

Engineering solutions



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LGS: An Innovative Solution for Mitigating Pipeline Free Span Fatigue

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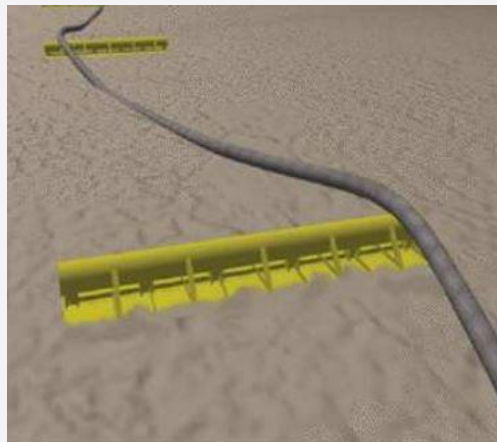
Agenda



1. Pipeline Free Spans
2. Mitigation options for free spans
3. LGS – development and testing
4. Predicting VIV response
5. Installation challenges
6. Example retrofit deployment

Pipeline Free Spans

- > Section of pipeline without seabed support
- > Causes:
 - Uneven seabed
 - Artificial pipeline supports
 - Changes in seabed topography



(Chee et al)



(Nordnes)

Pipeline Free Spans

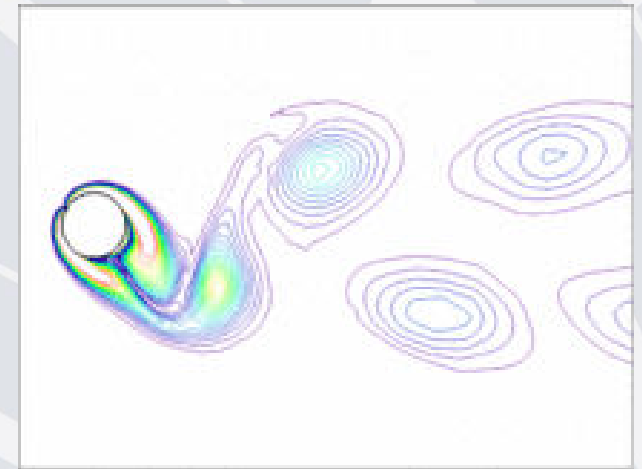
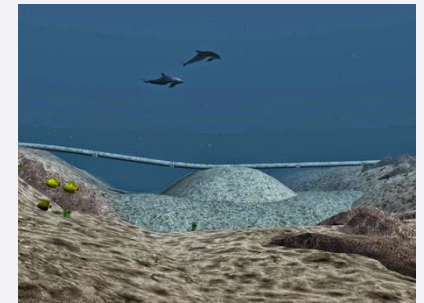
- > Section of pipeline without seabed support
- > Causes:
 - Uneven seabed
 - Artificial pipeline supports
 - Changes in seabed topography
- > Hook/snag risk for trawlers
- > Subject to wave and current loading



(Nordnes)

Pipeline Free Spans

- > Section of pipeline without seabed support
- > Causes:
 - Uneven seabed
 - Artificial pipeline supports
 - Changes in seabed topography
- > Hook/snag risk for trawlers
- > Subject to wave and current loading
 - VIV risk
 - Increased fatigue loading
 - Increased maintenance costs



(Wirbel)

Dealing with Free Spans

- > Rectification
 - Grout bags
 - Rock dumping
 - Jetting high spots



(Foundocean)

Dealing with Free Spans

- > Rectification
 - Grout bags
 - Rock dumping
 - Jetting high spots
- > VIV mitigation
 - Fairings
 - Strakes



(Trelleborg)



