Table of contents

Introduction

The target of alignment is to achieve positive static loads for all bearings (shaft line bearings and engine main bearings) under all normal ship service conditions, i.e. when the ship draught and the trim are within normal limits.

To meet this target, the influence of elastic ship hull bending needs to be adequately considered by adjusting an appropriate static load distribution already at design stage, i.e. in the alignment layout calculation (ALC) and further during engine and shaft line installation (alignment before chocking). Therefore, the following needs to be considered:

- The static loads of shaft line bearings need to have sufficient margins against zero load and against overload.
- The aft three engine main bearings need to have an appropriate static load distribution which refers to the ship design and the difference between the draught expected during alignment and the maximum service draught (so called 'scantling draught').
- The main engine needs to be installed straight or smoothly bent to a slight sagging or a very slight hogging by means of the full number of jacking screws (or alignment wedges resp.).

Regular crankweb deflection measurements and verification in service as well as regular inspection of crankcase are required for monitoring of main bearing alignment condition. **As soon as all main bearings have a positive static load, no excessive static load can develop on any main bearing. Consequently no maximum limits need to be defined.**

Cranks have a three-dimensional geometry with an uneven bending stiffness. This causes a variation of static main bearings loads which depends on the crank angle (see DG 9709 – “Engine alignment – Guidelines for measurements”).
The ALC as well as the installation and the evaluation of alignment measurement results need experience. Wärtsilä offers support based on long-term experience in

- assistance for creation of ALCs including recommendations for appropriate case specific static load distribution of main bearings
- evaluation and review of alignment measurement results by means of so called ‘reverse calculations’

Abbreviations

The following abbreviations are used in this document:

ALC	alignment layout calculation
cyl.	cylinder
cyl.1	aftmost cylinder #1
cyl.(n)	foremost cylinder
cyl.(n-1)	second foremost cylinder
DG	design group (Wärtsilä drawing set structure)
mb	engine main bearing
mb(n)	foremost engine main bearing

1 General

1.1 Static load distribution for the aft three engine main bearings under consideration of elastic ship hull bending

Elastic ship hull bending affects the alignment. In stopped flat-water conditions, the ship hull bending depends mainly on ship draught and trim and also on temperatures. Consequently the judgement of bearing loads and crankweb deflections need to consider these conditions. Regarding the main engine, mainly the aft three engine main bearings and the deflection of the aftmost crankweb are influenced as shown in table 1 below.

Table 1	**Influence of ship draught onto engine alignment**			
condition	**machinery foundation shape**	**static main bearing loads**		**crankweb deflection cyl.1**
		mb #1	**mb #2**	
light ballast draught usual for **alignment in new buildings**	sagging or low hogging	↘ reduced	↗ increased	_/+_
design to maximum draught	less sagging or more hogging	↗ increased	↘ reduced	_\-/_

Usually alignment of ship new buildings is performed in the empty ship at light ballast draught.

Depending on ship design and the difference between the expected draught during alignment and the maximum draught,

- a high static load has to be adjusted on mb #2 and mb #3 and
- in contrast an adequately low static load has to be adjusted on aftmost mb #1.

1.1.1 Lower and upper recommended values for aftmost mb #1

Lower and upper recommended values for aftmost mb #1 are provided in order to support the adjustment of an appropriate design related[1] static load distribution at the aft three engine main bearings during final alignment in afloat condition.

These lower and upper values refer to the installation type, however they are **not** provided as limits or recommended tolerance ranges!

[1] Referring to ship design and to propulsion shaft line design and to the difference in draught during alignment up to maximum draught.

Lower recommended values for aftmost mb #1:

The more of the following influences apply, the lower static load is recommended for aftmost mb #1 in cold – stopped condition at light ballast draught (i.e. during alignment):

- large draught increase from alignment to maximum draught, e.g. VLCCs and very large bulk carriers
- short distance, i.e. minimum recommended by WCH between foremost shaft bearing and main engine, e.g. WCH minimum recommended distance for shaft bearings
- light flywheel

If all three influences apply, then the lower value for aftmost mb #1 is recommended.

