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E-05 GENERATING SETS

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Foreword:

This Guide is a part of CCS Rules, which contains technical requirements, inspection and testing criteria related to classification and statutory survey of marine products.

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GENERATING SETS

1 General provisions

1.1 Application

This Guideline applies to inspections of diesel generating sets for main power source and emergency power source in ships.

1.2 Normative references

CCS Rules for Classification of Sea-going Steel Ships;

CCS Rules for Materials and Welding;

IEC 60529: Degrees of protection provided by enclosures (IP code);

IEC 60092-301:1994{Ed.3.0} Electrical installations in ships – Part 301: Equipment-Generators and motors.

1.3 Terms and definitions

1.3.1 Diesel generating set is a generating set consisting of a diesel engine, a generator and their common bedplate, including an engine governor and a simple local instrument panel. If the panel is replaced by a local control box with safety and protection functions, the control box is to comply with the requirements of CCS Rules for Classification of Sea-going Steel Ships and be separately inspected, unless the box is indicated in the diesel engine certificate.

1.3.2 Emergency diesel generating set is a generating set consisting of an emergency diesel engine, an emergency generator and their common bedplate, including an engine governor, a simple local instrument panel, a double power starting device, coolers and cooling fans. If the above-mentioned accessories are not covered by the emergency diesel engine certificate, the accessories are to be certified by CCS. If the panel is replaced by a local control box with safety and protection functions, the control box is to comply with the requirements of CCS Rules for Classification of Sea-going Steel Ships and be separately inspected, unless the box is indicated in the diesel engine certificate.

1.3.3 Degree of protection means the protection which enables the generating set to operate without any injury or harmful impacts under the environmental conditions as defined in IEC 60529.

1.3.4 Emergency load means the maximum emergency load to be applied in an emergency on ships.

1.3.5 Rated power of a diesel engine is the continuous power of the diesel engine under certain environmental conditions, to be corrected for inland-waters ships and sea-going ships according to

the actual environmental conditions.

1.3.6 Steady-state governing characteristic curve of generating sets

Operating at the rated load and speed, the load of the generating set with a fixed governing mechanism changes reciprocally in single direction within the range from no load to full load and the curve is formed by connecting arithmetrical means of speed power characteristic loops.

1.3.7 Steady-state speed governing rate of generating sets

Set at rated load and rated speed, with load changing from no-load to full load or in a reverse way evenly or abruptly, the rate of difference between the stable no-load speed n_i and the rated speed n_N to the rated speed n_N is shown in percentage

$$\delta st = \frac{n_i}{n_N} \times 100 \quad \text{.....(1)}$$

where: δst– steady-state speed governing rate, in %;

n_i – stable no-load speed, in r/min;

n_N– rated speed, in r/ min.

1.3.8 Transient speed governing rate and stabilization time for generating sets

(1) Transient speed governing rate of generating sets means the rate of the difference between the minimum transient speed (nmin) or the maximum transient speed (nmax)and the speed (ni) prior to load change or the rated speed (n_N) to the rated speed (n_N), shown in percentage, where the steady-state speed governing rate is stabilized and a specified symmetrical load is suddenly taken off and then suddenly applied at the rated load and speed.

The transient speed governing rate δd at the maximum transient speed is to be calculated according to Formula (2).

$$\delta d = \frac{n_{\max} - n_n}{n_N} \times 100 \quad \text{.....(2)}$$

The transient speed governing rate δd at the minimum transient speed is to be calculated according to Formula (3).

$$\delta d = \frac{n_{\max} - n_i}{n_N} \times 100 \quad \text{.....(3)}$$

(2) Stabilization time means the time required from the commencement of speed variation until the speed returns to a level where its deviation from the steady-state speed at the related load is within the range of speed fluctuation rate. See Figure 1.3.8.(2)