Dealing with Free Spans



> Rectification

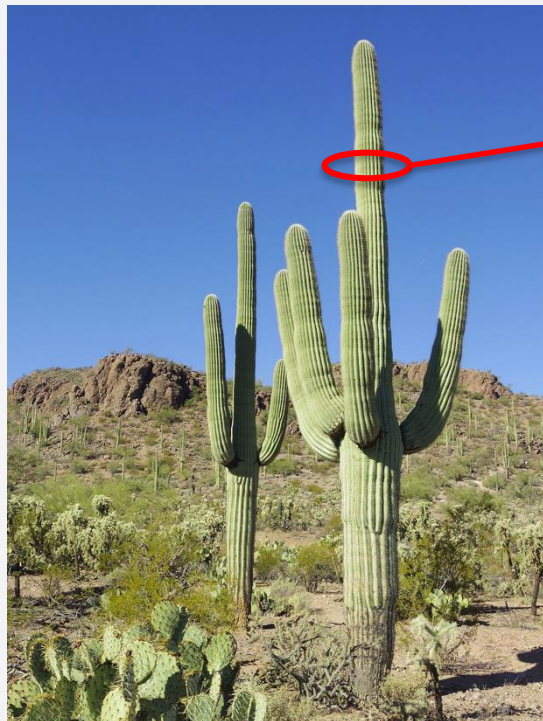
- Grout bags
- Rock dumping
- Jetting high spots

> VIV mitigation

- Fairings
- Strakes
- Longitudinally Grooved Suppression (LGS)

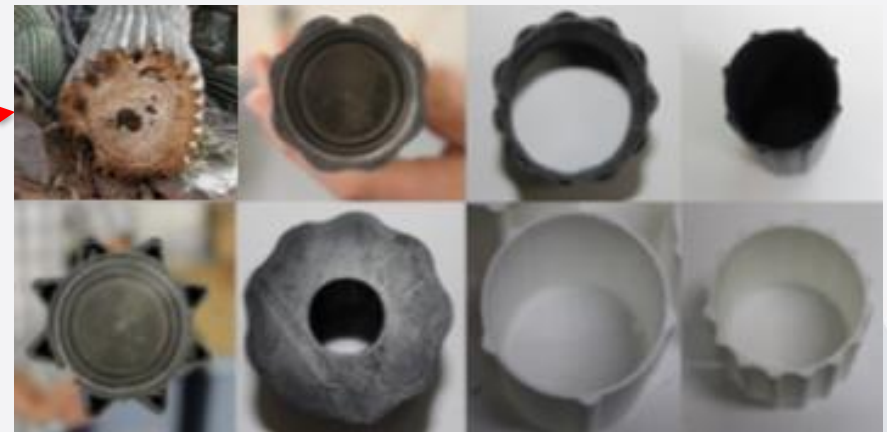
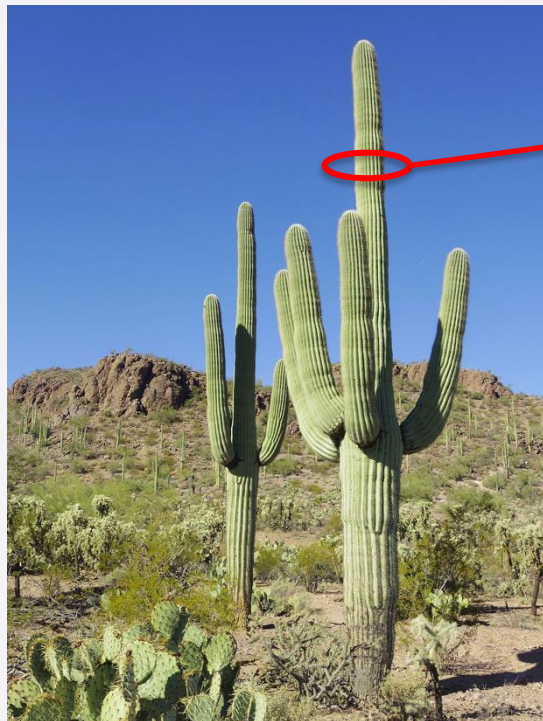
What is LGS?

LGS Conception



What is LGS?

