Guideline No.M-18(201510)

M-18

CONTROLLABLE-PITCH PROPELLER

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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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CONTROLLABLE-PITCH PROPELLER

1 Application

1.1 This Guideline covers controllable-pitch propeller, propeller shaft, intermediate shaft (if equipped), oil distributor, hydraulic power pack, and hydraulic system of controllable-pitch propeller.

1.2 This Guideline applies to the inspection of controllable-pitch propeller products used for main propulsion.

1.3 This Guideline may also be taken as a reference for the controllable-pitch propellers of other plants.

2 Basis for approval and inspection

2.1 *CCS Rules for Classification of Sea-Going Steel Ships;*

2.2 *CCS Rules for the Construction of Inland Waterways Steel Ships*

2.3 *CCS Rules for Materials and Welding*

3. Definitions

3.1 For the purpose of this Guideline, the definitions in *Rules for Classification of Sea-going Steel Ships* apply;

3.2 Controllable-pitch propeller (CPP): a propeller whose pitch can be altered by blade rotation via a control mechanism installed in the hub.

3.3 Hub: a component where the blade of CPP and the blade rotating mechanism are installed;

3.4 Oil distributor: the oiler of hydraulic CPP to supply pressure oil to the rotating shaft for the purpose of pitch control. If the oil distributor is installed on the intermediate shaft, then there is a short shaft with an oil filling port.

3.5 Propeller pitch: the theoretical advance of CPP which rotates a revolution under the working condition without slip and measured on the section of 0.7R.

3.6 Design pitch: the geometrical pitch measured on the section of 0.7R when the CPP has the same geometrical characteristics such as radial pitch distribution, section offset, blade outline, and propeller diameter as specified in the construction plan.

3.7 Pitch angle: the arc tangent of the ratio of the pitch to the distance travelled by a point in the measuring radius when it revolves about the propeller center for a revolution. The pitch angle measured at 0.7R is taken as the pitch angle of blade.

3.8 Propeller radius: the radius of propeller when the blade of CPP is in the position of design pitch.

4 Plans and documents

4.1 The following Plans and Technical Documents are to be submitted for approval:

(1) Shafting arrangement;

(2) General plan of controllable-pitch propeller;

(3) Plan of propeller blade (where a ship is equipped with 2 sets of controllable-pitch propeller, both the left-handed and right-handed blades are to be equipped);

(4) Plan of components for blade installation (e.g. blade bolts or blade fitting pin, if any)

(5) Calculation book of blade strength;

(6) General plan of hub (plan of longitudinal section and transverse section);

(7) Plan of mechanical components for pitch control (e.g. crank pin ring, piston rod, hub cylinder and other mechanical components);

(8) Plan of hub parts;

(9) Plan of oil distributor (oil distribution shaft, where applicable);

(10) Plan of shafting components (if any), including propeller shaft, intermediate shaft, stern tube (including front and rear bearings and sealing devices of stern shaft), coupling, connecting bolts, etc.;

(11) Calculation book of shafting strength, calculation book of torsional vibration (reviewed by ship plan approval authority), calculation book of whirling vibration (if any, reviewed by ship plan approval authority), and calculation book of alignment (if any, reviewed by ship plan approval authority);

(12) Plan of hydraulic system;

(13) List of alarm points (if the parameters of each alarm point are not indicated in the plan of hydraulic system);

(14) Main product performance specification table;

(15) List of physicochemical properties of main materials for parts and nondestructive test standard (including ultrasonic test, magnetic particle test and dye penetration test) (indication in each component plan is also acceptable);

(16) Test program (where applicable);

(17) Where the oil distributor is installed in the gearbox, a test program of component is to be submitted for component test.

4.2 The following Plans and Technical Documents are to be submitted for information:

(1) Product Operation Instructions

5 Material and components

5.1 Materials and components are to be controlled according to relevant requirements of the CCS Rules currently in effect.

5.2 The purchased oil distributors are to be supplied with the certificate of the manufacture.

6 Nondestructive test and heat treatment

6.1 Nondestructive test

(1) Upon completion, propeller shaft, stern tube shaft, and intermediate shaft of over 250 mm in diameter are to be subjected to ultrasonic test.

(2) See Section 4, Chapter 8 of Part Three of CCS Rules for Materials and Welding for the requirements for nondestructive test of hub and blade.

6.2 Heat treatment

(1) Heat treatment is to be in accordance with the provisions in Chapter 5, Part One of CCS *Rules for Materials and Welding*.

7 Design and technical requirements

7.1 Material requirements

(1) Shafting components (including propeller shaft, intermediate shaft and shafting coupling) are to be made of forged steel.

