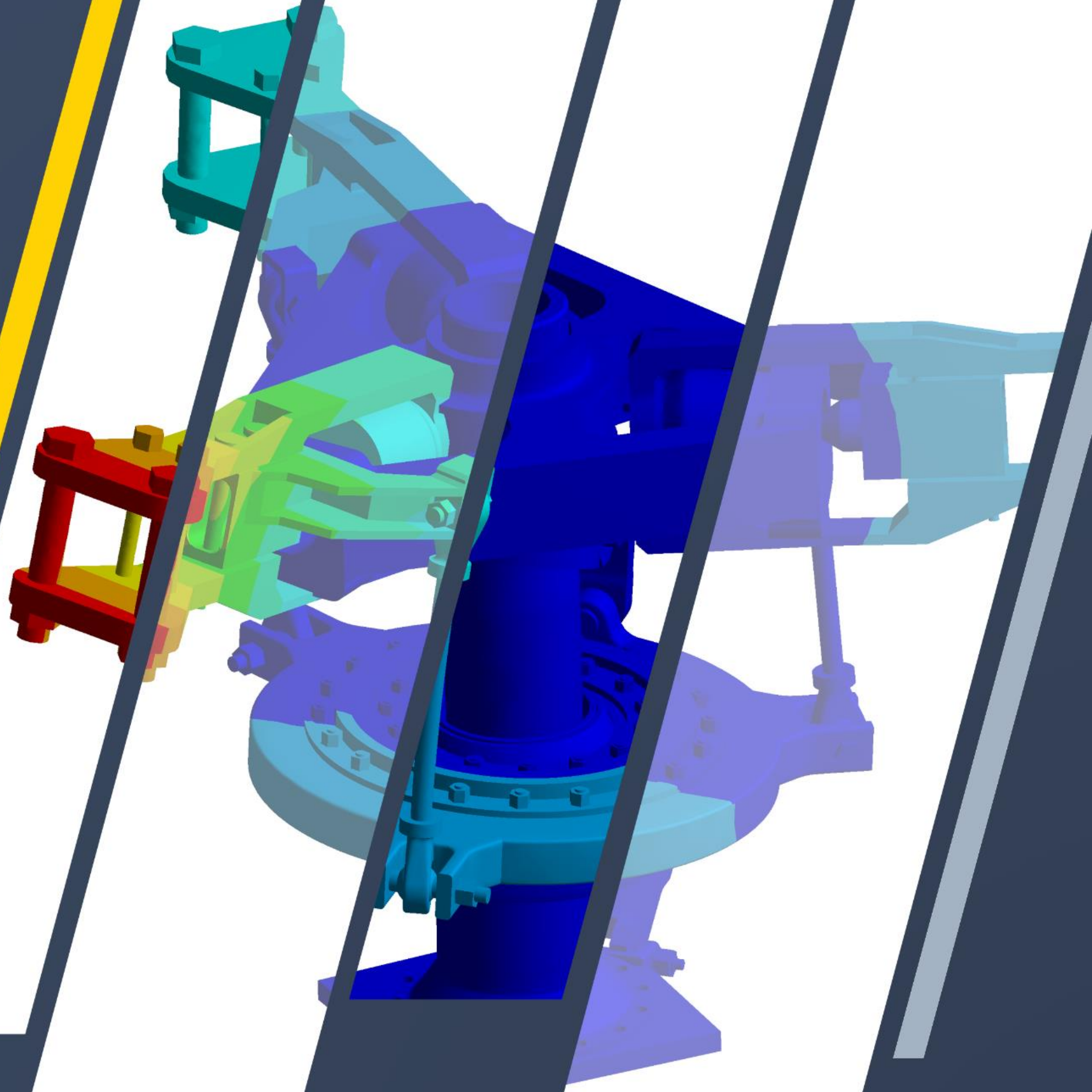
Module 01: Modeling Ocean Waves

ANSYS Mechanical Ocean Loading

Release 2020 R1



Module 01 Topics

1. Ocean Waves Modeling
2. Slender Body Wave Modeling
3. Large Body Wave Modeling
4. Solutions for Complex Ocean Environments
5. Scope of this training course
6. Workshop 01.1 – Jacket Structure

01.1 Ocean Waves Modeling

- Wave loading effects on offshore structures is a critical design feature for both strength and fatigue performance
- Design requirements vary depending upon the type of structure being designed

DNV Recommended Practice discusses four loading conditions

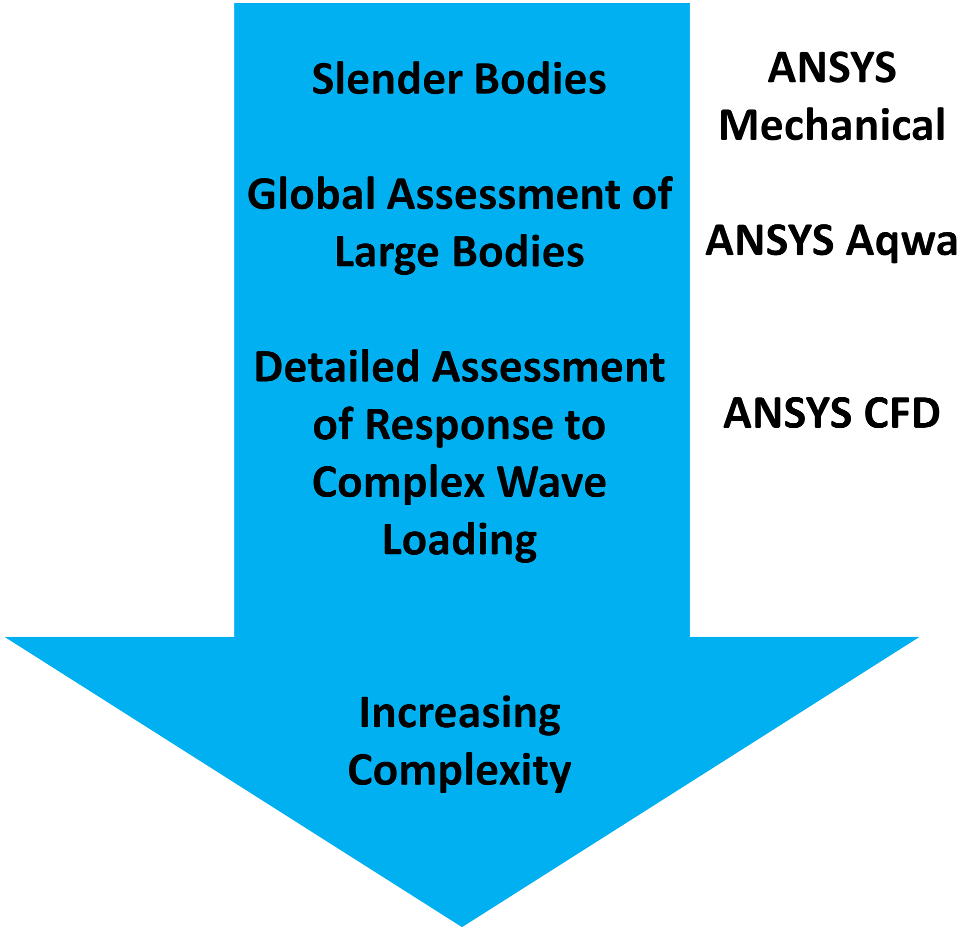
1. **Slender Members**
2. **Large Volume Structures**
3. **Air Gap/Slamming**
4. **Vortex Induced Motions**

