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Case study on the shaft line alignment for a 180 000 tdw bulk carrier vessel

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Abstract. Alignment means the determination of displacements and breaks between two shafts and their elimination so that the geometric axes of the shafts become approximately collinear, and the deviations are within the permissible limits. This paper presents the methodological steps of the shaft line alignment (as a case study for a bulk carrier vessel of 180 000 tdw) through two classic approaches: with the help of a ruler and feeler gauge (templet) respectively with the help of dial gauge. Comparative analysis of the performances of the two methods, can provide essential information to an engineer in choosing the optimal option for alignment of the shaft lines both in the case of vessels in service and, mainly, in the case of new building's. The originality of the work consists in carrying out the detailed calculations for displacements and breaks, with the graphical highlighting of the calculated values in the limit allowed intervals. Also, for each method are presented and commented the advantages and disadvantages.

Keywords: shaft line alignment, ships, shipyards, displacements and breaks

1. Introduction

The shaft line ensures the transmission of the torsion moment of the main engine to the propellant, as well as taking over the thrust and transmitting it to the hull. In current ships, one to five shaft lines can be mounted the length of which is determined by the location of the main engines (on the middle or stern of the vessel). The construction of the shaft line depends on the position of the engine room, the main machinery type, the type and number of thrusters and the shape of the hull at the stern. In general, a shaft line consists of the propeller carrier shaft, intermediate shafts, thrust shaft, thrust bearings, support bearings and sternpost tube.

The objective of the operation of centering the shaft lines is to achieve the installation of the shafts and the main engine in such a way that it is affected as little as possible by hull deformations. In order to achieve this objective, the following conditions must be pursued [1]:

- uniform distribution of loads in the sternpost tube and on the support bearings;
- the loads on the reduction bearings to be within the values prescribed by the supplier, regardless of the operating conditions;
- the loading of the bearings is such that, under all operating conditions, it forms and maintains the oil film necessary for proper lubrication;
- ensuring adequate flexibility for the system, taking into account the vibratory characteristics.

The numerous problems that occur during the functioning of the elements that make up the shaft line are due to their low flexibility. The slightest constructive deviation turns into additional tensions that can cause excessive load on the bearings.

The factors that influence the static centering of the shaft line are [2]:

- constructive factors (mounting tolerances of the shaft line);
- execution errors of shaft's: non-perpendicularity of flanges on the axis of the shaft; mismatch of flange axes, spindle non-coaxially or curved processing of the shaft;
- deformations caused by the elasticity of the vessel, under various loading and ballasting conditions during operation;

- atmospheric factors (through prolonged exposure to the sun, the main deck expands unevenly to the double bottom);
- navigational conditions (the ship on calm water or on the wave);
- flexibility of the bearings (the structure on which the bearings are laid is elastic);
- local thermal effects influencing the values of the reactions in the bearings.

2. Theoretical considerations on shaft line centering

The centering of the shaft line aims at placing the geometric axes of the shaft line and the crank shaft of the main engine in the direction of the theoretical axis. Alignment means the determination of displacements and breaks between two shafts and their elimination so that the geometric axes of the shafts become approximately collinear, and the deviations are within the permissible limits.
Displacement (δ) or offsetting is the distance between two geometrical axes of parallel but non-linear shafts. Breaking (φ) is the angle formed between the geometric axes of non-parallel and non-linear shafts (Figure 1).

