Guideline No.: M-04(201510)

M-04

TRANSMISSION GEARS

Issued date: October 20,2015

Foreword:

CCS Product Inspection and Testing Guideline (hereinafter referred to as this Guideline) contains the technical requirements, inspection and testing criteria related to classification and statutory survey of marine products to be applied for CCS approval/inspection.

This Guideline frees the users to adopt other test methods and requirements which are equivalent to or are stricter than this Guideline.

This Guideline is published and updated by CCS, and is released at http://www.ccs.org.cn. Your comments or suggestions are welcomed and may be sent to our email addressed mp@ccs.org.cn.

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TRANSMISSION GEARS

1 Application

This Chapter applies to type approval and inspection of forged steel inside and outside mesh involute straight-tooth gears, helical gears and herringbone gears which are capable of reversion, speed reduction, engaging and disengaging, and bearing propeller thrust, transmission gears used in main propulsion machinery and generator-driving auxiliary machinery where the transmitted power is equal to or more than 100 kW, and their variants (such as clutches, reduction gears). For other types of transmission gears, reference may be made to in this Chapter.

2 Normative references

2.1 CCS Rules for Classification of Sea-going Steel Ship.

2.2 CCS Rules for Materials and Welding.

3 Terms and definitions

3.1 For definitions of terms such as products inspection, design approval, type approval, prototype test, sample, unit/batch inspection and final testing, see 3.1.2 of Chapter 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ships.

3.2 For definitions such as product performance parameters, refer to Chapter 10 and its Appendix, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

4 Plans and documents

The following plans and technical documents are to be submitted by the applicant according to this paragraph together with an application for approval.

4.1 The following plans and documents are to be submitted for approval:

(1) General view (longitudinal and transverse sections);

(2) Details of pinions and wheels, including ring gear, where applicable, and parameters necessary for calculation of load capacity;

(3) Gear shafts;

(4) Bosses, if any;

(5) Driving shaft, clutches and/or couplings;

(6) Other power transmitting parts;

(7) Transmission gearing casing, incl. seating for propeller thrust, if any;

(8) Basic sizes of the tooth profile of the tools;

(9) Calculations of the load capacity of gears;

(10) Calculations of shaft strength;

(11) Calculations of clutch and (or) coupling strength;

(12) Calculations of combined dynamic reaction forces and their acting direction for sliding bearings of transmission gearing;

(13) Details of heat treatment of gears;

(14) Technical details (physical and chemical properties list and acceptance criteria) of materials of main parts such as casings, gears, shafts;

(15) Details of welding procedures for casing of gears or transmission gearing, if any;

(16) General view of built-in oil pump of transmission gearing and general view of cooler; if the oil pump and cooler are purchased, corresponding types and technical specifications are to be

provided (oil pumps and coolers with rated transmission capacity equal to or greater than 0.735 KW/r/min are to comply with paragraph 4.5.3);
(17) Schematic diagrams of lubricating oil system, cooler system, hydraulic schematic diagram of control system and electrical schematic diagram of safety alarms, if any;
(18) Main performance specifications;
(19) Routine test program, acceptance specifications for delivery and type test program.

4.2 The following plans and documents are to be submitted for information:
(1) Friction plate transmission torque calculation;
(2) Specimen of instructions, nameplates and manufacturer's quality certificates for products;
(3) Non-destructive test standard (including ultrasonic test, magnetic particle test and liquid penetrant test).

4.3 Other documents to be submitted:
(1) Particulars of the manufacturer (including history and current situation) and description of production history. If the products have been specifically verified or appraised, related reports and certificates may be attached;
(2) A quality control plan for the products to be approved is to be developed by the manufacturer and submitted to CCS for approval. This quality control plan is to specify the quality assurance and control methods used in the manufacturing process according to the technical requirements or standards for the products. The quality control plan is to include an inspection plan after approval, and to reflect in particular the inspection and test requirements of CCS;
(3) For manufacturers applying for CCS type approval A, a whole set of quality management system documents covering the products to be approved and complying with ISO9000 standard or an equivalent standard is also to be submitted, of which the procedure documents of inspections and tests according to requirements of CCS rules are to be approved by CCS.

5 Materials and components

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

6 Evaluation of welding procedure

The welding procedure for casings is to be evaluated according to CCS Rules for Materials and Welding.