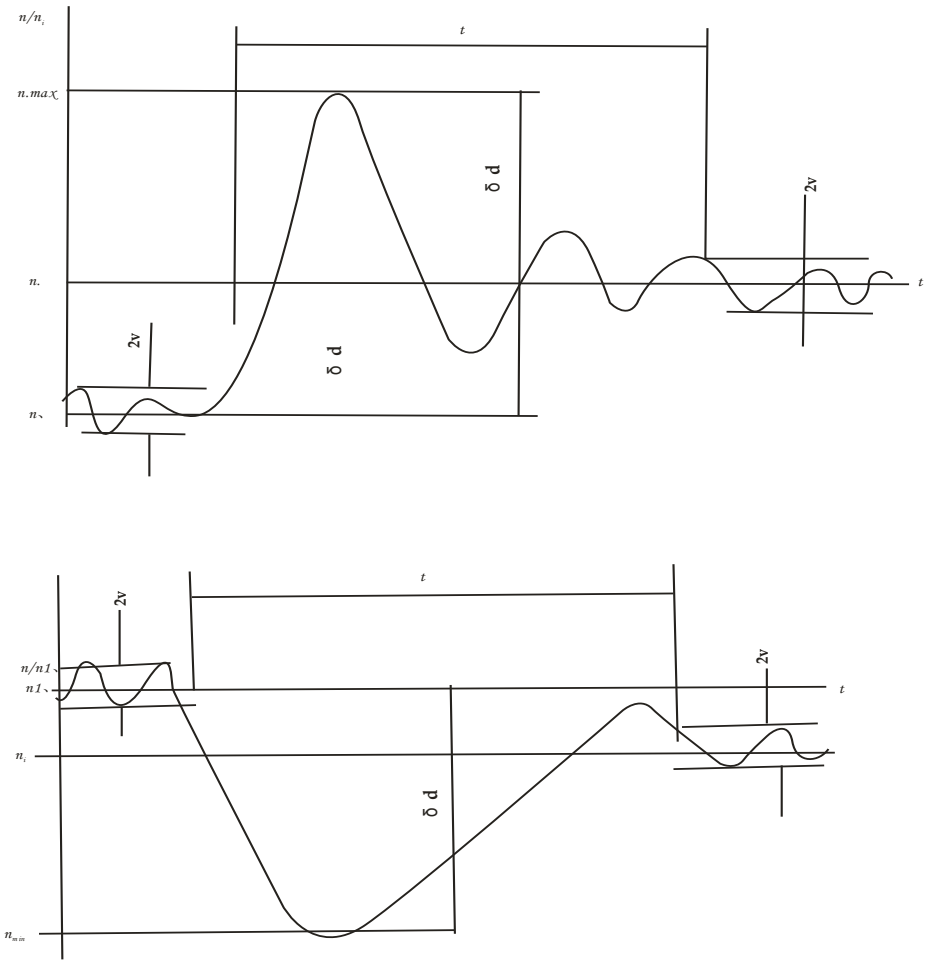

Figure 1.3.8.(2) Process of Transient Speed Change

n_N – rated speed; n_i – no-load speed; n_{max} , n_{min} – transient speed caused by load change

n_i – steady-state speed at applied load; t – time; ν – speed fluctuation

1.3.9 Insensitivity of governing system for generating sets

The insensitivity means the ratio of the maximum vertical distance Δ n between speed power characteristic loops to the rated speed n_N, shown in percentage, where the steady-state speed governing rate is stabilized and the load of the generating set changes reciprocally in single direction within the range from no load to full load. See Figure 1.3.9.

