

Guidance for Composite Propellers

(Development Review : For external opinion inquiry)

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Machinery Rule Development Team



2019

Guidance for Composite Propellers

APPLICATION OF "Guidance for Composite Propellers"

Unless expressly specified otherwise, the requirements in the Guidance apply to companies for certification of composite propellers is dated on or after 1 April 2019.

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CHAPTER 1 GENERAL

Section 1 General

101. Application

1. This Guidance applies to the composite propellers composed of resins, fiber reinforcement and core materials (hereinafter refer to FRP materials) used in ships which are to be certified or are intended for classification.
2. The matters not specified in this Guidance are subject to the respective requirements of **Pt 2** and **Pt 5** of the Rules and Guidance for the Classification of Steel Ships and of the Guidance for Approval of Manufacturing Process and Type Approval.
3. If it is impracticable to apply the requirements specified in this Guidance, alternative methods are to be discussed by the Society.

102. Definition of Terms

The definitions of terms are to be in accordance with the Rules and Guidance for Steel Ships unless otherwise specified in this Guidance.

1. “Composite material” refers to material containing two or more different materials (resin, reinforcement) to possess specific performance characteristics.
2. “Resin” refers to thermosetting resin for lamination constituting a composite material composed of various solid or semi-solid amorphous organic matter.
3. “Fiber” refers to reinforcing fibers that improve the physical properties of the composite material due to its high axial strength and stiffness.
4. “Core Material” refers to a structure of various types of foam for the purpose of weight reduction or thickness increment and stiffness improvement of a composite material.
5. “Mixing ratio” refers to the weight ratio of the curing agent and the accelerator to the resin solution.
6. Definition of test
 - (1) “Coupon test” refers to fabricating laminates in the same method using materials practically applied to the composite material and testing specimens for measuring the properties of the composite material.
 - (2) “Component test” refers to testing specimens obtained from a part of the practical size of the propeller blade or a part of the mould simultaneously used for forming the propeller blade to measure the properties of the composite material.
 - (3) “Full-size test” refers to testing the composite propeller blade of practical size for approval.

