RUSSIAN MARITIME REGISTER OF SHIPPING

CIRCULAR LETTER **No. 311-05-1929c** dated 25.04.2023

Re:
amendments to the Rules for the Classification and Construction of Sea-Going Ships, 2023, ND No. 2-020101-174-E

Item(s) of supervision:
steel forgings and castings

Entry-into-force date:
01.07.2023

~~Cancels / amends / adds Circular Letter No.~~ ~~dated~~

Number of pages: 1 + 19

Appendices:
Appendix 1: information on amendments introduced by the Circular Letter
Appendix 2: text of amendments to Part XIII "Materials"

Acting Director General Sergey A. Shishkin

Text of CL:
We hereby inform that the Rules for the Classification and Construction of Sea-Going Ships shall be amended as specified in the Appendices to the Circular Letter.

It is necessary to do the following:
1. Bring the content of the Circular Letter to the notice of the RS surveyors, interested organizations and persons in the area of the RS Branch Offices' activity.
2. Apply the provisions of the Circular Letter during review and approval of the technical documentation on materials applied on ships contracted for construction or conversion on or after 01.07.2023, in the absence of a ship's data, during review and approval of the technical documentation on materials requested for review on or after 01.07.2023.

List of the amended and/or introduced paras/chapters/sections:
Part XIII: Chapters 3.7 and 3.8

Person in charge: Maxim E. Yurkov 321 +7 (812) 314-07-34
"Thesis" System No. 23-49616

Appendix 1 to Circular Letter
No. 311-05-1929c dated 25.04.2023

Information on amendments introduced by the Circular Letter
(for inclusion in the Revision History to the RS Publication)

Nos.	Amended paras/chapters/ sections	Information on amendments	Number and date of the Circular Letter	Entry-into-force date
1	Chapter 3.7	Chapter has been revised considering IACS UR W7 (Rev.4 Feb 2022)	311-05-1929c of 25.04.2023	01.07.2023
2	Chapter 3.8	Chapter has been revised considering IACS UR W8 (Rev.3 Mar 2022)	311-05-1929c of 25.04.2023	01.07.2023

RULES FOR THE CLASSIFICATION AND CONSTRUCTION OF SEA-GOING SHIPS, 2023,

ND No. 2-020101-174-E

PART XIII. MATERIALS

3 STEEL AND CAST IRON

Chapters 3.7 and 3.8 are replaced by the following text:

"3.7 STEEL FORGINGS

3.7.1 General.

3.7.1.1 The present requirements are applicable to steel forgings intended for items of hull and machinery applications as specified in other parts of the Rules and having respective references to this Chapter. Where relevant, these requirements are also applicable to material for forging stock and to rolled bars intended to be machined into components of simple shape.

3.7.1.2 The requirements of this Chapter are applicable only to steel forgings (or rolled steel when used instead of steel forgings as specified in 3.7.1.1) where the designation is determined proceeding from the properties at room temperature.

Additional requirements for the forgings with confirmed cold resistance properties at the required sub-zero temperature are given in 3.5.5.

Requirements for the stainless steel forgings are given in 3.16.

Requirements for the forgings intended for operation at cryogenic temperatures are specified in Part IX "Materials and Welding" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk.

3.7.1.3 Alternatively to the manufacturing of steel forgings (or rolled steel when used instead of steel forgings as specified in 3.7.1.1), forgings, which comply with national or proprietary specifications, may be accepted by the Register. In this case, according to the procedure specified in 1.3.1.2, the equivalence of these alternative requirements or their justification for the given manufacture and/or application shall be confirmed to the Register.

3.7.1.4 Steel forgings (or rolled steel when used instead of steel forgings as specified in 3.7.1.1) shall be made by the manufacturer recognized by the Register in compliance with 1.3.1.2. The steel used in the manufacture of the forgings shall be made by the process approved by the Register.

In case the steel is produced at separate works, such manufacturer shall also be approved by the Register.

Adequate top and bottom discards (of a rolled blank) shall be made to ensure freedom from piping and harmful segregations in the finished forgings.

3.7.1.5 The plastic deformation (reduction ratio) shall be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio shall be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, the plastic deformation reached during this operation may be considered.

Unless otherwise stipulated or agreed the total reduction ratio shall be at least:

for forgings made from ingot or from forged bloom or billet, using continuous casting plant — 3:1 where $L > D$ and 1,5:1 where $L \leq D$;

for forgings made from rolled products, 4:1 where $L > D$ and 2:1 where $L \leq D$;

for forgings made by upsetting, the length after upsetting shall be not more than one-third of the length before upsetting or, in the case of an initial forging reduction of at least 1,5:1, not more than one-half of the length before upsetting;

for rolled bars, 6:1

where *L* and *D* are the length and diameter respectively of the part of the forging or its part.

3.7.1.6 For crankshafts, where grain flow is required in the most favourable direction in regard to the mode of stressing in service, the pressure shaping process shall be subject to agreement by the Register.

3.7.1.7 The shaping of forgings or rolled slabs and billets by flame cutting, scarfing or arc-air gouging shall be carried out before the final heat treatment. Preheating shall be employed when necessitated by the composition and/or thickness of the steel. For certain components, subsequent machining of all flame cut surfaces may be required.

3.7.1.8 When two or more forgings are joined by welding to form a composite component, the chemical composition and welding procedure shall be agreed by the Register; the welding procedure qualification approval shall be required.

3.7.1.9 The requirements of Section 6, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships are applicable to the welding procedure qualification tests of welded forgings intended to be used for the components of hull structures of ships and offshore installations.

Requirements for other WPS, qualification tests, welder certification and welding consumables are specified in the relevant parts of the Rules.

3.7.1.10 The requirements for welders intended to be engaged in fusion welding of steel forgings for hull structures are specified in Section 4, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

3.7.2 Chemical composition.

3.7.2.1 The chemical composition of steel for forgings shall be appropriate for the type of steel and the required mechanical and special properties of the forgings being manufactured.

The forgings shall be made from killed steel.

3.7.2.2 The chemical composition of each heat shall be determined by the manufacturer on a sample taken preferably during the pouring of the heat. When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

3.7.2.3 The chemical composition shall comply with the requirements of Table 3.7.2.3-1 (for hull steel forgings) and Table 3.7.2.3-2 (for machinery steel forgings) or with the requirements of the specification agreed by the Register.

Table 3.7.2.3-1[1]

Steel type	C	Si	Mn	P	S	Cr[2]	Mo[2]	Ni[2]	Cu[2]	Total residuals
Carbon, carbon-manganese	0,23[3,4]	0,45	0,3 — 15	0,035	0,035	0,30	0,15	0,40	0,30	0,85
Alloy[5]	–	0,45	–	0,035	0,035	–	–	–	0,30	–

[1] Composition in percentage mass by mass maximum unless shown as a range.

[2] Element is considered as residual element.

[3] The carbon content may be increased above this level, provided that the carbon equivalent (C_{eq}) is not more than 0,41 %, calculated using the following formula: $C_{eq}\ (\%) = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$.

[4] The carbon content of carbon and carbon-manganese steel forgings not intended for welded structures may be 0,65 % maximum.

[5] The content of C, Mn, Cr, Mo, Ni and the total content of residual elements shall be indicated in the specification to be submitted for agreement.