7 Design and technical requirements

7.1 Material requirements

7.1.1 Shafts, gears, wheel's rim (if any), couplings, etc. of the transmission gearing are to be made of steel forgings, and the materials of such forgings are to be in accordance with the requirements of Chapter 5, PART ONE of CCS Rules for Materials and Welding.

7.1.2 For gears of through-hardened steels, provision is to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified tensile strength of the wheel material is not to be more than 85% of that of the pinion and not to be less than 490 N/mm^2.

7.1.3 The full specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburized gearing.

7.1.4 Where it is proposed to use alloy steel forgings, the requirements in Chapter 7 and Chapter

8, PART ONE of CCS Rules for Materials and Welding are to be complied with.

7.2 Structural requirements

7.2.1 Tooth form is to comply with the following requirements:

(1) the roots of teeth are to be formed with smooth fillets of a radius not less than 0.25 mm;

(2) where the ratio of working length over the gear faces to reference diameter of pinion exceeds 1.5, the ends of the teeth are to be chamfered;

(3) the teeth of pinions and wheels are to be suitably relieved on flanks in cases where any of the following conditions applies:

① normal module of teeth exceeds 6 mm;

② addendum of pinion teeth exceeds 65% of total working depth of engagement;

③ ratio of total working depth of engagement to normal pitch of teeth exceeds 0.75.

7.2.2 Tooth face is to comply with the following requirements.

(1) The hardened layer of the surface-hardened gear is to be distributed over and extended to the whole tooth surfaces and fillets.

(2) For nitrided gears, the depth of nitrided layer is generally to be greater than 0.40 mm.

(3) For surface-hardened gears (expect the nitrided ones), the depth of hardened layer is generally not to be less than 0.15 mm.

(4) For carburized gears, the surface hardness is not to be less than HRC 58.

7.2.3 Gears are to comply with the following requirements.

(1) The grade of accuracy of gear cutting is not to be less than 7 for diesel engines and not less than 6 as specified in GB/T 10095 for turbines.

(2) Where bolts are used to secure the side plates to rim and boss of the wheels, the torque-transmitting bolts are to be reamer bolts tight fit in holes and the nuts are to be suitably locked.

7.2.4 Calculation of gear shaft diameter is to comply with the following requirements.

(1) The diameter d of quill shafts is not to be less than the value obtained from the following formula:

$$d = 100\sqrt[3]{\frac{400N_e}{n_e\sigma_b}}mm$$

where: N_e – maximum continuous output transmitted by the shaft, in kW;

n_e – speed of the shaft at N_e, in r/min;

σ_b – minimum tensile strength of shaft material, in N/mm^2, but not exceeding 1100 N/mm^2.

(2) The diameter of gear shaft is to be calculated in accordance with Chapter 11, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

(3) Where the gear is fitted on the gear shaft by key or shrink-fit, the diameter of gear shafts at the fitting area is to be increased by 5% over the value determined in 7.2.4(2).

(4) Where the wheel shaft is driven by only one pinion or by two pinions arranged to subtend an

angle at the centre of the shaft of less than 120°, the diameter of the wheel shaft between bearings is at least to be increased by 15% over the value determined by 7.2.4(2); where it is driven by two pinions arranged to subtend an angle at the centre of the shaft of more than 120°, the diameter of the wheel shaft between bearings is at least to be increased by 10% over the value determined in 7.2.4(2).

7.2.5 Gear casings are to comply with the following requirements:

(1) The manufacturing process of gear casings of welded construction is to be in accordance with the relevant requirements of CCS Rules for Materials and Welding.

(2) Gear casings are to be of sufficient strength and rigidity, and are to be provided with sight openings and adequate venting devices.

(3) Where thrust bearing is provided inside the gear casing, the latter is to be adequately strengthened.

7.2.6 Grade of meshing

Tooth faces are to be evenly meshed. For diesel or turbine transmission gearing, the contact marking is not to be less than Grade 7 or Grade 6 respectively defined in GB/T 10095.

7.2.7 Connections are to comply with the following requirements:

(1) Where the coupling of the output shaft is fitted by means of oil pressure injection, the actual shrinkage allowance δ is to comply with the requirements in Section 3, Chapter 11, PART THREE of CCS Rules for Classification of Sea-going Steel Ships. Where shrink-fit is employed, 0.03 in the formula may be ignored.

