Transactions on Modelling and Simulation vol 10, © 1995 WIT Press, www.witpress.com, ISSN 1743-355X

Simulated reactions of an underwater vehicle to constraints generated by a drive system

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ABSTRACT

The paper presents an attempt of describing movement properties of an underwater vehicle at the initial phase of designing. The author studies the flat motion of a vehicle on a vertical longitudinal plane for a certain drive system arrangement. The computer simulation makes it possible to predict the behaviour of a vehicle.

1 INTRODUCTION

Most of the drive systems of remotely operated vehicles (ROV) are designed to perform the motion of four degrees of freedom, i.e. three degrees of the rectilinear motion and the rotation around the vertical axis [1,7,8]. Such a kind of vehicle movements allows to perform various sophisticated tasks without diver assistance.

The most frequent redundant system is represented by a configuration of four propellers positioned on the horizontal plane with the fifth vertical propeller (or several vertical propellers). Movements of the ROV caused by such a drive system has been simulated. Results are discussed in the paper, ROV behaviour is predicted.

2 OBJECT OF INVESTIGATIONS

The author studies the flat motion of a vehicle on a vertical longitudinal plane, i.e. the motion whose trajectory is in x'y' inertial system plane, and xy plane of the reference system follows the x'y' every moment of the motion, fig.1. This is the motion of three degrees of freedom described by the set of differential equations presented in [3]. The motion is effected by Tx and Ty forces and Mz moment generated by propellers or ballast system.

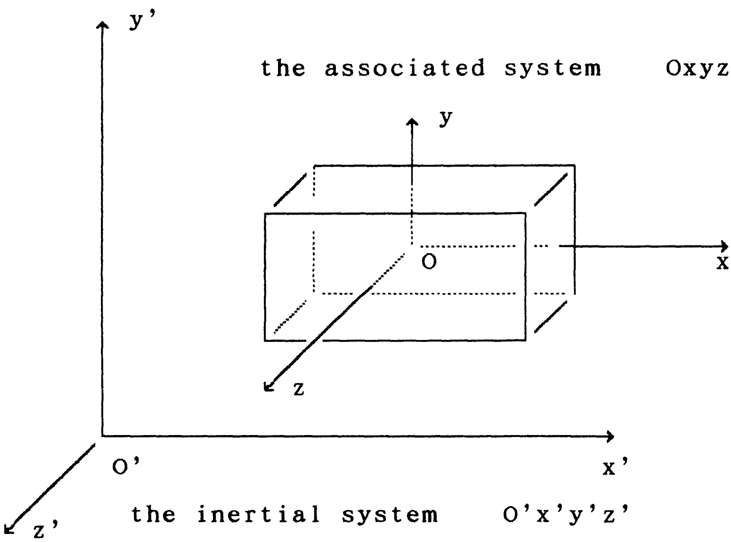

Fig.1. Systems of coordinates for the motion concerned

A certain drive system of a given arrangement X41 V31 used in a vehicle designed and being made by the author was subject to testing [2,5]. The drive system of X41 V31 type consists of four XY plane propellers and three vertical propellers, fig.2; each propeller effects 1/7 of the total thrust.

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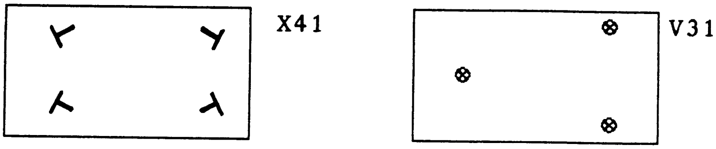

Fig.2. Location of propellers in drive system of the X41 V31 type (seen from the top)

3 SIMULATIONS OF VEHICLE MOVEMENTS AND RESULTS

The simulations have been carried out and the modified program called FREEG.EXE based on the fortran FREE.FOR program was used [6]. The vehicle motion has been simulated in the period of 50 s caused by the following constraints:

- T_x value (the horizontal component of the resultant thrust) according to fig.3;
- T_y = 0 (the vertical component of the resultant thrust);
- constant M_z = 115.5 Nm.

