LAZY WAVE RISER

Invitation to Joint Industry Project

Non-linear Time Domain Analysis for Slender Marine Structures Subjected to Vortex Induced Vibrations (VIV) – Phase III

The time domain VIV analysis program (VIVANA-TD) is under continuous development within Lazy Wave Riser JIP. The tool represents a game changer compared to today's design practice which uses frequency domain tools. It will improve accuracy in VIV prediction of deepwater riser systems, as well as power cables to the offshore floating wind turbines.

The slender marine structures are exposed to waves and currents. Vibrations due to periodic vortex shedding around the structure can lead to fast accumulation of fatigue damage and amplified drag loads. VIV often represents a safety risk and is a major design consideration adding notable costs to all stages of the system development.

A semi-empirical time-domain (TD) model has been implemented into the existing non-linear 3D finite element tool RIFLEX, as VIVANA-TD. VIVANA-TD intends to capture tension variation, geometry changes, multi-directional flow conditions as well as evaluating the wave frequency and VIV load contributions simultaneously. These alleviate some of the key limitations in the present linear frequency domain prediction tools.

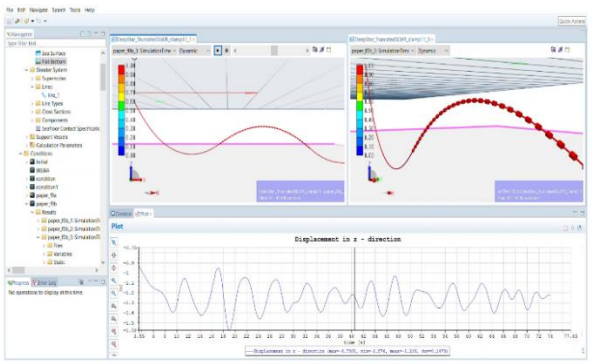

Figure 1 A time domain VIV prediction example shown in SIMA simulation workbench GUI

Overall Objective of LWR JIP

1) Close the gaps and reduce uncertainties in the existing VIV design practice for:
   - steady/oscillatory flow
   - non-linear structural behaviour, e.g., hysteresis damping, soil-pipe interaction
   - combination of other load effects, e.g., wave loads, slugging loads
2) Provide industry a TD VIV prediction tool, which will:
   - combine complex load effects and structural non-linearity in a time domain analysis.
   - increase safety and cost-effective design of slender marine structures, e.g., power cables, umbilical, risers/pipelines, mooring lines etc.

Accomplishment of LWR JIP Phase I/II

The main objective of Phase I/II work is to qualify VIVANA-TD for industry use with pure CF (cross-flow), combined CF and IL (in-line) response prediction in constant current or in oscillatory flow conditions. This was the first step to develop an integrated model to predict responses from waves and current in time domain.

The following has been achieved:

- Validated VIVANA-TD with the pure CF, as well as the combined IL and CF load model for constant flow conditions with focus on high mode VIV responses.
- Validated VIVANA-TD with the pure CF, as well as the combined IL and CF load model for vessel motion induced VIV.
- Implementation of hysteresis damping and stiffness model.
- Improvement of VIVANA-TD use as a design tool.

VIVANA-TD has been validated systematically against extensive model tests. A few examples are shown in Figure 2 and Figure 3:

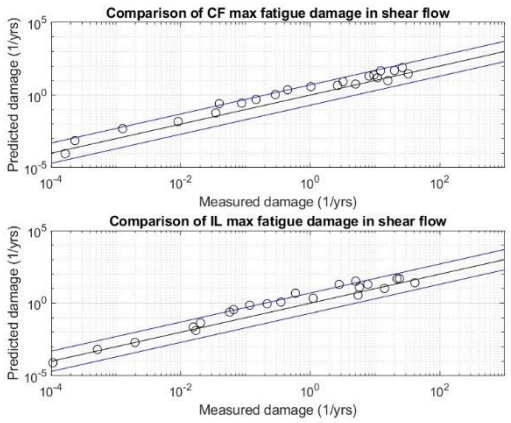

Figure 2 Example of VIVANA-TD CF and IL VIV fatigue damage prediction of a tension-beam subjected to sheared current. The difference between prediction an measurement is in general within a factor of 5.