(2) Shafting couplings made of nodular cast iron are also acceptable. The nodular cast iron is to be in accordance with the provisions in Section 3, Chapter 7 of Part One of *Rules for Materials and Welding.*

(3) See Chapter 6, Part One or Chapter 9, Part One of CCS *Rules for Materials and Welding* for the requirements for materials of hub and blade.

(4) The fastening bolts or fitting pins of blade are to be made of forged steel, with the tensile strength of material not less than 400 N/mm^2. The fastening bolts or fitting pins of blade are

to be made of materials resistant to seawater corrosion, or with measures of seawater corrosion resistance.

7.2 Requirements for construction and strength

(1) The construction and strength of propeller shaft, intermediate shaft and oil distribution shaft (where applicable, i.e. the oil distributor is integrated into the shafting) are to comply with the requirements in Section 2, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

(2) The construction and strength of stern tube bearings and sealing devices are to comply with the requirements in Section 2, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

(3) The construction and strength of shafting coupling and shafting connecting bolt are to comply with the requirements in Articles 11.3.2 and 11.3.3, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*. There is no requirement for the connection strength where the fitting pins are used. Where the propeller and the propeller shaft are connected by fitting pins, the diameter of the fitting pin, d_s, is to be not less than:

$$d_s = 16\sqrt{\frac{10^6 \cdot P_w}{n \cdot D \cdot z \cdot R_m}}$$

Where: P_w — the rated power transmitted by the shafting, in kW;

n — the revolving speed of shaft, in rpm;

D — the pitch diameter of pin, in mm;

z — the number of pins;

R_m— the tensile strength of pin, in N/mm^2;

(4) The strength of propeller blade is to be in accordance with the provisions in Section 4, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*. The requirements for the thickness of blade in the propeller with a skew angle (see Fig. 8.4.2.1, Section 4, Chapter 8 of Part Three of CCS *Rules for Materials and Welding* for the definition of skew angle) of over 25 °are as follows:

Where the skew angle equals to or is larger than 25 °but less than 50 °, the middle chord thickness, $TSK_{0.6}$, at 60% radius is to be not less than:

$$T_{SK0.6} = 0.54T_{0.6}\sqrt{1+0.1\theta_S}$$

The middle chord thickness at 25% or 35% radius, excluding the increased thickness due to transitional fillet, is to be not less than:

$$T_{skroot} = 0.75T_{root}\sqrt[4]{1+0.1\theta_s}$$

Where:

θs — skew angle adopted;

$T_{0.6}$ — thickness at 60% radius calculated in accordance with Article 11.4.3, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*, in mm;

T_{root} — thickness at 35% radius calculated in accordance with Article 11.4.3, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*, in mm.

(5) The diameter, dk, at thread root of blade fastening bolts is to be not less than the value calculated through the following formula:

$$d_k = 2.6\sqrt{\frac{W_{0.35R}R_{p0.2}\alpha_A}{dZR_{eH}}}$$

Where：

$W_{0.35R}$ — section modulus of cylindrical section developed at 0.35R, in mm^3; $W_{0.35R} = 0.11(Bt^2)_{0.35R}$, B is the blade width on the section at 0.35R, in mm; t is the maximum blade thickness on the section at 0.35R, in mm;

$R_{P0.2}$ — non-proportional elongation stress of propeller material, in N/mm^2;

α_A — tightening coefficient of fastening bolts, as 1.2 ~ 1.6, determined based on the tightening method adopted;

d — pitch diameter of bolt hole of fastening bolts, in mm;

Z — number of bolts;

R_{eH} — yield strength of fastening bolts, in N/mm^2.

The pre-tightening force of blade fastening bolt is to be larger than the minimum frictional force on the contact surface between blade root flange and hub crank pin ring, so as to prevent blade root flange from sliding and the exceedance of the yield strength of bolts. The pre-tightening force of blade fastening bolt is generally not more than 70% of the tensile strength or 56% of the yield strength of bolt material.

The blade fastening bolts are to be with looseness-proof measures.

(6) A sealing device, which is well water-proof, sand-proof and lubricating-oil-leakage-proof, is to be equipped between the blade and the hub of CPP.

(7) Shafting vibration and alignment are to comply with the requirements in Section 2, Chapter 12 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

(8) Strengthening for ice navigation: for ships intending to apply for the CCS class notation of ice classes B1*, B1, B2, B3, the construction and strength of intermediate shaft, thrust shaft, propeller shaft and propeller are to be in accordance with the provisions in Sections 2 and 3, Chapter 14 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

(9) Screwshaft condition monitoring (SCM): ships intending to apply for the CCS class notation of SCM are to be in accordance with the provisions in Section 5.12.4.1, Chapter 5 of Part One and Appendix 14 *Guidelines for Screwshaft Condition Monitoring System* to Chapter 5 of Part One.