$$\delta = \left|\frac{\Delta n}{n_N}\right| \times 100 \text{ .....(4)}$$

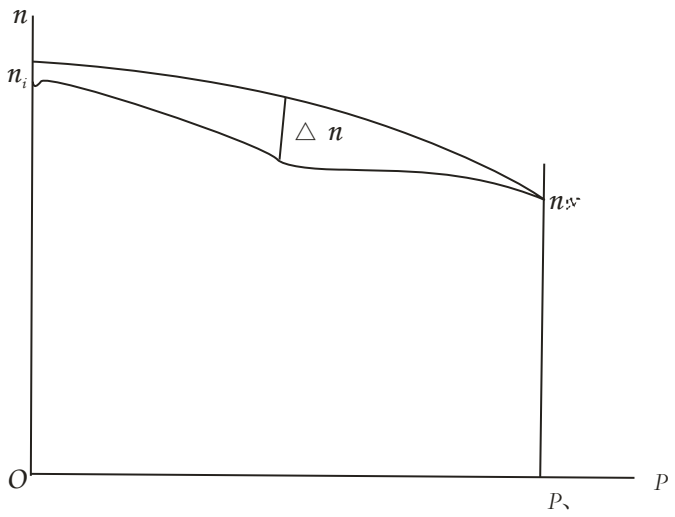

Figure 1.3.9 Insensitivity e of Governing System

1.3.10 Non-linearity of steady-state speed governing characteristics

The ratio of the maximum speed deviation as shown between the lines connecting the steady-state governing characteristic curve with the corresponding no load and rated load points to the rated speed, that is, the relative speed difference as shown between the line connecting no load and full load points of the governing characteristic curve and the straight line which is tangential to the steady-state speed governing characteristic curve and parallel to the connecting line. See Figure 1.3.10.

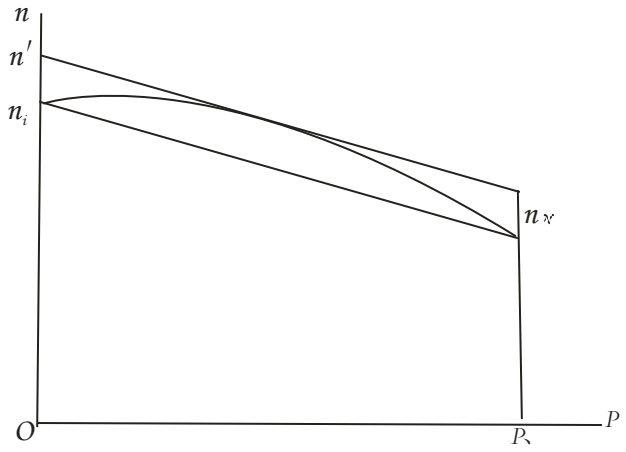

Figure 1.3.10 Non-Linearity of Steady-Speed Governing Characteristics

1.3.11 Speed fluctuation rate

Operating at any load within the range of no load to full load, the rate of the difference between the maximum speed n1 or minimum speed n2 measured at certain intervals and their average n_m to the average speed n_m is shown in percentage.

$$v = \frac{n_1 - n_m}{n_m} \times 100 \quad \text{or} \quad v = \frac{n_2 - n_m}{n_m} \times 100 \text{ ….. (5)}$$

where: v – speed fluctuation rate, in %;

m – average speed, i.e. $\frac{n_1 - n_2}{2}$, in r/min;

n1 – maximum speed, in r/min;

n2 – minimum speed, in r/min.

1.3.12 Steady-state voltage regulation rate

This is the ratio of the difference between the maximum or minimum voltage u within the loop reciprocally changing in single direction from no load to full load and the rated voltage u_N to the rated voltage u_N, shown in percentage, where the steady-state speed governing rate is stabilized and the excitation voltage regulation system remains unchanged to maintain the load power factor at its rated value.

$$\delta u = \frac{u - u_n}{u_n} \times 100 \text{ ……..…(6)}$$

where: δu– steady-state voltage regulation rate, in %;

u – maximum or minimum voltage, in V;

uN – rated voltage, in V.

1.3.13 Transient voltage variation and stabilization time

The rate of the difference between the minimum or maximum transient voltage u’ and the voltage u0 prior to load change to the rated voltage uN is shown in percentage where the steady-state speed governing rate is stabilized and a specified symmetrical load, of which the power factor is 0.4 (lag) or less, is suddenly applied and then suddenly taken off at the voltage regulation rate.

$$\Delta u = \frac{U' - u_0}{u_n} \times 100 \text{ ……..…(7)}$$

where: Δ u – transient voltage variation, in %;

U'– minimum or maximum transient voltage, in V;

u0– voltage prior to load change, in V.

Setting time is the time period starts from the voltage changes till the deviation between voltage and required voltage falls within 1-3% of rated voltage.

1.3.14 Voltage fluctuation rate

Operating at the set governing characteristics at any load from no load to full load, the rate of the difference between the maximum voltage u1 or the minimum peak voltage u2 measured at certain intervals and their average value um to the average voltage um is shown in percentage.

$$\theta = \frac{u1 - u_m}{um} \times 100 \text{ or } \theta = \frac{u2 - u_m}{um} \times 100 \text{ ….. (8)}$$

where: θ– voltage fluctuation rate, in %;

um– average voltage, i.e. $\frac{u1 - u2}{2}$, in V;

u1– maximum voltage, in V;

u2– minimum voltage, in V.