Upper recommended values for aftmost mb #1

The more of the following influences apply, the higher static load is recommended for aftmost mb #1 for cold – stopped condition at light ballast draught (i.e. during alignment):

- low draught increase from alignment to maximum draught,
  e.g. gas tankers, roro vessels, car carriers and livestock carriers
- large distance, i.e. maximum recommended by WCH between foremost shaft bearing and main engine, e.g. WCH maximum recommended distance for shaft bearings
- heavy flywheel

If all three influences apply, then the upper value for aftmost mb #1 load is recommended.

1.2 Re-alignment after repair

For engine re-alignment on board of vessels after a period of regular service, the recommended static loads provided for ship new buildings may not apply.
For such cases, the static bearing load distribution needs to be adjusted under consideration of the repair and its influence on alignment and the draught condition during re-alignment.
Wärtsilä should be contacted for assistance.

1.3 Alignment in partly afloat condition (not recommended)

If alignment is performed in partly afloat condition, i.e. when the ship hull touches the ground occasionally or continuously or if the ship floating condition depends on the tide, then the ship hull bending differs from fully floating condition to an unknown degree.
Thus WCH is not in a position to provide support for alignment which is performed in partly afloat conditions.

1.4 Alignment in dry-dock

Alignment in dry-dock lies within the experience of the shipyard. However, WCH has no such experience. Thus WCH is not in a position to provide support to alignment which is performed in dry-dock condition.

1.5 Bearing load measurement

The measurement of static bearing loads is usually performed by jack-up tests in fully coupled condition and together with measurements of all crankweb deflections. The measurements listed below are required to proof alignment during installation.
It is crucial to perform these measurements right after each other, without intermittent adjustments and without a change of draught or trim.

- Crankweb deflections of all cylinders
- Jack-up tests of all shaft bearings (except the inaccessible aft stern tube bearing)
- Jack-up tests of aftmost mb #1 to mb #3
- Additional jack-up tests for other main bearings would become necessary, if the maximum deviation indicator for vertical crankweb deflections[2] between two adjacent cranks has been exceeded. It can be exceeded between the two foremost cranks if a heavy external load is attached at the crankshaft forward end, e.g. a TV damper or a front disc or a free end PTO gear drive. In such a case the static loads for the two foremost main bearings need to be measured.
  However, if the maximum deviation indicator for vertical crankweb deflections between two adjacent cranks **is exceeded in way of cyl.2 to the second foremost cyl.(n-1), then Wärtsilä needs to be contacted.**

1.5.1 Recording of bearing load measurement results incl. essential additional information

Careful recording of bearing load measurement results is essential for a reliable analyse of the alignment condition. In addition to the measurement results, also further information about the measurement conditions and the measurement tools need to be included in the records for a clear understanding and a comprehensive judgement of the alignment measurement results.
See DG9709 - “Engine alignment – Guidelines for measurements“ - section “Recording of static bearing loads”.
Wärtsilä provides data record sheets in Microsoft Excel file format free of charge. See DG9707 - “Engine alignment – record sheets“. Please contact Wärtsilä, e.g. by email to: application.engineering.ch@wartsila.com or contact the local Wärtsilä office.

2 Details see DG9709 - “Engine alignment – Crankweb deflections - limits“ - section - “Crankweb deflection max. deviation indicator”

1.5.2 Evaluation of measurement results

Wärtsilä provides support which is **free of charge** for the evaluation of jack-up test results by means of so called 'reverse calculations'.
For this purpose also the following information is required:

- a full set of crankweb deflection measurements which has been measured directly before or after the jack-up tests;
- either the complete ALC or at least all necessary information to create the complete calculation model like used for the ALC[3].