7.3 System arrangement and safety alarm

(1) The hydraulic system (and the lubrication system of hub, if equipped) is to comply with the following requirements:

① The pump of hydraulic system is to be in accordance with the provisions in 11.3.6.1 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

The hydraulic transmission system of CPP is to be equipped with a separate spare pump with a capacity not less than that required for a single pump in normal operation.

For the propulsion unit of less than 200 kW in power, if another manual pump is equipped for pitch control, and the pump is able to change the blade from the ahead position to the astern position in a very short time, then the separate spare pump is optional.

② The pressure pipeline of the system is to be equipped with a duplex filter or fine filter with a bypass. See ISO 4406:1999 for the filter fineness of hydraulic oil.

③ The main hydraulic system of CPP on each axis is to be, generally, completely independent. The system is to be equipped with pressure control valves to meet the requirements of continuous operation and protection. The dimensions and arrangement of pipeline between oil pump and spill valve are to be such that the total pressure drop is not more than 25% of the actual pressure of spill valve under its maximum capacity. The total back pressure of spill valve is to be not more than 25% of the set pressure value.

④ The effective volume of main oil tank is to be not less than 3 times the displacement per minute of pumps (in pitch control and lubrication systems) or the total oil quantity of pitch control and lubrication systems, whichever is greater.

⑤ The oil temperature of hydraulic system is to be not higher than 70 ℃;

⑥ The hub lubrication system is to guarantee the lubrication of the pitch control mechanism in the hub, and to guarantee the positive pressure head at blade root seals in relation to seawater in the case of pitch control, so as to prevent seawater seepage.

⑦ "Materials", "pipelines", and "arrangement" of hydraulic transmission pipelines are to be in accordance with the provisions in Section 7, Chapter 4 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

(2) Alarm

The alarm items of CPP are to be in accordance with the provisions of 11.3.6.9, Chapter 11 of Part Three of *Rules for Classification of Sea-going Steel Ships*.

Ships intending to apply for the CCS class notation of automation are to meet the relevant requirements in Chapters 3 and 4 of Part Seven of *Rules for Classification of Sea-going Steel Ships*.

Ships intending to apply for the CCS class notation of dynamic positioning are to meet the relevant requirements in 11.5.10, Chapter 11 of Part Eight of *Rules for Classification of Sea-going Steel Ships*.

(3) Emergency unit

The CPP system is to be equipped with emergency control facility which can control the propeller in the case of remote control system failure. It is recommended to install a unit which can lock the blades in the "ahead" position.

In the case of emergency working condition of "fixed pitch propeller state", effective measures are to be taken to prevent pitch control operation.

The emergency oil circuit changeover valve is to be manually controllable and mechanically lockable; the solenoid valve for emergency pitch control is to be manually controllable;

Pitch angle indicator

The console in engine room and the wheel house are to be equipped with pitch angle indicators.

7.4 Performance requirements

(1) The control systems in engine room and wheel house are to be interlocked. For non-mechanical control system, a stand-by manual control unit is to be equipped aside.

(2) The control system of hydraulic CPP is to be capable of controlling the required blade angle in a sensitive and accurate way.

(3) The deviation of pitch angle indicator from the actual pitch angle of propeller is to be less than ±5%.

(4) Under any working condition, the CPP is to work stably and at the pitch angle of 0°, the fluctuation is to be not more than ±2.5%.

(5) At the rated revolving speed, the time required to change the CPP from 1/3 of positive (or negative) full-load pitch angle to 1/3 of negative (or positive) full-load pitch angle is to be not more than 15 s.

(6) The pitch control range of CPP is to ensure the main engine to output the rated power and the rated astern power at the rated revolving speed.

(7) Appropriate units are to be equipped to ensure changes in pitch are not to cause overload or stop of propulsion plant.

(8) In the case of control system failure, measures are to be taken to ensure that the blade remains unchanged in position or revolves to the ending position slowly to make enough time for the emergency control system to operate.

8 Product test

8.1 The test items include:

(1) Visual inspection;

(2) Dimension inspection;

(3) Pitch control test;

(4) Hydraulic test;

(5) Tightness test;

(6) Pitch angle calibration;

(7) Emergency control test;

(8) Safety protection and alarm function test;

(9) Oil distributor leakage test;

(10) Miscellaneous.

