Introduction to ship technology and its application to some local areas

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Abstract

Naval architecture is a very wide field, and one that is vitally important for all people. A large amount of goods are shipped on commercial ships and the majority of oil used in the world is brought via oil tankers. Ships will always need to be built for commercial, private, recreational, military, and government entities. The main focus of today's naval architect is safety for people and the environment. Indeed, designing a ship is an extremely challenging but immensely interesting task.

Concerning Tunisia, and despite its situation in the heart of the Mediterranean, and the north of Africa and the length of its coasts (1300 km). Tunisia does not have the necessary maritime infrastructure to play its naturally potential role as an international maritime centre. The lack of expertise and knowledge about naval architecture and marine design engineering is one of the major impediments to the development of the said maritime infrastructure. The ground for young engineers who want to specialize in the field is thus enormous and opportunities for business are attractive. In this paper, we will introduce some of the fundamental tools in ship design and we will discuss their application way in a kind of practical approach notably in the Sfax-Kerkennah islands maritime connection.

1. Introduction:

The Islands of Kerkenah are located off the southeast coast of Tunisia in the Gulf of Gabes. Its main village is Remla. . Kerkenah is actually the name of a group of islands. The main two are: Island Chergui and Island Gharbi, which are both inhabited. All other islands are smaller and uninhabited: Chermadia, Gremdi, Roumedia, Sifnou, Rakkadia and many smaller, unnamed ones.

Kerkenah is reached by ferry that operates all year long with more trips during the summer season. The Ferry is a passenger's ship, "transporter type". Its capacity is for 900 passengers and 68 cars loaded of luggage and containing fuel in its reservoirs. This transporter is destined to assure a regular service of transportation between Sfax harbor and Sidi-Youssef (Kerkenah islands) distant of about 11 miles in a shallow sea. The sea depth is - 4 meters in channel and – 3 meters in Sidi-Youssef port when the tide is zero in the hydro cards.

However, the current "ferry presents a series of drawbacks, among which the following are the most important:

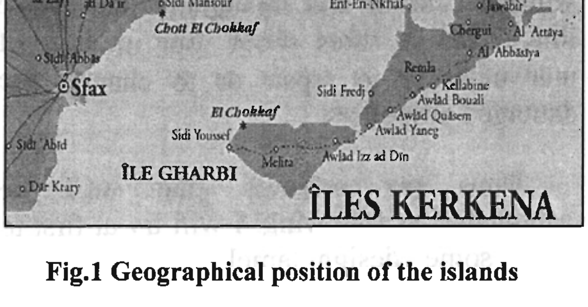


Fig.1 Geographical position of the islands

* **Limitation of the navigation by windy days** (up to strength 6 Beaufort scale/ 25 knots) because of the class of the ferry:

- Limited draught 2.65 m maximum.
- Uncovered deck
- Classic propulsion system at the stern side: two shaft lines and each one is driven by diesel engine, a gears box and fixed blade propeller.
- Surface of the superstructure which is important enough, what generates an extensive resistance to wind, especially by beam wind, south-east and the dominant northwest.

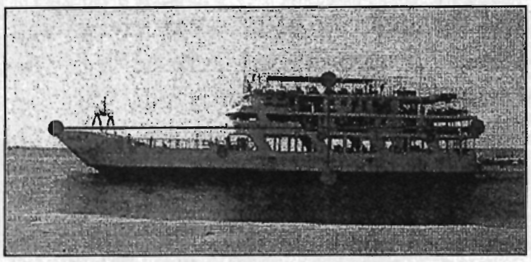


Fig.2 The current ferry

* **The position of the propellers** (at the stern of the ferry) in a classical propulsion system requires one only rail door at the bow which results on cars embarking and disembarking problems (it takes around 30 minutes for both operations each trip).

* **Berthing problems**: difference between the main deck level and the dock level (the Sea tides are about 1.50m,-1.70 m in Sfax and Sidi youssef Harbors). As consequence, the embarking and disembarking operations become more complicated.

* **Anchor ropes and chains** are at times trapped by the propelling system during maneuvering operations inside "Sidi-youssef" harbor and throughout the course line. Then it takes about four months of unavailability to repair or to change the damaged propellers.