1.5.3 Jack correction factors

For the evaluation of the shaft bearings' jack-up test results, the jack correction factors provided by the ALC should be used.
For the evaluation of the engine main bearings, the jack correction factors provided by the EnDyn program should be used.
However, if the ALC is based just on an equivalent two-dimensional crankshaft model, then the average jack correction factors provided by table 2 should be used for the engine main bearings.

Table 2	Jack correction factors for engine main bearings		
Bearing	**Jack position**	**Dial gauge position**	**Jack correction factor**
aftmost mb #1	below flywheel	either on top of flywheel or on top of crankshaft next to flywheel or on coupling flange next to flywheel	1.5
mb #2 (forward)	below aft crank of aft cyl.1	on top of aft crank of aft cyl.1	1*1
mb #3 (aft)	below forward crank of aft cyl.1	on top of forward crank of aft cyl.1	1
mb #4 to (n)	below crank next to relevant mb	on top of crank next to relevant mb	1

*1: The jack correction factor of mb #2 depends significantly on the static load of aftmost mb #1.

Variation of jack correction factors
The jack correction factor depends on

- the position of the jack in relation to the bearings and
- the actual static load distribution of bearings.

For most bearings the jack correction factor varies only within the negligible range of ±0.1 due to different static load distributions.

[3] Details see DG9709 - "Engine alignment – Procedure & measurements at shipyard" - section "Evaluation of static bearing loads" – subsection "Wärtsilä evaluation – free of charge"

In contrast the jack correction factor of mb #2 may change significantly, depending on the real static load distribution of mb #1 and mb #2.
If the ALC is based on an equivalent two-dimensional crankshaft model, then a jack correction factor of 1 can be used for mb #2.
If the ALC is based on an EnDyn integrated three-dimensional crankshaft model, then the specific jack correction factors should be used which are provided for each shaft line bearing and each engine main bearing.

2 Recommended static main bearing loads for layout calculations of ship new buildings in cold - stopped condition

The recommended static main bearing loads for ALC (table 3) are provided for the design of ship new buildings.
They are provided only for calculations which consider elastic main bearing supports[4] and top clearance in the bearings. Calculations which consider infinitely stiff main bearing supports are misleading and thus not supported by WCH.
The recommended static main bearing loads consider the requirements for **ship new buildings** where the alignment is usually related to the following conditions:

- **The ship hull is completed and the superstructure is in place, i.e. all major welding works are completed.**
- **The ship is in continuous afloat condition and at light ballast draught.**
- **The machinery space has ambient temperatures – including main engine, intermediate bearing supports and double bottom.**

The values are just provided as recommendation and for guidance only. They are **not** provided as **limits**. More important than adjusting the main bearing loads exactly according to the ALC results is to achieve a similar static load distribution for the main bearings, as explained in section 1.1 .
If the ALC is based on an equivalent two-dimensional crankshaft model[5], then the following needs to be considered:

- An equivalent two-dimensional crankshaft model cannot consider the varying stiffness of the cranks.
- Calculation results for mb #3 show limited deviations.
- Calculation results for mb #4 to foremost mb(n) are not realistic.

[4] According to the EnDyn integrated crankshaft models or according to the data table for the equivalent two-dimensional crankshaft model.

[5] Details see DG 9709 – “Equivalent two-dimensional crankshaft model”

Table 3 — Static main bearing loads [kN] recommended[*1] for design (ALC)

