OFFSHORE BOLT CORROSION

Welded and Non-Welded Connections

SPE/IMechE

MARCH 2021

The Issue

- How do you assess corrosion on bolted flanges?
- How are operators currently making assessments?

The Project

- Shared Research Project led by HSE
- Industrial Partners
  - Operators and service companies

The Project – Main work areas

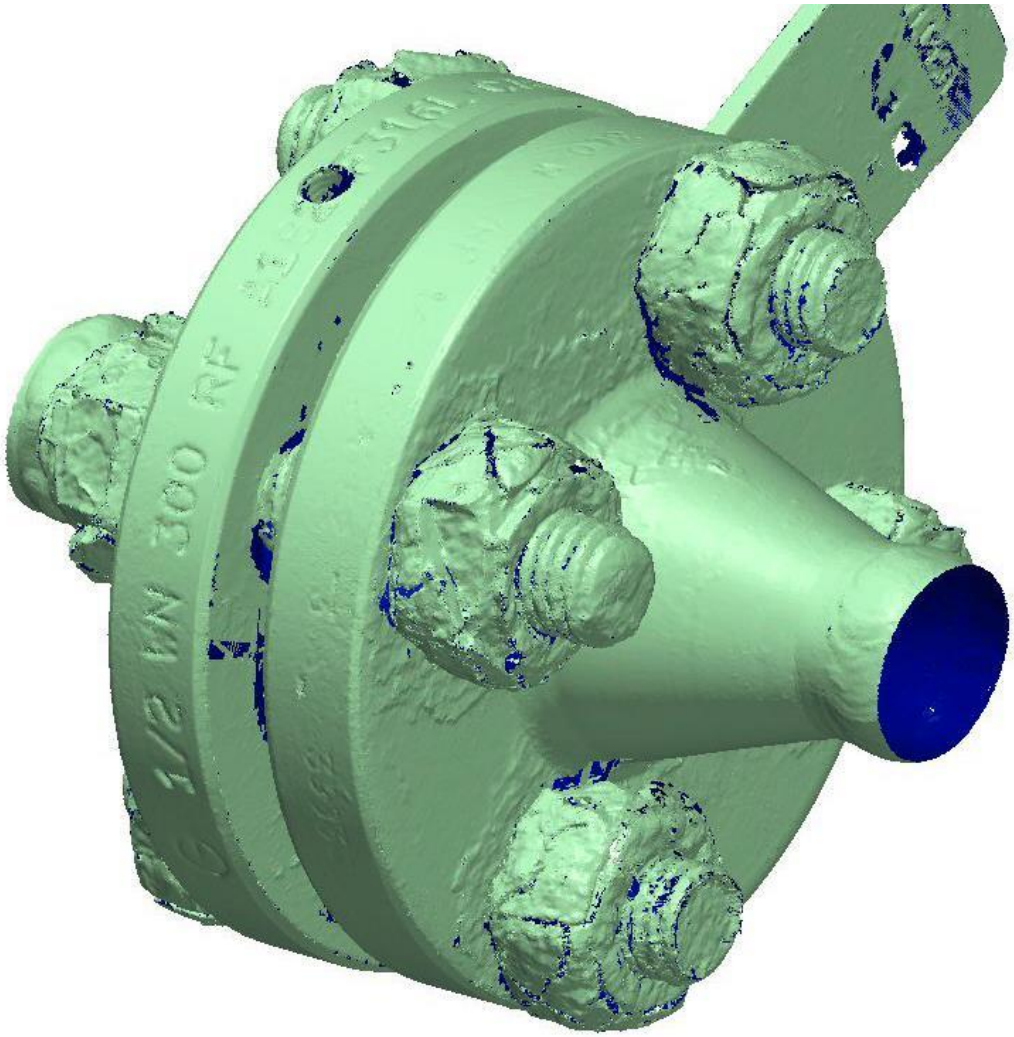
1. Information gathering
   - Literature review
   - Operator procedures
   - Sample assessments
2. Modelling
   - How does corrosion affect flange performance?