Simulations have been carried out for two values of the metacentric height, h:

- h_1 = 0.20 m,
- h_2 = 0.05 m.

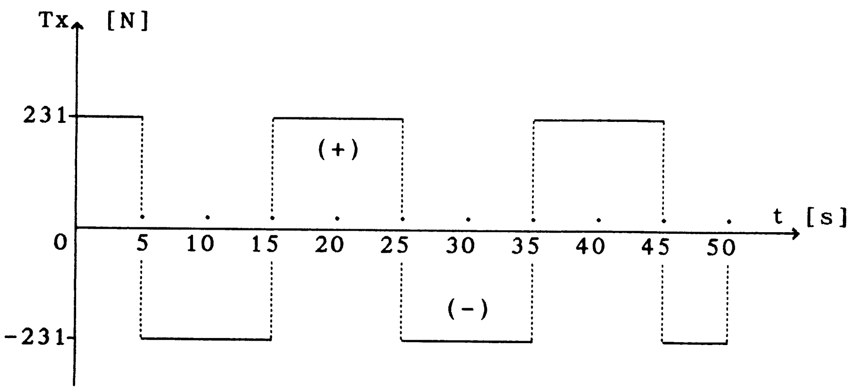

Fig.3. Tx value in vehicle motion simulations

There are following problems investigated:

- sensitivity of adopted hydrodynamic model subject to constraints to a selected drive system, i.e. influence of the metacentric height value on the trajectory;
- influence of an external moment M_z, generated by the propellers, on the vehicle trajectory.

The analysis of results shows that:

- in case of a greater value of the metacentric height h_1 the influence of moment M_z on the vehicle motion trajectory is insignificant due to too low moment values at given vehicle physical parameters. Vehicle performs rectilinear motion along axis x in case of horizontal oscillation motion (T_x changing according to fig.3) and in case of $T_x>0$ acting in the first 5 s, in accordance with expectations;
- in case of a smaller value of the metacentric height h_2 moment M_z affects the behaviour of the vehicle - rectilinear motion along axis x changes to a flat motion shown in figures 4 to 7.

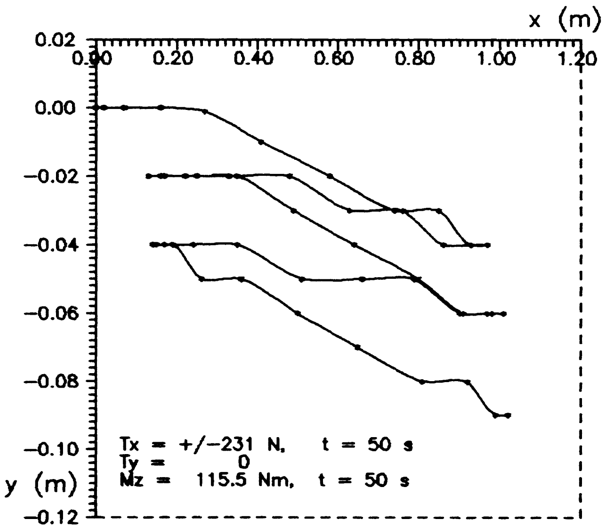

Fig.4. Disturbances of the oscillation motion caused by the moment M_z

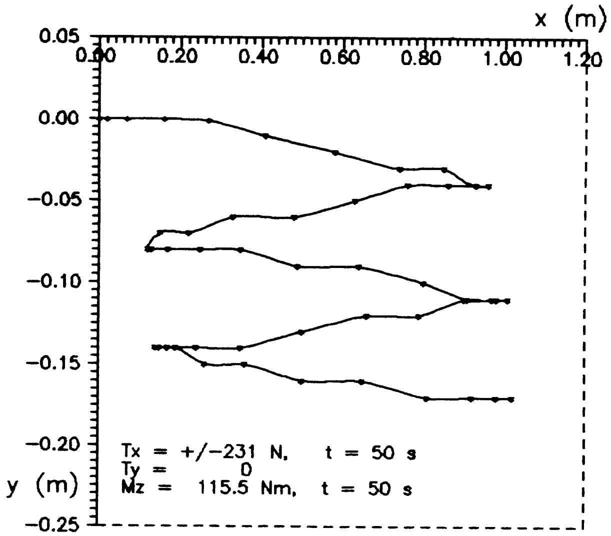

Fig.5. Disturbances of the oscillation motion caused by the moment Mz acting during the first 5 seconds

