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DNV-GL-RP-F105 Free-Spanning Pipeline and Application for Rigid Spools

Aravind Nair

19th DNV GL Technology Week: Offshore Pipeline Day

24th Feb. 2020

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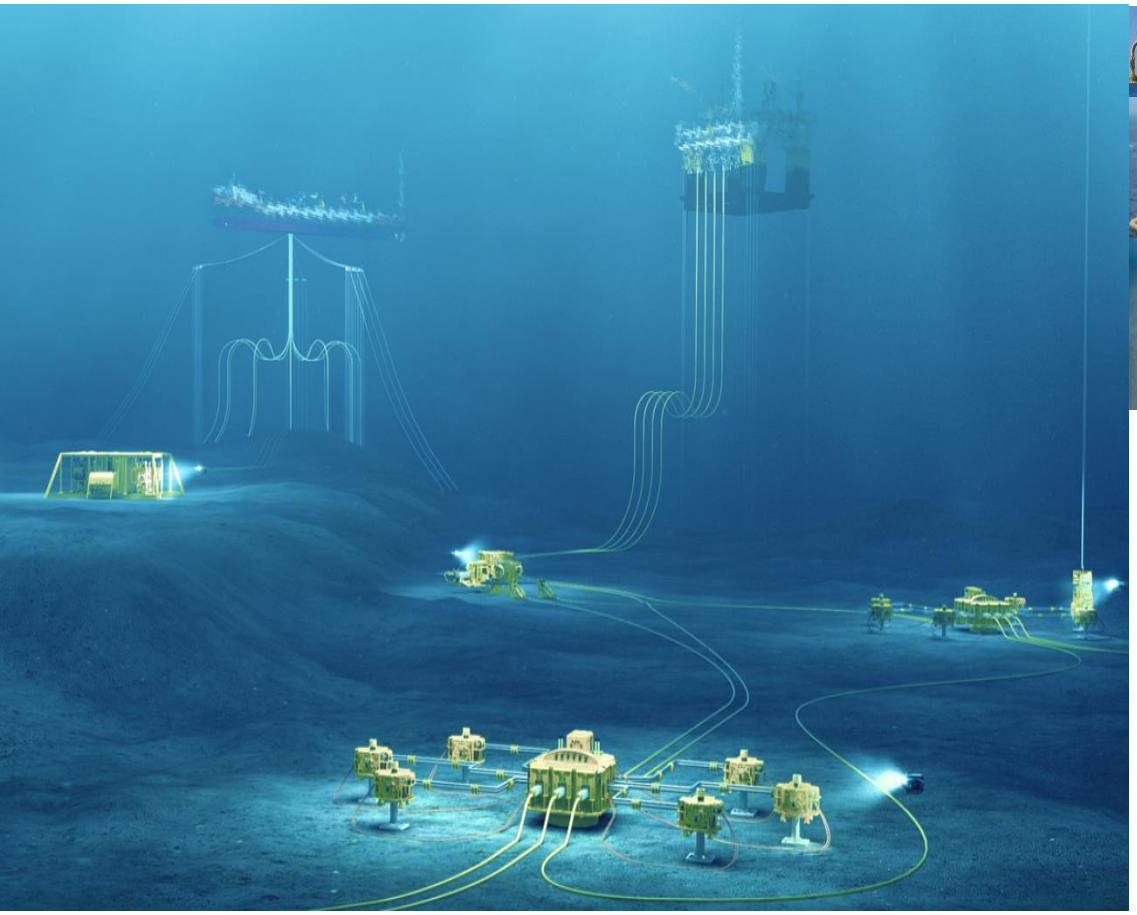
Jumper Systems



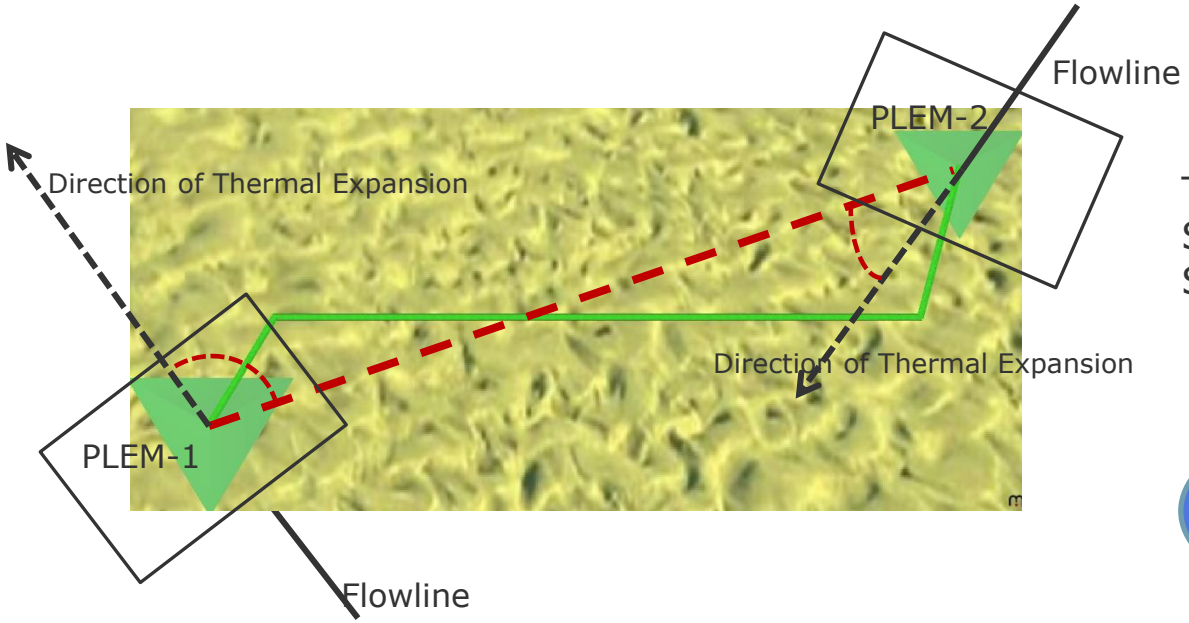
Objective: Raise Awareness

Agenda:

