# Guide for Optimized Shaft Alignment

*Effective from 15 February 2024*

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# GENERAL CONDITIONS

**Definitions:**

"*Administration*" means the Government of the State whose flag the Ship is entitled to fly or under whose authority the Ship is authorised to operate in the specific case.

*"IACS"* means the International Association of Classification Societies.

"*Interested Party*" means the party, other than the Society, having an interest in or responsibility for the Ship, product, plant or system subject to classification or certification (such as the owner of the Ship and his representatives, the ship builder, the engine builder or the supplier of parts to be tested) who requests the Services or on whose behalf the Services are requested.

"*Owner*" means the registered owner, the ship owner, the manager or any other party with the responsibility, legally or contractually, to keep the ship seaworthy or in service, having particular regard to the provisions relating to the maintenance of class laid down in Part A, Chapter 2 of the Rules for the Classification of Ships or in the corresponding rules indicated in the specific Rules.

*"Rules"* in these General Conditions means the documents below issued by the Society:

(i) Rules for the Classification of Ships or other special units;
(ii) Complementary Rules containing the requirements for product, plant, system and other certification or containing the requirements for the assignment of additional class notations;
(iii) Rules for the application of statutory rules, containing the rules to perform the duties delegated by Administrations;
(iv) Guides to carry out particular activities connected with Services;
(v) Any other technical document, as for example rule variations or interpretations.

"*Services*" means the activities described in Article 1 below, rendered by the Society upon request made by or on behalf of the Interested Party.

*"Ship"* means ships, boats, craft and other special units, as for example offshore structures, floating units and underwater craft.

"*Society*" or *"TASNEEF"* means Tasneef and/or all the companies in the Tasneef Group which provide the Services.

"*Surveyor*" means technical staff acting on behalf of the Society in performing the Services.

**Article 1**

**1.1.** The purpose of the Society is, among others, the classification and certification of ships and the certification of their parts and components. In particular, the Society:
(i) sets forth and develops Rules;
(ii) publishes the Register of Ships;
(iii) issues certificates, statements and reports based on its survey activities.

**1.2.** The Society also takes part in the implementation of national and international rules and standards as delegated by various G overnments.

**1.3.** The Society carries out technical assistance activities on request and provides special services outside the scope of classification, which are regulated by these general conditions, unless expressly excluded in the particular contract.

**Article 2**

**2.1.** The Rules developed by the Society reflect the level of its technical knowledge at the time they are published. Therefore, the Society, although committed also through its research and development services to continuous updating of the Rules, does not guarantee the Rules meet state-of-the-art science and technology at the time of publication or that they meet the Society's or others' subsequent technical developments.

**2.2.** The Interested Party is required to know the Rules on the basis of which the Services are provided. With particular reference to Classification Services, special attention is to be given to the Rules concerning class suspension, withdrawal and reinstatemen t. In case of doubt or inaccuracy, the Interested Party is to promptly contact the Society for clarification.
The Rules for Classification of Ships are published on the Society's website: www.tasneef.ae.

**2.3.** The Society exercises due care and skill:
(i) in the selection of its Surveyors
(ii) in the performance of its Services, taking into account the level of its technical knowledge at the time the Services are performed.

**2.4.** Surveys conducted by the Society include, but are not limited to, visual inspection and non-destructive testing. Unless otherwise required, surveys are conducted through sampling techniques and do not consist of comprehensive verification or monitoring of the Ship or of the items subject to certification. The surveys and checks made by the Society on board ship do not necessarily require the constant and continuous presence of the Surveyor. The Society may also commission laboratory testing, underwater inspection and other checks carried out by and under the responsibility of qualified service suppliers. Survey practices and procedures are selected by the Society based on its experience and knowledge and according to generally accepted technical standards in the sector.

**Article 3**

**3.1.** The class assigned to a Ship, like the reports, statements, certificates or any other document or information issued by the Society, reflects the opinion of the Society concerning compliance, at the time the Service is provided, of the Ship or product subject to certification, with the applicable Rules (given the intended use and within the relevant time frame).
The Society is under no obligation to make statements or provide information about elements or facts which are not part of th e specific scope of the Service requested by the Interested Party or on its behalf.

**3.2.** No report, statement, notation on a plan, review, Certificate of Classification, document or information issued or given as p art of the Services provided by the Society shall have any legal effect or implication other than a representation that, on the basis of the checks made by the Society, the Ship, structure, materials, equipment, machinery or any other item covered by such document or information meet the Rules. Any such document is issued solely for the use of the Society, its committees and clients or other duly authorised bodies and for no other purpose. Therefore, the Society cannot be held liable for any act made or document issued by other parties on the basis of the statements or information given by the Society. The validity, application, meaning and interpretation of a Certificate of Classification, or any other document or information issued by the Society in connection with its Services, is governed by the Rules of the Society, which is the sole subject entitled to make such interpretation. Any disagreement on technical matters between the Interested Party and the Surveyor in the carrying out of his functions shall be raised in writing as soon as possible with the Society, which will settle any divergence of opinion or dispute.

**3.3.** The classification of a Ship, or the issuance of a certificate or other document connected with classification or certificati on and in general with the performance of Services by the Society shall have the validity conferred upon it by the Rules of the Society at the time of the assignment of class or issuance of the certificate; in no case shall it amount to a statement or warranty of seaw orthiness,

structural integrity, quality or fitness for a particular purpose or service of any Ship, structur e, material, equipment or machinery inspected or tested by the Society.

