Assessment of empirical VIV analysis tools and benchmark with experiments

(OMAE 2008-57216)

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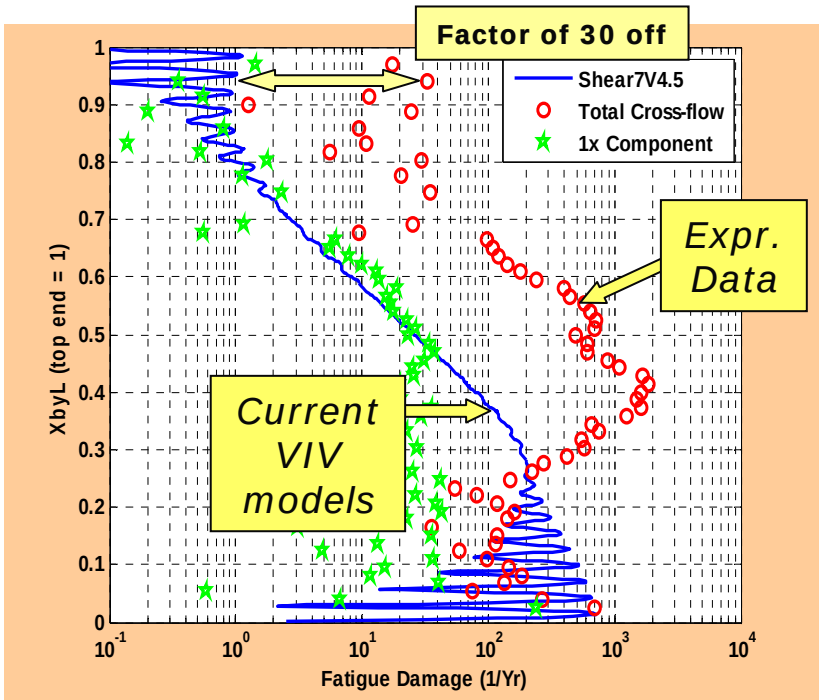
June 16, 2008

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



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

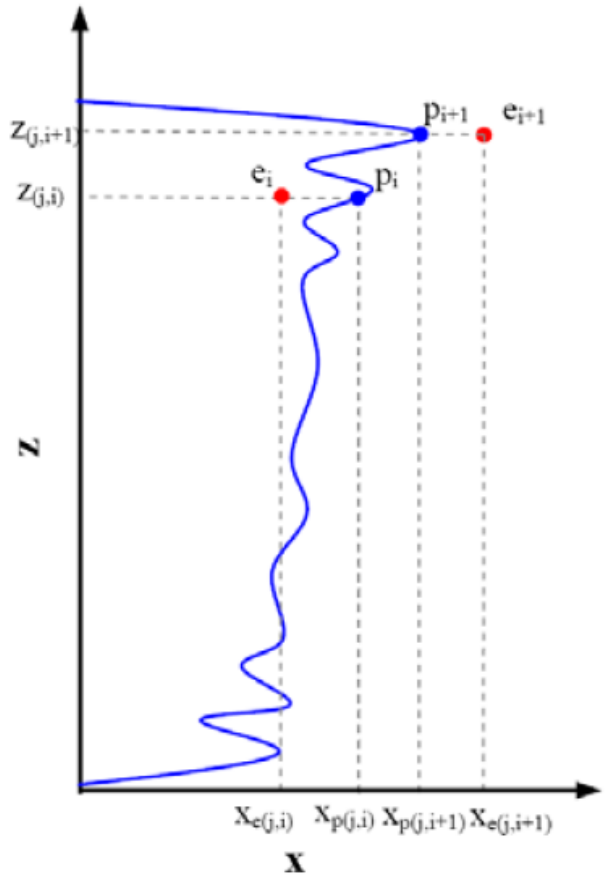
- Spatial comparison based on point measurement
- Define bias

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

- Mean and std of bias (spatial)