1.3.15 Difference of load sharing

The difference between the actual load on the ith one of generating sets operating in parallel and the total average load.

$$\Delta Pi = \left| \frac{Pi}{PiN} - \frac{SPi}{SPiN} \right| \times 100 \text{ …….....} \quad (9)$$

$$\Delta \Sigma i = \left| \frac{\Sigma i}{\Sigma iN} - \frac{S\Sigma i}{S\Sigma iN} \right| \times 100 \text{ …….....} \quad (10)$$

where: Δ Pi– difference of active load sharing, in %;

Qi – difference of passive load sharing, in %;

Pi – actual active power for the i^{th} generating set, in KW;

Qi – actual passive power for the i^{th} generating set, in Kvar;

ΣPi – total actual active power for generating sets in parallel operation, in KW;

ΣQi– total actual passive power for generating sets in parallel operation, in Kvar;

PiN– actual active power for the ith generating set, in KW;

QiN– actual passive power for the ith generating set, in Kvar;

ΣPiN– total rated active power of generating sets in parallel operation, in KW;

ΣQiN– total rated passive power of generating sets in parallel operation, in Kvar.

2 Plans and documents

2.1 The following plans and documents are to be submitted to CCS for information:

(1) General plans;

(2) List of components, including diesel engine and generator;

(3) Power load calculation of ship (where applicable)

2.2 Torsional vibration calculations should been approved by CCS (applicable to diesel engines rated over 100 kW for sea-going ships and diesel engines rated over 220 kW for inland-waters ships).

3 Materials and components

3.1 Materials and components are to comply with relevant requirements of CCS Rules.

4 Design and technical requirements

4.1 Generating sets are to comply with the requirements regarding main/emergency power sources in ships as specified in CCS Rules for Classification of Sea-going Steel Ships.

4.2 In general, the rated power of a generating set is not to be more than 85% of the rated power of the diesel engine (note: different cooling conditions in inland-waters ships and sea-going ships lead to different rated powers of diesel engines), unless the diesel engine is associated to the set such as to ensure compliance of the dynamic performance test with the requirements of CCS Rules for Classification of Sea-going Steel Ships.

4.3 The results of torsional vibration calculations are to comply with the requirements of CCS

Rules for Classification of Sea-going Steel Ships.

5 Selection of typical samples

Samples for type test are at least to be representative generating sets with maximum rated power.

6 Type test

6.1 The type test of generating sets are at least to include the following items:

(1) Visual examination;

(2) Cold insulation resistance test;

(3) Alarm for low pressure of lubricating oil;

(4) Alarm for high temperature of cooling water;

(5) Over speed protection test;

(6) Starting test;

(7) Operating test;

(8) Measurement of torsional vibration (according to comments on plans);

(9) Load test;

(10) Overload test;

(11) Measurement of steady-state governing characteristics;

(12) Measurement of speed fluctuation rate;

(13) Measurement of transient speed governing and stabilization time;

(14) Measurement of voltage regulation range;

(15) Measurement of steady-state voltage regulation;

(16) Measurement of voltage fluctuation rate;

(17) Measurement of transient voltage variation and stabilization time;

(18) Parallel operation test or load bridging test;

(19) Thermal insulation resistance test.

6.2.1 Test instrumentation

(1) The accuracy of ammeters, voltmeters, power meters, frequency meters and other electrical instruments is not to be less than grade 0.5, and the accuracy of power factor meters is not to be less than grade 1.0.

(2) The accuracy of thermometers, manometers and other measuring instrument of thermal parameters are not to be less than grade 2.5.

The local instrument panel may be used in routine tests of generating sets.

(3) The accuracy of instrument transformers is not to be less than grade 0.5.

(4) Load equipment

① In the case of water resistance as active load, unbalanced degree of three-phase current is to be less than 3% of rated current.

② In the case of induction regulator as passive load, operation is to be carried out in unsaturated zones.

