NONLINEAR DYNAMICS IN OCEAN ENGINEERING

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The international trade rests to a very large extent on maritime traffic and further growth is predicted. This growth will result in a rapid increase of ship size and the number of ships. The utilization of the oceans will be similar in the long-term. It is expected that the growth in maritime traffic and of offshore installations will cause increasing pollution as well as growing risks for humans and goods at sea. Economical and environmental risks are important, of course, but much more important is the danger to human life. From statistical data we learn that at least one third of total ship losses are due to severe weather conditions. Moreover, serious accidents of oil platforms in recent years have lead to losses of human lives and caused large environmental pollution. We observe, therefore, a growing interest in the improvement of safety measures and criteria in order to keep the risks as small as possible. In the following we will concentrate on floating structures in naval architecture and ocean engineering.

The current regulations and criteria for assuring the stability of a ship and preventing from capsizing (the so-called *prescriptive rules*, see the codes of the International Maritime Organization (IMO) [1]) are empirical and based on the properties of the righting lever of the ship, taking only hydrostatic restoring forces into account. Model tests show, however, that the current stability criteria do not always correlate with the danger of capsizing. The static criteria which neglect the motion of the ship (or only consider the motion in an implicit or very approximate manner) as well as the impact of seaway and wind do obviously not guarantee total stability. Hence, researchers agree that those criteria have to be modified. The IMO is working, therefore, on *performance based rules* which apply to a specific ship.

In order to analyze capsizing due to waves hydrodynamic models of the ship-sea system are necessary, by describing the sea as a (random) field and by analyzing the ship as a rigid body with six degrees of freedom using methods of nonlinear dynamics. Model tests can provide insight into the nature of capsizing, too, but they are quite expensive and do not allow for highly sophisticated analysis, unlike mathematical models.

In the past several computer models have been developed. Because of the complexity of the capsizing problem, they were used to evaluate statistical properties. The probability of the capsizing was estimated and heuristic arguments were used to interpret this probability and to derive stability criteria. More advanced analysis techniques were recently applied to simple single-degree-of-freedom and regular wave excitation models and with few exceptions to more complicated computer models. These techniques are based on nonlinear dynamics theory. Using them, it is possible to locate stability boundaries. The state of the art of (deterministic as well as stochastic) ship models has been recently very well documented in the Theme Issue of the Philosophical Transactions of The Royal Society London (series A) entitled “The nonlinear dynamics of ships”, edited by Spyrou and Thompson [2].

Floating offshore structures are usually held in position by means of mooring systems, which have, depending on the purpose of the structure and the water depth, different levels of complexity. Mooring lines might consist of a combination of chains and cables like spiral strands. Submerged buoyancy tanks might also be used along the mooring lines.

For a realistic motion analysis of floating offshore structures it is inevitable to take all these different properties into account. It is presently common practice to use rather simple models based on a quasi-static approximation for the mooring systems to describe the interaction between the motion of structures and the restoring forces. These simplified models disregard the dynamics of the mooring line including the interaction between the fluid and the line. They also do not consider that the position of a line, which is in contact with the sea bed, varies with respect to time. For lines in deep water, these effects may cause a tremendous increase in the tension force, which cannot be predicted by simplified models.

Under operational conditions an offshore structure and its compliant mooring system is subjected to a variety of environmental nonlinear forces, e.g. current, waves second-order drift forces. Therefore, it is mandatory to determine the dynamics by means of precise mathematical models.

This sectional lecture is intended to discuss some of the latest ideas of nonlinear dynamics of floating marine structures under wave excitation. We start with the discussion of the ship stability assessment based on conventional and modern approaches. In order to determine whether or not a marine vehicle will be capable of maintaining a stable stationary and upright position, it is necessary to examine all forces which act on the vehicle. Therefore, the modeling of freely floating bodies will be presented in detail. Moreover, the modeling of moored systems by means of a multibody systems approach is described such that the prediction of the complicated dynamics is visible. In order to explain the analysis procedure, three important examples from marine technology are considered, the dynamics of ships, a moored platform, and of crane vessels. The nonlinear dynamic responses to waves are investigated theoretically and experimentally. The main subject of interest is the appearance of nonlinear phenomena like bifurcations and the existence of multiple attractors.

References

[1] International Maritime Organization. Code on intact stability for all types of ships covered by IMO instruments. Resolution A.749(18). London: IMO, 1995.

[2] Spyrou, K.J.; Thompson, J.M.T.: The nonlinear dynamics of ship motions: a field overview and some recent developments. Phil. Trans. R. Soc. Lond., Series A (Theme Issue). The Royal Society, 2000.