LGS Evolution



- > Small scale (sub-critical R_E testing)
 - R_E : 3,000 to 16,000 (sub-critical)
 - 80 geometries tested

LGS Testing



> Large-scale testing

- Optimal variant selected (R8 profile)
- 1 : 3.8 scale test
- Fixed and free-vibration tests
- R_E up to 1,500,000 (critical R_E , post-critical R_E)

$$R_E = U D / \nu$$

Re: Reynolds Number

U: flow speed

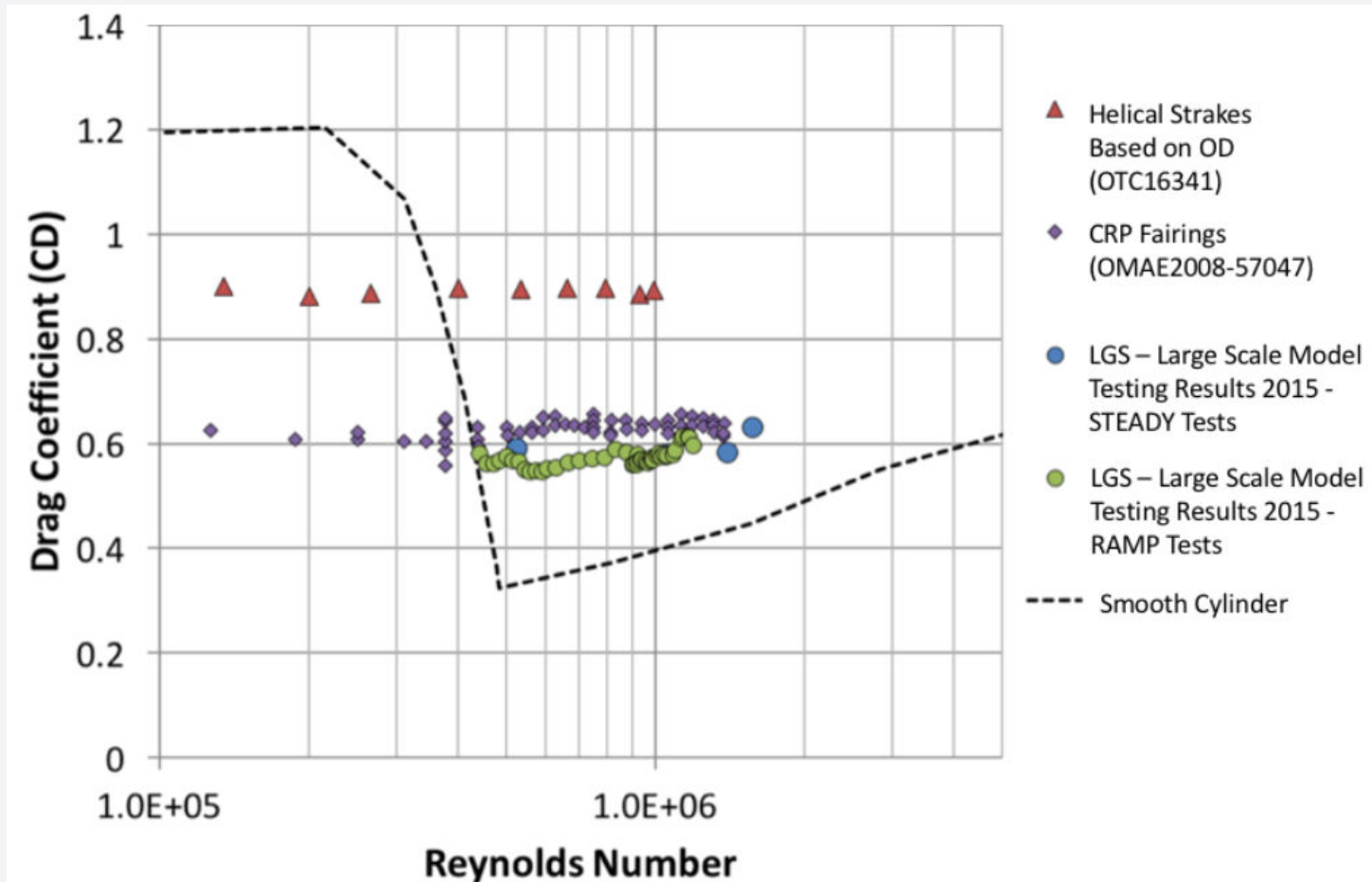
D: principal dimension (pipe diameter)

