RULES CHANGE NOTICE No.2 October 2022

Part 1 Seagoing Ships

Volume V

RULES FOR MATERIALS

Consolidated Edition 2022

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Foreword

This Rules Change Notices (RCN) No. 2 provide amendment and corrigenda to the Rules for Materials 2022 Consolidated Edition along with effective date from which these changes are applicable.

Amendments to the preceding edition are marked by strikethrough, red color, and expanded text. These new additions and amendments are to be read in conjunction with the requirements given in the 2022 consolidated edition of the Rules.

The summary of current amendments for each section including the implementation date are indicated in *Table 1 - Amendments Incorporates in This Notice*.

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Any quires or comments concerning these Rules are welcomed through communication with BKI Head Office.

Rules Changes Notice No. 2 – October 2022

Table 1 – Amendments Incorporates in This Notice

These amendments will come into force for ship contracted for construction on or after 1 July 2023 unless otherwise specified in table.

Paragraph	Title/Subject	Status/Remark
Section 3 – Non-Destructive Testings		
C.	**Requirements Applicable to the Inspection Body**	
C.1	-	To supersede requirement about ISO 9001 or ISO 17025 certification for manufacturer
C.3	-	To supersede requirement about ISO 9001 or ISO 17025 certification for external inspection body
Section 6 – Steel Forgings		
A	**General Rules**	
A.1	**Scope**	
A.1.1	-	Corrigenda
A.2	**Selection of steels**	
A.2.1		To provide requirements for steels forging specification according to IACS UR W7
A.3	**Requirements to be met by manufacturers**	
A.3.2	-	To add requirement for manufacturers of steel according to IACS UR W7
A.4	**Method of manufacture**	
~~A.4.2~~	-	Deleted
A.4.2 - A.4.4	-	Renumbering
A.4.4 & A.4.5	-	To add requirement for manufacturing method of forged steel according to IACS UR W7
A.4.6	-	Deleted
A.4.7	-	To make clear the requirements according to IACS UR W7
A.4.8 & A.4.9	-	To add requirement for welding of forged steel according to IACS UR W7
A.5	**Condition of supply and heat treatment**	
A.5.1	-	To clarify the heat treatment shall be done after hot working. according to IACS UR W7
A.5.5 - A.5.8	-	To add requirements for heat treatment of steel forgings according to IACS UR W7
A.5.9	-	Renumbering
A.6	**General characteristics of forgings**	
6.3	-	To revise the requirements for repair welding of forgings according to IACS UR W7
A.9	**General requirements applicable to the material**	

Paragraph	Title/Subject	Status/Remark
A.9.1.1- A.9.1.3	-	To replace the requirementss for chemical composition of steel forgings according to IACS UR W7
A.10	**Testing**	
A.10.1	Proof of chemical composition	To clarify the procedure for chemical composition testing according to IACS UR W7
A.10.2.3	-	To supersede the requirements for test batchs and test specimens according to IACS UR W7
A.10.4	**Non-destructive testings**	
A.10.4.1- A.10.4.7	-	To supersede the requirements for non-destructive testing of steel forgings according to IACS UR W7
A.10.5	**Retests in the event of failure of specimens**	
A.10.5.2	-	To add the requirements for retest of steel forgings according to IACS UR W7
A.11	**Identification and marking**	
A.11.2	-	To delete and replace some of markings
A.12	**Certificates**	To add the details to be included in the certificate
B.	**Forgings for Machine Construction and Shipbuilding**	
B.1	**Scope**	To harmonize the requirements with IACS UR W7
B.2	**Suitable grades of steel**	
B.2.1	-	To replace the obselete standard
B.3	**Condition of supply and heat treatment**	To supersede the requirements for heat treatment of steel forgings according to IACS UR W7
B.4.1.1	-	To replace the reference limit of chemical composition according to IACS UR W7
B.4.1.2 B.4.1.4	-	Deleted
Table 6.1	**Limit values for the chemical composition of forging steels for hull**	Renumbering and harmonizing the values according to IACS UR W7
Table 6.2	**Limit values for the chemical composition of forging steels for machinery**	Renumbering and harmonizing the values according to IACS UR W7
B.4.2.1	-	To renumber the tables and add alternative reference as acceptance criteria according to IACS UR W7
B.4.2.3	-	To add the requirements to be met by forgings
~~**Table 6.3**~~	~~**Differences permitted between tensile strength values**~~	Deleted
B.4.3	**Impact energy**	To remove the requirements for impact test for ships with ice class symbols
B.4.4.1	-	Corrigenda
B.4.4.2	-	Deleted
~~**Table 6.4**~~	~~**Differences permitted between hard-ness values**~~	Deleted
B.5.1	**Mechanical testing**	To change the requirements of mechanical testing of forgings according to IACS UR W7

Paragraph	Title/Subject	Status/Remark
~~Table 6.5~~	~~Mechanical and technological properties of carbon and carbon manganese steel forgings in normalized or quenched and tempered condition for room temperature~~	Deleted
~~Table 6.6~~	~~Mechanical and technological properties of alloy steel forgings in quenched and tempered condition for room temperature~~	Deleted
Table 6.3	Mechanical properties for hull steel forgings	To provide the new mechanical properties requirements replacing former requirements which stipulated in Table 6.5 and Table 6.6.
Table 6.4	Mechanical properties for machinery steel forgings	To provide the new mechanical properties requirements replacing former requirements which stipulated in Table 6.5 and Table 6.6.
Fig. 6.1	Location of specimens in unflanged shafts and rods	To change the drawing according to IACS UR W7
Fig. 6.2	Location of specimens in flanged shafts with thrust flange	To change the drawing according to IACS UR W7
Fig. 6.3	Location of specimens in flanged shafts	To change the drawing according to IACS UR W7
C.	Forgings for Crankshafts	
C.2	Approved materials	To renumber the table
C.3.1	-	To add acceptance criteria references for chemical composition and mechanical properties
C.5	Testing	
C.5.1.1	-	To modify information about selection of test specimen according to IACS UR W7
C.5.1.3	-	To change the requirements for test specimens direction according to IACS UR W7
Fig. 6.4	Location of test specimens in crankshafts	To change the figure according to IACS UR W7
C.5.1.4 C.5.1.5	-	Corrigenda
C.5.1.6	-	Deleted
C.5.2	-	Corrigenda
C.5.3.2	-	Deleted
D.	Forgings for Gears	
D.1	Scope	Corrigenda
D.2	Suitable grades of steel	
D.2.1	-	To change the EN standard into ISO
Table 6.6	Suitable steel grades for gears	To change the EN standard into ISO
D.4	Heat treatment	
D.4.2.1	-	To add requirement for tempering temperature
D.4.2.2	-	To add requirement for tempering temperature

Paragraph	Title/Subject	Status/Remark
D.4.2.3	-	To add requirement for tempering temperature
D.6	Requirements applicable to the material	
D.6.1.1	-	Corrigenda
D.6.2	Mechanical and technological properties	Corrigenda
Table 6.7	Required values for mechanical and technological properties of specimens made of coupons	Renumbering
D.7	Testing	
D.7.2.1	Pinions	To supersede requirements for pinions according to IACS UR W7
D.7.2.2	Small Pinions	To supersede requirements for small pinions according to IACS UR W7
Fig. 6.5	Pinios	To modify figure about test specimen location of pinions according to IACS UR W7
D.7.2.3	Gear wheels	To add an information to make clear reference
Fig. 6.6	Gear wheels	To modify figure of test specimen location of gear wheels according to IACS UR W7
D.7.2.4	Gear wheel rims (made by expanding)	To add requirements for gear wheel rims
Fig. 6.7	Wheel Gear rim (made by expanding)	To modify figure about test specimen location of pinions according to IACS UR W7
D.7.2.5	Hollow pinion	To change definitions & requirements of hollow pinions according to IACS UR W7
Fig. 6.8	Hollow pinions	To modify figure about test specimen location of hollow pinion according to IACS UR W7
D.7.2.6	Forged rings (such as slewing rings)	To add new requirements about forged rings according to IACS UR W7
Fig. 6.8a	Forged rings	To add new drawing of forged rings according to IACS UR W7
D.7.3	Tensile test on case-hardening steels	To change requirements of tensile test on case-hardening steels according to IACS UR W7
D.7.4	Strength differences in the forging	Deleted
D.7.4-D.7.5	-	Renumbering
D.7.6.3	-	Deleted
D.7.6-D.7.8	-	Renumbering
Section 7 – Cast Steel		
A.	General Rules	
A.1.2	-	To modify scope of this requirements according to IACS UR W8
A.2.1	-	To add information for selection of grade of cast steel according to IACS UR W8
A.4	Method of manufacture	To modify the method of manufacture of cast steel according to IACS UR W8
A.5	Condition of supply, heat treatment	To modify requirements of heat treatment of cast steel according to IACS UR W8
A.6	General characteristics of castings	To add requirements of quality of casting according to IACS UR W8

Paragraph	Title/Subject	Status/Remark
A.10.1	Testing of chemical composition	To add the requirements how sample to be taken for chemical test of castings according to IACS UR W8
A.10.2	Testing of the mechanical properties and the selection of specimens	To supersede the requirements of mechanical testing of castings according to IACS UR W8
Fig. 7.1a	Specimen positions relative to the test sample	To add figure about specimen position in the test sample according to IACS UR W8
Fig. 7.1b	Test sample gated to stern tube casting	To add figure about test sample for stern tube casting according to IACS UR W8
A.10.4	Non-destructive testings	To revise requirements for NDT of casting according to IACS UR W8
A.10.5	-	To add the requirement for rejection of defective castings according to IACS UR W8
A.10.6	Retests in the event of failure	To add requirement for retest condition of casting according to IACS UR W8
A.11.2	-	To delete specimen number and date of test from marking
A.12	-	To delete condition of supply and surface from certificate information
A.13	Repair of defects	To change the requirements for repair of defect according to IACS UR W8
B.	Steel Castings for Machine Construction and Shipbuilding	
B.1	Scope	To supersede the scope of requirements according to IACS UR W8
B.3	Condition of supply and heat treatment	To revise heat treatment method according to IACS UR W8
B.4.1	Chemical composition	Corrigenda
Table 7.1	Chemical composition limits for hull and machinery steel casting [%]	To replace the former table about chemical composition limits
B.4.2.2	-	To modify the information because replace the Table 7.4 contents
B.4.2.3	-	To modify the information because replace the Table 7.4 contents
Table 7.4	Mechanical properties of cast steels conforming to B.2.3	To modify table contents according to UR W8
B.5.4	Tightness test	To harmonize the requirements of pressure test with IACS UR W8

Section 3 Non-Destructive Testings

C. Requirements applicable to the inspection body

1. For performing non-destructive testings the manufacturer shall set up a qualified inspection body ~~which is~~ independent of the manufacturing departments, ~~and part of a manufacturing site~~ which is considered to have been met if the manufacturer has been certified according to ISO 9001, or ~~which is~~ accredited according to ISO/IEC 17025.

2. The inspection body shall have available the necessary regulations, testing specifications, testing equipment, accessories and, if required, comparators for the surface finish of castings.

3. If the manufacturer has no inspection body available, he shall demonstrate which external inspection body will perform the testings on his behalf if necessary.

This external inspection body shall ~~be accredited according to ISO/IEC 17025 or shall be part of a manufacturing site certified according to ISO 9001 and shall be approved by BKI~~ comply with the requirements specified in Rules for Approval of Manufacturers and Service Suppliers (Pt.1 Vol.XI) Sec. 3.

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Section 6 Steel Forgings

A. General Rules

1. Scope

1.1 This ~~part~~ sub-section contains general ~~R~~rules to be applied in the manufacture and testing of steel forgings.

In conjunction with the individual Rules which follow, this ~~part~~ Section is also applicable to rolled steel bar, ~~where~~ which it is to be used in place of forgings for the manufacture by machining of shafts, ~~arbors~~ tie-rods, pins and similar parts.

1.2 The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Section 2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyor.

2. Selection of steels

2.1 All steels shall be suitable for their application and shall satisfy the minimum requirements specified in the following individual Rules. Subject to these conditions, steels ~~conforming to the relevant standards or to material specifications approved by BKI may be used.~~ which comply with national or proprietary specifications may be accepted, provided that the specifications give reasonable equivalence to these requirements or are otherwise specially approved or required by BKI. As a minimum the following particulars shall be specified:

- manufacturing process
- chemical composition
- heat treatment
- mechanical properties and
- non-destructive testing

(IACS UR W7 1.3)

2.2 The steels shall be identified by the standardized designations or the designations given in the specifications.

3. Requirements to be met by manufacturers

3.1 Manufacturers wishing to produce forgings to these Rules shall fulfill the conditions stated in Section 1, C. and shall prove this before the commencement of supplies. In addition, an Approval test shall normally be performed on forgings selected for the purpose. The extent of the tests will be determined by BKI on a case to case basis.

(IACS UR W7 2.1)

3.2 The works at which the steel was produced is to be approved by BKI. Forges without their own steelmaking facility may only use starting material supplied by producers who have been approved by BKI.

(IACS UR W7 2.2)

4. Method of manufacture

4.1 Forging steel shall be produced by a basic oxygen process, in an electric furnace or by other methods approved by BKI and shall be killed. On request, BKI shall be informed of the steelmaking process used.

(IACS UR W7 2.2)

~~**4.2** A sufficient amount of material shall be cropped from the top and bottom ends of ingots to ensure that the forgings are free from harmful segregations. This term includes all inhomogeneities liable to impair the required characteristics.~~

4.3~~2~~ For forgings with a specified minimum ultimate tensile strength of 800 N/mm² or above, the molten steel shall be vacuum treated prior to or during pouring of the ingot in order to remove objectionable gases, particularly hydrogen and oxygen, and improve steel cleanliness. Other processes may be accepted provided adequate cleanliness is documented.

4.4~~3~~ Ingots for forgings shall be cast in chill moulds with the larger cross-section up, and with efficient feeder heads. Adequate top and bottom discards shall be made to ensure freedom from piping and harmful segregation in the finished forgings. Surface and skin defects, which may be detrimental during the subsequent working and forming operations, shall be removed.

(IACS UR W7 2.3)

4.5~~4~~ The material shall be progressively hot worked by hammer or press, and shall be forged as close as practical to the finished shape and size in order to give ~~Given a~~ reasonable machining allowance~~, work pieces shall as far as possible be forged to the final dimensions~~.

Excessive machining to give the forging its final shape ~~which~~ may impair its characteristics, e.g. by ~~laying open~~ exposing the core zone~~, is not allowed~~. The core zone may have lower mechanical properties, as well as higher density of inclusions and other imperfections. The manufacturer is responsible for evaluation of the machining allowance suitable for their products. As a general advice, machining allowance should not exceed 20% of final dimension.

Necks of shafts, pinions and journals exceeding 1/10 of the outer diameter shall be produced as far as possible by stepped forging. The degree of deformation shall be such that the core zone of the forging undergoes sufficient plastic deformation.

Surface hardening and surface carburizing caused by flame-scarfing or air-arc gouging will typically be removed if it is followed by grinding or machining to a depth of 1 mm or more.

4.5 The plastic deformation is to be such as to ensure soundness, uniformity of structure and satisfactory mechanical properties after heat treatment. The reduction ratio is to be calculated with reference to the average cross-sectional area of the cast material. Where the cast material is initially upset, this reference area may be taken as the average cross-sectional area after this operation. However, the initial free upsetting operation of the ingot shall not be considered as part of the total forging reduction ratio.

Unless otherwise approved the total reduction ratio is to be at least:

- for forgings made from ingots or from forged blooms or billets, 3 : 1 where L > D and 1,5 : 1 where L ≤ D
- for forgings made from rolled products, 4 : 1 where L > D and 2 : 1 where L ≤ D

- for forgings made by upsetting, the length after upsetting is to 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.