Thus my research plan will be established as following: I will try at first to give some design ameliorations to the current ferry. Consequently, I am required to estimate the manoeuvrability characteristics of the ship as an initial stage of design.

In general, there are three methods for predicting ship manoeuvring performing. One is the method due to data base, the second one is due to free running model test and third one is due to the numerical simulation of manoeuvring motion.

2. Experimental model test

The other important factor to be considered, especially in our study case, is the performance in shallow water. And this performance will be estimated usually by numerical simulation of the manoeuvring motion, because it is generally difficult to carry out sea trial of full scale ship in shallow water.

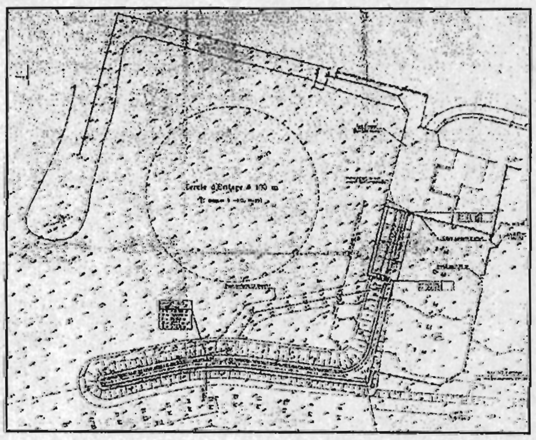


Fig.3 Current ferry turning manoeuvres inside Sidi Youssef harbour (Kerkenah islands)

To estimate the hydrodynamic force acting in on a ship in shallow water, many theoretical and experimental researches have been set out. However, the calculation used, especially, slender body theory or lifting surface theory will be not enough to give precisely the hydrodynamic forces including linear and non-linear components. On the other hand, those forces can be obtained by means of model tests, but it needs a plenty of time and cost for measurement of hydrodynamic force acting on a ship in shallow water. This measurement will be necessary to be carried out in every ship type, and also in every water depth. But more useful and simplified method for estimating the force is expected for predicting ship manoeuvrability at the initial design stage.

3. Numerical simulation of manoeuvring motion:

Hence, the approximate formulae for estimating the hydrodynamic force acting on a ship are proposed. These formulae are obtained semi-empirically by the results of numerical calculation based on lifting surface theory and experimental data model.

In the same way, different ship manoeuvring simulations will be carried out such as (zigzag test, turning test, autopilot test, ect). The said simulations will be required subsequently for the prediction of the manoeuvrability operations of full scale designed ferry (berthing, keeping the course line, steerage, turning manoeuvres inside both harbours, ect).[1]

Subsequently I will present the different steps we are following in a manoeuvring simulation program.

3.1 Fundamental variables used in mathematical model of ship motion:

We should as a first stage set all the general variables. They can be defined as follows:

u (sur. Vel.) : Surge velocity.
v (swa. Vel.) : Sway velocity.
r (yaw ang.vel.) : Yaw angular velocity.
n (rps) : Propeller revolutions per second.
ν (kin. Visc.) : Kinematic viscosity.
A_R (rud. Area) : Rudder Area.
U_R (sur.Vel.Rud.): Effective relative inflow velocity in x direction to rudder.
k (form coef.) : Form resistance factor.
Cw4, Cw5, Cw6: Hull resistance coefficient.
DP (prop. Dia.) : Propeller diameter.
fa(Λ) (prop.coef.) : Rudder normal force coefficient.
t (thr. Ded. (Exp.): Effective thrust deduction factor.
U_p (sur.Vel.Prop.): Effective relative inflow velocity in x direction to propeller.
δ (Rud. Ang.) : Rudder angle.
X_R (cen.rud.force): x-coordinate of the center of rudder normal force.
a_H (rud.force ratio): Ratio of the lateral force induced on the hull by the rudder to the rudder normal force.

Estimation of hydrodynamic forces:

To estimate the hydrodynamic forces acting on a ship, many theoretical and experimental researches have been carried out. Thus the model test results database are analyzed and used after to construct the original approximate formulae for hydrodynamic derivatives.