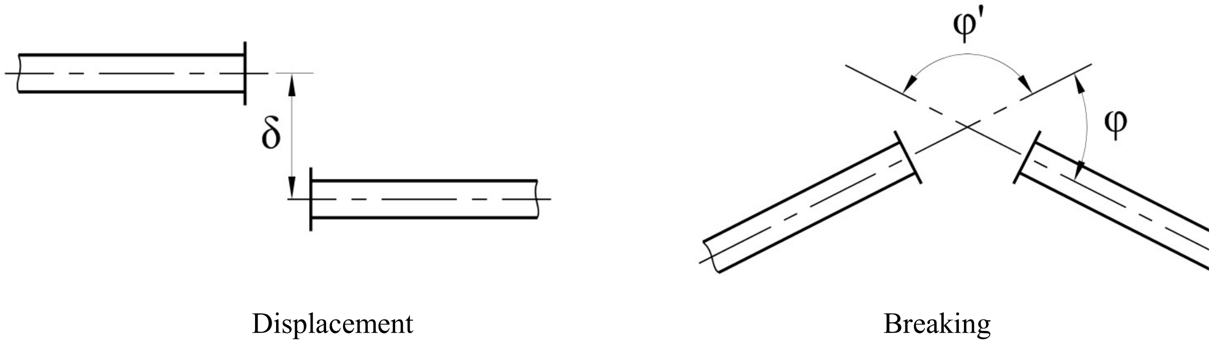


Figure 1. Displacement and breaking of the shaft line

The centering is made starting from the stern (from the propeller carrier shaft considered fixed) towards the bow, with the first intermediate shaft.
The centering can be done when the ship is on the mounting berth or after launching to the water.
For centering it is necessary that the main engine and the intermediate shaft are mounted on devices that allow their position to be changed both vertically and horizontally.
In this case it is used: special bearings for the assembly of shaft lines; bearings of shaft lines mounted on jacks; hydraulic screws or presser.
Before starting the alignment operations, it is checked that each flange rotates freely. Usually, the centering of the shaft line will be done by the following methods: with the help of a ruler and feeler gauge (templet) respectively with the help of dial gauge.

2.1. Centering the shaft line with the help of ruler and feeler gauge (templet)

The measurement of the breaks and the displacements of the shafts with the help of the of a ruler and feeler gauge (templet) is carried out when between the centering flanges there is a distance of (0.5 – 1.0) mm.
Measurement of the displacement of the shaft in the vertical plane (δ_V) it is made according to the scheme illustrated in Figure 2a), thus:

- place the ruler on the generator of the shaft flange, in the highest position, on the axial direction and measure with feeler gauge (templet) the clearance, a_1, between the ruler and the cylindrical surface of the flange of the second shaft;
- keeping the shafts in the same position, place the ruler on the generator of the shaft flange, in the lowest position and measure with feeler gauge (templet) the clearance, a_2,between the ruler and the cylindrical surface of the flange of the second shaft.

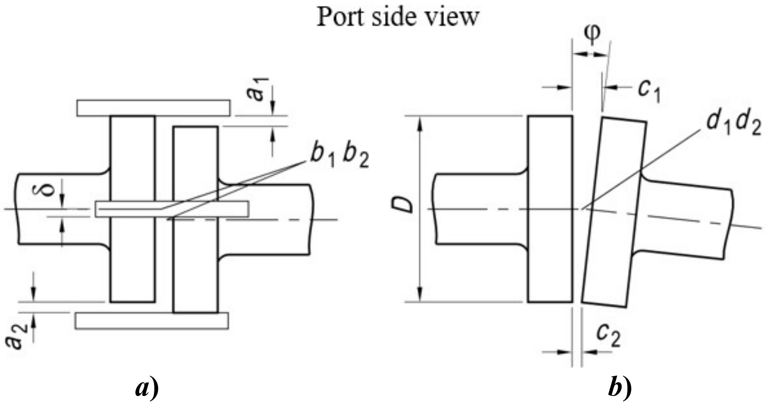


Figure 2. Centering line shaft with ruler and feeler gauge (templet)

Vertical displacement can be determined with the relation:

$$\delta_V = \frac{a_1 + a_2}{2} \quad \text{[mm]}. \tag{1}$$

Measuring the displacement of the shaft in the horizontal plane (δ_O) it is made according to the scheme in Figure 2a) thus:

- place the ruler sideways, in the starboard, on the most shifted flange in this board and measure with feeler gauge (templet) the clearance, b_1, between the ruler and the flange of the second shaft;
- measure the clearance, b_2, in the same way and on port side board.

Horizontal displacement can be determined with the relation:

$$\delta_O = \frac{b_1 + b_2}{2} \quad \text{[mm]}. \tag{2}$$

Determination of the bend-in of the axis of the centered shaft in relation to the axis of the other horizontal shaft (φ_V) and vertical shaft (φ_O) it is made according to the scheme in Figure 3 b) as follows:

- measure with feeler gauge (templet) the clearance, c_1 and c_2,between the front ends of the flanges at the top and bottom of the checked shafts and determine the bend-in φ_V;
- measure clearances d_1 and d_2 of starboard and portboard between the edges of the flanges and determine the bend-in (φ_O).

The measured values of displacements and bend-in shall be centralized in accordance with Table 1.