**3.4.** Any document issued by the Society in relation to its activities reflects the condition of the Ship or the subject of certifi cation or other activity at the time of the check.

**3.5.** The Rules, surveys and activities performed by the Society, reports, certificates and other documents issued by the Society are in no way intended to replace the duties and responsibilities of other parties such as Governments, designers, ship builders, manufacturers, repairers, suppliers, contractors or sub-contractors, Owners, operators, charterers, underwriters, sellers or intended buyers of a Ship or other product or system surveyed.

These documents and activities do not relieve such parties from any fulfilment, warranty, responsibility, duty or obligation (also of a contractual nature) expressed or implied or in any case incumbent on them, nor do they confer on such parties any right, claim or cause of action against the Society. With particular regard to the duties of the ship Owner, the Services undertaken by the Society do not relieve the Owner of his duty to ensure proper maintenance of the Ship and ensure seaworthiness at all times. Likewise, t he Rules, surveys performed, reports, certificates and other documents issued by the Society are intended neither to guarantee the buyers of the Ship, its components or any other surveyed or certified item, nor to relieve the seller of the duties arising out of the law or the contract, regarding the quality, commercial value or characteristics of the item which is the subject of transaction.

In no case, therefore, shall the Society assume the obligations incumbent upon the above-mentioned parties, even when it is consulted in connection with matters not covered by its Rules or other documents.

In consideration of the above, the Interested Party undertakes to relieve and hold harmless the Society from any third party claim, as well as from any liability in relation to the latter concerning the Services rendered.

Insofar as they are not expressly provided for in these General Conditions, the duties and responsibilities of the Owner and Interested Parties with respect to the services rendered by the Society are described in the Rules applicable to the specific Service rendered.

**Article 4**

**4.1.** Any request for the Society's Services shall be submitted in writing and signed by or on behalf of the Interested Party. Such a request will be considered irrevocable as soon as received by the Society and shall entail acceptance by the applicant of all relevant requirements of the Rules, including these General Conditions. Upon acceptance of the written request by the Society, a contract between the Society and the Interested Party is entered into, which is regulated by the present General Conditions.

**4.2.** In consideration of the Services rendered by the Society, the Interested Party and the person requesting the service shall be jointly liable for the payment of the relevant fees, even if the service is not concluded for any cause not pertaining to the Society. In the latter case, the Society shall not be held liable for non-fulfilment or partial fulfilment of the Services requested. In the event of late payment, interest at the legal current rate increased by 1.5% may be demanded.

**4.3.** The contract for the classification of a Ship or for other Services may be terminated and any certificates revoked at the request of one of the parties, subject to at least 30 days' notice to be given in writing. Failure to pay, even in part, the fees due for Services carried out by the Society will entitle the Society to immediately terminate the contract and suspend the Services.

For every termination of the contract, the fees for the activities performed until the time of the termination shall be owed to the Society as well as the expenses incurred in view of activities already programmed; this is without prejudice to the right to compensation due to the Society as a consequence of the termination.

With particular reference to Ship classification and certification, unless decided otherwise by the Society, termination of the contract implies that the assignment of class to a Ship is withheld or, if already assigned, that it is suspended or withdrawn; any st atutory certificates issued by the Society will be withdrawn in those cases where provided for by agreements between the Society and the flag State.

**Article 5**

**5.1.** In providing the Services, as well as other correlated information or advice, the Society, its Surveyors, servants or agents operate with due diligence for the proper execution of the activity. However, considering the nature of the activities performed (see art. 2.4), it is not possible to guarantee absolute accuracy, correctness and completeness of any information or advice supplied. Express and implied warranties are specifically disclaimed.

Therefore, except as provided for in paragraph 5.2 below, and also in the case of activities carried out by delegation of Governments, neither the Society nor any of its Surveyors will be liable for any loss, damage or expense of whatever nature sustained by any person, in tort or in contract, derived from carrying out the Services.

**5.2.** Notwithstanding the provisions in paragraph 5.1 above, should any user of the Society's Services prove that he has suffered a loss or damage due to any negligent act or omission of the Society, its Surveyors, servants or agents, then the Society will pay compensation to such person for his proved loss, up to, but not exceeding, five times the amount of the fees charged for the specific services, information or opinions from which the loss or damage derives or, if no fee has been charged, a maximum of AED5,000 (Arab Emirates Dirhams Five Thousand only). Where the fees charged are related to a number of Services, the amount of the fees will be apportioned for the purpose of the calculation of the maximum compensation, by reference to the estimated time involved in the performance of the Service from which the damage or loss derives. Any liability for indirect or consequential loss, damage or expense is specifically excluded. In any case, irrespective of the amount of the fees charged, the maximum damages payable by the Society will not be more than AED5,000,000 (Arab Emirates Dirhams Five Millions only). Payment of compensation under this paragraph will not entail any admission of responsibility and/or liability by the Society and will be made without prejudice to the disclaimer clause contained in paragraph 5.1 above.

**5.3.** Any claim for loss or damage of whatever nature by virtue of the provisions set forth herein shall be made to the Society in writing, within the shorter of the following periods: (i) THREE (3) MONTHS from the date on which the Services were performed, or (ii) THREE (3) MONTHS from the date on which the damage was discovered. Failure to comply with the above deadline will constitute an absolute bar to the pursuit of such a claim against the Society.