Section 2 Approval Procedure

201. Approval procedure

1. The approval procedure for the composite propeller is to be in accordance with **Fig 1.1**.

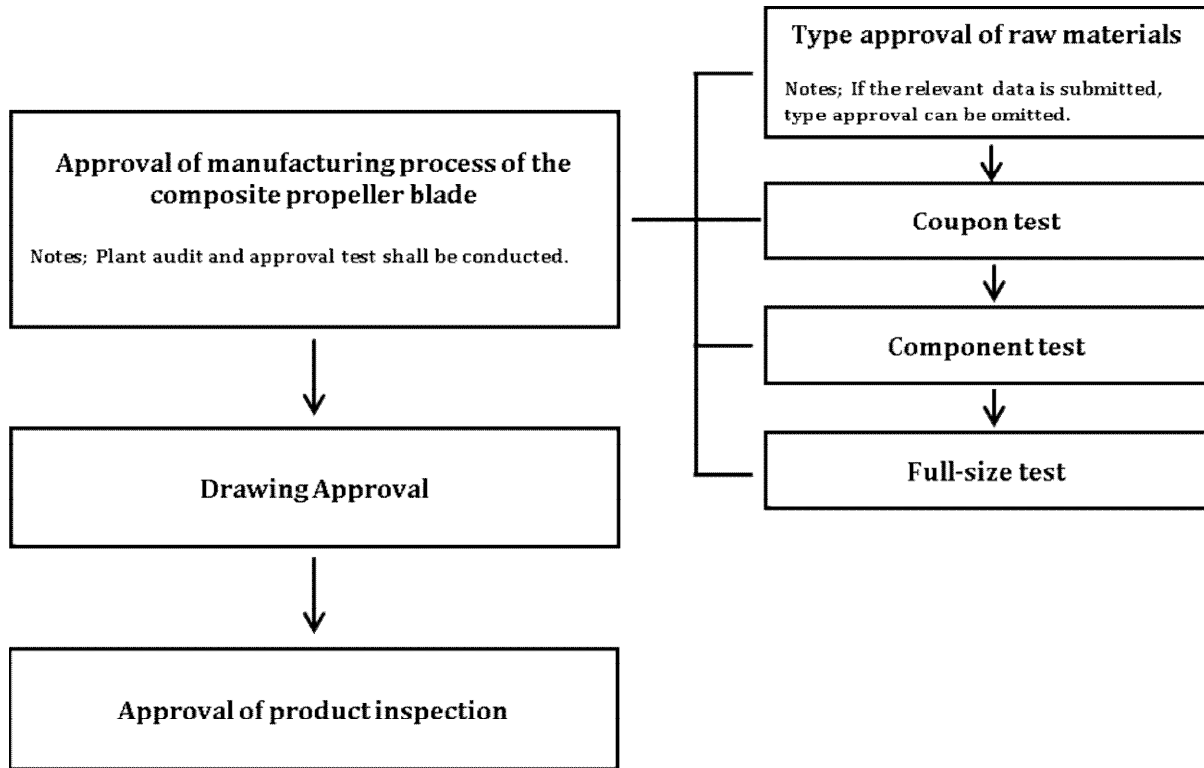


Fig 1.1 Approval procedure for the composite propeller

CHAPTER 2 APPROVAL OF MANUFACTURING PROCESS

Section 1 General

101. General

1. This requirements of this chapter apply to approval procedure and tests for the approval of manufacturing process of the composite propeller blade.
2. Approval of the manufacturing process may be omitted for composite propellers of smaller diameter than those having the same structure and approved by the Society.

102. Approval application

1. For manufacturers of composite propeller blades, the following approval procedures is to be conducted.
2. The manufacturer wishing to obtain the approval of manufacturing process of the composite propeller blade is to submit a copy of the application of approval for manufacturing process of the Society together with three copies of the required data for the approval and two copies of the required data for reference to the Society. The following reference data in addition to those specified in **Ch 2 Sec 1 102.** of the Guidance for Approval of Manufacturing Process and Type Approval are to be submitted to the Society.

(1) Raw material

- (A) For the type approval of the raw materials, the following data is to be provided. However, it may be omitted by submission of relevant data with the approval of the Society.

(B) Resin

- (a) Manufacturer, Model name
- (b) Type, Physical properties
- (c) Mechanical properties
- (d) Curing agent type and mixing ratio
- (e) Data of gel coat or top coat resin

(C) Reinforcements

- (a) Manufacturer, Model name
- (b) Weave type and direction data
- (c) Density of fiber material and width of manufactured reinforcement
- (d) Mechanical properties
- (e) Binder type and content

(D) Core materials

- (a) Manufacturer, Model name
- (b) Type of material
- (c) Density
- (d) Description, etc.

(2) Coupon data

- (A) Coupon test plan, test method including applied standard, criteria, record of the approval test
- (B) Coupon specimen sampling location, orientation and manufacturing information
- (C) Location for test

(3) Component data

- (A) Component test plan, test method including applied standard, criteria, record of the approval test
- (B) Component specimen sampling location, orientation and manufacturing information
- (C) Location for test

(4) Full-size data

- (A) Full-size test plan, test method including applied standard, criteria, record of the approval test
- (B) Location for test

- (C) Document on static load test including design load data
- (5) Quality standard
- (6) Non-destructive testing standards
- (7) Other documents required by the Society

Section 2 Plant Audit

201. Plant audit

1. Purpose

The Society will, where deemed appropriate upon review of documents and data submitted, carry out the plant audit in the presence of the Surveyor to verify that the manufacturer has a technical capability to continuously produce the proposed products of equal level in quality under the stable workmanship to the satisfaction of the Society.

2. Items to be audited

The plant audit is to apply to the following items in the presence of the Surveyor

- (1) Quality system in general
 - (A) Establishment and implementation of quality system
 - (B) Observance and establishment of procedure for handling of customer complaints
 - (C) Education and training of employees
- (2) Control of process and quality
 - (A) Observance of work instruction
 - (B) Observance and confirmation of Q.C flow charts
 - (C) Control of nonconforming product and corrective action
- (3) Control of manufacturing and inspection equipment
 - (A) Observance and establishment of maintenance procedure for manufacturing equipment
 - (B) Calibration and control of inspection equipment
- (4) Others
 - (A) Updating of documents such as applicable standards, etc.
 - (B) Comprehension of related requirements for class surveys
- (5) Audit methods and acceptance criteria are to be as deemed appropriate by the Society.

