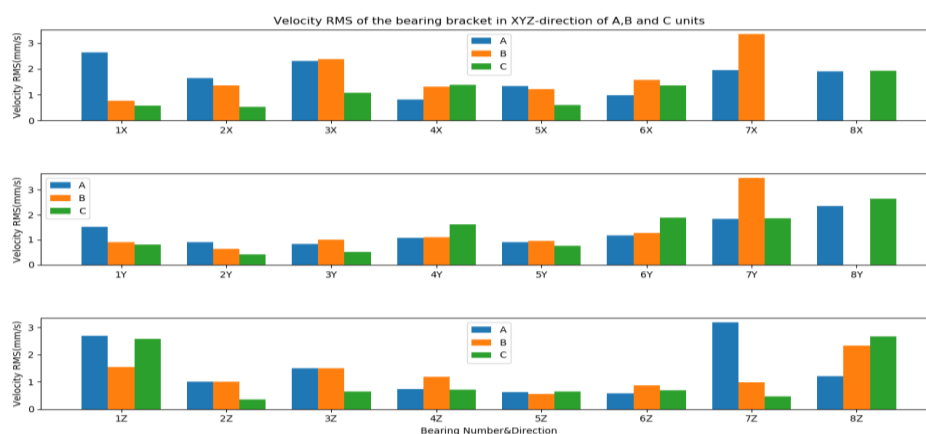


Figure 5. The RMS value of vibration velocity of the bearing bracket of ABC units.

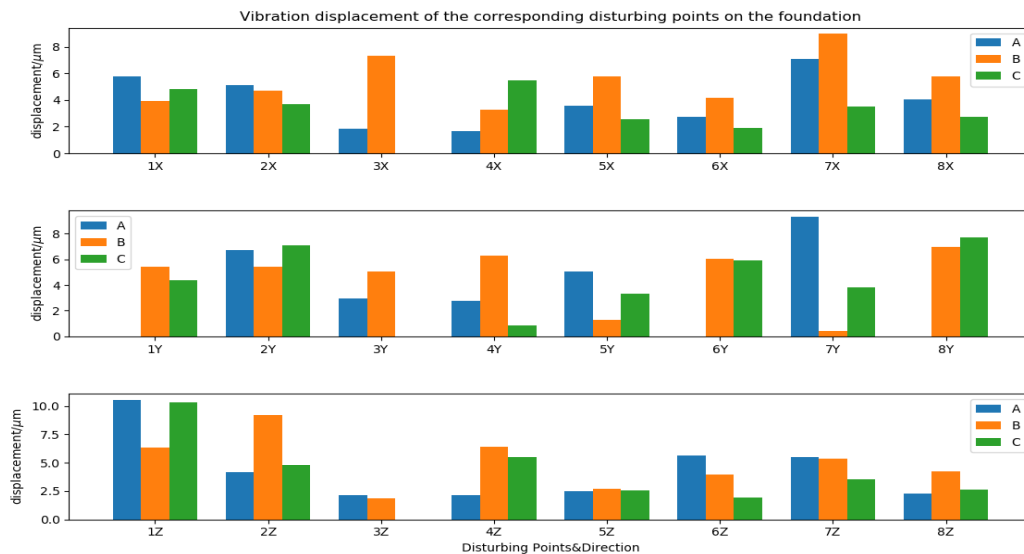


Figure 6. The vibration displacement of the corresponding disturbing points of ABC units.

5.2 Comparison of Safety Coefficient

For comparing the severity of GB50040-96 and ISO10816-2, this paper introduced a concept of safety coefficient, that is, for different system of standards, get the safety coefficient of controlled point by dividing actual measured value with permitted value for evaluation their severity. Fig.7 are comparison of safety coefficients of GB50040-96 and ISO10816-2 based generator units on different directions. It is found that:

1. Seen from vibration data for three generator units, the safety coefficient values of C are usually higher than the other two units, those of both unit A and unit B are almost equal (generally A is slightly higher than that of B). Seen from their values of safety coefficient on different directions, all three units are almost equal.

2. The maximum value of safety coefficient was obtained according to ISO10816-2 B/C zone boundary values, and the minimum comes from ISO10816-2 A/B zone boundary value. Which identify that ISO10816-2 A/B zone boundary values are the most stringent, ISO10816-2 B/C zone boundary values are the most easing, those of GB50040-96 are between both.

3. It is recommended that newly-operated unit shall be evaluated according to ISO10816-2 A/B zone boundary value (recommended vibration velocity root-mean-square value of bearing bracket is 3.8 mm/s), more conservative, higher operability; for long-term operation of unit, GB50040-96 is more conservative for safety purpose.

4. All analysis above only emphasis the comparison of the severity of both standards, their applicability shall be combined with engineering practice from aspects of operability and convenience, select the applicable standards for evaluation the dynamic characteristics of generator unit and foundation.

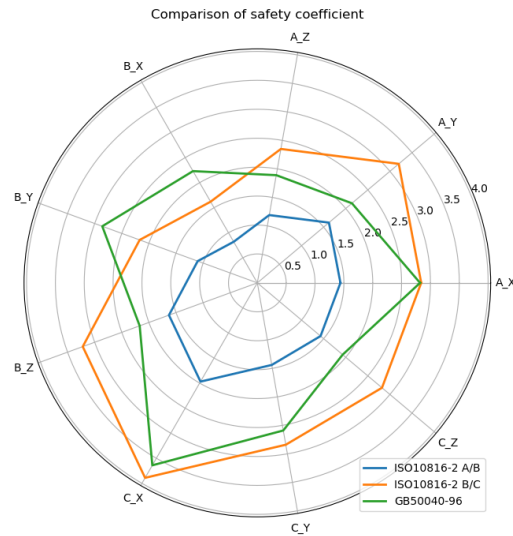


Figure 7. Comparison of safety coefficient of the corresponding units .

6. Conclusions

1. This paper summarizes the applicable standards for verifying the steam turbine foundation, especially the applicability of GB50040-96 and ISO10816-2.

2. Seen from dynamic characteristic test for three typical 600MW units under full load conditions: the root mean square value of bearing bracket vibration velocity and foundation disturbing point values of bearing brackets are discrete, no obvious law of distribution. Higher the vibration of bearing bracket, higher the vibration of corresponding foundation disturbing point, this trend was reflected in the test results, however, for uneven spatial distribution of foundation rigidity, the vibration of bearing brackets at different portion is not always synchronized with those corresponding disturbing points.

3. The safety coefficient was introduced and to analyze the severity of relating standards accordingly, in general, the boundary values for ISO10816-2 A/B zones are the most stringent, on the contrary, those for ISO10816-2 B/C zones are the most easing, those of GB50040-96 are between both. For a newly-operated unit, recommend ISO10816-2 A/B zone boundary values (recommended vibration velocity mean-root-square values of bearing bracket 3.8mm/s) for evaluation.

Acknowledgements

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