③ Locked-rotor asynchronous motors or water resistance with linear reactors may be used as active load and if not restricted, induction regulators may be used as passive load.

④ The load test of generating sets may be carried out by means of energy feedback grid.

Such means is not to be used in test of governing and voltage regulating characteristics of generating sets.

(5) The instruments, meters and oscilloscopes used in test are to be furnished with certificates of periodical calibration.

(6) The expected maximum range of test data is to be within 20% to 90% of the range of measuring instruments.

6.2.2 Visual examination of generating sets

Prior to the test, the installation quality of common bases, coupling screws and various components and the alignment of shafting is to be examined; governor handle is to be examined for its required position and flexibility in stopping the generating set; the normal levels of lubricating oil and fuel oil are to be checked; the fuel system is to be deaerated; accessories, pipelines and electrical lines are to be examined for their reliable connection; pipelines are to be examined for leakage of oil or water; the starting system is to be examined for its normal condition (whether the pressure of the starting air receiver is within the specified range or battery capacity is normal); and ready-for-operation condition of valves is to be checked.

6.2.3 Examination of insulation resistance for generators

Check whether the winding insulation resistance of generating sets falls within the range as specified in 5.16 before starting and after shutdown. The voltage rating of the insulation test instrument used is to be as specified in Table 6.2.3.

Table 6.2.3

Rated voltage of generators, in V	Voltage rating of insulation test instruments, in V
≤ 500	500
500 ~ 1000	1000
3000 ~ 6300	2500

6.2.4 Examination of test run of generating sets

When the generating set is considered to be in normal condition upon visual examination and insulation resistance examination, the diesel engine is to be started and its speed gradually increased to the rated one according to the procedure specified in its operation and maintenance instructions, checking whether the diesel engine has any abnormal noise, whether its thermal parameters are within the required range, whether there is leakage of oil or water, whether the voltage of the generating set is ready for excitation and to what extent the voltage may be basically regulated.

6.2.5 Inclination test of generating sets

Generating sets with rigid coupling are to be subject to trim test. Mounted on the bench with a fixed inclination angle of 10^{o}, the generating set is to operate for 1 h respectively at trim by bow and trim by stern under rated operating conditions. The operation is to be smooth without abnormal vibration, continuous shock or friction of bearings or leakage of lubricating oil.

6.2.6 Starting performance test of generating sets

Starting is to be smooth at the ambient temperature of not less than 5℃without preheating of cooling water and lubricating oil for generating sets and at the ambient temperature of not less than 0℃ (preheating allowed if it is difficult to start) for emergency generating sets. Five satisfactory starts of six consecutive ones at intervals not exceeding 1 min qualify the generating set.

Determination of starting time:

During the type test, starting time is to be recorded by the oscilloscope whereby speed signals are sent to the transient speed gauge and then to the oscilloscope for photographing. During the routine test, starting time may be recorded by a stopwatch and is to be the algebraic sum of all starting times divided by the number of successful starts.

The time required for emergency generating sets from starting to no-load speed is not to be more than 10 s.

6.2.7 Examination of range of steady-state speed governing rate

The steady-state speed governing knob is to be put at the minimum position on the governor. The generating set is to operate at the rated load and speed. The no-load speed or frequency after removing all loads is to be recorded. The knob is then to be put at the maximum position on the governor to repeat the above test and obtain the minimum and maximum permanent steady-state speed governing rate.

6.2.8 Measurement of steady-state speed governing characteristics

The generating set is to operate at the rated active load and rated speed with steady-state speed governing within 3% to 5%. The governing handle is to be fixed to slowly change the load from 100% to 0% and then from 0% to 100% of the rated load in single direction (reciprocal load governing in one load condition not allowed and measuring points in loading direction or unloading direction not to be less than 5). The steady-state speed or frequency and corresponding power after load change is to be measured. Tests are to be carried out continuously for three times (a single test allowed for the routine test). Where the characteristics are basically stable in each test cycle, the average characteristic curve of one of the cycles is to be taken for obtaining the insensitivity ε of the governing system, the non-linearity ν of governing characteristics and the steady-state speed governing rate δst.