DNV

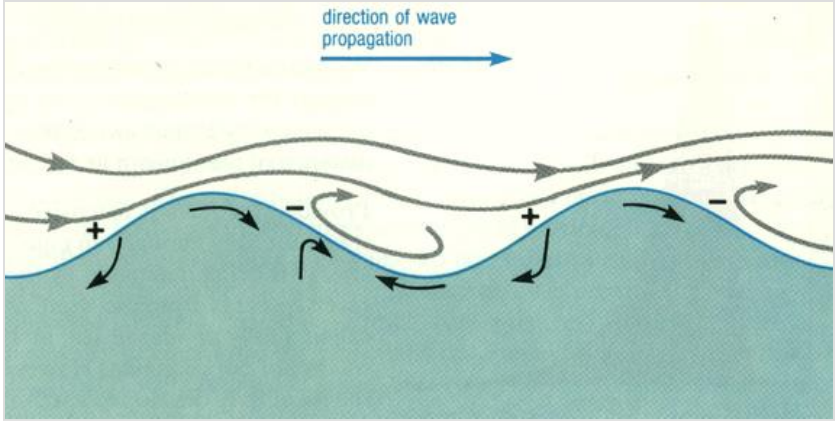
RECOMMENDED PRACTICE
DNV-RP-C205

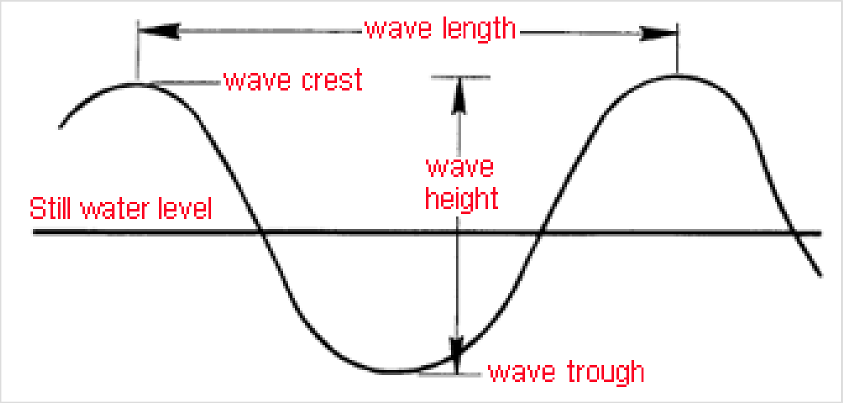
ENVIRONMENTAL CONDITIONS
AND ENVIRONMENTAL LOADS

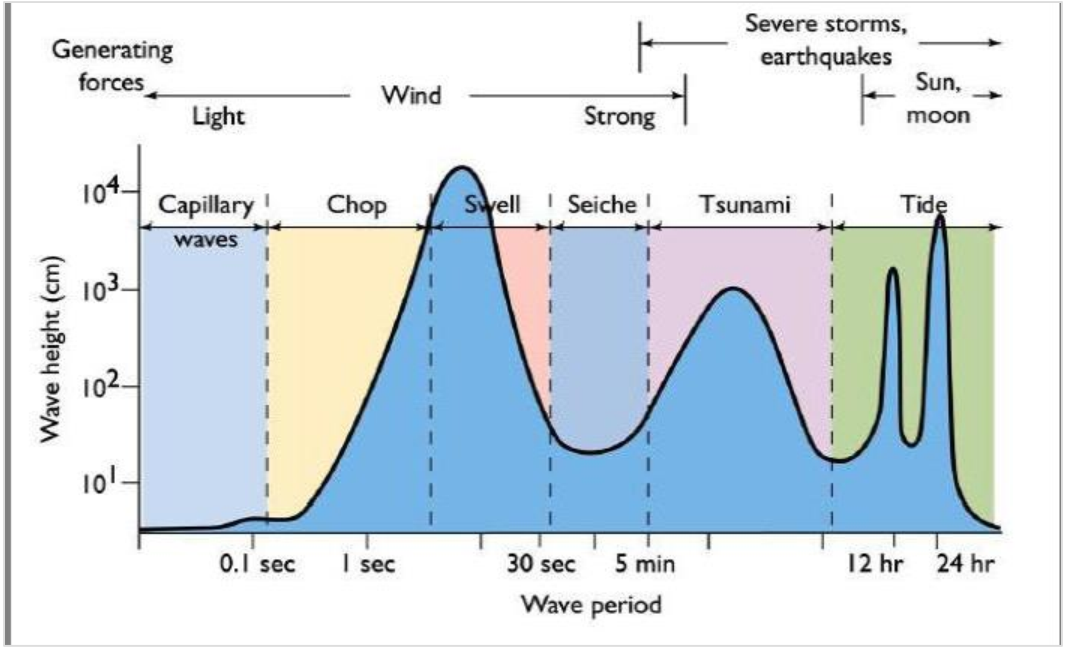
OCTOBER 2010



01.1 Ocean Waves Modeling



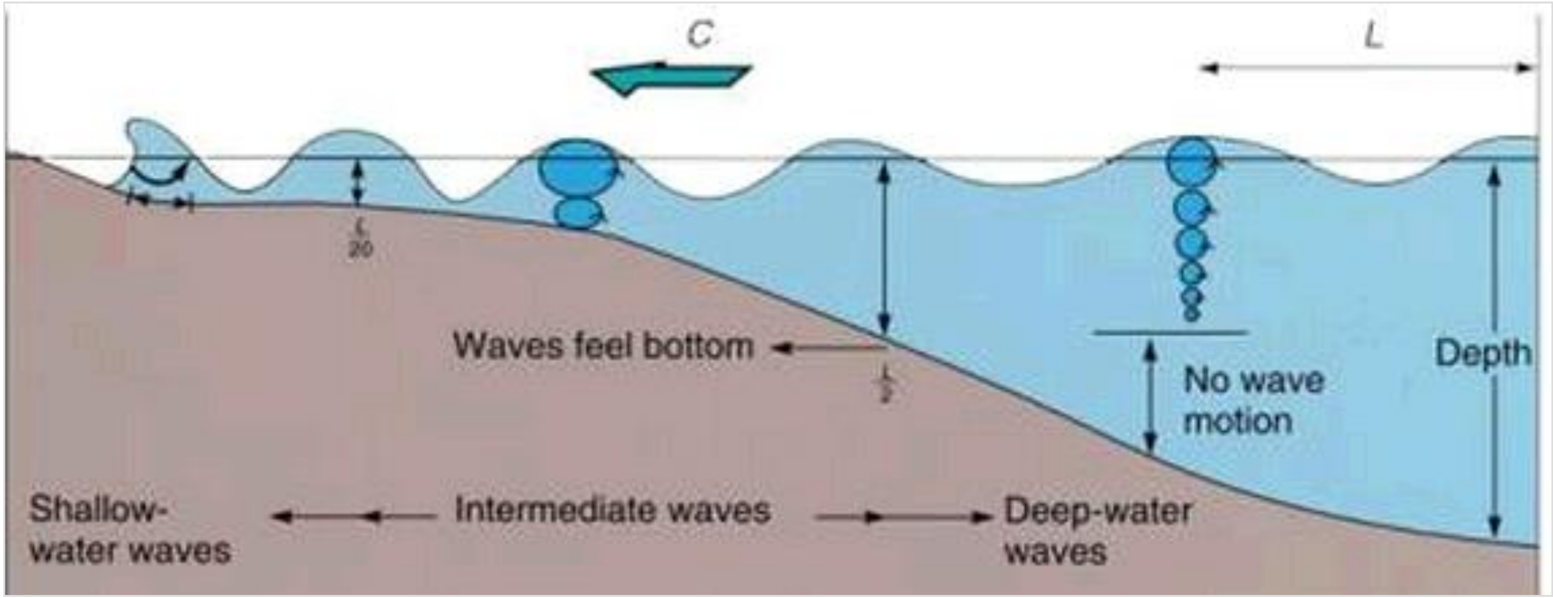




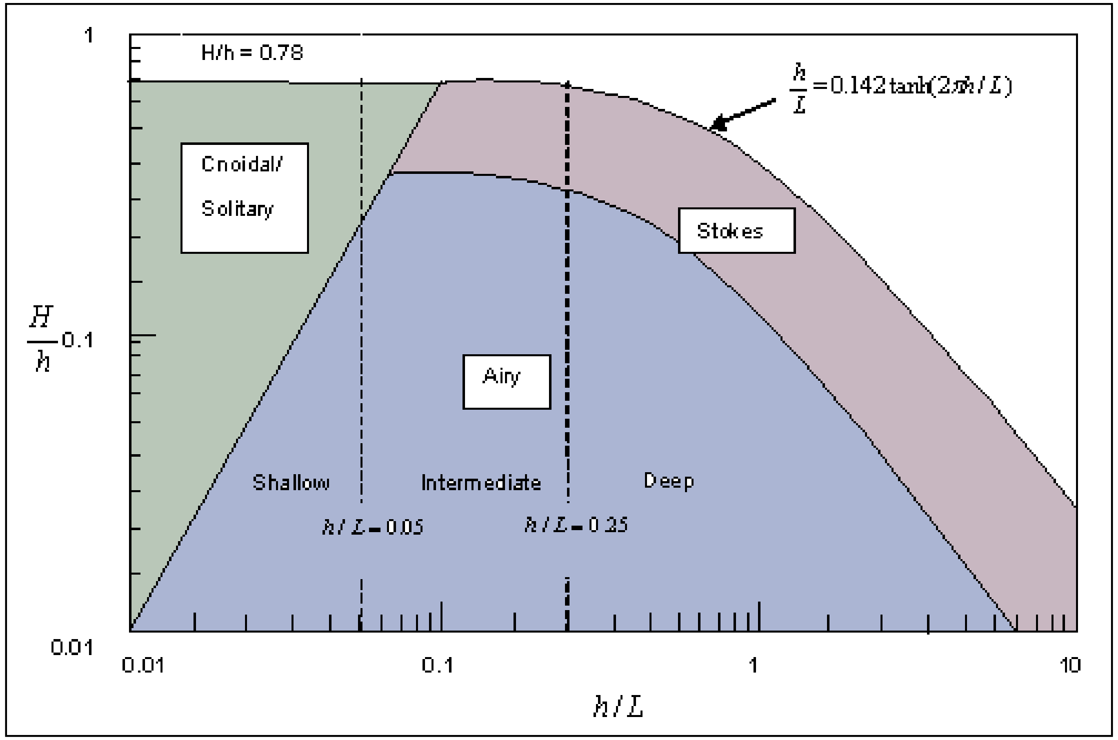
01.1 Ocean Waves Modeling

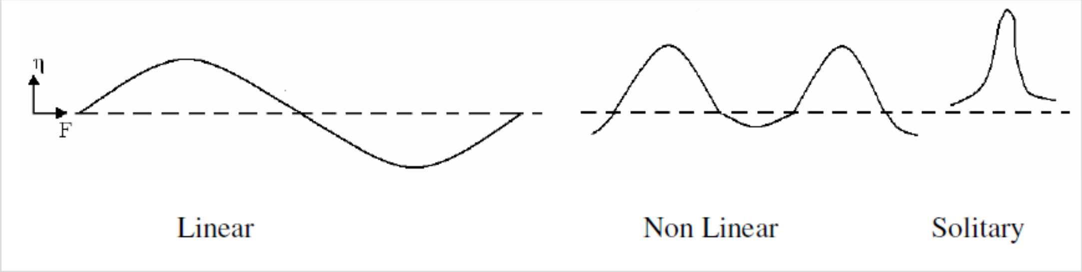
The solution of the complete wave equation is not possible without approximations.
Different wave theories exist with different mathematical approximations.

In deep water, the phase speed depends on wave length: Longer waves travel faster.