(2) For the shrink-fit of rim to boss, boss to shaft and the shrink-fit of other items, a safety factor against slippage in design is not to be less than 2.8 C, where C is a coefficient having the following values:

(3) C = 1 for gears driven by turbines or electric motors and gears driven through a hydraulic, electromagnetic or high elasticity coupling;

(4) C = 1.2 in other cases.

(5) Clutches and couplings in the transmission gearing are to comply with the requirements in Section 3, Chapter 11, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.3 Non-destructive tests

7.3.1 An ultrasonic examination is to be carried out on all gear blanks where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm.

7.3.2 Magnetic particle or liquid penetrant examination is to be carried out on all surface-hardened teeth and on the finished machined teeth of through-hardened gears.

7.3.3 An ultrasonic examination is to be carried out on input shafts and intermediate shafts where the finished diameter is equal to or more than 250 mm.

7.4 Heat treatment

Heat treatment is to be in accordance with relevant requirements in Chapter 5, PART ONE of CCS Rules for Materials and Welding.

7.5 System arrangement and alarm devices

7.5.1 Lubrication and cooling systems are to comply with the following requirements.

(1) The construction and arrangement of lubricating oil and cooling systems of transmission gearing are to be in accordance with the requirements in 1.2.1.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

(2) Lubricating oil is to be efficiently conveyed to all bearings, meshed gears and other portions requiring lubrication. The arrangement of oil pockets of sliding bearings is to be such that the effect of combined dynamic force of bearings is taken into account.

(3) The lubricating oil system of transmission gearing for diesel engines is to be independent.

(4) Where lubricating oil for the transmission gearing is circulated separately under pressure, a standby lubricating oil pump is to be provided. For ships having more than one transmission gearing, a single standby lubricating oil pump may be accepted.

(5) Thermometers and pressure gauges are to be provided in the pressure lubricating oil systems.

① A working oil pressure gauge is to be fitted in addition when a hydraulic system is employed.

② An oil level indicator is to be provided for the oil sump of splash lubrication.

(6) Where the lubricating oil for the transmission gearing having a rated transmission capacity equal to or greater than 0.735 KW/r/min is circulated under pressure, provision is to be made for efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the supply of filtered oil. Magnetic filters are to be provided for turbine transmission gearing.

(7) The lubricating oil temperature in the transmission gearing is not to exceed 70℃, and not to exceed 80℃ if a roller bearing is fitted.

(8) Cooling pipes passing through gear casings are not to have any detachable joint.

7.5.2 Alarm

Transmission gearing is to be fitted with alarm devices for low pressure of lubrication oil and in addition, an alarm device for high temperature of lubrication oil is to be fitted in case of transmission gearing whose input power is more than 1470 kW.

7.5.3 Emergency devices

For hydraulically controlled transmission gearing, emergency mechanical means are to be provided to ensure that the ship can run at a reasonable speed in the event of failure of hydraulic control systems.

7.5.4 Markings

For reversible gearing, the directions of the lever or hand wheel for ahead and astern running are to be marked at the control station. As a common practice, to push the lever forward or to turn the hand wheel clockwise is the way to move the ship ahead.

7.6 Performance requirements

7.6.1 For reversible gearing, the speed at free clutching and declutching is not to be less than 50% of the rated speed.

7.6.2 For reversible gearing, the time required for reversal is not to be more than 15 s (the time required for reversal is the time from starting to reverse ahead (astern) running to start of astern (ahead) running at normal reversal speed).

7.6.3 Reversible gearing is to be capable of transmitting a reversing power equal to 70% of the

rated ahead running power.

7.6.4 The friction elements of clutches are not to give any slip in normal running. While the clutch is disengaged, the propulsion shafting is not to be dragged along by the driving shaft.

7.6.5 The maximum torque transmitted by the transmission gearing clutch is, in general, not to be less than 1.5 times the rated torque of the main engine.

7.6.6 No abnormal vibration, impact, noise, heating and oil leakage is allowed during running of transmission gearing.

7.6.7 The external painting of transmission gearing is to be fine, firm, uniform and of same color; no scaling or peeling is allowed.

7.6.8 Direct reading instrumentation to monitor oil temperature and pressure is to be provided for transmission gearing, and the instrumentation panel is to be well capable of reducing vibration.