L and D are the length and diameter respectively of the part of the forging under consideration.

(IACS UR W7 2.4)

~~4.6 Annular and hollow shapes shall be produced from sections cut from the ingot or bloom which have been suitably punched, drilled or trepanned before the parts are rolled or expanded over a suitable mandrel.~~

4.~~7~~6 The shaping of forgings or rolled products by flame cutting and flame scarfing and gouging shall be performed using established methods prior to the final heat treatment unless otherwise agreed with BKI. Depending on its composition and/or thickness the workpiece shall be preheated. Where necessary, surfaces produced by flame cutting shall be machined.

(IACS UR W7 2.6)

4.~~8~~7 Where two or more forgings are to be welded together to form a composite component, details of the welding ~~method~~ procedure specification shall be submitted for approval. BKI reserves the right to call for a welding procedure approval test in these cases.

(IACS UR W7 2.7)

4.8 The requirements in Rules for Welding (Pt.1 Vol.VI) Sec.12, F. are applicable for welding procedure qualification tests of steel forgings intended to be used for the components of hull construction and marine structures. Requirements for type approval of welding consumables are to be in accordance with Rules for Welding (Pt.1 Vol.VI) Sec.5.

(IACS UR W7 2.8)

4.9 Welders intended to be engaged in fusion welding of steel forgings for hull structures are to be qualified in accordance with Rules for Welding (Pt.1 Vol.VI) Sec.3.

(IACS UR W7 2.9)

5. Condition of supply and heat treatment

5.1 At an appropriate stage of manufacture, after completion of all hot working operations, ~~All~~ forgings shall be suitably heat treated ~~according to the material~~ for obtaining a fine grain homogeneous microstructure condition as well as the required mechanical properties.

(IACS UR W7 5.1)

5.2 Heat treatments shall be applied in suitable furnaces, which shall be properly and regularly maintained. They shall be fitted with devices for controlling and indicating the temperature; these devices are to be checked at regular intervals. The furnace dimensions shall enable the whole forging to be raised uniformly to the required heat treatment temperature. In the case of very large forgings alternative methods of heat treatment will be specially considered by BKI.

Sufficient thermocouples are to be connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

(IACS UR W7 5.3)

5.3 The forge is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature and time at temperature. The records are to be presented to the surveyor on request.

(IACS UR W7 5.9)

5.4 All hot forming operations shall be concluded prior to the final heat treatment. Should it be necessary for some reason to reheat a forging for a further hot forming operation, then the final heat treatment shall be repeated.

(IACS UR W7 5.4)

5.5 Where a forging is ~~subjected to hot~~ locally reheated or ~~cold~~ any straightening operation is performed after the final heat treatment, subsequent stress relief heat treatment to remove the residual stresses may be required. 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 forging.

(IACS UR W7 5.8)

5.6 Where it is intended to surface harden forgings, full details of the proposed procedure and specification are to be submitted for the approval of BKI. For the purposes of this approval, the manufacturer may be required to demonstrate by test that the proposed procedure gives a uniform surface layer of the required hardness and depth and that it does not impair the soundness and properties of the steel. ~~Forgings whose section is substantially altered by machining after the forging operation may only be quenched and tempered after they have undergone adequate rough machining.~~

~~The weight of the quenched and tempered forging shall not exceed 1,25 times that of the finished part.~~

(IACS UR W7 5.5)

5.7 Where induction hardening or nitriding is to be carried out, forgings are to be heat treated at an appropriate stage to a condition suitable for this subsequent surface hardening.

(IACS UR W7 5.6)

5.8 Where carburizing is to be carried out, forgings are to be heat treated at an appropriate stage (generally either by full annealing or by normalizing and tempering) to a condition suitable for subsequent machining and carburizing.

(IACS UR W7 5.7)

~~5.7~~ 5.9 If the prescribed heat treatment is to be replaced by an equivalent temperature cycle during and after the hot forming process, appropriate tests shall be performed to prove to BKI that the method is indeed equivalent.

6. General characteristics of forgings

6.1 All forgings shall be free from defects such as flakes, cracks, shrinkage cavities, segregation, peripheral blow holes and major non-metallic inclusions which are capable of having a more than insignificant adverse effect on their application and treatment. Forgings delivered in the unmachined condition shall have a smooth surface consistent with the method of manufacture.

(IACS UR W7 3.1)

6.2 Defects may be removed by grinding or chipping and grinding provided the component dimensions are acceptable. The resulting grooves are to have a bottom radius of approximately three times the groove depth and are to be blended into the surrounding surface so as to avoid any sharp contours ~~in the case of surfaces which are to be machined, lies within the machining allowance~~. The complete

removal of the defects shall be proved by a magnetic particle or dye penetrant test with the consent of the Surveyor.

(IACS UR W7 9.1)

6.3 ~~The removal of defects by welding is permitted only in exceptional cases with the agreement of BKI if the defects are of limited extent and occur at points which are subject to low operating loads~~ Repair welding of forgings except those subjected to torsional fatigue, such as crankshaft forgings and propeller shaft forgings, may be permitted subject to prior approval of BKI.

In these cases, full details of the ~~proposed~~ extent and location of the repair, the proposed welding procedure, heat treatment and subsequent inspection procedures ~~and of the subsequent test method~~ shall be submitted to BKI for approval before the start of the repair. In addition, the test report shall be submitted with a description or sketch showing the position and extent of all repairs together with details of the subsequent heat treatment and non-destructive testings applied.

(IACS UR W7 9.2)

6.4 The forging manufacturer is to maintain records of repairs and subsequent inspections traceable to each forging repaired. The records are to be presented to the surveyor on request.

(IACS UR W7 9.3)

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9. General requirements applicable to the material

9.1 Chemical composition

9.1.1 The chemical composition of each heat is to 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. ~~The chemical composition of forged steels shall conform to the limit values indicated in the Tables given in this section and/or in the relevant standards or specifications. If use is made of standardized steels whose nominal carbon contents agree with the limit values indicated in the Tables, the limits specified in the standards may be recognized. The steels shall also contain the quantities of deoxidizers needed to kill the steel.~~

~~Where steels are deoxidized by the vacuum-carbon method the lower limits for the Si and Al contents are inapplicable in all the rules specifying chemical composition.~~

(IACS UR W7 4.2)

9.1.2 At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported. ~~The steelmaker shall take appropriate steps to ensure that elements liable to impair the characteristics of the products cannot enter the heat by way of scrap or other materials used in the steelmaking process.~~

(IACS UR W7 4.4)

9.1.3 Elements designated as residual elements in the individual specifications are not to be intentionally added to the steel. The content of such elements is to be reported.

(IACS UR W7 4.5)

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10. Testing

10.1 Proof of chemical composition

The manufacturer shall determine the chemical composition of each heat on a sample taken preferably during the pouring of the heat and present a corresponding certificate to the Surveyor. The certificate shall indicate the chemical composition of the heat characteristic of the steel grade concerned.

Should there be any doubt as to the composition or where the connection between the certificate and the forgings cannot be proved, a product analysis shall be performed.

When multiple heats are tapped into a common ladle, the ladle analysis shall apply.

(IACS UR W7 4.2)

10.2 Test of mechanical properties and selection of specimens

10.2.1 The mechanical properties shall be ascertained by tensile test to determine tensile strength, yield strength or 0,2 % proof stress, elongation and reduction in area.

10.2.2 Unless otherwise specified, the impact energy shall be determined by notched bar impact tests on each forging or each test batch, as appropriate.

10.2.3 Unless otherwise specified, the following shall apply to the verification of the mechanical properties with regard to the test batches and the test specimens:

.1 Forgings with similar dimensions which originate from the same heat and have been heat treated together shall be grouped into a test batch.

.2 Testing of normalized forgings with unit weights of ≤ 1000 kg or quenched and tempered forgings with unit weights of ≤ 500 kg shall be performed in test batches. A batch is to 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 tonnes for normalized forgings and 3 tonnes for quenched and tempered forgings, respectively.

(IACS UR W7 6.11)

~~Unless otherwise agreed with BKI, the size of the test batch shall be as detailed in Table 6.1.~~

~~Surplus quantities up to 10 % of the number of forgings per test batch can be allotted to a test batch.~~

Forgings with unit weights > 1000 kg (normalized) and > 500 kg (quenched and tempered) shall be tested individually.

~~Table 6.1 Heat treatment weights of individual forging and number of forgings per test batch~~

~~Heat treatment weight of individual forging [kg]~~	~~Number of forgings per test batch~~
~~up to 15~~	~~≤ 300~~
~~> 15 to 150~~	~~≤ 100~~
~~> 150 to 300~~	~~≤ 50~~
~~> 300 to 1000~~	~~≤ 25~~

~~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 is to be related to the total length and mass of the original multiple forging.~~

.3 ~~The number of test sections required for the tensile test and the notched bar impact test is as follows:~~

- ~~normalized forgings: one test section from one forging per test batch~~
- ~~quenched and tempered forgings: per test batch one test section from two forgings. With batches of 10 forgings or less, a test section is required from only one forging.~~

~~At least 5 % of all quenched and tempered forgings which undergo batchwise testing shall be subjected to a hardness test.~~

~~In the case of products ≥ 3 m in length and weighing over 4000 kg in heat-treated condition which do not undergo heat treatment in a continuous furnace, one test section shall be taken from each end of the forging to be tested.~~

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 is to be related to the total length and mass of the original multiple forging.

(IACS UR W7 6.8)

.4 ~~Depending on the conditions agreed on placing the order, the test sections shall be taken as follows:~~

- ~~from a forging (which is then destroyed in its entirety)~~
- ~~from additional material provided on the forging~~
- ~~from a sample of similar dimensions from the same heat, which has been forged in the same way as the other forgings and heat treated together with them~~

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

(IACS UR W7 6.3)

.5 The location of the test specimens in the cross section of the heat-treated region shall be as follows:

a) ~~for thickness or diameter up to maximum 50 mm, the axis is to be at the mid-thickness or the center of the cross section.~~ For forgings having a thickness, t, or diameter D up to a maximum of 50 mm, the longitudinal axis of the test specimen is to be located at a distance of t/2 or D/2 below the heat-treated surfaces.

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

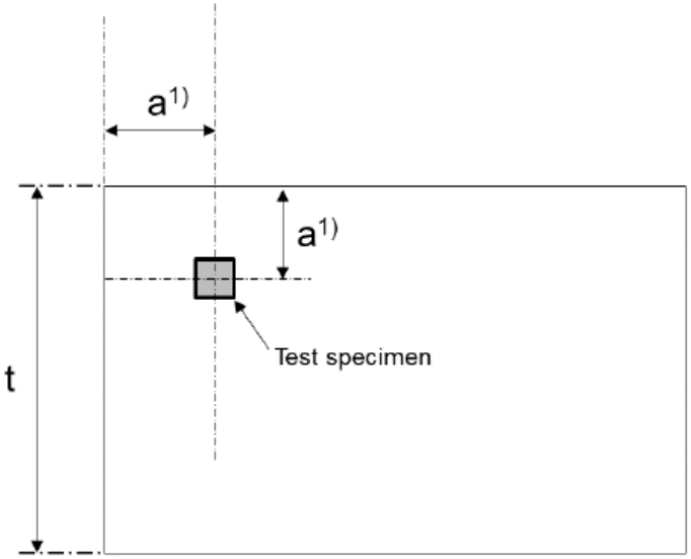
Test specimen is to be located with its longitudinal axis at a distance from any heat-treated surface as shown in Fig. 6.1a.

c) For ring and disc forgings (noting that the test specimen locations for these shaped forgings may be different to elongated or free-form forgings), tangential

sample shall be taken at t/2 for thickness ≤ 25 mm and 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 specimen shall be closer than 12,5 mm to any heat treated surface, as shown in Fig. 6.1a.

(IACS UR W7 6.4)



1) "a" is the distance from the test specimen to heat treated surface based on the above b) or c).

Fig.6.1a Position of the test specimen

Where the manufacturer can demonstrate that a proposed testing location or orientation is more representative of the required mechanical properties of a component, this may be agreed with BKI. In such cases, the heat treatment process, a proposed testing location or orientation, and technical justification shall be submitted to BKI for approval.

(IACS UR W7 6.5)

.6 It may be necessary to distinguish between the geometrical position of the specimens in the forging and their location in relation to the direction of the fibre.

For forgings, the references in the tables to longitudinal, tangential and transverse orientations refer to the position of the specimen in relation to the direction of the fibre and should be understood as follows:

Longitudinal : The longitudinal axis of the test specimen is parallel to the main direction of fibre deformation ~~elongation of the non-curved fibre pattern~~;

Transverse/Tangential : The longitudinal axis of the test specimen ~~traverses the curved fibre pattern in the form of a chord (and thus "slopes", so to speak, in relation to it);~~ perpendicular to the principal direction of fibre deformation.

~~Transverse : The longitudinal axis of the specimen traverses the fibre pattern at right angles. Specimens with a longitudinal axis lying in the direction of an additional compression (perpendicular to an expansion) of the fibre pattern (so-called location "in the thickness direction") are not covered by the specimen positions termed "transverse".~~

.7 Normally, test specimens shall be taken from the test sections forged together with the work pieces. This test section may normally be separated from the forging only after the latter has undergone final heat treatment. In this context, subsequent heat treatment for stress relief may be disregarded. Except

for components which are to be carburized or for hollow forgings where the ends are to be subsequently closed, test material is not to be cut from a forging until all heat treatment has been completed. In these circumstances, the forging and the test section shall be heat treated together.

(IACS UR W7 6.9)

.8 All test sections shall be forged with the same degree of deformation to a cross section corresponding to the relevant cross section of the forging. The test sections shall be large enough to provide material not only for the specimens required for the initial test but also for specimens needed for possible retests.

This test section is to be integral with each forging except as provided in 10.2.3.2 and 10.2.3.3. Where batch testing is permitted according to 10.2.3.2, the test section may alternatively be a production part or separately forged. The separately forged test section is to have a reduction ratio similar to that used for the forgings represented.

All test sections and samples shall be so marked that they can be clearly related to the forgings or test batches which they represent.

(IACS UR W7 6.1)

10.2.4 For forgings whose method of manufacture is subject to special approval by BKI, see 5.5, the number and position of the test sections shall be specially determined with regard to the method of manufacture.

10.3 Test of surface finish and dimensions

10.3.1 The manufacturer shall inspect each forging for surface finish and compliance with the dimensional and geometrical tolerances and shall then submit the forgings to the Surveyor for final inspection. The inner surfaces of hollow forgings and bores are to be included in these inspections.

(IACS UR W7 8.1)

10.3.2 The surface of the forgings shall be clean and properly prepared for inspection. Surface defects are to be removed. Where necessary this condition shall be achieved by pickling, local grinding, shot or sand blasting, cleaning with wire brushes or by chemical means, unless the parts are submitted in the rough machined condition.

10.3.3 If the surface condition suggests that welds have been carried out on the forging, the Surveyor may demand local etching to reveal possible welds.

10.4 Non-destructive testings

10.4.1 Where non-destructive testings are called for, these are to be performed ~~by the manufacturer and/or finishing plant. Tests may also be arranged by BKI.~~ before acceptance and the results are to be reported by the manufacturer.

(IACS UR W7 8.2)

~~Non-destructive tests are to be performed in accordance with the specifications stated in H. in consideration of the specifications in Section 3.~~

10.4.2 Ultrasonic examination is to 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 are to be carried out where appropriate for the shape and the dimensions of the forgings being examined.

(IACS UR W7 8.3)

10.4.3 Non-destructive testings are to be performed in accordance with the specifications stated in H. in consideration of the specifications in Section 3. Unless otherwise agreed, acceptance criteria stated in H. shall be complied with. Alternatively, acceptance criteria complying with national or international standards or specifications may be agreed with BKI provided such standards or specifications give reasonable equivalence to the requirements stated in H. or are especially approved.