**Article 6**

**6.1.** These General Conditions shall be governed by and construed in accordance with United Arab Emirates (UAE) law, and any dispute arising from or in connection with the Rules or with the Services of the Society, including any issues concerning responsibility, liability or limitations of liability of the Society, shall be determined in accordance with UAE law. The courts of the Dubai International Financial Centre (DIFC) shall have exclusive jurisdiction in relation to any claim or dispute which may arise out of or in connection with the Rules or with the Services of the Society.

**6.2.** However,

(i) In cases where neither the claim nor any counterclaim exceeds the sum of AED300,000 (Arab Emirates Dirhams Three Hundred Thousand) the dispute shall be referred to the jurisdiction of the DIFC Small Claims Tribunal; and

(ii) for disputes concerning non-payment of the fees and/or expenses due to the Society for services, the Society shall have the

right to submit any claim to the jurisdiction of the Courts of the place where the registered or operating office of the Interested Party or of the applicant who requested the Service is located.

In the case of actions taken against the Society by a third party before a public Court, the Society shall also have the right to summon the Interested Party or the subject who requested the Service before that Court, in order to be relieved and held harmless according to art. 3.5 above.

**Article 7**

**7.1.** All plans, specifications, documents and information provided by, issued by, or made known to the Society, in connection with the performance of its Services, will be treated as confidential and will not be made available to any other party other than the Owner without authorisation of the Interested Party, except as provided for or required by any applicable international, European or domestic legislation, Charter or other IACS resolutions, or order from a competent authority. Information about the status and validity of class and statutory certificates, including transfers, changes, suspensions, withdrawals of class, recommendations/conditions of class, operating conditions or restrictions issued against classed ships and other related information, as may be required, may be published on the website or released by other means, without the prior consent of the Interested Party.

Information about the status and validity of other certificates and statements may also be published on the website or released by other means, without the prior consent of the Interested Party.

**7.2.** Notwithstanding the general duty of confidentiality owed by the Society to its clients in clause 7.1 above, the Society's clients hereby accept that the Society may participate in the IACS Early Warning System which requires each Classification Society to provide other involved Classification Societies with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and used to facilitate the proper working of the IACS Early Warning System. The Society will provide its clients with written details of such information sent to the involved Classification Societies.

**7.3.** In the event of transfer of class, addition of a second class or withdrawal from a double/dual class, the Interested Party undertakes to provide or to permit the Society to provide the other Classification Society with all building plans and drawings, certificates, documents and information relevant to the classed unit, including its history file, as the other Classification Society may require for the purpose of classification in compliance with the applicable legislation and relative IACS Procedure. It is the Owner's duty to ensure that, whenever required, the consent of the builder is obtained with regard to the provision of plans and drawings to the new Society, either by way of appropriate stipulation in the building contract or by other agreement.

In the event that the ownership of the ship, product or system subject to certification is transferred to a new subject, the latter shall have the right to access all pertinent drawings, specifications, documents or information issued by the Society or which has come to the knowledge of the Society while carrying out its Services, even if related to a period prior to transfer of ownership.

**Article 8**

**8.1.** Should any part of these General Conditions be declared invalid, this will not affect the validity of the remaining provisions.

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## 1. PURPOSE and APPLICATION

### 1.1 Purpose

The purpose of this Guide for Optimized Shaft Alignment is to provide guidance to owners, designers, shipyard, and operators who wish to perform a more exhaustive shaft alignment analysis and an extensive installation assessment with the aim of minimizing the risks of damaging of propulsion plant components and to increase the operating life span.

### 1.2 Application

The Additional Class Notation OSA or OSA-PR is assigned to new ships which are designed, constructed, surveyed, operated, and maintained in compliance with the requirements of this Guide.
Assignment of the OSA Notation requires assessment of plans and calculations to be submitted by the designer in accordance with the requirements of this Guide and surveys in accordance with applicable Tasneef Rules for the classification of Ships.
Assignment of the OSA-PR Notation requires assessment of plans and calculations to be submitted by the designer and compliance with the installation, measurements and sea trials requirements, in accordance with the requirements of this Guide and applicable Tasneef Rules for the classification of Ships.
In addition, the OSA-PR Notation requires the attendance of a Tasneef Surveyor during the shaft alignment and during any additional shafting alignment effort works which are in addition to requirements foreseen in Tasneef Rules for the classification of Ships, as elucidated in this Tasneef Guide.

## 2. DEFINITIONS

### 2.1 Shaft alignment

Shaft alignment is the process of positioning shaft bearings (in way that may be different from a straight-line condition) so that an acceptable bearing load distribution is achieved and will satisfy the limits for:

- the bearing loading,
- the shaft-bearing misalignment angles,
- the bending moments in the shafts,
- the stresses in the shaft, and
- other parameters established by equipment manufacturers such as shaft deflections in way of gears**.**

### 2.2 Shaft alignment optimization

Alignment optimization is method to identify a condition, such as a set of bearing offsets (see 1.2.3), which, when applied in the dry dock or at the light ship draft condition produces the more satisfactory bearings load distribution for more than one alignment condition and that will satisfy the bearing loading conditions, the limits prescribed by the Manufacturers of shaft line components including machineries and the limits stated in the Rules, in all service drafts of the vessel (e.g., from ballast to fully-laden).
The goal of shaft alignment optimization is to determine a condition that, for any given vessel loading case will reduce, as far as possible, the risks of damaging of propulsion plant components.