Note. Shaft and rudder stocks forgings shall be of weldable quality.

Table 3.7.2.3-2[1]

Steel type	C	Si	Mn	P	S	Cr	Mo	Ni	Cu[2]	Total residuals
Carbon, carbon-manganese	0,23[3, 4]	0,45	0,3 — 1,5	0,035	0,035	0,30	0,15	0,40	0,30	0,85
Alloy[5]	0,45	0,45	0,3 — 1,0	0,035	0,035	Min 0,40[6]	Min 0,15[6]	Min 0,40[6]	0,30	–

[1] Composition in percentage mass by mass maximum unless shown as a range or as a minimum.
[2] Element is considered as residual element.
[3] The carbon content may be increased above this level, provided that the carbon equivalent (C_{eq}) is not more than 0,41 %, calculated using the following formula: $C_{eq}\ (\%) = C + \frac{Mn}{6} + \frac{Cr+Mo+V}{5} + \frac{Ni+Cu}{15}$.
[4] The carbon content of carbon and carbon-manganese steel forgings not intended for welded structures may be 0,65 % maximum.
[5] Where alloy steel forgings are intended for welded structures, the proposed chemical composition shall be indicated in the specification to be submitted for agreement.
[6] The content of one or more of the specified elements shall comply with the minimum content.

3.7.2.4 If not otherwise stated, grain refining elements such as aluminium, niobium or vanadium may be added at the discretion of the manufacturer. The content of such elements shall be reported in the results of the chemical analysis.

3.7.2.5 Elements designated as residual elements shall not be contained in steel in great quantity. The content of such elements shall be reported in the results of the chemical analysis.

3.7.3 Mechanical properties.

3.7.3.1 Tables 3.7.3.1-1 and 3.7.3.1-2 give the minimum requirements of the Register for yield stress, elongation, reduction in area and impact test energy values corresponding to the different strength levels.

Table 3.7.3.1-1

Mechanical properties for hull steel forgings

Steel type	Tensile strength[1] R_m, min, MPa	Yield stress R_e, min, MPa	Elongation A_5, min, %		Reduction in area Z, min, %		Impact energy[2] KV, J		
			Longitudinal	Tangential	Longitudinal	Tangential	Test temperature °C	Longitudinal	Tangential
Carbon, carbon-manganese	400	200	26	19	50	35	0	27	18
	440	220	24	18	50	35			
	480	240	22	16	45	30			
	520	260	21	15	45	30			
	560	280	20	14	40	27			
	600	300	18	13	40	27			
Alloy	550	350	20	14	50	35			
	600	400	18	13	50	35			
	650	450	17	12	50	35			

[1] The tensile strength values obtained at tensile testing shall not exceed the set values by more than:
120 MPa for the specified R_m < 600 MPa;
150 MPa for the specified R_m ≥ 600 MPa.
[2] Tests shall be carried out on the V-notch type specimens. The values of minimum average impact energy are specified on three test specimens. Alternative testing conditions and stipulated values may be reviewed by the Register on the basis of design solutions and operation conditions.

Table 3.7.3.1-2

Mechanical properties for machinery steel forgings

Steel type	Tensile[1] strength R_m, min, MPa	Yield stress R_e, min, MPa	Elongation A_5, min, %		Reduction in area Z, min, %		Brinell hardness[2]	Impact energy[3, 4] KV, J		
			Longitudinal	Tangential	Longitudinal	Tangential		Test temperature °C	Longitudinal	Tangential
Carbon, carbon-manganese	400	200	26	19	50	35	110 — 150	AT[5]	27	18
	440	220	24	18	50	35	125 — 160			
	480	240	22	16	45	30	135 — 175			
	520	260	21	15	45	30	150 — 185			
	560	280	20	14	40	27	160 — 200			
	600	300	18	13	40	27	175 — 215			
	640	320	17	12	40	27	185 — 230			
	680	340	16	12	35	24	200 — 240			
	720	360	15	11	35	24	210 — 250			
	760	380	14	10	35	24	225 — 265			
Alloy	600	360	18	14	50	35	175 — 215			
	700	420	16	12	45	30	205 — 245			
	800	480	14	10	40	27	235 — 275			
	900	630	13	9	40	27	260 — 320			
	1000	700	12	8	35	24	290 — 365			
	1100	770	11	7	35	24	320 — 385			

[1] The following ranges for tensile strength may be additionally specified:
the tensile strength values obtained at tensile testing shall not exceed the following:
150 MPa for the specified R_m < 900 MPa;
200 MPa for the specified R_m ≥ 900 MPa.

[2] The hardness values are given for information purposes only.

[3] For ships with ice class marks **IA Super**, **IA**, **IB** and **IC**, materials used in machinery under sea water temperature such as propeller shafts and shaft bolts, the impact tests shall be carried out at – 10 °C. The average impact energy value *KV* for a series of longitudinal specimens shall be at least 20 J. No more than for one of three specimens the result may be by 30 % below the required.

[4] Alternative testing conditions and stipulated values may be reviewed by the Register on the basis of design decisions and operation conditions.

[5] The design ambient temperature (AT) value may be taken as AT value in accordance with ISO 148-1:2016, equal to 23±5 °C.

Where it is proposed to use a steel with a specified minimum tensile strength intermediate to those given, corresponding minimum values required by the Register for the other properties specified in the above tables may be obtained by interpolation.

Forgings may be used where their properties are those established in the relevant RS-agreed standards.

3.7.3.2 Hardness tests may be required by the Register on the following:

.1 gear forgings after completion of heat treatment and prior to machining the gear teeth.

The hardness shall be determined at four positions equally spaced around the circumference of the surface where teeth will subsequently be cut. Where the finished diameter of the toothed portion exceeds 2,5 m, the above number of test positions shall be increased to eight. Where the width of a gear wheel rim forging exceeds 1,25 m, the hardness shall be determined at eight positions at each end of the forging;

.2 small crankshaft and gear forgings, which have been batch tested.

In such cases at least one hardness test shall be carried out on each forging.

The results of hardness tests shall be reported to the representative of the Register. Corresponding Brinell hardness values are given in Table 3.7.3.1-2 for information purposes.

Hardness tests may also be required on forgings, which have been induction hardened, nitrided or carburized. For gear forgings these tests shall be carried out on the teeth after, where applicable, they have been ground to the finished profile. The results of such tests shall comply with the documentation agreed and recognized by the Register (refer to 3.7.4.6).

3.7.3.3 Where the test results are unsatisfactory re-testing shall be conducted in accordance with 1.3.2.3.

3.7.4 Heat treatment (including surface hardening and straightening).

3.7.4.1 All the forgings shall be suitably heat treated to obtain the required mechanical properties and metal structure, and to refine the grain structure. The procedure of heat treatment shall be chosen by the manufacturer proceeding from the chemical composition of steel, the purpose and dimensions of the forging.

3.7.4.2 Except as provided in 3.7.4.6 and 3.7.4.7 forgings shall be supplied in one of the following conditions:

.1 carbon and carbon-manganese steels:

fully annealed;

normalized;

normalized and tempered;

quenched and tempered;

.2 alloy steels:

normalized;

normalized and tempered;

quenched and tempered.

The tempering temperature shall not be less than 550 °C.