- Main Design Considerations
- State of Practice, Developments and gaps

OPTIMIZATION

- Jumpers to accommodate end-displacements (thermal Expansion, riser base motions)
- Increased flexibility desired
- Given a certain distance between end locations (such as location of PLETS and PLEMS; complex shapes to handle displacements



Thermal Damage:
Simple Pipe> U Shaped > M Shaped > Z Shaped (3D)

Jumper "KIT"

Design Considerations

- Installation
  - splash Zone
  - Installation connection tolerance (inclination angles)
  - Buoyancy module distribution
- Metrology Tolerance
- End displacement tolerance/ strength
- Corrosion/ erosion etc.
- Settlement potential
- Clearance
- Fatigue

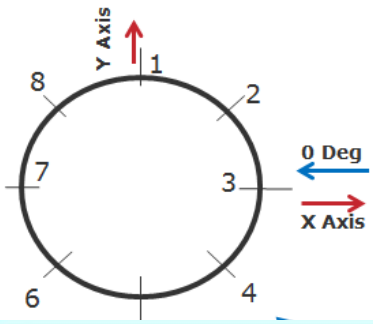
API RP 17R-2015

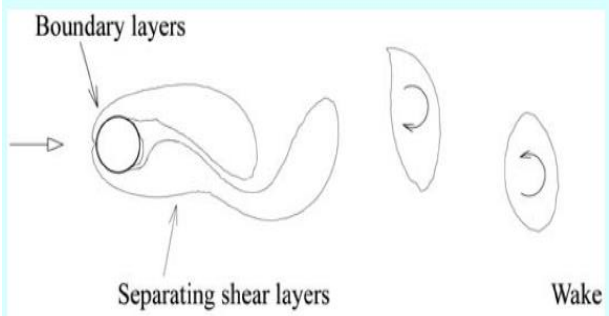
VIV and FIV should be evaluated using dedicated programs, spreadsheets…
VIV Analysis should be performed **according to principles in DNV RP F105**, DNV RP C203…

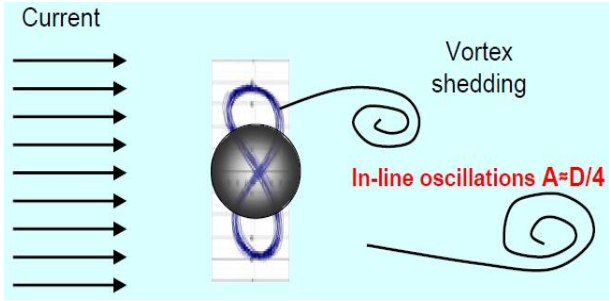
State of the Art on VIV Analysis

- CROSS-FLOW VIV
- INLINE VIV

- Response Based Models
- Force Based Models
- Flow Based Models







Report from the vortex induced vibration, specialist committee of the 25th ITTC (2008)

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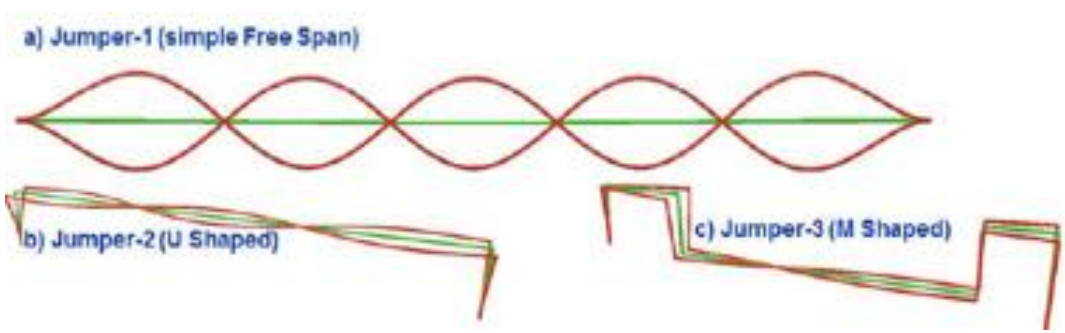
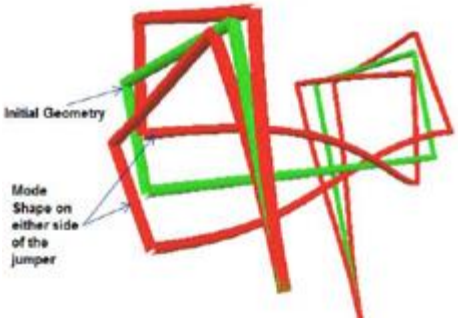
Challenges-Category

CHALLENGES

- **STRUCTURE**
- **FLUID INTERACTION**
- **DAMAGE ESTIMATION**





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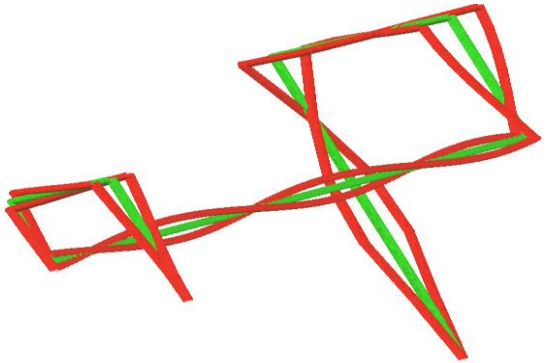
The issue

Designers discretion and judgement: What am I comfortable with?