### 2.3 Offsets

Offsets are the initial vertical and horizontal positions of a bearing, in respect of a reference line, fixed by the alignment procedure. Offsets may be affected by the flexibility of the structure, the loading deformations and thermal expansion depending on the considered condition. [mm]

### 2.4 Elastic Shaft Alignment (ESA)

Elastic Shaft Alignment (ESA) means the iterative calculation method for shaft alignment.

### 2.5 FEA, FSI, and CFD

FEA: Finite Element Analysis
FSI: Fluid Structure Interaction (calculation method used to find the pressure distribution inside the oil lubricant, based on Reynolds equation. The equation is derived from Navier-Stokes and continuity equations)
CFD: Computational Fluid Dynamics.

### 2.6 Global Reference Line

In the shaft alignment sighting, the global reference line is the 0 (zero) datum line used as the reference for all bearing offsets. All bearing offset values are recorded based on this datum.

### 2.7 MCR

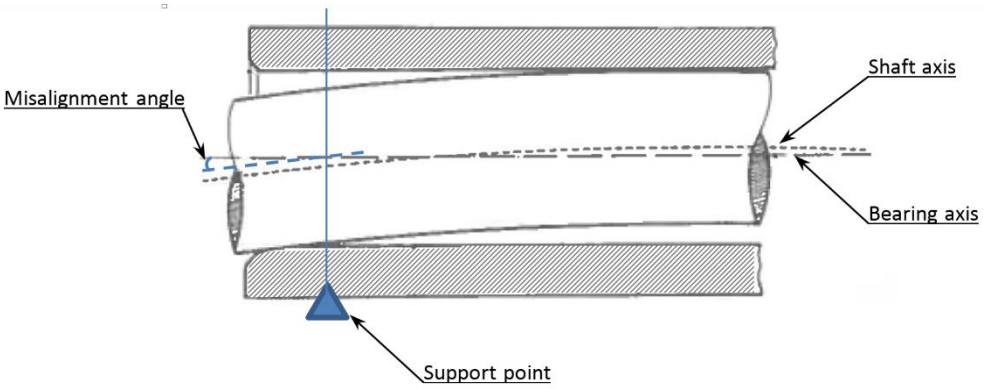
Maximum Continuous Rating of the propulsion plant [kW]

### 2.8 Q
Q is a torque at Maximum Continuous Rating of the propulsion plant [Nm].

### 2.9 Campbell Diagram
Campbell diagram is a plot which represents a system's response spectrum as a function of its oscillation regime. In case of lateral vibrations (whirling), the plot represents the shaftline natural flexural frequencies (Y-axis) against the shaftline rotational speeds of operation (X-axis).

### 2.10 Misalignment Angle (for bearing with single point of support)
Misalignment angle is defined as the angle between the bearing axis and the tangent line to the shaft at the equivalent point of support.

**Figure 1**




### 2.11 Mean shaft misalignment angle (in radians) for bearings modeled as multiple point of support
Mean shaft misalignment angle is defined as the difference between the displacement of the shaft centerline relative to the bearing centerline calculated at the aftmost point of support and the forwardmost point of support of the considered bearing divided by the bearing effective length.

### 2.12 Mon-Shaft
Mon-Shaft is the Tasneef additional class notation “Shaft Monitoring” according to Pt F, Ch 5, Sec 2.

### 2.13 Very Light Ballast Condition
Very Light Ballast Condition is the condition where the vessel is either in dry-dock or afloat (at quay) with minimum ballast nearing a “lightship” condition. On a case by case basis, it is to be verified if this condition can be assumed as the condition having the least amount of influence in hull deflections that would affect the shaft alignment.

## 3. GENERAL REQUIREMENTS

### 3.1 Design requirements

Class Notation OSA or OSA-PR may be assigned to new ships designed with one or more propulsion shaft lines that comply with the following:

1. Propulsion types of direct drives and geared drive installations, (see Tab 1),

**Table 1: Propulsion types**

| Propulsion type | Prime mover | Propulsion system under consideration |
|---|---|---|
| **Direct drive installation** | Low-speed diesel/gas engine | from propeller to crankshaft (included) |
| **Direct drive installation** | Electric motor | from propeller to fore end of the rotor shaft of motor (included) |
| **Geared drive installation** | Medium-speed diesel/gas engine<br>or<br>Steam/gas turbine<br>or<br>Electric motor | from propeller to fore end of the gearbox output shaft (included) |

2. The additional calculation requirements set in Section 4 of this Guide, including hull deflections and shaft alignment optimization,
3. The shaft alignment processes outlined in Section 6 of this Guide for OSA-PR,
4. Tasneef Class additional notation “Shaft Monitoring” (Mon-shaft) according to Pt F, Ch 5, Sec 2.

In cases of non-conventional shafting arrangements not covered by these Rules (see Tab 1), Tasneef reserves the right to require additional calculations, drawings and documentation as deemed necessary to verify compliance with the OSA or OSA-PR notation requirements.

