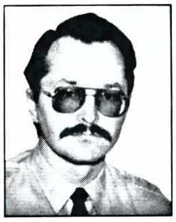

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Filtering and reconstruction of course parameters of the shiphandling training boat „Kołobrzeg"

SUMMARY

The shiphandling training boat „Kołobrzeg" used during courses for navigators is described and a transformation method is presented of the mathematical model of dynamic and kinematic behaviour of the ferry ship [1] into that of the training boat. Also, a method is described of ship course filtration and reconstruction of turn angular velocity by means of the Extended Kalman's Filter.

INTRODUCTION

The shiphandling training boat „Kołobrzeg" is used at the lake Silm near Iława by the Foundation of Shipping Safety and Environment Protection for training navigators in manoeuvring the passenger ferry in various navigation situations (coming alongside, turning short around, approaching the ferry quay by stern etc). The boat is an isomorphous model of the ferry „Stena Germanica" (shortly described a.o. in [1]), built of the epoxide resin laminate, in 1:16 scale. It is equipped with a battery-fed electric drive and the control-steering post at the bow, so placed as to obtain the trainee's eye height over water level corresponding, in 1:16 scale to the eye height over water level of the navigator in the real ferry wheelhouse. The main particulars of the „Kołobrzeg" are as follows :

Length overall	10.98 m	Draught	0.39 m
Breadth	1.78 m	Speed	5 knots
Weight displacement	4 tons		

In Fig.1. side view of the boat is presented.

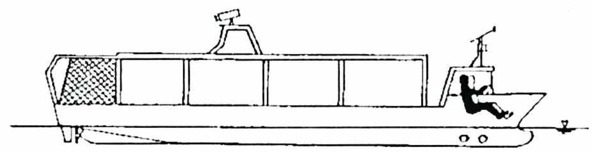

Fig.1.Side view of the shiphandling training boat „Kołobrzeg"

The driving-manoeuvring system of the boat consists of :

- 2 main electric motors together with CP propellers
- 2 blade rudders
- 2 bow thrusters.

SIMULATION MODEL OF THE TRAINING BOAT MOTION

The simulation model describing the dynamic and kinematic behaviour of the ferry ship, presented in [1] was transformed into that of the training boat „Kołobrzeg". For this purpose the principles of geometrical, kinematic and dynamic similarity were applied [2]. In result the model coefficients were to be multiplied by the numbers dependent on the relevant scale factors, as shown in Tab.1.

Tab.1. Multipliers applicable to the simulation model parameters of the „Kołobrzeg"

Parameters	Multiplier
Linear dimensions	6.25000E-02
Areas	3.90625E-03
Forces	2.44140E-04
Masses	2.44140E-04
Moments	1.52587E-05
Inertia moments	9.53674E-07

Thus, the linear velocities of the training boat were made four times smaller than those of the ferry, and the angular velocities four times greater. In the converted model all dynamic phenomena occur four times faster.

The time constants in the dynamic models of the driving-manoeuvring system were so modified , by using results of the experiments carried out on the „Kołobrzeg", as to make them corresponding to those of the training boat.

Comparison of dynamic properties of the simulation model of the ferry ship and that of the training boat (which simultaneously forms an assessment method of model transformation quality) is presented in Fig.2.

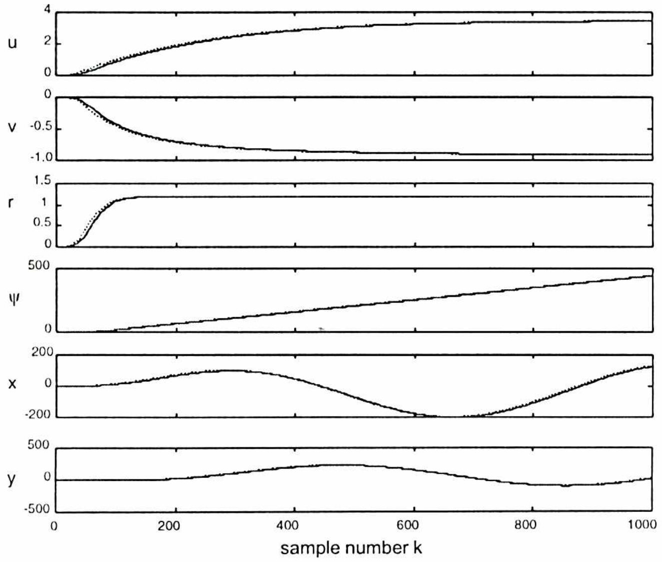

Fig.2. Comparison of the behaviour simulation courses of the ferry ship and training boat during speeding-up