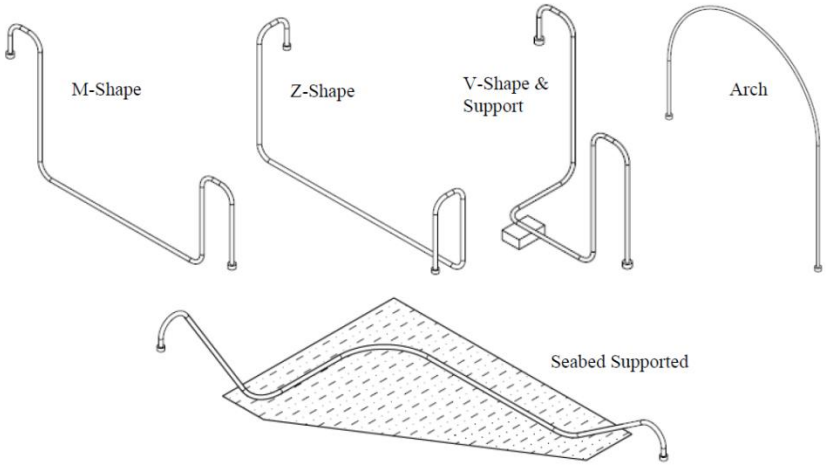
Jumpers		In-line VIV Fatigue Lives (years)	Cross-flow VIV Fatigue Lives (years)
		SCF = 1.25	SCF = 1.25
16inch	OD	3.1	VIV not Expected
	ID (Sour Service)	1.1	

"The Significance of Low Velocity Near Bottom Currents on the In-Line Vortex-Induced Vibration Response of Rigid Subsea Jumpers:, Madhu Hariharan, Mark E. Cerkovnik (2Hoffshore Inc) and Hugh M. Thompson (ChevronTexaco), ?



Damage/ Fatigue Life	LOCATION-1		LOCATION-2	
	Flexure	Torsion	Flexure	Torsion
Damage Rate (1/Yr)	45.64	0.05	0.13	1.43
Fatigue Life (Days)	8	7602	2791	255

"VIV Assessment of Rigid Jumper Systems-A comparative study on Jumper shapes", A. Nair, P. Sharma, G. Grytøyr, O. Fyrileiv, K. Vedeld, ISOPE 2013



"New Approach to the Design of Rigid Jumpers for Free Standing Hybrid Risers", S Plouzennec, M. Sonawane, T. Eyles,IBP1708-1

CAMERON

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Damage Estimation Contd..

Fatigue life (years)	Mode 1 out-of-plane	Mode 2 in-plane	Mode 3 out-of-plane	Mode 4 in-plane	Mode 5 out-of-plane
Out-of-plane flow / No marine growth	2.0	0.04	∞	∞	∞
In-plane flow / No marine growth	0.32	0.50	500	∞	∞
Out-of-plane flow / MG at small bores	0.16	0.014	500	∞	∞
In-plane flow / MG at small bores	0.017	0.024	0.76	12000	∞
Out-of-plane flow / MG at all pipes	0.99	0.24	90000	∞	∞
In-plane flow / MG at all pipes	∞	15000	∞	∞	∞

Geometry/ Client: Undisclosed

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DNVGL-RP-F105 (2017)

- App.A Application of DNVGL-RP-F105 to jumpers, spoolers, flexible loops and subsea piping
  - New section providing detailed guidance on how to conservatively apply this RP to fatigue and ultimate limit state calculations of spools, jumpers, flexible loops and other non-straight piping systems.

APPENDIX A APPLICATION OF DNVGL-RP-F105 TO JUMPERS, SPOOLS, FLEXIBLE LOOPS AND SUBSEA PIPING

A.1 General

A.1.1

Jumpers, spools, flexible loops and piping systems have traditionally been designed according to avoidance criteria for VIV. When avoidance criteria have been difficult to satisfy for a proposed design, environmental covers, re-routing or re-design have historically been applied to achieve VIV avoidance. Recently, it has become increasingly common to allow fatigue damage due to VIV and environmental loading on jumpers, spools, flexible loops and subsea piping systems, defined generally here as non-straight geometries. Because of lack of specific design guidelines for VIV design of non-straight pipes, this recommended practice has become a common design code for such systems.

A.1.2

Fatigue and extreme environmental design of subsea pipelines and risers have been performed for decades, but non-straight geometries present a new and substantial challenge for conservative and reliable VIV fatigue and extreme environmental loading design. This appendix gives guidance on how to apply this document to such systems.

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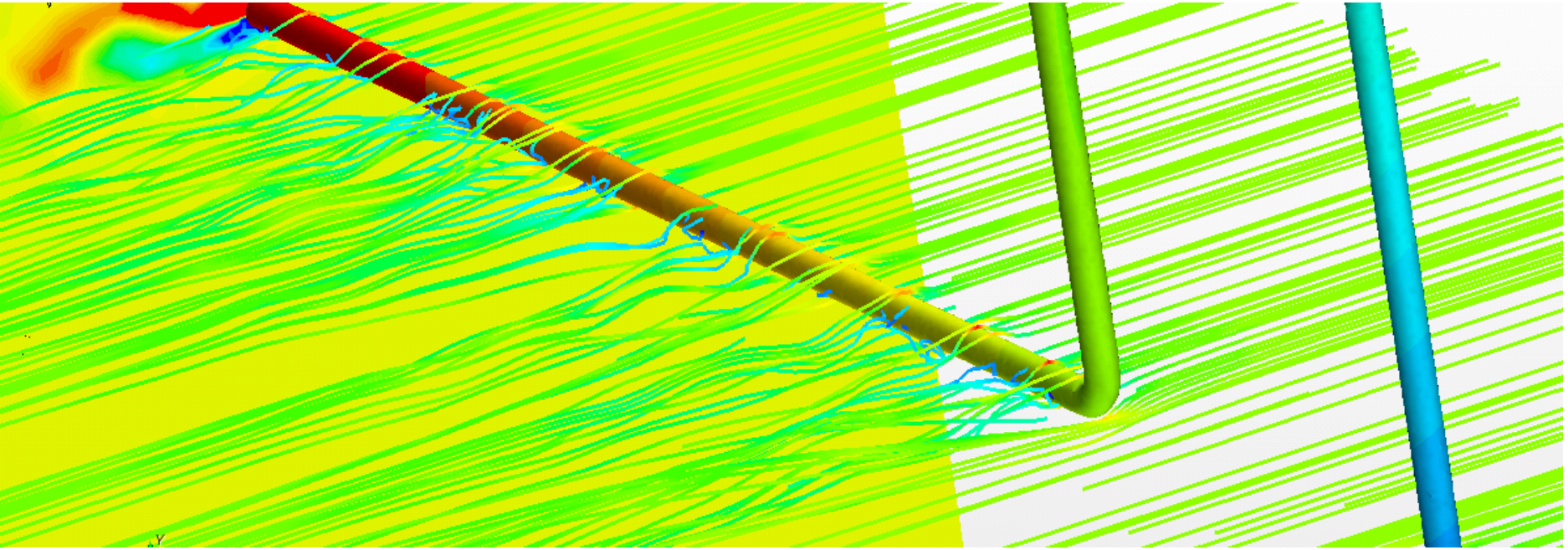

