ΑΡΙΘΜΗΤΙΚΕΣ ΜΕΘΟΔΟΙ, ΥΠΟΛΟΓΙΣΤΙΚΑ ΠΑΚΕΤΑ

ΕΦΑΡΜΟΓΕΣ και ΠΑΡΑΔΕΙΓΜΑΤΑ

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NUMERICAL METHODS

General Taxonomy: FINITE DIFFERENCE, FINITE ELEMENTS, FINITE VOLUME, SPECTRAL METHODS, MESHLESS METHODS

Some popular algorithms:

- **SIMPLE (Semi-Implicit Method for Pressure Linked Equations)**

  S.V. Patankar, and D.B. Spalding, "A calculation procedure for heat, mass and momentum transfer in three-dimensional parabolic flows", International Journal of Heat and Mass Transfer, Vol. 15, pp. 1787-1806 (1971).

- **SIMPLER (SIMPLE Revised)**

  S.V. Patankar, "A calculation procedure for two dimensional elliptic situations", Numerical Heat Transfer, Vol. 14, pp. 409-425 (1984).

- **SIMPLEC (SIMPLE Consistent)**

  J.P. Van Doormaal and G.D. Raithby, "Enhancements of the SIMPLE method for predicting incompressible fluid flows", Numerical Heat Transfer, Vol. 7, pp. 147-163 (1984).

- **PISO (Pressure- Implicit with Splitting of Operators)**

  R.I. Issa and A.D. Gosman and A.P. Watkins "The computation of compressible and incompressible recirculating flows by a non-iterative implicit scheme", Journal of Computational Physics, Vol. 62, pp. 66-82 (1986).

Methods for tracking the free surface location

- **MAC (Marker and Cell) Harlow and Welch, 1965**
- **VOF (Volume - of- Fluid) Hirt and Nichols, 1981**

IMPORTANT ISSUES TO HAVE IN MIND WHEN USING CFD

- **<u>MODELING</u>: Validation & Verification of <u>Models</u>**
- **<u>NUMERICS</u>: Mesh Independent <u>Solutions</u>**

COMPUTER PACKAGES

A. GENERAL PURPOSE COMMERCIAL SOFTWARE PACKAGES

A1. ANSYS- FLUENT

A2. ANSYS- CFX

A3. FLOW-3D

A4. COMSOL (previously FEMLAB)

B. OPEN SOURCE SOFTWARE

OpenFOAM Free, open source, C++ library

References:

C. J. Morgan and Jun Zang, “Application of OpenFOAM to Coastal and Offshore Modelling”, In the 26th IWWWFB. Athens, Greece.

Jacobsen, D. R. Fuhrman and J. Fredsøe “A wave generation toolbox for the open-source CFD library: OpenFoam” Int. J. Numer. Meth. Fluids 70: 1073-1088, 2012.

C. SPECIALITY SOFTWARE

C1. COBRAS (Cornell Breaking and Structure)

- RANS & modified k- epsilon model
- VOF method to track the movement of the free surface

References:

P. Lin and P.L.-F. Liu "A numerical study of breaking waves in surf zone", J. Fluid, Mech. 359, 239-264. 1998.

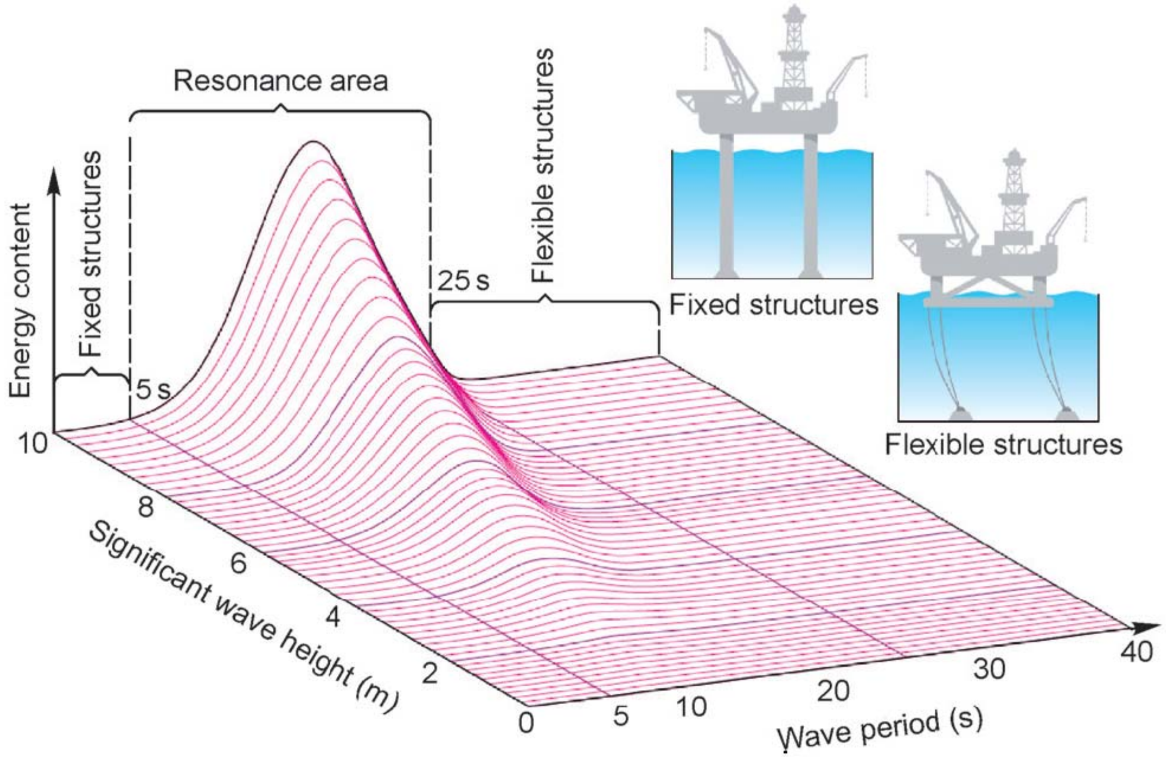
C2. ComFlow (Netherlands)

References:

- Kleefsman K.M.T., Fekken G., Veldman A.E.P., Iwanowski B. and Buchner B., 2005. "A volume-of-fluid based simulation method for wave impact problems". Journal of Computational Physics, 206(1), pp. 363-393.
- Veldman A.E.P., Luppes R., Bunnik T., Huijsmans R.H.M., Duz B., Iwanowski B., Wemmenhove R., Borsboom M.J.A., Wellens P.R., van der Heiden H.J.L. and van des Plas P., 2001. "Extreme wave impact on offshore platforms and coastal constructions". In 30th Conf. on Ocean, Offshore and Arctic Eng. OMAE2011, Rotterdam (The Netherlands), 19-24 June, paper OMAE2011-49488.

OFFSHORE ENGINEERING APPLICATIONS (1)