(IACS UR W7 8.4)

10.4.4 Unless otherwise agreed, examinations are to be carried out by the manufacturer, although Surveyors may request to be present in order to verify that the examination is being carried out in accordance with the agreed procedure.

(IACS UR W7 8.5)

10.4.5 If the forging is supplied in the 'as forged' condition for machining at a separate works, the manufacturer is to ensure that a suitable ultrasonic examination is carried out to verify the internal quality of the forging.

(IACS UR W7 8.6)

10.4.6 Where advanced ultrasonic testing methods are applied, e.g. PAUT or TOFD, reference is made to Section 3, M., for general approach in adopting and application of these advanced methods.

In such cases, acceptance levels regarding accept/reject criteria may be as per the applicable requirements in H.

(IACS UR W7 8.7)

10.4.7 In the event of any forging proving defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

(IACS UR W7 8.9)

10.5 Retests in the event of failure of specimens

10.5.1 If the required values of tensile strength or notched bar impact tests are not achieved or if a notched bar impact test produces an individual value which is lower than 70 % of the required average value, then, before the forging or the unit test quantity is rejected, the procedure for repeat tests prescribed in Section 2, H. may be applied. The additional test specimens shall be taken either from the same test section as the original specimen or from other test sections or samples which are representative of the forging or test batch concerned.

(IACS UR W7 7.6, 7.7, 7.8)

10.5.2 At the option of the manufacturer, when a forging or a batch of forgings has failed to meet the test requirements, it may be reheat-treated and re-submitted for acceptance tests. They may not be reaustenitized or solution treated more than twice. All the tests previously performed shall be repeated after re-heat treatment and the results shall meet the specified requirements.

(IACS UR W7 7.9)

11. Identification and marking

11.1 The manufacturer shall institute a monitoring system enabling all forgings to be traced back to the original heat, and this shall be demonstrated to the Surveyor on request.

(IACS UR W7 10.1)

11.2 Prior to final inspection, all forgings shall be stamped by the manufacturer in at least one place with the following marks:

- ~~s~~Steel grade
- ~~m~~Manufacturer's mark
- ~~i~~Item or heat number, or another mark enabling the manufacturing process to be traced back
- ~~BKI initials or symbol~~
- ~~Abbreviated name of BKI branch office~~
- ~~Personal stamp of BKI Surveyor responsible for inspection~~
- ~~specimen number~~ Test pressure where applicable
- ~~d~~Date of ~~test~~ final inspection

The area receiving the stamp marks shall be ground.

(IACS UR W7 10.2)

11.3 In the case of small, series-manufactured forgings, agreement may be reached with the Surveyor to apply stamp marks other than those stated in 11.2.

(IACS UR W7 10.3)

12. Certificates

For each consignment the manufacturer shall supply to the Surveyor a certificate containing at least the following details:

- purchaser's name and order number
- newbuilding number and project number, if known
- nature of forging and grade of steel
- purpose and drawing number, if necessary
- weight of the forging
- method of forging
- item number and number of units
- steelmaking process, heat number
- chemical composition of the heat
- condition of supply
- details of heat treatment, including temperature and holding times
- results of the mechanical tests
- results of any special tests applied, e.g. test of resistance to intercrystalline corrosion, determination of proof stress at elevated temperatures or non-destructive testings

(IACS UR W7 11.1)

B. Forgings for Machine Construction and Shipbuilding

1. Scope

1.1 These ~~Rules~~ requirements are applicable to steel forgings made of unalloyed and low alloy steels intended for the manufacture of hull and machinery components ~~and structural parts in machine construction and shipbuilding~~, e.g. shafts, piston rods, connecting rods, rudder stocks, ~~and~~ heel pintles, etc.

~~They~~ These requirements are also applicable to material for forging stock and to rolled ~~round~~ bars intended to be machined into components of simple shape ~~for the manufacture of~~ e.g. shafts, pins, tie-rods and similar components ~~which are given their final shape by machining~~.

(IACS UR W7 1.1)

1.2 These requirements are applicable only to steel forgings where the design and acceptance tests are related to mechanical properties at ambient temperature. For other applications, additional requirements may be necessary especially when the forgings are intended for service at low or elevated temperatures.

(IACS UR W7 1.2)

2. Suitable grades of steel

On condition that they meet the requirements specified in 4., the following steels may be used:

2.1 Suitable grades of forging steel conforming to recognized standards, e.g. ~~EN 10083~~ ISO 683-1, ISO 683-2, EN 10250-2, EN 10250-3.

2.2 Other unalloyed and low alloy steels conforming to other standards or material specifications, provided that their suitability has been confirmed by BKI. An initial test of product suitability may be required for this purpose.

3. Condition of supply and heat treatment

3.1 ~~All forging shall be properly heat treated. Acceptable methods of heat treatment are:~~ Except as provided in A.5.7 and A.5.8 forgings are to be supplied in one of the following conditions:

a) Carbon and carbon-manganese steels
   - Fully annealed
   - Normalized
   - Normalized and tempered at temperature of not less than 550°C
   - Quenched and tempered at temperature of not less than 550°C

b) Alloy steels
   - Normalized
   - Normalized and tempered at temperature of not less than 550°C
   - Quenched and tempered at temperature of not 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.

(IACS UR W7 5.2)

~~3.2 Alternatively, alloy steel forgings may be supplied in the normalized and tempered condition, in which case the specified mechanical properties are to be agreed with BKI.~~

~~3.3~~ 3.2 Large forgings of complex shape made of carbon or carbon-manganese steel which are to be supplied in normalized condition shall undergo additional stress-relieving heat treatment if they have been extensively machined subsequent to normalizing.

4. Requirements applicable to the material

4.1 Chemical composition

4.1.1 The chemical composition ~~of the forging steels is subject to the limit values in **Table 6.2.**~~ shall comply with the overall limits given in Tables 6.1 and 6.2 or, where applicable, the requirements of the approved specification.

(IACS UR W7 4.3)

Table ~~6.2a~~ 6.1 Limit values for the chemical composition[1)] of forging steels for hull[6)]

Steel type	C	Si	Mn	P	S	Cr[4)]	Mo[4)]	Ni[4)]	Cu[4)]	Total residuals
C- and CMn	0,23[2),3)]	0,45	0,30 – ~~1,70~~ 1,50	0,035	0,035	0,30[4)]	0,15[4)]	0,40[4)]	0,30	~~0,80~~ 0,85
Alloy	[5)]	0,45	[5)]	0,035	0,035	[5)]	[5)]	[5)]	0,30	-

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

2) The carbon content may be increased above this level provided that the carbon equivalent (Ceq) is not more than 0,41%, calculated using the following formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} (\%)$$

3) The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0,65 maximum.

4) Elements are considered as residual elements.

5) Specification is to be submitted for approval.

6) Rudder stocks and pintles should be of weldable quality.

Table 6.2~~b~~ Limit values for the chemical composition[1)] of forging steels for machinery[6)]

Steel type	C	Si	Mn	P	S	Cr[4)]	Mo[4)]	Ni[4)]	Cu[~~3)~~ 4)]	Total residuals
C- and CMn	~~0,65~~ 0,23 [2) 3)]	0,45	0,30– ~~1,70~~ 1,50	0,035	0,035	0,30[~~3)~~]	0,15[~~3)~~]	0,40[~~3)~~]	0,30	~~0,80~~ 0,85
Alloy[~~4)~~ 5)]	0,45	0,45	0,30–1,00	0,035	0,035	Min. 0,40[~~5)~~ 6)]	Min. 0,15[~~5)~~ 6)]	Min. 0,40[~~5)~~ 6)]	0,30	-

1) Composition in percentage mass by mass maximum unless shown as a range or as a minimum.

2) ~~The carbon content of C and C-Mn steel forgings intended for welded construction is to be 0,23 maximum.~~ The carbon content may be increased above this level provided that the carbon equivalent (Ceq) is not more than 0,41%.

3) The carbon content of C and C-Mn steel forgings not intended for welded construction may be 0,65 maximum.

~~3)~~4) Elements are considered as residual elements unless shown as a minimum.

~~4)~~5) Where alloy steel forgings are intended for welded constructions, the proposed chemical composition is subject to approval by BKI.

~~5)~~6) One or more of the elements is to comply with the minimum content.

~~**4.1.2** Elements designated as residual elements in the individual specifications are not to be intentionally added to the steel. The content of such elements is to be reported.~~

4.1.3~~2~~ Where forgings are to be used in welded assemblies, the composition shall be specially determined by reference to the welding method used and shall be submitted to BKI for approval.

~~**4.1.4** At the option of the manufacturer, suitable grain refining elements such as aluminium, niobium or vanadium may be added. The content of such elements is to be reported.~~

4.2 Mechanical and technological properties

4.2.1 The required values of yield strength, reduction in area, ~~and~~ elongation and impact test energy shown in Tables 6.~~5~~3 and 6.~~6~~4 respectively in relation to the prescribed minimum tensile strength or, where applicable, the requirements of the approved specification shall be met.

(IACS UR W7 7.3)

4.2.2 The strength levels ~~of 40 and 50 N/mm²~~ stated in Tables 6.~~5~~3 and 6.~~6~~4 ~~respectively~~ should not be regarded as minimum tensile strengths for certain grades of forging steel, but are intended to enable the required property values (yield strength, elongation, reduction in area and impact energy) to be determined by interpolation in relation to the prescribed minimum tensile strengths.

(IACS UR W7 7.1)

4.2.3 ~~If two test specimens are taken from forgings, the difference between the measured tensile strength values may not exceed the magnitudes stated in Table 6.3.~~ Forgings may be supplied to any specified minimum tensile strength selected within the general limits detailed in Tables 6.3 or 6.4 but subject to any additional requirements of the relevant construction Rules.

(IACS UR W7 7.2)

~~Table 6.3 Differences permitted between tensile strength values~~

~~Minimum tensile strength R_m [N/mm²]~~	~~Difference permitted between tensile strength values [N/mm²]~~
~~< 600~~	~~70~~
~~≥ 600 < 900~~	~~100~~
~~≥ 900~~	~~120~~

4.3 Impact energy

The required impact energy values shown in Tables 6.~~5~~3 and 6.~~6~~4 in relation to the specified minimum tensile strength shall be met.

~~Irrespective of this, for heel pintles and rudderstocks an impact energy of at least 27 J shall be attained with longitudinal Charpy V-notch specimens measured at 0°C for ships with ice class symbols ES3 and ES4 and at –20°C for ships with the arctic ice class symbols PC7 to PC1. One individual value may be below the average value but shall not be less than 19 J.~~

~~For propeller shafts intended for ships with ice class an impact energy of at least 27 J with longitudinal Charpy V-notch specimens measured at –10°C shall be attained.~~

4.4 Hardness

4.4.1 The hardness values prescribed in the approval drawings or specifications of the forgings are mandatory. The figures shown in ~~Tables 6.5 and 6.6 are~~ Table 6.4 is guide values only.

~~**4.4.2** Where a hardness test is stipulated, the hardness values measured at different points on the forging or on different units within a unit test quantity respectively may not differ by more than the amounts stated in Table 6.4.~~

~~If the hardness is measured in other units, the values shall be converted into the corresponding Brinell units.~~

~~Table 6.4 Differences permitted between hard-ness values~~

~~Minimum tensile strength R_m [N/mm^2]~~	~~Difference in hardness Brinell units~~
~~< 600~~	~~up to 25~~
~~≥ 600 < 900~~	~~up to 35~~
~~≥ 900~~	~~up to 42~~

5. Testing

5.1 Mechanical testing

5.1.1 Testing shall be accomplished by tensile tests and notched bar impact tests in accordance with A.10.2. ~~Quenched and tempered~~ For forgings ~~grouped into test batches~~ which have been induction hardened, nitrided or carburized ~~shall~~ may also be subjected to additional hardness testing.

(IACS UR W7 7.5)

5.1.2 Notched bar impact testing of propeller shafts, rudderstocks and heel pintles for ships with ice class symbols shall be carried out with Charpy V-notch specimens. For all other products, the selection of the specimen shape according to Section 2, E.1. and E.2. shall be at the manufacturer's discretion.

5.1.3 The test specimens ~~may~~ 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 ~~samples in longitudinal, tangential or transverse direction in relation to the fibre pattern; see~~ Fig. 6.1 to Fig. 6.3 may be used. Where a forging exceeds both 4000 kg in mass and 3 m in length, one set of tests is to be taken from each end. These limits refer to the 'as forged' mass and length but excluding the test material.

(IACS UR W7 6.6 (a))

5.1.4 A batch testing procedure may be used for hot rolled bars. A batch is to consist of either:

- material from the same rolled ingot or bloom provided that where this is cut into individual lengths, these are all heat treated in the same furnace charge, or
- bars of the same diameter and heat, heat treated in the same furnace charge and with a total mass not exceeding 2,5 tonnes.

(IACS UR W7 6.12)

5.2 Non-destructive testings

The specifications in H. do apply. The components indicated in I. are to be tested according to the scope prescribed there.

5.3 Test of surface finish and dimensions

All forgings shall be presented to the Surveyor in the condition in which they are delivered for testing of the surface finish and the dimensions.

Table 6.5 Mechanical and technological properties of carbon and carbon manganese steel forgings in normalized or quenched and tempered condition for room temperature

Minimum tensile strength [1), 2)] R_m [N/mm²]	Relevant heat treatment diameter [mm]	Yield strength R_{eH} [N/mm²] min.	Elongation (for $L_O = 5{,}65 \cdot \sqrt{S_O}$) A [%] min.			Reduction in area Z [%] min.			Impact energy KV [3)] [J] min.			Impact energy KU [J] min.			Brinell hardness HB (Guide values)
			long.	tang.	trans.	long.	tang.	trans.	long.	tang.	trans.	long.	tang.	trans.	
360	≤ 250	180	28	24	20	50	42	35	40	32	25	38	30	25	95 – 125
	> 250 – ≤ 500								32	25	18	30	25	20	
	> 500 – ≤ 1000								32	25	18	29	23	18	
400	≤ 250	200	26	23	19	50	42	35	40	32	25	38	30	25	110 – 150
	> 250 – ≤ 500								32	25	18	30	25	20	
	> 500 – ≤ 1000								32	25	18	27	22	17	
440	≤ 250	220	24	21	18	50	42	35	38	30	22	35	27	22	125 – 160
	> 250 – ≤ 500								32	25	18	30	25	20	
	> 500 – ≤ 1000								30	24	18	25	20	15	
480	≤ 250	240	22	19	16	45	38	30	35	27	22	32	25	22	135 – 175
	> 250 – ≤ 500								32	25	18	30	25	20	
	> 500 – ≤ 1000								26	24	14	22	17	12	
520	≤ 250	260	21	18	15	45	38	30	32	25	20	30	25	20	150 – 185
	> 250 – ≤ 500								25	20	15	25	20	17	
	> 500 – ≤ 1000								24	18	13	20	15	11	
560	≤ 250	280	20	17	14	40	34	27	25	20	15	25	20	17	160 – 200
	> 250 – ≤ 500								25	20	15	25	20	17	
	> 500 – ≤ 1000								23	14	12	19	12	10	
600	≤ 250	300	18	16	13	40	34	27	18	15	12	20	17	15	175 – 215
	> 250 – ≤ 500								18	15	12	20	17	15	
	> 500 – ≤ 1000								18	14	12	17	12	10	
640	≤ 250	320	17	15	12	40	32	27	18	15	12	20	17	15	185 – 230
	> 250 – ≤ 500								18	15	12	20	17	15	
680	≤ 250	340	16	14	12	40	32	27	18	15	12	20	17	15	200 – 240
	> 250 – ≤ 500								18	15	12	20	17	15	
720	≤ 250	360	15	13	11	40	32	27	18	15	12	20	17	15	210 – 250
	> 250 – ≤ 500								18	15	12	20	17	15	
760	≤ 250	380	14	12	10	35	30	24	18	15	12	20	17	15	225 – 265
	> 250 – ≤ 500								18	15	12	20	17	15	

[1)] Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements are to be determined by interpolation, see 4.2.2.