### 3.2 Documentation to be submitted (for both additional class notation OSA or OSA-PR)

#### 3.2.1 Drawings

1. Shafting arrangement plan,
2. Intermediate shaft, propeller shaft constructional drawings (with details of integral coupling flange) including material properties,
3. constructional drawings, including material properties, of non-solid forged flange couplings (keyed or shrink-fit), shrunk couplings, coupling bolts and keys’ drawings,
4. Shaft bearing constructional drawings including material properties and clearances, specifying locations (Stern tube, intermediate etc.),
5. Shaft seals’ drawings,
6. Propeller drawings,
7. Gearbox drawings (at least output shaft and bearings), as applicable.

#### 3.2.2 Data

i) Rated power of main engine and shaft rpm
ii) Allowable bearing loads
iii) Propeller mass, inertia, and geometric data (pitch ratio, expanded area ratio etc.)
iv) Hull deflections data for ballast and fully laden condition at the bearing points of support positions. Hull deflections are to be analyzed with the aft peak tanks full or as full asapplicable, in accordance with the vessel’s loading manual.
Hull deflections may be estimated by finite element calculations or by measurements from similar vessels (same type, similar vessel size, similar double bottom height in the area of the engine room, similar stern tube and stern arrangement) or other recognized or benchmarked calculation methodologies.

Hull deflections are to be estimated at the bearing points of support positions for the appropriate required loading cases.
The hull deflection calculation report is to be submitted for information.

v) Allowable bending moment and shear force values at the thrust shaft flange of the main engine (static condition)
vi) Bearing stiffness values, bearing clearances, lubricant type (e.g. vegetable oils, synthetic esters and polyalkylene glycols, etc.), grade and properties and maximum & minimum allowed bearing load including max local pressure for stern bushes,
vii) For geared installations, gear forces and moments, bearing stiffness values, bearing clearances, lubricant properties, maximum and minimum allowed bearing load, and allowable difference between AFT and FWD actual bearing load.
viii) Main engine crankshaft equivalent model for Shaft Alignment purpose
ix) Hydrodynamic propeller loads (forces and moments) for the following conditions:
a) Straight course, at full speed, in a fully laden condition
b) Straight course, at full speed, in the ballast condition
c) Full rudder starboard and port turns, at full speed, in a fully laden condition
d) Full rudder starboard and port turns, at full speed, in the ballast condition

Transverse and Vertical Hydrodynamic propeller loads are to be used. These can be estimated by calculations (lifting surface method, boundary panel method, CFD, etc.) or based on empirical/database formulae duly justified.
In case hydrodynamic propeller loads are not available, the following table 2 shows moments acting in a longitudinal/vertical plane obtained from regression of calculated and measured data, which may be used in the absence of other validated values.
A turning condition is hereby defined as the condition in which the vessel is performing a steady state full rudder turn to port or starboard, commencing from a straight course at a ballast or full scantling draft at MCR condition.

**Table 2: Hydrodynamic propeller loads (obtained from regression of calculated and measured data)**

| | **Straight ahead condition** | **Turning condition** |
|---|---|---|
| **For single screw vessel** | +/-5% of Q | +/-30% of Q |
| **For twin screw vessel** | +/-20% of Q | +/- 30% of Q |

Where:
Q, torque at MCR
Positive sign (+) implies upward moment about the horizontal transverse axis.
Negative sign (-) implies downward moment about the horizontal transverse axis.

### 3.2.3 Calculations

1. Details of shaft alignment calculation as required on Section 3 of this Guide
2. Details of shaft alignment optimization calculation
3. Aft Stern Tube Bearing Contact Analysis detailing the maximum misalignment angle between the shaft and the bearing, as well as the estimated contact area, contact pressure, and the lubricant film thickness, considering the conditions set in Section 4, 4.1.1 of this Guide.
4. Lateral Vibration (Whirling) Calculations
5. Hull deflection calculation report (for information only).

Tasneef reserves the right to require electronic submission of the actual FE model used to determine hull deflection.

### 3.2.4 Procedures applicable for the OSA Notation

Details of shaft alignment procedure.

### 3.2.5 Procedures applicable for OSA-PR Notation

i) Details of shaft alignment procedure.
ii) Details of bearing run-in procedure.

### 3.2.6 Measurements applicable for the OSA Notation

i) Shaft Alignment Measurements: jack-up tests
ii) Measurement report as per the Guide requirements

### 3.2.7 Measurements applicable for the OSA-PR Notation

i) Bearing temperature measurements and recording during run-in phase before sea trials
ii) Shaft Alignment Measurements including jack-up tests and analyses or strain gauge recordings and reverse engineering analyses,
iii) Measurement report as per the Guide requirements given on Sections 5 and 6
iv) Lateral vibration measurements (only for propulsion plants: with no forward stern tube bearing installations or where whirling calculations indicate the possibility of critical speeds within the range of ±20% of maximum continuous ratings speed) as per the Guide requirements in section 6 an 7.

Tasneef may require additional calculations, drawings or documentation, or any other justification and or information about data, calculation method, simplified approach, etc. used for performing the analysis as deemed necessary.

## 4. Calculation Requirements for OSA and OSA-PR Notations

### 4.1 General

### 4.1.1 Shaft Alignment Calculations scope and goal

The objective of shaft alignment calculations is to provide all the data and information needed by the shipyard to achieve a satisfactory alignment under all intended operating conditions of the vessel (from ballast to full load).

It is known that different ship loading conditions, such as ship in ballast or ship fully loaded may produce different bearing reaction results, and these may also vary depending on whether the aft peak tank is full or empty.