In shallow water, the phase speed is independent of the wave; it depends only on the depth of the water.



01.1 Ocean Waves Modeling





Applicability Ranges of Various Wave Theories:

- **First order Airy wave theory**
  - Linear
  - Small amplitude
  - Shallow to deep liquid depth

- **Stokes wave theories**
  - Non linear
  - Finite amplitude
  - Intermediate to deep water range. (h/L > 0.1)

- **Cnoidal & Solitary**
  - Non linear
  - Finite amplitude
  - Shallow water

H - Wave height
h - Water depth
L - Wave length

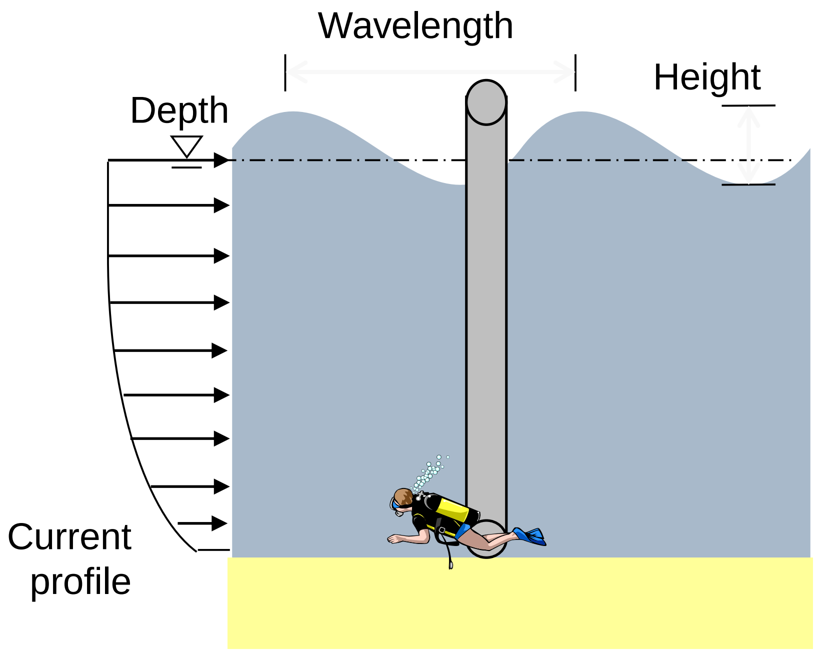
01.2 Slender Body Wave Loading

When the characteristic dimension of a body is less than 1/5 of the shortest wavelength, it is common to refer to this as a slender body

