Guideline No.: M-02(201510)

# M-02 TURBOCHARGERS

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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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# TURBOCHARGERS

## 1 Application

1.1 This Guideline applies to marine diesel engine exhaust-gas turbochargers.

## 2 Normative references

2.1 The approval and inspection in This Guideline are to be based on the following documents:
(1) CCS Rules for Classification of Sea-going Steel Ships;
(2) CCS Rules for Materials and Welding.

## 3 Definitions

3.1 The definitions given in CCS Rules for Classification of Sea-going Steel Ships, 2006 are applicable to This Guideline.

3.2 For the purpose of this Guideline:
(1) Turbocharger is a machine which uses a turbine operating with exhaust gas of the diesel engine to drive the air compressor to improve inlet pressure of the diesel engine. It consists mainly of an air compressor and a turbine.
(2) Special test is the test carried out additionally in type test or routine test according to the special requirements of the customer, such as impact, high back pressure and crash stop.
(3) Maximum allowable speed is the allowable maximum speed marked on the turbocharger nameplate, which is not to be exceeded even the engine is in overloading condition. The maximum speed is allowed for 1 h.
(4) Maximum allowable temperature is the allowable maximum temperature marked on the turbocharger nameplate, which is not to be exceeded even the engine is in overloading condition. The maximum temperature is allowed for 1 h.

## 4 Plans and documents

4.1 The following plans and documents are to be submitted for approval:
(1) Main performance specifications (including air flow, pressure ratio, rated speed, maximum allowable speed, rated temperature, maximum allowable temperature and charger type of the entire series of products to be approved);
(2) List of physical and chemical properties of main parts;
(3) General assembly;
(4) Rotor assembly and parts;
(5) Bearings and parts, if any;
(6) Nozzle ring;

(7) Diffuser;
(8) Casing;
(9) Built-in pump, if any;
(10) Rotor lock, if any;
(11) Schematic diagram of lubricating oil system, cooling system and air-seal system;
(12) Rotor critical speed calculations;
(13) Type test programme.

4.2 The following plans and documents are to be submitted for information:
(1) Main acceptance criteria, such as those for non-destructive test, castings and forgings, dynamic balance and hydraulic test;
(2) Main procedure documents, such as rotor shaft welding procedure (if applicable);
(3) Turbocharger operation and maintenance manual;
(4) List of suppliers of main parts (such as rotor parts).

## 5 Design and technical requirements

5.1 The technical requirements for turbochargers are given in Table 5.1.

**Technical Requirements for Turbochargers** **Table 5.1**

| No. | Item | Technical requirements | Basis of inspection | Remarks |
|---|---|---|---|---|
| 1 | Ambient conditions | Marine turbochargers are to operate normally with the ship having 15 °heel, or 22.5 °roll, or 5 °trim or 7.5 °pitch. | 1.2.1.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |
| 2 | Lubricating oil systems | The lubricating oil system of exhaust gas turbocharger may be separate from, or in common with, that of the main engine. If lubricating oil pumps are not directly driven by turbocharger, an independent standby lubricating oil pump is to be provided | 9.6.1.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |
| 3 | Instruments and alarms | Exhaust gas turbochargers are in general to be provided with instruments for measuring temperature of exhaust gas before turbine, pressure of supercharged air, temperature of lubricating oil, etc., and also with pressure gauges and alarms for excess temperature and low pressure of lubricating oil except those lubricating oil systems directly driven by turbochargers | 9.6.2.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |
| 4 | Air filters and silencers | Turbochargers are to be fitted with inlet air filters and silencers | 9.6.3.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |
| 5 | Rotor shaft locking devices | Turbocharger rotor shafts are to be provided with locking devices. If not, by-pass connections or other suitable devices are to be fitted to pipes before and after turbines to ensure normal operation of main engines in case of turbocharger breakdown | 9.6.4.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |

**Continued Table 5.1**

| No. | Item | Technical requirements | Basis of inspection | Remarks |
|---|---|---|---|---|
| 6 | Critical speed | Critical speed of turbocharger rotor is to be calculated. In the case of rigid rotor shafts, critical speed is not to be less than 1.3 times the rated speed | 9.6.5.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |
| 7 | Rotors and rotor shafts | Where rotor shafts are of welded construction, they are to comply with the following requirements: | | |
| 7.1 | | Before the commencement of welding, rotor shafts are to be uniformly preheated and the temperature is to be strictly maintained during welding. The preheating temperature is to be dependent on the materials used | 8.2.1.2, PART THREE of CCS Rules for Materials and Welding | |
| 7.2 | | Prior to the commencement of welding, test assemblies are to be prepared in accordance with the welding procedures approved by CCS, and deposited metal tensile test, transverse tensile test, face bend and root bend tests, and macro-structure examination are to be carried out | 8.2.2.1, PART THREE of CCS Rules for Materials and Welding | Welding procedure approval test |
| 7.3 | | Rotor shafts are to be properly heat treated on completion of welding. The requirements for heat treatment are to be dependent on the grade of steel and the welding process used, subject to approval by CCS | 8.2.3.1, PART THREE of CCS Rules for Materials and Welding | Post-weld heat treatment |
| | | All superficial and internal defects in the welds are to be completely removed and rewelded prior to the post-weld heat treatment | 8.2.3.2, PART THREE of CCS Rules for Materials and Welding | |
| 7.4 | | Prior to finish machining, welded rotors are to be subjected to surface inspection by means of magnetic particle detection or other equivalent method. Any cracks and other defects thus revealed are to be thoroughly cut out and repaired by welding and then the components are to be heat treated for stress relieving | 8.2.4.1, PART THREE of CCS Rules for Materials and Welding | Non-destructive test |
| 7.5 | | After assembly, rotors are to be dynamically balanced | 9.6.6.2, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |
| 8 | Hydraulic tests | Hydraulic test of turbocharger cooler space at 1.5 times the maximum working pressure or 0.4Mpa (whichever is the greater) is required. The test is to last at least 5 min and no leakage is permitted | 9.10.2.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships | |

## 6 Type test

6.1 Selection of typical samples

(1) When applying for approval for the first time, the turbochargers selected are to cover the manufacturer's processing ability and manufacturing level, etc. Usually the larger impeller, larger diffuser and the turbocharger with maximum pressure ratio in each product series are selected for type test. If the product series has a narrow performance scope, the turbocharger with the largest impeller diameter may be selected. The manufacturer's marketing and stocks as well as testing equipment in the selected test location may be taken into account when selecting turbochargers for test.

(2) When renewing the approval, only one type which is the most representative or the most demanded in market may be selected from each product series.

6.2 Type test items are to include:

(1) test of physical and chemical properties of raw materials of main parts;

(2) non-destructive test of main parts;

(3) examination of key dimensions of main parts;

(4) air compressor performance test;

(5) turbocharger running durability test;

(6) hot running test;

(7) impeller overspeed test;

(8) dismantling after the test.

6.3 Methods and requirements of type test

(1) Test of physical and chemical properties of raw materials of main parts

Raw material of main parts, such as rotor shaft (solid-forged), turbine disk, turbine blade, air compressor impeller, inducer, turbine casing and compressor housing, are to be tested for physical and chemical properties, except for those purchased raw materials or castings having CCS product certificates.

(2) Non-destructive test of main parts

Rotor shaft (solid-forged), turbine disk, turbine blade, air compressor impeller, inducer are to be subjected to non-destructive test according to design plans and technical documents.

(3) Examination of key dimensions of main parts

Throat area of diffuser and nozzle ring is to be measured and recorded.

(4) Air compressor performance test

① on the test bench, the performance test may be carried out without silencer and air filter or air-suction bend. See Appendix 1 for measurement items. The pressure ratio, efficiency, relationship between surge line and flow, and performance curve are required;

② when determining the surge limit, the capacity of air compressor is to be not less than that of associated inlet system of the diesel engine.

(5) Turbocharger running durability test

The speed of turbocharger in running durability test condition is to be 90% of the maximum speed. Turbine inlet temperature is to be 30~50℃ lower than the maximum temperature. See Appendix 1 for measurement items.

① Durability test time

For turbochargers with new design and significantly improved flux or bearing and produced by another manufacturer, the test time is 100 h;

For imported products, the test time is 75 h;

For large-size turbochargers with an air compressor impeller greater than 350 mm, the test time and test items may be agreed between the manufacturer and CCS;

② During the durability test, parameters are to be measured every 2 h after a stable condition is reached. There is no fault of the turbocharger allowed in the test. Stops not caused by the turbocharger are not to exceed 2 times and each stop is not to exceed 1 h. The durability test time for re-approval may be agreed between the manufacturer and CCS.

(6) Hot running test

Hot running test is to last 1 h at turbine inlet maximum allowable temperature and maximum allowable speed. The turbocharger is to be dismantled after test.