[2)] The tensile strength determined by testing may not exceed the specified minimum tensile strength, if less than 600 N/mm², by more than 120 N/mm². Where the minimum tensile strength is ≥ 600 N/mm² not more than 150 N/mm² may be exceeded.

[3)] The propeller shafts, rudderstocks and heel pintles of ships with ice class symbols are subject to the impact energy values stipulated in 4.3.

Table 6.6 Mechanical and technological properties of alloy steel forgings in quenched and tempered condition for room temperature

Minimum tensile strength [1), 2)] R_m [N/mm²]	Relevant heat treatment diameter [mm]	Yield strength [3)] R_{eH} [N/mm²] min.	Elongation (for $L_O = 5{,}65 \cdot \sqrt{S_O}$) A [%] min.			Reduction in area Z [%] min.			Impact energy KV [4)] [J] min.			Impact energy KU [4)] [J] min.			Brinell hardness HB (Guide values)
			long.	tang.	trans.	long.	tang.	trans.	long.	tang.	trans.	long.	tang.	trans.	
550	≤ 250	0,6 × minimum tensile strength	20	18	16	50	45	35	41	32	24	35	30	24	160 – 200
	> 250 – ≤ 500		18	16	14				32	25	18	30	25	20	
600	≤ 250		20	18	16	50	45	35	41	32	24	35	30	24	175 – 215
	> 250 – ≤ 500		18	16	14				32	25	18	30	25	20	
650	≤ 250		18	16	14	50	45	35	32	28	22	30	27	23	190 – 235
	> 250 – ≤ 500		17	15	13				25	18	13	25	20	15	
700	≤ 250		17	15	13	50	45	35	32	28	22	30	27	23	205 – 245
	> 250 – ≤ 500		16	14	12				25	18	13	25	20	15	

~~750~~	~~≤ 250~~		~~17~~	~~15~~	~~13~~	~~45~~	~~40~~	~~30~~	~~32~~	~~26~~	~~20~~	~~30~~	~~26~~	~~22~~	~~215 – 260~~
	~~> 250 – ≤ 500~~		~~15~~	~~13~~	~~11~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~800~~	~~≤ 250~~	~~0,7 × minimum tensile strength~~	~~15~~	~~14~~	~~12~~	~~45~~	~~40~~	~~30~~	~~32~~	~~26~~	~~20~~	~~30~~	~~26~~	~~22~~	~~235 – 275~~
	~~> 250 – ≤ 500~~		~~14~~	~~12~~	~~10~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~850~~	~~≤ 250~~		~~14~~	~~13~~	~~11~~	~~45~~	~~40~~	~~30~~	~~27~~	~~23~~	~~18~~	~~29~~	~~25~~	~~20~~	~~245 – 290~~
	~~> 250 – ≤ 500~~		~~13~~	~~11~~	~~10~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~900~~	~~≤ 250~~		~~14~~	~~13~~	~~11~~	~~40~~	~~35~~	~~27~~	~~27~~	~~23~~	~~18~~	~~29~~	~~25~~	~~20~~	~~260 – 320~~
	~~> 250 – ≤ 500~~		~~13~~	~~11~~	~~10~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~950~~	~~≤ 250~~		~~13~~	~~11~~	~~10~~	~~40~~	~~35~~	~~27~~	~~25~~	~~21~~	~~16~~	~~29~~	~~25~~	~~20~~	~~275 – 340~~
	~~> 250 – ≤ 500~~		~~12~~	~~10~~	~~10~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~1000~~	~~≤ 250~~		~~12~~	~~11~~	~~10~~	~~40~~	~~35~~	~~27~~	~~25~~	~~21~~	~~16~~	~~25~~	~~22~~	~~18~~	~~290 – 365~~
	~~> 250 – ≤ 500~~		~~12~~	~~10~~	~~10~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~1050~~	~~≤ 250~~		~~11~~	~~10~~	~~8~~	~~40~~	~~35~~	~~27~~	~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	~~310 – 375~~
	~~> 250 – ≤ 500~~		~~11~~	~~10~~	~~8~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	
~~1100~~	~~≤ 250~~		~~11~~	~~10~~	~~8~~	~~40~~	~~35~~	~~27~~	~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	~~320 - 385~~
	~~> 250 – ≤ 500~~		~~11~~	~~10~~	~~8~~				~~25~~	~~18~~	~~13~~	~~25~~	~~20~~	~~15~~	

~~1) Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements are to be determined by interpolation, see 4.2.2.~~

~~2) The tensile strength determined by testing may not exceed the specified minimum tensile strength, if less than 900 N/mm², by more than 150 N/mm². Where the minimum tensile strength is 900 N/mm² not more than 200 N/mm² may be exceeded.~~

~~3) For case hardening steels a value of 60 % of the specified minimum tensile strength is sufficient irrespective of the value of the tensile strength.~~

~~4) Where the heat treatment diameter is > 500 mm, the requirements shall be agreed with BKI.~~

Table 6.3 Mechanical properties for hull steel forgings

Steel type	Tensile strength [1] R_m min. N/mm²	Yield stress R_e min. N/mm²	Elongation A_5 min. %		Reduction of area Z min. %		Charpy V-notch impact test[2]		
			Long.	Tang.	Long.	Tang.	Test temperature (°C)	Minimum average energy (J)	
								Long.	Tang.
C and C-Mn	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 following ranges for tensile strength may be additionally specified:

specified minimum tensile strength: < 600 N/mm² ≥ 600 N/mm²

tensile strength range: 120 N/mm² 150 N/mm²

[2] Special consideration may be given to alternative requirements for Charpy V-notch test, depending on design and application, and subject to agreement by BKI.

Table 6.4 Mechanical properties for machinery steel forgings

Steel type	Tensile strength [1] R_m min. N/mm²	Yield stress R_e min. N/mm²	Elongation A_5 min. %		Reduction of area Z min. %		Charpy V-notch impact test[2), 4)]			Hardness[3)] (Brinell)
			Long.	Tang.	Long.	Tang.	Test temperature (°C)	Minimum average energy (J)		
								Long.	Tang.	
C and C-Mn	400	200	26	19	50	35	AT[5)]	27	18	110 – 150
	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	AT[5)]	27	18	175 – 215
	700	420	16	12	45	30				205 – 245
	800	480	14	10	40	30				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:

specified minimum tensile strength: < 900 N/mm² ≥ 900 N/mm²

tensile strength range: 150 N/mm² 200 N/mm²

[2)] For materials used for machinery exposed to sea water temperature, such as propeller shafts and shaft bolts, intended for ships with ice class notation **ES1**, **ES2**, **ES3** and **ES4**, Charpy V-notch impact testing is to be carried out for all steel types at –10°C and the average energy value is to be minimum 20 J (longitudinal test). One individual value may be less than the required average value provided that it is not less than 70% of this average value.

[3)] The hardness values are typical and are given for information purposes only.

[4)] Special consideration may be given to alternative requirements for Charpy V-notch test, depending on design and application, and subject to agreement by BKI.

[5)] AT refers to ambient temperature (i.e. 23°C ± 5°C), which is specified in ISO 148-1:2016.

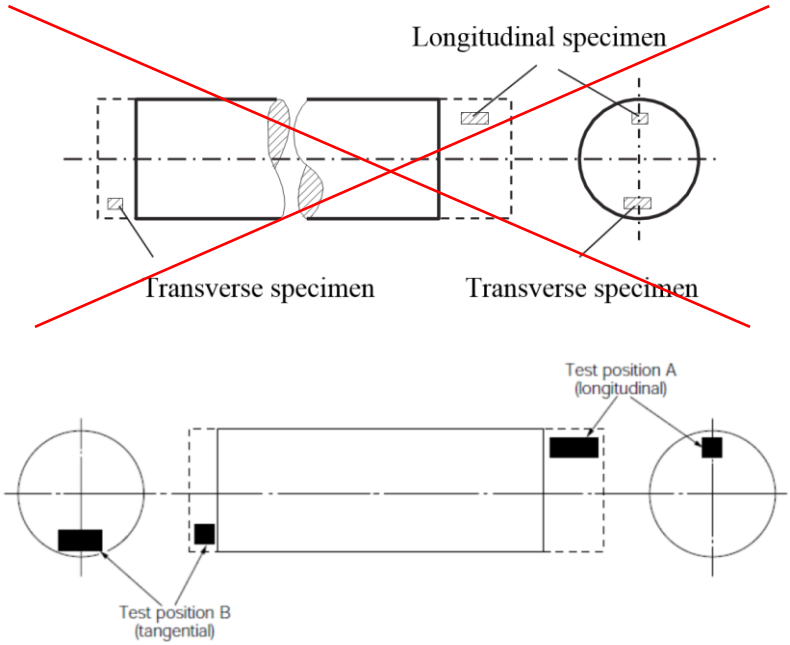


Fig. 6.1 Location of specimens in unflanged shafts and rods

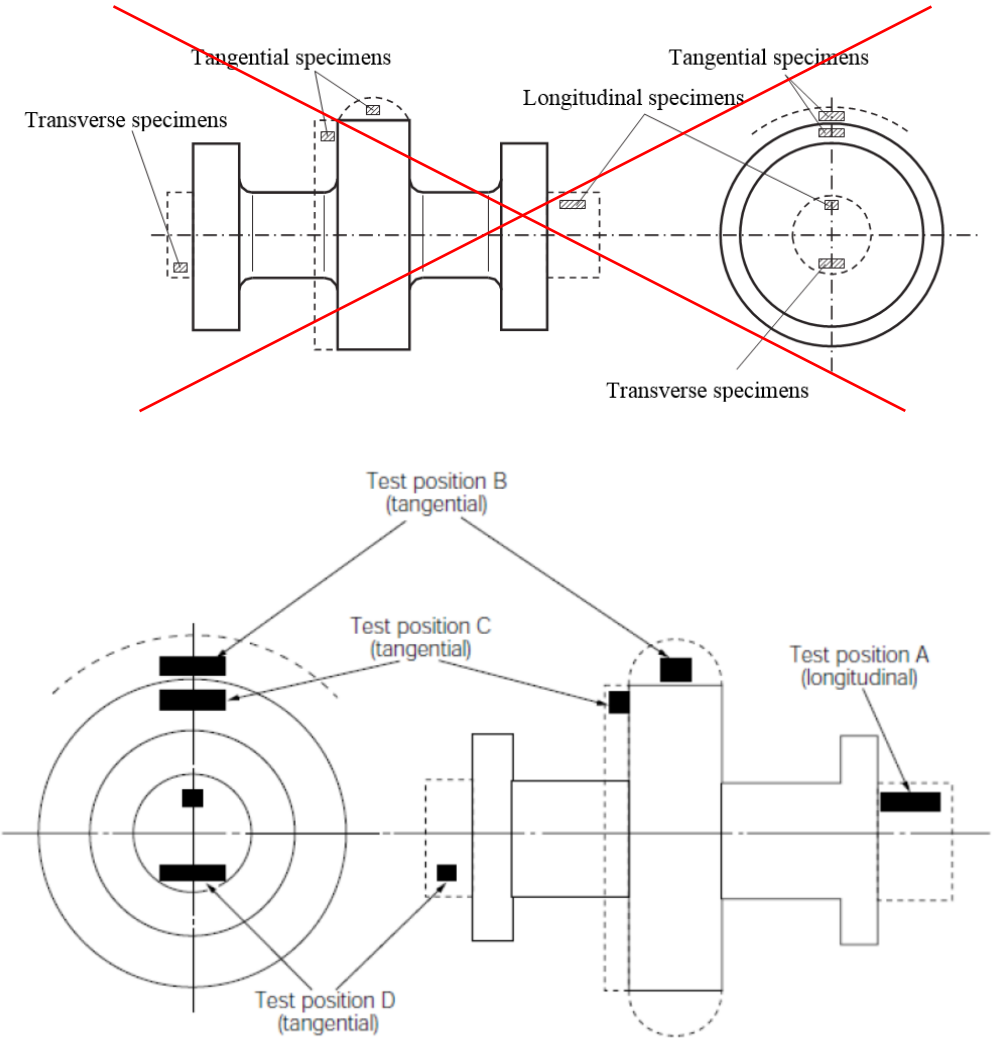


Fig. 6.2 Location of specimens in flanged shafts with thrust flange

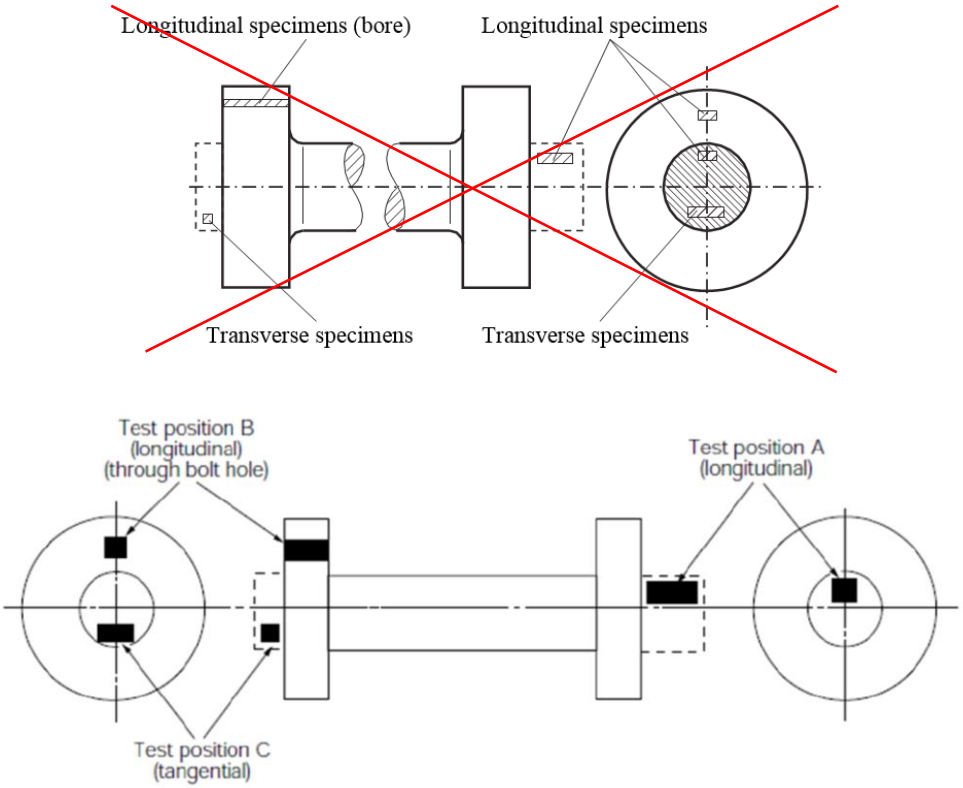


Fig. 6.3 Location of specimens in flanged shafts

----------*end*----------

C. Forgings for Crankshafts

2. Approved materials

Only materials which have been approved by BKI as suitable for the intended application may be used. To this end, the engine manufacturer shall submit to BKI for approval specifications and/or drawings containing all the data required for evaluating the material, e.g. method of manufacture, chemical composition, heat treatment and mechanical properties. The minimum requirements as per Tables ~~6.5~~4 ~~and 6.6~~ are to be satisfied.

3. Requirements applicable to the material

3.1 With regard to the chemical composition, mechanical properties and required impact energy and hardness values of the steel, the data contained in Table 6.2 and Table 6.4 or the requirements of the approved specifications or drawings are applicable.