ν : kinematic viscosity

Low Reynolds number testing

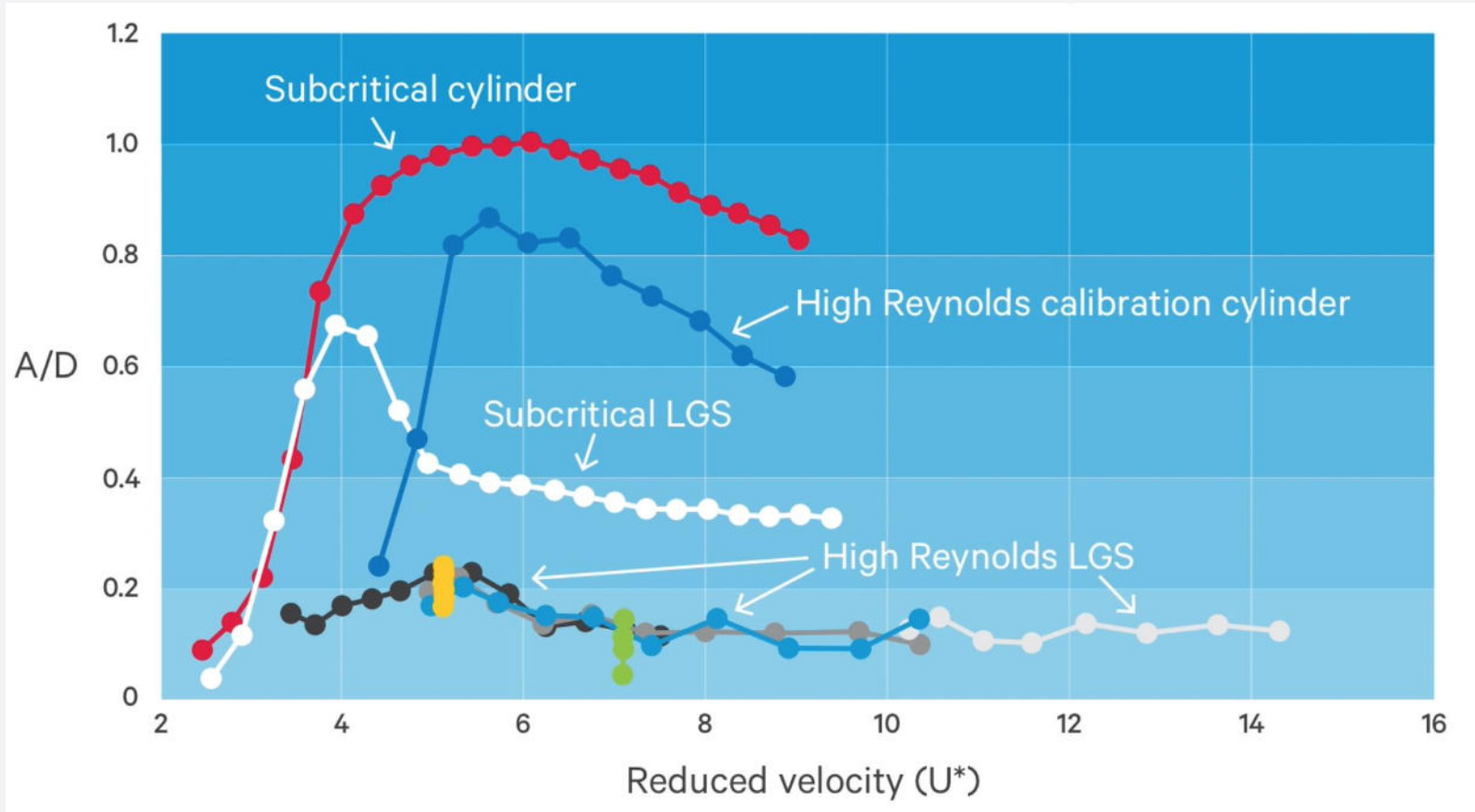
LGS Testing

Fixed (static) Drag Coefficients



LGS Testing

VIV Amplitude



$$U^* = U / f D$$

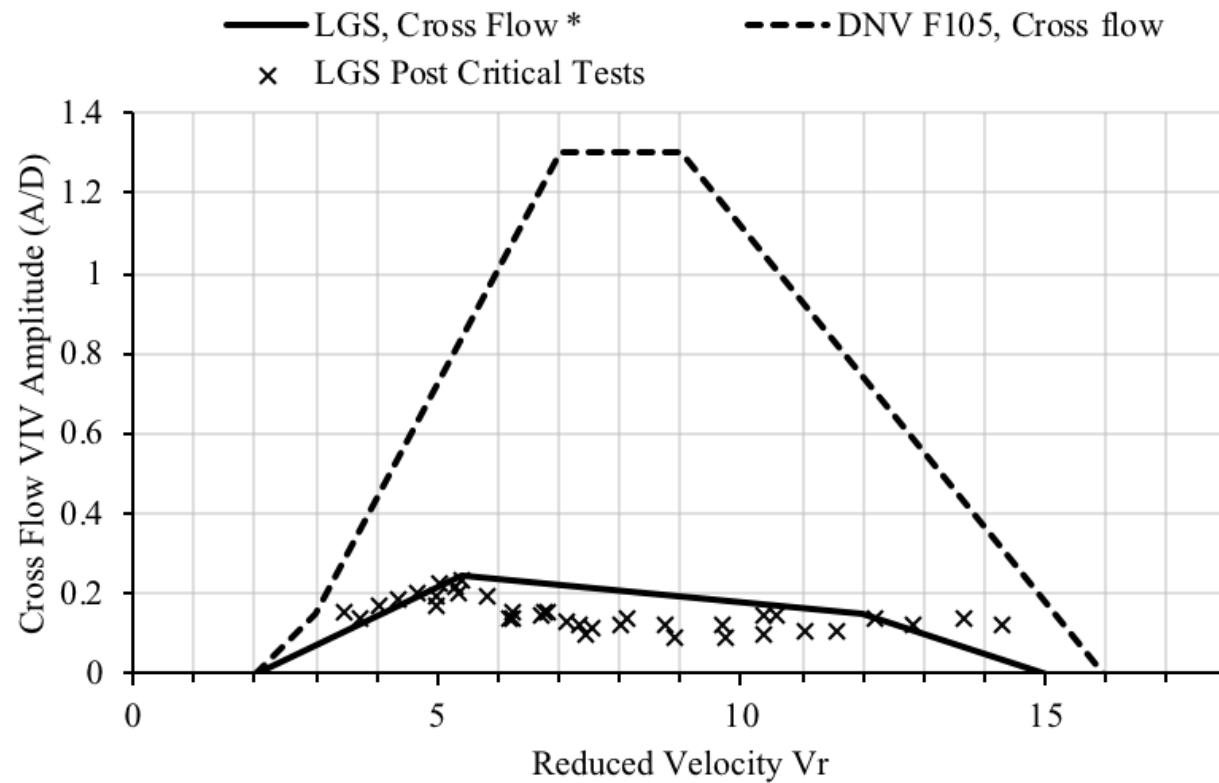