7.7 Tests

7.7.1 Material tests

Chemical composition and tests of materials are to comply with the relevant requirements of CCS Rules for Materials and Welding.

7.7.2 Gear balance tests are to comply with the following requirements:

(1) All pinion and gear wheels are to be statically balanced. Where the linear velocity at the reference circle exceeds 25 m/s, dynamic balance test is to be made. Driven parts of the coupling are to be attached to the gear before balancing. The residual dynamic unbalance is not to exceed:

$6.0\ m/n \times 10^2$ N mm, for transmission gearing of diesel engines;

$2.4\ m/n \times 10^2$ N mm, for transmission gearing of turbines.

where: m – mass of rotating components, in kg;

n – maximum working speed of components, in r/min.

(2) The balance test may, however, be omitted for diesel engine gearing, provided that the rotating components are of solid forged construction or have a solid forged centre with shrunk-on rim, and in both cases are machined to give a concentric and uniform cross-section.

7.7.3 Gear mesh tests

Gear mesh tests are to be carried out and gear contact spots are not to be less than the values in Table 10.4.3.1 of PART THREE of CCS Rules for Classification of Sea-going Steel Ships.

7.7.4 Bench trials

The transmission gearing is to be tested according to the type test program approved by CCS during bench trials. See 10 and 11 of this Chapter.

8 Strength requirements

Appraisal of gear strength is to comply with the requirements in Appendix 1 “Appraisal of Gear Strength”, Chapter 10, PART THREE of CCS Rules for Classification of Sea-going Steel Ships. In respect to transmission gearing for main propulsion machinery and generator-driving auxiliary machinery where the transmitted power is less than 100 kW, the calculation of load capacity of gears need not satisfy the requirements of this paragraph.

9 Selection of typical samples

When applying for CCS approval for the first time, usually one sample is to be selected from each series of gearboxes for type test. The technical parameters of the sample are to cover the series from which it is selected, and the sample is to be representative of construction and manufacturing process of the same series and reflect the manufacturer's processing ability and manufacturing level.

10 Type test

10.1 Tests items

10.1.1 Type test items are usually to include:

(1) no-load operation test;
(2) load test;
(3) clutch performance test;
(4) reversion test;
(5) no-load drag test;
(6) temperature test;
(7) pressure test;
(8) mechanical emergency means test;
(9) noise test;
(10) alarm device test;
(11) reliability test;
(12) dismantling;
(13) retrial.

10.1.2 Exemption from type test items

(1) Approval for the first time

Usually all test items applicable in 4.10.1.1 above are to be carried out when the applicant applies for approval for the first time. The manufacturer may apply for exemption from some of the test items in writing, and CCS Surveyor will consider the application according to the manufacturer's production, history of production and usage record of his products and will fax the manufacturer's written application together with comments to the Classed Newbuildings Department of the Headquarters, and can grant an exemption from some test items only upon approval by the Department, provided that the following conditions are met:

① the applicant is to be able to provide a test report of corresponding test items issued by an authoritative technical organization (e.g. General Administration of Quality Supervision, or a national defense laboratory) recently;

② the applicant is to be able to provide a test report of corresponding test items signed by an IACS member society within last 12 months.

(2) Renewal of approval certificate

If there is no change to product design and if there is no change to technical requirements of CCS Rules for Classification of Sea-going Steel Ships for such type of products, type test may be omitted. However, CCS still reserves the right to require type test again.

10.2 Methods and requirements of type test

10.2.1 Test location

If the test bench of the manufacturer is taken as approval test location, it is to be able to complete the test items specified in the test program. CCS will check the testing ability, testing means and testing personnel to confirm compliance with relevant requirements. Otherwise, the tests are to be carried out at places deemed appropriate by CCS.

10.2.2 Tests methods

(1) No-load operation test

The transmission gearing is to run ahead and astern at an input speed equal to 50%, 75% and 100% of rated speed for 10 min respectively.

(2) Load test

The transmission gearing is in general to run ahead for 2 h and astern for 1 h at an input speed equal to 100% of rated speed and at 100% of rated power, and to run ahead for 1 h at 100% of rated speed and 110% of rated power.

During the test, lubricating oil temperature and lubricating oil pressure are to be recorded every half an hour.

