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Physical and Numerical Tests as a Key Factor for New FPSO/FLNG Designs

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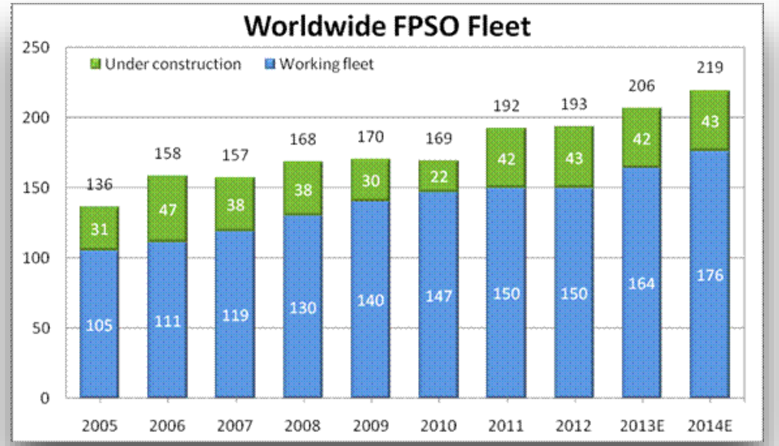
Agenda

- *Floating Units*
  - *History*
  - *Present and Future*
  - *New Frontiers*
- *Case Study*
- *Physical and Numerical Tests*
  - *Wind Tunnel and Wave Basin tests*
  - *Berthing Simulations*
  - *Side-by-Side Motion and Mooring analyses*
  - *Sloshing studies*
- *Conclusions*

Floating Units – History

- *First FPS (1975): Transworld 58, Argyll field, North Sea, UK*
- *First FPSO (1977): Shell Castellon (about 70,000 t displ.) field, Mediterranean Sea, Spain. She operated in 117 m water depth and she had just one well.*
- *About 200 units in operation or under construction / conversion in 2015; many of them are VLCC size (350,000 t displ.), in more than 1,000 m water depth and having 50+ risers.*



Floating Units – Present and Future

- *Modular "turnkey" FPSO*
- *FPSO new concept (e.g. Sevan)*


- *FLNG (e.g. Prelude, Petronas PFLNG1/2, Golar LNG) and FSRU*


Floating Units – New Frontiers

- *Peculiarities:*
  - *Increasing water depth (up to more than 2,000 m);*
  - *New fluids to be stored (e.g. LNG, LPG, CNG);*
  - *Offloading (e.g. Side-by-Side in offshore environment for cryogenic fluid);*
  - *Size (400,000+ t displacement);*
  - *Robust design (up to 10,000 years return period);*
  - *Novelties in process (e.g. marinization of LNG onshore plants) and structural (e.g. two rows of LNG tanks) design.*

- *These characteristics move design out of "comfort zone".*

Case Study – Coral South FLNG project

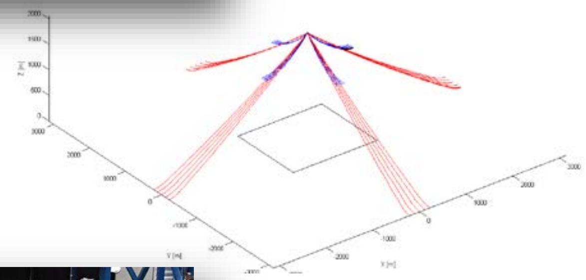
- *FLNG installed in 2,000 m water depth offshore Mozambique;*
- *Topside facilities processing both natural gas and condensate;*
- *Displacement in excess of 400,000 t;*
- *Main dimensions:*
  - *LBP: 404.0 m;*
  - *B: 66.0 m;*
  - *D: 38.5 m;*
- *LNG Side-by-Side Offloading by means of Marine Loading Arms;*
- *Condensate Tandem Offloading by means of Hose Reel;*
- *Internal Turret.*

Physical and Numerical Tests

- *As part of the design process, project performed (and is performing) both physical and numerical tests in order to validate and assess correctly FLNG responses, calibrate software calculations and provide missing inputs for design.*
  - *Wind Tunnel and Wave Basin tests;*
  - *Berthing Simulations;*
  - *Side-by-Side Motion and Mooring analyses;*
  - *Sloshing studies.*

