Assessment of empirical VIV analysis tools and benchmark with experiments (OMAE 2008-57216)
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Introduction and Background

- Most VIV designs are based on empirical VIV tools
- Empirical tools combine a frequency domain structural solution with an empirical hydrodynamic model
  - Linear frequency domain structural model (FE, FD, modal superposition)
  - Forced 1DOF CF hydrodynamic database (no inline)
  - Various assumptions on strip theory and VIV
  - Examples: Shear 7, VIVA, VIVANA, others (15+ years in development)
- Popular among designers due to ability to analyze a big number of cases fast
- Accuracy and validity often questioned especially with latest experimental findings
- Careful benchmark and understanding of modeling limitations is very important
  - Ensure safe design
  - Drive improvements
Objectives

- Develop a benchmark methodology meaningful to design
- Demonstrate application on 2 selected software
- Ongoing work over years to aid design
- Compare only 1st crossflow harmonic not total fatigue

![Graph showing factor of 30 off and current VIV models]
What to compare – design driven approach

- Production risers consist of ~40ft joints welded together
- Weld locations are critical for design
- Location and components at the ends are also critical
- Ability to predict local stresses in these areas
- Compare local measurements with prediction along riser
- Strain measurements are preferred
- Acceleration or a combination of motion with frequency is a second alternative
Definitions

- Spatial comparison based on point measurement
- Define bias

\[ b(j,i) = \frac{x_p(j,i)}{x_e(j,i)} \]

- Mean and std of bias (spatial)

\[ \mu_b(j) = \frac{1}{n} \sum_{i=1}^{n} b(j,i) , \]

\[ \sigma_b(j) = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (b(j,i) - \mu_b(j))^2} . \]

p (prediction)

e (experimental sensor data)
Benchmark case selection

- Nonlinear physics require extensive benchmark in a range of operating conditions
- Empirical tools require even further testing due to the different assumptions used
- For production risers ensure success in modeling:
  - Geometry (0, 50, 75, 100 Strake coverage)
  - Riser Response (low/high mode...)
  - Current profiles
  - Hydrodynamics (High Re)
  - High Harmonics
- Validation against available field measurements
- Validation
  - NDP experiments L/D~1407, L=38m (Geometry, Low/Med mode, simplified currents) (presented here)
  - Field full scale, DeepStar high L/D, full scale CFD cases (not published)
Benchmark against NDP experiments

Experiment designed to understand VIV and validate tools

L/D ~1407, L=38m

Strain gauges, accelerometers

**Benchmark Cases**

1. Shear current with 0\% strakes (Bare)
2. Shear current with 50\% strakes
3. Shear current with 75\% strakes
4. Shear current with 100\% strakes
5. Uniform current with 0\% strakes (Bare)
6. Uniform current with 50\% strakes
7. Uniform current with 75\% strakes
8. Uniform current with 100\% strakes
Procedure

- Analyze experimental data and create benchmark database
  - Select “steady-state”
  - Separate harmonic content
  - Calculate fatigue damage (index)
- Select 2 empirical tools and use them as used in design
- Model experiment with empirical tool and run cases
- Compare results and generate statistics
Results for selected cases - strain

Soft. A

Soft. B

Uniform flow

Linear shear flow
Results for selected cases - strain

Uniform flow

Linear shear flow

Soft. A

Soft. B
Summary plots 50% strake - fatigue

- Soft A – Uniform 50% strakes
- Soft A – Shear 50% strakes
- Soft B – Uniform 50% strakes
- Soft B – Shear 50% strakes

Overestimate

Underestimate

10
1
0.1
Fatigue bias summary – Software A

- Statistics of bias for all cases
- Represent spatial variation and deviation
- Log of bias $\mu$ and $\sigma$

Note: High harmonics contribution not included
Fatigue bias summary – Software B

- Statistics of bias for all cases
- Represent spatial variation and deviation
- Log of bias $\mu$ and $\sigma$

Note: High harmonics contribution not included
Conclusions

- Benchmark methodology has been proposed and applied to empirical VIV models focusing on 1st CF harmonic.
- Benchmark shows wide deviation from experiments:
  - Scatter varies across geometries and velocities
  - Challenges in modeling strakes
  - Overall one tool is better than the other
  - No inclusion of fatigue due to high harmonics
  - Not fit for generic geometries
- Given difficulties in matching laboratory scale VIV, effectiveness at full scale and other experiments is in question.
- Calibration and enhancements are critical.
- Education of developers, designers and analysts on limitations and state of the art.
Thank you!