RISK FORECAST SYSTEM FOR MOORED SHIPS

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ABSTRACT
Port terminals downtimes lead to large economic losses and largely affect the port's overall competitiveness. In the majority of cases, port activities such as ships' approach maneuvers and loading/unloading operations, are conditioned or suspended, based solely on weather or wave forecasts. These forecasts do not always result in effective hazardous conditions for the ships. Additionally, moored ships often experience problems of excessive movements and mooring forces in apparent good weather conditions. If, instead, one could forecast the ships' movements and mooring forces, risk assessment would be much more accurate. This would allow selecting an appropriate reinforced mooring arrangement and thus minimizing effective terminal downtime.

In this paper, the development of a risk forecast system for moored ships, that takes into account all of the moored ship's system, is detailed and an illustration on how it applies to real ports is presented. The system was first developed to the Praia da Vitória Port (Pinheiro *et al.* 2018), followed by the ports of S. Roque do Pico and Madalena do Pico, in the Azores archipelago and is now being developed for the port of Sines, Portugal.

The system consists of four modules:

I. Waves characteristics - Forecast (72 hours with a 3-hour interval) sea-wave characteristics offshore, together with regional wind forecast data and astronomical tidal data, are used as inputs to a set of numerical models to determine wave characteristics inside the port. SWAN (Booij *et al.* 1996) 3rd generation spectral modelfor modeling non-linear wave generation and propagation and BOUSS-WMH (Pinheiro 2007) Boussinesq Wave Model for Harbours for a more accurate description of sea states evolution into varying-depth sheltered regions by taking into account refraction, diffraction, partial reflection and nonlinear interactions as well as energy dissipation due to bottom friction and wave breaking;
II. Port operations – Wave effects in terms of excessive vertical movements of a maneuvering ship that enters or leaves a harbor basin or in terms of forces on mooring lines and fenders as well as of motions of a ship moored at a quay, are determined using numerical package MOORNAV (Santos, 1994), which includes: WAMIT hydrodynamic panel method numerical model (Korsemeyer *et al.* 1988) for the assembly of hydrodynamic response from the radiation and diffraction problems and BAS (Mynett *et al.* 1985) time domain solver of moored ship motion equations taking into account external forces such as incident sea waves, wind, currents and mooring system elements;
III. Risk assessment - Comparison of the relevant variables computed values with pre-set maximum values and probability assessment of exceedance of those values results in a risk level assessment;
IV. Warning system. Based on the forecasted risk level, corresponding warnings can be issued. Emergencies and port operations disruptions can be mitigated.

This modular system can be tailored to any port, providing decision-makers with accurate and complete information on the behavior of moored ships, movements and mooring loads, allowing them better planning and integrated management of port areas.

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