PARTICULARITIES OF THE MAGNETIC COMPASS ADJUSTMENT ON THE SCHOOL SHIP "MIRCEA"

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Abstract – The School Ship „Mircea” is a sail ship of the barque type, with three masts: foremast, middle mast and mizzen mast with thirteen sailyards. The orientation of the sail yards is made in either of the boards depending on the sailing needs, operation called bracing, or may be displayed on a perpendicular position on the ship`s longitudinal axis at the square mark. At the foremast and middle mast the three superior sailyards may have a vertical slide. For this reason the magnetic compass compensation deviation tables have to be determined for different situations.

Keywords: *school ship, barque, magnetic field, compensation, magnetic compass, magnetic deviation*

1. INTRODUCTION

The magnetic compasses on board ships play more of a secondary role for orientation at sea, the gyrocompass being the main equipment used for this purpose because of its high precision and lack of influence from the magnetic fields of the Earth and of the ship. However, the compensation, calibration and determination of the deviations tables of the magnetic compasses have to be made thoroughly because these systems do not depend on the existence of electrical power on board and are more efficient.

Accurate deviations tables are needed for the correct use of the on board magnetic compass and their compensation has to be done in such a way, so that no significant differences should occur related to the gyrocompass.

For military and merchant ships with mechanical propulsion, the compensation of the magnetic compasses is done annually or when significant changes occur due to prolonged anchorage in a port, when hull repairs are made made, or when the cargo, due to its nature alters the magnetism of the ship. From this point of view sail vessels have a unique characteristic; due to their masting and rigging (important iron masses that extend beyond the hull), but mostly because of the variable orientation of the sail yards during sailing. The School Ship "Mircea" is a sail ship of the barque type, with three masts: foremast, middle mast and mizzen mast with thirteen sailyards. The orientation of the sail yards is made in either of the boards depending on the sailing needs, operation called bracing, or they may be displayed on a perpendicular position on the ship`s longitudinal axis at the square mark. At the foremast and middle mast the three superior sailyards may have a vertical slide. For this reason, the magnetic compass compensation deviation tables have to be determined for different situations.

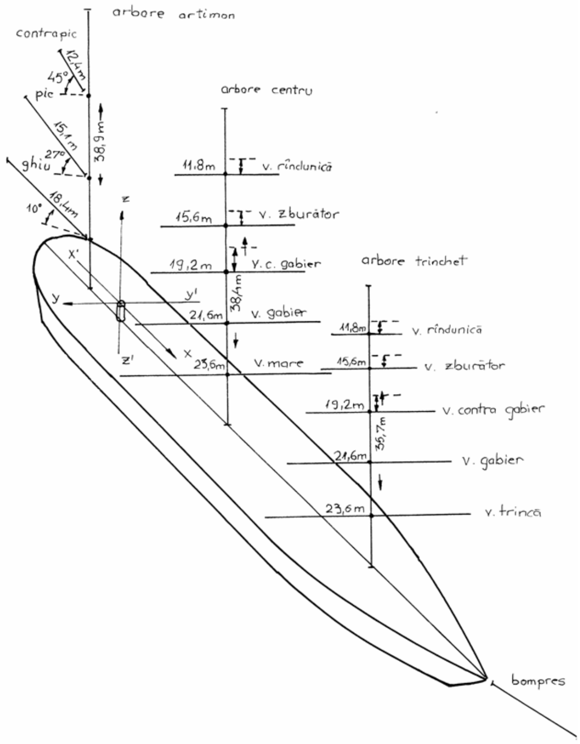

Figure 1: Sailyards display on the School Ship ”Mircea”

2. DEVIATION AND COMPENSATION THEORY NOTIONS

2.1 Magnetic field components that influence the dial card Poisson-Smith Equations

The magnetic field components that influence the dial card are:

- the Earth’s magnetic field:

$$\vec{T}=\vec{H}+\vec{Z}=\vec{X}+\vec{Y}+\vec{Z};$$

- the component of the relative permanent magnetism of the ship:

$$\vec{\varphi}=\vec{P}+\vec{Q}+\vec{R}$$

- the relative temporary magnetism of the ship Ψ. In order to study this, the ship`s hull is considered to be fabricated form vertical and transversal and longitudinal equivalent iron bars. So the components of the field on the axes of the cartezian cooordination system will be:

$$\overrightarrow{\Psi x}=\overrightarrow{ax}+\overrightarrow{dx}+\overrightarrow{gx}$$
$$\overrightarrow{\Psi y}=\overrightarrow{by}+\overrightarrow{ey}+\overrightarrow{hy}$$
$$\overrightarrow{\Psi z}=\overrightarrow{cz}+\overrightarrow{fz}+\overrightarrow{kz}$$