(3) Clutch performance test

① The reserve factor of the clutch is to be determined as follows:

(a) to increase load gradually at rated input speed to make the clutch slip and record the maximum torque Tmax when the clutch begins to slip and calculate the reserve factor β by the following formula:

$$\beta = Tmax/Tn$$

where: Tn – nominal torque of clutch, in N . m.

(b) to reduce the working pressure of the clutch gradually at rated input speed and rated load to make the clutch slip, and record the working pressure P_1, in MPa when the clutch begins to slip, using the following formula:

$$\beta = Pn/P_1$$

where: Pn – rated working pressure of clutch, in MPa.

② Clutching performance test (in no-load condition):

to measure the working oil pressure curve when clutching and declutching ahead and astern at a speed not less than 50% of rated speed and at normal working oil temperature, and to record clutching time and declutching time for confirming compliance with design requirements.

(4) Reversion test

To reverse from running ahead to running astern and from running astern to running ahead respectively for 3 times at an input speed of the transmission gearing equal to 50 - 60% of rated speed and under a load corresponding to the propulsion curve of the associated diesel engine. The time required for reversing is not to exceed 15 s.

(5) No-load drag test

The handle is to operate to stop position ahead and astern with transmission gearing being at rated speed and in no-load condition, and drag torque of the clutch is not to be more than 1.5% of rated torque.

(6) Temperature test

External temperature of high-speed shaft/low-speed shaft bearings, lubricating oil temperature,

difference between external temperature of high-speed shaft/low-speed shaft bearings and lubricating oil temperature and difference between external temperatures of bearings of shafts with the same speed are not to exceed those required by technical documents approved by CCS.

(7) Pressure test

Working oil pressure and lubricating oil pressure and pressure fluctuation are to be measured at lowest stable working speed and rated speed, and at low oil temperature, normal working oil temperature and high temperature. The results are to comply with the requirements of technical documents approved by CCS.

(8) Mechanical emergency means test

To press the friction plates by mechanical means, to increase the lubricating oil to 30 ~ 50 mm above the full line and to run continuously for 4 h at a speed not less than 75% of rated speed and with not less than 42% of rated load. The emergency means is to be dismantled and examined after the test.

(9) Noise test

The noise limit at 1 meter from the transmission gearing with rated load in running ahead condition is to comply with the requirements of the figure 10.2.2(9) (special requirements may be agreed between the customer and the manufacturer).

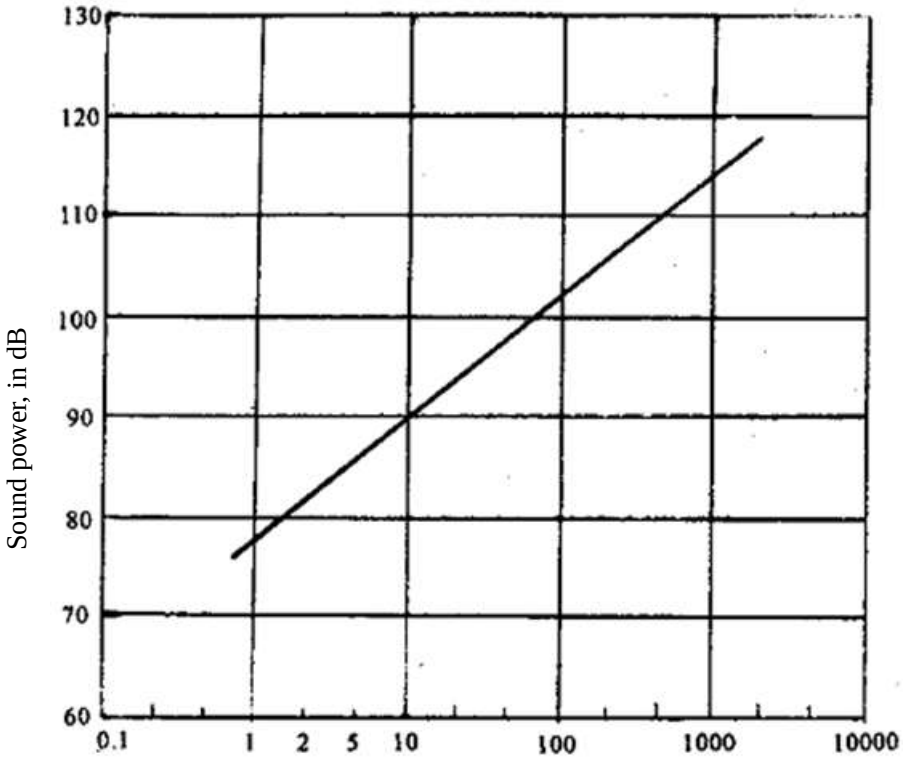

Figure 10.2.2(9) Power, in kW

(10) Alarm device test

The alarm temperature and pressure are to be measured for transmission gearing fitted with high oil temperature and/or low oil pressure alarm devices. Analog test is allowed.