Note : To make the comparison easier the results obtained from the training boat model were multiplied by the relevant multipliers as follows :

velocity components : surge u × 4 , sway v × 4
angular velocity : yaw r × 0.25
displacements : x × 16, y × 16

The simulation time of the ferry ship model was 800 s , and that of the training boat 200 s.

Filtration and reconstruction of the course and angular velocity of the ship

The training boat „Kolobrzeg" was equipped with a gyro-compass measuring its course, and it had no device to measure the turn angular velocity necessary for synthesis of the ship motion control systems. An analysis of the recorded course measurements revealed that they were subject to an error which could be modelled by means of the Gauss white noise $N(0,\sigma_e^2)$ with the standard deviation $\sigma_e = 0.3$ deg.

The Extended Kalman's Filter (EFK) was used to receive real course values and to reconstruct the non-measurable angular velocity [3].

The filter is based on a simplified linear model of ship behaviour to get her trajectory, angular velocity and course angle (see also Fig.3).

$$\begin{bmatrix} r(k+1) \\ \psi(k+1) \end{bmatrix} = \begin{bmatrix} a1_{rr}(k) & a2_{rr}(k) \\ a1_{pr}(k) & a1_{pp}(k) \end{bmatrix} \cdot \begin{bmatrix} r(k) \\ \psi(k) \end{bmatrix} +$$

$$+ \begin{bmatrix} l_{rr}(k) & r_{rr}(k) & dl_{rr}(k) & dr_{rr}(k) & s1_{rr}(k) & s2_{rr}(k) \\ l_{pp}(k) & r_{pp}(k) & dl_{pp}(k) & dr_{pp}(k) & s1_{pp}(k) & s2_{pp}(k) \end{bmatrix} \cdot$$

$$\cdot \begin{bmatrix} n_l^*(k) \\ n_r^*(k) \\ \delta_l^*(k) \\ \delta_r^*(k) \\ thr1^*(k) \\ thr2^*(k) \end{bmatrix} + \begin{bmatrix} e_1(k) \\ e_2(k) \end{bmatrix} \tag{1}$$

$$z(k) = \begin{bmatrix} 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} r(k) \\ \psi(k) \end{bmatrix} + v(k) \tag{2}$$

where :

- r - angular velocity (yaw): $r(k) = \dot{\psi}(k)$
- ψ - real course angle
- z - measured course angle
- e_1, e_2 - process modelling errors
- v - measurement noise
- $a1_{rr}$,..., $a1_{pp}$ - coefficients determining dynamic changes of output quantities
- l_{rr},...$s2_{pp}$ - coefficients determining influence of respective intput signals
- n_l^* - preset value of the left propeller revolution
- n_r^* - preset value of the right propeller revolution
- δ_l^* - preset value of the inclination angle of the left blade rudder
- δ_r^* - preset value of the inclination angle of the right blade rudder
- thr1* - preset value of the relative pitch angle of the first thruster
- thr2* - preset value of the relative pitch angle of the second thruster.