Summing up the componets of the three magnetic fileds on coordination axes we obtain the Poisson-Smith equations:

$$\overrightarrow{X'}=\overrightarrow{X}+\overrightarrow{P}+\overrightarrow{ax}+\overrightarrow{by}+\overrightarrow{cz}$$

$$\overrightarrow{Y'}=\overrightarrow{Y}+\overrightarrow{Q}+\overrightarrow{dx}+\overrightarrow{ey}+\overrightarrow{fz}$$

$$\overrightarrow{Z'}=\overrightarrow{Z}+\overrightarrow{R}+\overrightarrow{gx}+\overrightarrow{hy}+\overrightarrow{kz}$$

2.2 Deviation forces. Transformation of the Poisson-Smith equations.

For the study of the deviation forces are used only the horizontal components of the Poisson-Smith equations X' şi Y'.

Projecting the Poisson-Smith equations on Nm a deviation of the magnetic compass is obtained deviation composed of the following deviation forces:

- Deviation force AλH, where:

$$\lambda=1+(a+e)/2$$

,and A – transformation factor; this produces a constant deviation: δ_A=A, of small values 1°-3° deviation that can pe compensated by turning the compass card axis;

Deviation force BλH produces the deviation

$$\delta_B=B\cdot\sin Dm$$

This semicircular deviation peaks at Dm=90° (270°) and is zero when Dm=0° (180°). This cand be compensated with fore-and-aft corrector magnetsgnets; Deviation force CλH produces the deviation: $\delta_C=C\cdot\cos Dm$

This semicircular deviation is zero when Dm=90° (270°) and maximum when Dm=0° (180°). It is compensated with transversal permanent magnets.

- Deviation force DλH produces the deviation:

$$\delta_D=D\cdot\sin 2Dm$$

Această deviaţie cuadrantală este maximă în Dm=45° (135°, 225°, 315°) şi zero în Dm=0° (90°, 180°, 270°). Aceasta se compensează cu ajutorul unor magneţi cu remanenţă mică (fier moale) care să urmeze cu fidelitate variaţiile câmpului magnetic indus al navei.

- Forţa deviatoare EλH care produce deviaţia:

$$\delta_E=D\cdot\cos 2Dm$$

This quadrantal deviation is zero when Dm=45° (135°, 225°, 315°) and maximum when Dm=0° (90°, 180°, 270°). It can be compensated in the same way as DλH.

The total deviation of the compass will take the following form:

$$\delta_C=\delta_A+\delta_B+\delta_C+\delta_D+\delta_E+\ldots$$

, and depending on the magnetic heading:

$$\delta_C=A+B\cdot\sin Dm+C\cdot\cos Dm+D\cdot\sin 2Dm+E\cdot\cos 2Dm+\ldots$$

2.3. The heeling error.

Forces on the vertical axis ZZ` produce a deviation on the ship`s heel only by their projection on the transversal horizontal axis YY`. The same phenomenon occours when trimming by the bow-stern, projecting on the horizontal longitudinal axis XX`, but because the trimming angle is much narrower than the heeling angle, the influence is discardable.

This deviation force:

$$J\lambda H=\sin i\cdot(ez-kz-R)$$

, where *i* is the heeling angle, produces and extra deviation in the form of: $\Delta\delta c=J\cdot i\cdot\cos Dm$

It is compensated by adding a vertical permanent magnet which assures its cancellation on a certain magnetic latitude.

3. SPECIFIC MAGNETIC INFLUENCES FOR THE SCHOOL SHIP “MIRCEA”

3.1. MAGNETIC EQUIVALENCE

The total magnetic influence of the masting and standing rigging can be equivalent with a triplet of magnets with medium remanence, displayed on the three rectangular axes, with limited mobility around the axes, according to the masting mobility of elements.

The axiomatic characteristic of the triplet will be:

- the induced component will be variable with the magnetic fairway, the trim angle, and the heel angle.
- the induced component will be variable with the magnetic latitude

- the components on the rectangular axes will be variable with the position of masting's mobile elements. From all these characteristics the biggest variability is produced by the: magnetic fairway, heeling angle, bracing, vertical position of the sailyards, magnetic latitude change.

The considered equivalent magnetic triplet is a component of the magnetic field of the ship, and it complies with the same rules and methodologies; it is described by the Poisson-Smith equations.

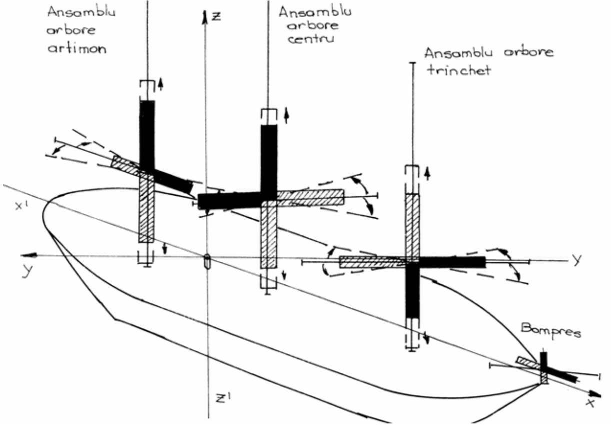

Figure 2: The masting's magnetic equivalence.