3. Time for audit

The time of the audit is to correspond, in principle, to either the time when the proposed product is manufactured or the time when the approval test is carried out. In this case, the manufacturer is to provide the necessary information related to this audit.

4. Exemption of audit

When the manufacturer submits the application of newly produced product with the same manufacturing facilities and similar method of manufacture for products which have been approved by the Society, the audit items may be exempted wholly or partly according to the review result of the documents.

5. Workshops

The workshops manufacturing composite propellers intended to be registered to the Society, are to comply with the requirements in **Table 2.1** to maintain sufficient mechanical properties and a good quality of moulding.

Table 2.1 Facility standard for Composite propeller manufacturing workshop

Facility	Equipment	Facility standard
General		(1) The laminating shops are to be of such construction as to be free from penetration of draught, dust and moisture, and to be provided with heating system to keep to keep the temperature above 15 °C. In this case, the method partially beaming the infrared rays is not to be generally permitted. (2) The shops are to be designed so that resin and fibreglass, carbon fiber are

		<p>not to be deteriorated with the elapse of the time and the fibreglass reinforcements are not to be contaminated by soil, dust, moisture, etc.</p> <p>(3) The standard specification for the construction and repair of composite propeller shall be clearly established and moulding of composite propeller is to be carried out under the supervision of a well-experienced technical expert.</p>
Standard of facilities		The manufacturer of composite propeller is to provide with the facilities which can manufacture the composite propeller about G/T 20 tons by hand lay-up.
Laminating shops	Area	The laminating shops are to have sufficient spaces to carry out the laminating works for the largest propeller intended to be manufactured.
Facilities in laminating shops	Ventilation systems	Ventilation systems in accordance with the relevant law are to be provided to exhaust styrene gases and other harmful gases.
	dust collectors	The suitable dust collectors are to be provided in order to exhaust dusts yielded during laminating operation.
	Lighting and shields	Lighting equipment are to be so arranged that the operation of laminating are not disturbed. Also, the skylights and windows of the laminating shops are to be provided with suitable means of shielding so that the laminates are not exposed to direct sunlight.
	Transportation	Transportation equipment of suitable capacity are to be provided and arranged.
	Fire fighting and detection systems	Fire fighting and detection systems are to be provided in accordance with the relevant law. The caution sign of "Flammables" is to be indicated in shops. The smoking room is to be arranged outside the laminating shops.
	Electric equipment	Electrical equipment in the laminating shops is to be of explosion-protected electrical appliance, except that the ventilation systems are provided completely.
	Glass cutting	The glass cutting tables are to be so arranged as to be properly subdivided or separated from the laminating shops.
	Resin mixing	The mixing equipment and the weighing machines are to be provided in any case.
Other facilities of the laminating shops	Cleaning	The separated room with the ventilator is to be provided so as to clean the laminating equipment and FRP components weighing machines.
	Storage	A catalyst, resin, solvent, etc., are to be stored in cool and dark spaces in accordance with the relevant law, and the fibreglass, carbon fiber reinforcements and core materials are to be stored in dust-free and dry spaces.
	Sanitary	A washstand, a bathroom, necessary medicine for eye-washing, etc., are to be provided considering the number of workers.
	Storage for moulds	Moulds used repeatedly are to be stored free from rain and wind, and they are to be properly kept so that the internal surface of moulds can not be contaminated and distorted.
	Air compressor	The air compressors of suitable capacity with an air cleaner are to be provided outside the laminating shops.
	Management of waste matter	The incinerators for waste matters are to be equipped and the waste matters are to be treated considering a fire and environmental pollution. Where the incinerator is not provided, the waste matters are to be requested to the speciality dealers concerned of industrial waste products. Also, the procedure of management for ashes incinerated and incombustibles is to be established in accordance with the relevant law.

Section 3 Approval Test

301. Approval test

1. The approval test is to be carried out in the presence of the Surveyor in accordance with the test method described in each Section of the Guidance or equivalent method thereof. However, the test may be partly or entirely omitted subject to the approval by the Society in case any of the following (1) is relevant.
 - (1) In case where the manufacturer has been approved by other Classification Society or an inspection organization recognized by the Society.
2. In principle, the approval test is to be carried out at the manufacturing sites. If the testing facilities are not available at the works, the tests are to be carried out at accredited laboratories.