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

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



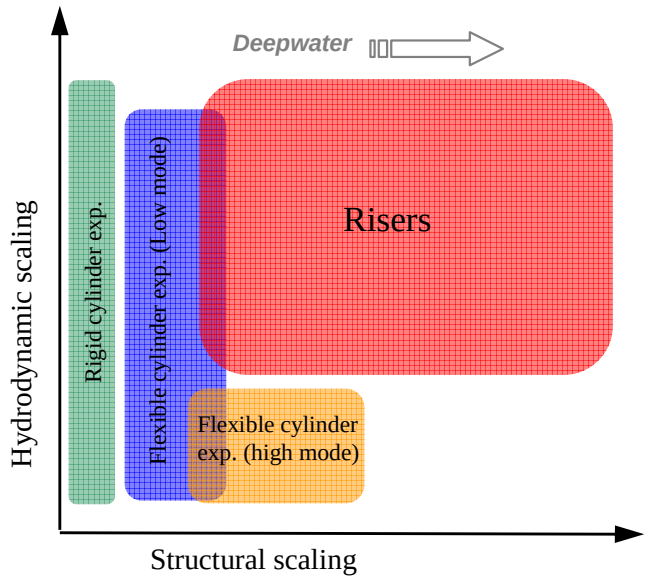
p (prediction)

e (experimental sensor data)

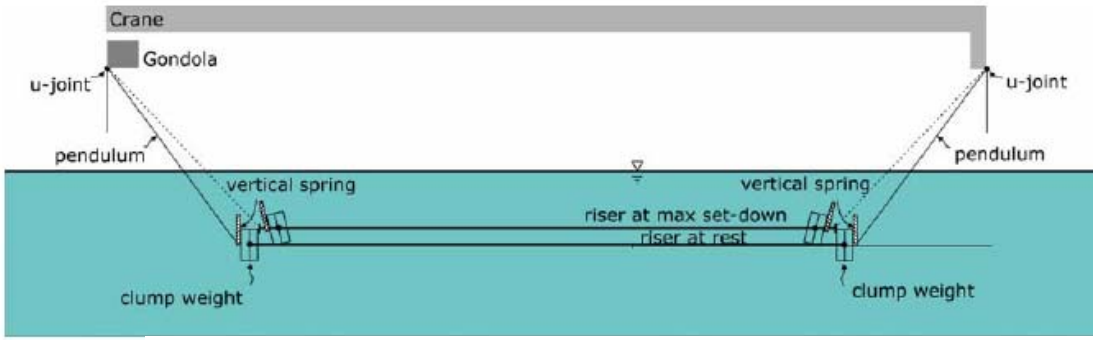
Benchmark case selection

- 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)