3.2 The steel shall undergo vacuum degassing following its production to ensure that the hydrogen content of the heat does not exceed 2 ppm.

----------*end*----------

5. Testing

5.1 Tensile test

The mechanical properties shall be verified by tensile test. Test specimens shall be taken for this purpose in accordance with 5.1.1 to 5.1.4~~5~~.

5.1.1 Independently of the selection of test specimens according to test batches as prescribed in 5.1.~~3~~4, for solid open die forged crankshafts at least one longitudinal ~~or transverse~~ tensile test specimen shall be taken from the driven side of each crankshaft. Where a solid forged crankshaft weighs more than 3000 kg, test specimens shall be taken from both ends (test positions A and B in Fig. 6.4), on the driven side as a transverse specimen. The weight applicable is the weight of the crankshaft in the heat-treated condition minus the weight of the test sections.

(IACS UR W7 6.6 (h))

5.1.2 For closed die crankshaft forgings and crankshaft forgings where the method of manufacture has been specially approved in accordance with 4.4, the number and position of test specimens is to be agreed with BKI having regard to the method of manufacture employed.

(IACS UR W7 6.7)

5.1.3 Where the throws are machined or flame cut from a preforged crankshaft, a second set of test specimens shall be taken in the ~~transverse~~ tangential direction from the material removed from the throw ~~furthest from the driven side, see Fig. 6.4.~~ at the end opposite the driving shaft end (test position C in Fig. 6.4). For this test, the material affected by the flame cutting (heat affected zone) shall be completely removed by machining. This rule does not apply to webs which are cut out of the starting material before the specified heat treatment is applied.

~~The test sections may not be removed prior to quenching and tempering.~~

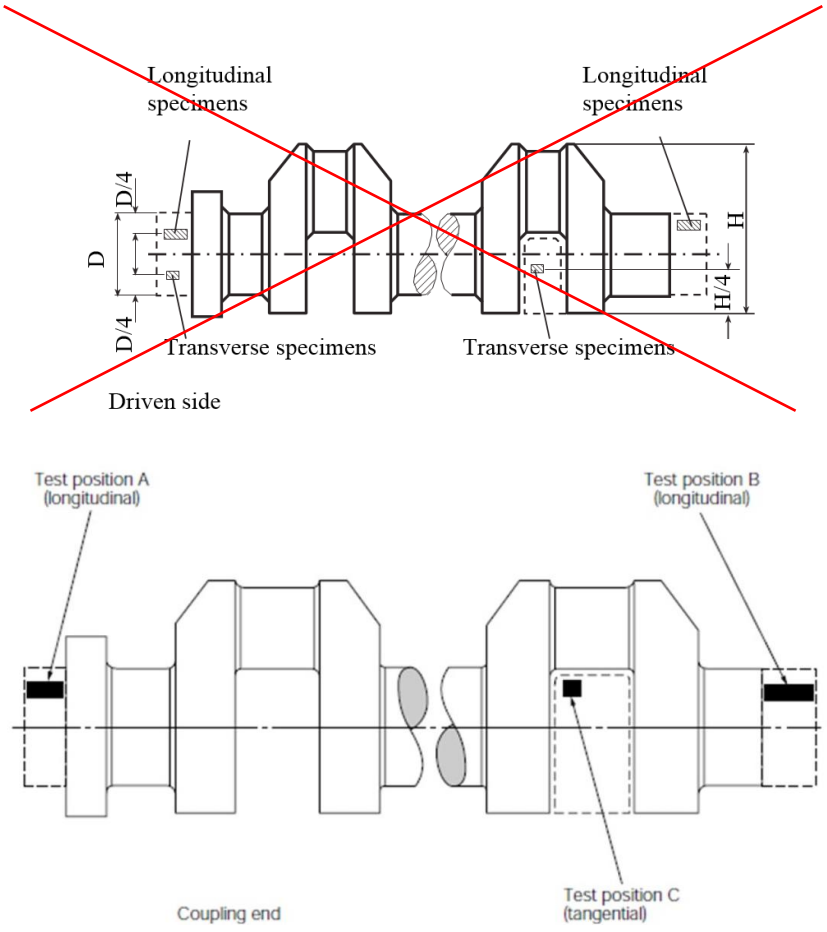


Fig. 6.4 Location of test specimens in crankshafts

(IACS UR W7 6.6 (h))

5.1.4 Crankshafts of the same dimensions up to a weight in heat-treated condition of 500 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches ~~in accordance with~~ Table 6.1~~,~~ ~~A.10.2.3.~~ For quenched and tempered crankshafts, two tensile test specimens shall be taken from each test batch; for normalized shafts, one specimen is sufficient.

5.1.5 Transverse test specimens shall be taken from forged throws. Unless otherwise agreed with BKI, at least one specimen shall be taken from each forging.

(IACS UR W7 6.6 (g))

~~5.1.6 Where two test specimens are taken from large crankshafts, the difference between the measured tensile strength values may not exceed the magnitudes stated in B.4.2.3.~~

5.2 Notched bar impact test

Each forging or unit test quantity, as applicable, shall be subjected to the notched bar impact test. The number of sets of specimens (each comprising 3 specimens) and their positions are subject to the conditions stated in 5.1.1 to 5.1.45 for tensile test specimens.

5.3 Hardness testing

5.3.1 Where testing is performed in test batches, at least 10 % of the crankshafts shall be subjected to hardness tests. For small crankshaft at least one hardness test is to be carried out on each forging.

The method of hardness testing, ~~and~~ the position of the hardness testing impressions on the forgings and acceptance criteria shall be agreed with BKI.

~~5.3.2 The differences in the hardness values measured at different points on the forging or on different units within a test batch may not exceed the magnitudes stated in B.4.4.2.~~

5.3.~~3~~2 Hardness tests may also be required on forgings which have been induction hardened, nitride or carburized.

----------*end*----------

D. Forgings for Gears

1. Scope

These ~~Rules~~ requirements are applicable to forgings made of carbon, carbon-manganese and low alloy steels which are intended for the manufacture of wheels and wheel rims for the gears of the main engine and auxiliary equipment.

2. Suitable grades of steel

On condition that they satisfy the requirements of 6., the following grades of steel may be used:

2.1 Quenched and tempered steels conforming to ~~EN 10083-1~~ ISO 683-2:2016, case hardening steels conforming to ~~EN 10084~~ ISO 683-3:2016 and nitriding steels conforming to ~~EN 10085~~ ISO 683-5:2017, provided that proof has been furnished of the suitability of the individual grade of steel for the intended purpose. Table 6.~~7~~6 contains a selection of suitable steel grades.

Table 6.~~7~~6 Suitable steel grades for gears

Steel grade	Standard
42CrMo4	~~EN 10083-1~~ ISO 683-2:2016
16MnCr5	~~EN 10084~~ ISO 683-3:2016
20MnCr5	
18CrNiMo7-6	

end

4. Heat treatment

4.1 Forgings for which surface hardening after the cutting of the teeth is not specified shall be quenched and tempered. Carbon and carbon-manganese steels may also be normalized and tempered.

4.2 In the case of forgings which undergo surface hardening after the cutting of the teeth, the heat treatment depends on the nature of the surface hardening process, as follows:

4.2.1 After carburization, case-hardening steels are to be ~~hardened and then tempered at low temperature~~ either fully annealed or normalised and tempered. Tempering temperature shall be not less than 550°C. The depth of case hardening, the time-temperature cycle and the hardness range (min/max) shall be stated in the specification.

(IACS UR W7 5.7)

4.2.2 Steels for induction hardening shall normally be quenched and tempered at a temperature not less than 550°C prior to hardening. Carbon and carbon-manganese steels may also be normalized instead of quenching and tempering. The nature of the heat treatment, the depth of hardening, the hardening temperatures, the quenching media and the hardness range (min/max) shall be stated in the specification.

(IACS UR W7 5.6)

4.2.3 Nitriding steels shall be quenched and tempered at a temperature not less than 550°C prior to nitriding. Where possible, nitriding shall be affected by the action of gases. The nature of the heat treatment, the nitriding depth and the hardness range (min/max) shall be stated in a specification.

(IACS UR W7 5.6)

4.3 The heat treatments and surface hardening processes referred to in 4.2 shall be carried out in such a way as to produce uniform hardening of the depth and hardness stipulated in the specification. BKI reserves the right to require the manufacture of samples on which the uniformity, depth and hardness of the surface layer shall be demonstrated.

(IACS UR W7 8.8)

5. Dimensions, dimensional and geometrical tolerances

The data shown in the drawings relating to the order are applicable.

6. Requirements applicable to the material

6.1 Chemical composition

6.1.1 The chemical composition is subject to the limit values specified in Table 6.2 or, where applicable, the requirements of the relevant standard or the approved specification.

6.1.2 Where forgings are to be used for welded wheel assemblies, their composition shall be specially determined to suit the method of welding and shall be submitted to BKI for approval.

6.2 Mechanical and technological properties

~~For quenched and tempered steels,~~ ~~t~~The minimum required values for the yield strength, elongation and reduction in area specified in Table 6.5~~4~~ ~~and 6.6 in C~~. shall be met in relation to the prescribed minimum tensile strength or, where applicable, the requirements of the approved specification.

For case-hardening steels, the requirements specified in Table 6.~~8~~7 apply to specimens which have undergone heat treatment together with the forging (coupons).

Table 6.~~8~~7 Required values for mechanical and technological properties of specimens made of coupons

Steel grade	Sample dia. Ø [mm]	Yield strength R_{eH} [N/mm²] min.	Tensile strength R_m [N/mm²]	Elongation A [1] [%] min.		Reduction in area Z [1] [%] min.		Impact energy			
								KV [1] [J] min.		KU [1] [J] min.	
				l	t, q	l	t, q	l	t, q	l	t, q
16MnCr5	30	590	780 – 1080	10	8	40	27	22	16	24	18
20MnCr5		690	980 – 1280	8	6	35	27	18	13	20	15
18CrNiMo7-6		785	1080 – 1320	8	6	35	27	18	13	20	15
16MnCr5	63	440	640 – 940	11	9	40	27	22	16	24	18
20MnCr5		540	780 – 1080	10	8	35	27	22	16	24	18
18CrNiMo7-6		685	980 – 1280	8	6	35	27	18	13	20	15

[1] Orientation of specimen axis: l = longitudinal, t = tangential, q = transverse

6.3 Hardness

For all gear components, the hardness values prescribed for the tooth area in the specification or approval drawing are mandatory.

7. Testing

The following tests shall be performed:

7.1 Test of chemical composition

The material manufacturer shall determine the composition of each heat and issue a relevant certificate.

7.2 Tensile test on finally heat-treated, induction-hardened and nitrided forgings

The mechanical properties shall be verified by tensile test. Test specimens shall be taken as follows:

7.2.1 Pinions ~~over 200 mm in diameter:~~

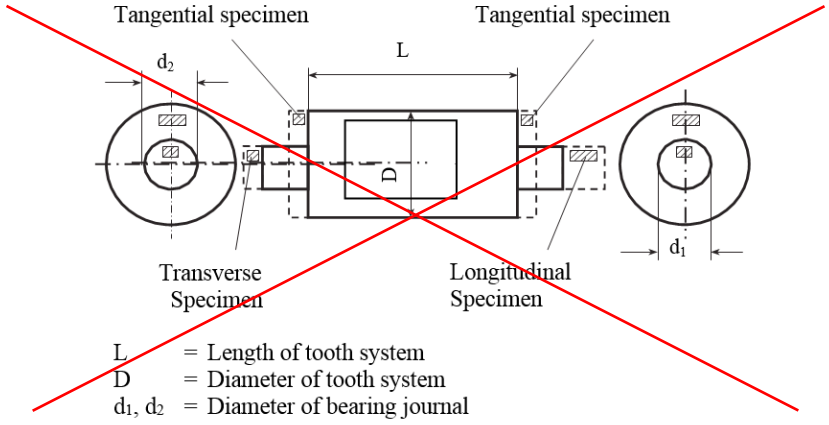
If the finished machined diameter ~~in the area~~ of the ~~teeth~~ toothed portion is greater than 200 mm, ~~a tangential~~ one test specimen shall be taken from ~~a position adjoining~~ each forging in a tangential direction adjacent to the ~~tooth area~~ toothed portion~~, see~~ (test position B in Fig. 6.5). If the dimensions ~~of the blank do not allow a specimen to be taken from this position, then a transverse specimen may be taken from an extension of the bearing journal~~ preclude the preparation of tests from this position, tests in a tangential direction are to be taken from the end of the journal (test

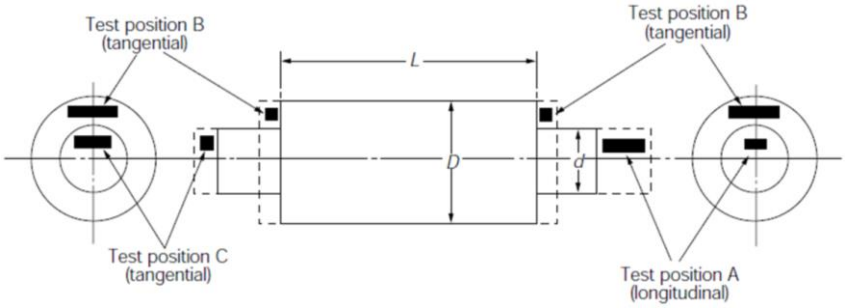
position C in Fig.6.5). If, however, the journal diameter ~~of the bearing journal~~ is 200 mm or less, then a longitudinal specimen ~~may~~ shall be taken (test position A in Fig.6.5). If the length of the finished ~~tooth system~~ toothed portion is more than 1250 mm, one test specimen shall be taken from both ends of the blank.

(IACS UR W7 6.6 (b))

7.2.2 Small ~~P~~pinions ~~up to 200 mm in diameter:~~

In the case of small pinions with diameters of up to 200 mm in the area of the teeth, ~~a~~ one ~~longitudinal~~ test specimen shall be taken ~~from the bearing journal, see~~ in a longitudinal direction (test position A in Fig. 6.5).





L = length of toothed portion
D = diameter of toothed portion
d = journal diameter

Fig. 6.5 Pinion

(IACS UR W7 6.6 (c))

7.2.3 Gear wheels~~:~~

A tangential test specimen shall be taken from gear wheel blanks~~, see~~ (test position A or B in Fig. 6.6).

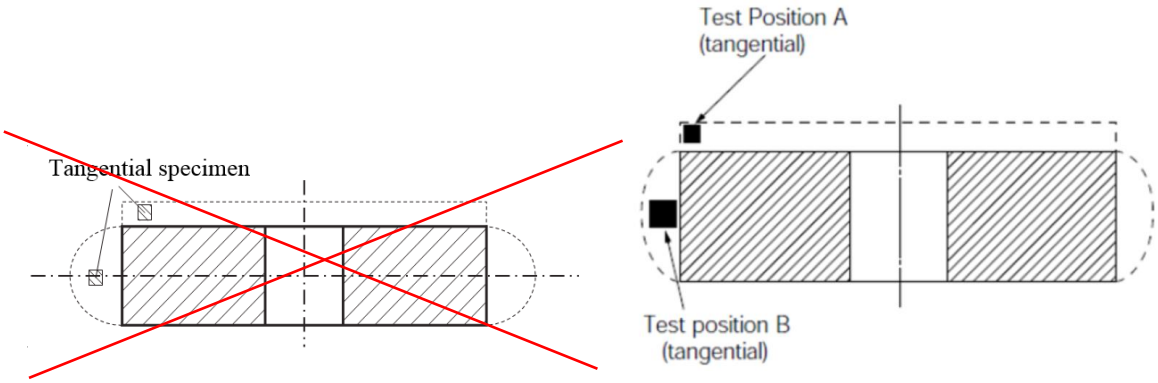


Fig. 6.6 Gear wheel

(IACS UR W7 6.6 (d))

7.2.4 Gear ~~W~~wheel rims~~:~~ (made by expanding)

In the case of wheel rims which are normally made by piercing a bar and enlarging the hole by forging or rolling, ~~a tangential~~ one test specimen shall be taken from each forging in a tangential direction~~,~~ ~~see~~ (test position A or B in Fig. 6.7). Where the finished diameter exceeds 2,5 m or the mass (as heat treated including test material) exceeds 3 tonnes, two test specimens are to be taken from diametrically opposite positions (test positions A and B in Fig. 6.7). The mechanical properties for longitudinal test are to be applied.