(11) Reliability test

① Loading operation test

50 h loading operation test is to be carried out for the prototype of newly designed

transmission gearing. Every 10 h is a circle in which 9 h are for running ahead and 1 h for running astern in rated condition. After 5 circles, running with 110% of rated load is to last 1 h.

② Continuous reversion test

Reversion from running ahead (astern) to running astern (ahead) is to be repeated continuously for at least 100 times according to the requirements of reversion test. The time required for each reversing is not to exceed 15 s.

(12) Dismantling

After all tests are finished, the gear is to be dismantled to examine the following items:

① meshing of tooth faces;
② wearing of friction plates of the clutch and thickness measurement of the friction plates;
③ bearings;
④ cleanness of lubricating oil;
⑤ external inspection of other parts.

(13) Retrial

The re-assembled gearing is to be tested for oil leakage according to the requirements of the manufacturer.

11 Unit/batch inspection

11.1 Unit/batch inspection is adopted by CCS for transmission gears. CCS unit/batch inspection may be requested only for those transmission gears which have been satisfactorily inspected/tested by the manufacturer and are ready for delivery.

11.2 Unit/batch inspection for manufacturers with CCS type approval B

11.2.1 Inspection items

(1) Inspection items are to be in accordance with the approved routine test programme, including at least the following:

① no-load operation test;

② load test (if the maximum power of the manufacturer's test bench for routine test is less than the rated power of products, the power of rated power test is to be the maximum power of the test bench and overload test is not necessary);

③ reversion test; if any;

④ no-load drag test;

⑤ temperature test;

⑥ pressure test;

⑦ noise test;

⑧ alarm device test, if any;

⑨ dismantling (depending on product construction).

Test methods are the same with 10.2.2.

(2) The above tests may be carried out by the manufacturer independently and a complete test report is to be submitted to the Surveyor for review.

(3) The quantity of samples to be selected is to be determined by the Surveyor depending on the quantity of products submitted by the manufacturer for inspection. In principle, 2% but not less than 2 units are to be taken for mass-produced products. Samples for products manufactured unit by unit are to be taken as appropriate, usually at least 1 unit for each type. Selected products are to be re-tested according to the above test items or the test of which is to be witnessed at the manufacturer.

(4) The following documents are to be submitted to the Surveyor for review when the manufacturer applies for unit/batch inspection:

① material quality certificates of main parts;

② examination record of processing of main parts;

③ gear heat treatment inspection report;

④ gear non-destructive test report;

⑤ gear measurement report;

⑥ whole set assembly inspection report;

⑦ manufacturer’s trial report.

Where deemed necessary by the attending Surveyor, he may require checking one or more of the above items.

11.3 Inspection of products of manufacturers with CCS type approval A

11.3.1 The inspection is basically to review reports and all tests are to be completed by the manufacturer independently; application for inspection is to be submitted before product delivery, together with test reports and inspection reports specified in 4.11.2.1(1) and (4) for review by CCS Surveyor.

11.3.2 Periodical audits are to be requested in time by manufacturers with CCS type approval A according to the requirements in Section 4, Chapter 3, PART ONE of CCS Rules for Classification of Sea-going Steel Ships.

11.4 Unit/batch inspection for manufacturers without CCS approval

11.4.1 The inspection is to include plan examination and type test.

11.4.2 Plan examination

Related plans and technical documents are to be submitted to CCS by the manufacturer as required in 4.4.1 and 4.4.2 of this Chapter.

11.4.3 Type test

For marine transmission gears to be inspected, at least 1 unit is to be selected randomly from each series for all type test items required in 4.10 of this Chapter.

11.4.4 Marine transmission gears, which have not been selected as samples, are to be inspected and tested at least according to 4.11.2 of this Chapter.