3.2. Variations of the coefficient extensions

The suplementary influence of the masting is considered to be found in the forces „X", „Y", „Z", which are added to the general influence of the magnetic field of the ship. The suplementary forces are the sum of the strictly permanent component (coefficient 1) and of the variable component (coefficient 2), with the zero hysteresis area, as follows; :

$$\overrightarrow{X''} = \overrightarrow{X''}_1 + \overrightarrow{X''_2}$$

$$\overrightarrow{Y''} = \overrightarrow{Y''}_1 + \overrightarrow{Y''_2}$$

$$\overrightarrow{Z''} = \overrightarrow{Z''}_1 + \overrightarrow{Z''_2}$$

3.2.1. The influence of the components on a horizontal plan

These will modify the general permanent magnetic field, according to the bracing angle (b) and also according to the vertical position of the sailyards (h).

On a horizontal plan they will act according to the formula: (figure 3) XX': $P'' = P + X_1''\cdot\cos b \pm Y_1''\cdot\sin b$

(+at starboard and – at port)

The longitudinal magnetic component P'' will be slightly influenced by sailyards: $(Y_1''\cdot\sin b)$

,but strongly influenced by the position of the booms and gaffs: $X_1''\cdot\cos b$;

They will produce variations in the BλH force, because b<33,7°.

A. YY': $Q'' = Q + Y_1''\cdot\cos b \pm X_1''\cdot\sin b$

(+ at starboard and – at port)

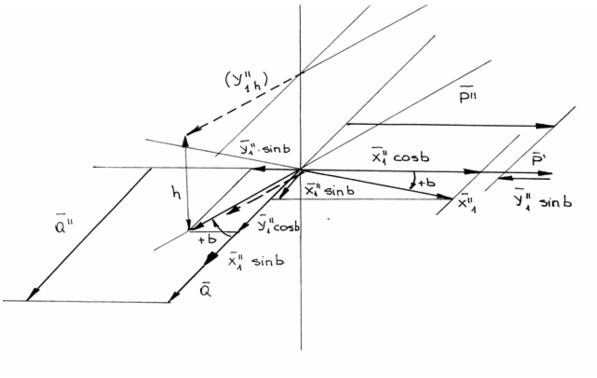

Figure 3

The transversal component Q''will be slightly influenced by the boom and by the gaffs, but stongly influenced by by the position of the sailyards; they will produce variations in the CλH force.

3.2.2. The influence of the permanent components on a horizontal plan.

The temporary components stress the value and orientation of the resultant Ψx (boom, gaffs) on a longitudinal plan, and of the resultant Ψy on a transversal plan (sailyards); they will become:

$$\overrightarrow{\Psi x''} = \overrightarrow{x''_2} + \overrightarrow{\Psi x}$$

$$\overrightarrow{\Psi y''} = \overrightarrow{y''}_2 + \overrightarrow{\Psi y}$$

The projection of the suplementary forces on the horizontal axes will be:

XX': $\overrightarrow{X''}_2\cdot\cos b + \overrightarrow{Y''}_2\cdot\sin b$

YY': $\overrightarrow{Y''}_2\cdot\cos b + \overrightarrow{X''}_2\cdot\sin b$

So, the expression of the total projections on the axes will be:

$$\overrightarrow{\Psi x''} = \left(a + x''_2\cdot\cos b\right)\vec{x} + \left(d \pm x''_2\cdot\sin b\right)\vec{x} \text{ (fig. 4)}$$

$$\overrightarrow{\Psi y''} = \left(b \pm y''_2\cdot\sin b\right)\vec{y} + \left(e + y''_2\cdot\cos b\right)\vec{y} \text{ (fig. 5)}$$