The Project – Main work areas

3. Accelerated corrosion testing
   - Subjecting new samples to corrosive environment and testing

Sample RPM8

Laser Scans – RPM8



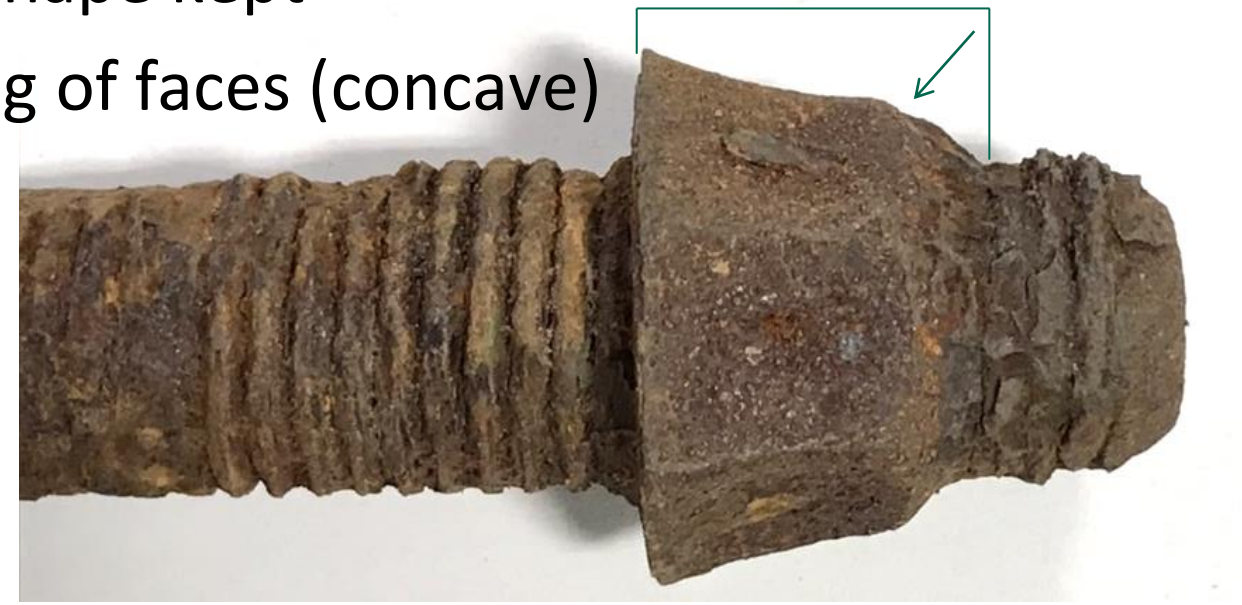
Samples Received

Samples – Common features

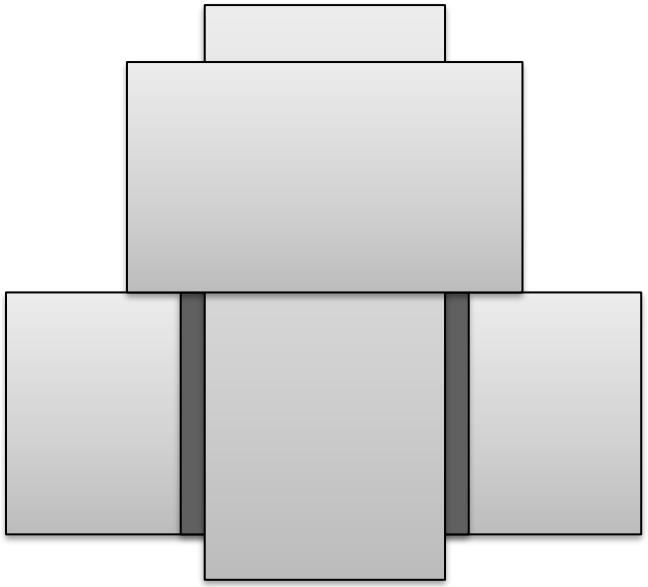
- Contact protects
  - Threads within nuts clean
  - No loss from nut face contact area

