COMPARATIVE STUDY OF DYNAMIC NAUTICAL FEATURES OF TURNING COMPUTER ASIST AND SEA TRIAL

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Abstract: The responsibility of the ship designer consist in made design methodologies and construction technologies which, on the actions act in the natural medium on body ship's, to permit performing exploitation, suitable with their functionality.
The paper have the main aim to made a comparative study between a simulation model (made on sketchy base of data – available in initial design phase – referring on ship and navigation medium) on ship turning moving and the real behavior of these in the trial sea.
The compatibility of results will consist the reason to extend and generalization the simulating models for computerizing workstation, like efficacious work device in the complex problem of study the general behavior of ship in the real navigation conditions.
The study was made on maritime ship chemical tank on 37000 tdw, with unlimited navigation area, the choice is justified by the validation possibility – through sea trial – on result obtained by numeric simulation. For made the model, we use *OCTOPUS/SEAWAY* software, who let the assist study of ship behavior on waves, in real navigation conditions and MATLAB software.
Key words: turning, sea trial, simulation; *OCTOPUS / SEAWAY*; *MATLAB*

1. INTRODUCTION

Regarding the concerning of naval architecture's engineers, is to establish the correlation between ship functionality and his nautical qualities, obtained from the fabrication process and turn account in exploitation time. Thus, is necessarelly that, in manner way, any ship must assure to have all nautical properties. It is known the fact that, between the hydrostatics and hydrodynamics knowledges, we design the ship that assure the nautical properties on quiet water, however, rarely the ship is in this situation of sailing and moving.
Otherwise, we are interesting in theoretical and practical methods through can be overfulfilled, in design activities, complications gived by the marine waves about general movings of ship.
The recorded progress of the researches in the last years in naval domain, are materialized through approaching problems in behavior ship from sistemic long term (for designing, fabrication and ship exploitation) and clasic mechanical criterions that accept the valability of the superpozition effects principle (for real navigation environment).
Checking constructive and exploitation perfomances, as and validation of nautical properties of them through sea trial method in real conditions, on prototypes, assume expensives costs and long time of fabrication. Thus, mondial community of naval architectures engineer recommend, for preliminary designing phases, anticipating the ship movements on sea waves through using numerical modelling methods, analysis and prediction methods also.
Mathematical methods of analysis proof their utility and eficiency in competition with phisical modelling, specified of hydrodynamic testing in tank, their facilitate the calculus for hull in natural dimenions and theoretical study of ship behavior on sea waves in real time.
We enforce, however, corections, results from comparison with experimental-practical elements, after that can be done generalizations (this paper, are signing up in this way).
These methods offering the posibility of making, in short time and low costs, for a great number of studies variants for a analized problem, give the facility to make optimal choice.
We mention that is nor recommended to drop out at experiments making in hydrodynamics laboratory and at complex trial sea in real sea, because these reprezents the compulsory complement in validation the results obtained through mathematical modelling.

2. THEORETICAL CONSIDERATIONS

The description of behavior ship body – considering at free rigid solid – in time navigation in real hidrometeorological conditions is a dificult problem, that solving are conditioned of perturbation parameters actions of different grades.

General equations of ship movement are based, in esence, on perturbations apreciation that appear in ship governing with the help of propulsion systems and of navigation enviroment, apriori through sea waves actions.

The simulation program made permiting the ship movement analysis, with regard at four from six degree of fredom of a free rigid solid in space (we neglected the translation movements after vertical rotation axis around transversal axis, that was considering insignificant for the conditions in which ship made the turning trials in real sea).

Although the simulation program results can offer multiple possibilities of interpretations and analysis of dynamic ship behavior (answering spectra in amplitude for weight ship center, informations regarding the position, speed and acceleration of interest points from body ship, informations regarding forces and moments that acts in different transversal sections of ship, selected by user, etc).

The aim of this paper are to give informations regarding the trajectory of the weight ship center in horizontal plane, as on base of results given by simulation program and on base of turning trials sea ship made in real sea, for the making head series ship. The comparized results follow the validation simulation program made, on his base we can make a significant numbers of simulations test and interpretation of dynamic behavior of ship even the trials sea make on prototype ship in real sea.