Hull deflection analysis such as FEA enables an accurate evaluation of hull deflections in different loading conditions. The influence of the resulting localized hull deflections onto the bearing loads are to be assessed by means of calculations. The assessment is to be conducted for an empty aft peak tank and for a full aft peak or an aft peak tank filled to the maximum level as defined in the vessels' loading manual. The below list of calculations is to be considered as initial reference and maybe modified taking into account the ship loading conditions and power-train:

1) dry dock or afloat at very light ballast or lightship condition with cold engine and with propeller partially immersed,
2) fully ballasted vessel with hot engine and propeller fully immersed in static condition,
3) fully ballasted vessel with hot engine and propeller fully immersed in dynamic running condition including a simulation of a straight ahead run and full port and starboard turns as defined in section 2, 2.2.2 of this Guide,
4) Fully laden vessel with hot engine and propeller fully immersed in static condition.
5) Fully laden vessel with hot engine and propeller fully immersed in dynamic running condition including a simulation of a straight ahead run, and vessel full port and starboard turns turning simulation (i.e., straight, port, and starboard) with propeller hydrodynamic loads, as defined in section 2, 2.2.2 of this Guide.

### 4.2 Additional Calculations

### 4.2.1 Requirements

All the design and installation requirements for shaft alignment calculations stated in the Tasneef Rules for the classification of Ships are to be applied.

Additional calculation requirements to those specified in **Pt.C, Ch.1, Sec.7, Para.3.3** of Tasneef Rules for the classification of Ships are:

a) Optimization of Bearing Offsets

The Shaft Alignment Optimization Calculation is to determine a set of bearing offsets that, when applied during shaft alignment works at the drydock or afloat at very light ballast condition, result the optimum bearing reactions over the full range of vessel loading conditions.

The calculation report is to detail the calculation process and the assumptions made. The submitted calculations are to include a clear definition of the shaft alignment optimization method including the

relevant definitions of the design optimization such as the objective function, the state variables, and the design variables.

b) Aft Stern Tube Bearing Contact Analysis:

Modelling techniques, such as bearing multi-point of support or 3D finite element modelling with fluid structure interaction (FSI) between the bearing, the oil film and the rotating shaft can be acceptable, provided appropriate assumptions and recognized engineering practices are demonstrated in the submitted calculation report.

When a single point of support is utilized for the bearing model criteria given in **Pt.C, Ch.1, Sec.7, Para.3.3** of Tasneef Rules for the classification of Ships apply.

When a 3D finite element model with fluid structure interaction between the bearing the oil film and the rotating shaft is utilized, in addition to the misalignment angle criterion the following criteria, as applicable, are also to be used for the assessment: oil film thickness > 30 μm, maximum local contact pressure, nominal contact pressure, bearing load limits.

Aft stern tube bearing bush are to be inclined or internally slope-bored or tapered, when the outcome of calculation indicates that thjs is needed to comply with all criteria.

The slope design criteria given in **Pt.C, Ch.1, Sec.7, Para.3.3** of Tasneef Rules for the classification of Ships apply.

c) Lateral Vibration (Whirling) Calculations

For the assignment of OSA or OSA-PR Notation, the whirling vibration calculation is to be submitted for all shafting systems, even if not required by **Pt.C, Ch.1, Sec.9.4** of Tasneef Rules for the classification of Ships.

The scope of calculations is to investigate the excitation frequencies giving rise to all critical speeds which may result in significant vibration amplitudes throughout the working speed range.

The calculations are to consider bearing stiffness including oil-film and bearing support/housing stiffness or other structural stiffness considerations.

The bearing stiffness calculation including oil-film and bearing seating stiffness or the other structural stiffness considerations are to be included in the calculation report, as well as all the assumptions made.

The assessment in terms of calculating critical speed locations throughout the working speed range is to be conducted for the following conditions:

i) all bearings are positively loaded per the alignment calculation report results, while applying the appropriate bearing stiffness for each bearing.
ii) same as above but with an unloaded forward stern tube bearing.

The calculated critical speeds, of both the above conditions i) and ii), are not to be in the speed range between 80% and 120% of the main engine speed at MCR.

Critical speed presentation for lateral-whirling vibration is through a Campbell diagram.

The influence of the gyroscopic effect is to be considered and shown in the Campbell diagram.

Excitation orders, shaft first order (shaft unbalance) and the blade passing frequency (i.e. first propeller blade excitation order), are to be overlaid on the graph and clearly show the critical speeds as intersections between the excitation orders lines and the natural frequency lines.

Furthermore, critical speeds are also to be listed in RPM, in a tabular format. Those that fall in the operating speed range are to be distinctly highlighted.

Lateral-whirling vibration measurements are required in the following cases:

- where the calculations indicate the possibility of dangerous critical speeds in or near the operating speed range,
- where the accuracy of some data is not deemed sufficient,
- propulsion plant with no forward stern tube bearing installations.

The measurements are to be carried out during sea trial in the whole engine speed range: by means of reliable apparatus, with sensors placed in a position in which are expected to have the significant values of parameter measured and in presence of Tasneef Surveyor.

d) Geared Installation Calculations.

Both Shaft Alignment Calculation and Shaft Alignment Optimization Calculation of shafting system driven via gearbox is to consider the total dynamic tooth forces and moments[1)] in each direction

*Note 1: moments due to unbalanced axial components of tooth force of single helical gears.*

## 5. Hull Deflection

### 5.1 Hull Deflection Calculation

Shaft alignment optimization analysis requires to know the values of the hull's deflections.