3.3 Non-dimensionalization:

Basically, the following equations can be applied to the case of shallow water by correcting the hydrodynamic derivatives and coefficients which have been originally obtained for deep water.

$$X_{vv}' = \frac{X_{vv}}{\frac{1}{2}\rho L d} \quad (1)$$

$$Y_v' = \frac{Y_v}{\frac{1}{2}\rho L d U} \quad (2)$$

$$N_v' = \frac{N_v}{\frac{1}{2}\rho L^2 d U} \quad (3)$$

3.4 Calculation of surge-sway-yaw acceleration:

The equations for surging, swaying and yawing motion of ship can be written in

[1] Ref. (1)

following form using coordinate system in figure below[2]:

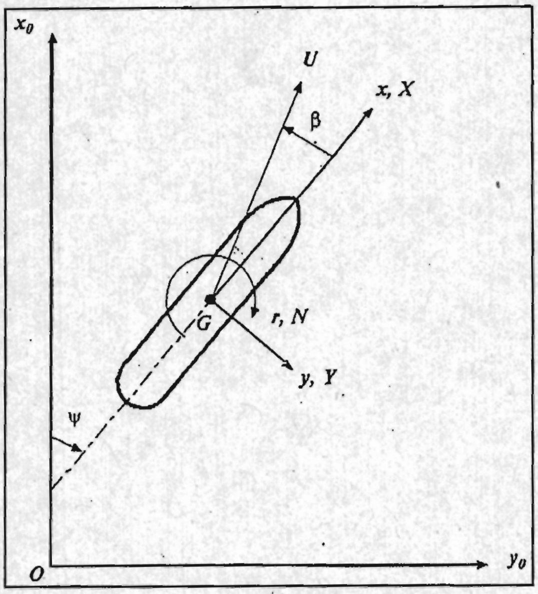


Fig.4 coordinate systems

$$m(\dot{u} - vr) = X_{\dot{u}}\dot{u} + X_{vv}v^2 + (X_{vr} - Y_{\dot{v}})vr + X_{rr}r^2 + X_{vvvv}v^4 + (1-t)T - X_u(U) - 2F_N \sin\delta \quad (4)$$

$$m(\dot{v} + ur) = Y_{\dot{v}}\dot{v} + Y_{\dot{r}}\dot{r} + Y_v v + (Y_r + X_{\dot{u}}u)r + Y_{vvv}v^3 + Y_{vvr}v^2 r + Y_{vrr}vr^2 + Y_{rrr}r^3 - 2(1+a_H)F_N \cos\delta \quad (5)$$

$$I_{ZZ}\cdot\dot{r} = N_{\dot{v}}\dot{v} + N_{\dot{r}}\dot{r} + N_v v + N_r r + N_{vvv}v^3 + N_{vvr}v^2 r + N_{vrr}vr^2 + N_{rrr}r^3 - 2(1+a_H)x_R \cdot F_N \cos\delta \quad (6)$$

Where

$X_u(U) = C_T \cdot \frac{1}{2}\rho S U^2$: *Resistance*

$T = 2K_T \cdot \rho \cdot n^2 \cdot D_P^4$: *propeller thrust (2 Is for twin propeller use)*

$F_N = \frac{1}{2}\rho \cdot A_R \cdot f_\alpha(\Lambda) \cdot U_R^2 \sin\delta$: *rudder force*

(Number 2 in the previous formula is referring to the twin rudders)

Using the above equation we can first determine the surge acceleration $\dot{u}$ at initial time t_0. Then the sway and yaw accelerations respectively $\dot{v}$ and $\dot{r}$ can both be written in the following system:

$$B_1\dot{v} + B_2\dot{r} = B_0 \quad (7)$$

$$D_1\dot{v} + D_2\dot{r} = D_0 \quad (8)$$

After that we can write the following matrices relation:

$$\begin{bmatrix} B_1 & B_2 \\ D_1 & D_2 \end{bmatrix}\begin{bmatrix} \dot{v} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} B_0 \\ D_0 \end{bmatrix} \quad (9)$$