The results of simulation of dynamic behavior of ship are referring the solving vectorial equation of movement (1), the meaning terms are established (Fossen & Fjellstad,1995):

$$M_\eta(\eta)\ddot{\eta} + C_\eta(\nu_r,\eta)\dot{\eta} + D_\eta(\nu_r,\eta)\dot{\eta} + g_\eta(\eta) = \tau_{M\eta} + \tau_\eta \quad (1)$$

For obvious the possibilities of conexions SEAWAY and MATLAB software's, we keep the particular case of coupling the translations movements after the longitudinal axis and transversal axis and the rotation axis around vertical and longitudinal axis (rigid solid with four degree of freedom).

For situation analyzed, the movement equations system become

$$\begin{cases} m\left(\dot{u} - vr - x_G r^2 + z_G pr\right) = X \\ m\left(\dot{v} - ur - x_G \dot{r} + z_G \dot{p}\right) = Y \\ I_x \dot{p} - mz_G\left(\dot{v} + ur\right) = K - W\overline{GM}_T \cdot \varphi \\ I_z \dot{r} + mx_G\left(\dot{v} + ur\right) = N \end{cases} \quad (2)$$

3. EXPERIMENTAL AND SIMULATION MODEL

Choosing the particular case mention, was conditionally by the possibility of validation results obtained through the computer aided with the resulting data by trials sea.

The experimental model and simulation model for the source program made for ship NORIENT SATURN, type chemical tank (type 3 – oil tank), with zone of unlimited navigation (make to deliver oil products with different specific weights).

Follow the synthetic characterization necessarily of ship.

a) geometrical particularities and constructive: hull with bulb in bow and aft in mirror; the construction of rudder post adequate of making a semisuspended rudder with weld caisson, semicompensed, with hydrodynamic profile, done in diametral plane (having the shim area of surface $S_p = A_R = 34{,}2\ \text{m}^2$ and relative elongation $\lambda = 1{,}9327$); principal dimensions – calculus length $L = 172$ m, width $B_x = 32{,}2$ m, draught $T = 10{,}5$ m; machine area put on aft part of the ship;

b) static mechanical particularities: displacement deadweight 40435 tdw; abscissa of geometric center of floating of full loading $x_F = 78{,}385$ m; dimensions of hull center $\overline{KB} = 5{,}78$ m, weight center $\overline{KG} = 8{,}92$ m, transversal metacenter $\overline{KM}_T = 9{,}352$ m, longitudinal metacenter $\overline{KM}_L = 212{,}783$ m; transversal height metacenter $\overline{GM}_T = 0{,}432$ m and longitudinal $\overline{GM}_L = 203{,}863$; transversal metacenter radius $\overline{BM}_T = 5{,}23$ m and longitudinal $\overline{BM}_L = 198{,}072$ m;

c) dynamic mechanical particularities: service speed $v = 15$ Nd; kinematical chain of propulsion is made by propeller with 4 fixed blades, dispose in diametral plane (having the diameter $D = 6{,}533$ m, pitch ratio $P/D = 0{,}721$ and disk ratio $A_E/A_0 = 0{,}64$ at turation $n = 127$ rot/min), a azial line with reducer and one semispeed engine 6L52/55A, in four time, reversible, with supercharge and direct injection, having nominal power $P = 6100$ CP and nominal turation $n = 127$ rot/min.

In source MATLAB program structure use for computer aided study, the equations systems (2) is writing in according the primare rules of normalization imposed by SNAME (Society of Naval Architects and Marine Engineers) in the 1950 year, for working with nondimensional dimensions, given in (Fossen & Fjellstad,1995)

$$\begin{cases} \left(m' + m'_x\right)\dot{u}' - \left(m' + m'_y\right)v'r' = X' \\ \left(m' + m'_y\right)\dot{v}' - \left(m' + m'_x\right)u'r' + m'_y\alpha'_y\dot{r}' - m'_y l'\dot{p}' = Y' \\ \left(I'_x + J'_x\right)\dot{p}' - m'_y l'_y\dot{v}' - m'_x l'_x u'r' + W'\overline{GM}'_T\varphi' = K' \\ \left(I'_z + J'_z\right)\dot{r}' + m'_y\alpha'_y\dot{v}' = N' - Y'x'_G \end{cases} \quad (3)$$

4. RESULTS

In the sea trials made with ship NORIENT SATURN, the total duration of experiments are made in 10 minutes.

