CHALLENGES OF A LARGE TURNKEY TRANSPORT PROJECT
PART 1

WRITTEN BY LINDSAY MCDOUGALL
TECHNICAL DIRECTOR, MALIN ABRAM

Transporting the blocks for something as large as the Queen Elizabeth class of aircraft carriers from build yard to integration yard is always going to be technically challenging. The same applies for any large transportation project where cargo is split into diff erent types, sizes and weights. If there is more than one load out location across the project then the level of complexity increases further.

Carrying out these types of turnkey transport projects requires the incumbent heavylift engineer to carry a whole range of skill sets encompassing hydrodynamics, stability analysis, FE analysis (see page 15), lifting plans, stow plans, 3D draughting, float off studies, towage analysis and mooring design in order to meet that challenge.

Getting the required information flow into a project of this size can also be challenging. The ability to source, collate and understand the technical details of the cargo, carrying vessels, ports, yards and handling equipment is an essential skill that a heavylift engineer also requires. Using the Queen Elizabeth class details as an example, which can be repeated for other complex transport projects, we have a typical range of:

- Lightest Cargo – 10 Te
- Heaviest Cargo – 11,337 Te
- Smallest Cargo - 8 x 4 x 5m
- Largest Cargo - 85 x 40 x 23m

Therefore the level of checks and engineering required across such a diverse range, varies from standard empirical seagoing force checks and lashing calculations to full motion response studies and FE analysis.

An example of the type of FE analysis a heavylift engineer might be asked to undertake is one that contains both cargo and carrying vessel. Once cargo reaches a certain size in relation to the carrying vessel, understanding the interaction between the two starts to become critical. Simplifi ed assumptions such as making the deck supports fi xed or springs start to become harder to justify. Th e clearest way to check this interaction is to build a detailed FE model of both the cargo and the barge, along with the supports and seafastening, to ensure that the load paths and reactions are fully captured with minimum assumptions. This can result in models of hundreds of thousands of elements. Even with the computers and software currently at the disposal of a heavylift engineer, these models can still take a long time to solve, especially if there are non-linear elements involved.

Having the right soft ware at your disposal can aid this process dramatically. If the software has a visual indicator of convergence it allows engineers to tell at a glance if modelling is going to solve or not (see page 14). With run times stretching into 12 hours or more this can be indispensable as it allows the engineer to cancel runs early if trends show the model is unlikely to converge.

Heavier loads will often push the cargo and

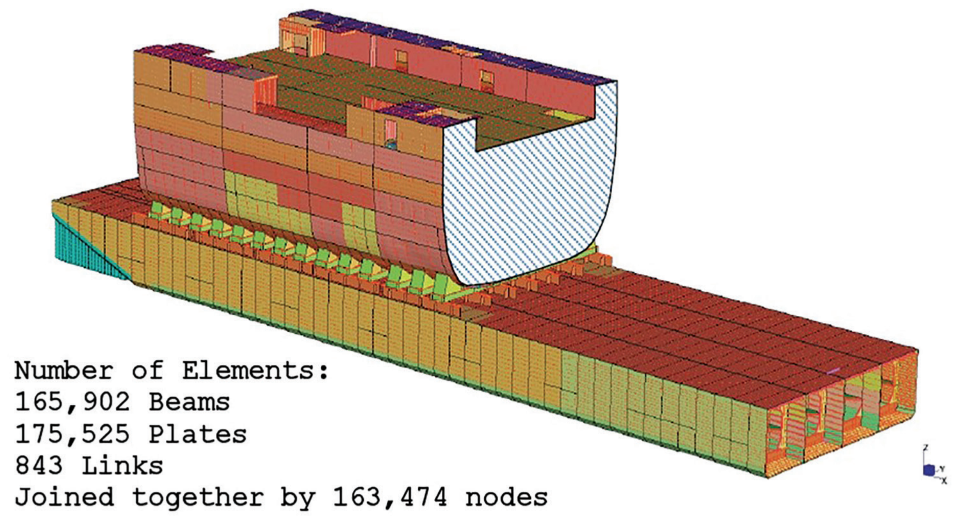

fig. 04/ FE model plot showing full model

the marine plant to its limits. So normal design input and assumptions can oft en be too limiting. A pragmatic client and/or warranty surveyor will recognise this and will be willing to accept reductions where justification is given. For example, trying to justify the cargo and barge for accelerations associated with a maximum forward speed in a "worse case" design wave is overly conservative. The tug and barge would not be capable of making forward progress in such a sea state, nor would you want it to, so a more pragmatic approach is to use zero speed accelerations for input into the FE analysis.