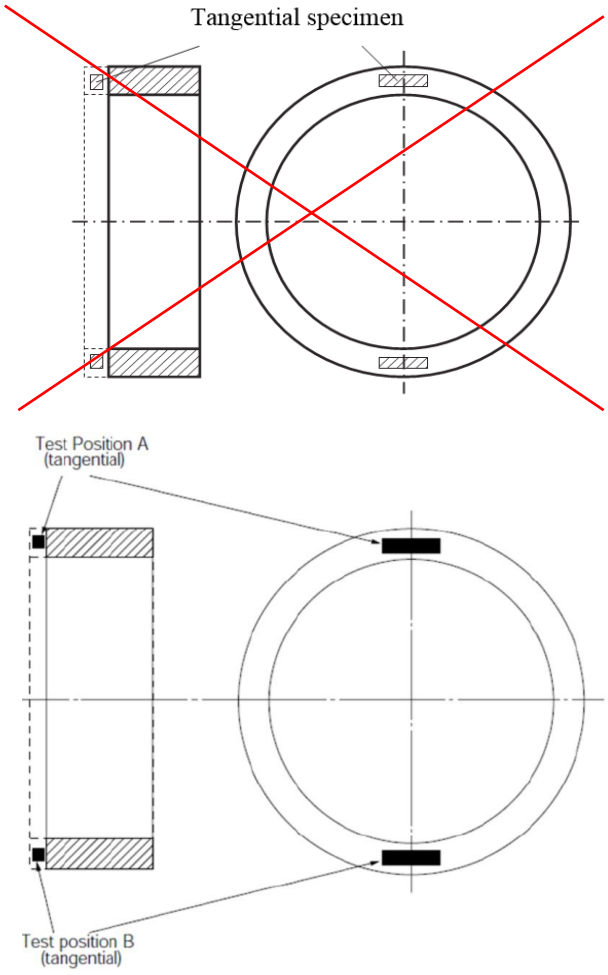


Fig. 6.7 ~~Wheel~~ Gear rim (made by expanding)

(IACS UR W7 6.6 (e))

~~If the diameter of the tooth system exceeds 2500 mm or the heat treated work piece, excluding the material for testing, weights more than 3000 kg, specimens shall be taken from two diametrically opposite points on the rim.~~

7.2.5 Hollow ~~P~~pinion ~~blanks:~~

~~From hollow pinion blanks, the length of whose finished tooth system is 1250 mm or less, a~~ One test specimen shall be taken from ~~one end at right angles to the longitudinal axis of the work piece;~~ each forging in a tangential direction (test position A or B in Fig. 6.8). ~~w~~Where the length of the tooth system is more than 1250 mm, specimens shall be taken from both ends~~, see Fig. 6.8~~.

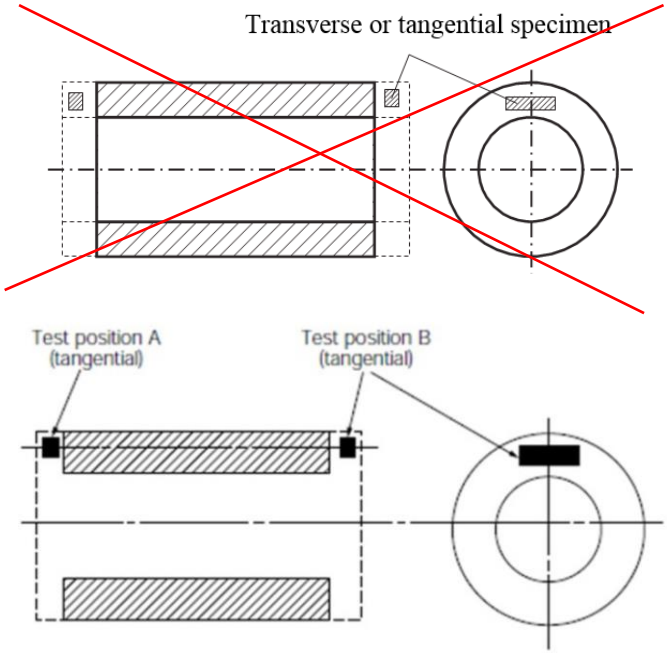


Fig. 6.8 Hollow pinion

(IACS UR W7 6.6 (f))

A distinction is to be made here according to whether the workpiece has been forged as a solid blank and then drilled or has been produced by piercing a rough forging and opening up the hole over a mandrel.

Where the workpiece is drilled, ~~the specimens are considered to be transverse~~ the tangential sample will be transverse to the grain flow, and the requirements for tangential direction given in Table 6.4 apply, but where the blank is expanded over a mandrel ~~the specimens are considered to be tangential~~ the tangential sample will be parallel to the grain flow and the requirements for longitudinal direction given in Table 6.4 apply.

7.2.6 Forged rings (such as slewing rings)

One set of test specimen is to be taken from each forging in a tangential direction (test positions are shown in Fig. 6.8a). Where the finished diameter exceeds 2,5 m or the mass (as heat treated, including test material) exceeds 3 tonnes then two sets of tests are to be taken in diametrically opposite positions.

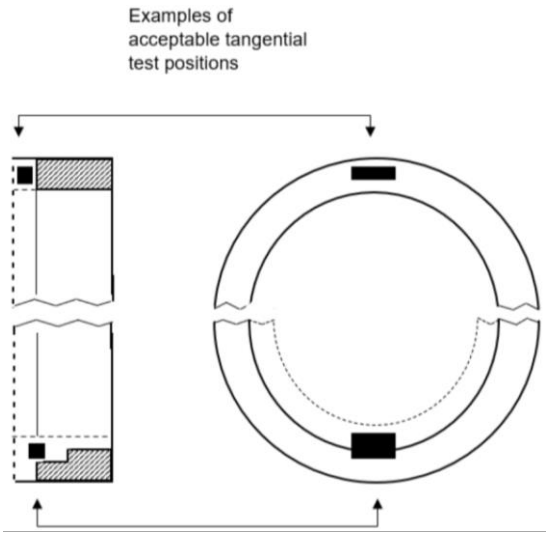


Fig. 6.8a Forged rings

(IACS UR W7 6.6 (i))

7.3 Tensile test on case-hardening steels

7.3.1 ~~The respective test sections are to be heat- treated together with the associated gear component or the test batch.~~ When forgings are to be carburized, sufficient test section is to be provided for both preliminary tests at the forge and for final tests after completion of carburizing. For this purpose, duplicate sets of test sections are to be taken from positions as detailed in 7.2, 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, are to be cut in a longitudinal direction.

The test sections are to be machined to a diameter of D/4 or 60mm, whichever is less, where D is the finished diameter of the toothed portion. ~~corresponding to the smaller of the following two values:~~

~~0,25 × diameter of tooth system or~~

~~63 mm diameter~~

~~If the diameter of the test specimen is less than 63 mm, in agreement with the surveyor a test specimen with standardized dimensions may be used (e.g. 30 mm diameter according to DIN 17210).~~

~~Tensile test specimens shall then be taken from the positions as detailed in 7.2, in the case of forgings with integral journals, are to be cut in a longitudinal direction.~~

For preliminary tests at the forge, one set of test section 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 second set of test section shall be blank carburized and heat treated along with the forgings which they represent.

(IACS UR W7 6.10)

7.3.2 At the discretion of the forgemaster or ~~The~~ gear manufacturer, ~~has the option of producing~~ test sections with a cross section greater than that specified in 7.3.1 may be either carburized or blank carburized, but these are to be machined to the required diameter

prior to the final quenching and tempering heat treatment. ~~However, for the final hardening and tempering the pieces shall be given the specified dimensions.~~

Alternative procedures for testing of forgings which are to be carburized may be specially agreed with BKI.

(IACS UR W7 6.10)

~~7.4 Strength differences in the forging~~

~~Where two test specimens are taken from large forgings, the difference between the measured tensile strength values may not exceed the magnitudes specified in B.4.2.3.~~

~~7.5~~ 7.4 Notched bar impact test

Each forging or unit test quantity, as applicable, shall be subjected to the notched bar impact test. The number of sets of specimens (each comprising 3 specimens), the positions in the forgings or test sections from which the specimens are taken and their heat treatment are subject to the provisions of 7.2 and 7.3, as appropriate.

The test may be carried out on Charpy V- or Charpy U-notch samples as chosen by the manufacturer.

~~7.6~~ 7.5 Hardness test

~~7.6~~7.5.1 After heat treatment but before the cutting of the teeth, hardness tests are to be carried out 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 is to be increased to eight. Where the width of a gear wheel rim forging exceeds 1,25m, the hardness is to be determined at eight positions at each end of the forging.

For small gear forgings at least one hardness test is to be carried out on each forging.

(IACS UR W7 7.4)

~~7.6~~7.5.2 On all surface-hardened gear parts, additional hardness tests are to be carried out on the teeth where applicable, they have been ground to the finished profile. The results of such tests are to comply with the approved specifications (see 4.3). The number of measuring points shall be such that compliance with the specified hardness values can be verified over the periphery and the width of the tooth system.

(IACS UR W7 7.5)

~~7.6.3 The differences in the values measured at the prescribed points on a forging or on different units within a test batch may not exceed the magnitudes specified in B.4.4.2.~~

~~7.7~~ 7.6 Test of surface finish and dimensions

The gear manufacturer shall check the surface finish and dimensions of the tooth system. The products shall then be presented to the Surveyor for final inspection and he shall be given the measurement records. For retests by the Surveyor, the gear manufacturer shall hold the necessary measuring instruments in readiness.

~~7.8~~ 7.7 Batchwise testing

Forgings with similar dimensions up to a weight in heat-treated condition of 300 kg which originate from the same heat and form part of the same heat treatment batch may be grouped into test batches in accordance with A.10.2, Table 6.1. Two test sections shall be taken from each test batch for the tensile test and the notched bar impact test. Every forging shall be subjected to a hardness test.

~~7.9~~ 7.8 Non-destructive testings

~~7.9~~7.8.1 The manufacturer shall carry out an ultrasonic test on the tooth area of all forgings where the diameter of the tooth system exceeds 200 mm.

~~7.9~~7.8.2 The entire tooth system of gear parts with surface-hardened teeth shall be tested for cracks using the magnetic particle or dye penetrant method.

The welds of gear wheels built up of separate parts shall be subjected to non-destructive testing of the scope specified at the time of the process approval.

The tests shall be performed in compliance with H.

----------*end*----------

Section 7 Cast Steel

A. General Rules

1. Scope

1.1 This Section contains general rules to be applied in the manufacture and testing of steel castings. Also applicable are Sections 1 - 3.

1.2 ~~For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by BKI.~~ Additional requirements will typically be required for castings for offshore units depending on applicable service temperature and environment.

(IACS UR W8 1.2)

2. Selection of grades of cast steel

2.1 All cast steel shall be suitable for the intended application and shall satisfy the minimum requirements specified in the following individual Rules. Subject to these conditions, grades of cast steel conforming to the relevant standards or to the material specifications approved by BKI may be used provided such standards or specifications give reasonable equivalence to these requirements.

(IACS UR W8 1.3)

2.2 The grades of cast steel shall be identified by the standardized designations or the designations given in the specifications.

3. Requirements to be met by foundries

3.1 Foundries wishing to supply castings in accordance with these Rules shall be approved by BKI. This is conditional upon their fulfilling the manufacturing and quality control requirements stated in Section 1.C. and furnishing proof of this to BKI prior to the commencement of supplies.

(IACS UR W8 2.1)

3.2 Irrespective of the requirements stated in 3.1, the manufacturer shall demonstrate by approval tests carried out on the products that these can be manufactured in accordance with the conditions imposed. The scope of these tests will be determined by BKI.

4. Method of manufacture

4.1 Cast steel shall be produced in an electric furnace, by a basic oxygen process, in an induction furnace or by other methods approved by BKI and shall be killed. On request, the steel-making process shall be made known to BKI for approval. For certain components including steel castings subjected to surface hardening process, the proposed method of manufacture may require special approval by BKI.

(IACS UR W8 2.2 & 2.4)

4.2 Where castings are produced by welding together two or more separate components, ~~details of the method shall be submitted for approval. This normally calls for a test of the welding procedure.~~ the requirements for welding procedure qualification tests specified in Rules for Welding (Pt.1,

Vol VI) Section 4 and for welder qualification tests specified in Rules for Welding (Pt.1, Vol VI) Section 3 are to be followed, unless otherwise agreed.

(IACS UR W8 2.5)

4.3 Temporary welds made for operations such as lifting, handling, staging, etc., are to be in accordance with approved welding procedures and qualified welders, and are to be removed, ground and inspected using suitable NDT methods.

(IACS UR W8 2.6)

5. Condition of supply, heat treatment

5.1 All castings shall undergo heat treatment appropriate to the material. The heat treatments shall be performed in suitable furnaces which are efficiently maintained and have adequate thermocouples which are connected to the furnace charge to measure and record that its temperature is adequately uniform unless the temperature uniformity of the furnace is verified at regular intervals.

The dimensions of the furnace shall enable the entire casting to be raised uniformly to the required heat treatment temperature. Where, in the case of large castings, the size of the furnace does not allow the entire casting to be normalized at once, other arrangements shall be agreed with BKI.

(IACS UR W8 5.3)

5.2 Where, following final heat treatment, a casting is heated locally or undergoes hot or cold straightening, subsequent stress relief heat treatment may be required to remove residual stresses. 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.

(IACS UR W8 5.4)

5.3 The foundry is to maintain records of heat treatment identifying the furnace used, furnace charge, date, temperature, and holding time temperature. The records are to be presented to the Surveyor on request.

(IACS UR W8 5.5)

~~5.3~~ 5.4 Flame cutting, flame scarfing or flame gouging to remove excess material or feeders shall be carried out by a recognized method prior to final heat treatment. Preheating shall be applied where the chemical composition and/or the thickness of the casting make this necessary. Where required, the heat- affected zones of the casting shall be machined or ground off.

(IACS UR W8 2.3)

6. General characteristics of castings

6.1 All castings shall have a ~~clean~~ surface finish compatible with the conditions of manufacture and be free from surface or internal defects, which would be prejudicial to their proper application in service. Minor casting defects such as small sand and slag marks, small cold shuts and small scabs may be trimmed off within the negative tolerance on the wall thickness.

(IACS UR W8 3.1)

6.2 Defects liable to impair the use and workability of the material to a more than minor degree is not allowed. They may be removed by one of the methods named in 13.

----------*end*----------

10. Testing

10.1 Testing of chemical composition

The manufacturer shall determine the chemical composition of each heat on a sample taken preferably during the pouring of the heat or~~, where necessary,~~ of each ladle when multiple heats are tapped into a common ladle and shall present corresponding certificates to the Surveyor.

(IACS UR W8 4.1)

Should there be any doubt as to the chemical composition of the products, a product analysis shall be performed.

10.2 Testing of the mechanical properties and the selection of specimens

10.2.1 The mechanical properties shall be ascertained by tensile test to determine tensile strength, yield strength or 0,2 % proof stress, reduction in area and elongation. The notched bar impact test shall also be performed where specified for particular grades of cast steel.