U: free stream velocity

f: frequency

D: hydrodynamic diameter

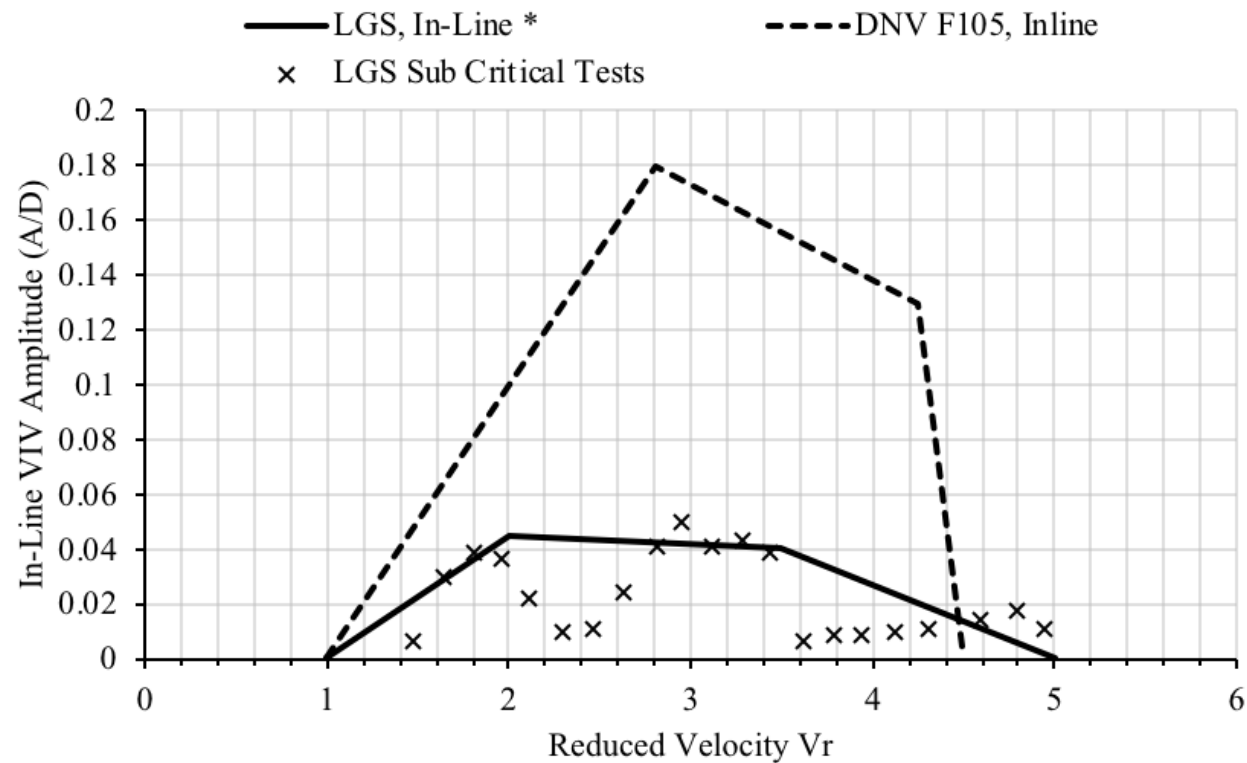
Application of LGS Data to Pipe Spans

Cross-flow response model



Application of LGS Data to Pipe Spans