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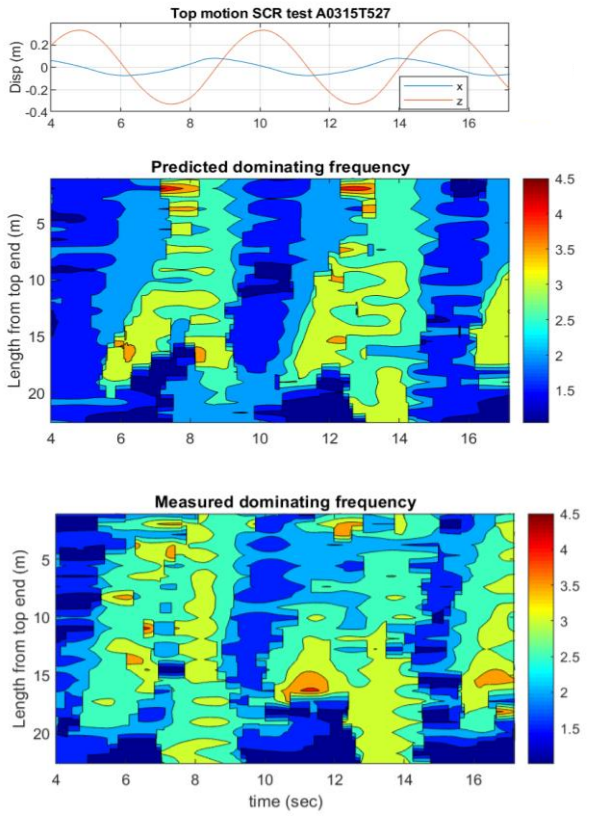

Figure 3 Example of VIVANA-TD CF dominating frequency prediction of a SCR (Steel Catenary Riser) model due to vessel motion induced VIV. Spatial and temporal VIV frequency variation due to oscillatory flows were well predicted.

LWR JIP Phase III

The wave effects on VIV responses have also been evaluated in additional studies. The preliminary results showed that VIV responses and drag amplification can be suppressed by the increasing wave loads. One example was shown in Figure 4. The reduction in drag amplification can have a strong impact on the bending stiffener design in the wave zone. The fatigue damage can be reduced when VIV and waves are considered in one integrated analysis in VIVANA-TD compared to the traditional practice, where these two load processes are evaluated independently. This is of particular interest for marine risers and power cables in shallow water where waves can be experienced in the entire water column. Therefore, the objective of Phase III is to validate VIVANA-TD under complex environmental conditions for marine risers and dynamic power cables. Both laboratory and field measurements will be used.

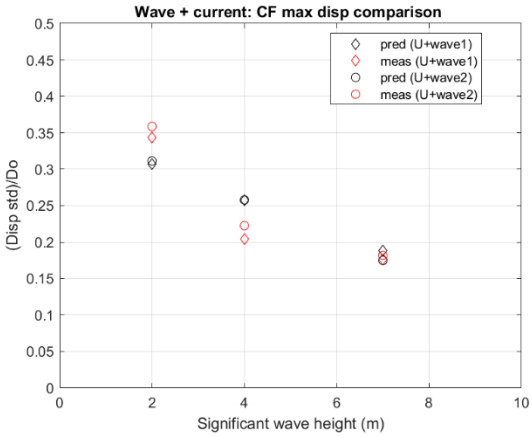

Figure 4 Example of VIVANA-TD CF displacement amplitude prediction of a SCR (Steel Catenary Riser) model due to simultaneously acting waves and VIV loads. The prediction agrees well with measurements and suppression of VIV responses can be observed for increasing wave heights.

Phase III work consists of five work packages (WPs):

WP1	Validation of prediction model in combined waves and current conditions
WP2	Evaluation of VIV responses under directional currents
WP3	Validation of prediction model for umbilicals/power cables with hysteresis stiffness and damping
WP4	Design case study of various types of structures
WP5	Workshop and future work

The scope will be readily extended with new participants.

Phase III Deliverables

1) Technical reports for WPs.
2) VIVANA-TD software/license, including documentation.
3) Access to Phase III software improvements.
4) Scientific Publications.

One free stand-alone TD-VIVANA license with the newly included TD module will be supplied to each sponsor.

Practical JIP Details

Planned year:	2024 Q2 – 2026 Q2 (two years)
Potential participants:	Operators, Engineering companies Class societies & Regulators
Planned budget:	Operators (600 kNOK/year) Others (125 kNOK/year)

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