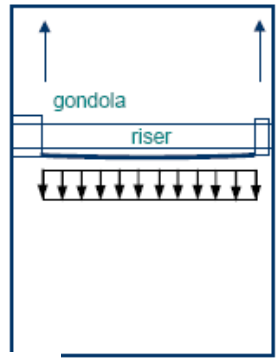
Experiments and Scaling

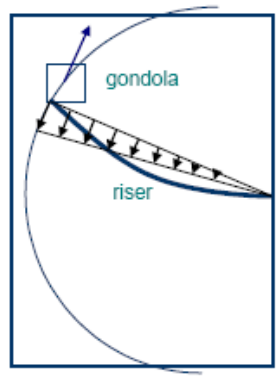


Benchmark against NDP experiments



Uniform Flow





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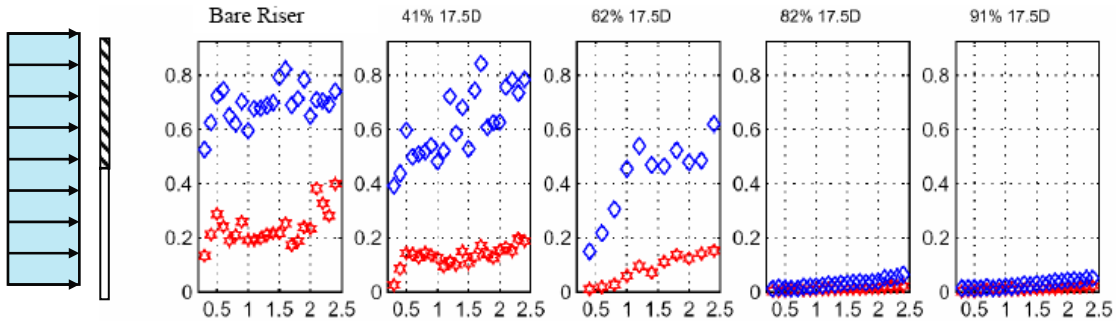
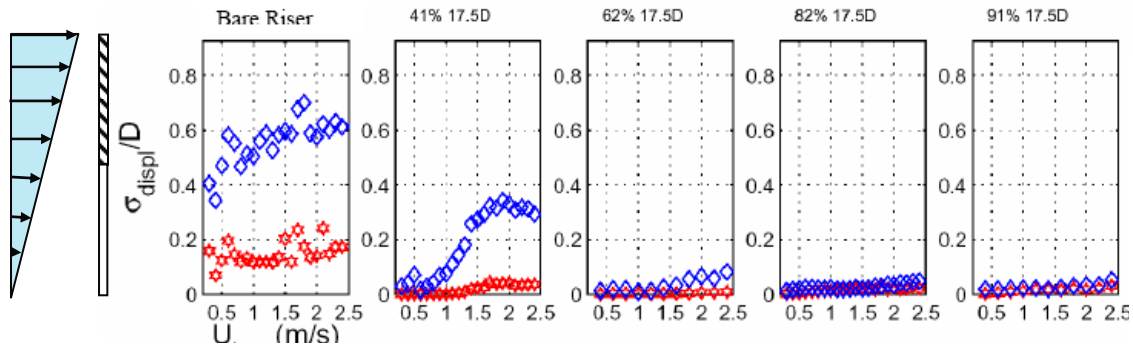