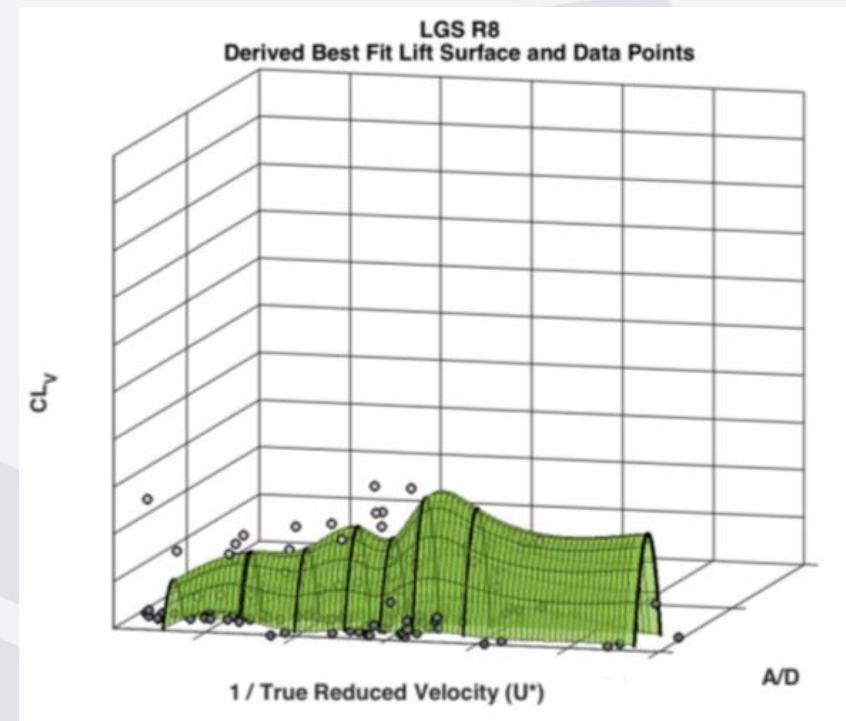
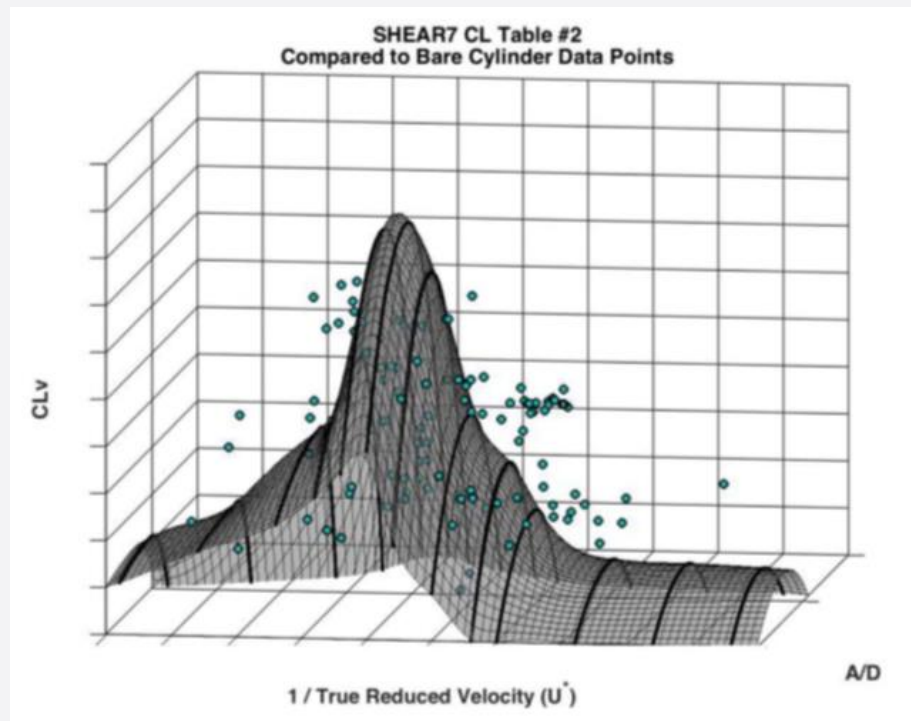
In-Line response model



Application of LGS Data to Pipe Spans

Force-based Model

> Comparison of Lift Curves:



Installation of Pipe Span LGS

Installation Challenges

- > High pipe diametrical tolerance
- > Low under-pipe clearance
- > Robustness
- > Low near-seabed visibility
- > Extended design life
- > ROV deployment challenges and timings