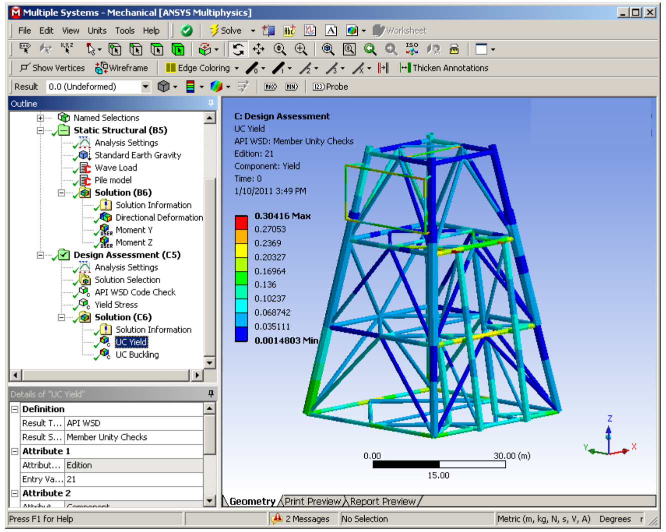
Use Morison's equation to solve generated load

$$F = 0.5 C_d \rho D |U_r| U_r + C_m \rho A \dot{U}_w - C_a \rho A \dot{U}_s = F_w - M_a \dot{U}_s$$

- C_d is drag coefficient
- C_m is inertia coefficient
- C_a is added mass coefficient; defined as $C_a = C_m - 1$
- U_r is relative velocity of fluid to structure
- U_s is structural acceleration
- U_w is wave kinematic acceleration



01.2 Slender Body Wave Loading



ANSYS Mechanical enables Morison loading on

- PIPE288/289
- BEAM188/189
- LINK180

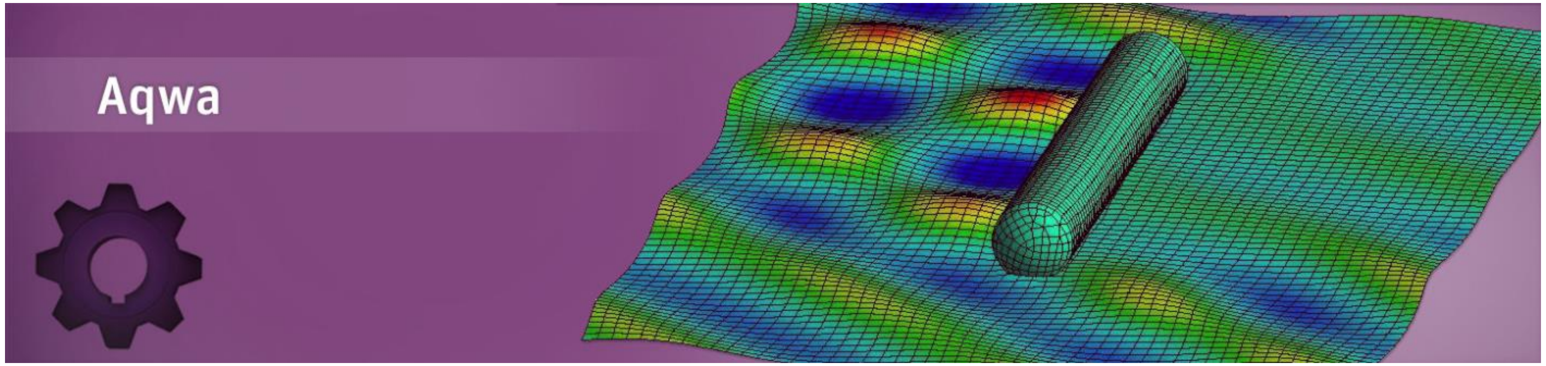
Wave theories

- AIRY - Small amplitude Airy wave without modifications (default).
- WHEELER - Small amplitude wave with Wheeler empirical modification of depth decay function.
- STOKES - Stokes fifth order wave.
- STREAMFUNCTION - Stream function wave.
- RANDOM - Random (but repeatable) combination of linear Airy wave components.
- SHELLNEWWAVE - Shell new wave.
- CONSTRAINED - Constrained new wave.
- DIFFRACTED - Diffracted wave (using imported hydrodynamic data)

01.3 Large Body Wave Loading

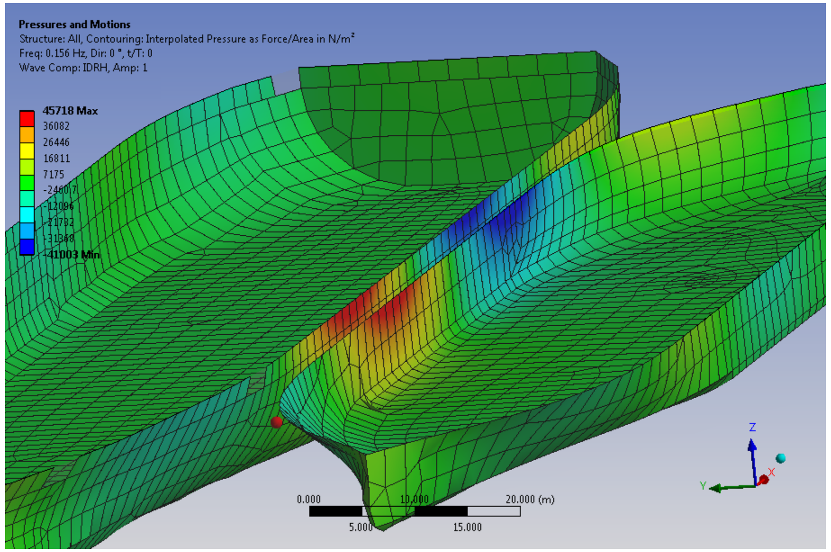
When a body is large enough to interfere with an approaching wave then it is necessary to include wave interference effects. If the body is also free to move this can generate additional waves.

A common solution for *global* analysis of such systems is to use three dimensional radiation diffraction theory which computes the linearized hydrodynamic fluid wave loading. This is based upon fluid potential flow.