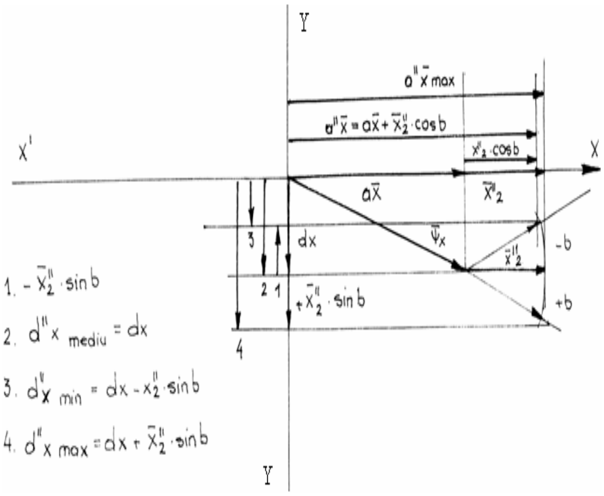

Figure 4

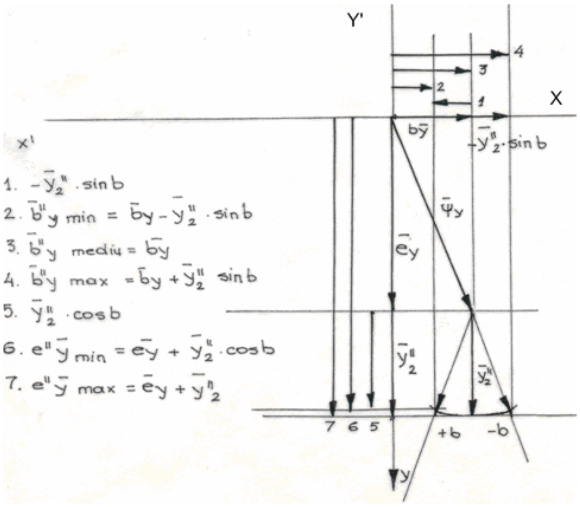

Figure 5

4. CONCLUSIONS

1. In the case of the school ship „Mircea' the parameters *a* and *e* of soft iron have high values, slightly variable according to bracing; so, coefficient λ=1+(a+e)/2 will be extremely low, fact which has been proven to be true in practice.

Knowing that force DλH=H(a+e)/2, produces deviation δD=D sin 2Dm, it appears that D will have lower and less variable values, regardless of the bracing board.

2. On the school ship „Mircea" when bracing is done, the variation is converse (one rises and the other goes down), so, knowing that AλH=H(b-d)/2, this force varies significantly when bracing operations are done. The force EλH=H(b+d)/2 does not have an important variation when bracing is done, which is also proven in practice..

The influence of the suplementary forces on a vertical plan:

These suplementary forces lead to the accentuation of the heeling error. The suplementary force: $\overrightarrow{Z''} = \overrightarrow{Z''}_1 + \overrightarrow{Z''}_2$ will not depend on the position of the mobile elements on the masting, they will only depend on the magnetic latitude.

On the vertical axis the sum of the forces will be: ZZ': $\overrightarrow{Kz} + \overrightarrow{Z''}_2 + \overrightarrow{gx} + \overrightarrow{hy} + \overrightarrow{R} + \overrightarrow{Z''}_1 + \overrightarrow{Z}$, where gx and hy are zero (figure 6 a).

On the school ship „Mircea" the vertical induction (in the masts), as well as the permanent vertical component (masts and fixed metal riggings) have high values. $\overrightarrow{K''z} = \overrightarrow{Kz} + \overrightarrow{Z''_2}$ _ $\overrightarrow{R''} = \overrightarrow{R} + \overrightarrow{Z''_1}$

$$\text{ZZ'}:\_\ \overrightarrow{Z'} = \overrightarrow{K''z} + \overrightarrow{R''} + \overrightarrow{Z}$$

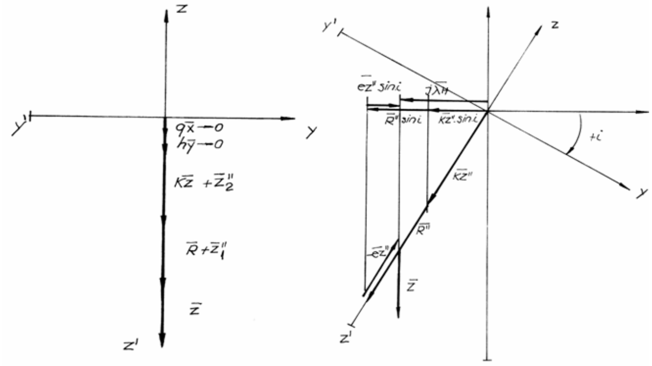

Figure 6. a and b

When the ship heels the suplementary induction negative force, which has a high value valoare –R''z (fig. 6 b). On the horizon plan, and also on the transversal axis, there results

$$J''\lambda H = \sin i \cdot \left(e''z - K''z - R''\right)$$

Unlike other ships, on the school ship „Mircea", coefficient „J" is expected to have high values (practice has proven) especially due to the induced component (Z''2 ,K''z respectively); the masts and the sailyards made of soft metal are predominant, as magnetic mass, unlike fixed, metal rigging made of hard metal.

From this reason, it appears that „J" (the heeling deviation coefficient) as well as heeling deviation δj has big variations when the magnetic latitude is changed; it can have values even at the Equator, due to the R component, which is high.

References

[1] F. Bozianu, *Navigation Equipment Handbook*, Ex Ponto Publishing House, Constanța, 2007.