And solving these matrices equations we will have finally $\dot{v}$ and $\dot{r}$ at t= t_0, as;

$$\dot{v} = \frac{\begin{vmatrix} B_0 & B_2 \\ D_0 & D_2 \end{vmatrix}}{\begin{vmatrix} B_1 & B_2 \\ D_1 & D_2 \end{vmatrix}} = \frac{B_0 \cdot D_2 - B_2 \cdot D_0}{B_1 \cdot D_2 - B_2 \cdot D_1}$$

$$\dot{r} = \frac{\begin{vmatrix} B_1 & B_0 \\ D_1 & D_0 \end{vmatrix}}{\begin{vmatrix} B_1 & B_2 \\ D_1 & D_2 \end{vmatrix}} = \frac{B_1 \cdot D_0 - B_0 \cdot D_1}{B_1 \cdot D_2 - B_2 \cdot D_1} \quad (10)$$

3.5 Calculation of surge-sway-yaw velocity:

Using Runge-Kutta method or Euler method we can find different velocities at time t=t_1.

$< Runge - Kutta >$

$For\ n = 0,1,2\cdots,N-1\ do:$

$k_1 = \Delta t \cdot f(t_n,\ x_n)$

$k_2 = \Delta t \cdot f(t_n + \frac{1}{2}\cdot\Delta t,\ x_n + \frac{1}{2}\cdot k_1)$

[2] Ref. (3)

$$k_3 = \Delta t \cdot f(t_n + \frac{1}{2}\cdot\Delta t,\ x_n + \frac{1}{2}\cdot k_2)$$
$$k_4 = \Delta t \cdot f(t_n + \Delta t,\ x_n + k_3)$$
$$t_{n+1} = t_n + \Delta t$$
$$x_{n+1} = x_n + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$
end

$<Euler>$

$$For\ n = 0,1,2\cdots,N-1\ do:$$
$$k_1 = \Delta t \cdot f(t_n,\ x_n)$$
$$t_{n+1} = t_n + \Delta t$$
$$x_{n+1} = x_n + k_1$$
end

3.6 Calculation of x, y – coordinate of ship:

We need to change the (x,y) coordinate systems from ship coordinate to earth coordinate following the equations below:

$$\dot{x}_0 = u\cos\psi - v\sin\psi \quad (11)$$
$$\dot{y}_0 = u\sin\psi + v\cos\psi \quad (12)$$
$$\psi = \psi_0 + \Delta t \cdot \dot{\psi}_0 \quad (13)$$
$$x = x_0 + \Delta t \cdot \dot{x}_0 \quad (14)$$
$$y = y_0 + \Delta t \cdot \dot{y}_0 \quad (15)$$

We can finally plot the time trajectory of ship as follows:

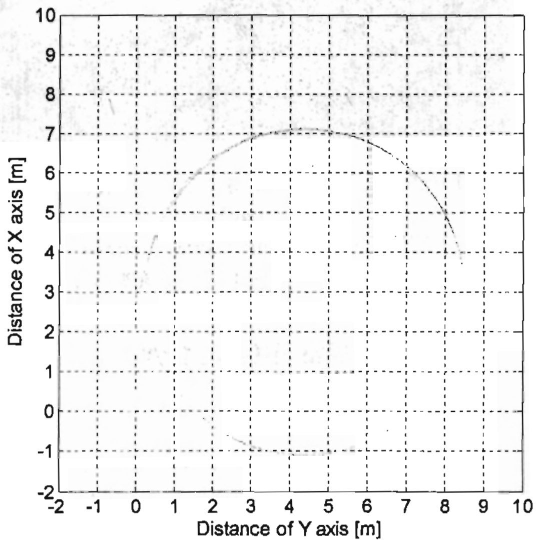


Fig.4 Turning test time trajectory of ship (rudder angle: +30°)

Indeed, the sea trial results of full scale ship include the effects of wind, wave and current. Especially in my research case the wind factor has to be essentially taken in consideration. As I mentioned before, it is considered as one of the main influential factor of the current ferry course line keeping and berthing manoeuvres.

These simulations data will be a good help in order to delineate the main harbour and offshore operations enhancement. The channel depth, location and orientation will be also reconsidered.

However it is in fact that the sea trial results of full scale ship also include measurement errors such as errors due to measurement method or measurement process.