The delivery condition shall meet the design and application requirements. It is the manufacturer's responsibility to select the appropriate heat treatment method to obtain the required mechanical properties. Where forgings for gearing are not intended for surface hardening, lower tempering temperature may be allowed.

3.7.4.3 Heat treatment shall be carried out in properly equipped furnaces, which have adequate means for temperature recording. The furnace shall provide the required quality of operation and proper level of control over the process regardless of forging dimensions. In the case of very large forgings, or lack of the required equipment methods of heat treatment will be specially considered by the Register on a separate request.

3.7.4.4 If for any reasons a forging is subsequently heated for further hot working, the forging shall be reheat treated.

3.7.4.5 Where it is intended to surface harden forgings, the proposed procedure and specification shall be agreed by the Register. The results of tests to verify the uniformity and depth of surface layer shall be submitted to the Register.

3.7.4.6 Where induction hardening or nitriding shall be carried out, forgings shall be heat treated at an appropriate stage and condition suitable for this subsequent surface hardening.

3.7.4.7 Where carburizing shall be carried out, forgings shall be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) and condition providing the required level of mechanical properties and hardening.

3.7.4.8 If a forging is locally reheated or any straightening operation is performed after the final heat treatment, it shall be heat treated to relive the subsequent stress. The manufacturer shall have strict control of this temperature in order to avoid any detrimental effects to the resultant microstructure and mechanical properties of the forging following the final heat treatment.

3.7.4.9 The forge shall maintain records of heat treatment identifying conditions, the furnace used, furnace charge, time of charging, temperatures and time of conditioning. The records shall be presented to the Register on request.

3.7.5 Sampling.

3.7.5.1 The sample, sufficient for the required tests and for possible retest purposes, shall be provided with a cross-sectional area of not less than that part of the forging, which it represents. This sample shall be integral with each forging except as provided in 3.7.6.1.10 and 3.7.6.1.13. Where batch testing is permitted according to 3.7.6.1.13, the sample may alternatively be a production part or separately forged. Separately forged sample shall have dimensions not less than those of the forgings represented.

3.7.5.2 Generally, a tensile test specimen and, when required, a set of impact tests specimens shall be cut from a sample.

3.7.5.3 Test specimens shall normally be cut with their axes either mainly parallel (longitudinal test) or mainly tangential (tangential test) to the principal axial direction of each product.

Test specimens shall be cut the following way:

.1 for forgings having a thickness *t*, or diameter *D* up to 50 mm, the longitudinal axis of the test specimen shall be located at a distance of *t/2* or *D/2* below the heat treated surfaces;

.2 for forgings having a thickness, *t*, or diameter *D* greater than 50 mm, the longitudinal axis of the test specimen shall be located at a distance of *t/4* or *D/4* (mid-radius) or 80 mm, whichever is less, below any heat treated surface.

Test specimen shall be located with its longitudinal axis at an equal distance from any heat treated surface as shown in Fig. 3.7.5.3;

.3 for ring and disc forgings, tangential sample shall be taken at *t/2* for thickness ≤ 25 mm or 12,5 mm below the surface for thickness > 25 mm, in both the vertical and horizontal direction.

Where achievable, for thickness > 25 mm, no part of the test material shall be closer than 12,5 mm to any heat treated surface, as shown in Fig. 3.7.5.3.

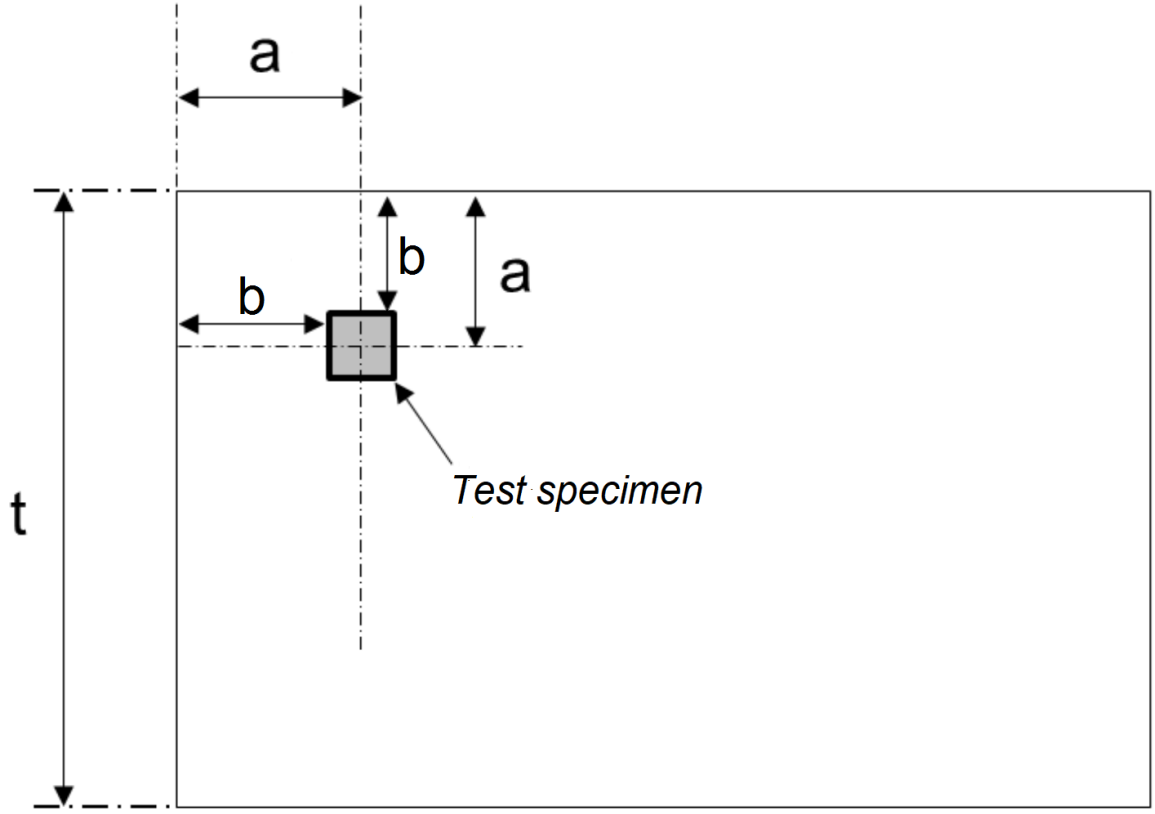

Fig. 3.7.5.3

a — the distance from the axis of the test specimen to heat treated surface in accordance with 3.7.5.3.2;
b — the distance from the test specimen surface to heat treated surface in accordance with 3.7.5.3.3

3.7.5.4 Alternative location of test specimens, their orientation and relevant heat treatment process which are more representative of the mechanical properties, may be proposed by the manufacturer together with the technical justification and confirming test results. In such case, the heat treatment process, a proposed sampling point and orientation shall be approved by the Register.

3.7.6 Scope of testing.

3.7.6.1 Forgings shall be submitted for testing individually or in batches. Except as provided in 3.7.6.13 the number and direction of tests shall correspond to the listed below:

.1 hull forgings (such as rudder stocks, pintles, etc.) and general machinery components (such as shafting, connecting rods, etc.):

one sample shall be taken from the end of each forging in a longitudinal direction except that, at the discretion of the manufacturer, the alternative directions or positions as shown in Fig. 3.7.6.1.1-1, 3.7.6.1.1-2 and 3.7.6.1.1-3 may be used.