OIL & GAS

Jumper VIV JIP

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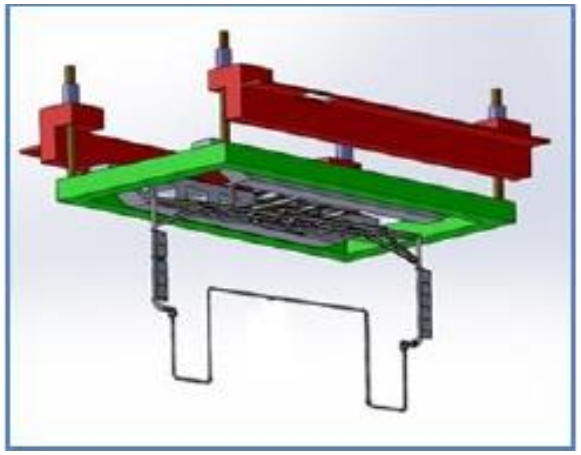
JIP Activities

- ExxonMobil Model Test Data (2013)
  - JIP Validation process
- Development of new response model
- New Guidance on Jumper VIV based on JIP
- Proof-of-concept FSI study (benchmark against test)
- Phase-II pre-engineering

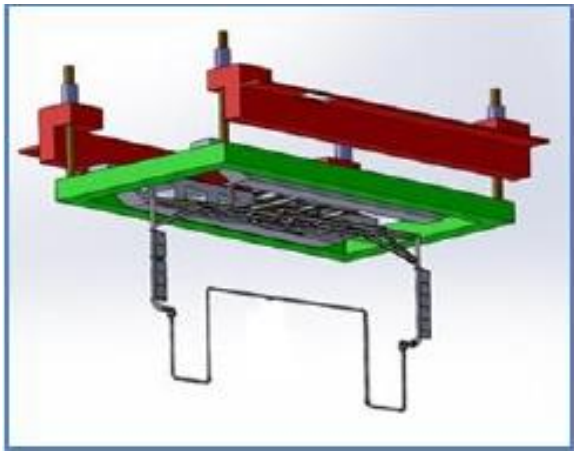


Zheng, Haining et.al (OMAE 2015)

Guidance Note: As part of the JIP Study, new response curves are developed for jumper systems. The response curves are developed using the ExxonMobil model test data, provided to DNV GL as part of the first phase of the JIP. The response curve presented here shall be used for Jumper VIV response prediction until further information is available that necessitates further update to the model. This may include additional test data on various iterations of jumper lengths, sizes and types (including 3D jumper systems).

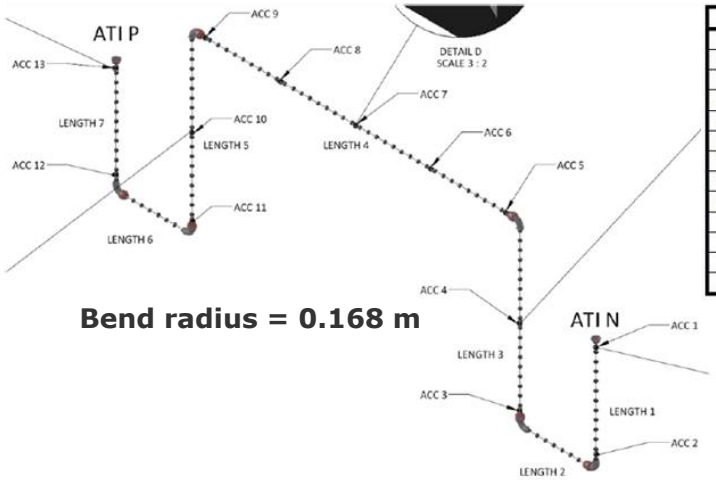
Cautionary Note: At this point it is assumed that the force-based models need to be calibrated for response of complex pipe systems and subsequently verified for different pipe lengths, sizes, orientations, etc. and for any complex pipe systems (jumpers, manifold pipework, subsea tree systems, etc.).

Model Test Geometry



Zheng, Haining et.al (OMAE 2015)

segment	length	Units
L1	1.495	m
L2	1.000	m
L3	2.323	m
L4	4.327	m
L5	2.326	m
L6	1.000	m
L7	1.495	m