3. Test records

- (1) After completion of the approval test, the manufacturer is to prepare a record of the approval test and operation records relevant to composite making of the test products and is to submit three copies to the Society upon receiving confirmation by the Surveyor.
- (2) All results, which are in any case to comply with the requirements of the Rules, are evaluated for the approval; depending on the results, particular limitations or testing conditions, as deemed appropriate, may be specified in the approval document.

4. Coupon test

- (1) Approval test of coupon test item, test method and acceptance criteria are to be conducted in accordance with the requirements in **Table 2.2**.
- (2) The number of test specimens from each sample to be tested is to be in accordance with the standard.
- (3) Retest procedure
 - (A) Where test material fails to meet the specified requirement, two additional tests of the same type may be made at the discretion of the Surveyor.
 - (B) Where an individual test result in a group (minimum five) deviates from the mean by more than two standard deviations in either the higher or lower direction, the result is to be excluded and a re-test made. Excluded results of tests are to be reported with confirmation that they have been excluded. Only one exclusion is acceptable in any group of tests.

Table 2.2 Test methods and acceptance criteria of the coupon tests

Test	Standard	Test orientation	Acceptance criteria
Tensile test	ISO 527-4, ISO 527-5	The test orientation is to be as deemed appropriate by the Society to confirm the mechanical properties of the laminates.	Manufacturer design value
Compression test	ISO 14126		Manufacturer design value
In-Plane shear test	ISO 14129		Manufacturer design value
Interlaminar shear test	ISO 14130		Manufacturer design value
Bending test	ISO 14125		Manufacturer design value
Seawater immersion test	After immersed in seawater at least 35°C for 28 days, tensile test, interlaminar shear test, in-plane shear test, and bending test		The property of the material should not be lowered by more

	shall be performed.		than 25% compared to initial state before immersion.
Fiber volume fraction	ISO 3451, ISO 14127, ISO 1172, ASTM D3171, ASTM D2584, ASTM D5630. However, the thickness measurement method is excluded.		Manufacturer design value
Glass transition temperature	ISO 11357, ASTM D7028		Should be at least 10 °C above the design temperature.
<p>Notes;</p> <p>1) The Manufacturer should provide the data that the fiber orientation is produced as designed.</p> <p>2) The number of specimens for test shall be at least 5.</p> <p>3) Test methods not specified in this table are to comply with the standards deemed appropriate by the Society.</p>			

5. Component test

- (1) Approval test of component test item, test method and acceptance criteria are to be conducted in accordance with the requirements in **Table 2.3**.
- (2) The component test is carried out by extracting at least three samples from any area in the propeller blade or the mould of practical size manufactured by the same manufacturing method as in the coupon test.
- (3) Where a part of the results of the test not comply with the requirements, but the remainders are satisfactory, additional test specimens twice in number may be taken from the same material and retests for the failed test may be carried out. In such a case, all of the test specimens are to comply with the requirements.

Table 2.3 Test methods and acceptance criteria of the component tests

Test	Standard	Test orientation
Fiber volume fraction	ISO 3451, ISO 14127, ISO 1172, ASTM D3171, ASTM D2584, ASTM D5630. However, the thickness measurement method is excluded.	The result is to be same as the coupon test result within ±5% in Table 2.2.
Glass transition temperature	ISO 11357, ASTM D7028	The result is to be same as the coupon test result within ±10% in Table 2.2.
<p>Notes;</p> <p>1) The Manufacturer should provide the data that the fiber orientation is produced as designed.</p>		

6. Full-size test

- (1) Approval test of full-size test item, test method and acceptance criteria are to be conducted in accordance with the requirements in **Table 2.4**.
- (2) The full-size test is carried out using the practical size manufactured composite propeller which is manufactured by the same method as in the coupon test.
- (3) The static load test is to be carried out on the full-size propeller blade. The finite element analysis is to be performed, and bending moment ($M_{0.25}, M_{0.6}$) and shear stress ($\tau_{0.25}, \tau_{0.6}$) at 0.25R and 0.6R of the propeller radius (R) are to be obtained by using the design load applied to the finite element model. Test loads and load points are to be as follows. The load point and test load can be changed if more severe bending moment and shear stress is applied.
 - (A) To be carried out with a test load that satisfies both the bending moment not less than $M_{0.25} \times 2$ and the shear stress not less than $\tau_{0.25} \times 2$ at 0.25R.
 - (B) To be carried out with a test load that satisfies both the bending moment not less than $M_{0.6} \times 2$ and the shear stress not less than $\tau_{0.6} \times 2$ at 0.6R.