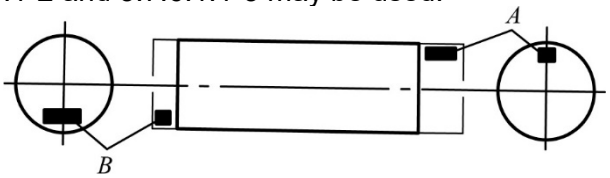

Fig. 3.7.6.1.1-1

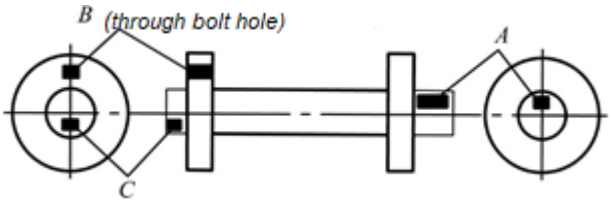

Fig. 3.7.6.1.1-2

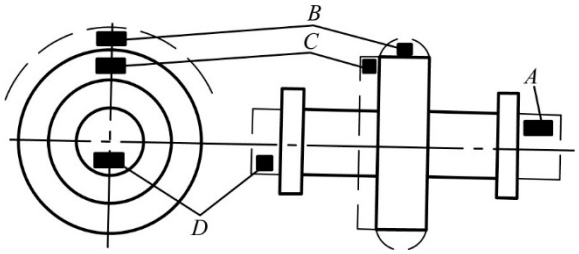

Fig. 3.7.6.1.1-3

where a forging exceeds both 4 t in mass and 3 m in length, one sample shall be taken from each end. These limits refer to the "as forged" mass and length but excluding the sample material;

.2 pinion forgings:

where the finished machined diameter of the toothed portion exceeds 200 mm, one sample shall be taken from each forging in a tangential direction adjacent to the toothed portion according to Fig. 3.7.6.1.2 (position B). Where the dimensions preclude sampling from position B, sample in a tangential direction shall be taken according to Fig. 3.7.6.1.2 (position C);

if however, the journal diameter is 200 mm or less, the sample shall be taken in a longitudinal direction according to Fig. 3.7.6.1.2 (position A);

where the finished length of the toothed portion exceeds 1,25 m, one sample shall be taken from each end;

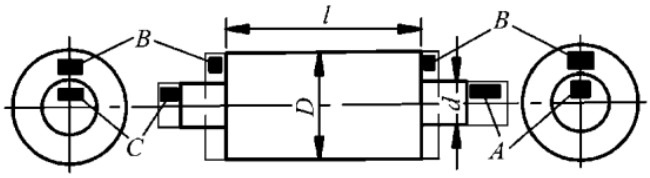

Fig. 3.7.6.1.2

.3 small pinion forgings:

where the diameter of the toothed portion is 200 mm or less, one sample shall be taken in a longitudinal direction according to Fig. 3.7.6.1.2 (position A);

.4 gear wheel forgings:

one sample shall be taken from each forging in a tangential direction according to Fig. 3.7.6.1.4 (position A or B);

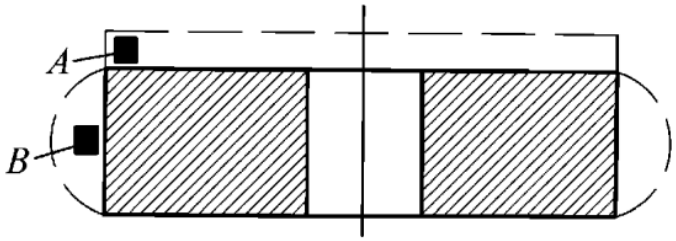

Fig. 3.7.6.1.4

.5 gear wheel rim forgings (made by expanding):

one sample shall be taken from each forging in a tangential direction according to Fig. 3.7.6.1.5 (position A or B);

where the finished diameter exceeds 2,5 m or the mass (as heat treated including test material) exceeds 3 t, two samples shall be taken from diametrically opposite positions according to Fig. 3.7.6.1.5 (positions A and B).

The mechanical properties may as well be determined on longitudinal test specimens;

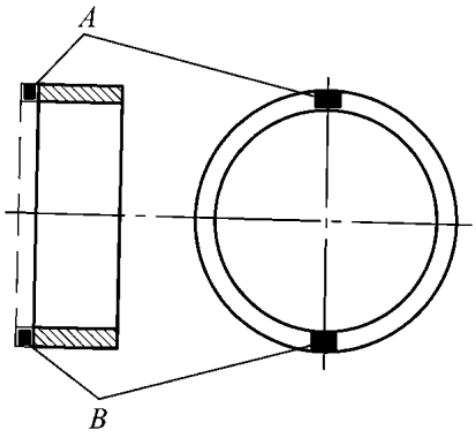

Fig. 3.7.6.1.5

.6 pinion sleeve forgings:

one sample shall be taken from each forging in a tangential direction according to Fig. 3.7.6.1.6 (position A or B);

where the finished length exceeds 1,25 m, one sample shall be taken from each end;

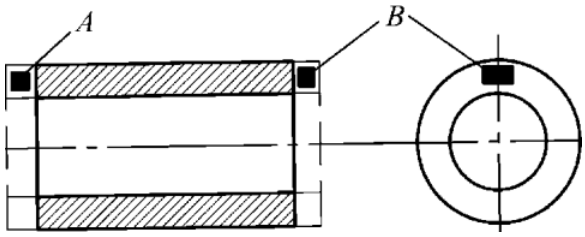

Fig. 3.7.6.1.6

.7 crankweb forgings:

one sample shall be taken from each forging in a tangential direction;

.8 solid-forged crankshafts:

one sample shall be taken in a longitudinal direction from the driving shaft end (from coupling) of each forging according to Fig. 3.7.6.1.8 (position A);

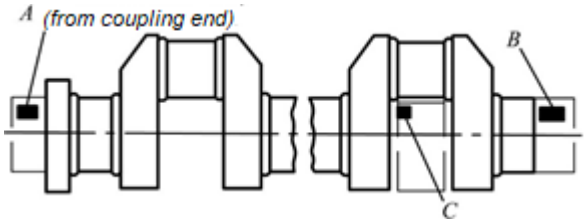

Fig. 3.7.6.1.8

where the mass (as heat treated but excluding test material) exceeds 3 t, one sample in a longitudinal direction shall be taken from each end according to Fig. 3.7.6.1.8 (positions A and B);

where, however, the crankthrows are formed by machining or flame cutting, the second sample shall be taken in a tangential direction from material removed from the crankthrow at the end opposite the driving shaft end (from coupling) according to position C;

.9 forged rings (such as slewing rings):

One test specimen shall be taken from each forging in a tangential direction in accordance with Fig. 3.7.6.1.9. Where the finished diameter exceeds 2,5 m or the mass (as heat treated,

including test material) exceeds 3 t then two sets of tests shall be taken diametrically opposite positions.