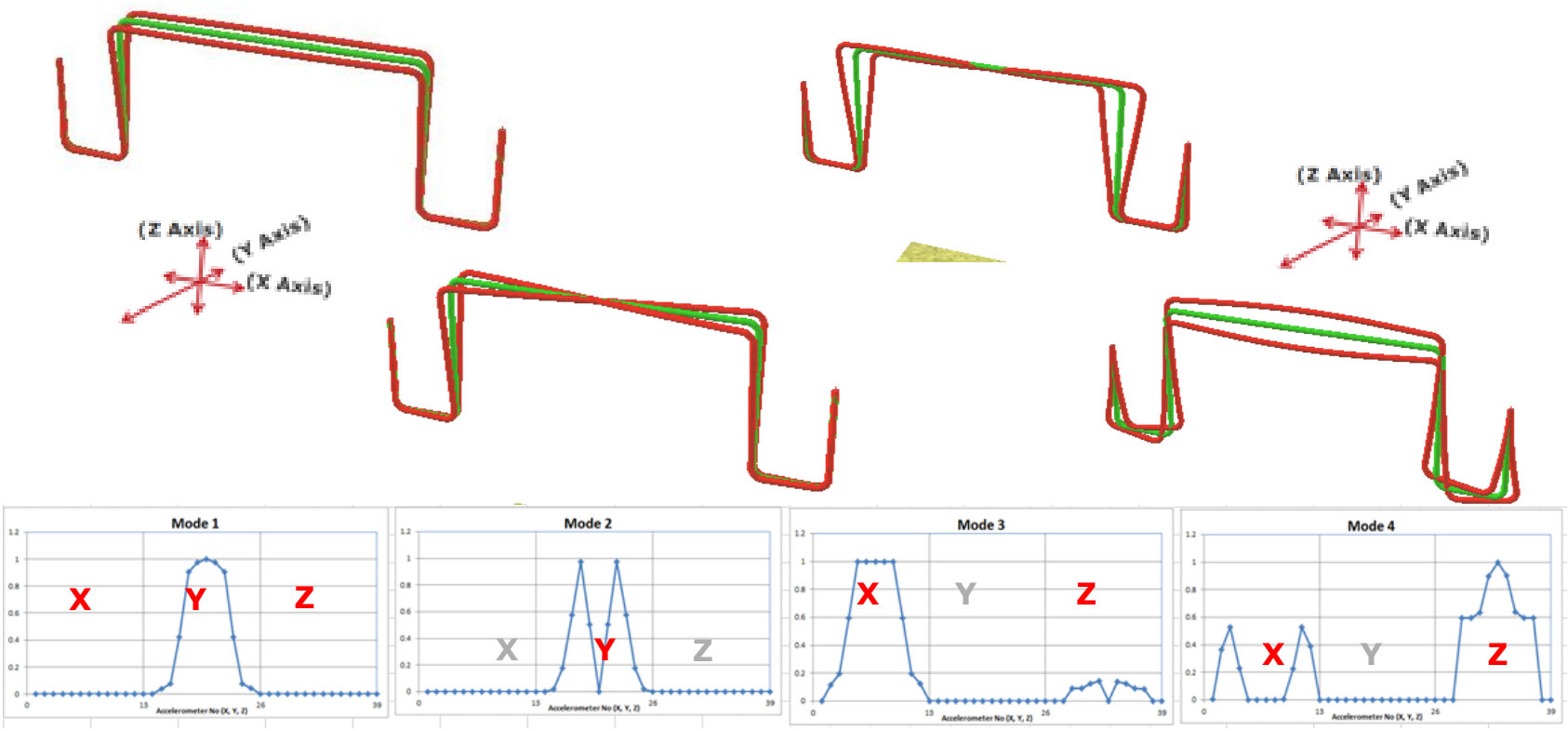


Bend radius = 0.168 m

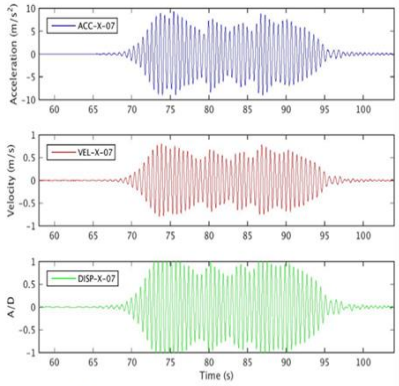
Accel #	x (m)	z (m)	Jumper Pipe
1	-3.165	0.93	L1 ATI_N
2	-3.165	2.14	L1
3	-2.157	2.148	L3
4	-2.157	1.158	L3
5	-1.98	0	L4 (reading erroneously)
6	-0.99	0	L4
7	0	0	Origin centre L4
8	0.99	0	L4
9	1.98	0	L4
10	2.157	1.158	L5 (local x dead)
11	2.157	2.148	L5
12	3.165	2.14	L7
13	3.165	0.93	L7 ATI_P

Test Description	# of tests	Tow speed range (m/s)	Orientation (degrees)
Bare jumper	83	0.05-0.98 (1)	10 (2), 45, 90
Straked jumper	54	0.05-1.24	10(2), 45, 90

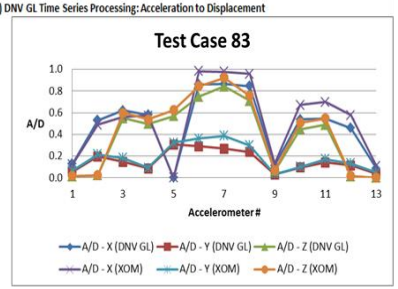
Mode Shape



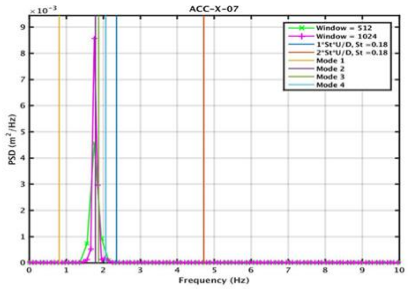
Guidance Note: Safety factor of 1.05 corresponding to well defined span characteristics shall be applied only when Shell or Solid FEA model has been used for frequency estimation. This is primarily because of the differences between the JIP beam model FEA with that of the pluck test frequencies. It was noticed that the shell FEA models resulted in frequencies closer to the pluck frequencies than the beam models.



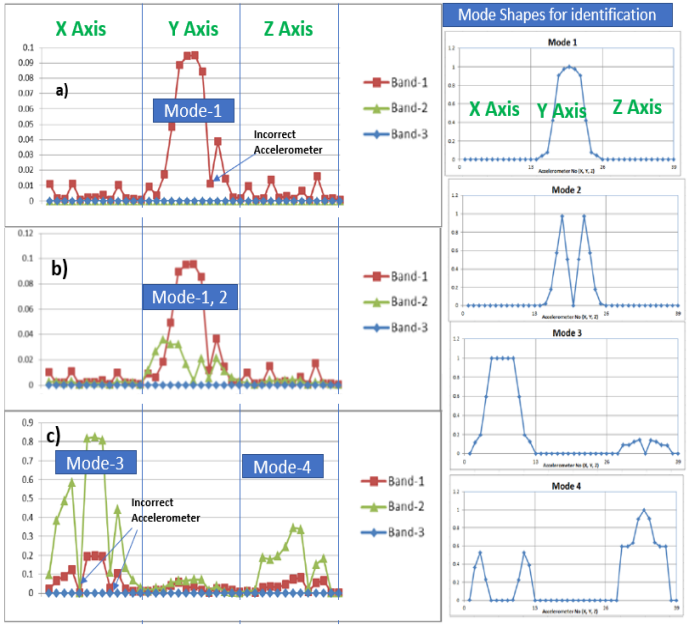
a) DNV GL Time Series Processing: Acceleration to Displacement