8.2 Test method and requirements

(1) Visual inspection

① The main components, such as the assembled controllable-pitch propeller (mainly including oil distributor, propeller housing, propeller blade, blade bolts), stern shaft

and tube (mainly including propeller shaft, front and rear bearings of stern shaft, fore and after sealing devices), oil distributor, intermediate shaft, shafting connecting bolts, pitch angle indicator, equipment of hydraulic system and connection tubes, are to be subjected to visual inspection and touch inspection;

② The components of product are to be complete and the appearance of units is to be in good condition with intact protection packing and tight fasteners.

③ The pipelines of hydraulic units are to be well arranged and smoothly curved, with fixed long pipes and shortest hose without sharp turns and twist.

(2) Dimension inspection

① See CCS Guidelines for *Copper Alloy Propellers* for the requirements for dimension inspection of the assembled controllable-pitch propeller.

② The overall dimensions of intermediate shaft, propeller shaft and oil distributor are to be measured, with the results in line with those specified in the approved plans.

③ The following important mounting dimensions are to be measured, with the results in line with those specified in the approved plans.

the distance between the blade fitting surface to the centerline of shaft;

the fit dimension of main oil circuit control follow-up sliding valve for pitch control and the valve sleeve;

the fit clearance of high-pressure seal of oil distributor.

(3) Pitch control test

Tests of time for pitch control, pitch control stability, pitch control accuracy, pitch indication accuracy are to be conducted.

Time for pitch control is to comply with the requirement of 7.4(5) in the above, and the time is to be measured in the full-scale test.

The pitch control stability is to comply with the requirement of 7.4 (2) in the above.

The pitch control accuracy is to comply with the requirement of 7.4 (4) in the above.

The pitch indication accuracy is to comply with the requirement of 7.4 (3) in the above.

(4) Hydraulic test

For the hydraulic transmission and control system of CPP, the pipelines and hydraulic power units are to be subjected to 1.5 times the working pressure in the hydraulic test before being assembled.

See the requirement of Chapter 10 of Part Two “Guidelines for Inspections of Products” for the hydraulic test of blade root seal and hub.

(5) Tightness test

Before the tightness test, the pipelines of hydraulic transmission and control system of CPP is to be oil-flushed.

For the hydraulic transmission and control system of CPP, the pipelines and hydraulic power units are to be subjected to 1.25 times the working pressure in the tightness test after being assembled, and the stationary seals and pipe joints are to be free from leakage.

(6) Pitch angle calibration

In three positions of control handle, namely “maximum pitch”, “zero pitch” and “minimum pitch”, the deviation between actual pitch and commanded pitch is to be inspected with the deviation less than 1 °blade pitch angle.

“Actual pitch” is the reading on the mechanical pitch indicator of hub or oil distributor of CPP.

(7) Emergency control test

First the measures to ensure that the blade remains unchanged in position or revolves to the ending position slowly in the case of control system failure are to be tested.

The emergency control unit is to be operated to see if it can control the propeller in the case of the failure of remote control system.

It is recommended that the emergency control unit is such that can lock propeller blades in the “ahead” position.

When CPP is set to be in “fixed pitch propeller state” through emergency unit, effective measures are to be taken to prevent pitch-related operations, and the revolving speed of shaft at this time is generally not more than 75% of rated revolving speed.

(8) Alarm/safety function test

① By the method of intentional change of oil level, oil (gas) pressure, temperature or artificial simulated fault input, the following items are to be tested:

Alarm of low pressure in hydraulic system;

Alarm of low oil level of main hydraulic oil tank;

Alarm of oil filter blockage;

Alarm of low lubrication oil pressure of hub (except in the case of grease lubrication);

Alarm of over-high temperature of hydraulic oil (if oil cooler is equipped);

Alarm of pitch control failure;

Alarm of pressure indication and low pressure of hydraulic system for pitch control (applicable to ships applying for the mark of automation);

Alarm of over-high hydraulic oil pressure (applicable to ships applying for the CCS class notation of dynamic positioning);

Alarm of over-high temperature of oil-lubricated stern tube bearing (where applicable);

Alarm of low oil level of stern tube lubrication oil tank (where applicable);

② The alarm value of the above alarm items is to comply with the requirements of design plans.

③ All alarms are to be indicated on the bridge.

④ Test to check if blade position remains unchanged/returns slowly in the case of control system failure.

(9) Oil distributor leakage test

① The test method and indices are to comply with the design requirements.

(10) Miscellaneous

See CCS Guidelines for *Copper Alloy Propellers* for the requirements for type test of propeller.

Inspection of shafting components

See guidelines for CPP electrical control system for the type test of electrical control system.