ship new buildings, cold - stopped condition, light ballast to ballast draught

	mb #1	mb #2	mb #3	mb #4 to (n)[*3]
W-X35	5 - 15	> 25	> 30	> 12
W-X40	7 - 20	> 40	> 40	> 15
W-X62	10 - 75	> 130	> 150	> 40
W-X72	10 - 110	> 160	> 200	> 50
W-X82	10 - 120	> 290	> 280	> 90
W-X92	10 - 120	> 310	> 300	> 90
RT-flex48T-D RTA48T-D	10 - 40	> 65	> 70	> 30
RT-flex50-B / -D RT-flex50DF	10 – 40	> 65	> 75	> 30
RT-flex58T- D / T- E[*4], RTA58T-D	10 – 60	> 100	> 110	> 30
RT-flex60C-B	10 – 65	> 120	> 130	> 40
RT-flex68-D RTA68-D	10 – 90	> 160	> 170	> 40
RT-flex82C RTA82C	10 – 130	> 260	> 260	> 90
RT-flex82T / T-B RTA82T / T-B	10 – 120	> 290	> 280	> 90
RT-flex84T-D RTA84T-D	10 – 110	> 290	> 280	> 90
RT-flex96C-B RTA96C-B	10 – 140	> 330	> 330	> 90

*1: **The values are recommended and for guidance only.** They are **not** provided as **limits** (see sections 1 and **Error! Reference source not found.**).
As soon as the minimum recommended static load is provided for each main bearing, no excessive static load can develop on any main bearing.

*3: These minimum values have to be maintained for each crank angle position.

*4: Also valid for RT-flex58T-ER-3

3 Recommended static main bearing loads before chocking

In general the static loads provided by the ALC - “cold - stopped” - condition have to be adjusted at alignment before chocking:

- For the static loads of the propulsion shaft line bearings, either the tolerance according to class rules or according to ALC applies – whatever is tighter.
- Simultaneously **the static loads of the aft three engine main bearings need to show a similar static load distribution as provided by the ALC**.
  Due to the very close distances between the main bearings; a tolerance like usually considered for propulsion shaft line bearings (e.g. ±20%) can hardly be applied.

The following requirements have to be met for alignment measurements, which are performed before chocking of main engine:

- **The ship hull is completed and the superstructure is in place, i.e. all major welding works are completed.**
- **The ship is in continuous afloat condition and at light ballast draught.**
- **The machinery space has ambient temperatures – including main engine, intermediate bearing supports and double bottom.**
- **Any heat supply to the double bottom inside the engine room has to be out of operation at least 8 hours prior to the measurement until it is completed**, i.e. the **heating of the main lubricating oil sump tank** below the main engine, **the pre-heater of the main lubricating oil separator**, etc.

The given values (table 4) are recommended and guidance only. They are **not** provided as **limits**. More important than adjusting the main bearing loads exactly according to the ALC results, is to achieve a similar static load distribution for the main bearings, as explained in section 1.1 .
If the ALC is based on an equivalent two-dimensional crankshaft model[6], then the following needs to be considered:

- An equivalent two-dimensional crankshaft model cannot consider the varying stiffness in way of the cranks.
- Calculation results for mb #3 show limited deviations.
- Calculation results for mb #4 to foremost mb #(n) must not be considered.

The given values are **not valid for alignment measurements which refer to partly afloat or dry-dock condition**.
For jack correction factors see section 1.5.3 .

[6] Details see DG 9709 – “Equivalent two-dimensional crankshaft model”

Table 4	Static main bearing loads [kN] recommended[*1] before chocking new buildings, cold - stopped condition, light ballast to ballast draught			
	mb #1	**mb #2**	**mb #3**	**mb #4 to n[*3 *4]**
W-X35	5 – 20	> 20	> 15	> 10
W-X40	7 – 25	> 30	> 20	> 15
W-X62	10 – 80	> 110	> 70	> 30
W-X72	10 – 140	> 120	> 80	> 30
W-X82	10 – 130	> 220	> 100	> 40
W-X92	10 – 150	> 220	> 140	> 40
RT-flex48T-D **RTA48T-D**	10 – 45	> 55	> 35	> 20
RT-flex50-B / -D **RT-flex50DF**	10 – 45	> 55	> 35	> 20
RT-flex58T-D / T-E[*5] **RTA58T-D**	10 – 70	> 85	> 50	> 20
RT-flex60C-B	10 – 70	> 110	> 60	> 30
RT-flex68-D **RTA68-D**	10 – 110	> 140	> 70	> 30
RT-flex82C **RTA82C**	10 – 140	> 200	> 100	> 40
RT-flex82T / T-B **RTA82T / T-B**	10 – 130	> 220	> 100	> 40
RT-flex84T-D **RTA84T-D**	10 – 130	> 230	> 120	> 40
RT-flex96C-B **RTA96C-B**	10 – 170	> 260	> 160	> 40