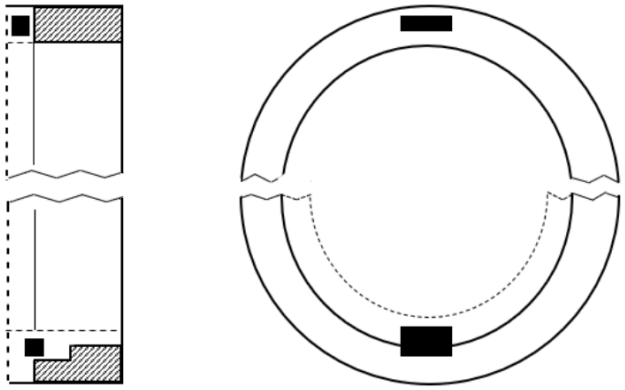

Fig. 3.7.6.1.9

.10 forgings with grain flow in the most favorable direction where the method of manufacture is subject to approval by the Register in accordance with 3.7.1.6:

the number and position of samples shall be agreed in the course of approval of respective procedure and recognition of the firm (manufacturer);

.11 when a forging is subsequently divided into a number of components, all of which are heat treated together in the same furnace charge, for test purposes this may be regarded as one forging and the number of tests required shall be related to the total length and mass of the original multiple forging;

.12 except for components, which shall be carburized, or for hollow forgings samples shall not be cut from a forging until all heat treatment has been completed;

.13 when forgings shall be carburized, the sample size shall provide for both preliminary tests (after the forge) and for final tests (after completion of carburizing). For this purpose, duplicate sample shall be taken from positions as detailed in 3.7.6.1, except that irrespective of the dimensions or mass of the forging, tests are required from one position only and, in the case of forgings with integral journals, shall be cut in the longitudinal direction.

Samples shall be machined to a diameter of $D/4$ or 60 mm, whichever is less, where D is the finished diameter of the toothed portion.

For preliminary tests (after the forge) the samples shall be given a blank carburizing and heat treatment cycle simulating that which subsequently will be applied to the forging. For final acceptance tests, the rest of samples shall be blank-carburized and heat-treated along with the forgings, which they represent. At the discretion of the forge or gear manufacturer, test samples of larger cross section may either be carburized or blank-carburized, but these shall be machined to the required diameter prior to the final quenching and tempering heat treatment.

Alternative procedures for testing the forgings to be carburized are subject to the approval by the Register as part of the submitted documentation;

.14 normalized forgings with a mass up to 1000 kg each and quenched and tempered forgings with mass up to 500 kg each may be batch tested. A batch shall consist of forgings of similar shape and dimensions, made from the same heat of steel, heat treated in the same furnace charge and with a total mass not exceeding 6 t for normalized forgings and 3 t for quenched and tempered forgings, respectively;

.15 a batch testing procedure may also be used for hot rolled bars. Batch quantity is determined proceeding from the following:

.15.1 material from the same rolled ingot or bloom provided that these are all heat treated in the same furnace charge;

.15.2 bars of the same diameter and heat, heat-treated in the same furnace charge and with a total mass not exceeding 2,5 t;

.16 the preparation of test specimens and testing procedures shall comply with the relevant requirements of Section 2.

Unless otherwise agreed, all tests shall be carried out in the presence of the Register representative.

3.7.7 Non-destructive testing and repair of defects.

3.7.7.1 All forgings shall be subjected to a 100 % visual testing of all accessible surfaces by the manufacturer and made available to the Register representative. Where applicable, this visual testing shall include the examination of internal surfaces and bores. Unless otherwise agreed, the verification of dimensions is the responsibility of the manufacturer.

The forgings shall be free from defects, which would be prejudicial to their proper application.

3.7.7.2 When required by the relevant parts of the Rules or by the Register approved technical documentation, the forgings, including forged composite components, which shall be welded (refer to 3.7.1.8), appropriate non-destructive testing shall also be carried out. The results shall be reported to the Register representative and included in a relevant quality document of the manufacturer on a forging or batch. In compliance with the requirements of this Part and 2.5, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships, ultrasonic testing shall be carried out after the forgings have been machined to a condition suitable for this type of examination and after the final heat treatment. Both radial and axial scanning shall be carried out where appropriate for the shape and the dimensions of the forgings being tested.

The method and extent of testing and acceptance criteria shall be agreed with the Register.

3.7.7.3 The requirements of 2.5, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships shall be taken as a base level for non-destructive testing.

For mass produced forgings the individual extent of testing for such production is subject to be agreed with the Register.

3.7.7.4 Unless otherwise agreed, visual testing shall be carried out by the manufacturer, although the Register reserves the right to request the presence of its representative in order to verify that the tests are is being carried out in accordance with the agreed procedure.

3.7.7.5 If the forging is supplied without any further processing of the forging, the manufacturer shall ensure that suitable ultrasonic testing is carried out to verify the internal quality of the forging.

3.7.7.6 Where advanced ultrasonic testing methods are applied, e.g. PAUT or TOFD, the requirements of Section 3, Part XIV "Welding" shall be applied to these methods.

In such cases, acceptance levels regarding accept/reject criteria shall comply with the relevant requirements of 2.5, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

3.7.7.7 When surface hardening of forgings is required (refer to 3.7.4.5), additional samples may be selected at the time of inspection. These samples shall be subsequently sectioned in order to determine the hardness, shape, area and depth of the locally hardened zone and which shall comply with the requirements of the Register approved documentation.

3.7.7.8 In the event of any forging proving defective in accordance with the Rules or Register approved documentation during subsequent machining or testing, it shall be rejected notwithstanding prior survey results.

3.7.7.9 It is permitted to remove surface defects by grinding or chipping and grinding within mechanical allowances. The resulting grooves shall have a bottom radius of approximately three times the groove depth. Sharp contours are not permitted. Complete elimination of defective material shall be verified by magnetic particle or penetrant testing.

3.7.7.10 Repair welding of forgings (except those subjected to torsional fatigue, such as crankshaft forgings and propeller shaft forgings), is defined by the forgings documentation approved by the Register. Procedure and location of the repair, subsequent heat treatment and inspection methods and criteria shall, for each case, be entered into a separate document and approved by the Register.

3.7.7.11 The forging manufacturer shall maintain records of repairs and subsequent inspections, which results shall be shown in a drawing or sketch of the forging. Respective information shall be submitted to the Register representative at the latter's request.

3.7.8 Identification and marking.

3.7.8.1 The manufacturer of forgings shall adopt a system of identification, which will enable all finished forgings, at the stage of being submitted to the Register, to be traced to the original cast, and the data pertinent to the process of a particular forging (batch) manufacture, which shall be recorded during the above process, including heat treatment and repair, shall be presented to the Register representative on request.

3.7.8.2 All forgings shall be clearly marked in a specified place and in a specified manner with the Register stamp or brand to include at least the following particulars:

manufacturer's name or trade mark;

identification number or other marking, which will enable the full history of the forging to be traced;

steel grade;

test pressure at relevant testing where applicable;

date of final inspection.

3.7.8.3 Where small forgings are manufactured in large numbers, modified arrangements for identification may be specially agreed by the Register.

3.7.8.4 The Manufacturer's Certificate to be submitted to the Register representative shall include the following particulars:

purchaser's name and order number;

steel grade and description of forgings;

identification number;

steel melting process, cast number and chemical composition as per the ladle analysis;

results of mechanical tests;

results of non-destructive testing, where applicable;

details of heat treatment, including temperature and time of conditioning.

3.8 STEEL CASTINGS

3.8.1 General.

3.8.1.1 Steel castings subject to survey by the Register, when produced in conformity with the relevant parts of the Rules, shall be manufactured and tested in accordance with the requirements stated below.