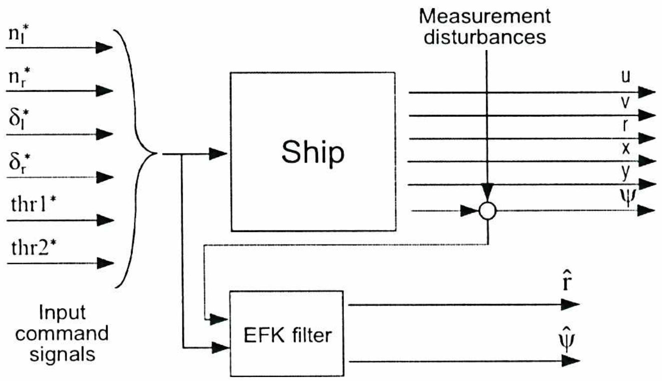

Fig.3. Block diagram of the course filtration and angular velocity reconstruction process

The simulation investigations demonstrated that values of the coefficients a_{ij} of (1) are almost constant in any working conditions therefore they were not estimated with the use of the proposed filter. For filtration purposes the following estimation state vector is formed :

$$x(k) = [r(k)\ \psi(k)\ r(k\text{-}1)\ l_{rr}(k)$$
$$r_{rr}(k)\ dl_{rr}(k)\ dr_{rr}(k)\ s1_{rr}(k)\ s2_{rr}(k) \tag{3}$$
$$l_{pp}(k)\ r_{pp}(k)\ dl_{pp}(k)\ dr_{pp}(k)\ s1_{pp}(k)\ s2_{pp}(k)]^T$$

In this case, on the assumption of mutual independence of $e(k)$ and $v(k)$ noises appearing in (1) and (2), the recurrent Extended Kalman's Filter takes the form as follows :

- **for updating**

$$\hat{\Sigma}(k \mid k) = (I - L(k)c_{15})\hat{\Sigma}(k \mid k-1)$$
$$\hat{x}(k \mid k) = \hat{x}(k \mid k-1) + L(k)\left[z(k) + c_{15}^T \hat{x}(k \mid k-1)\right] \tag{4}$$

where: $$L(k) = \frac{\hat{\Sigma}(k \mid k-1)}{c_{15}{}^T \hat{\Sigma}(k \mid k-1) c_{15} + \kappa}$$

◆ **for predicting**

$$\hat{\Sigma}(k+1\,|\,k) = F_0(k)\hat{\Sigma}(k\,|\,k)F_0(k)^T + \lambda$$
$$\hat{x}(k+1\,|\,k) = G_0(k)\hat{x}(k\,|\,k) + H_0 u_c(k)^T \qquad (5)$$

where :

$$F_0 = \left[\begin{array}{ccc|cccccccccccc} a1_{rr} & 0 & a2_{rr} & n_l^* & n_r^* & \delta_l^* & \delta_r^* & thr1^* & thr2^* & 0 & 0 & 0 & 0 & 0 & 0 \\ a1_{pr} & a1_{pp} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & n_l^* & n_r^* & \delta_l^* & \delta_r^* & thr1^* & thr2^* \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline & 0_{12x3} & & & & & & & I_{12x12} & & & & & & \end{array}\right]$$

$$G_0 = \left[\begin{array}{ccc|cccccccccccc} a1_{rr} & 0 & a2_{rr} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ a1_{pr} & a1_{pp} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \hline & 0_{12x3} & & & & & & & I_{12x12} & & & & & & \end{array}\right]$$

$$H_0 = \left[\begin{array}{cccccccccccc} \hat{l}_{rr} & \hat{r}_{rr} & d\hat{l}_{rr} & d\hat{r}_{rr} & s\hat{1}_{rr} & s\hat{2}_{rr} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & \hat{l}_{pp} & \hat{r}_{pp} & d\hat{l}_{pp} & d\hat{r}_{pp} & s\hat{1}_{pp} & s\hat{2}_{pp} \\ \hline & & & & & 0_{13x12} & & & & & & \end{array}\right]$$

$$u_c = \left[n_l^* \quad n_r^* \quad \delta_l^* \quad \delta_r^* \quad thr1^* \quad thr2^*\right]^T \qquad c_{15} = \left[0 \; 1 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0 \; 0\right]^T$$

κ, λ - constant values dependent on noise and disturbance levels

Note : *For better legibility notation of the current time instant k was omitted.*

In Fig. 4a,b,c the courses are presented which illustrate work of the filter in question.