Linear shear flow



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

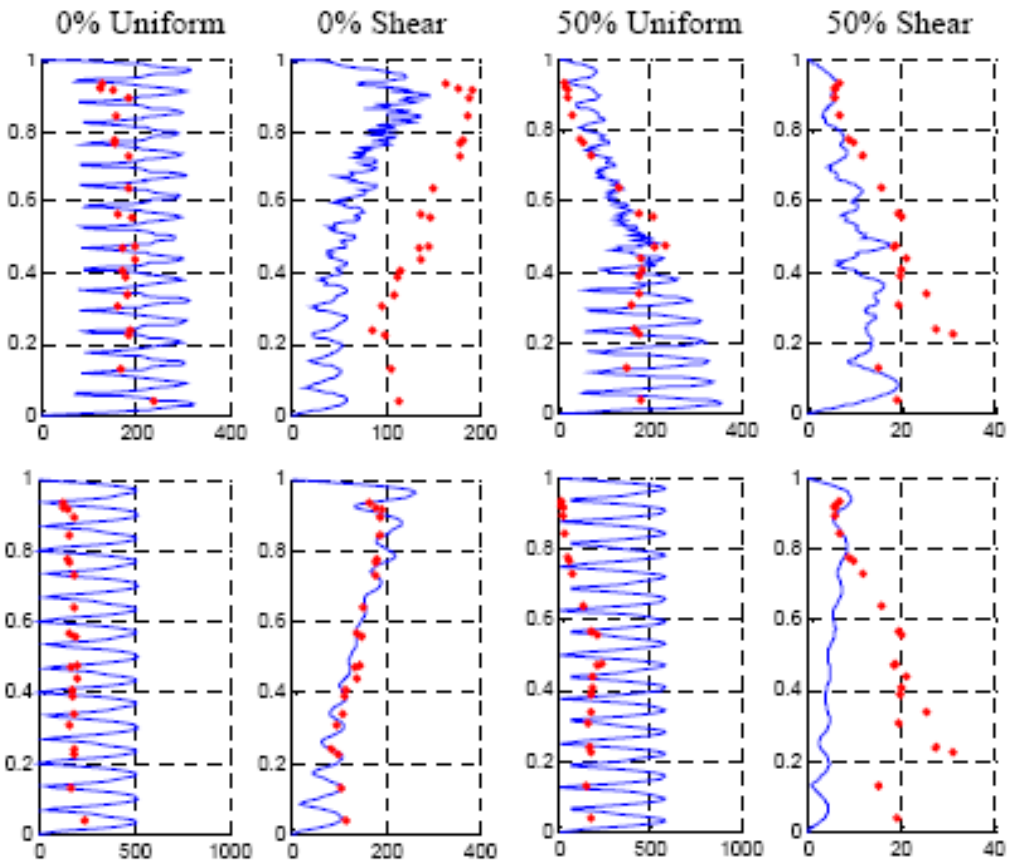
Procedure

- 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



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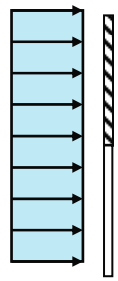

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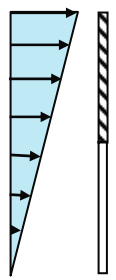

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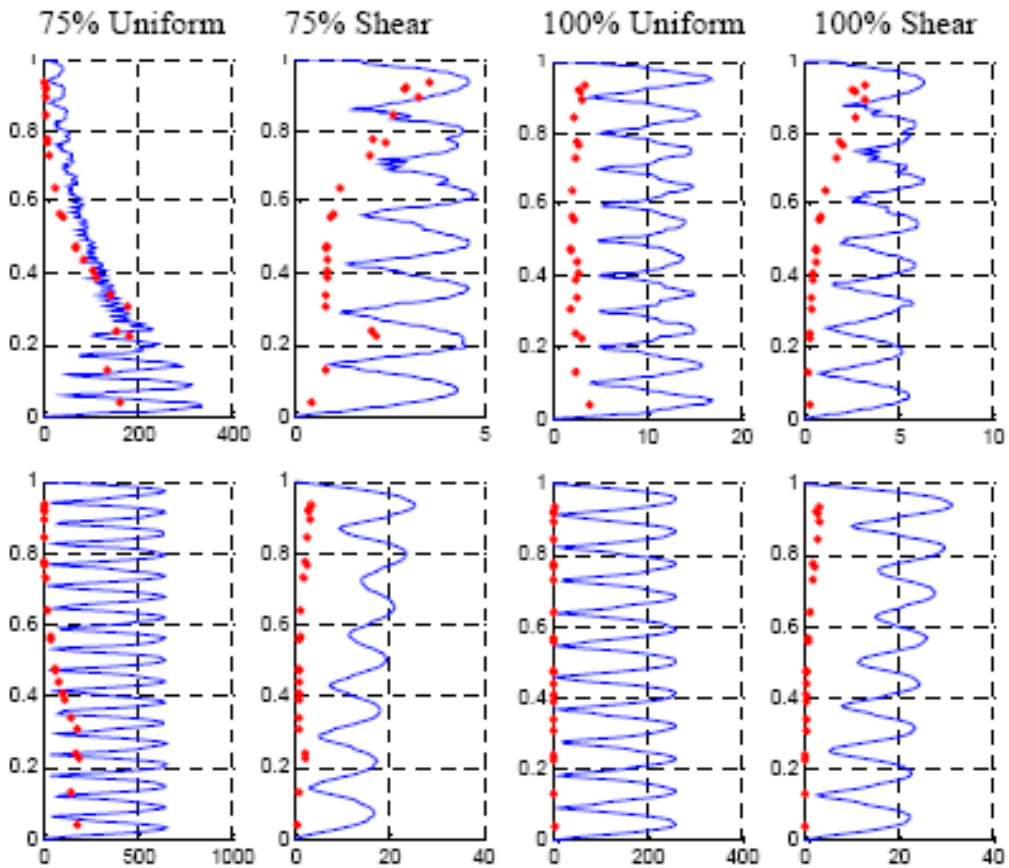