Table 2.4 Test methods and acceptance criteria of the full-size tests

Test	Standard	Test orientation
Natural frequency ^{(1),(2)}	Modal test is required.	To be as deemed appropriate by the Society
Static load test ^{(1),(3)}	Test is to be conducted in accordance with (3).	To be sustained for more than 10 seconds.
Fatigue load test ^{(1),(3)}	The manufacturer defines the fatigue test direction.	Design values is to be satisfied.
Notes; (1) The manufacturer should submit a detailed test plan in consultation with the Society. (2) Weight measurement is required. (3) The static load test and the fatigue load test are to be carried out by connecting the manufactured propeller blade to the boss.		

7. Visual Inspection

Prior to the full-size test, the surface of the composite propeller blade is to be visually inspected. No harmful defects is to be found in the test.

8. Non-destructive inspection

Prior to the full-size test, non-destructive inspection is to be performed to check for internal defects of the composite propeller blade. No harmful defects in is to be found in the test.

9. Dimension measurement

Prior to the full-size test, dimension measurement is to be performed to check the difference of design drawing.

CHAPTER 3 INDIVIDUAL PRODUCT

Section 1 General

101. General

1. This requirements of this chapter apply to approval procedure and tests for the approval of product inspection of the composite propeller blade.

Section 2 Drawing Approval

201. Drawing approval

1. The applicants for plan approval are to submit the approval drawings for the composite propeller for the ship as follows.
 - (1) Propeller design drawings (including details of the connections and documents of the joining method between blades and boss)
 - (2) Design assessments and analysis data for propeller including followings
 - (A) Selection of loading conditions
 - (B) Hydrodynamic loads applied to blades
 - (C) Finite element model and boundary conditions (if requested by the Society, blades model data are to be provided.)
 - (D) Strength assessments including fatigue assessments (especially, stress concentration parts such as root fillet of blades)
 - (E) Bucking assessment of blades
 - (F) Strength assessments of boss and connecting accessories
 - (G) Plans and documents considered necessary by the Society

Section 3 Product Inspection

301. Testing and Inspection

1. Approval test of coupon test item, test method and acceptance criteria are to be conducted with attendance of the surveyor in accordance with the requirements in **Table 3.1**. However, the test may be partly or entirely omitted subject to the approval by the Society in case any of the following (1) is relevant.
 - (1) In case where the manufacturer has been approved by other Classification Society or an inspection organization recognized by the Society.
2. The coupon and the product shall be manufactured in the same method by applying the same material approved by the Society, and the test result between the coupon and the product shall be compared.
3. If the same product is manufactured continuously, the coupon test can be made once.

Table 3.1 Test methods and acceptance criteria of the coupon tests for product inspection

Test	Standard	Test orientation
Tensile test	ISO 527-4, ISO 527-5	The result is to be same as the cou-

		pon test result within $\pm 10\%$ in Table 2.2.
Interlaminar shear test	ISO 14130	The result is to be same as the coupon test result within $\pm 10\%$ in Table 2.2.
Bending test	ISO 14125	The result is to be same as the coupon test result within $\pm 10\%$ in Table 2.2.

4. The following approval test of product inspection in addition to those specified in **Pt 5 Ch 3 Sec 3 307**. of the Rules and Guidance for the Classification of Steel Ships, test item, test method and acceptance criteria are to be conducted with attendance of the surveyor under the following requirements.

- (1) Test of fiber volume fraction and glass transition temperature
 - (A) The test is carried out by extracting samples from any area in the propeller blade or the mould of the product.
 - (B) Test method and acceptance criteria are to be conducted in accordance with the requirements in Table 2.3
- (2) Visual Inspection
 - (A) The surface of the composite propeller blade is to be visually inspected. No harmful defects is to be found in the test.
- (3) Non-destructive inspection
 - (A) Non-destructive inspection is to be performed to check for internal defects of the composite propeller blade. No harmful defects in is to be found in the test.
- (4) Dimension measurement
 - (A) Dimension measurement is to be performed to check the difference of design drawing.

5. Marking

The approval product which satisfy the tests and inspections of this Guidance are to be identified by a mark showing that it is the product approved by the Society.