Vulnerability and risk assessment of ship structures via a Bayesian network model

Hyun-Joong Kim*, Rainer Hamann†, Jörg Peschmann† and Daniel Straub*

* Technische Universität München (TUM)
Engineering Risk Analysis Group
Theresienstr. 90, 80333, Munich, Germany
e-mail: hj.kim@tum.de, straub@tum.de

† DNV GL SE, Hamburg, Germany
Brooktorkai 18, 20457, Hamburg, Germany
e-mail: rainer.hamann@dnvgl.com, joerg.peschmann@dnvgl.com

ABSTRACT

The EU research project SAFEPEC develops a risk model for prioritizing ships for inspection. The risk model consists of four sub-models: *cause, vulnerability, consequence* and *inspection*. These models are based on readily available information, such as ship type, ship size, Class, operational conditions. This enables a fast risk assessment of a larger number of ships, even if only limited information is available on some or all of these ships. A Bayesian network (BN) framework is selected to incorporate the sub-models into a single integrated risk model. It also facilitates the updating of the risk whenever new information is available, e.g. through inspections of parts of the ship.

In this contribution, we focus on the development of the vulnerability model. Its objective is the quantification of the effect of deterioration (corrosion, fatigue) on ship safety in terms of the probability of a set of failure modes. To comply with the overall objective of the project, the model is set up in a generic manner, with parameters that are related to readily available information a fleet level (the *indicators*). Although each ship has its specifics, key characteristics of the ships are fairly uniform over a wider range of vessels. For example, most ships of the same type are designed with a similar utilization factor. The indicators are determined by consideration of their availability, statistics of the relevant parameters as well as expert/engineering judgment. On this basis, representative ship models are selected, which are parameterized by the indicators and quantities that can be (probabilistically) related to the indicators. The selected models are used to estimate the variation of structural capacity in function of the deterioration state, e.g. corrosion depth, fatigue crack length. Response surfaces are built to obtain a computationally efficient function, linking the indicators to the structural capacity of the vessel. To compute failure probabilities, the identified resistance model is combined with a stochastic load models, which also utilizes readily available ship information. The models are incorporated into a BN, which facilitates (1) the construction of a large probabilistic model that jointly considers multiple deterioration mechanisms, failure modes and consequence scenarios; (2) the straightforward inclusion of new information and data over the lifetime of the ship, e.g. from inspection and operation; (3) the communication of the model to non-experts.

Exemplarily, this contribution presents the generic vulnerability model for container vessels. The response surfaces describing the ultimate moment capacity of mid-ship cross sections are presented. They take as inputs indicators such as ship type, size, and TEU. We demonstrate how the calculated failure probabilities allow to rank different ships as well as different sections in each ship with respect to inspection priority. Additionally, we show how new data and inspection results affect the probability of failure. Ultimately, the vulnerability model provides improved understanding on the probability of incident occurrence based on limited information and in this way supports the inspection and maintenance planning.