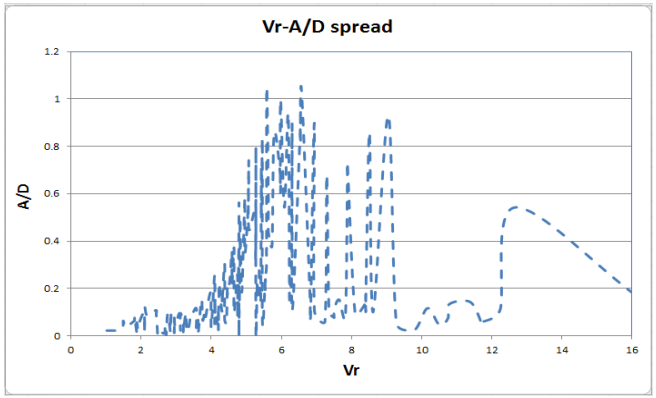


b) Max. A/D response at each sensor location



c) PSD of x displacement at accelerometer # 7





Classifying Response

Response Direction

(in-Plane Horizontal)

Current Direction

Classification

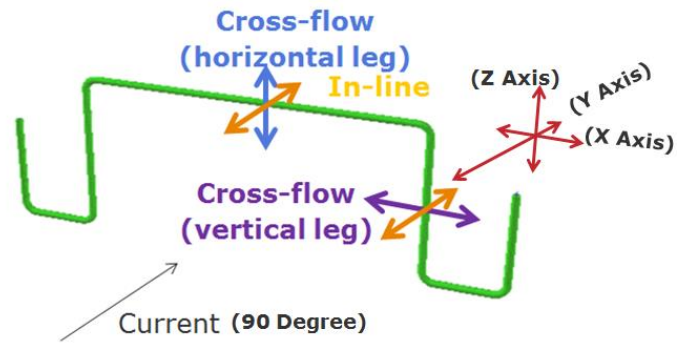
X DIRECTION					
0Deg		45 Deg		90Deg	
INLINE		Cross or Inline		CROSS	
Vr	A/D	Vr	A/D	Vr	A/D

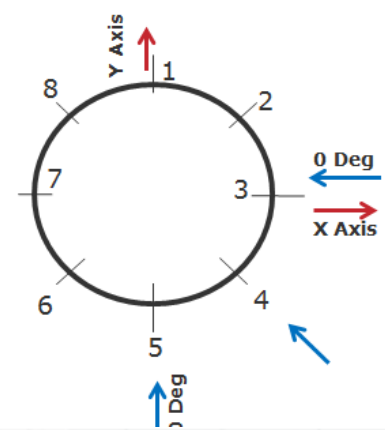
Only Mode 3 and Mode 4 falls this group

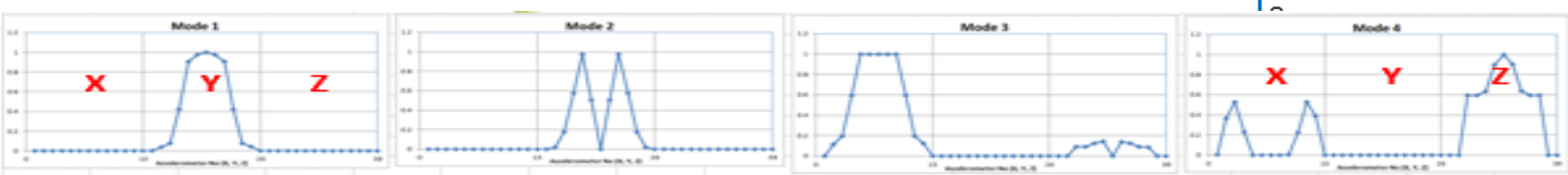
Y DIRECTION					
0Deg		45Deg		90Deg	
CROSS		Cross or Inline		INLINE	
VR	A/D	VR	A/D	Vr	A/D

Only Mode 1 and Mode 2 falls this group

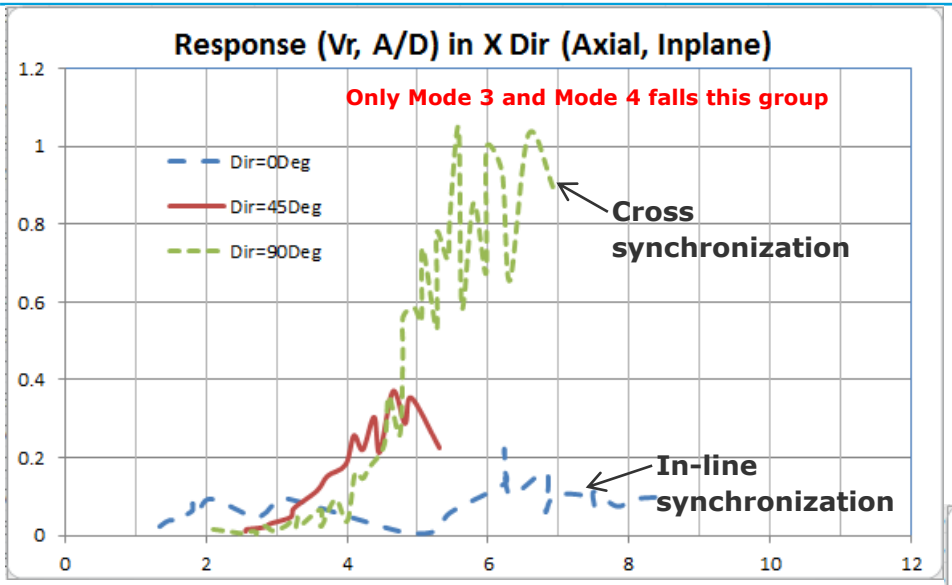
Z DIRECTION					
0Deg		45Deg		90Deg	
CROSS		CROSS		Cross	
Vr	A/D	Vr	A/D	Vr	A/D