Table 1. Measured values of displacements and breaks

Measuring place	Displacement			Bend-in			
	Value of the clearance[mm]	Sum of the clearances[mm]	Displacement [mm]	Value of the clearance [mm]	Flange diameter D [mm]	The difference in clearance Δ [mm]	Bend-in $\varphi = \Delta/D$ [mm]
Up	a_1	a_1+a_2	$\delta_V = \frac{a_1 + a_2}{2}$	c_1	D	$\Delta_V = c_1+c_2$	$\varphi_V = \Delta_V/D$
Down	a_2			c_2			
Starboard	b_1	b_1+b_2	$\delta_O = \frac{b_1 + b_2}{2}$	d_1	D	$\Delta_O = d_1+d_2$	$\varphi_O = \Delta_O/D$
Portside board	b_2			d_2			

The allowable values of shafts displacements and bend-in for different variants of couplings are centralized in Table 2 [3].

Table 2. Allowable values for displacements and breaks

Place of centering	Type of centering							
	With the flange		With channelling		Elastic		Hydraulic	
	δ	φ / l	δ	φ / l	δ	φ / l	δ	φ / l
On berth	0,05	0,05	0,05	0,10	0,10	0,15	0,60	0,70
On the sea	0,10	0,15	0,15	0,20	0,20	0,30	1,20	1,40

The maximum displacement is given by the relation

$$\delta_{\max} = \sqrt{\delta_V^2 + \delta_O^2} \quad \text{[mm]}. \tag{3}$$

The direction in which there is maximum displacement is determined by the angle α, given by the relation

$$\alpha = \tan \frac{\delta_V}{\delta_O} \quad \text{[mm]}. \tag{4}$$

The breaking for very small angles is determined with the relations [4]

$$\begin{cases} \varphi_V = \dfrac{\Delta_V}{D} \quad \text{[mm]}; \\ \varphi_O = \dfrac{\Delta_O}{D} \quad \text{[mm]}. \end{cases} \tag{5}$$

After the values for displacements and bend-in have been established, they are compared with the values set at the construction. If the values obtained do not correspond to those specified in the measurement tables, the centering operations are resumed by modifying the height of the liners or by horizontally shifting the support belts of the shafts and repeating the measurements. The centering operations are repeated until values are obtained within the allowable limits.

2.2. Centering the shaft line with the help of dial gauge

The measurement of the bend-in and the displacements of the shafts with the help of the of a ruler and feeler gauge (templet) is carried out when between the centering flanges a distance of (0,5 – 1,0) mm exist. The method is applied to the centering of the axis line for new construction vessels.

The verification with the help of the centering dial gauge shall be carried out according to the principle scheme of Figure 3. The significance of the notations in Figure 3 is as follows: *1* – inner dial gauge; *2* – outer dial gauge; *3*, *4* – adjustment screws; *a*, *b*, *c*, *d* – clearances.

On the flange or crown of the centering shaft and on the fixed shaft it is mounted and fixed, with the help of screws, two pairs of devices, arranged diametrically in relation to each other.

In the control device *1*, are fixed the adjustment screws *4,* which also shall be fixed in devices *2*. Screws 4 and the device 1 serve to measure the relative displacement of the axes of the base shaft and the shaft to be centred. Screws *3* and device *2* are used to measure the bend-in between the two axles.

Before measuring the displacement and breaking of the axis, the devices are positioned in such a way that the tips of the screws stand in front of the polished surfaces, after which a clearance of (1-2) mm is established between the tips of the adjustment screws and the plates, in this position the screws being fixed with the help of countertops.

It is measured the distance between the adjustment screws *3*, denoted by *l*. During the measurements, the devices must remain paired, executing rotational movements composed of sequences of 90°, as a rule, clockwise.