*1: The values are recommended and for guidance only. They are **not** provided as **limits**. The static loads of engine main bearings need to show a similar static load distribution as provided by the ALC (see sections 1 and **Error! Reference source not found.**). **As soon as the minimum recommended static load is provided for each main bearing, no excessive static load can develop on any main bearing.**

*3: Usually the static loads of mb #1 to #3 are measured by jack-up tests. Further measurements become required if indicated by the vertical crankweb deflections (see section 1.5).

*4: These minimum values have to be maintained at each crank angle position.

*5: Also valid for RT-flex58T-ER-3

4 Required static main bearing loads before ship delivery

Alignment measurements which refer to ship delivery (e.g. during or after sea trial) in light ballast or ballast draught need to meet the requirements provided by table 5.
The following requirements have to be met for relevant alignment measurements:

- **The ship is completely built.**
- The alignment measurements are performed **in continuous afloat condition and at light ballast or ballast draught.**
- The main **engine is stopped**.
- Depending on the engine temperature condition, any **heat supply to the double bottom inside the engine room has to be out of operation prior to the measurement until it is completed**, i.e. the heating of the main lubricating oil sump tank below the main engine, the pre-heater of the main lubricating oil separator, etc.:
  - at least 8 hours for measurements **at cold conditions**
  - at least 4 hours for measurements **at warm conditions**
  - at least 1 hour for measurements **at hot conditions**

The given values (table 5) are provided as requirements for static main bearing loads at ship delivery (e.g. during or after sea trial) in light ballast or ballast draught at normal trim and in cold-stopped or hot-stopped condition.
The given values are **not valid for alignment measurements which refer to design or maximum ship draught** – even if they would have been measured at ship delivery (e.g. during or after sea trial).
Alignment measurements which refer to design or maximum ship draught need to meet the “Minimum limits for normal ship service” provided in table 6.
The limits “before ship delivery” can be applied also for additional measurements **after chocking**. However, if the ship has not yet been in operation, then the limit should not be maxed out, as influences by settling effects and welding stress release in ship hull cannot be predicted exactly.
These limits are not valid for the condition before chocking and they are **not valid for alignment measurements which refer to partly afloat or dry-dock condition**.
For jack correction factors see section 1.5.3 .

Table 5 — Static main bearing loads [kN] required[*1] before ship delivery

new buildings, stopped condition, light ballast to ballast draught[*2]

	mb #1	mb #2	mb #3	mb #4 to n[*4 *5]
W-X35	5 – 25	> 15	> 15	> 10
W-X40	7 – 30	> 25	> 20	> 15
W-X62	10 – 100	> 100	> 70	> 30
W-X72	10 – 160	> 100	> 80	> 40
W-X82	10 – 170	> 200	> 100	> 40
W-X92	10 – 180	> 220	> 140	> 40
RT-flex48T-D **RTA48T-D**	10 – 55	> 45	> 35	> 20
RT-flex50-B / -D **RT-flex50DF**	10 – 55	> 45	> 35	> 20
RT-flex58T-D / T-E[*6] **RTA58T-D**	10 – 85	> 70	> 50	> 20
RT-flex60C-B	10 – 90	> 90	> 60	> 30
RT-flex68-D **RTA68-D**	10 – 130	> 120	> 70	> 30
RT-flex82C **RTA82C**	10 – 180	> 180	> 100	> 40
RT-flex82T / T-B **RTA82T / T-B**	10 – 170	> 200	> 100	> 40
RT-flex84T-D **RTA84T-D**	10 – 160	> 210	> 120	> 40
RT-flex96C-B **RTA96C-B**	10 – 200	> 240	> 160	> 40

*1: **The given values are provided as requirements** for static main bearing loads measured at ship delivery (e.g. during or after sea trial) in light ballast or ballast draught at normal trim and in cold-stopped or hot-stopped condition.
As soon as the minimum required static load is provided for each main bearing, no excessive static load can develop on any main bearing.