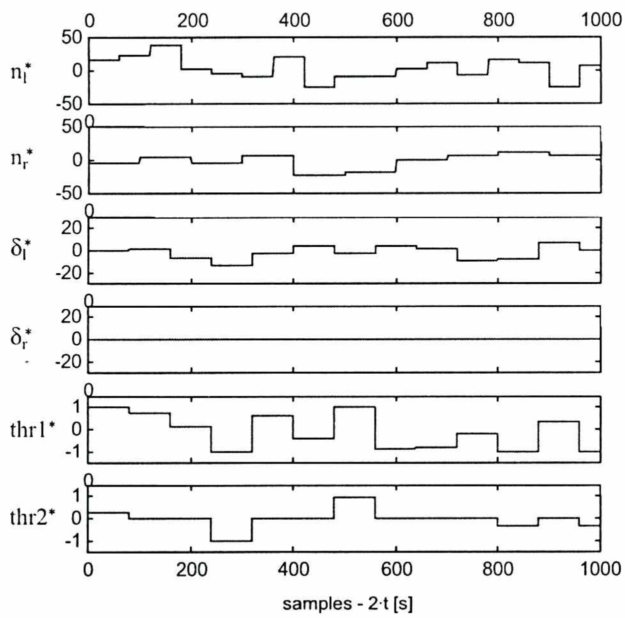

Fig.4a. *Preset input signals sent to the ship and filter*

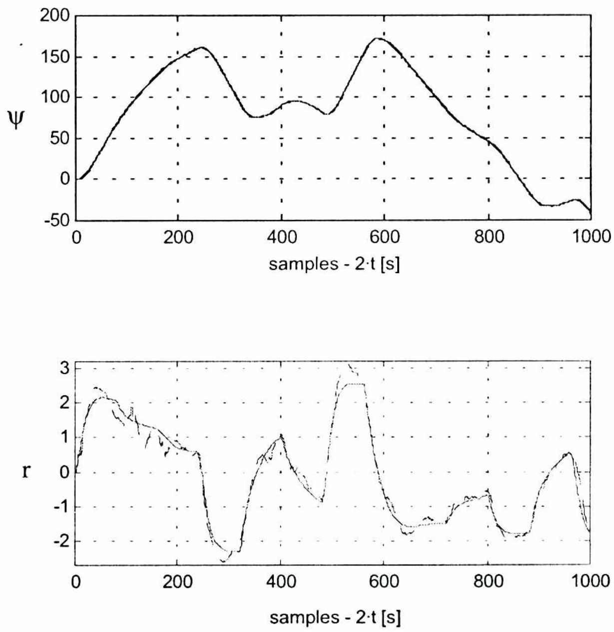

Fig.4b. *Recorded values of the ship course angle and angular velocity*
——— *real values* - - - - - - - *estimated values*

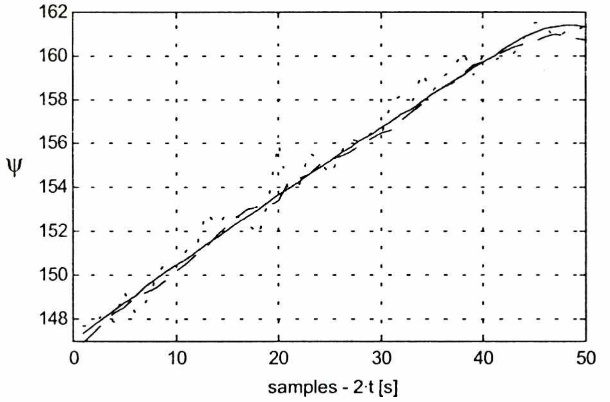

Fig.4c. Enlarged fragment of a ship course angle record
Sample size : 200 to 250
——— *real course angle* ········ *measured course angle*
- - - - - - *estimated course angle*

FINAL REMARKS

- The appropriate and consistent application of the principles of geometrical, kinematic and dynamic similarity [2] to calculation of the simulation model coefficients makes it possible to obtain the new model whose behaviour conforms to the scaled behaviour of the initial model (Fig.2). Full conformity is not attainable at least due to identical values of viscosity of the real and model fluids.

- Many ship manoeuvring control systems are based on measuring the linear and angular velocities. If results of such measurements are not available it is very hard – and often at all impossible - to synthesize the regulator. The training boat „Kołobrzeg" is not equipped with the instruments for measuring the aforementioned velocities hence in this case the only solution is to reconstruct the non-measurable magnitudes.