Installation of Pipe Span LGS

Challenges

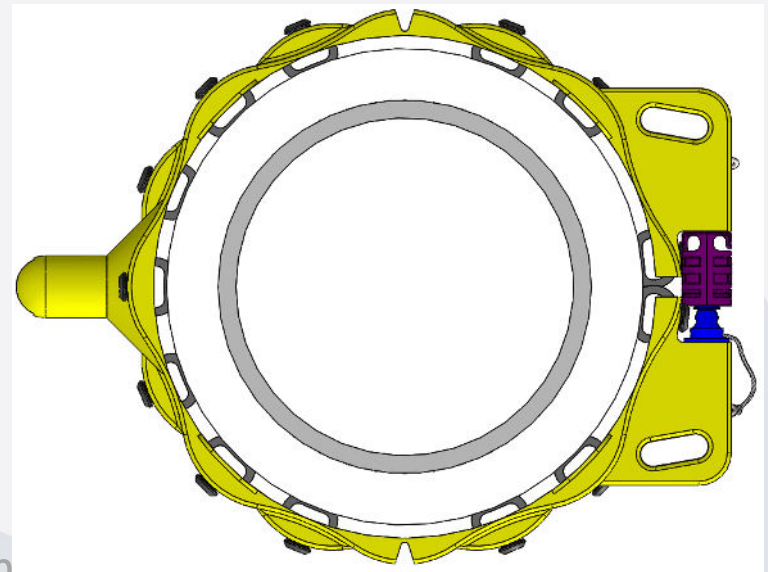
- > High pipe diametrical tolerance
 - Pipe insulation
 - Field joints
- > Low under-pipe clearance
- > Robustness
- > Low near-seabed visibility
- > Extended design life
- > ROV deployment challenges and time



Installation of Pipe Span LGS

Challenges

- > High pipe diametrical tolerance
- > Low under-pipe clearance
 - Low profile of LGS
 - Low profile installation tooling
- > Robustness
- > Low near-seabed visibility
- > Extended design life
- > ROV deployment challenges and timings



Installation of Pipe Span LGS

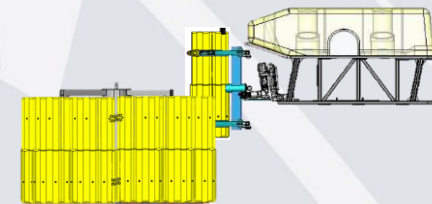
Challenges

- > High pipe diametrical tolerance
- > Low under-pipe clearance
- > Robustness
- > Low near-seabed visibility
- > Extended design life
- > ROV deployment challenges and timings



ROV Interface Design:

- > Fail safe mode
- > Spring loaded latches
- > Optimised shrouds/frame



Installation of Pipe Span LGS

Challenges

- > High pipe diametrical tolerance
- > Low under-pipe clearance
- > Robustness
- > Low near-seabed visibility
- > Extended Design Life
 - LLDPE material – field proven
 - Non-metallic parts
- > ROV deployment challenges and timings

Installation of Pipe Span LGS

Challenges

- > High pipe diametrical tolerance
- > Low under-pipe clearance
- > Robustness
- > Low near-seabed visibility
- > Extended design life
- > ROV deployment challenges and timings
 - SIT (Site Integration Testing)

Installation of Pipe Span LGS

SIT

- > Site Integration Testing (SIT) to test critical aspects of installation
 - Retrieval from deployment frame
 - Tool interfaces
 - Field joints
 - Installation orientation and methodology
 - Deployment frame optimisation
 - Strength testing
- > SIT identified fail safe modes:
 - Recovery features added to deployment frame
 - Fail open hydraulics



Field Installation [Video]

Detail design

Installation of Pipe Span LGS

Successful Field Installation

- > **455 shrouds** installed in **21 days**
- > Average installation time **13 minutes**
- > Fastest **6 ½ minutes**

In Review



- > Pipeline free spans → reduced fatigue life of pipeline
- > LGS – a viable VIV mitigation solution for pipeline free spans
 - **Low profile**
 - **Robust**
 - **Increased free span coverage**
- > ~ 85% reduction in design VIV amplitude
- > Installation methodology is field-proven
- > Retro-fit OR pre-deploy as contingency for free span growth

Thank You



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