Physical and Numerical Tests – Wind Tunnel and Wave Basin tests

- *Activities:*
  - *Wind Tunnel tests;*
  - *Wave Basin tests;*
  - *Tested both Single body and Side-by-Side configurations;*
  - *Tested both operational and extreme conditions.*
- *Peculiarities of the project:*
  - *Wave makers may not be capable of modelling cyclonic conditions with large return periods due to high wave steepness;*
  - *Shielding effects cannot be disregarded (especially in Side-by-Side configurations), as well as 2-body hydrodynamic gap interaction;*
  - *Large water depth implies mooring / riser / umbilical system truncation;*
  - *Motions resonance occurs with different periods with respect to traditional vessels and some tests (especially in Side-by-Side configurations) are more sensible to basin test reflections (crossed waves with smaller Hs and long Tps, such was Side by side offloading waves and 1-yr non cyclonic.*
  - *Numerical Calibration (eg. Roll damping and gap water elevation) is important to properly simulate FLNG responses.*



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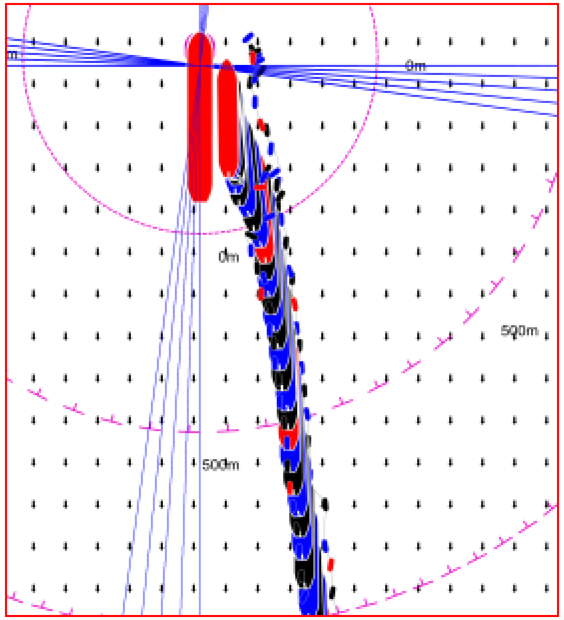
Physical and Numerical Tests – Berthing Simulations

- **Activities:**
  - *Numerical simulations;*
  - *Full Mission Bridge simulations;*
  - *Tested different LNG carriers and approaches (positive, neutral and negative headings);*
- **Peculiarities of the project:**
  - *Berthing is safer in terms of tug's maneuvering if FLNG maintains its neutral/slightly positive headings (with reference with LNGC drift);*
  - *The most stringent limits for a safe berthing come from Tug operability, however it is also associated with the LNGC roll, rate of turn, drift speed, clearance between vessels, thruster power, etc,;*
  - *High thrusters load is not required to stabilize the heading;*



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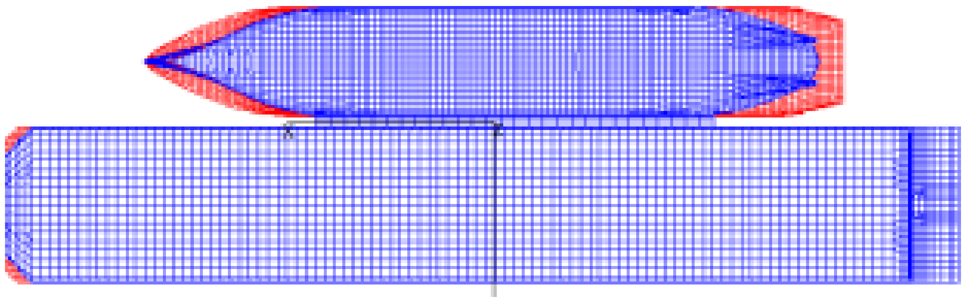
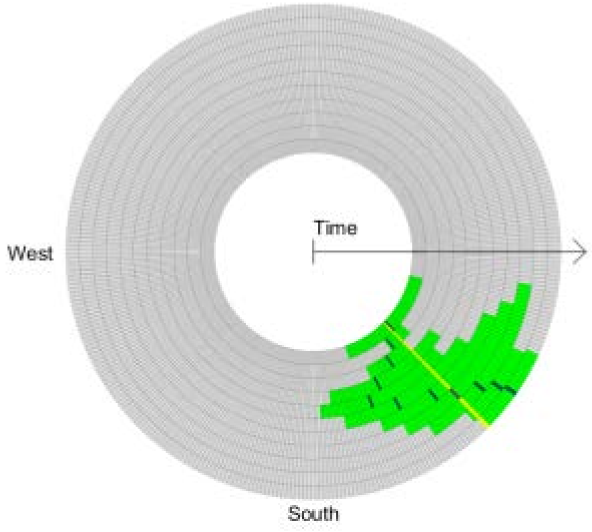
Physical and Numerical Tests – Side-by-Side Offloading Analyses

