Hull-Structure Damage and Future Consequences

Forensic Analysis

Forensic analysis of hull-structures, after damaging events, can provide critical data and assist in the determination of necessary actions to ensure future safety and feasibility of company assets. Such analysis can also be requested to see exactly what took place to bring upon the damage, how to fix the damage, as well as placing blame on a party at fault. The following information is pulled from work conducted on the side shell of a converted double-hull floating ship-shape structure, damaged in multiple locales, while in transit to its work site.

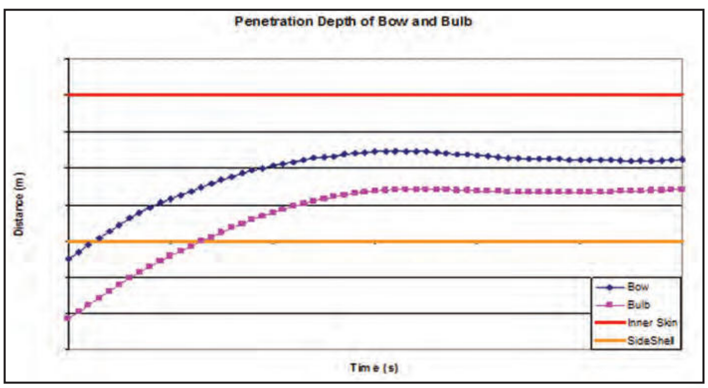
In order to conduct successful advanced analysis in a forensic case, provider of services must obtain the ability to assess and interpret the situation and data with both a quantitative and qualitative approach. To begin advanced analysis for such situations there are many factors to take into consideration; vessel type and size, work site environmental conditions, original design life expectations, nature of operations for the structure, class society designation, etc. The FEA damage assessment can be performed on local FEA models created in way of the areas of interest. Areas of interest are the most severely damaged areas from the damaging incident, as these findings will generate the most conservative answers for an owner and operator.

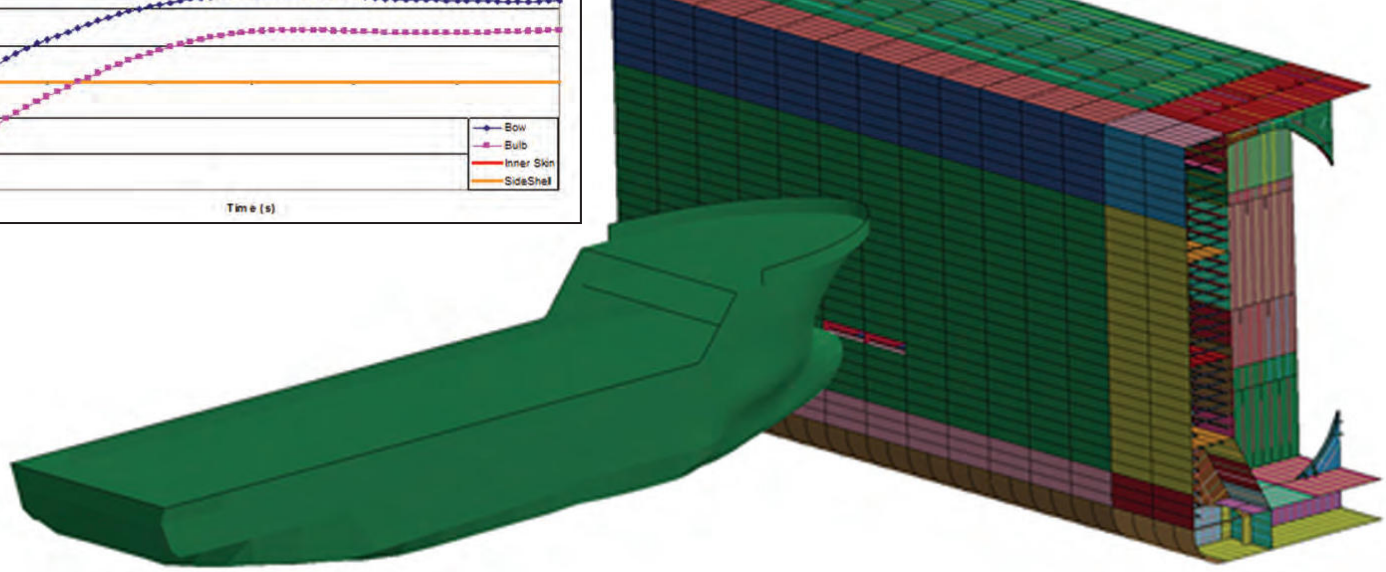
Models of both the original as built configuration and the damaged shape configuration are loaded with the original class-required conversion loads, damage-specific DLA cases designed to maximize the global and local load conditions, as well as our intuitive knowledge gained through our history of operation as an engineering support services company. Performing a spectral fatigue life calculation is also critical to show the new minimum fatigue life values for the areas of interest. Generating these values using both at conversion and end-of-life scantlings gives the conservative answer as to whether the vessel can still function on its last planned day of service – as previously decided at construction or conversion. The specific vessel focused upon in this editorial is one that is in service in a benign environment, giving the owner a wider range of options when deciding how to handle the damage and generate a solution for moving forward.