Offshore platforms   Design goal: prevent resonance with water wave frequencies

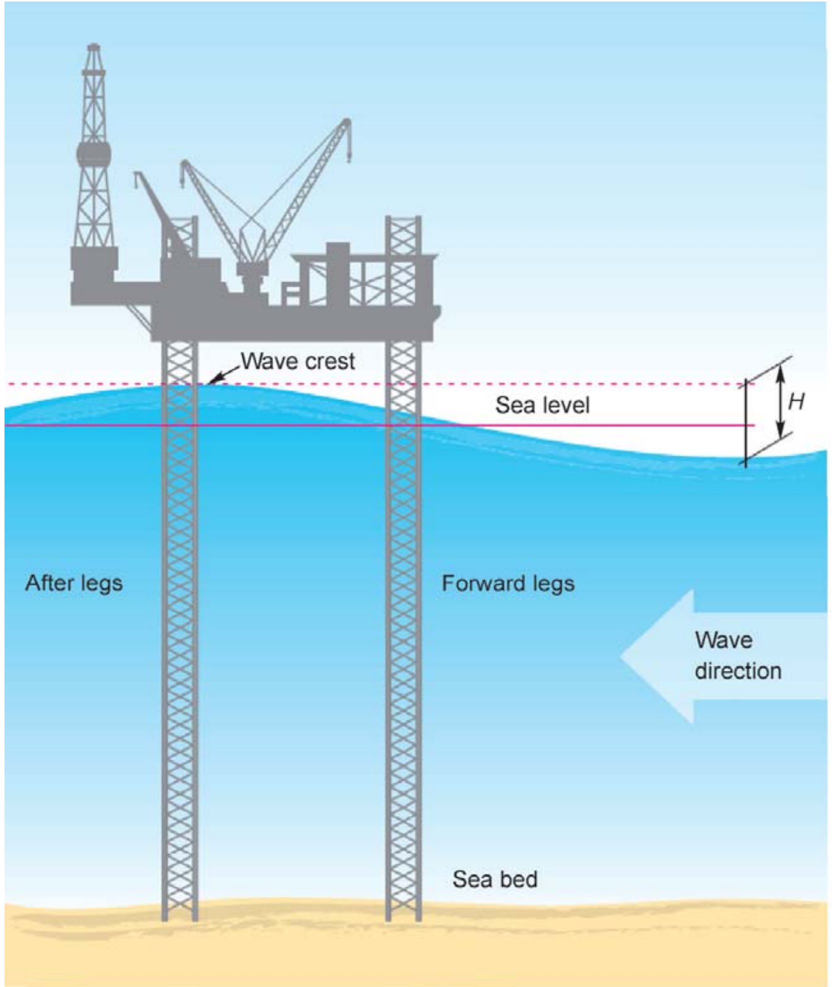


Wave spectra for the North Atlantic

Source: P.T. Pedersen, J.J. Jensen. Marine structures: Consuming and producing energy. In.: C.B. Hansen, ed. Engineering Challenges: Energy, Climate Change & Health. Copenhagen: Technical University of Denmark, 2009: 6-17.

OFFSHORE ENGINEERING APPLICATIONS (2)

Offshore platforms   Goal: Estimate wave loads on offshore structures



Overturning wave loading on a jack-up rig

Source: P.T. Pedersen. Marine Structures: Future Trends and the Role of Universities. Engineering 1(1): 131-138, 2015

OFFSHORE ENGINEERING APPLICATIONS (3)

Wave - energy extraction

A 1:2 scale jack up structure that draws energy from the waves by means of floating point absorbers.

Source: O.M. Faltinsen. Hydrodynamics of High-speed Marine Vehicles. Cambridge: Cambridge University Press, 2005.

COASTAL ENGINEERING APPLICATIONS (1)

- HARBOR DESIGN
- PROTECTION OF STORM IMPACT ZONES
- BEACH NOURISHMENT
- OFFSHORE BREAKWATERS

COASTAL ENGINEERING APPLICATIONS (2)

WAVE BREAKING PROCESS

Case I Impermeable beaches (applicable to sandy beaches)

Case II Gravel beaches (wave propagation over rough and permeable beds)

- Experiments
- Numerical simulation of breaking waves
  - potential flow theory (can model the evolution of the wave from deep water up to wave breaking point)
  - depth-integrated wave theory (e.g. Boussinesq-type eqs.)
  - [(RANS) + (Turbulence closure mode)] (1990-present)
  - LES. Large Eddy Simulation (2000-present)

Selected publications on applications of CFD in Coastal and Offshore Engineering

Veldman A.P., Luppes R., van der Heiden H.J.L., VAN DER Plas P., “Turbulence Modeling, Local Grid Refinement and Absorbing Boundary Conditions for Free-Surface Flow Simulations in Offshore Applications”, Proceedings of the 33rd International Conference on Ocean, Offshore and Arctic Engineering OMAE2014, June 8-13, 2014, San Francisco, California, USA.

Liu P.L.-F., Losada I.J.: “Wave propagation modeling in coastal engineering”, Journal of Hydraulic Research, Vol. 40, No. 3, pp. 229-240, 2002.

J.L. Lara, N. Garcia, I.J. Losada, “RANS modelling applied to random wave interaction with submerged permeable structures”, Coastal Engineering 53 (2006) 395–417, 2006.

Pablo Higuera, Javier L. Lara, Inigo J. “Simulating coastal engineering processes with OpenFOAM®”, Coastal Engineering 71 (2013) 119–134, 2012.

Szydlowski M., Zima P.: “Two –Dimensional Vertical Reynplds-Averaged Navier-Stokes Equations Versus One-Dimensional Saint-Venant Model for Rapidly Varied Open Channel Water Flow Modelling”, Vol. 3, No. 4, pp. 295-309, 2006.