*2: Alignment measurements which refer to design or maximum draught need to meet the "Minimum limits for normal ship service" provided in table 6.

*4: Usually the static loads of mb #1 to #3 are measured by jack-up tests. Further measurements become required if indicated by the vertical crankweb deflections (see section 1.5).

*5: These minimum values have to be maintained for each crank angle position.

*6: Also valid for RT-flex58T-ER-3.

5 Minimum limits for normal ship service

The basic requirement that all engine main bearings need to have a positive static load under all normal ship service conditions is met, if

- **the minimum bearing loads according to table 6 are granted**
- **for each main bearing and**
- **under all normal ship service conditions**.

The following requirements have to be met for alignment measurements which are performed in **normal ship service**:

- The alignment measurements are performed **in continuous afloat condition and at any normal service draught** (light ballast to maximum draught) **and at normal trim.**
- The main **engine is stopped**.
- Depending on the engine temperature condition, any **heat supply to the double bottom inside the engine room has to be out of operation prior to the measurement** until it is completed, i.e. the heating of the main lubricating oil sump tank below the main engine, the pre-heater of the main lubricating oil separator, etc.:
  - at least 8 hours for measurements **at cold conditions**
  - at least 4 hours for measurements **at warm conditions**
  - at least 1 hour for measurements **at hot conditions**.

The given values (table 6) are **also valid for alignment measurements which refer to ship delivery at design draught or maximum draught** (so called 'scantling draught').
The given values are **not valid for alignment measurements which refer to partly afloat or dry-dock condition**.
For jack correction factors see section 1.5.3 .

Table 6 — Static main bearing loads [kN] minimum limits[*1] for normal ship service

cold or hot - stopped condition, light ballast to maximum draught

	mb #1	mb #2 to (n)[*2]
W-X35	>5	>10
W-X40	>7	>15
W-X62	>10	>20
W-X72	>10	>20
W-X82	>10	>20
W-X92	>10	>20
RT-flex48T-D RTA48T-D	>10	>20
RT-flex50-B / -D RT-flex50DF	>10	>20
RT-flex58T-D / T-E[*3] RTA58T-D	>10	>20
RT-flex60C-B	>10	>20
RT-flex68-D RTA68-D	>10	>20
RT-flex82C RTA82C	>10	>20
RT-flex82T / T-B RTA82T / T-B	>10	>20
RT-flex84T-D RTA84T-D	>10	>20
RT-flex96C-B RTA96C-B	>10	>20

*1: **These minimum values have to be maintained for each crank angle position. As soon as all main bearings meet the minimum limit required, no excessive static load can develop on any main bearing.** Jack-up tests of engine main bearings are only required in case of significant change of crank web deflections or in case of damage. Prior to such measurements, Wärtsilä should be contacted for assistance.

*2: These minimum values have to be maintained for each crank angle position.

*3: Also valid for RT-flex58T-ER-3.

WinGD-2S - Alignment - main bearing loads recommendation+limits

TRACK CHANGES

DATE	SUBJECT	DESCRIPTION
2016-10-25	DOCUMENT	First web upload

Winterthur Gas & Diesel Ltd.
Winterthur Gas & Diesel AG.
Winterthur Gas & Diesel S.A.

Schützenstrasse 3
PO Box 414, CH-8401
Winterthur, Switzerland

Tel. +41 (0)52 264 8844
Fax +41 (0)52 264 8866