To provide further insight to the change in global hull strength and shear force, a midship section was modeled to determine the change in hull girder ultimate strength by comparing the strength in the as-built configuration and damaged configuration by eliminating the damaged members from the calculation of overall hull girder section properties. The still water allowables for vertical shear force are determined to calculate the total shear force capacity of the hull structure, and calculates the still water allowables by subtracting the wave induced load component. This analysis concludes the impact of the dent on the shear flow through the global structure, and the impact on the total shear force capacity of the hull structure.

For this specific side shell case, away from the area of interest, primary stiffeners and minor panel breakers are modeled with beam elements with cross-sectional moments of inertia modified to account for the effectiveness of the associated plating. Material properties, such as mild steel and any high-tensile steel in the surrounding structure are also modeled.

As it pertains to the FEA loading description for both class required cases and additional cases, the initial analysis of the damage to the vessel side shell has been completed using the original





design load cases developed for conversion analysis. Also, new dent-specific DLA cases have been created to maximize the global load components in way of each of the damage locations. The full global hull FEA model has been solved with these new load cases. The local fine mesh models have been loaded with the resulting pressures and enforced displacements from the global model. Additionally, new damage heel cases were developed to investigate the effect of the additional hydrostatic pressure on the dents. These specific cases have been selected as most likely to produce the greatest hydrostatic pressure at each dent location due to vessel pitch and heel.

Conducting fatigue life assessment consists of the calculation of fatigue damage from the past wave induced stress ranges resulting from the vessel history prior to conversion, the damage accrued along the transit route to the operating site, and the expected fatigue damage from desired design life in its operating environment, as well as damage resulting from the on and off loading of the vessel's operating purpose (if applicable). As previously mentioned, it is typical to use site conditions that are all corroded to the end-of-life scantlings - ensuring the most conservative results. The local fine mesh model of the damaged side shell, in their respective locations, were analyzed for fatigue using the element centroidal stress results from the elements in way of the areas of interest and the detail specific S-N curves.

Within Viking's structural assessment software suite, SAGA, there is a crack growth program integrated that performs a fracture mechanics analysis on the most highly stressed locations of the damaged structure to determine the likelihood a crack will grow to critical length. The crack propagation analysis was performed on two locations within each of the areas of interest, chosen as the worst location for fatigue in the side shell and side shell longitudinal in way of the dents, and the worst location for fatigue at the transverse web frame cutouts in way of the dents. The crack propagation analysis showed that the probability of a crack in the side shell plating or side shell long growing to critical length is low. However, a crack developing in the web frame plating in way of the long stiffener cutout at the dented area may become critical within the design life of the vessel. As a service provider for forensic analysis, this conclusion leads to the recommendation to increase inspection frequency by a specific period of time to ensure continued vessel safety and avoid any downtime.

To approximate the effect of the residual stresses remaining in the dented steel from the original impact, a nonlinear impact analysis was performed. To the best ability, a similar shape of the projectile was modeled and the impact was recreated using the same mass, moving at a velocity calculated to deform the side shell plate to approximate the observed dent depth. It is not feasible to exactly match the dent depth observed in the original 3-D laser reports, due to the size and shape of the projectile chosen for these tests. Failures begin to occur in the side shell plating as the corners of the coarse-meshed projectile contact the side shell. The determined factors allow for interpretation of the stress locked in the structure, which will work its way out over time – relieving itself of the pressure can also help give an indication of how fast a crack could grow if one were to appear.

Experience in such advanced forensic analysis cases is key to prevent future pain and expense for owner and operators of maritime assets. An approach both quantitative and qualitative, while acting as doctors for vessels, leads to the most accurate diagnosis.

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