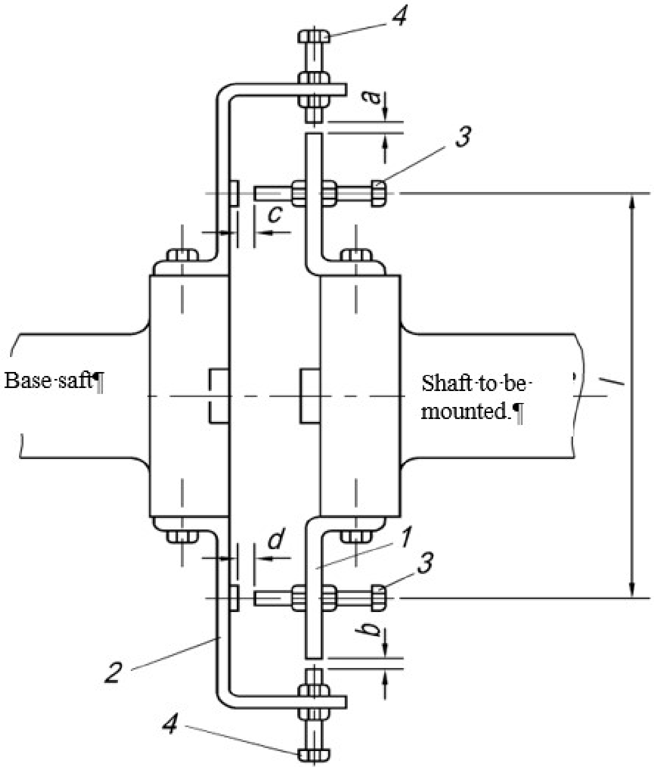


Figure 3. Centering the shaft line with the help of dial gauge

When measuring the displacement and bend-in, the following methodology is adopted [4]:

- a pair of screws *3* and *4* are placed vertically up, and the other pair vertically down, so that the tips of the screws come nearby with the surface of the protrusions on the paired devices. The pair of devices pointing upwards is conventionally called "the first pair", and the one pointing down, "the second pair";
- it is choose the axial distance of the driven shaft (which is mounted) by its movement in either direction, stern or bow, establishing between the screws *3* and 4 a distance of (1-2) mm;
- with the help of thick dial gauge (the spy) the clearance, *a*, between screw *4* and device *1*, which will determine the movement of the axes, is measured. The clearance, *c,* between screw *3* and device *2* that will cause the axis bend-in will also be measured;
- the same measurements will be executed for the *b* and *d* clearance of the second pair. The results are centralized in Table 3 (a_1, b_2), respectively in Table 4 (c_1, d_2). Rotate the base shafts and the one to be mounted so that the first pair of devices is oriented horizontally in starboard, and the second pair of devices is pointing horizontally in port side;
- the axial distance of the shaft to be mounted is checked and maintained;
- it is measured using the thick dial gauge the games *a*, *b*, *c*, *d* between the tips of the screws and the devices of both pairs, and the results of the measurements are centralized in Table 3 (a_3 ,b_4), respectively Table 4 (c_3, d_4);
- rotate the shafts in the same direction, with 90°;
- the axial distance of the shaft to be mounted is checked and maintained;
- it is measured with dial gauge the thickness of the clearance *a*, *b*, *c*, *d* between the ends of the screws and the measuring devices, and the values are centralized in Table 3 (a_2, b_1), respectively Table 4 (c_2, d_1);
- the basic shafts and the one that is mounted are rotated so that the first pair of devices is directed horizontally on portside board, and the second pair is directed horizontally on starboard;

- check and maintain the axial distance (the clearance) of the shaft to be mounted;
- it is measured with dial gauge the thickness of the clearances *a*, *b*, *c*, *d* at the tips of the measuring screws, and the results are centralized in Table 3 (a_3, b_4), respectively Table 4 (c_4, d_3).

The measurements must be accompanied by information on the part of the line of axles on which the external devices have been fitted and the distance "*l*" between screws *3* (see Figure 3).

Table 3. Measured values for displacements at centering with the help of the dial gauge

Position of centering devices	Displacement [mm]				
	The value of the clearance		Sum of the clearance	Difference of the clearance sumΔ	Displacement value Δ/4
	I	II	$\Sigma = a+b$		
Up	a_1	b_1	a_1+b_1	$(a_1+b_1) - (a_2+b_2)$	Δ/4
Down	a_2	b_2	a_2+b_2		
Starboard	a_3	b_3	a_3+b_3	$(a_3+b_3) - (a_4+b_4)$	Δ/4
Port side board	a_4	b_4	a_4+b_4		

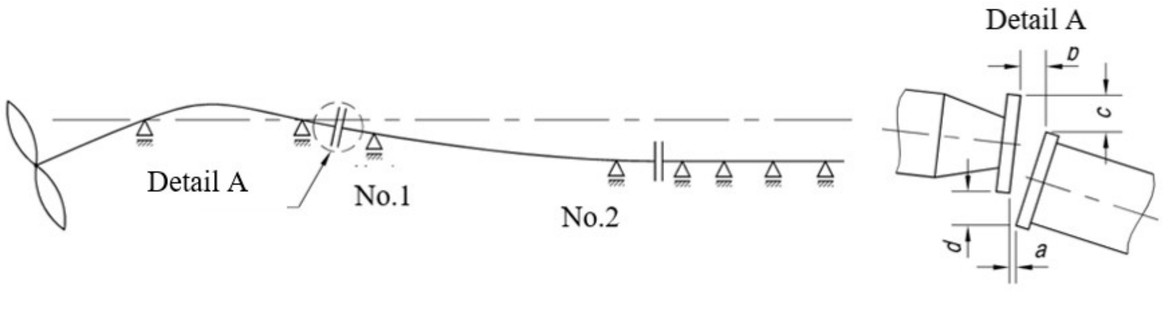
Table 4. Measured values for the bend-in at the centering with the help of dial gauge

