Lower steel weight with nonlinear analysis

Structural engineer, Ville Valtonen, has investigated how to improve safety in high ice class vessels while simultaneously reducing the amount of steel needed using nonlinear analysis methods.
The benefits are lower costs, easier production methods and environmental benefits.

The International Association of Classification Societies (IACS) Polar Class rules divide the hull structure analysis into two parts: shell plate and frames (secondary structures) and stringers and web frames (primary structures). The secondary structures are designed with rule equations, which are based on the plastic capacity of the structure. The primary structures are typically designed based on linear elastic analysis, as it is a straight-forward and well-established practice.

Imbalance in structures

Experience has shown, however, that using linear-elastic analysis methods to design primary structures in ice-going vessels often leads to an imbalance between the primary and secondary structures, particularly in high ice class vessels. The imbalance is seen as excessively heavy primary structures compared to the shell and frame structures. Furthermore, new vessel designs produced using linear techniques differ significantly from successful designs with proven track records in Arctic operations.

Nonlinear analysis methods provide an alternative for designing primary structures. To investigate the potential benefits of nonlinear methods, Ville Valtonen, Structural engineer at Aker Arctic, compared designs produced using linear and nonlinear tools for both low and high ice classes.

Less steel

The results of the study show that for low ice class vessels (PC6) the weight difference between structures dimensioned based on linear and nonlinear analysis is insignificant. However, for a high ice class vessel, typically PC3 and above, the nonlinear calculations provide significant reduction in the scantlings of primary structures, thus significantly lowering the steel weight for the vessel. For medium ice classes, the usefulness of nonlinear calculation depends on how weight-critical the vessel is.

Furthermore, nonlinear analysis improves the safety of the structures since it provides the designer a better understanding of the failure modes of the structures and the design margins in overload situations.

“By using nonlinear methods, the structures are more balanced, and steel weight is significantly reduced, therefore saving money and the environment,” Valtonen highlights. “My calculations also show that the structures reflect older high ice class vessels, which have a proven track-record of safety in ice, thus confirming the results.”

Valtonen presented his research at the 25th International Conference on Port and Ocean Engineering under Arctic Conditions (POAC 2019) in the Netherlands. ■