3.8.1.2 These requirements are applicable to carbon, carbon-manganese and alloy steel castings used for construction of ships, mobile offshore drilling units and manufacture of machinery items subject to technical supervision, the purpose of which shall be established by other parts of the Rules. This Chapter contains requirements for castings that intended for fabrication by welding, as well as castings not intended for welding.

3.8.1.3 Additional requirements for the castings with confirmed cold resistance properties at the required sub-zero temperature are given in 3.5.6.

Requirements for the castings intended for operation at cryogenic temperatures are specified in Part IX "Materials and Welding" of the Rules for the Classification and Construction of Ships Carrying Liquefied Gases in Bulk.

Additional requirements for castings designed for boilers and systems shall be established by the designer.

The requirements of this Chapter shall not apply to stainless steel castings.

Additional requirements for castings of MODU/FOP shall be established by the designer and shall be based on the design temperature and operation conditions.

3.8.1.4 Application in shipbuilding industry of joining of two or more castings by welding to form a composite component involves compliance of the welding procedure with the requirements of Section 6, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

When applying castings in steel welded structures, welders shall be qualified in accordance with Section 4, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

Requirements for other WPS of steel castings, welder certification and choice of welding consumables shall be submitted to the Register in each particular case.

3.8.1.5 The castings shall be manufactured at works recognized according to 1.3.1.2 in conformity with the procedure approved by the Register. Use of surface hardening in the production process shall be also agreed with the Register.

3.8.1.6 Temporary welds made for operations such as lifting, handling, staging, etc., shall be in accordance with approved welding procedures and carried out by qualified welders. Tack welding left after separation of temporary welds shall be removed. Weld areas shall be grounded and inspected using suitable NDT methods.

3.8.2 Chemical composition.

3.8.2.1 The chemical composition of a particular type of steel will be established proceeding from the mechanical and special properties required. The castings shall be made from killed steel.

3.8.2.2 For carbon and carbon-manganese steel castings the chemical composition of ladle samples shall comply with the requirements of Table 3.8.2.2 and of the documents (specifications, standards, etc.) agreed with the Register.

Table 3.8.2.2

Steel grade	Application	C, max	Si, max	Mn,	S, max	P, max	Residual elements, max				Total number of residual elements, max
							Cu	Cr	Ni	Mo	
Carbon, carbon-manganese	Non-welded structures	0,40	0,60	0,50 — 1,60	0,035	0,035	0,30	0,30	0,40	0,15	0,80
	Welded structures	0,23	0,60	0,50 — 1,60	0,035	0,035	0,30	0,30	0,40	0,15	0,80
Alloy							Alloying elements[1], min				
	Non-welded structures	0,45	0,60	0,50 — 1,60	0,030	0,030	0,30	0,40	0,40	0,15	–
	Welded structures	Established by the approved documentation									–

[1] At least one of the elements shall comply with the specified requirements.

3.8.2.3 Suitable grain-refining elements may be used at the discretion of the manufacturer and shall be agreed with the Register on request.

3.8.3 Mechanical properties.

3.8.3.1 The mechanical properties of steel castings shall meet the requirements of Table 3.8.3.1 and/or of documentation approved by the Register. Table 3.8.3.1 give minimum values of yield stress, elongation, reduction in area and impact test energy established depending on the steel grade and required level of the tensile strength values for the steel castings.

Table 3.8.3.1

Steel grade	Tensile strength R_m[2, 3], min, MPa	Yield stress R_{eH} or $R_{p0,2}$, MPa	Elongation A_5, %	Reduction in area Z, %	Average impact energy[4] KV, min, J
Steel intended for welding[1]					
Carbon, carbon-manganese	400	200	25	40	27
	440	220	22	30	
	480	240	20	27	
	520	260	18	25	
	560	300	15	20	
	600	320	13	20	
Alloy	550	355	18	30	27
	600	400	16	30	
	650	450	14	30	
	700	540	12	28	
Steel not intended for welding[5]					
Carbon, carbon-manganese	400	200	25	40	27
	440	220	22	30	
	480	240	20	27	
	520	260	18	25	
	560	300	15	20	
	600	320	13	20	
Alloy	550	340	16	35	27
	600	400	16	35	
	650	450	14	32	
	700	540	12	28	

[1] The impact tests of the steel intended for welding shall be carried out at temperature 0 °C.
[2] Minimum yield stress value 150 MPa is allowed.
[3] For intermediate tensile strength values, the minimum values of yield stress, elongation and reduction in area may be determined by linear interpolation.
[4] Alternative requirements for temperature and impact test criteria, depending on operation conditions, are subject to agreement by the Register.
[5] Impact tests of steel not intended for welding shall be performed at an ambient temperature (AT), i.e. 23 ± 5 °C as specified in ISO 148-1:2016.

3.8.3.2 Where tensile test results are unsatisfactory, retesting shall be conducted in compliance with the requirements of 3.8.6.4.

3.8.4 Heat treatment.

3.8.4.1 To ensure the required structure and mechanical properties the castings shall undergo heat treatment. The procedure of heat treatment shall be chosen by the manufacturer proceeding from the chemical composition of steel, the purpose and shape of the castings. The following conditions shall be observed:

the tempering temperature shall not be less than 550 °C;

the stress relief heat treatment of castings for components such as crankshafts and engine bedplates where dimensional stability and freedom from internal stresses are important, shall be carried out at a temperature of not less than 550 °C followed by furnace cooling to 300 °C or lower;

if a casting is reheated or any straightening operation is performed after the final heat treatment, a subsequent stress relieving heat treatment may be required.

3.8.4.2 The steel castings shall be supplied in the following condition:

.1 carbon and carbon-manganese steels:

completely annealed;

after normalizing;

after normalizing and tempering;

after quenching and tempering.

.2 alloy steel:

after normalizing;

after normalizing and tempering;

after quenching and tempering.

All necessary data on the heat treatment process including procedures and appropriate instrument readings shall be submitted to the Register representative on his demand. The delivery condition shall meet the design and application requirements. It is the manufacturer's responsibility to select the appropriate heat treatment method to obtain the required mechanical properties.

3.8.4.3 In case where steel casting after final heat treatment is subjected to local heating or to operations producing additional strain, heat treatment may be required to relieve residual stress. The manufacturer shall have strict control of this temperature in order to avoid any detrimental effects to the final heat treatment and resultant microstructure and mechanical properties of the casting.

3.8.4.4 Heat treatment shall be carried out in properly constructed furnaces which are efficiently maintained and have adequate means for control and recording of temperature. The furnace dimensions shall be such as to allow the whole casting to be uniformly heated to the necessary temperature.

In the case of very large castings alternative methods for heat treatment will be specially considered by the Register.

3.8.5 Sampling.

3.8.5.1 When preparing samples, their size shall be such as to ensure the performance of tests including re-tests, if required. Samples shall be provided for each casting or batch of castings.

3.8.5.2 Sampling may be effected directly from the casting or the test samples may be cast to it. All samples shall be identified.

3.8.5.3 The size of the test blocks for mechanical testing shall be such that the heat treatment and microstructure are representative for the section of the casting with the ruling section for which the mechanical properties specified in 3.8.3 apply. Refer also to ISO 683-1:2018 and ISO 683-2:2018.