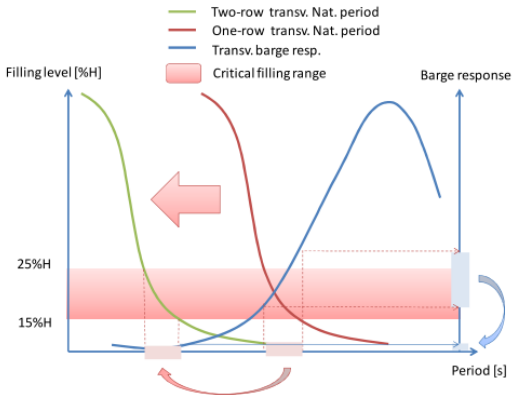
- *Activities:*
  - *Heading, Mooring and Motion analyses;*
  - *Frequency and time domain analyses;*
  - *Operability / availability analysis;*
- *Peculiarities of the project:*
  - *There are a large number of non-linearities (e.g. mooring lines, fenders, etc.);*
  - *Water elevation gap damping correction needed to predict realistic relative motions*
  - *Contact between LNG carrier and topside facilities may occur;*
  - *LNG carrier's bridges are close to liquefaction modules;*
  - *Sloshing may impact both FLNG and LNG carrier tanks; Tank's coupling effects shall be taken into account.*
  - *Fenders position and efficiency depends mainly from selected LNG carrier parallel bodies and shoulder's position;*
  - *Operability mainly depends from season (summer / winter).*

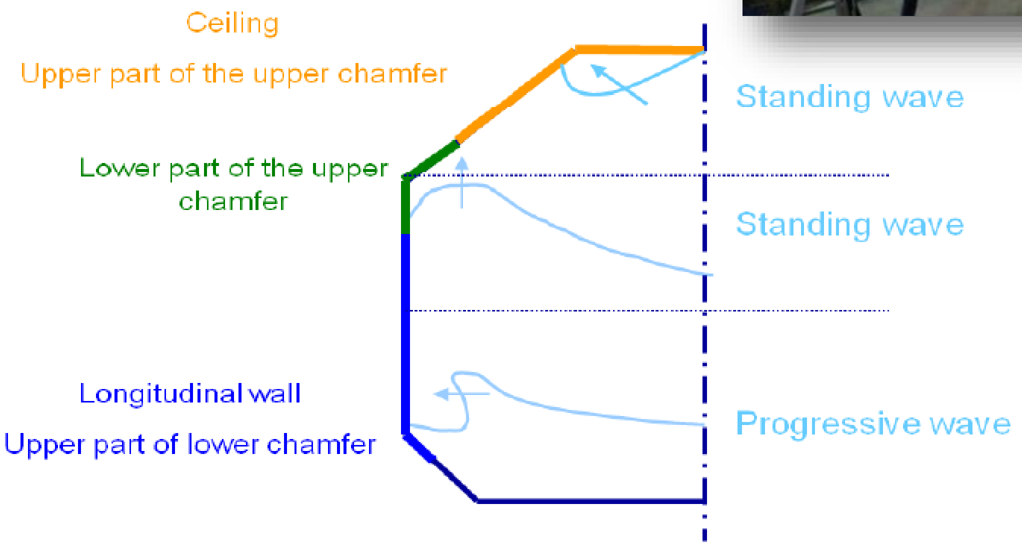




Physical and Numerical Tests – Sloshing studies

- *Activities:*
  - *Sloshing assessment (tests) on FLNG (operational and extreme);*
  - *Sloshing assessment (tests) on LNG carriers in an offshore environment (empty, full and partially filled loading conditions) [by others]*
- *Peculiarities of the project:*
  - *Traditional sloshing methodologies are not fully applicable;*
  - *Sloshing risks decrease in FLNG because of its two-LNG tank-rows configuration and natural period;*
  - *LNG carrier sloshing may impact FLNG operability.*





Conclusions

- *Despite the progress in numerical software, physical tests cannot be avoided when innovative concepts (e.g. FLNG) or peculiar operations (e.g. side-by-side operation) are selected.*
- *Depending on project requirements, current facilities may experience issues in modelling something which is outside the current “state–of–art” technology.*
- *Experience is required on both Owner and Contractor side to drive the process toward the best compromise for the design activities.*

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Thank You

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Claudio is a Naval Architect with MSc degree from University of Trieste who has been working in the offshore industry for more than 10 years in the Eni group.

He started his career in 2008 with Tecnomare SpA (now EniProgetti) as a Naval Architect where he was in charge of naval design for both floating and fixed structures. His floating structures experience includes feasibility and FEED studies as well as EPCI projects for new built and converted FPSO.

Beginning in 2014 he led the hull and turret team for the Mozambique Coral South FLNG project starting from the competitive FEED preparation phase through FEED and the tender evaluation phase.

He is currently in South Korea as Hull Engineering Coordinator for the EPCIC phase of the Coral South FLNG project responsible for overseeing all the hull design technical work being performed by the EPCIC contractor.