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M-02

TURBOCHARGERS

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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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Main changes:

Main changes included UR M73 type test and inspections of turbochargers. The requirements of type test apply to turbochargers with the date of an application for certification of the new turbocharger type on or after 1 July 2016. The requirements of inspections apply to turbochargers with the date of application for certification of an individual turbocharger on or after 1July 2016.

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TURBOCHARGERS

1 Application

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

2 Basis for approval and inspection

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 Terms and 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. Turbochargers are categorized in three groups depending on served power by cylinder groups (e.g. for a V-engine with one turbocharger for each bank, the size is half of the total engine rated power) with: (1) Category A: ≤ 1000 kW; (2) Category B: > 1000 kW and ≤ 2500 kW; (3) Category C: > 2500 kW.

(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 to CCS for drawings approval:

(1) Category A:

- ① Containment test report;
- ② Cross sectional drawing with principal dimensions and names of components;

(2) Category B and C:

- ① Cross sectional drawing with principal dimensions and materials of housing components for

containment evaluation;

- ② Documentation of containment in the event of disc fracture (see Table 5.1 7.6);
- ③ Operational data and limitations, including maximum permissible operating speed (rpm), alarm level for over-speed, maximum permissible exhaust gas temperature before turbine, alarm level for exhaust gas temperature before turbine, minimum lubrication oil inlet pressure, lubrication oil inlet pressure low alarm set point, maximum lubrication oil outlet temperature, lubrication oil outlet temperature high alarm set point, maximum permissible vibration levels (i.e. self- and externally generated vibration);(Note: Alarm levels may be equal to permissible limits but are not to be reached when operating the engine at 110% power or at any approved intermittent overload beyond the 110%.)
- ④ Arrangement of lubrication system, all variants within a range;

(3) In addition to the provisions of (2) above, the following plans and documents for category C turbochargers are to be submitted:

- ① Drawings of the housing and rotating parts including details of blade fixing;
- ② Material specifications (chemical composition and mechanical properties) of all parts mentioned above;
- ③ Welding details and welding procedure of above mentioned parts, if applicable;
- ④ Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit;
- ⑤ Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue;
- ⑥ Operation and maintenance manuals.(Note: * Applicable to two sizes in a generic range of turbochargers.)

4.2 The following plans and documents are to be submitted to CCS for type approval:

- (1)Particulars of the manufacturer, including the name, address, history, production capacity, technical and inspection personnel, main products, subordinate relationship, trademark, etc.;
- (2) Details of the products for approval;
- (3) Main production equipment;
- (4) Main test equipment;
- (5) Brief production technology of the products for approval;
- (6) Quality management documents;
- (7) Document of entering to the register of enterprise;
- (8) Qualification certificate and/or production license;
- (9) Specimen of products quality certificate;
- (10) Quality control scheme;
- (11)List of qualified suppliers;
- (12)Asbestos-free Declaration;
- (13) Type test programme.

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
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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	For all turbochargers of Categories B and C are to be provided with indications and alarms as speed of turbochargers, temperature of Exhaust gas at each turbocharger inlet, temperature of Lub. oil at turbocharger outlet, pressure of Lub. oil at turbocharger inlet.	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	
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	9.6.6.3, PART THREE of CCS Rules for Classification of Sea-going Steel Ships	
7.6	Containment	Turbochargers are to fulfil containment in the event of a rotor burst. This means that at a rotor burst no part may penetrate the casing of the turbocharger or escape through the air intake. For documentation purposes (test/calculation), it is to be assumed that the discs disintegrate in the worst possible way.	9.6.10.1, PART THREE of CCS Rules for Classification of Sea-going Steel Ships	
		For category B and C, containment is to be documented by testing. Fulfilment of this requirement can be awarded to a generic range of turbochargers based on testing of one specific unit. Testing of a large unit is preferred as this is considered conservative for all smaller units in the generic range. In any case, it must be documented (e.g. by calculation) that the selected test unit really is representative for the whole generic range.	9.6.10.2, 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	9.6.12.3(6), PART THREE of CCS Rules for Classification of Sea-going Steel Ships	

6 Materials and components

Materials and components are to be controlled according to relevant requirements of CCS Rules currently in effect; Turbocharger mainly materials and components includes: rotor shaft (solid-forged), turbine disk, turbine blade, air compressor impeller, inducer, turbine casing and compressor housing. The list of Manufacturer for the mainly materials and components should not

be changed without the Society's approval. For category C, rotating parts and casing are to have CCS marine product certificates.

7 Type test

7.1 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.

7.2 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) Turbocharger load cycles test;
- (5) Turbocharger running durability test;
- (6) Hot running test;
- (7) Impeller overspeed test;
- (8) Dismantling after the test.

7.3 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) Turbocharger load cycles test

Turbochargers are to be subjected to at least 500 load cycles at the limits of operation. This test may be waived if the turbocharger together with the engine is subjected to this kind of low cycle testing.

(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°C 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 75h;

For large-size turbochargers with an air compressor impeller greater than 350mm, 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 at least 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 of all compressor wheels for a duration of 3 min at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio.

(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.

8 Unit/batch inspection

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

8.1.1 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) Hot running test: running for 20 min at the turbocharger's maximum allowable temperature and maximum allowable speed;
- (2) Vibration values;
- (3) 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;
- (4) Special test: corresponding tests are to be carried out if the customer has special requirements for impact, high back pressure and crash stop.

8.1.2 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.

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

8.1.4 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) Chemical composition of material for the rotating parts;
- (4) Mechanical properties of the material of a representative specimen for the rotating parts and the casing;
- (5) UT and crack detection of rotating parts;
- (6) Dimensional inspection of rotating parts;
- (7) Rotor dynamic balancing test;
- (8) Hydraulic testing of cooling spaces (if applicable);
- (9) overspeed test of all compressor wheels for a duration of 3 min at either 20% above alarm level speed at room temperature or 10% above alarm level speed at 45°C inlet temperature when tested in the actual housing with the corresponding pressure ratio. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method.
- (10) Routine bench test report.

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

8.2.1 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.

8.2.2 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.

8.3 Unit/batch inspection for manufacturers without CCS approval

8.3.1 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 batch/each specification 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	√	√	√