Table no.1 Results on turning trial

Meas .no.	Time [min,s]	Position		Distance		True course [°]
		Longitude L[°]	Latitude B[°]	[sm]	[m]	
1	0-00	29.007397	44.159485	0.000	0.0	359.65
2	20	29.007427	44.160790	0.078	145.0	359.47
3	40	29.007390	44.162113	0.158	292.1	358.15
4	1-00	29.007342	44.163448	0.238	440.5	358.86
5	20	29.007328	44.164785	0.318	589.0	359.37
6	40	29.007312	44.166113	0.398	736.6	359.22
7	2-00	29.007250	44.167410	0.476	880.8	358.92
8	20	29.007209	44.168650	0.550	1018.6	359.88
9	40	29.007210	44.169873	0.623	1154.5	0.51
10	3-00	29.007250	44.171020	0.692	1282.0	1.01
11	20	29.007283	44.172129	0.759	1405.3	1.32
12	40	29.007295	44.173212	0.824	1525.6	1.40
13	4-00	29.007303	44.174255	0.886	1641.5	1.13
14	20	29.007355	44.175248	0.946	1752.0	0.85
15	40	29.007358	44.176207	1.004	1858.5	0.06
16	5-00	29.007345	44.177138	1.059	1962.0	359.97
17	20	29.007338	44.178048	1.114	2063.1	1.58
18	40	29.007372	44.178957	1.169	2164.1	1.38
19	6-00	29.007392	44.179808	1.220	2258.7	0.28
20	20	29.007384	44.180610	1.268	2347.8	359.35
21	40	29.007363	44.181395	1.315	2435.1	358.20
22	7-00	29.007325	44.182182	1.362	2522.6	359.15
23	20	29.007297	44.182932	1.407	2606.0	0.14
24	40	29.007297	44.183675	1.452	2688.5	1.00
25	8-00	29.007317	44.184383	1.494	2767.2	3.44
26	20	29.007377	44.185072	1.536	2843.9	6.45
27	40	29.007525	44.185713	1.575	2916.1	11.35
28	9-00	29.007753	44.186318	1.612	2985.7	18.46
29	20	29.008053	44.186862	1.647	3050.6	25.87
30	40	29.008443	44.187318	1.679	3109.9	34.03
31	10-00	29.008885	44.187713	1.709	3165.9	42.68
32	20	29.009355	44.188033	1.737	3217.3	50.37

The trials was made for different speed variable between 6,5 m/s and 9,5 m/s respectively between 12,6 Nd and 18,5 Nd, witch correspond a turation of propeller shaft between 80 rot/min and 150 rot/min. The rudder was striping through larboard, from 10^0 to 35^0 with a pitch of 50. The results obtained in sea trial time, was centralization in a set of tables like present in table no.1 for speed 15 Nd, at a turation of propeller shaft 127 rot/min and at strip rudder angle of 20^0.

Informations obtains give the possibility to make the trajectory of ship weight center, in a horizontal plane, aproximatively parallel with the silence surface of sea, like we suggest in fig.1