(7) If the manufacturer has the equipment for testing turbochargers on an engine, 1 h overload (110% of rated output) running test may be accepted in lieu of hot running test.

(8) Impeller overspeed test

Overspeed test is to be carried out for all impellers (air compressor impellers and inducers) in one of the following ways:

Running for 3 min at the speed of 120% of maximum allowable speed and at room temperature;

Running for 3 min at the speed of 110% of maximum allowable speed and at working temperature.

(9) Dismantling after the test

The turbocharger is to be dismantled after type test. All main parts other than rotor assembly and silencer assembly are to be dismantled and examined. Items to be examined are:

① Change of assembly clearance;

② Re-check of rotor dynamic balance and non-destructive test;

③ Wear of bearings and damping devices as well as change of fit clearance;

④ Change of nozzle ring, turbine casing and blade diffuser, etc;

⑤ Change of turbine moving blade;

⑥ Use of air seal and oil seal.

If any damage of main parts is revealed in examination, the test is to be deemed as failed.

## 7 Unit/batch inspection

### 7.1 Unit/batch inspection for manufacturers with CCS type approval B

7.1.1 Unit/batch inspection for manufacturers with CCS type approval B is to be carried out according to the approved inspection plan (related items in quality control plan), generally including:

(1) performance point examination test: after a stable condition is reached during self-circulation running, measurements are to be carried out according to items in Appendix 1 and the air compressor's pressure ratio, efficiency and the turbocharger's overall efficiency are to be calculated;

(2) hot running test: running for 20 min at the turbocharger's maximum allowable temperature and maximum allowable speed;

(3) vibration values;

(4) running down time: close the fuel oil valve suddenly until the turbocharger stops at a speed of 60% of the highest speed of turbocharger during self-circulation running and record the lasting time;
(5) special test: corresponding tests are to be carried out if the customer has special requirements for impact, high back pressure and crash stop.

7.1.2 The test items in the inspection plan may be carried out by the manufacturer independently and a complete test report is to be submitted to the Surveyor for review.

7.1.3 At least one turbocharger is to be selected randomly from each batch/each specification and re-tested by the Surveyor according to the above test items or the test of which is to be witnessed at the manufacturer.

7.1.4 The following technical documents for delivery of each unit/batch are to be submitted to CCS Surveyor for review when applying for unit/batch inspection:
(1) Manufacturer's quality certificate;
(2) Raw material quality certificates of main parts;
(3) Rotor shaft material test report (for welded construction);
(4) Non-destructive test report for main parts;
(5) Dynamic balance report;
(6) Hydraulic test report (if applicable);
(7) Routine bench test report.

7.2 Unit/batch inspection for manufacturers with CCS type approval A

7.2.1 The inspection is basically to review reports and all test items are to be completed by the manufacturer independently. The inspection application is to be submitted before product delivery, together with reports/records/documents of all test/inspection items specified in the inspection plan for review by CCS Surveyor.

7.2.2 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.

7.3 Unit/batch inspection for manufacturers without CCS approval

7.3.1 Inspections are to include plan examination and type test:
(1) Plan examination: Plans/technical documents are to be prepared by the manufacturer as required in This Guideline and submitted to CCS for approval/information;
(2) Type test: Each turbocharger is to be subjected to all type test items as required in This Guideline.

## Appendix 1 Test and Measurement Items

| No. | Measuring parameter | Type of test | | |
|---|---|---|---|---|
| | | Routine test | Air compressor performance test | Durability test |
| 1 | Atmospheric pressure, temperature and humidity | √ | √ | √ |
| 2 | Speed | √ | √ | √ |
| 3 | Torsion | | √ | |
| 4 | Air compressor flow | √ | √ | |
| 5 | Air compressor inlet temperature and pressure | √ | √ | √ |
| 6 | Air compressor outlet temperature and pressure | √ | √ | √ |
| 7 | Turbine inlet temperature and pressure | √ | | √ |
| 8 | Turbine outlet temperature and pressure | √ | | √ |
| 9 | Cooling water inlet temperature and pressure | √ | | √ |
| 10 | Cooling water outlet temperature | √ | | √ |
| 11 | Lubricating oil inlet temperature and pressure | √ | √ | √ |
| 12 | Lubricating oil outlet temperature | √ | √ | √ |
| 13 | Lubricating oil flow | | √ | |
| 14 | Turbocharger vibration value | √ | √ | √ |
| 15 | Running down time | √ | | |
| 16 | Noise level | | √ | √ |
| 17 | Items agreed by customer and manufacturer | √ | √ | √ |