Samples – Common features

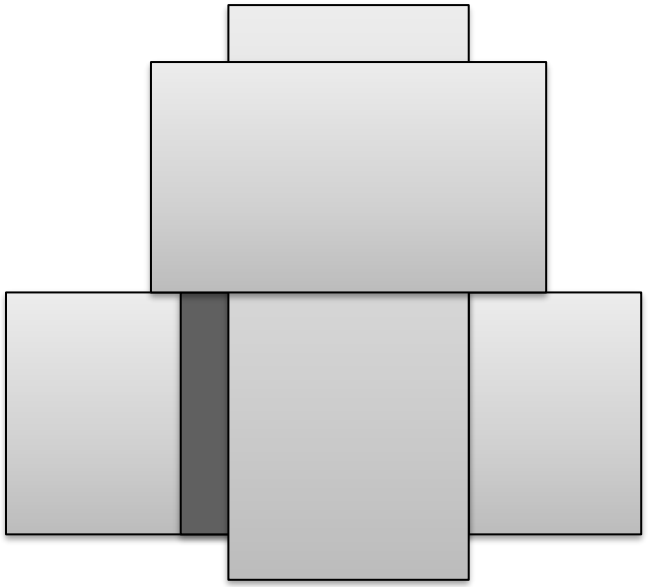
- NUT Features
  - Corrosion at bottom limited by contact area
  - Height and diameter lost from top
  - Hexagonal shape kept
  - Slight dishing of faces (concave)