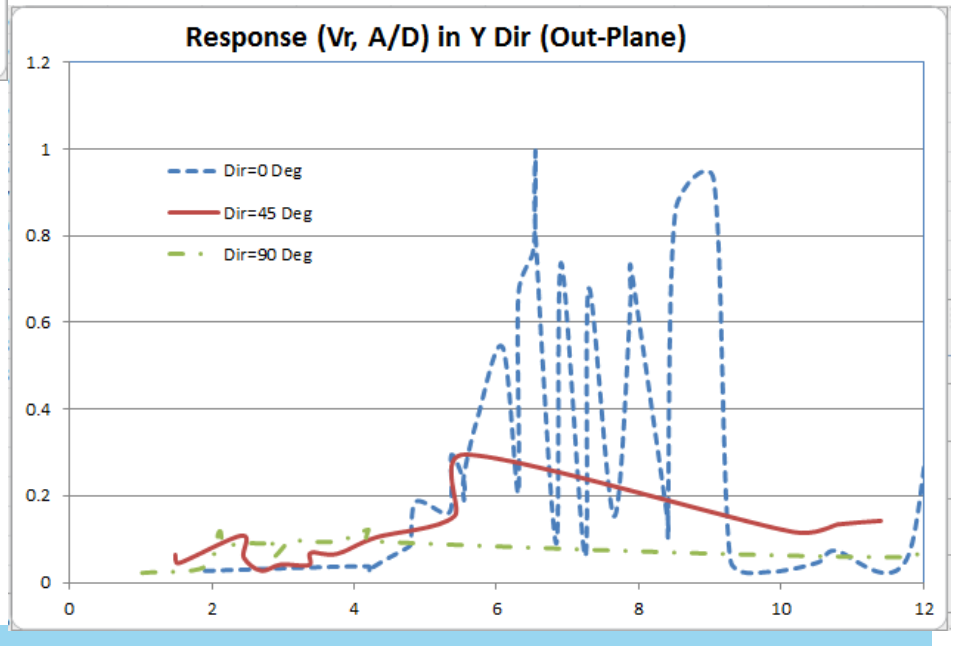


Response direction classification

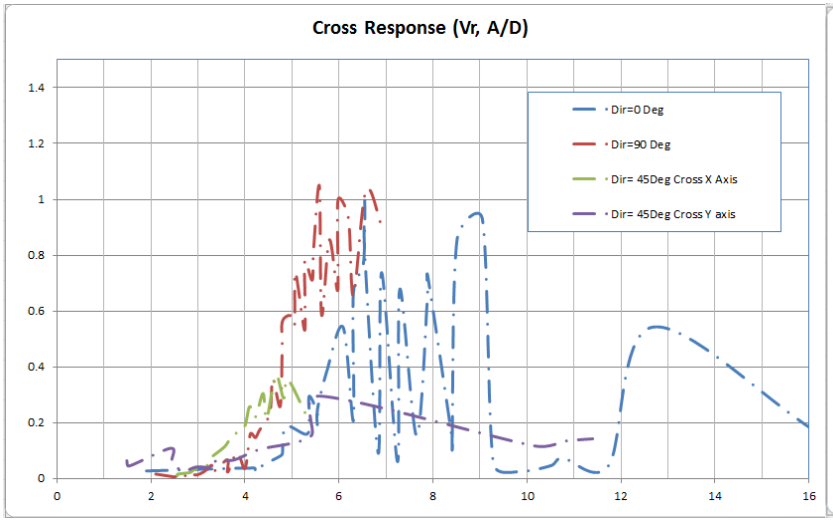


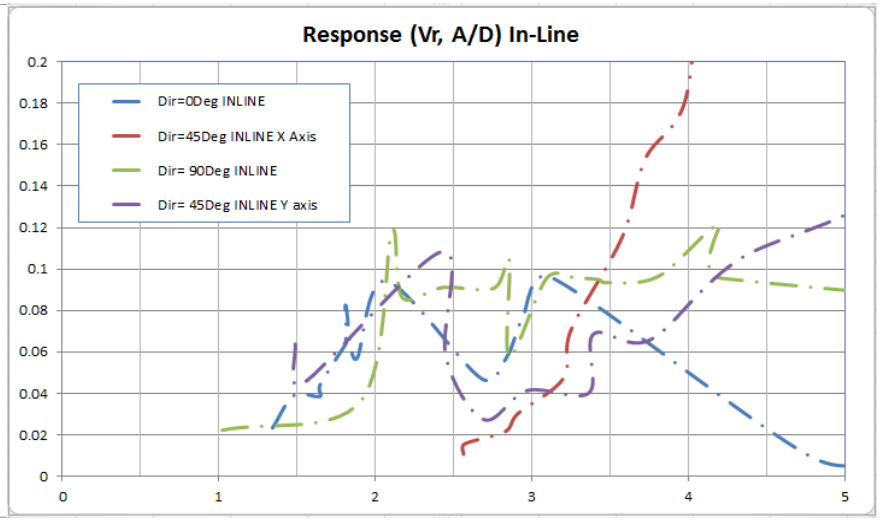
- X direction response: 45-degree and 90-degree current cases show similar trend. [0-degree current represents in-line VIV~ Ref. DNVGL-RP-F105]
- Y direction response: 45-degree and 0-degree show similar trend. [90-degree current represents in-line VIV~ Ref. DNVGL-RP-F105]
- Z direction response: 45-degree and 90-degree current cases show similar trend [vertical response from 0-degree currents are negligible].

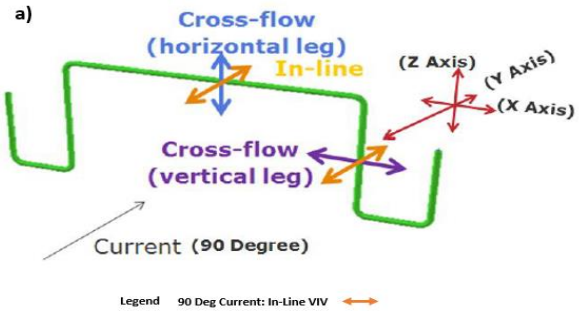
Guidance Note: Due to the limited data from 45-degree cases, this guidance note does not recommend reduction in response amplitudes accounting for the directionality in the angle of attack.