The preparation of test specimens and the procedures used for mechanical testing are to comply with the relevant requirements of Section 2. Unless otherwise agreed all tests are to be carried out in the presence of the Surveyors.

(IACS UR W8 6.11)

10.2.2 The tests shall be performed on a heat-by-heat basis. Castings from each heat that undergo the same heat treatment shall be grouped into test batches. ~~of up to 4500 kg. Residual quantities of up to 1250 kg shall be allocated to the preceding test batch. Parts with unit weights > 1000 kg shall be tested individually.~~

~~If the finished weight exceeds 10000 kg, at least two test specimens shall be taken. For this purpose, test samples spaced as widely as possible shall be cast integrally with the casting.~~

10.2.3 For each casting or for each test batch, as applicable, a sufficient number of samples shall be provided which shall normally be cast integrally with or gated to the cast component. The number of samples shall be sufficient to provide material for the test specimens needed for possible retests. The sample may only be removed from the casting after the final heat treatment. ~~The thickness of the sample shall be matched to the relevant wall thickness of the casting, but shall be at least 30 mm. In the case of thick-walled steel castings, the sample thickness need not exceed 100 mm.~~

(IACS UR W8 6.1, 6.2, & 6.9)

10.2.4 Where a number of small castings of approximately the same dimensions, each of which is under 1000kg in mass, are produced from the same heat and are heat treated in the same furnace charge, then, notwithstanding the provisions stated in 10.2.3, specimens may be taken from separately cast samples. For this purpose, at least one sample per furnace charge shall be provided, which shall be heat treated together with the castings to which it relates.

(IACS UR W8 6.8)

10.2.5 If the casting is of complex design or the finished weight exceeds 10000 kg, ~~at least~~ two test samples ~~specimens~~ shall be taken from the heaviest section. For this purpose, test samples spaced as widely as possible shall be cast integrally with the casting.

(IACS UR W8 6.5)

10.2.6 Where large castings are made from two or more casts, which are not mixed in a ladle prior to pouring, two or more test samples are to be provided corresponding to

the number of casts involved. These are to be integrally cast at locations as widely separated as possible.

(IACS UR W8 6.6)

10.2.7 The size of the test samples for mechanical testing is to be such that the heat treatment and microstructure are representative for the section of the casting with the ruling section, i.e. the section for which the specified mechanical properties apply, see also ISO 683-1:2018 and ISO 683-2:2018, respectively.

For C, C-Mn steel castings, the thickness of the sample (t_S) shall be matched to the ~~relevant wall thickness~~ ruling section of the casting, but shall be at least 30 mm. In the case of thick-walled steel castings other than stern tube, stern frame, anchor and rudder horn, the sample thickness (t_S) need not exceed ~~100~~ 150 mm. Length and width of the test sample is normally to be at least three times (t_S), unless otherwise agreed with BKI, as shown in Fig. 7.1a. (Longer or wider test samples may be necessary in order to accommodate the required test specimens.)

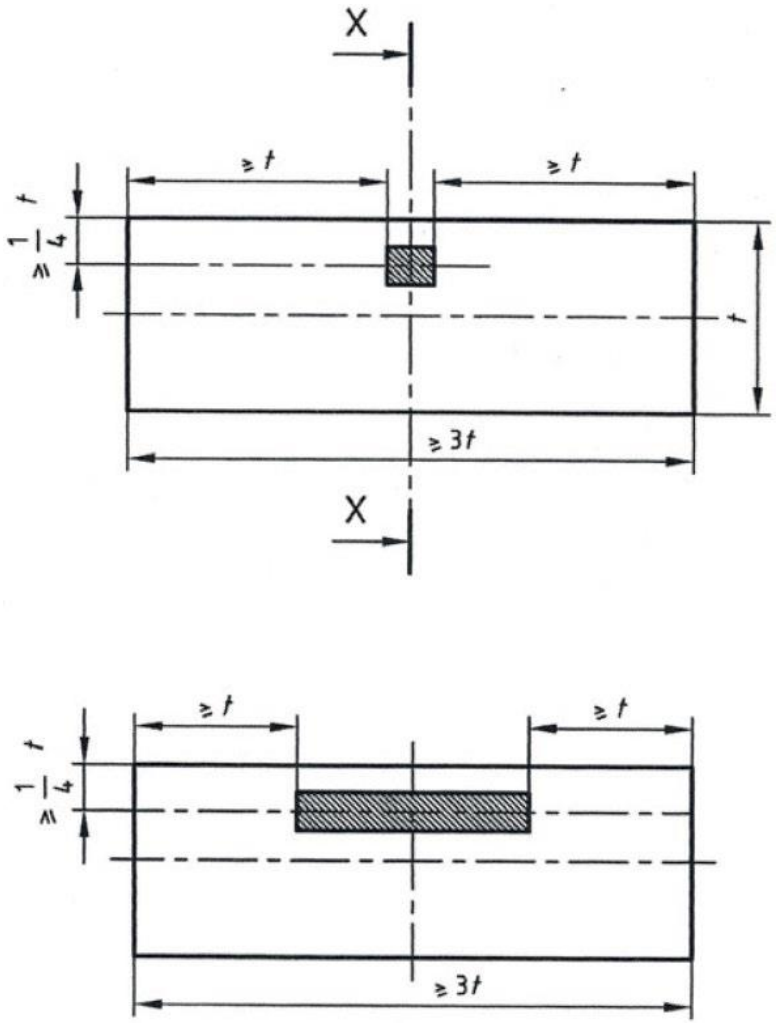


Fig. 7.1a Specimen positions relative to the test sample

For castings for stern tube, stern frame, anchor and rudder horn the test sample thickness (t_S) shall represent the ruling section, as shown in Fig. 7.1b.

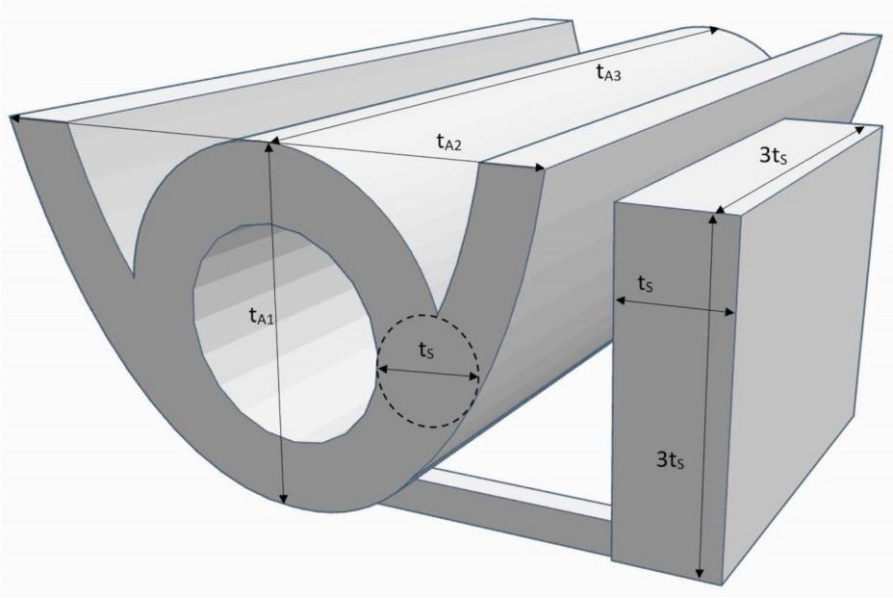


Fig. 7.1b Test sample gated to stern tube casting

Guidance:

Shorter width or length may be accepted for test samples where the actual casting width or length (t_A) is in the range between t_S and $3t_S$.

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

For alloy steel castings the manufacturer shall propose dimensions for the test sample and demonstrate the representative nature of it.

(IACS UR W8 6.3)

10.2.8 For test samples with thickness ≤ 56 mm, the longitudinal axis of the test specimens is to be located at ≥ 14 mm from the surface in the thickness direction. For test samples with thickness > 56 mm, the longitudinal axis of the test specimens is to be located at ≥ ¼ t_S from the surface. Test specimens shall be taken in such a way that no part of the gauge length is machined from material closer than t_S to any of the other surfaces. For impact testing, this requirement shall apply to the complete test specimen - refer to Fig. 7.1a for the location of test specimens in relation to the test sample.

(IACS UR W8 6.4)

~~10.2.5~~ 10.2.9 If separately cast samples are used, these shall be cast in moulds made of the same moulding material as that used for the castings themselves.

~~10.2.6~~ 10.2.10 All samples shall be marked in such a way that they can be clearly related to the castings which they represent. The type of marking shall be agreed with the Surveyor.

~~10.2.7~~ 10.2.11 Where castings are manufactured by a method subject to the special approval of BKI, see 4.1, the number and position of the samples shall be specially agreed so as to take account of the method of manufacture.

(IACS UR W8 6.7)

10.3 Testing of surface finish and dimensions

10.3.1 All castings shall be inspected by the manufacturer for surface finish and compliance with the dimensional and geometrical tolerances and shall then be presented to the Surveyor for final inspection. Inside surfaces are to be included in the inspection.

(IACS UR W8 8.2)

10.3.2 The surface of the castings shall be free from material from the mould and shall be properly prepared for inspection. Where necessary, this condition shall be achieved by pickling, local grinding, shot or sand blasting, cleaning with wire brushes or by chemical means. Chipping and hammering are allowed only if this does not conceal surface defects.

(IACS UR W8 8.1)

10.3.3 Where there is reasonable suspicion that welds have been carried out on a casting, the Surveyor may require certain areas of the surface to be etched in order to reveal possible welds.

10.4 Non-destructive testings

10.4.1 Where non-destructive testings are required, these shall be performed before acceptance and the results are to be reported by the manufacturer ~~of the castings and/or the finishing plant. Tests may also be arranged by BKI~~.

10.4.2 Non-destructive testings shall be performed in accordance with the specifications stated in G. ~~to J.~~ in consideration of the specifications in Section 3. Unless otherwise agreed, acceptance criteria stated in G. shall be complied with. Alternatively, acceptance criteria complying with national or international standards or specifications may be agreed with BKI provided such standards or specifications give reasonable equivalence to the requirements stated in G. or are especially approved.

(IACS UR W8 8.3)

10.5 In the event of any casting proving to be defective during subsequent machining or testing, it is to be rejected notwithstanding any previous certification.

(IACS UR W8 8.5)

~~10.5~~ 10.6 Retests in the event of failure

10.6.1 If tensile test specimens fail to meet the required values under test, if the specified average value is not achieved in a notched bar impact test or if an individual value is less than 70 % of the required average value, then, before the unit test quantity or the casting is rejected, the procedures for retests prescribed in Section 2, H. may be applied.

(IACS UR W8 7.4)

10.6.2 The additional test specimens shall be taken either from the same test sample as the original specimen or from other samples which are representative of the casting or of the unit test quantity.

(IACS UR W8 7.5)

10.6.3 At the option of the manufacturer, when a casting or batch of castings has failed to meet the test requirements, it may be reheat treated but it may not be solution treated or re-austenitized more than twice. All the tests previously performed shall be repeated after reheat treatment and the results shall meet the specified requirements.

(IACS UR W8 7.6)

11. Identification and marking of castings

11.1 The manufacturer shall institute a monitoring system enabling all castings to be traced back to the original heat, and this shall be demonstrated to the Surveyor on request.

(IACS UR W8 10.1)

11.2 Prior to final inspection, all castings shall be provided by the manufacturer in at least one place with the following marks:

- cast steel grade
- manufacturer's mark
- heat number, casting number, casting date or an abbreviated symbol enabling the manufacturing process to be traced
- ~~specimen number~~
- ~~date of test~~
- test pressure, where applicable

(IACS UR W8 10.2)

11.3 In the case of series-manufactured castings, agreement may be reached with the Surveyor to apply marks other than those specified in 11.2.

(IACS UR W8 10.3)

12. Certificates

For each consignment the manufacturer shall supply to the Surveyor a certificate or delivery specification containing at least the following details:

- purchaser and order number
- new building and project number, as applicable, if known
- nature of castings and grade of cast steel
- purpose and drawing number, if necessary
- item numbers and numbers of units
- weight of delivery
- method of manufacture
- heat numbers
- chemical composition
- ~~condition of supply~~
- details of heat treatment, including temperatures and holding times
- test pressures, where applicable
- results of the mechanical tests
- results of any special tests applied, e.g. non-destructive testings and test of resistance to inter-crystalline corrosion
- ~~condition of surface~~

(IACS UR W8 11.1)

13. Repair of defects

~~**13.1 Methods**~~

~~Defects may be repaired by machining, grinding, flame scarfing or gouging, or by welding. The method is to be agreed with the Surveyor except where the approval of the Head Office of BKI is required for the welding of highly stressed castings, e.g. diesel engine parts and turbine casings.~~

~~13.2 Machining and grinding~~

~~The repair shall be performed in such a way as to remove the defect completely and provide a gradual transition between the resulting depression and the contour of the casting. The transition shall be 2 to 3 times the depression. The depth of the repair may not have more than an insignificant effect on the strength of the component and the wall thickness shall not be reduced below the minimum tolerance.~~

~~13.3 Flame scarfing and gouging~~

~~Defects may be removed by flame scarfing and gouging. Cast materials liable to hardening shall be appropriately preheated. The depressions caused by the removal of metal shall afterwards be bright ground. The grinding shall be sufficiently thorough to ensure the removal of any metal with a heat-affected structure.~~

13.1 General

13.1.1 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.

13.1.2 The approval of BKI is to be obtained where steel castings from which defects were removed are to be used with or without weld repair.

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

13.1.4 Where the defective area is to be repaired by welding, the excavations are to be suitably shaped to allow good access for welding. The resulting grooves are to be subsequently ground smooth and complete elimination of the defective material is to be verified by magnetic particle test or liquid penetrant test.

13.1.5 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 are to be subsequently ground smooth and complete elimination of the defective material is to be verified by magnetic particle test or liquid penetrant test. Small surface irregularities sealed by welding are to be treated as weld repairs, see 13.2.

(IACS UR W8 9.1)

13.2 Weld Repairs

In addition to the requirements given in 13.1, the following apply for weld repairs:

13.2.1 For C and C-Mn steel castings weld repairs shall be suitably classified as major or minor. For alloy steel castings, repair requires approval from BKI.

a) 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 are to be considered as one weld.

b) Weld repairs not classified as major are considered as minor and need to be carried out in accordance with a qualified welding procedure.

(IACS UR W8 9.2 (i))

13.2.2 The following is required for major repairs:

a) Shall be carried out before the final delivery heat treatment condition

b) Shall comply with the requirements in 13.2.4

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

(IACS UR W8 9.2 (ii))

13.2.3 The following is required for minor repairs:

a) Shall be carried out before the final delivery heat treatment condition

b) Shall comply with the requirements in 13.2.4 (also with respect to records, see 13.2.4 f) and g).

c) With the exception of alloy steels, do not require prior approval by BKI, except as given in d)

d) BKI may request minor repairs in critical areas to be treated as major repairs.