It is not always the size or weight of the cargo that represents a challenge. If the cargo is to be floated on or off then the geometry is an important factor as well. Floating cargo will lend its stability to the barge during float offs but if the cargo has an unusual geometry, as in the case for ship sections, this may not happen at the stage you want it to, leading to issues with the stability overall. To ensure stability it may be required to fit additional buoyancy. This can come in the form of temporary buoyancy boxes, either on the cargo or the barge. Float offs have to be designed in a very systematic manner and time steps between calculated stages must be sufficiently fi ne to ensure stability is acceptable during the whole float off operation. If the stages are not sufficiently granular then a minimum stability condition may be missed.

Smaller cargo is also not without its trials. The challenges can be different but no less interesting. Often it would not justify the

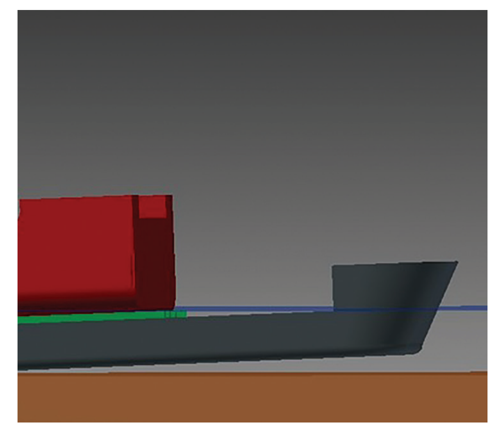

fig. 05/ float off screen grab

WHAT IS **CONVERGENCE?**

Where an FE model has non-linear elements or the engineer expects large deflections, the solution will require a large number of iterative steps to accurately predict the structural response. This is because, as load is applied, the response of the model may change significantly. To accurately model this, a single load case is broken down into a series of sub steps where the final load is "stepped" into the structure. Th eend result of each individual load case then forms the starting point of the next, slightly greater one. Convergence occurs where the model deflects or reacts only marginally between one load case and the next and the model "settles" into a final solution. If there are large changes in displacement or force then the solver will insert additional, finer load steps until the model displacement and force is within the specified tolerance (convergence) or remains out with the tolerance (no convergence).

WHAT IS **FINITE ELEMENT ANALYSIS (FEA)**

Finite Element Analysis (FEA) is a computer modelling tool that allows engineers to determine the stress and strain on different materials. The software works by breaking a structure down into smaller elements and determining the displacement on each one based on the input forces and boundary conditions. Once the displacement is known the stress can be determined from that. There are several diff erent types of elements available in computer analysis ranging from beams to plates and bricks. Some software offers advanced analysis such as non-linear material properties. One example of this is timber cribbing, which has a couple of non-linear properties. It only works in one direction and the stress vs strain curve is not a straight line. Therefore the model has to run several iterations until it reaches a balanced solution.

fig. 06/ 12000 Te mid-body section of Aircraft Carrier towing under Forth Rail Bridge

level of engineering analysis discussed above so the use of default motion criteria is standard practice. However, the default criteria, by its nature, is fairly conservative. Sea fastening design and deck strength justification starts to become problematic as the cargo weight increases. Diligent engineering is required and on site checks need to be robust to ensure technical requirements are put into practice. For example, if a design assumption is that the cargo needs to be supported across 5 transverse frames then the stowage on the day needs to be surveyed to ensure the cargo is bearing on all 5 frames.

Small barges can often present more difficulties than large ones especially in terms of load outs and load ins. To minimise project cost and availability pressures it is normal to try and use the smallest barge feasible, resulting in coming alongside quays that are not really designed with small barges in mind. The challenge here is to ensure that there are lots of reserve to account for cut in tide, weight discrepancies and slack water and to have ready-made back-up plans as a contingency.

With respect to quaysides it is not only the quay height that sometimes presents a challenge to a heavy lift engineer. Load outs will often happen at quays that were not designed for RoRo operations or, if they were, then for loads perhaps much smaller than you are now planning. Th is, coupled with ageing infrastructure, oft en raises greatest issues with site services, ground capacities and in particular, the mooring points themselves. Oft en mooring points will not have SWL or MBL marked on them and the heavylift engineer needs to be fore-armed with this information so that they can arrange testing and adjust their designs to suit. Snatch-blocks can be used to reduce loading into an individual mooring point, if others are available to take a share of the load. Counterweights can be used as an alternative if bollards are unsuitable or not present. The Heavy Lift Engineer knows that "Everyday is a school day" on big transport projects and only by facing challenging problems and solving them can an engineer develop.