6.2.9 Measurement of speed fluctuation rate of generating sets

The speed variation of the generating set at the rated speed and at 100%, 75%, 50% and 20% of the rated load and no load is to be recorded by the oscilloscope (associated with a transient speed gauge), and each operating condition is to be maintained for 1 to 2 min. Frequency meter is allowed in routine tests.

6.2.10 Measurement of transient speed governing rate and stabilization time of generating sets

The generating set is to operate for 5 to10 min at the rated active load, then all loads are to be suddenly taken off, and 50% of the rated load applied. Additional 50% of the rated load is again to be applied after stabilization. Speed variation and stabilization time are to be recorded by the oscilloscope (associated with a transient speed gauge) or other effective test means.

The test is to be carried out continuously for three times (one sudden load change test to be carried out when one condition is stabilized), and the average values of three tests are to be taken as test results.

Steady-state speeds (frequencies) before or after the sudden load changes are to be recorded by

measuring instruments.

6.2.11 Examination of setting range of no-load voltage of generating sets

When the generating set is started to no-load speed, the generator is to be ready for excitation and then the voltage-setting potential device is to be adjusted to observe any voltage change within 95% to 105% of the rated voltage.

6.2.12 Measurement of steady-state voltage regulation of generating sets

The generating set is to operate into the hot condition at the rated power and speed. Then the load is to be taken off, and the generating set is to operate from no load to 100% of the rated load and again to no load, with the power factor of 0.8 (lag) being kept and the load changed slowly in single direction. Measuring points in each direction is not to be less than 5, including 20% of the rated load. The load, current, voltage and frequency are to be recorded at each point.

6.2.13 Measurement of voltage fluctuation rate of generating sets

The generating set is to operate at the rated power factor, and the voltage fluctuation at 20%, 50%, 75% and 100% of the rated load is to be recorded by the oscilloscope. Voltmeter is allowed in routine tests.

6.2.14 Measurement of transient voltage variation and recovery time of generating sets

After measuring the steady-state voltage regulation, the load is to be taken off, and then a symmetric current equal to 60% of the rated current is to be suddenly imposed and taken off at no-load operation, with the power factor being less than 0.4 (lag).

The changes in three-phase voltage and one-phase current are to be recorded by the oscilloscope for three times, of which the average values of the maximum ones are to be taken as test results.

6.2.15 Measurement of noise of generating sets

The generating set is to operate at the rated speed and load, and the noise at 50% and 100% of the rated load and in no-load condition is to be measured. This may be done in conjunction with the load test.

Measurement can be carried out by means of weighting network A in a noise laboratory or an ordinary laboratory complying with GB 1859.

Ambient noise level is to be at least 10 dB less than the noise of the generating set to be tested, without any interference by any accidental sound source.

Measuring point is to be as high as the cylinder end, 1 m from the main body of the generating set, especially the supercharger of the diesel engine and the air outlet of the generator.

Three measurements are to be taken at each measuring point, and the difference between every two measurements is not to be more than 2 dB. The ambient temperature, humidity, atmospheric pressure, date, noise lever LP (A) at each measuring point and ambient noise level are to be recorded.

6.2.16 Measurement of torsional vibration of generating sets

(1) The amplitudes and stresses (or torques and angles) of torsional vibration in no-load condition is to be measured from the minimum steady-state speed to 110% of the rated speed.

(2) The amplitudes and stresses (or torques and angles) of torsional vibration at the rated load is to be measured within 95% to 100% of the rated speed.

6.2.17 Load test of generating sets

The generating set is to operate with a stabilized speed governing rate and the factor power of 0.8 (lag) and with no load for 5 min, and to operate at 25%, 50% and 75% of the rated load for 10 min respectively. Then the load is to be increased to the rated one and the speed governed to the rated one for at least 2 h continuous operation. The power, frequency, voltage and oil consumption are to be recorded at half-an-hour intervals.

6.2.18 Overload test of generating sets

After the load test, the overload test is to be carried out at once to 110% of the rated load for 0.5 h.

6.2.19 Test of over speed protective devices of generating sets

The setting speed of the over speed protective device is to be adjusted in no-load condition and when the speed of the diesel engine reaches 113 º to 115 º of the rated speed, the over speed protective device is to act promptly to stop the diesel engine. The test is to be carried out successfully for three times.