Position of centering devices	Bend-in[mm/m]					
	The value of the clearance		Sum of the clearance	Difference of the clearance sumΔ	Displacement value Δ/2	Breakingper one linear meter
	I	II	$\Sigma = c+d$			
Up	c_1	d_1	c_1+d_1	$(c_1+d_1) - (c_2+d_2)$	Δ/4	φ/l
Down	c_2	d_2	c_2+d_2			
Starboard	c_3	d_3	c_3+d_3	$(c_3+d_3) - (c_4+d_4)$	Δ/4	φ/l
Port side board	c_4	d_4	c_4+d_4			

3. Verification of the alignment of the shaft line for the vessel BK 180000 tdw

3.1. *Checking the centering of the propeller carrier shaft with the intermediate shaft (*with ruler and feeler gauge (templet))

The values imposed by the designer are [5]: displacement $\delta = 0{,}41$ +/- 0,10; bend-in $\varphi = 0{,}15$ +/- 0,10. The propeller carrier shaft rests on the two bearings in the sternpost tube, and the intermediate axis on the two provisional lines (no.1, respectively no. 2 in Figure 4 *a*).The alignment between the two flanges corresponds to that in detail *A* (Figure 4 *b*).



a) ***b)***

Figure 4. Checking the centering of the propeller carrier shaft with the intermediate shaft

The values measured after the center clearance check are centralized in Table 5.

Table 5. Measured values for displacements and bend-in at the centering of the proppeler carrier and intermediate shaft (BK 180000 tdw)

Location	Up	Portside board	Down	Starboard
Bend-in	+0,50	+0,40	+0,40	+0,40
Displacement	+0,50	0,00	-0,50	0,00

3.2. Checking the centering of the intermediate shaft with the engine flywheel (with dial gauges)
The values imposed by the designer are [5]: displacement δ = 1,16 +/- 0,10;bend-inφ = 0,74 +/- 0,10. The intermediate shaft rests on the no. 2 technology linet and the engine is centered at the end, it can no longer be moved to starboard or portboard (Figure 5 *a*). The alignment between the two flanges corresponds to that in detail *B* (Figure 6 *b*).

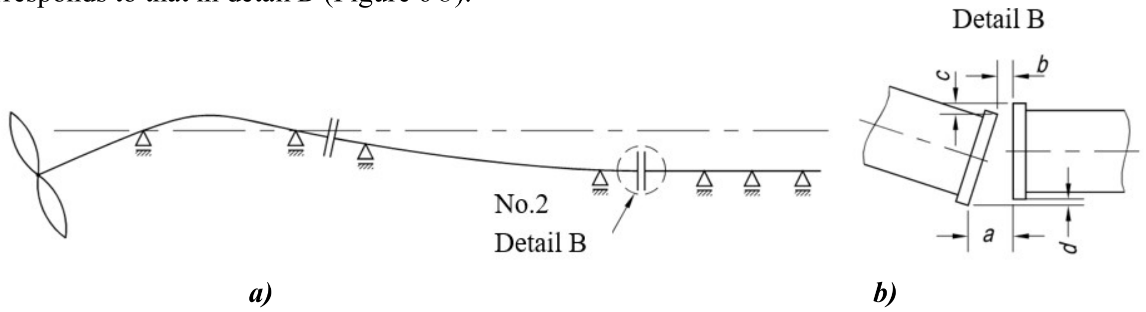


Figure 5. Checking the centering of the intermediate shaft with the engine flywheel

Table 6. Measured values for displacements and breaks when centering the intermediate shaft with the engine flywheel(BK 180000 tdw)

Location	Up	Portside board	Down	Starboard
Bend-in	0,00	+0,41	+0,73	+0,41
Displacement	0,00	+1,12	+2,34	+1,12

4. Interpretation of measurement results

Following the measurements, displacement and bend-in are calculated according to the previous formulae, the graphic representation being found in the diagrams below, thus:

- Figure 6: *a* – the displacement measured at the centering between the propeller carrier shaft and the intermediate shaft; *b* – the breaking measured at the centering between the propeller carrier shaft and the intermediate shaft;