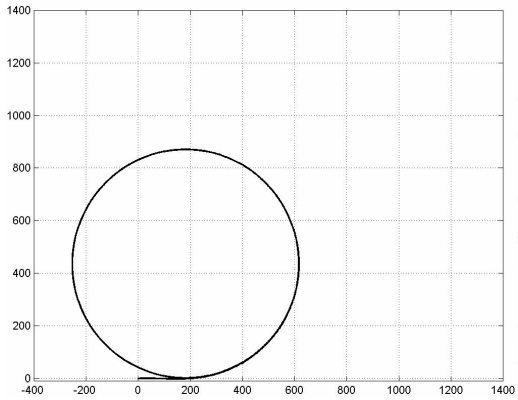
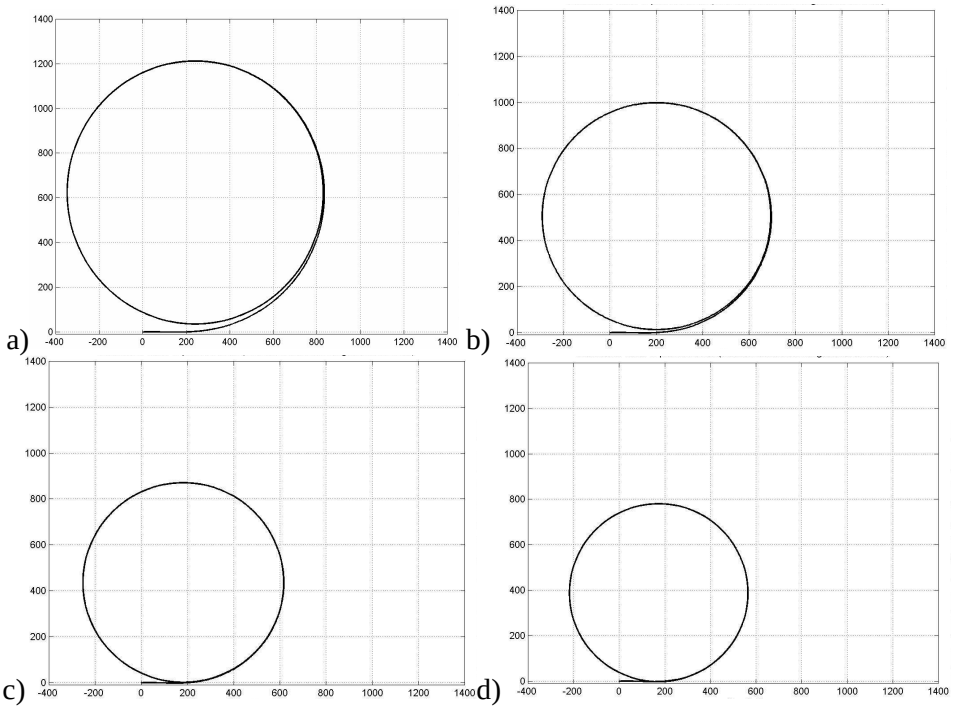


Fig.1. Trajectory of weight center in horizontal plane

The ensemble of results given by MATLAB permits graphical illustration of the study made and refer at the processing data given by SEAWAY software finalize through complex diagrams referring at: ship trajectory in horizontal plane, graphics of rolling angle variations, graphics of angle of turning movements variations, graphics of command angle variations and the effective made by shim rudder, graphics of variation of longitudinal component speed ship, graphics of leeway speed variations, graphics of speed rolling movements variations etc.

This paper presents only the aspects regarding at compose behavior at rolling and turning movements for NORIENT EXPRES ship, partial reflected and selective in figure 2.



a) b) c) d)

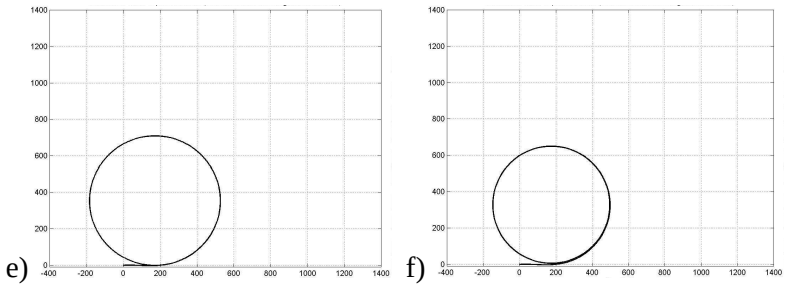


Fig.2 Turning trajectory – partial exemplification
ship speed V=7,5 m/s, command turation n_c = 120rpm and strip angle variing in range d_c ∈ [10°-35°], with pitch of 5°
a)10°; b) 15°; c) 20°; d) 25°; e) 30°; f) 35°