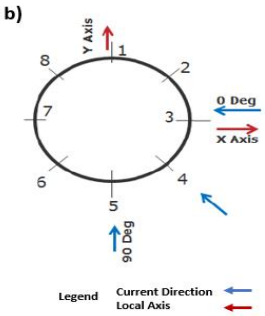


Cross-Flow and In-line Classification







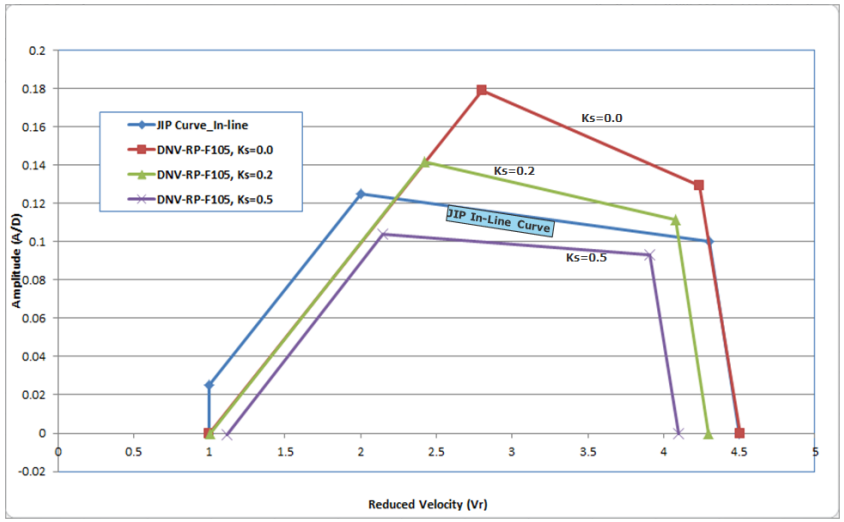


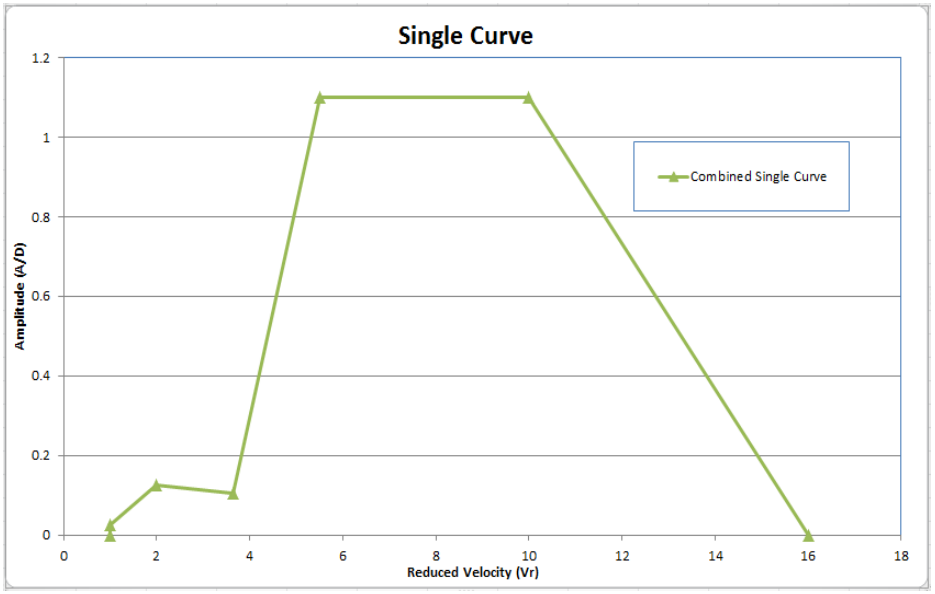
Few immediate observations:

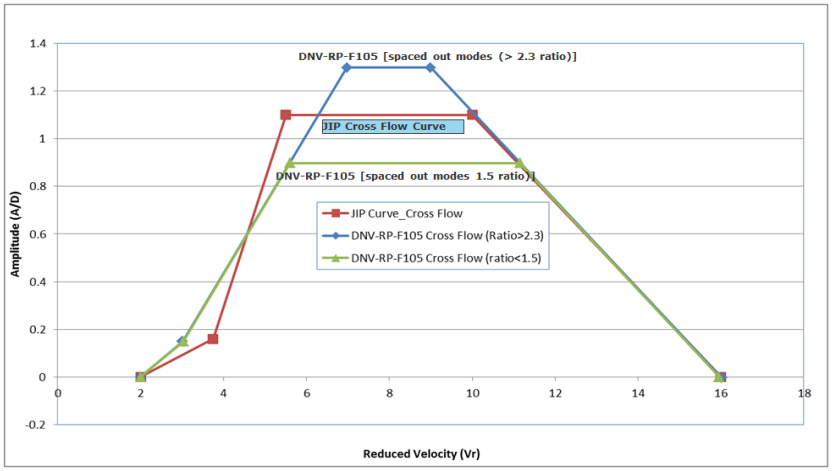
- Cross-flow response window: 0-degree and 90-degree cases show similar trend and amplitudes.
- In-line Response window: 0-degree and 90-degree cases show similar trend and amplitudes.

JIP Curves

New Response Model Unique to Jumper Systems







* Jumper VIV Guidance Report

Summary

- Failure occurs every other year (not a single cause)
- Gaps in Industry Guidance
  - Design may not check all relevant failure modes
  - How to check/ Industry acceptable procedure not available.
- System becoming more complex, action is needed

25m tall jumper→ is it a Riser or a Pipeline?

?????

Assurance
Aravind.Nair@dnvgl.com
Mobile: +1-979-204-9657 | Direct: +1-281-396-1348

www.dnvgl.com

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