Amendment on 27 June 2024
Resolved by Technical Committee on 30 January 2024

Fatigue Tests for Crankshafts

Object of Amendment

Rules for the Survey and Construction of Steel Ships Parts D and K
Guidance for the Survey and Construction of Steel Ships Part D
Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use

Reason for Amendment

IACS Unified Requirement (UR) M53 specifies requirements related to the design of crankshafts of reciprocating internal combustion engines. These requirements have already been incorporated into the NK Rules.

IACS recently revised the fatigue strength evaluation formulae for crankpins and journal fillets specified in the UR, and an amended version of the UR was adopted as UR M53(Rev.5) in May 2023.

Although the revised evaluation formulae now consider additional bending stress, IACS states it expects the impact the revised formulae have on the relevant fatigue strength evaluations to be minimal because the additional bending stress being considered is small in comparison to overall fatigue strength.

Accordingly, relevant requirements are amended in accordance with UR M53(Rev.5).

In addition, references related to crankshafts in Chapter 2, Part D of the Rules for the Survey and Construction of Steel Ships related to the crankshaft and other related requirements were reviewed, and amended as needed.

Outline of Amendment

The main contents of this amendment are as follows:

(1) Amends the evaluation formula for crankshaft dimensions in fatigue tests in Appendix 2, Annex 2.3.1, Part D of the Rules for the Survey and Construction of Steel Ships.
(2) Amends the references to requirements related to solid-forged and semi-built crankshafts in Parts D and K of the Rules for the Survey and Construction of Steel Ships, and the Guidance for the Approval and Type Approval of Materials and Equipment for Marine Use.

Effective Date and Application

(1) 4.1.3, Appendix 2, Annex 2.3.1, Part D of the Rules for the Survey and Construction of Steel Ships
This amendment applies to crankshafts for which the application for approval is submitted to the Society on or after 1 July 2024.
(2) Amendments other than (1)
Effective date of this amendment is 1 July 2024.

An asterisk (*) after the title of a requirement indicates that there is also relevant information in the corresponding Guidance.

ID: DD23-22

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS **Part D MACHINERY INSTALLATIONS** **Chapter 2 RECIPROCATING INTERNAL COMBUSTION ENGINES** **2.3 Crankshafts** **2.3.3 Shaft Couplings and Coupling Bolts*** **1** The diameter of coupling bolts at the joining face of the coupling between crankshafts, between a crankshaft and a thrust shaft, or between a crankshaft and a shaft mentioned in **2.2.4** is to be not less than the value obtained by the following formula. $d_b = 0.75\sqrt{\frac{(0.95d_c)^3}{nD}\left(\frac{440}{T_b}\right)}$ where d_b : Diameter of coupling bolts (*mm*) n : Number of bolts D : Diameter of pitch circle (*mm*) d_c : Required diameter of crankshaft (*mm*), as deemed appropriate by the Society. T_b : Specified tensile strength of bolt material (N/mm^2) When the specified tensile strength of the bolt material exceeds 1000 N/mm^2, the value used for the formula is to be	**RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS** **Part D MACHINERY INSTALLATIONS** **Chapter 2 RECIPROCATING INTERNAL COMBUSTION ENGINES** **2.3 Crankshafts** **2.3.3 Shaft Couplings and Coupling Bolts*** **1** The diameter of coupling bolts at the joining face of the coupling between crankshafts, between a crankshaft and a thrust shaft, or between a crankshaft and a shaft mentioned in **2.2.4** is to be not less than the value obtained by the following formula. $d_b = 0.75\sqrt{\frac{(0.95d_c)^3}{nD}\left(\frac{440}{T_b}\right)}$ where d_b : Diameter of coupling bolts (*mm*) n : Number of bolts D : Diameter of pitch circle (*mm*) d_c : Required diameter of crankshaft calculated by the formula in **2.3.1-1** when the values of K_m, K_s and K_h are replaced with 1.0 (*mm*). T_b : Specified tensile strength of bolt material (N/mm^2) When the specified tensile strength of the bolt material exceeds 1000 N/mm^2, the value used for the formula is to be	Review and amend references.

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
as considered appropriate by the Society. EFFECTIVE DATE AND APPLICATION **1.** The effective date of the amendments is 1 July 2024.	as considered appropriate by the Society.	