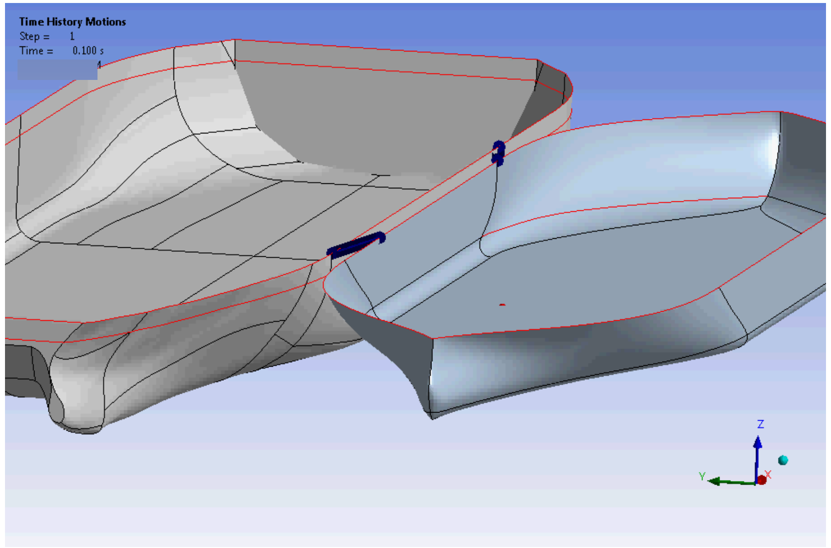


01.3 Large Body Wave Loading

ANSYS Aqwa is a multi-body hydrodynamic program that utilizes the three dimensional radiation/diffraction theory for global loading and motions simulations

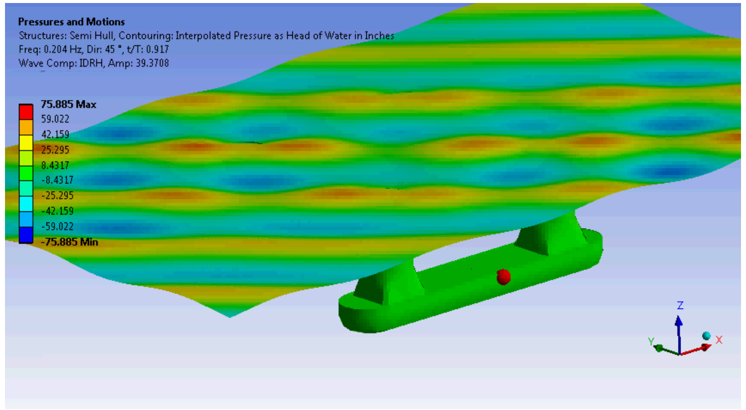


Hull Pressures

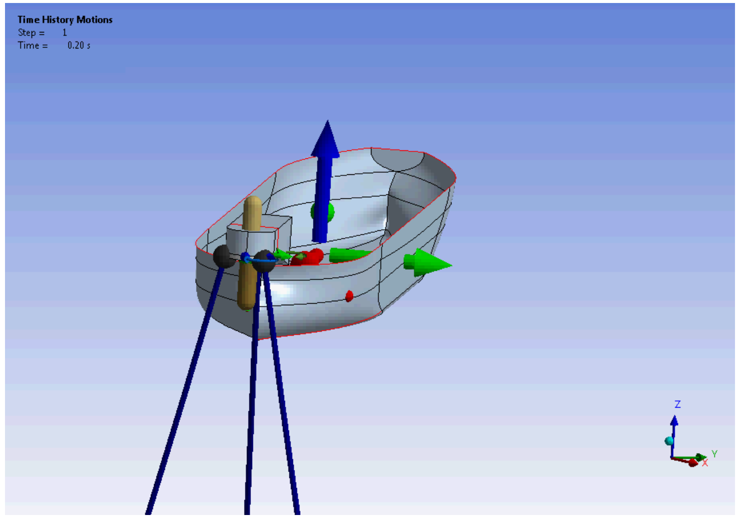


Coupled Motions

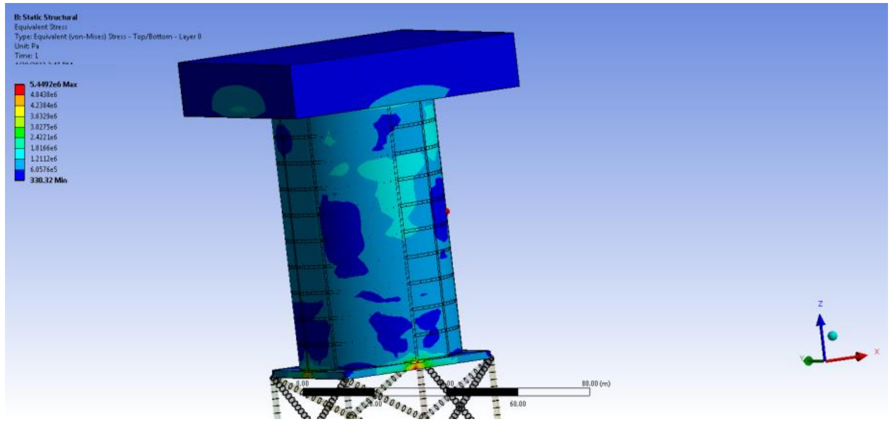
01.3 Large Body Wave Loading

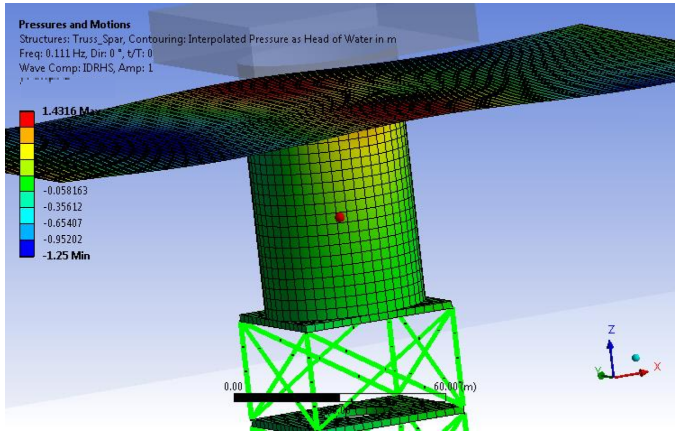


Diffracted Wave Patterns



Motions Simulation





Global Load Mapping to Structural Model

01.3 Large Body Wave Loading

Loading Global Assessment of Semi-Submersible

- Assess global structural model integrity

Hull Configuration and Design Parameters

ANSYS Structural Model

- Shell Model w/ primary structure
  - Bulkheads
  - Girders
  - Stanchions
- Coarse Panel Mesh size.
- Load Condition Dependent Mass Properties

ANSYS Aqwa Hydrodynamic Model

- Wetted Surface Area
- Load Condition Dependent Mass Properties
- Hydrodynamic Dampening
- Aqwa used to Generate Hydrodynamic Loading
- Transfer Functions Generated