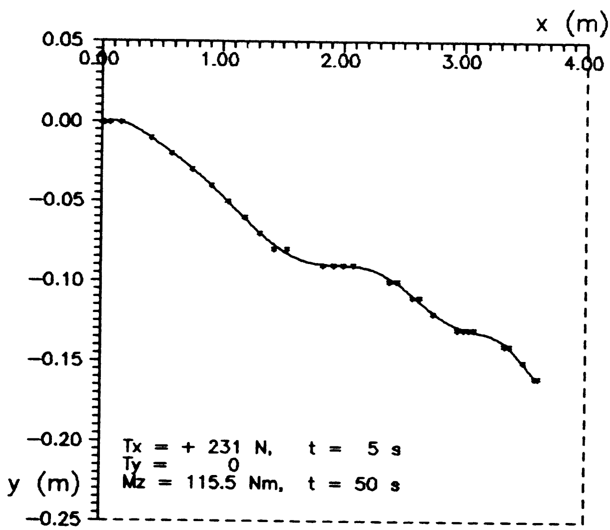

Fig.6. Disturbances of the rectilinear motion trajectory caused by the moment Mz

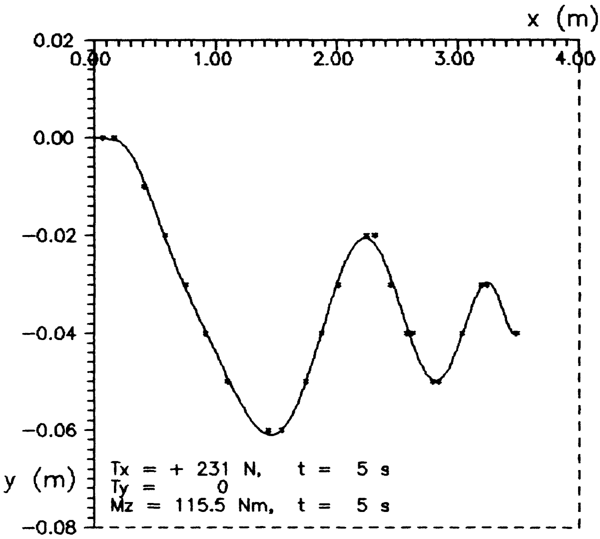

Fig.7. Disturbances of the rectilinear motion trajectory caused by the moment Mz acting during the first 5 seconds

Description of the motion presented in the figures:

- fig.4: Tx and Mz acting during 50 s; there is the motion of 'the leaf falling down';
- fig.5: Tx acting during 50 s, Mz acting during the first 5 s; there is also the motion of 'the leaf falling down';
- fig.6: Tx acting during the first 5 s, Mz acting during 50 s; there is the falling down wave motion;
- fig.7: Tx and Mz acting during the first 5 s; there is the fading vertical oscillation.

4 CONCLUSIONS

Results of simulations show that at small values of metacentric height the motion system should be designed to produce a resultant of the generated thrust without additional moment. It means that resultant thrust vector should act along the line at the centre of vehicle buoyancy. Failure to do so may not guarantee the repeatability of movement while positioning, as the generated turning moment produces additional disturbances for the vehicle movement.

As the analysis of the simulation carried out proves, the model may be useful to define the ROV behaviour and estimate the drive system at the initial designing phase without expensive model tests.

The verification of some properties of the model through basin tests would make it possible to improve simulations to greater extent.

ACKNOWLEDGEMENTS

The author thanks the Research Committee in Warsaw for financial support of the project called "System of Detecting Technical Objects in Depth" within which the paper has been prepared.

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