6.2.20 Test of parallel operation of generating sets

(1) The test is to be carried out after satisfactory testing of individual generating sets. The steady-state speed governing rate of generating sets in parallel operation is to be consistent so far as practicable.

(2) The load of the generating set in operation is to be increased to 40% of the rated load with the power factor being 0.8 (lag), and the voltage and frequency of the generating set to be put into parallel operation are to be regulated to a level slightly higher than those of the generating set in operation. When the generating sets are in parallel operation, the total load is to be increased to 75% of the rated load as a reference point for speed governing of generating sets in parallel operation to reach a basically consistent sharing between active power and passive power. Once power sharing is made, further adjustment is not allowed. The total load is then to be changed in single direction: 75%→100%→75%→50%→20%→50%→75%, with the power factor of total load being kept at 0.8 (lag), and the active power sharing Δ P and passive power sharing Δ Q are to be calculated. Operation at 90% of total power is to last for 1 h for observation of the stability of parallel operation.

When the generating sets operate in parallel at 25% to 50% of the load, the asynchronous motor having 25% of the capacity of the smaller generating set is to be started directly to observe the stability of parallel operation.

6.2.21 Measurement of mechanical vibration of generating sets

The maximum vibration point is to be checked from the starting speed to the rated speed. After setting the rated speed and load, the effective vibration speed is to be measured at each measuring point in operating parts of the generating set in three directions at 50%, 100% and 110% of the rated load. The distribution of measuring points is shown in Figure 6.2.22.

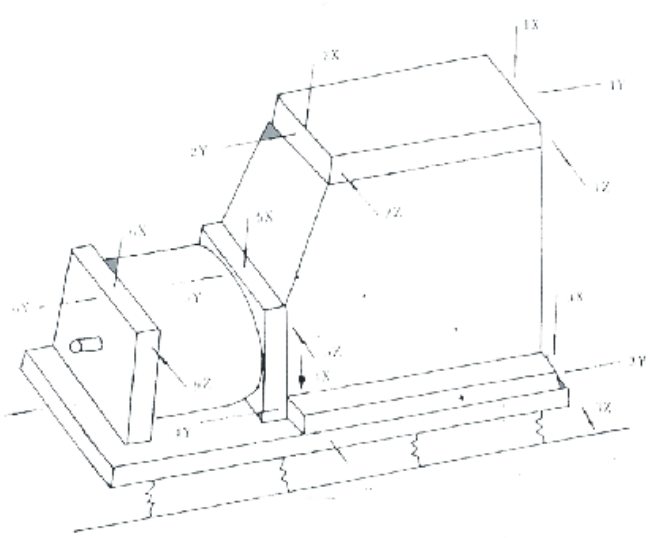

Figure 6.2.22 Distribution of Measuring Points

7 Unit/batch inspection

7.1 Upon approval of design and after completion of installation, commissioning and routine inspections by the assembling manufacturer, the unit/batch inspection is to be carried out.

7.2 The routine inspection report is to be submitted together with an application for inspection to CCS.

7.3 Where generating sets in large batches are to be delivered not ship by ship, the Surveyor is to sample at least 5% of them, based on 100% routine tests by the manufacturer.

7.4 Unit/batch test is to include the following items:

(1) Visual Examination;

(2) Cold insulation resistance test;

(3) Alarm for low pressure of lubricating oil;

(4) Alarm for high temperature of cooling water;

(5) Over speed protection test;

(6) Starting test (applicable to generating sets with starting batteries or starting air supply only);

(7) Operating test;

(8) Load test for 2 h and overload test for 0.5 h;

(9) Measurement of steady-state governing characteristics;

(10) Measurement of speed fluctuation rate;

(11) Measurement of transient speed governing and stabilization time;

(12) Measurement of voltage regulation range;

(13) Measurement of steady-state voltage regulation;

(14) Measurement of voltage fluctuation rate;

(15) Measurement of transient voltage variation and stabilization time;

(16) Parallel operation test or load bridging test;

(17) Thermal insulation resistance test.

7.5 The generating sets, of which diesel engines and/or generators are not certified by CCS, are to comply with the requirements for type test, with their diesel engines and/or generators being subjected to type test.