As a rule, for carbon and carbon-manganese steels the grade shall have a thickness t_s of not less than 30 mm of the ruling section of the casting, or 30 mm, whichever is larger.

For large thickness castings other than stern tube, stern frame, anchor and rudder horn, t_s normally shall not exceed 150 mm. Length and width of the test block shall normally be at least three times t_s, as shown in Fig. 3.8.5.3-1 unless otherwise agreed with the Register. Longer or wider test blocks may be necessary in order to accommodate the required test specimens. Shorter width or length may be accepted for castings where actual width or length t_A is in the range between t_s and $3t_s$.

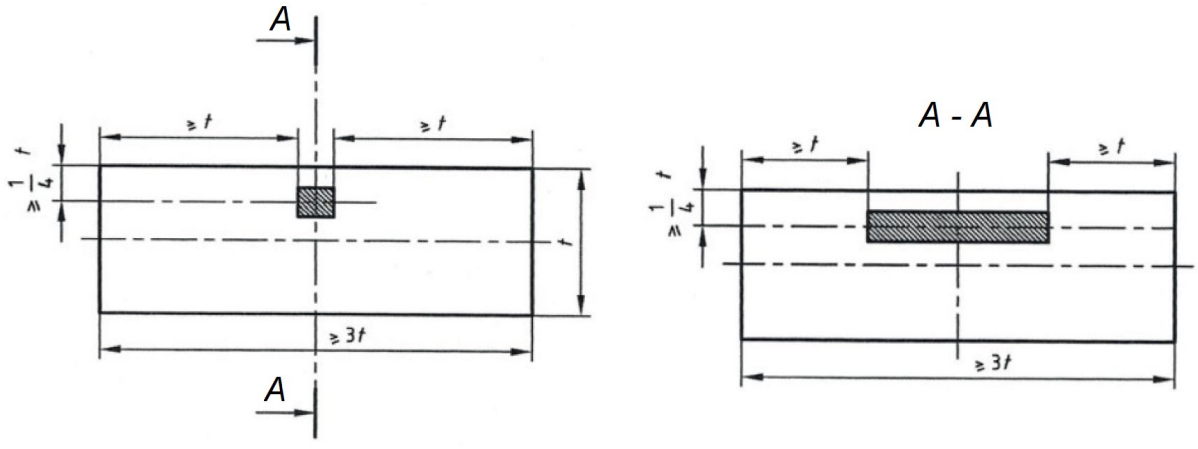

Fig. 3.8.5.3-1
Specimen positions relative to the test block in accordance with ISO 4990:2015

For castings for stern tube, stern frame, anchor and rudder horn the test block thickness t_s shall represent the ruling section.

Example 1. For a general casting with dimensions 140 x 160 x 1250 mm the required test block size may typically be 140 x 160 x 420 mm (that is: t_s x t_A x $3t_s$).

Example 2. For a stern tube casting with ruling section t_s = 170 mm and width/height/length t_{A1} x t_{A2} x t_{A3} = 1000 x 600 x 1800 mm, the required test block size may typically be 170 x 510 x 510 mm (that is: t_s x $3t_s$ x $3t_s$) as shown in Fig. 3.8.5.3-2.

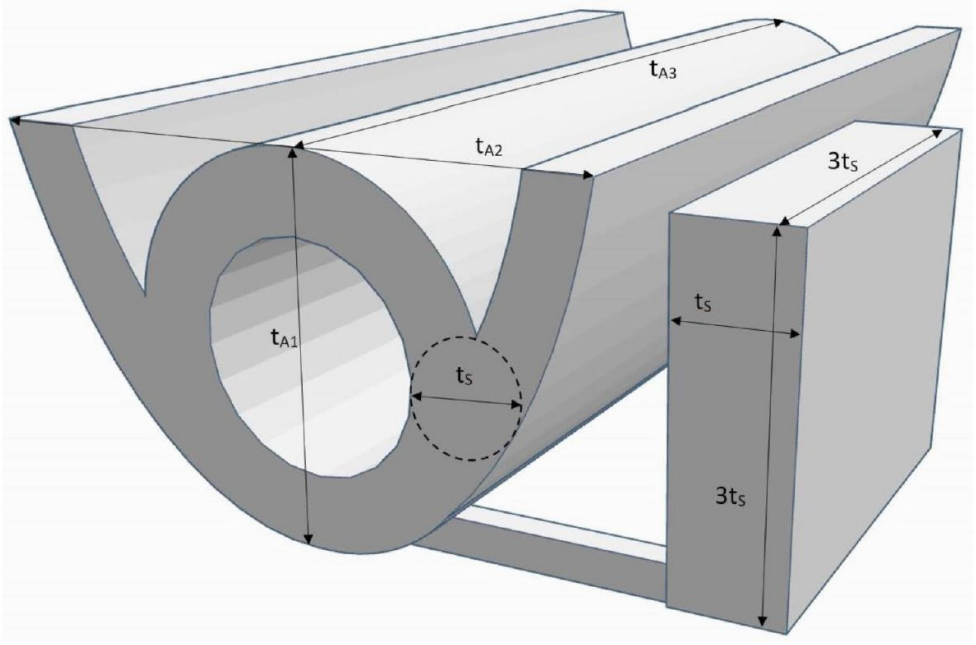

Fig. 3.8.5.3-2
Test block gated to stern tube casting

3.8.5.2 Where two or more samples shall be provided for a casting they shall be cast at locations as widely separated as possible.

3.8.5.3 The samples shall be heat treated together with the castings, which they represent.

3.8.5.4 For test blocks with thickness ≤ 56 mm, the longitudinal axis of the test specimens shall be located at ≥ 14 mm from the surface in the thickness direction.

For test blocks with thickness > 56 mm, the longitudinal axis of the test specimens shall be located at ≥ ¼ t_s from the surface.

Specimen cutout and processing shall be performed in such a way that the design length of test specimens shall not be closer than t_s to any of the other surfaces. For impact testing, this requirement shall apply to the surfaces of test specimens as shown on Fig. 3.8.5.3-1.

3.8.6 Scope of testing.

3.8.6.1 At least one sample shall be provided for each casting. Where one casting is made from several casts (without mixing) the number of samples shall be equal to the number of casts involved. The condition of 3.8.5.2 shall be met in this case.

Where the casting is of complex design or where the finished mass exceeds 10 t, at least two cast on test blocks shall be provided from the heaviest section, located as far as practicable from each other.

3.8.6.2 A batch testing procedure may be adopted for castings. A batch shall consist of castings of approximately the same size and shape made from one cast and heat treated in the same furnace charge and having the total mass equal to or less than 1000 kg.

Such batch may be represented by one of the castings considered as a sample or by a separately cast sample, the dimensions of which shall correspond to the castings comprising the batch.

3.8.6.3 At least one tensile test specimen and one set of impact tests specimens shall be taken from each sample.

Test specimens shall be prepared and the tests conducted in conformity with the requirements of Section 2.

Unless otherwise stated, tests shall be conducted in the presence of the Register representative.

3.8.6.4 Where the tensile tests yield unsatisfactory results the tests shall be repeated on two additional specimens preferably cut out from the same sample. In case the cutting out of additional specimens from the same sample is not possible, specimens may be cut out from other sample or casting.