(IACS UR W8 9.2 (iii))

~~**13.4 Fabrication welding**~~

~~**13.4.1** If major defects have to be welded on steel castings the details of the proposed welding method are to be submitted to BKI by means of WPS [1] for approval. The latter shall be amended with sketches or photographs showing the location of major defects which impair the mechanical strength.~~

~~For the purpose of these Rules, the term "major defect" includes any defects, the depth of which exceeds 25 % of the wall thickness or 2,5 cm, the area of which exceeds 1250 cm^2, and those which due to their amount and distribution exceed an area of 2 % of the casting surface.~~

~~The characteristics of the weld shall be verified by welding procedure tests. These are to be performed on test pieces according to Section 17, Annex 2, using filler metals approved by BKI. Welding procedure tests and welder's qualification tests respectively which have been performed by means of above mentioned test pieces remain valid for 3 years and cover thicknesses up to 1,5 "t", with "t" being the thickness of the test piece.~~

~~In the case of minor repairs, the decision as to the execution of the repair shall rest with the Surveyor, and the method shall be agreed with him. Minor repairs are those which the total weld area (length x width) exceeds 500 mm^2.~~

~~[1] WPS = Welding Procedure Specification~~

~~It is a basic principle that the welding of major defects may only be started after authorization has been granted and the castings have been presented to the Surveyor in the condition prepared for welding.~~

~~13.4.2 Companies wishing to carry out fabrication welds on castings shall have available the necessary workshops, lifting gear, welding appliances, preheating and heat treatment facilities, testing instruments and equipment as well as qualified welders and competent welding supervisors so that the work can be properly executed. As a preliminary measure, compliance with these conditions shall be proved to BKI and a description of the welding facilities and procedures shall be submitted.~~

~~13.4.3~~ 13.2.4 The following ~~conditions shall be complied with in carrying out welding work~~ requirements apply for all weld repairs (major and minor):

- ~~Highly stressed parts and alloy steel castings shall be in the prescribed heat-treated condition for welding. This also applies to other castings on which major defects have to be repaired.~~
- ~~Defects are to be gouged out in such a way as to provide good accessibility for welding. Having been prepared for welding, the sites concerned shall be subjected to non-destructive tests to establish that the defective material has been completely removed. The castings prepared for welding are to be submitted to the Surveyor.~~

a) Steel castings shall be suitably preheated for welding. The level of preheating shall be deter-mined in each case by reference to the chemical composition, the carbon equivalent and the wall thickness~~,~~ ~~see B.4.1.4~~. All castings in alloy steels and all castings for crankshafts are to be suitably 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. Exceptions to this Rule are austenitic grades of cast steel and, with the consent of the Surveyor, unalloyed grades of cast steel of small wall thickness which because of their composition (C ≤ 0,18 %) are considered to be unsusceptible to cracking.

b) Welding procedures are to be qualified and shall match the delivery condition of the casting. Qualification of welding procedures shall follow Rules for Welding (Pt.1 Vol.VI) Section 12, F. or, subject to agreement with BKI, a recognized standard e.g. ISO 11970:2016.

Note:

For steels with C ≥ 0,23 or Ceq ≥ 0,45, the WPQT on which the WPS is based should be qualified on a base material having a Ceq not fall below more than 0,02 of the material to be welded. (e.g. WPQT for a material with actual Ceq = 0.50 may be qualified on a material with Ceq ≥ 0.48.)

c) All welding work is to be performed by qualified welders, whose work is supervised while in progress, in bays which are protected from draughts and the effects of the weather. Wherever feasible, welding shall be performed in the downhand position.

d) The filler materials to be used shall produce a weld deposit with mechanical characteristics ~~matching~~ similar and in no way inferior to those of the parent casting. In the case of stainless grades of cast steel, the deposit shall ensure the sufficient chemical stability of the weld. Wherever possible the work shall be performed by manual arc welding using basic-coated electrodes with controlled, low hydrogen content. Welding procedure tests are to be carried out by the manufacturer to demonstrate that satisfactory mechanical properties can be obtained after heat treatment.

e) ~~After~~ When repair welding is done after the castings ~~shall be properly~~ have been heat treated ~~as follows:~~ for mechanical properties, the repaired casting shall be given a furnace stress-relieving heat treatment. Unless otherwise agreed, stress-relieving heat treatment shall be carried out at a temperature in the range of 550°C to 620°C, except for quenched and tempered steels. Quenched and tempered steels shall be

stress relieved at a temperature at least 30°C lower than the final tempering temperature, but not below 550°C. 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. Subject to prior approval, local stress relieving heat treatment may be accepted for minor repairs. Special consideration may be given to the omission of stress relieving heat treatment for minor repairs in areas of low operating stress and provided that the combination of material and welding procedure is such that tensile residual stresses and hardness are minimised.

~~unalloyed steel castings: stress relief heat treatment in temperature range 580–620°C, or renewed normalizing treatment~~

~~quenched and tempered steel castings: renewed tempering or quenching and tempering~~

~~ferritic stainless steel and all grades of austenitic steel castings: the heat treatment prescribed in the relevant standard or recognized material specification, as applicable.~~

~~Attention shall be paid to the effect of the heat treatment on the mechanical properties of the weld metal.~~

f) Following welding and heat treatment, the welds and their surrounding areas are to be ground smooth and inspected by the magnetic particle or dye penetrant method. Depending on the nature and size of the original defect, further non-destructive testing by ultrasonic or radiographic inspection may be required. For the evaluation of the indications, 10.4.2 is applicable. Satisfactory results are to be obtained from all forms of non-destructive testing used.

g) The manufacturer is to 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 are to be available to the Surveyor and copies provided on request.

(IACS UR W8 9.2 (iv))

~~**13.4.4** After repair and subsequent heat treatment, all castings shall be presented to the Surveyor for reinspection, and the tests for cracks and the ultrasonic tests shall be performed wholly or partly in the Surveyor's presence at his discretion. In the case of radiographic tests, the radiographs shall be submitted to the Surveyor for expert appraisal.~~

~~**13.4.5** For large welds on highly stressed or alloy steel castings, the manufacturer shall hand the Surveyor a report containing full details of the repair, including the results of the non-destructive tests. In this report he shall also confirm that the weld has been made in accordance with an approved welding procedure.~~

B. Steel Castings for Machine Construction and Shipbuilding

1. Scope

These ~~Rules~~ requirements are applicable to castings made of ~~unalloyed~~ C, C-Mn, and alloyed grades of cast steel which are intended for the manufacture of components and structural parts in machine construction and shipbuilding, ~~e.g. diesel engine components (excluding crankshafts), gears, couplings, and also stem and stern posts, stern tubes, shaft struts, rudder bearings and anchors.~~ and offshore units for worldwide services as specified in the relevant requirements of BKI Rules for Classification and Construction.

These requirements also make consideration for grades that are intended for fabrication by welding, as well as grades not intended for welding.

(UR W8 1.1)

2. Suitable grades of cast steel

On condition that they meet the requirements specified in 4., the following grades of cast steel may be used:

2.1 General purpose and quenched and tempered cast steels conforming to EN 10293.

2.2 General-purpose cast steels with enhanced weldability and toughness conforming to EN 10213.

2.3 Other grades of cast steel with minimum impact energy values conforming to other standards or material specifications, provided that they are equivalent to the grades described in 2.1 and 2.2 and their suitability has been confirmed by BKI. An initial test of product suitability may be required for this purpose.

3. Condition of supply and heat treatment

3.1 All castings shall be properly heat treated. Acceptable methods of heat treatment are:

a) Carbon and carbon-manganese steels:

- Fully annealed
- normalizing
- normalizing and tempering at temperature of not less than 550° C
- quenching and tempering at temperature of not less than 550° C

b) Alloy steels:

- normalizing
- normalizing and tempering at temperature of not less than 550° C
- quenching and tempering at temperature of not less than 550° C

The condition of supply 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.

(IACS UR W8 5.1)

3.2 Where castings are subject to special requirements with regard to their geometrical and dimensional stability or to the absence of internal stresses, e.g. diesel engine bedplates, stem and stern post parts, additional stress-relieving heat treatment is required. ~~For carbon and carbon-manganese steels~~Unless otherwise approved, the heat treatment shall be performed at a temperature of at least 550°C followed by cooling in the furnace to below 300°C. ~~For quenched and tempered steel castings, the heat treatment temperatures shall be specially determined.~~ The stress-relieving heat treatment may be dispensed with in the case of quenched and tempered steel castings where tempering is followed by a cooling rate of up to 15°C/h.

(IACS UR W8 5.2)

~~**3.3** The foundry is to mantain records of heat treatment identifiying the furnace used, furnace charge, date, temperature, and holding time temperature. The records are to be presented to the Surveyor on request.~~

4. Requirements applicable to the material

4.1 Chemical composition

4.1.1 ~~Carbon and carbon manganese steel castings~~ The chemical compositions, including the grades of cast steel described in 2.3, are subject to the limits for the chemical composition of the heat specified in Table 7.1.

(IACS UR W8 4.2)

Where necessary or as agreed with BKI, the manufacturer may add suitable grain refining elements, e. g. aluminium.

(IACS UR W8 4.3)

4.1.2 For grades of cast steel conforming to 2.2 and 2.2, the limits for the chemical composition specified in the standards are applicable.

4.1.3 For cast alloy steels conforming to 2.3, the limits for the chemical composition specified in the recognized standards or material specifications shall apply.

Table 7.1 Chemical composition limits for hull and machinery steel casting [%]

Application	Steel Type	C max.	Si max.	Mn	S max.	P max.	Cu	Cr	Ni	Mo	Total residuals (max.)
Castings for non-welded construction	C, C-Mn	0,40	0,60	0,50 – 1,60	0,035	0,035	Max. 0,30	Max. 0,30	Max. 0,40	Max. 0,15	0,80
	Alloy	0,45	0,60	0,50 – 1,60	0,030	0,035	Min. 0,30[1)]	Min. 0,40[1)]	Min. 0,40[1)]	Min. 0,15[1)]	-
Castings for welded construction	C, C-Mn	0,23	0,60	0,50 – 1,60	0,035	0,035	Max. 0,30	Max. 0,30	Max. 0,40	Max. 0,15	0,80
	Alloy	alloying element values to be agreed with BKI									-

[1)] for alloy steel type, at least one of the elements shall comply with the minimum content.

~~Table 7.1 Limits for chemical composition [%]~~

~~Application~~	~~C max.~~	~~Si max.~~	~~Mn~~	~~S max.~~	~~P max.~~	~~Residual elements~~				~~Sum of the max. permissible residual elements~~
						~~Cu~~	~~Cr~~	~~Ni~~	~~Mo~~	
~~Castings for general shipbuilding and machinery application~~	~~0,40[1)]~~	~~0,60~~	~~0,50 – 1,60~~	~~0,040~~	~~0,040~~	~~0,30~~	~~0,30~~	~~0,40~~	~~0,15~~	~~0,80~~
~~Castings for welded structures for shipbuilding~~	~~0,23~~	~~0,60~~	~~1,60 max.~~	~~0,015~~	~~0,020~~	~~0,30~~	~~0,30~~	~~0,40~~	~~0,15~~	~~0,80~~

~~[1)] for welded structures for machinery application $C \leq 0,23$ or $C_{eq} \leq 0,49$.~~

4.1.4 Where the weldability of the casting is subject to special requirements, the carbon equivalent shall be calculated according to the following formula:

$$C_{eq} = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \qquad [\%]$$

----------*end*----------

4.2 Mechanical and technological properties

4.2.2 Other grades of cast steel as per 2.3 shall have the characteristic properties of the respective grade according to the standard or the specification. In addition, the minimum requirements for yield stress, elongation, reduction of area, and impact test energy values corresponding to steel types and different strength levels specified in Table.7.4 are ~~applicable to castings made of C and CMn cast steels~~ to be complied with.

(IACS UR W8 7.1 & 7.3)

4.2.3 The cast steels shown in Table 7.4 may be supplied ~~with~~ to any specified minimum tensile strength within the limits specified in the table, but subject to any additional requirements of the relevant construction Rules. ~~The values graduated in steps of 40 N/mm^2 do not represent the minimum tensile strengths of particular grades of cast steel but are intended to provide means of determining the required mechanical characteristics by interpolation in relation to specified minimum tensile strengths.~~

(IACS UR W8 7.2)

4.3 Impact energy

All grades of cast steel shall meet the energy impact values prescribed for the grade in question.

5. Testing

5.1 Tensile test

The mechanical properties shall be verified by tensile test. One tensile test specimen shall be taken from each test sample. The test specimens shall be prepared in accordance with A.10.2.~~2~~1.

(IACS UR W8 6.10)

~~Table 7.4 Mechanical properties of cast steels conforming to B.2.3~~

~~Grades of steel~~	~~Minimum tensile strength 1), 2) R_m [N/mm^2]~~	~~Yield strength R_{eH} [N/mm^2] min.~~	~~Elongation A [%] min.~~	~~Reduction in area Z [%] min.~~	~~Impact energy 3)~~	
					~~KV [J] min.~~	~~KU [J] min.~~
~~Ordinary quality C and CMn cast steel~~	~~400~~	~~200~~	~~25~~	~~40~~	~~25~~	~~25~~
	~~440~~	~~220~~	~~22~~	~~30~~	~~20~~	~~22~~
	~~480~~	~~240~~	~~20~~	~~27~~	~~18~~	~~20~~
	~~520~~	~~260~~	~~18~~	~~25~~	~~15~~	~~17~~
	~~560~~	~~280~~	~~15~~	~~20~~	~~12~~	~~15~~
	~~600~~	~~300~~	~~13~~	~~20~~	~~10~~	~~12~~
~~Special quality C and CMn cast steel~~	~~400~~	~~200~~	~~28~~	~~45~~	~~32~~	~~30~~
	~~440~~	~~220~~	~~26~~	~~45~~	~~28~~	~~27~~
	~~480~~	~~240~~	~~24~~	~~40~~	~~25~~	~~25~~
	~~520~~	~~260~~	~~22~~	~~40~~	~~20~~	~~22~~
	~~560~~	~~280~~	~~20~~	~~35~~	~~18~~	~~20~~
	~~600~~	~~300~~	~~18~~	~~35~~	~~15~~	~~17~~

~~1) Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements may be determined by interpolation.~~

~~2) The tensile strength determined by testing may not exceed the specified minimum tensile strength by more than 150 N/mm^2 in case of the ordinary qualities and 120 N/mm^2 in the case of the special qualities.~~

~~3) Average value of 3 tests (individual value not less than 70%).~~

Table 7.4 Mechanical properties of cast steels conforming to B.2.3

Application	Steel Type	Minimum tensile strength [1), 2)] R_m [N/mm²]	Yield strength R_{eH} [N/mm²] min.	Elongation A [%] min.	Reduction in area Z [%] min.	Impact energy [3)]	
						Test Temp. (°C)	KV [J] min.
Castings for non-welded construction	C, C-Mn	400	200	25	40	AT[4)]	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	AT[4)]	27
		600	400	16	35		
		650	450	14	32		
		700	540	12	28		
Castings for welded construction	C, C-Mn	400	200	25	40	0	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	0	27
		600	400	16	30		
		650	450	14	30		
		700	540	12	28		

1) Where the minimum tensile strength of a steel grade falls between two of the graduated values, the requirements may be determined by interpolation.
2) The tensile strength determined by testing may not exceed the specified minimum tensile strength by more than 150 N/mm²
3) Average value of 3 tests (individual value not less than 70%).
4) AT refers to Ambient Temperature (i.e. 23°C±5°C), which is specified in ISO 148-1:2016

5.2 Notched bar impact test

Notched bar impact testing shall be performed on each test sample ~~batch or, where applicable, each casting~~. The test specimens shall be prepared in accordance with A.10.2.~~2~~1. The type of specimen is governed by the relevant standard or specification.

(IACS UR W8 6.10)

5.3 Non-destructive testings

5.3.1 In case non-destructive testings are prescribed for castings they shall be performed in accordance with G. to J.

5.3.2 Where castings are welded together, the welds shall be subjected to magnetic particle and ultrasonic or radiographic inspection. The extent of the inspection shall be as specified on the approval drawing or will be determined at the time of approval of the welding procedure.

5.4 Tightness test

Castings subjected to internal pressure, e.g. stern tubes, shall be subjected to a hydraulic pressure test in the presence of the Surveyor. The test shall be performed with the casting in machined condition. The test pressure is to be 1,5 times ~~of~~ the service pressure and for stern tubes uniformly 2 bars. The test pressure shall be kept for at least 10 min.

(IACS UR W8 8.4)

----------*end*----------