- Further efforts will be focussed on elaboration of filters for measuring of ship's position and reconstruction of linear velocities.

Appraised by Józef Lisowski, Prof.,D.Sc.

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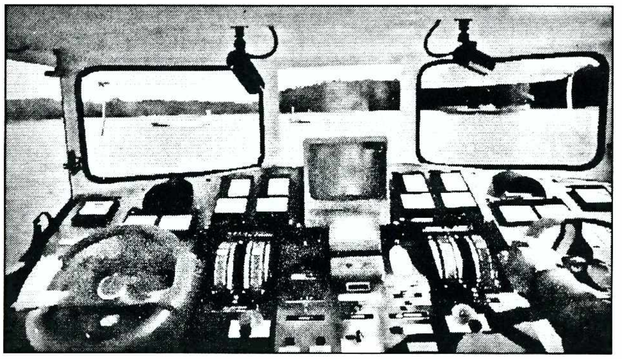

Conference

Marine Technology 2000

From 4 to 6 May 2000, XIX Scientific Conference of Naval Architects and Marine Engineers was held under the slogan :

Marine Technology on the Threshold of XXI Century

It was organized and hosted by the Faculty of Maritime Technology, Technical University of Szczecin and the Society of Polish Naval Architects and Marine Engineers – KORAB.

On 4 May the opening ceremony of the conference and its 1st plenary session was held at the Faculty of Maritime Technology in Szczecin. During the session 3 papers were presented :

- *World Shipbuilding in XXI Century* (by Prof. J.W.Doerffer)
- *IMO NOx Certification of Marine Diesel Engines* (by H.J. Gatjens, D.Sc.)
- *Energy Efficiency of Hydraulic Cylinders in Servo-Mechanisms* (by Prof. Z.Paszota)

After visiting of Szczecin Shipyard the conference participants moved to Dziwnówek, a resort on the Baltic coast, where another part of the conference was held, covering two plenary and 7 topical sessions.

During the plenary sessions the following papers were read :

- *Safety against capsizing – Road for the future* (by Prof. Lech K. Kobyliński)
- *Shipbuilding industry research and development activities in the European Union and Poland* (by Jan Dudziak, D.Sc.)
- *Transport system of a flexible shipyard* (by Tomislav Zapatić)
- *Education at the shipbuilding faculty of Technical University of Gdańsk in the period of 1945 ÷ 2000, prospects and development lines* (by Prof. Krzysztof Rosochowicz)
- *Education of shipbuilding engineers in Szczecin in the period of 1945 ÷ 2000* (by Prof. Mieczysław Hann)
- *Marine pollution risk control* (by Prof. Yuri N. Semenov)
- *Unconventional methods of investigation of vibroacoustic effects in ships* (by Prof. Stefan Weyna)

The topical sessions covered 58 papers split into the following topic groups :

I Hydrodynamics and design of ships and offshore units (17 papers)
II Ship structures, process engineering and management aspects (17 papers)
III Marine engineering and power plants, ship equipment and protection engineering and environmental issues (24 papers)

From 7 Polish universities took part in the conference 119 scientific workers and experts, mainly from: the Technical University of Szczecin (30 persons), Technical University of Gdańsk (14 persons), maritime universities (7), as well as of 4 foreign universities : in Rostock, Zagreb, Hamburg-Harburg and Kaliningrad. Also, representatives of the ship classification societies : Germanischer Lloyd, Lloyd's Register, Bureau Veritas and Polish Register of Shipping took part in it.

The conference appeared interesting to over 40 Polish institutions linked with the shipbuilding industry : research centres, design offices, shipyards and subcontractor firms, as well as to 4 foreign institutions of the kind.

During the conference many vivid discussions were held, continued even beyond the agenda. This made it possible to tighten professional links among different circles of shipbuilding specialists from Poland and foreign countries.

Undoubtedly, the organized informal parties and visits to places of interest in that region of Poland contributed to integration of the shipbuilding professional circle.