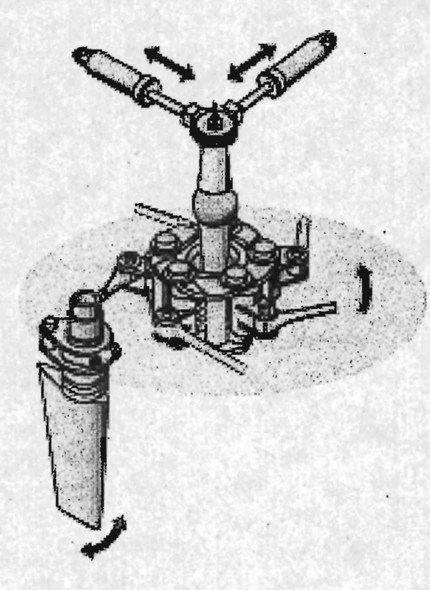
From these discussions, it is not too much to say that the present method can predict definitive ship manoeuvrability at the initial stage design. For using those methods at that phase, they will be expected to be as simple as possible from point of view of practical design.

4. The double ended ferry proposition with VSP propulsion system:

Voith-Schneider propellers (VSP) have proved themselves as reliable propulsion systems for double-ended ferries (DEF) for more than 65 years. The VSP gives DEF excellent maneuverability and realizes the propulsion with very good efficiency.

In recent years, Voith Schiffstechnik has improved the efficiency of the VSP by using the CFD technology - coupled with experimental methods - and especially further deepened their knowledge of the interaction between the propeller and the ship

It has to be mentioned that a common DEF will be equipped with only two VSP. The installation of four VSP may be required by only very specific design requirements like limited draft or high power requirements.



Kinematical principle of Voith-Schneider Propeller.

Numerical and experimental methods have been used to improve the hydrodynamics of DEF with Voith-Schneider-Propeller. The flow around the hull is calculated both using potential-theoretical methods and by solving the Reynolds Average Navier-Stokes equations (RANS). In order to bring about better knowledge of the interactions between the propeller and the ship's hull, a measuring device was developed which allows simultaneous measurement of the thrust and transverse force of the individual VSP. The propulsive power of the initial design and an optimized ship hull were compared. Based on the methodology used, a significant reduction of the propulsive power requirement was achieved. The calculation processes were automated to the greatest degree possible, so that optimization of hull ship forms of DEF is possible in a very efficient way.

The double ended ferry alternative will help to solve many cumbersome problems:

- better maneuverability, high safety and economical efficiency,
- reduction of loading and unloading time,
- increase of car and passenger capacity by multiplying by two the ferry length,
- no need any more for complicated and sensitive harbor maneuverings as the ferry is double ended,
- reduction of number of decks resulting in decreasing of the superstructure area as well as the wind resistance phenomenon,
- better position for the wheelhouse and better control for the passengers and different ferry compartments,
- more protection for the propulsion system: Insensitivity to foreign objects, such as driftwood and chains. It can also be noted that the blade usually impacts such foreign objects with its front edge, where the blade has the highest section modulus relative to the effective direction of the attack force,
- Low pressure impulses on the ship's hull.

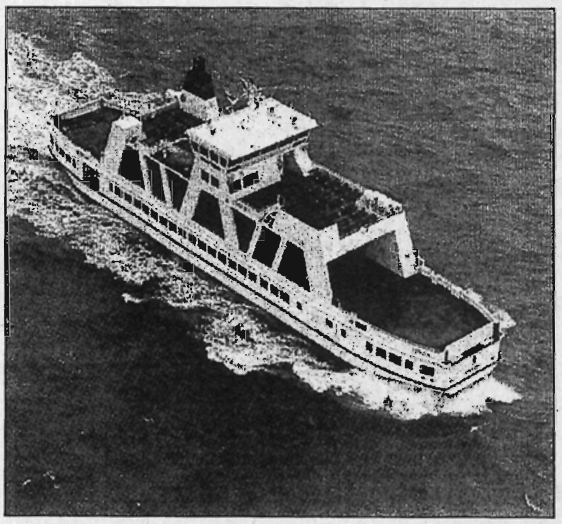


Fig.5 DEF FRISIA, 4 x VSP 16KG/100 - each VSP 470 kW input power, working in the North Sea in extreme shallow water.