Hull deflections for the ballast and the fully laden conditions can be established by utilizing specialized computer programs and methodologies, such as the finite element model method. Hull deflections are to be obtained at each bearing supporting point, including at the main engine bearings (as applicable).

The set of hull deflections may be provided using either an absolute coordinate system or as relative displacement values through a transformation based on a reference line defined by the aft most stern tube bearing and the most forward bearing of the shaft line including the engine, gearbox, or any other prime mover machinery.

### 5.2 FEM method

Where the finite element (FE) method is used for performing hull deflection calculation, the model is to include all structural parts and all steelwork of the engine room and the double bottom.
Where an FE model is constructed, a reference to any modeling procedures such as element types, ratios of element sizes, material properties, elements warping ratio limits, etc., is to be included in the calculation report. The Society may require electronic submission of the actual FE model used for the hull deflection modeling.

### 5.3 Alternative Hull Deflection Calculation

Hull deflection calculation carried out with programs using simple beam theory for the or other programs related to the vessel's stability and loading calculations may be accepted provided that: sufficient information in terms of data and calculations demonstrating that the obtained hull deflection values are reliable are included in the report.

### 5.4 Proven service experience and measurements

Proven service experience and measurements from sister vessels can also be accepted for the determination of hull deflections at the bearing location positions for the appropriate required loading cases.

## 6. Alignment Procedure Applicable for the OSA-PR Notation

### 6.1 Milestone Step

The following shaft alignment procedural steps are reported for guidance:

- Sighting through (bore sighting)
- Engine bedplate pre-sagging
- Reactions measurements
- Bearing-shaft misalignment evaluation
- Shaft eccentricity (run-out) verification
- Intermediate shaft bearing offset readjustment
- Crankshaft deflection measurements
- Engine bedplate deflections measurement
- Gear contact evaluation
- Gear-shaft bearings reaction measurements

### 6.2 Requirements

Beyond the requirements outlined in the Tasneef RULES, the Shipyard must generate a record documenting every step of the shaft alignment installation process, including recorded sighting data. This log is then to be submitted to the Society for verification against limits or tolerances of the components.

i) The final bearing sighting should not occur until the vessel's stern blocks are completely welded, and all substantial and heaviest stern structures, including the main engine, are fully assembled.

ii) The ultimate bearing sighting should span from the rearmost bearing (whether it be the stern tube or strut, as applicable) up to the engine or gearbox output flange. This process is employed to fine-tune the relative positioning between the engine/gearbox and the offsets of the stern tube bearing. Intermediate bearing offsets can be adjusted during the final sighting. The final sighting of the bearing bush aims to confirm the following conditions:

- The slope(s) and offset of both the aft and forward bush, as installed, are to be measured concerning a reference line. This should be done at a minimum of three longitudinal positions in the aft bush. In the case of a bush with multiple slopes aft, the minimum number of measuring positions should be multiplied by the number of slopes. For instance, for a double-sloped bush, measurements should be taken in at least six positions in the aft bush. The positions need to include the knuckle point or transition point positions between the slopes.
- The hull deflections between dry-dock and afloat lightship conditions are to be considered. Otherwise, another final bore sighting should be conducted afloat. Afloat sighting is deemed entirely acceptable.
- In situations where there is no forward stern tube bearing, the slope and offset of the aft bush and the offset of the rearmost intermediate bearing, as installed, are to be determined. The offset of the

aftmost intermediate bearing should be secured, and its offset should not be altered after completing the bore sighting and verifying the stern tube bearing clearance. If hull deflections between dry-dock and afloat lightship conditions are acknowledged and factored in, there is no need for corrective measures on the intermediate bearing offset or another final bore sighting afloat. Afloat sighting is satisfactory.

- All recorded bearing offsets must align with the calculated values, adhering to a tolerance of [+/-] 0.1mm, and the bearing slopes are expected to match the calculated values, staying within a tolerance of [+/-] 0.1 mrad.

iii) Laser sighting and optical sighting are, in order of preference, recognized methods for the sighting procedure.
iv) The final sighting is also required to validate that the horizontal offsets of all bearings are minimized and do not surpass the clearance values of adjacent bearings.
v) The offsets of the shaftline bearings and the engine/gearbox (both vertical and horizontal) are expected to align with the values calculated.

### 6.3 Means of Bearing Reaction Measurement and Verification

Bearing reactions are to be assessed employing the following techniques:
i) Jack up
ii) Strain gauge
iii) Laser techniques involving shaft deflection
The strain gauge and laser methods are to be combined with jack-up measurements to validate the accuracy of the measurement outcomes.

### 6.4 Recordings

To meet the requirements of the OSA-PR Notation, the shipyard must document all relevant measurements in a well-organized log file, which is then submitted to Tasneef for assessment.
This includes:

- Bearing reaction measurements for all reachable shaft bearings, the rearmost three main engine bearings, and the gearbox bearing (when applicable), recorded for each vessel loading condition accounted in the shaft alignment calculation.
- Generate a tabular or bar chart format for comparing the measured bearing reactions at each accessible shaft bearing with the calculated bearing reaction for the corresponding condition.