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
Annex 2.3.1 CALCULATION METHOD OF CRANKSHAFT STRESS **Appendix 2 GUIDANCE FOR EVALUATION OF FATIGUE TESTS** **4.1 Full-Size Testing** **4.1.3 Use of Results and Crankshaft Acceptability** **1** In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability (*See* **1.8, Annex 2.3.1**), the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases: (1) At the crankpin fillet: $$Q = \left(\sqrt{\left(\frac{\sigma_{BH} + \sigma_{add}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_H}{\tau_{DWCT}} \right)^2} \right)^{-1}$$ where σ_{DWCT} : fatigue strength by bending testing τ_{DWCT} : fatigue strength by torsion testing for other parameters see **1.3.1-3, 1.3.2-2** and **1.5, Annex 2.3.1**	**Annex 2.3.1 CALCULATION METHOD OF CRANKSHAFT STRESS** **Appendix 2 GUIDANCE FOR EVALUATION OF FATIGUE TESTS** **4.1 Full-Size Testing** **4.1.3 Use of Results and Crankshaft Acceptability** **1** In order to combine tested bending and torsion fatigue strength results in calculation of crankshaft acceptability (*See* **1.8, Annex 2.3.1**), the Gough-Pollard approach and the maximum principal equivalent stress formulation can be applied for the following cases: (1) Related to the crankpin diameter: $$Q = \left(\sqrt{\left(\frac{\sigma_{BH}}{\sigma_{DWCT}} \right)^2 + \left(\frac{\tau_{BH}}{\tau_{DWCT}} \right)^2} \right)^{-1}$$ where σ_{DWCT} : fatigue strength by bending testing τ_{DWCT} : fatigue strength by torsion testing (Newly added)	UR M53(Rev.5) Appendix IV 4.3 Although the evaluation formulae are revised based on additional bending stress, it is recognized that the additional bending stress does not affect much to crankshaft acceptability in IACS consideration because the additional bending stress is small in comparison to overall fatigue strength. Since NK approves the fatigue strength of the fillet of the crankpin based on the permissible fatigue strength (σ_{DW}) of the crankshaft specified in 1.7.1-1, Annex 2.3.1 of Part D. There is no experience of fatigue strength evaluation using actual size crank throw according to Appendix 2, Annex 2.3.1 of Part D.

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
(2) Related to crankpin oil bore: $Q = \frac{\sigma_{DWOT}}{\sigma_V};\ \sigma_V = \frac{1}{3}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right]$ where σ_{DWOT} : fatigue strength by means of maximum principal stress from torsion testing (3) At the journal fillet: $Q = \frac{\left(\sqrt{\left(\frac{\sigma_{BG} + \sigma_{add}}{\sigma_{DWJT}}\right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}}\right)^2}\right)^{-1}}{}$ where σ_{DWJT} : fatigue strength by bending testing τ_{DWJT} : fatigue strength by torsion testing for other parameters see **1.3.1-3, 1.3.2-2 and 1.5, Annex 2.3.1** **2** In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location in accordance with the calculation where the surface treatment had not been taken into account.	(2) Related to crankpin oil bore: $Q = \frac{\sigma_{DWOT}}{\sigma_V};\ \sigma_V = \frac{1}{3}\sigma_{BO} \cdot \left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\sigma_{TO}}{\sigma_{BO}}\right)^2}\right]$ where σ_{DWOT} : fatigue strength by means of maximum principal stress from torsion testing (3) Related to the journal diameter: $Q = \frac{\left(\sqrt{\left(\frac{\sigma_{BG}}{\sigma_{DWJT}}\right)^2 + \left(\frac{\tau_G}{\tau_{DWJT}}\right)^2}\right)^{-1}}{}$ where σ_{DWJT} : fatigue strength by bending testing τ_{DWJT} : fatigue strength by torsion testing (Newly added) **2** In case increase in fatigue strength due to the surface treatment is considered to be similar between the above cases, it is sufficient to test only the most critical location in accordance with the calculation where the surface treatment had not been taken into account.	

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
EFFECTIVE DATE AND APPLICATION **1.** The effective date of the amendment is 1 July 2024. **2.** Notwithstanding the amendments to the Rules, the current requirements apply to crankshafts other than those for which the application for approval is submitted to the Society on and after the effective date.		

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS **Part K MATERIALS** **Chapter 5 CASTINGS** **5.1 Steel Castings** **5.1.13 Additional Requirements for Crank Throws*** **2** Where the manufacturing processes using the surface treatments are adopted to reduce the size of crank throw according to the requirements in **2.3.1-4, Part D**, the preliminary tests instructed by the Society are to be carried out. **Chapter 6 STEEL FORGINGS** **6.1 Steel Forgings** **6.1.13 Additional Requirements for Crankshafts*** **3** Where the special forging processes are adopted to reduce the size of crank shaft according to the requirements in **2.3.1-4, Part D**, the preliminary tests instructed by the Society are to be carried out.	**RULES FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS** **Part K MATERIALS** **Chapter 5 CASTINGS** **5.1 Steel Castings** **5.1.13 Additional Requirements for Crank Throws*** **2** Where the manufacturing processes using the surface treatments are adopted to reduce the size of crank throw according to the requirements in **2.3.1-1, Part D**, the preliminary tests instructed by the Society are to be carried out. **Chapter 6 STEEL FORGINGS** **6.1 Steel Forgings** **6.1.13 Additional Requirements for Crankshafts*** **3** Where the special forging processes are adopted to reduce the size of crank shaft according to the requirements in **2.3.1-1, Part D**, the preliminary tests instructed by the Society are to be carried out.	Review and amend references. Review and amend references.

