IDENTIFICATION OF MULTIVARIABLE MODELS OF FAST FERIES

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ABSTRACT

Since the end of the Second World War the shipping industry has focused on using light metal alloys and plastic laminates to create units that are larger and more comfortable for passengers. A striking example of these kinds of ships is the so-called Fast Ferries, used on regular lines for transporting passengers and cars. The construction and exploitation of these kinds of vehicles is a growing market, with over 200 companies using 1,250 fast ferries at present. In 2000 just in Europe, fast ferries transported 82.6 million passengers and 12.8 million cars.

Maritime transport's main competitor is air transport. Consequently, the keen interest shown by maritime passenger transport firms (shipping companies, ship owners and builders) in increasing their competitiveness with air transport is understandable.

One of the most unpleasant disadvantages of maritime transport is the motion sickness suffered by both passengers and crew as a result of the vertical accelerations associated with the induced heave and pitch motions. The decrease as far as possible in this motion sickness will lead to greater comfort and safety. In order to solve this problem using a control algorithm, first of all it is necessary to obtain a mathematical model of the process to be controlled.

There are two very different parts in the process model, on the one hand, the vertical dynamics of the high-speed ship and on the other hand, the mechanical actuators (fins, flaps,...) that will be used to offset the heave and pitch motions.

The vertical dynamics can also be represented by the four transfer functions: G_{1h}, G_{2H}, G_{1P}, G_{2P}, where:

- $G_{1H}(s)$ is the transfer function where the input is the wave height w(m) and the output the heave force F_H(KN).
- $G_{2H}(s)$ is the transfer function where the input is the heave force F_H(KN) and the output the heave motion h(m).
- $G_{1P}(s)$ is the transfer function where the input is the wave height w(m) and the output the pitch moment M_P(KN·m).
- $G_{2P}(s)$ is the transfer functions where the input is the pitch moment M_P(KN·m) and the output the pitch motion p(º).

One possible way of obtaining the four transfer functions of the vertical dynamics of a fast ferry is identification in frequency domain for this it is necessary to have data of magnitude and phase at different encounter frequencies for G_{1h}, G_{2H}, G_{1P}, G_{2P}.

These data were obtained with the numerical simulation program PRECAL, which is based on a CAD description of the hull of the ship to be analysed. This program solves the physical equations of the vertical dynamics of a high-speed ship numerically using the *Band Theory*. This theory basically consists of decomposing the ship's volume into narrow transversal bands on which the non-linear differential equations of the ship's dynamics are solved by numerical integration.

Thus, for identifying continuous transfer functions G_{1h}, G_{2H}, G_{1P}, G_{2P}.of the vertical dynamics of a high-speed ship it is necessary to solve four non-linear optimisation problems with linear restriccions.

In the identification process of the filters G_{1H} and $G_{2H,}$ a hybrid optimisation method has been used formed by a genetic algorithm GA and a classic non-linear optimisation algorithm with restrictions. While in the

identification of the filters G_{1P} and $G_{2P,}$ a pure classic non-linear optimisation method has been used with restrictions.

For the implementation of the classic optimisation part of both methods two algorithms in Matlab were developed: ident_G1 for the identification of G_{1H} and $G_{1P,}$ and ident_G2 for the identification of G_{2H} and G_{2P}.

The difference between the pure method and the mixed method of identification is the choice of the initial values of the parameters to be identified from the transfer function structure used as the model. In the mixed method where a GA is used first and then a classic non-linear optimisation method with restrictions and a considerable calculation time, some excellent initial values are achieved. The initial values are close to the global optimum, so it takes very few iterations for the algorithm of square minimums to reach the global optimum. In the pure method, the initial values are chosen randomly and there is no prior calculation time, so the classic non-linear optimisation algorithm with restrictions requires a greater number of iterations to converge to the global optimum. In fact, it may not even converge or just converge to a local optimum.

Bearing in mind the characteristics of both methods, in the identification process of the filters G_{1P} and $G_{2P,}$ so the pure method was used because the random generation of the initial value of the parameter vector θ was sufficient to achieve the right convergence of the classic non-linear optimisation algorithm with restrictions. However for the identification process of the filters G_{1P} and G_{2P} the mixed method was preferred.

The experience acquired in the identification of the continuous models indicates that in models with not many parameters it is recommendable to use the pure method, because although it uses some random initial values it does not take long to converge to the global optimum, so it is not worth having a calculation time first to obtain good initial values using GA. While in models with many parameters the mixed method is highly recommendable.

The continuous models that have been identified can be considered as good since they fulfil the requirements indicated in the validation process to which they were subjected, i.e., they present a good adjustment in the frequency domain to the amplitude and phase data obtained with PRECAL, and moreover their time simulations both with regular and irregular waves when compared with the experimental time series present a small average quadratic error.