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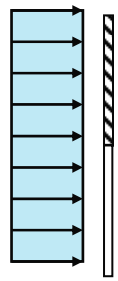

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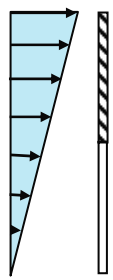
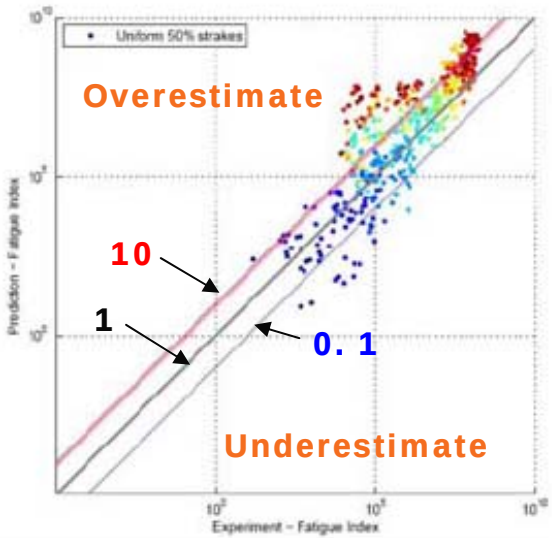
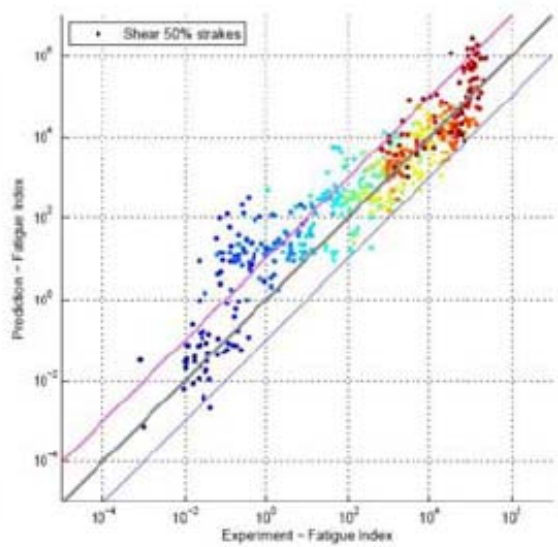