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
EFFECTIVE DATE AND APPLICATION **1.** The effective date of the amendments is 1 July 2024.		

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS **Part D MACHINERY INSTALLATIONS** **D2 RECIPROCATING INTERNAL CONBUSTION ENGINES** **D2.3 Crankshafts** **D2.3.3 Shaft Couplings and Coupling Bolts** **1** The wording "as deemed appropriate by the Society" in **2.3.3-1, Part D of the Rules** is the value calculated by the formula in **D2.3.1-2** when the values of K_m, K_s and K_h are replaced with 1.0 (*mm*). **2** The wording "to be of sufficient strength" in **2.3.3-2, Part D of the Rules** means to be in accordance with the following **(1)** or **(2)**: ((1) and (2) are omitted.)	**GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF STEEL SHIPS** **Part D MACHINERY INSTALLATIONS** **D2 RECIPROCATING INTERNAL CONBUSTION ENGINES** **D2.3 Crankshafts** **D2.3.3 Shaft Couplings and Coupling Bolts** (Newly added) The wording "to be of sufficient strength" in **2.3.3-2, Part D of the Rules** means to be in accordance with the following **(1)** or **(2)**: ((1) and (2) are omitted.)	Review and amend references.

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
GUIDANCE FOR THE APPROVAL AND TYPE APPROVAL OF MATERIALS AND EQUIPMENT FOR MARINE USE **Part 1 METALLIC MATERIALS** **Chapter 4 APPROVAL OF MANUFACTURING PROCESS OF CRANKSHAFTS UNDER SPECIAL REQUIREMENTS** **4.1 General** **4.1.1 Scope** **1** The requirements of this chapter apply to the tests and inspection carried out for the approval of the manufacturing processes specified in the following **(1)** or **(2)** in order to reduce the crankshafts dimensions in accordance with the requirements of **2.3.1-4 of Part D, 5.1.13-2** and **6.1.13-3 of Part K of the Rules for the Survey and Construction of Steel Ships** (hereinafter referred as "the Rules"): ((v) and (vi) are omitted.) **4.3 Approval Tests** **4.3.1 General** Approval tests are to be carried out in accordance with **3.4** to adopt the manufacturing process mentioned in **4.1.1-1(1)** or **(2)**. In this regard, the requirements in **3.4.3** are to be applied as follows. (1) (Omitted)	**GUIDANCE FOR THE APPROVAL AND TYPE APPROVAL OF MATERIALS AND EQUIPMENT FOR MARINE USE** **Part 1 METALLIC MATERIALS** **Chapter 4 APPROVAL OF MANUFACTURING PROCESS OF CRANKSHAFTS UNDER SPECIAL REQUIREMENTS** **4.1 General** **4.1.1 Scope** **1** The requirements of this chapter apply to the tests and inspection carried out for the approval of the manufacturing processes specified in the following **(1)** or **(2)** in order to reduce the crankshafts dimensions in accordance with the requirements of **2.3.1-1 of Part D, 5.1.13-2** and **6.1.13-3 of Part K of the Rules for the Survey and Construction of Steel Ships** (hereinafter referred as "the Rules"): ((v) and (vi) are omitted.) **4.3 Approval Tests** **4.3.1 General** Approval tests are to be carried out in accordance with **3.4** to adopt the manufacturing process mentioned in **4.1.1-1(1)** or **(2)**. In this regard, the requirements in **3.4.3** are to be applied as follows. (1) (Omitted)	Review and amend references.

Amended-Original Requirements Comparison Table (Fatigue Tests for Crankshafts)

Amended	Original	Remarks
(2) Approval test for crankshafts with surface treatments (a) (Omitted) (b) Tests Instead of the items listed in **3.4.3(3)**, the tests are to consist of the followings: ((i) to (iii) are omitted.) iv) Bending fatigue test on actual crank throw (Tests are, in principle, to be carried out on both the crank throws with and without surface treatments. In this case, the number of test specimens is to be sufficient to verify the strength improvement ratio ρ specified in **D2.3.1-2, Part D of the Guidance for the Survey and Construction of Steel Ships**. In this connection, the torsional fatigue tests on the actual crank throws or the test specimens having sizes similar to them are also to be carried out.) ((v) and (vi) are omitted.) EFFECTIVE DATE AND APPLICATION **1.** The effective date of the amendments is 1 July 2024.	(2) Approval test for crankshafts with surface treatments (a) (Omitted) (b) Tests Instead of the items listed in **3.4.3(3)**, the tests are to consist of the followings: ((i) to (iii) are omitted.) iv) Bending fatigue test on actual crank throw (Tests are, in principle, to be carried out on both the crank throws with and without surface treatments. In this case, the number of test specimens is to be sufficient to verify the strength improvement ratio ρ specified in **2.3.1-1, Part D of the Rules**. In this connection, the torsional fatigue tests on the actual crank throws or the test specimens having sizes similar to them are also to be carried out.) ((v) and (vi) are omitted.)	Review and amend references.