ANSYS Mechanical

Global Strength Analysis

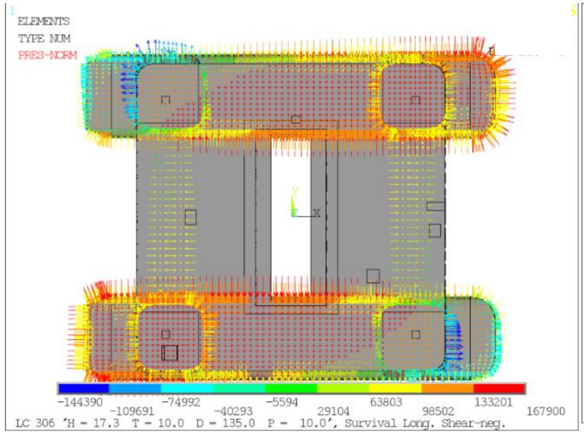
- Direct Pressure Mapping
- Nearly unrestrained structure response

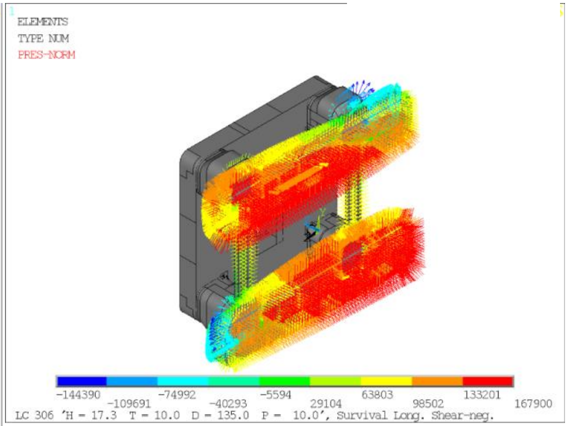
Courtesy of Friede & Goldman Ltd

01.3 Large Body Wave Loading

Dynamic Loading Condition

- All loading conditions involve the application of design wave which are selected as per ABS MODU
- Direct Mapping is used between ANSYS Aqwa and ANSYS Mechanical
  - Pressure Loads Applied to Mesh Points
  - Accelerations as calculated by Aqwa
- Boundary Conditions to Minimize Rigid Body Motion
  - Minimal restraints at convenient locations of little interest
  - Weak Springs
  - Inertia Relief

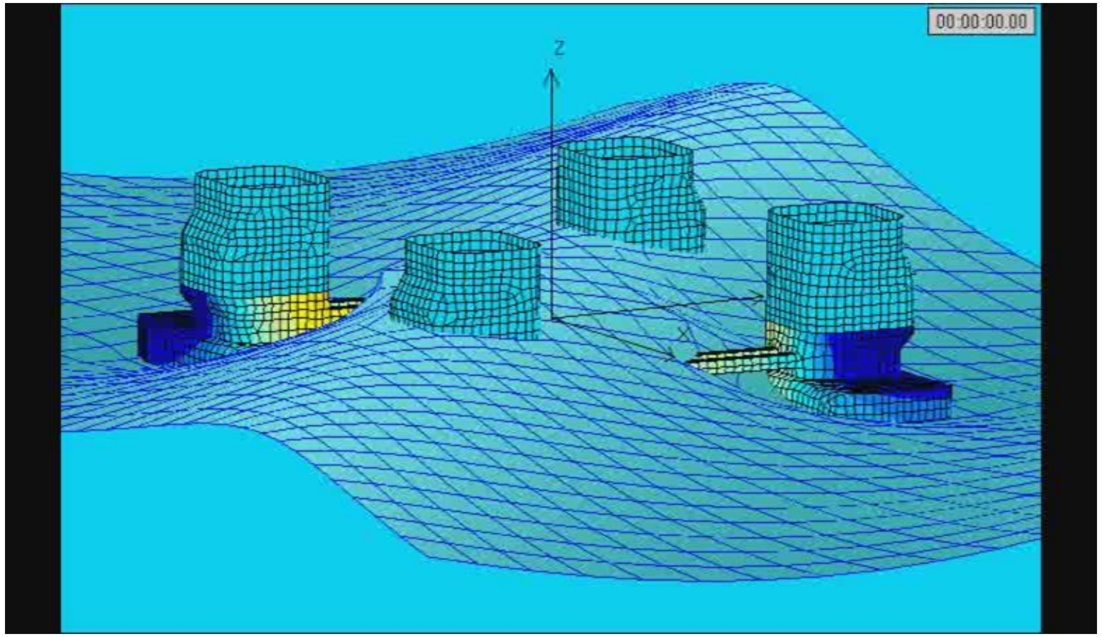


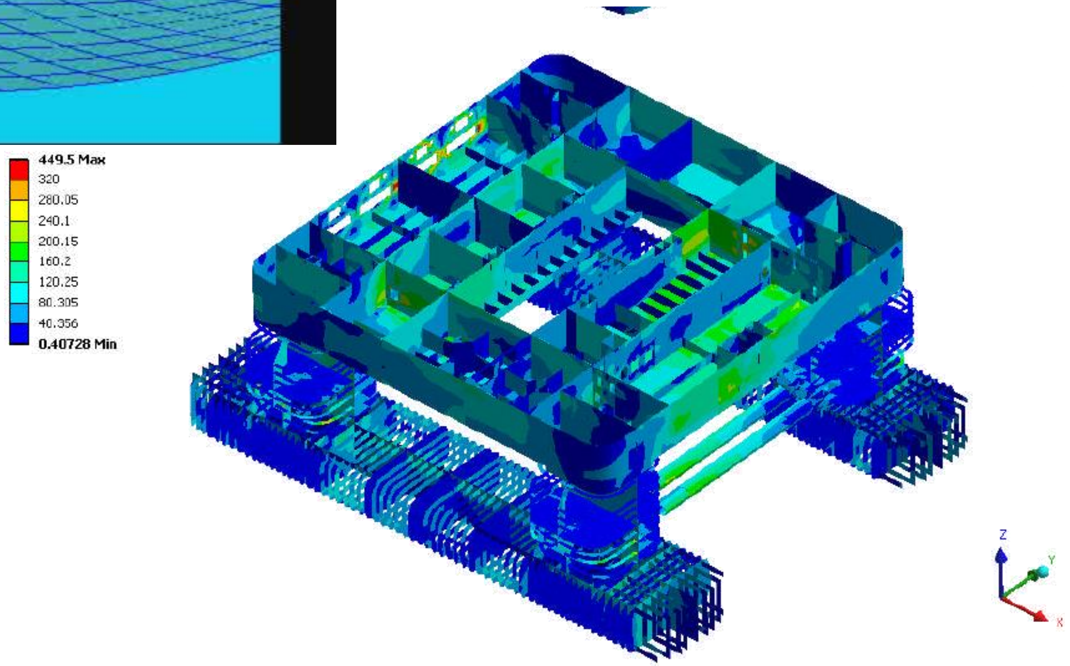


Courtesy of Friede & Goldman Ltd

01.3 Large Body Wave Loading

Analysis Results





Courtesy of Friede & Goldman Ltd

01.4 Solutions for Complex Ocean Environments

Loading Need for More Rigorous Solutions

Limitations of Potential Flow Solvers

- Not capable for viscous dominated problems
  - ➢ Green water behavior,
  - ➢ FPSO roll motions,
  - ➢ VIV,
  - ➢ Hull drag calculation etc
- Non linear waves
- Turbulence