Where the tests carried out on two additional specimens yield satisfactory results, the casting and the batch if represented by the casting shall be accepted.

Where the test result on at least one of two additional specimens is unsatisfactory, the casting submitted shall be rejected. However, the remaining semi-finished products of the batch may be accepted by the Register, provided that satisfactory test results are obtained on two more castings comprising the batch involved. Where unsatisfactory test results are obtained on one of two additionally selected castings, the entire batch shall be rejected.

At the manufacturer's discretion, the batch or casting rejected may be submitted to re-tests on the same conditions after repeated heat treatment.

3.8.6.5 Where relevant requirements shall be found in other parts of the Rules, the castings shall be subjected to additional tests, such as pressure tests.

3.8.6.6 Where upon completion of all tests, owing to machining of the castings or as a result of any structural tests a defect is found, which interferes with the use of casting for its designated purpose, the batch shall be rejected irrespective of the availability of the relevant certificates.

3.8.7 Inspection and repair of defects.

3.8.7.1 The castings submitted for inspection and control testing shall be cleaned, de-gated, free of risers and burrs, etc.

Where castings are to be repaired, the manufacturer shall exercise robust controls of all repair operations regarding the repair of castings, with respect to dimensions, heat treatment, inspection and quality control.

3.8.7.2 The castings shall be free from defects prejudicial to their proper application in service.

3.8.7.3 Surface defects may be removed by grinding, or by chipping and grinding, or by arc air-gouging and grinding. Thermal methods of metal removal shall only be allowed before the final heat treatment. All grooves shall have a bottom radius of approximately three times the groove depth and shall be smoothly blended to the surface area with a finish equal to that of the adjacent surface.

3.8.7.4 Where relevant requirements are found in other parts of the Rules or following the instructions of a surveyor the castings shall undergo non-destructive testing. The testing procedure and the allowances for defects shall be in conformity with documentation approved by the Register. Requirements on approval of technical documentation and on non-destructive testing are specified in 2.5, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships.

3.8.7.5 Where the defective area is to be repaired by welding, the excavations shall be suitably shaped to allow good access for welding. The resulting grooves shall be subsequently ground smooth and complete elimination of the defective material shall be verified by MT or PT.

3.8.7.6 Shallow grooves or depressions resulting from the removal of defects may be accepted provided that they will cause no appreciable reduction in the strength of the casting or affect the intended use, and the depth of defect removal is not over 15 mm or 10 % of wall thickness, whichever is less. The resulting grooves or depressions shall be subsequently ground smooth and complete elimination of the defective material shall be verified by MT or PT. Small surface irregularities sealed by welding shall be treated as weld repairs.

3.8.8 Weld repairs.

3.8.8.1 For carbon and carbon-manganese steel castings weld repairs shall be suitably classified as major or minor. For alloy steel castings, repair requirements are developed separately and submitted to the Register for approval with substantial justification.

Major repairs are those where:

the depth is greater than 25 % of the wall thickness or 25 mm whichever is less; or

the total weld area on a casting exceeds 0,125 m^2 of the casting surface noting that where a distance between two welds is less than their average width, they shall be considered as one weld.

Weld repairs not possessing any above-listed features shall be deemed as minor and carried out in accordance with an approved welding procedure.

3.8.8.2 Requirements for major weld repairs.

3.8.8.2.1 The repair shall be carried out before the final delivery heat treatment condition.

3.8.8.2.2 The repair shall comply with the requirements of 3.8.8.4.

3.8.8.2.3 Before welding is started, full details of the extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures shall be submitted to the Register for approval.

3.8.8.3 Requirements for minor weld repairs.

3.8.8.3.1 The repair shall be carried out before the final delivery heat treatment condition.

3.8.8.3.2 The repair shall comply with the requirements in 3.8.8.4.

3.8.8.3.3 The Register may classify the minor repair in the critical areas to be treated as major repair.

3.8.8.3.4 With the exception of alloy steel repair, preliminary agreement with the Register is not required.

3.8.8.4 General requirements for weld repairs.

3.8.8.4.1 Defects may be repaired by welding in accordance with 2.6.3, Part XIV "Welding". Prior to carrying out weld repairs, alloy steel castings and castings for crankshafts may be pre-heated prior to welding. Castings in carbon or carbon-manganese steel may also require to be pre-heated depending on their chemical composition and the dimensions and position of the weld repairs.

3.8.8.4.2 Welding procedures shall be approved by the Register and shall comply with the requirements of Section 6, Part III "Technical Supervision during Manufacture of Materials" of the Rules for Technical Supervision during Construction of Ships and Manufacture of Materials and Products for Ships or approved standards (e.g. ISO 11970:2016).

3.8.8.4.3 Repair welding shall be done at workshops protected against draughts, wind and adverse weather conditions by qualified welders under technical supervision of the Register representative. As far as possible, all welding shall be carried out in the downhand (flat) position.

3.8.8.4.4 The welding consumables used shall be of an appropriate chemical composition, giving a weld deposit with mechanical properties similar and in no way inferior to those of the parent castings. Welding procedure tests shall be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment as detailed in 3.8.4.

3.8.8.4.5 On completion of the repair welding, the carbon and carbon-manganese castings shall be subjected to heat treatment in accordance with 3.8.4 or to relieve residual stress at temperature not lower than 550 °C. The type and procedure of heat treatment depends on the type and nature of repair work performed previously as well as on the material and size of the castings. For alloy steel castings, the heat treatment shall be agreed with the Register. The type of heat treatment employed will be dependent on the chemical composition of the casting and the dimensions, positions and nature of the repairs, and shall not affect the properties of the casting.

Refusal to carry out the above postweld heat treatment is generally acceptable for small scopes of repair.

3.8.8.4.6 On completion of heat treatment the weld repairs and adjacent material shall be ground smooth and examined by magnetic particle or liquid penetrant testing. Supplementary examination by ultrasonics or radiography ultrasonic testing may also be required depending on the dimensions and nature of the original defect. Satisfactory results shall be obtained from all forms of non-destructive testing used.

3.8.8.4.7 The manufacturer shall maintain full records detailing the extent and location of repairs made to each casting and details of weld procedures and heat treatments applied for repairs. These records shall be available to the Register representative on request and copies shall be submitted to the Register.

3.8.9 Marking and documentation.

3.8.9.1 The manufacturer of the castings shall have an identification system, which enables to identify the casting with the ladle at a stage of submission to the Register, while upon the request of the Register representative, the manufacturer shall present the data, recorded in course of manufacture referred to the production process of a particular casting, or a batch, including thermal treatment and repair.

3.8.9.2 Every casting shall have clearly visible stamp or brand of the Register marked by the specified method and in specified location, and, at least, shall contain the following data:

name or designation of the firm (manufacturer);

number or other marking, which enables to identify the presented material and the process of its production;

grade or mark of steel.

3.8.9.3 Where small castings are manufactured in large numbers the castings identification system may be agreed with the Register separately.

3.8.9.4 Manufacturer's Certificate, submitted to the Register representative, shall contain the following data:

name of purchaser and number of purchase order;

grade, (mark) of steel, type of casting;

identification number;

steel melting process, cast number and chemical composition as per the ladle analysis;

mechanical test results;

non-destructive testing results, if necessary;

heat treatment type, including temperature and time of conditioning.".