Summary plots 50 % strake - fatigue

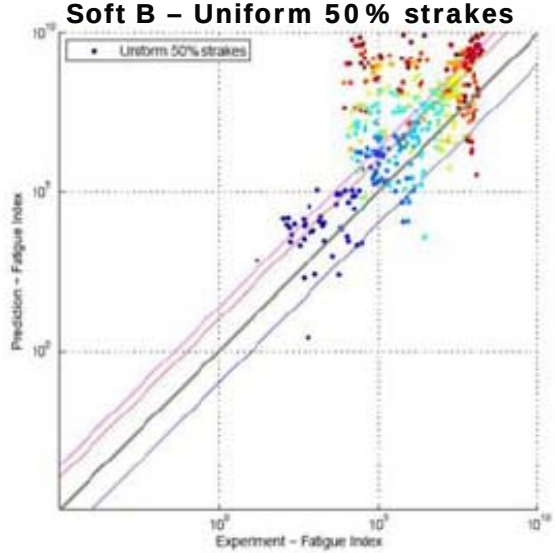
Soft A – Uniform 50 % strakes



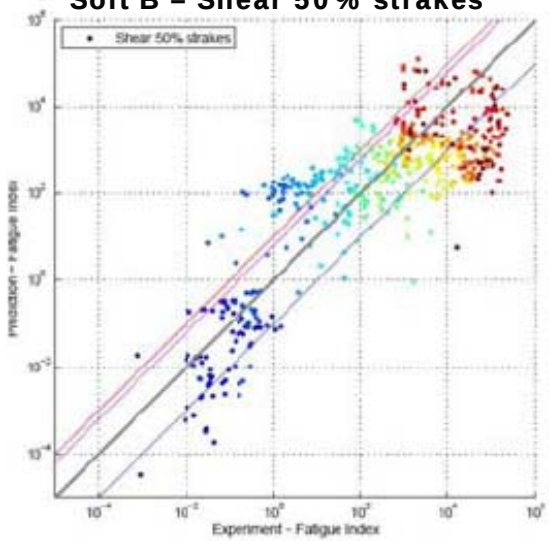
Soft A – Shear 50 % strakes



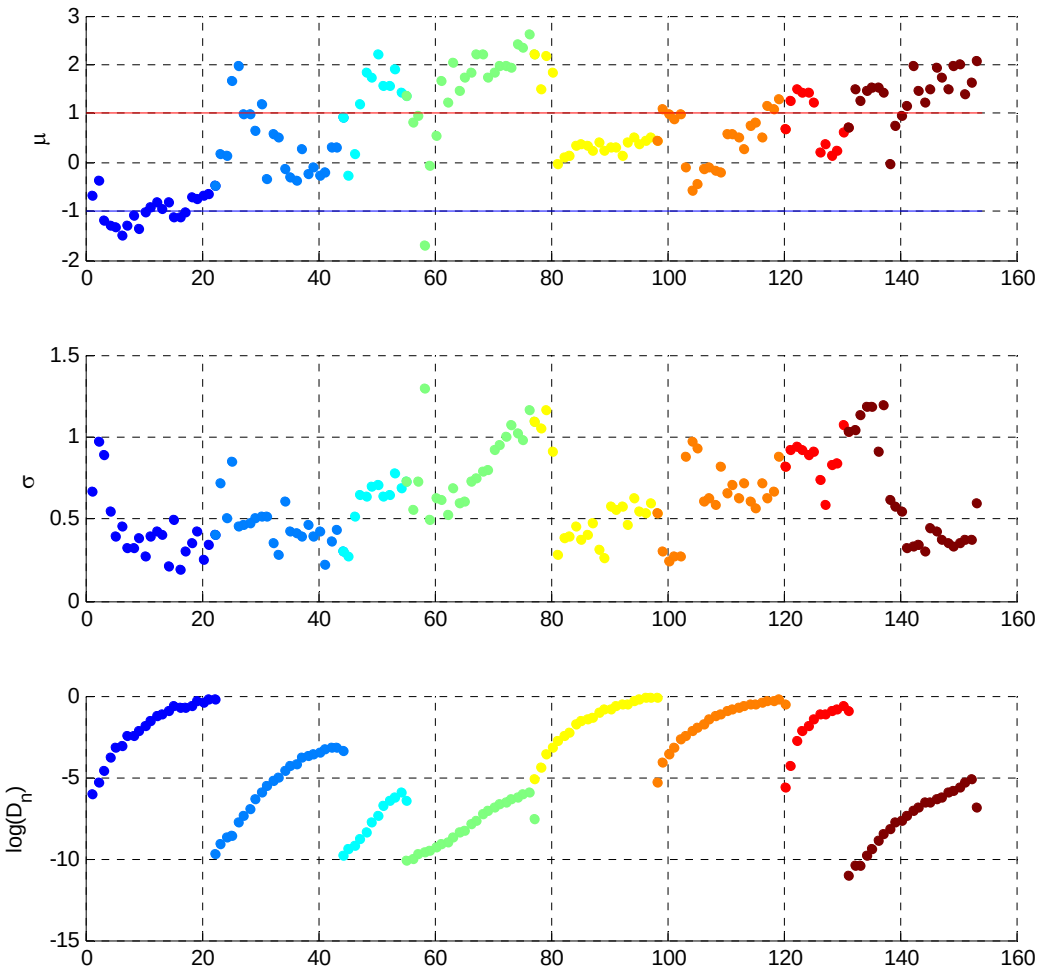
Soft B – Uniform 50 % strakes



Soft B – Shear 50 % strakes



Fatigue bias summary – Software A

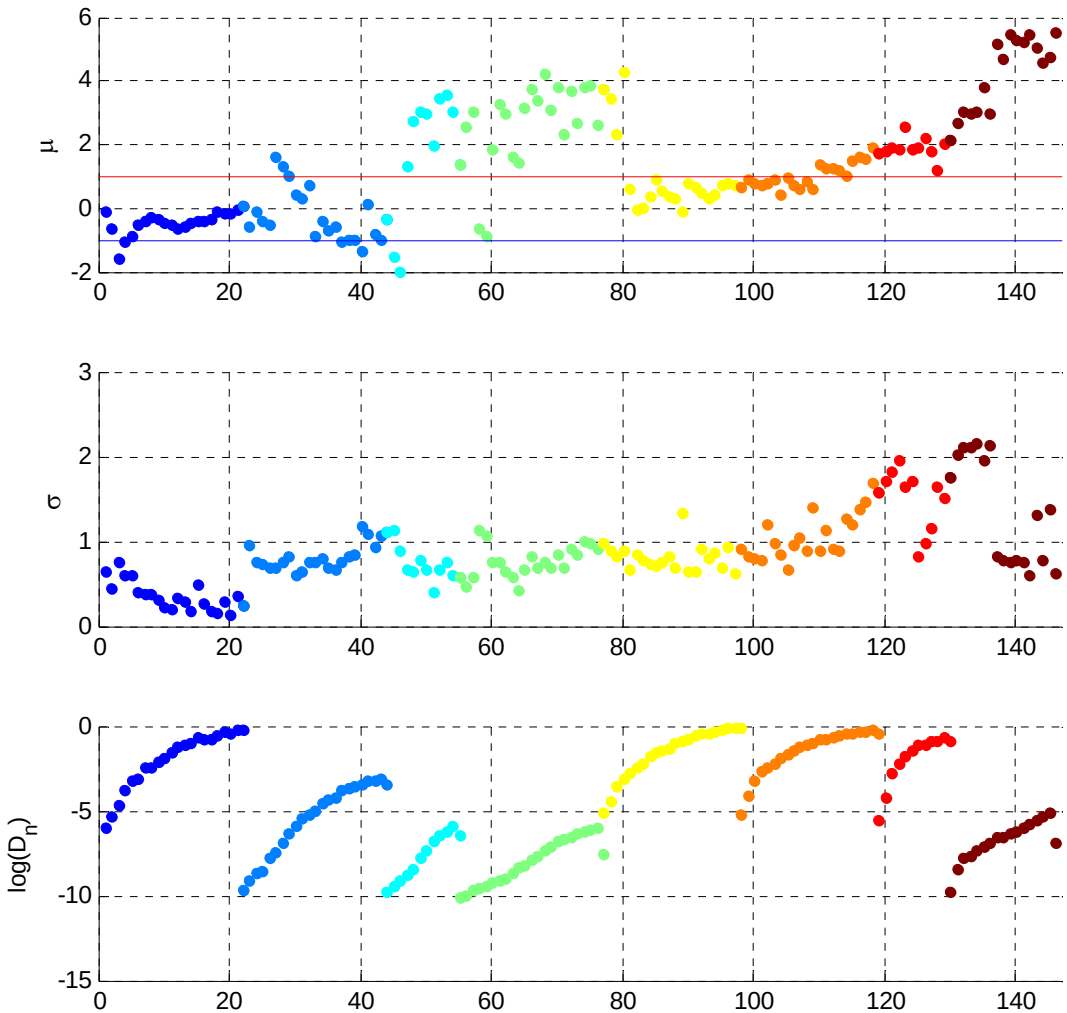


- Statistics of bias for all cases
- Represent spatial variation and deviation
- Log of bias μ and σ

- Shear Bare
- Shear 50% strakes
- Shear 75% strakes
- Shear 100% strakes
- Uniform Bare
- Uniform 50% strakes
- Uniform 75% strakes
- Uniform 100% strakes

Note: High harmonics contribution not included

Fatigue bias summary – Software B



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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 !