Importance

- Key factor in design of offshore structures
- Green water behaviors on the deck of ship (FPSO)
- Wave run up on the structures

General Requirements

- Wave-in-deck loads (LRFD design criteria)
  - ➢ Hydrodynamic force on the structure
  - ➢ Maximum and Minimum pressures
  - ➢ Duration of pressure peaks
- Wave induced motion (violent free surface)
  - ➢ Green water behavior
  - ➢ Wave run-up

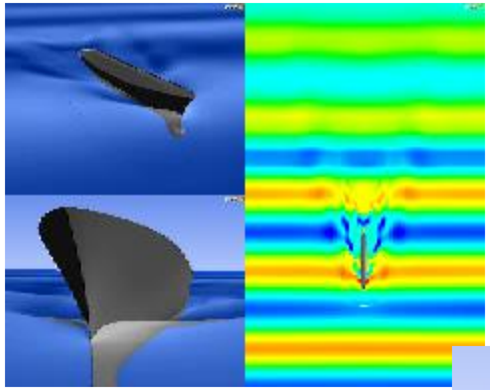
Challenges

- Complex environmental loads
- Turbulence,
- Non linear waves,
- Wave interaction with the structure

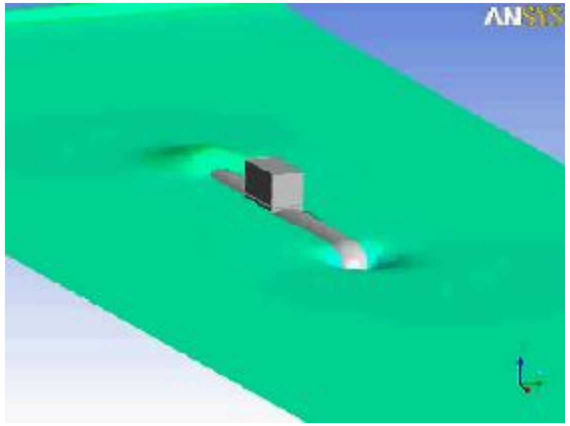
01.4 Solutions for Complex Ocean Environments

Examples using Linear/Stokes Wave Theories

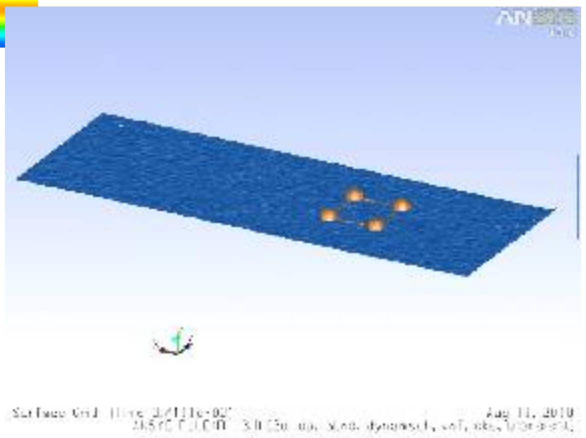
CFD is the simulation of fluid flow and heat and mass transfer by solving conservation equations for mass, momentum, and energy