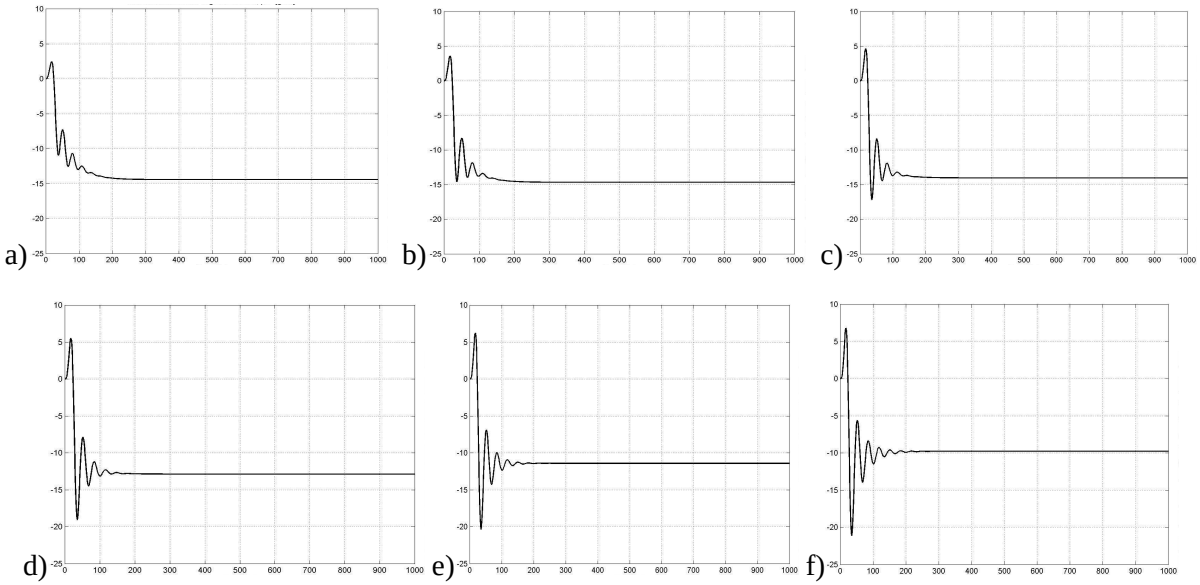


Fig.3. Roll angle variation – partial exemplification
ship speed V=7,5 m/s, command turation n_c = 120rpm and strip angle variing in range d_c ∈ [10°-35°], with pitch of 5°
a) 10°; b) 15°; c) 20°; d) 25°; e) 30°; f) 35°

In the figure 3 we represent the time range period when the rolling motion are stabilized.

5. CONCLUSIONS

The performance of simulating program was validate by the behavior ship in the real navigation conditions, that permits using with trustworthy the results given by the program and which not obvious directly in time in the trial sea.

We keep next observations: after the strip rudder and keeping him at the impose angle, the weight center of ship darkling in forward at a specific speed, describe a curbilinium trajectory which, at stable turning, is approximate a circle; the turning diameter depends direct by the strip rudder angle, being smallest at this angle increase; for high speed of moving ship, it recommended avoid strip rudder with great angles, the ship is in danger overthrowing; for small speed of movements ship, it recommended to avoid strip rudder with small angles, the turning diameter increase to much, with negative consequences regarding the efficiency of ship maneuverability; rolling ship is insignificant stricken by the speed motion ship, him stabilize after aproximative 300 s from the beginning motion; in the turning time, the ship is bending at the board were we strip the rudder, value angle of bending being directly proportional with square speed of forward ship.

Modeling use for workstations it prove a device with major efficiency in solving the complex problem give it by the study of general ship behavior in real navigation conditions and enforcing like a technical necessity, and economical also.

6. REFERENCES

1. Domnişoru, L.,(1997), *Dinamica navei în mare reală*, University "Dunărea de Jos" of Galati, pp. 23-29, Galati

2. Edward, V.L., (1988), *Principles of naval architecture, New Jersey*, The Society of naval architects and Marine Engineers

3. Fossen, T., Fjellstad, O.E., (1995), *Nonlinear modeling of marine vehicles in 6 degrres of freedom*, Journal of Mathematical Modeling of Systems.

4. Maier, V.,(1989), *Mecanica şi construcţia navei*, pp. 34-39, Editura Tehnică Bucureşti

5. Newman, J.N., (1977). *Marine hydrodynamics*, MIT Press, Cambridge, Massachutes

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