5. <u>The bridge alternative:</u>

The second part of the researches will be devoted to the bridge design study alternative. In fact, it is the dream of every islander to get linked to the mainland. During wintertime, the service of the ferry stops when there are bad weather conditions. Additionally, the maritime transportation penalizes the islands development at all levels (merchandise transportation, passengers transportation, ect). The yearly cost overrun comparing to road transportation rises up to 4 Millions Dinars[3] (3 Millions Dinars for passengers shipping and 1 Million Dinars for the vehicles). The Kerkenians are paying a yearly cost overrun equivalent to the construction of 3.3 Km of freeway or 1.6 Km of road in sea.[4]

To solve the spiny and sensitive problem of the maritime transportation between Sfax and Kerkenah, and after examining the maritime chart, the geology of the site and the topography of the land, I suggest the construction of two routes with a free maritime circulation (as shown in the chart in the right hand side). The first part, long of 6 Km, will start from Sidi Mansour and the second part, long of 14 km, will start from Sidi Youssef. A maritime canal of about 5 Km will be kept to permit the ships transit through kerkenah canal. Both routes sides will be reached within 10 minutes with the same current ferries speed.

At first, Sidi Youssef harbour will keep operating and the ferries flotilla will be affected to cross the ship canal between both route sides. The said routes will be constructed using the dredging and embankment methods. Indeed, the city of Sfax is facing serious problems for elimination of the domestic trashes and the non toxic industrial garbage. The embankment of big expanses with alternating a bed of that garbage (1 meter) and a bed of sand / stones (1 meter) could solve at the same time the problem of waste riddance and the decrease of the project fees at the same time.

The second stage is to join the two sides by a mixed steel – concrete bridge. The bridge would bring life and dynamism for the archipelago and a new economic impetus for the whole region of Sfax.

The bridge will be a way of communication and transportation for water (desalinated on the premises and of bad quality), gas (absent whereas the flares burn in sea), electricity (by submarine cable), the telephone (by hertzian way), the evacuation of oil (actually made by barges). It will be a new birth for Kerkenah islands.

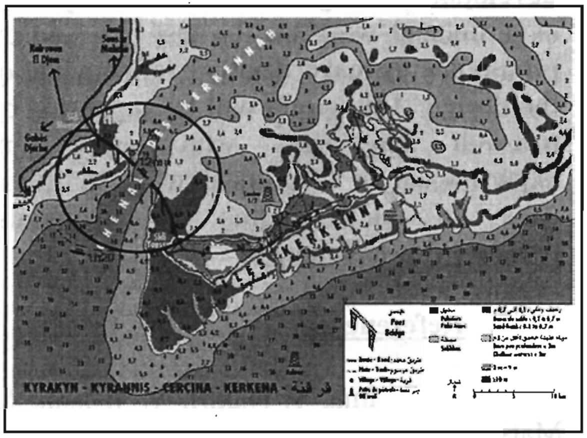


Fig.6 The bridge alternative proposition

Some people though, are opposed to the idea of building a bridge, arguing that it would disrupt the peace and quiet of the island. Adding more hotels is thought to cause the island to lose its charm and become polluted. However, a bridge is obviously a big investment and several other transportation and infrastructure improvements have to be made also. Coming to Kerkenah only in the summer would not expose its transportation problems all over the whole year.

6. Conclusion:

From all the above mentioned, we can say that unlike a market economy in which new design is a response to a perceived market need, ship design is typically in response to an expressed need coming from such sources as the advent of new technologies,

[3] 1 Tunisian Dinar= 0.75 U.S dollars.
[4] Ref. (2)

changes in world politics, new strategies and, lessons learned from previous ship development. This need is identified by Naval planners in the form of a design brief, which will be the basis for subsequent development. This brief will be taken up by designers, who will explore ways in which the design brief can be met, and will eventually develop the most promising of these into detailed instructions for manufacture. In this effort, they will be assisted by design analysts, who use analysis and simulation techniques to test the fitness for purpose of the design proposals, and development engineers who carry out experimental work on the test rigs and on prototypes to make detailed refinements of the design. This group will be supported by research engineers, who carry out experimental or theoretical work to fill in gaps in understanding of materials, processes, or techniques.

7. References:

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