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A Force Allocation Strategy for Dynamic Positioning

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ABSTRACT

A force allocation strategy used in connection with dynamic positioning of ships and semi-submersibels is presented. The strategy dynamically allocates force, and in case of azimuth thrusters - force directions, to a set of thrusters. The strategy handles *n* thrusters ($n \geq 2$) in an arbitrary configuration.
The decision making of the strategy is based on minimum power consumption taking into account effects of reversing thrusters, thruster/hull interaction and partly the effects of interaction between thrusters. The functions of the full allocation strategy is illustrated through a number of examples. Finally the strategy is compared with a more classical allocation strategy to show that significant reductions in energy consumption can be achieved.

INTRODUCTION

Dynamic positioning interpreted as an automatic control of the horizontal position and the heading of a vessel may be applicable in a number of fields within the maritime industry. One such example is the docking of a ferry and more directly related to the present development is positioning of a drilling platform/vessel. In both cases the horizontal position and heading of the platform or vessel shall be controlled. The precision required to the positioning of an offshore structure yields quite a challenge. It is therefore necessary to be assured that the most efficient use of the thruster capacity is acquired.
In general terms the problem has three constraints, the desired position and heading. With a ship or semi- submersible platform utilising more than two thrusters or combinations of propeller/rudder and thrusters more than three parameters are available to adjust the control of the position resulting in an mathematically underdetermined problem. Often this problem of having an under-determined system is solved by allocating individual units to perform a certain task i.e. azimuthing thruster in the bow of a FPSO are allocated for heading control and consequently provides only a side-force near the bow.
From the point of view of the control system involved in a DP system, dynamic positioning is challenging. Mainly due to the stochastic nature of the disturbances to the state of the system. However, this topic and the related problems of control theory has been treated thoroughly before by several authors. A specific treatment of the force allocation problem in connection with a DP system for a semi submersible has been given by Moberg S. and S.A. Hellström (1983). In their work the dynamic allocation of thrust forces, but not directions are considered.
The present paper concentrates on the problems associated with realising the forces required to counterbalance the position disturbances, i.e. the force allocation. A force allocation algorithm based on a minimum power consumption strategy is describe in detail. To the best knowledge of the authors only Brink, A.W. and J.S. Chung (1980) have considered specifically an optimum strategy for the force allocation it self. They, however touches upon the subject only very briefly.

In the present paper *n* thrusters in an arbitrary configuration are considered. Each thruster being represented as a force and a force direction, both of variable size. The basic idea of the developed strategy is a dynamically adjustment of these variables such that the force demands are met in such a way as to minimise the total power consumption required to run the system.

THE ELEMENTS OF THE DYNAMICALLY POSITIONING SYSTEM.

Before continuing the development of the force allocation strategy we will, however, take a brief look at the components of a DP-system. The complete DP-system may be divided into the four main parts:

- State Estimator module
- Controller module
- Wind Feed Forward module
- Force Allocation module

The function of the State Estimator module is to estimate the states of the surge, sway and yaw motions by filtering the measured positions obtained from a position device. From measurements of the wind, the Wind Feed Forward module computes a compensation for the wind generated forces and moments on the vessel. This wind compensation is added to the output of the position control. The horizontal position and the heading is, in the Controller module, controlled by three mutually de-coupled state feedback controllers using the state estimates from the three state estimators to command the desired force and moment (F_X, F_Y, M_Z). Finally in the Force Allocation module a combination of thruster forces and azimuth angles is determined such