## 7. Sea Trials for OSA-PR Notation

### 7.1 Test Procedure

In addition to the sea trials procedures specified in the Tasneef RULES, further information is requested and listed below. Throughout these trials, various performance parameters of the propulsion shaft bearings need to be recorded at predetermined intervals by experienced shipyard personnel and/or the ship's crew. These records are then periodically reviewed by the attending Surveyor during the trials.
The parameters to be recorded and presented in a time chart are:
a) Temperature of all shaft bearings, including the aftmost three main engine bearings and, if present, the gearbox bearing.
b) Rudder angle in degrees.
c) Shaft RPM.

### 7.2 Bearing Run-in Procedure

A bearing run-in procedure is to be agreed upon between the surveyor and the yard.
The Run-In procedure allows the correct bedding of the tail shaft with the stern tube bearing, gradually exposing the stern bearing to an increased load. This procedure helps the stern tube withstand fluctuating service loads without incurring damage.
The run-in procedure is to be conducted as early as possible, before starting full operational sea trials and should be conducted preferably with a fully immersed propeller. The run-in procedure is to be conducted in deep waters in the open sea. If the vessel reaches the sea trial location in a light ballast condition, the lowest RPM for navigation and the lowest possible helm angle should be used, to avoid exposing the new bearings to high stress and temperatures. The run-In procedure is to be conducted with ballasted vessel, according to the pre-determined sea trial draft.
During the bearing Run-In procedure, the aft stern tube bearing temperature should be closely monitored. If bearing temperature rises at a rate faster than a previously agreed rate, such as 5°C/min, or exceeds expected temperature threshold then the procedure shall be aborted: rudder angle should be immediately set to zero

and the engine speed should be immediately reduced to the minimum, or shut down, until the bearing temperature lowers to an acceptable level and stabilizes accordingly. Temperatures exceeding the high-temperature alarm threshold and high-temperature increase rate should be reported.
If limits/criteria/alarms are exceeded, the shipyard may request to repeat the bearing run-in procedure. Repeating should be subject to agreement; otherwise, further investigation should be carried out.
The procedure is to be considered as failed and further investigations are deemed necessary if limits/criteria/alarms are exceeded during a repeat run-in procedure.
Once a bearing run-in procedure is completed satisfactorily, the parts of the sea trials addressing the propulsion system and shaftline may commence.

### 7.3 Shaft alignment verification during sea trials

The stern tube lubricant used during sea trials needs to be the same as specified in the shaft alignment calculation report. The aft stern tube bearing temperature is to be recorded during the navigation tests included in the sea trial program. The vessel is to stabilize at a full ahead setting, with a zero-rudder angle (straight ahead) and at the required ballast condition, before carrying out the below tests:

i) Perform one 360 degrees turn to the port by swiftly changing the rudder angle from 0 to the maximum declared steering angle, as defined in UI SC242 and a full ahead setting. At the completion of the turn, return the rudder angle to zero (straight ahead).
ii) Keep the rudder angle to zero for five (5) minutes at a full ahead setting.
iii) Perform one 360 degrees turn to the starboard by swiftly changing the rudder angle from 0 to the maximum declared steering angle, as defined in UI SC242 and a full ahead setting. At the completion of the turn, return the rudder angle to zero (straight ahead).
iv) Keep the rudder angle to zero for five (5) minutes and at a full ahead setting.

Provided the recorded stern bearing temperature does not exceed a previously agreed rate, such as 5°C/min, or triggers a temperature alarm, the sea trial bearing performance for shaft alignment is regarded as satisfactory. If acceptable limits, design criteria, and alarm settings are exceeded it may be required to repeat the whole testing procedure (i), ii), iii), iv), as above). In this case, the test will be considered as passed if satisfactory results are demonstrated twice. As a minimum, the test record is to include the maximum rate of temperature rise, the maximum bearing temperature, as well as the alarm set points. Test results are to be included in the sea trial report and sent to Tasneef, to be retained for information purposes.
A root cause analysis should be initiated to reveal the possible cause of the damage if the bearing is deemed to be damaged.

### 7.4 Jack-up Tests in hot static condition

Society requires further bearing reaction measurements for the hot static condition, in addition to jack-up measurements conducted during drydock and in the lightship condition, and the results of jack-up tests are to be submitted to Tasneef for review.

## 8. Maintenance of OSA and OSA-PR Notations

The OSA and OSA-PR Notation may be withdrawn in case of modifications or in the event of incidents that affect the parameters or values specified in Sections 3 or 4 of this guide. To re-obtain the notation after its withdrawal, it is essential to submit to the Society a detailed report for review. This report should describe the actions taken, including a calculation report that proves that the requirements outlined in Sections 3 and 4 have been reinstated.
Regardless of this, it is crucial to promptly inform Tasneef of incidents that could impact the shaft alignment or modifications to any powertrain component, both during the design phase, at the time of Notation assignment, and throughout the operational life of the vessel.

## 9. Surveys

### 9.1 Initial Surveys

The OSA-PR Notation requires the attendance of a Tasneef Surveyor during the shaft alignment and during any additional shafting alignment procedure which is not a specified requirement foreseen in Tasneef Rules for the classification of Ships, as elucidated in this Guide.
After compliance with the installation, measurements and sea trials requirements are verified, the OSA-PR notation can be assigned.

### 9.2 Surveys after construction

The survey requirements outlined in Tasneef Rules for the classification of Ships regarding periodic surveys after construction are to be met to maintain the OSA-PR Notation.