Wave interaction with hull



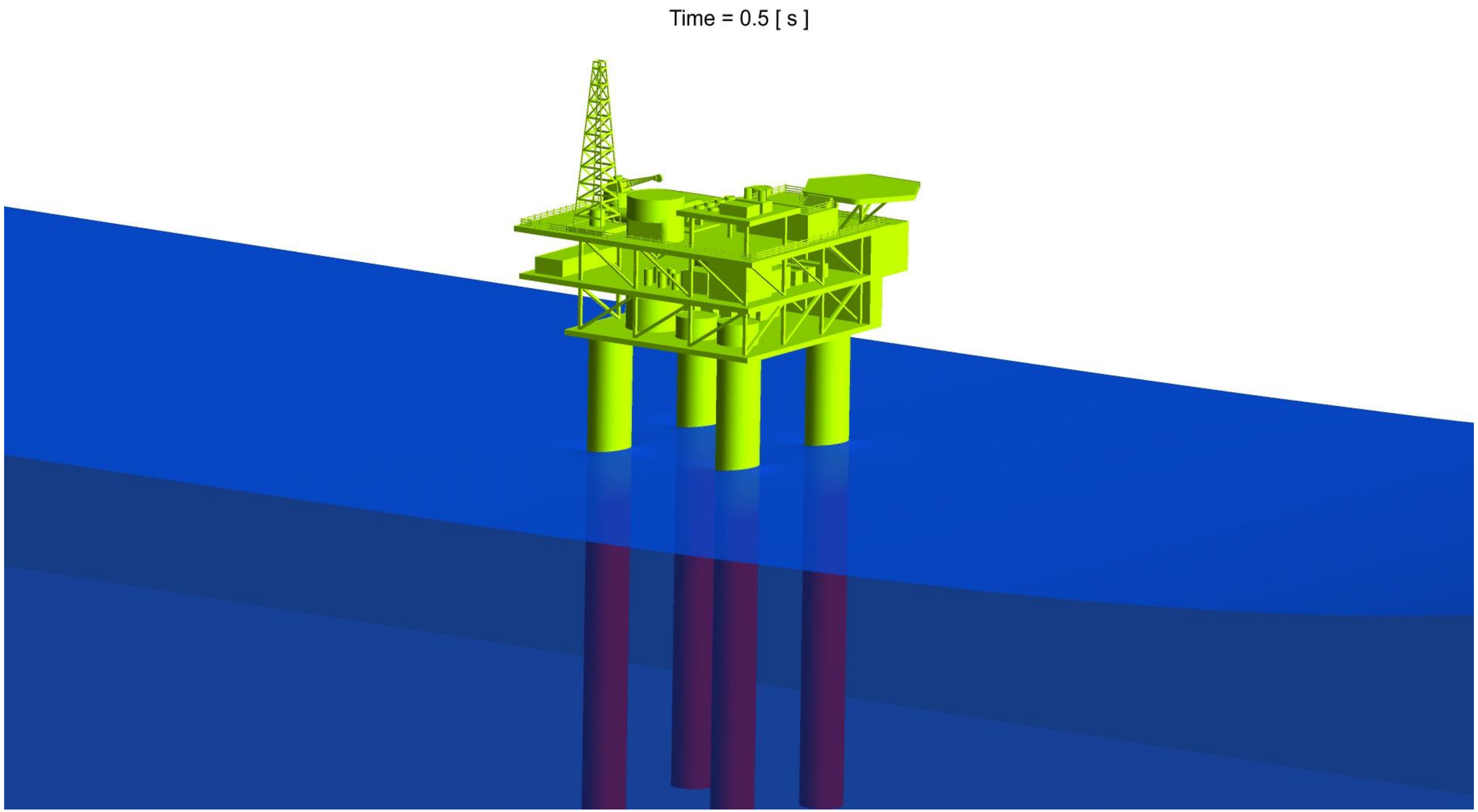
Wave slamming on submarine



Wave-body interaction

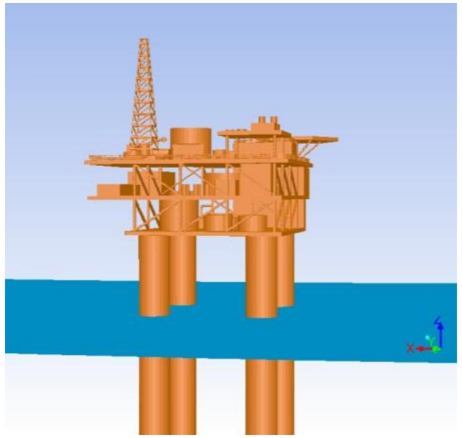
01.4 Solutions for Complex Ocean Environments

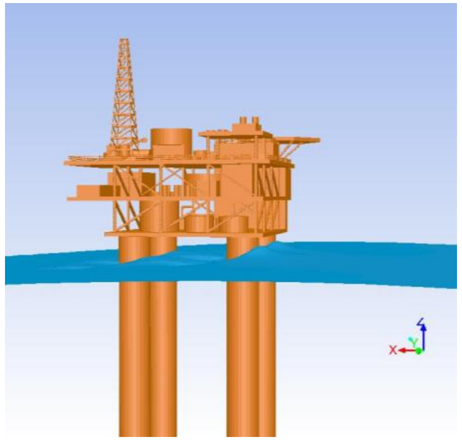
Wave Impact Loading on an Offshore Oil Rig (Animation)

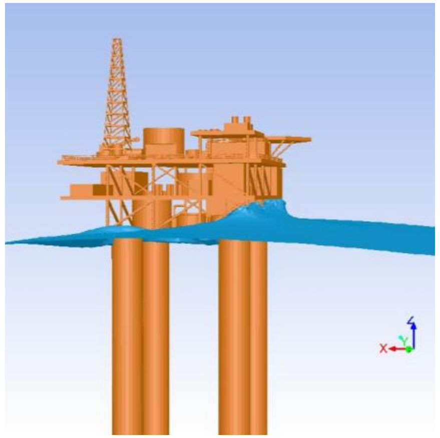


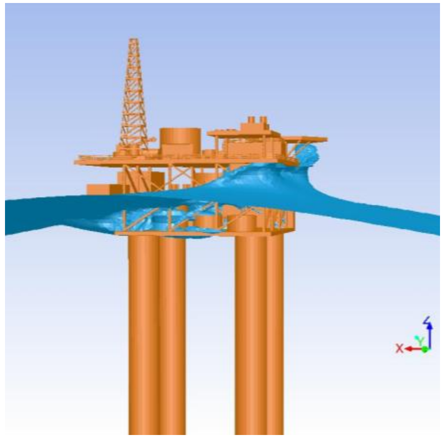
01.4 Solutions for Complex Ocean Environments

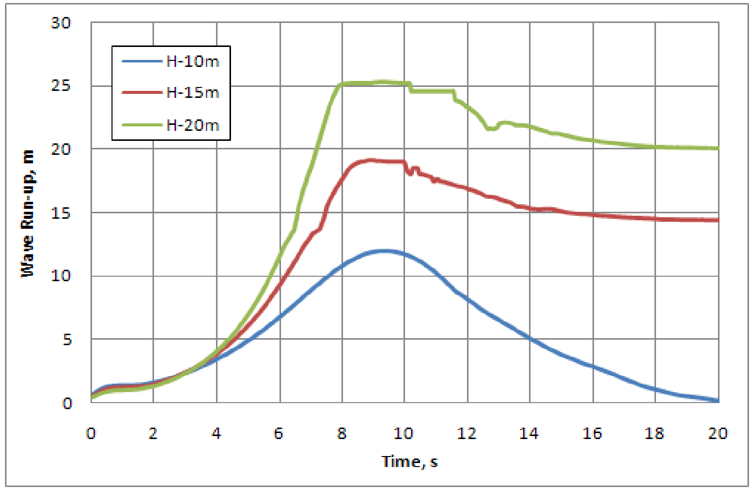
Effect of Wave Height on the Wave Run-up

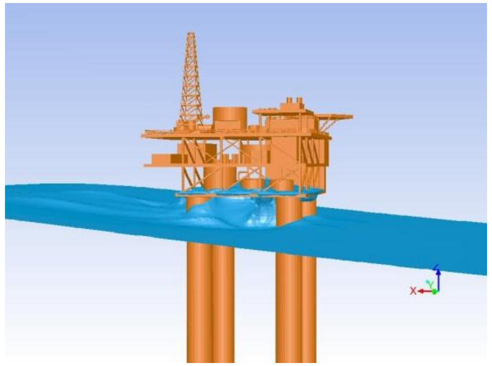


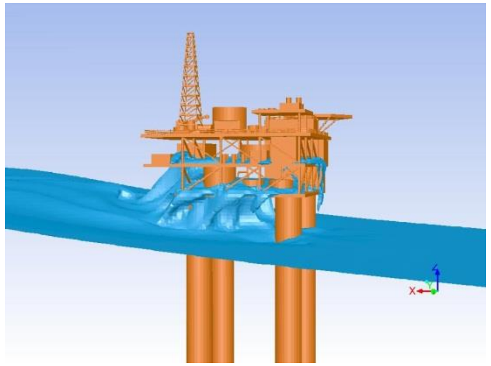










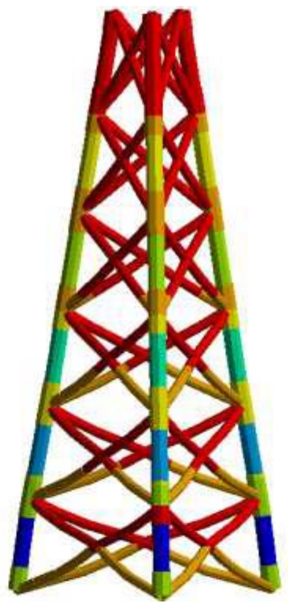


01.5 Scope of this training course

This training course describes analyses with ocean loading in the case of slender bodies.

Therefore, Beam structures modeling in Mechanical is a prerequisite. You can refer to the appropriate modules of Introduction to Spaceclaim and Introduction to ANSYS Mechanical as necessary to become familiar with the interface.

Dedicated methods for wave and current loading are needed and will be described.



01.6 Workshop 01.1 – Jacket Structure

Please refer to your Workshop Supplement for information on:

<u>Workshop 01.1 – Jacket Structure</u>