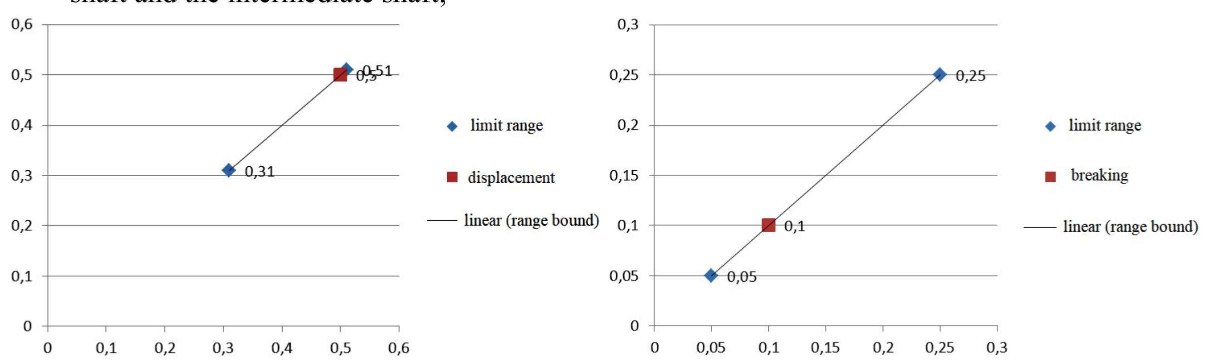
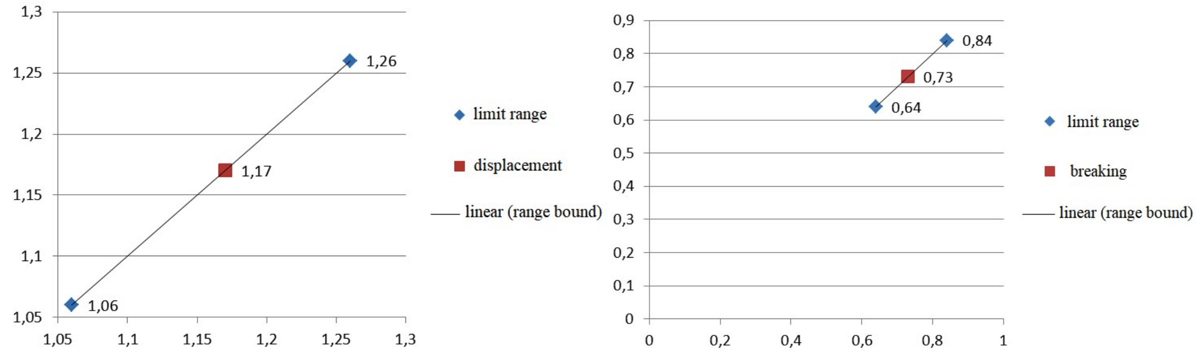


Figure 6. Displacement and breaking measured at the centering of the propeller carrier shaft and the intermediate shaft

- Figure 7: *a* – the displacement measured when coupling the intermediate shaft with the engine flywheel; *b* – the bend-in measured when the intermediate shaft is coupled with the engine flywheel.



a) ***b)***

Figure 7. Displacement and braking measured at the center of the intermediate shaft with the engine flywheel

5. Conclusions

As a result of the measurements made, it is noticed that the method of dial gauges and a comparator clock is much more accurate than the ruler and feeler gauge (templet) method. In the case of measurements made with the ruler and feeler gauge (templet), human errors occur, each measurement carried out by different individuals giving different values, while at the method with dial gauge and clock comparator errors are eliminated, any measurement for breaking and moving between the coupling flanges giving identical values. The disadvantage of the method with dial gauge and comparator clock is that it can only be used for couplings that can be rotated (e.g. flywheel and intermediate shaft).

References

[1] Costică A., *Maşini şi instalaţii navale de propulsie*, Editura Tehnică, Bucureşti, 1991

[2] Bidoae I., *Tehnologia fabricării navei şi montării mecanismelor*, Editura Didactică şi Pedagogică, Bucureşti, 1997

[3] Pintilie A., *Tehnologia montării şi probării instalaţiilor navale. Îndrumar de laborator*. Universitatea „Ovidius", Constanţa, 2004

[4] Pintilie A., *Tehnologia montării şi probării instalaţiilor navale. Note de curs*, Universitatea „Ovidius", Constanţa, 2004

[5] ***, *Technical documentation, BK 180000 tdw. Axial line alignment*, 2011