Nut Sections – High Corrosion



Nut Sections – High Corrosion

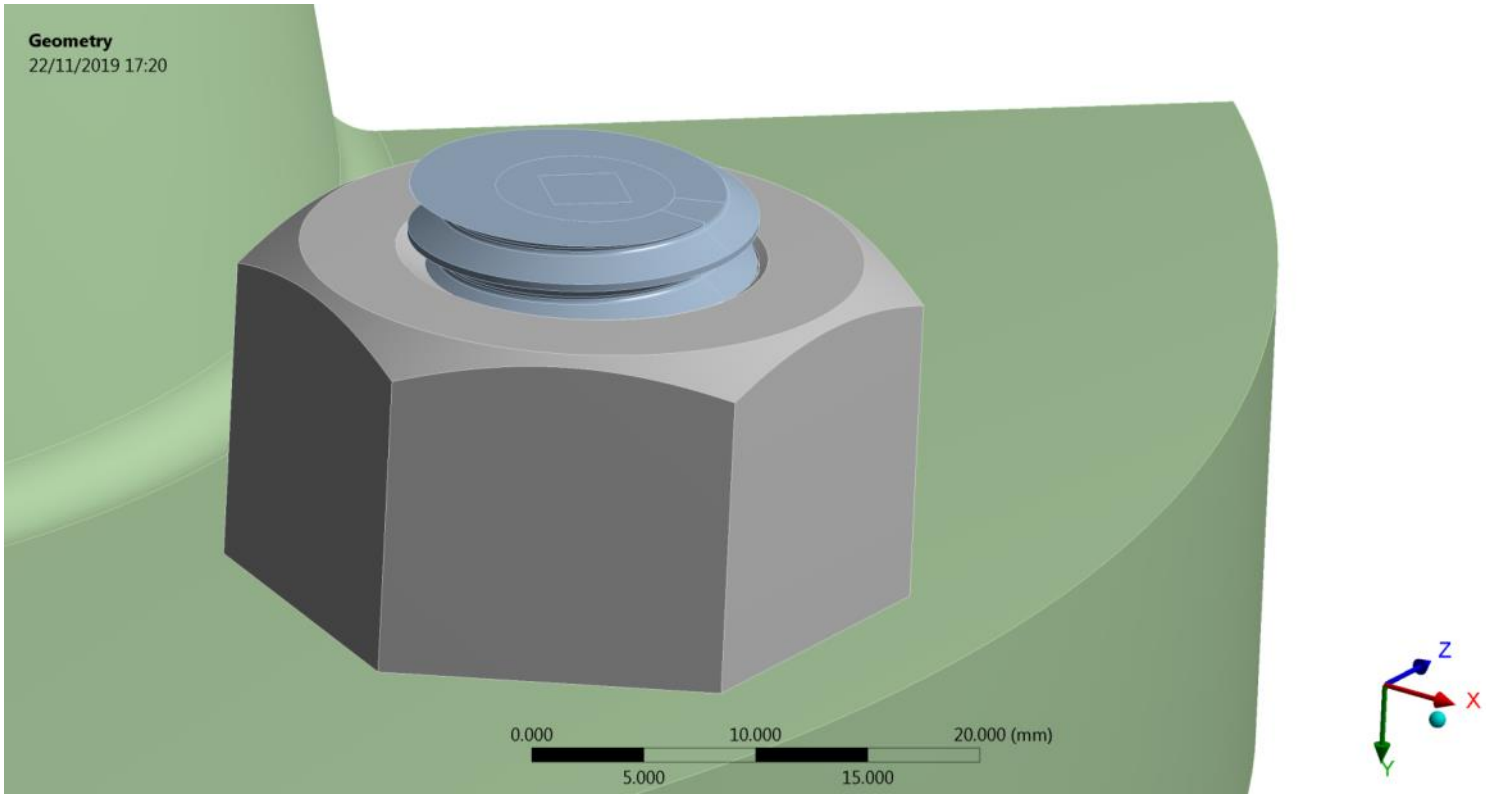


Nut Section

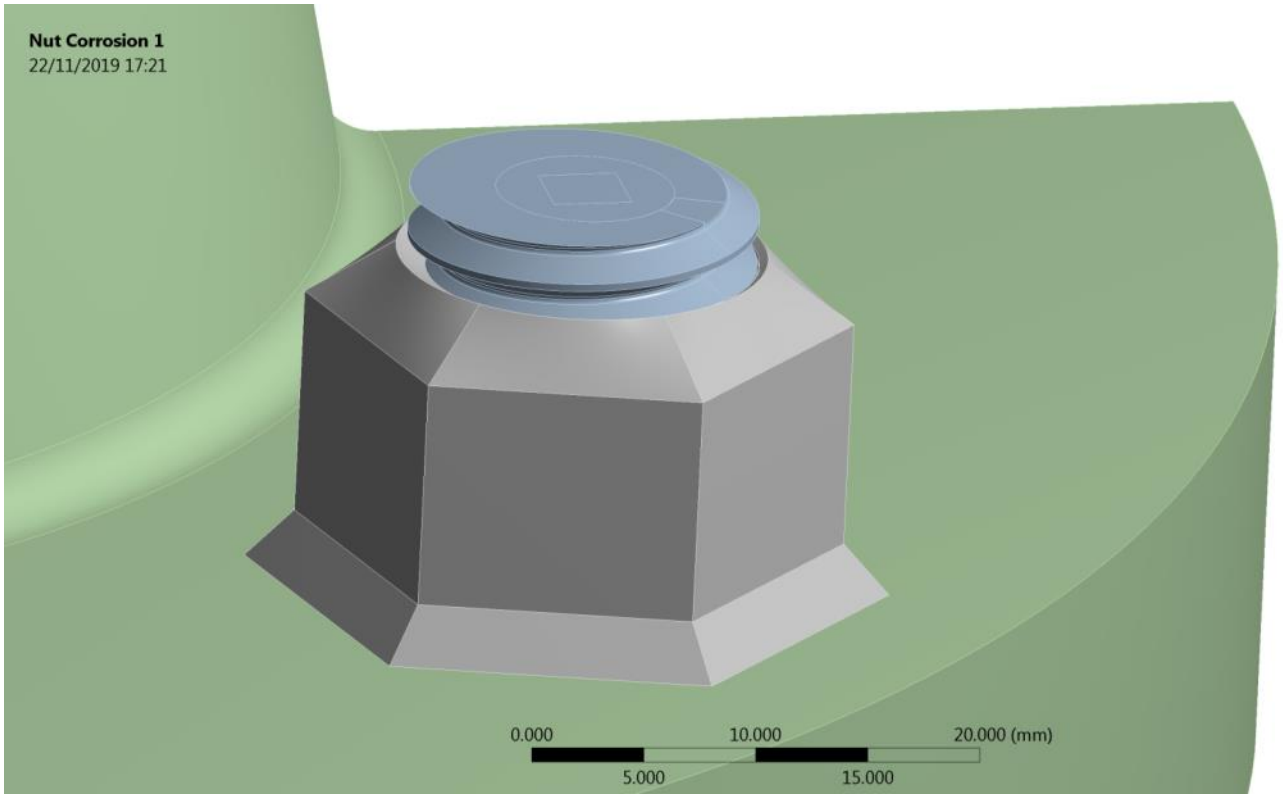
Modelling

- Critical sized identified
  - 3” NB Class 150
  - Four 5/8” studs
- Understanding of mechanisms

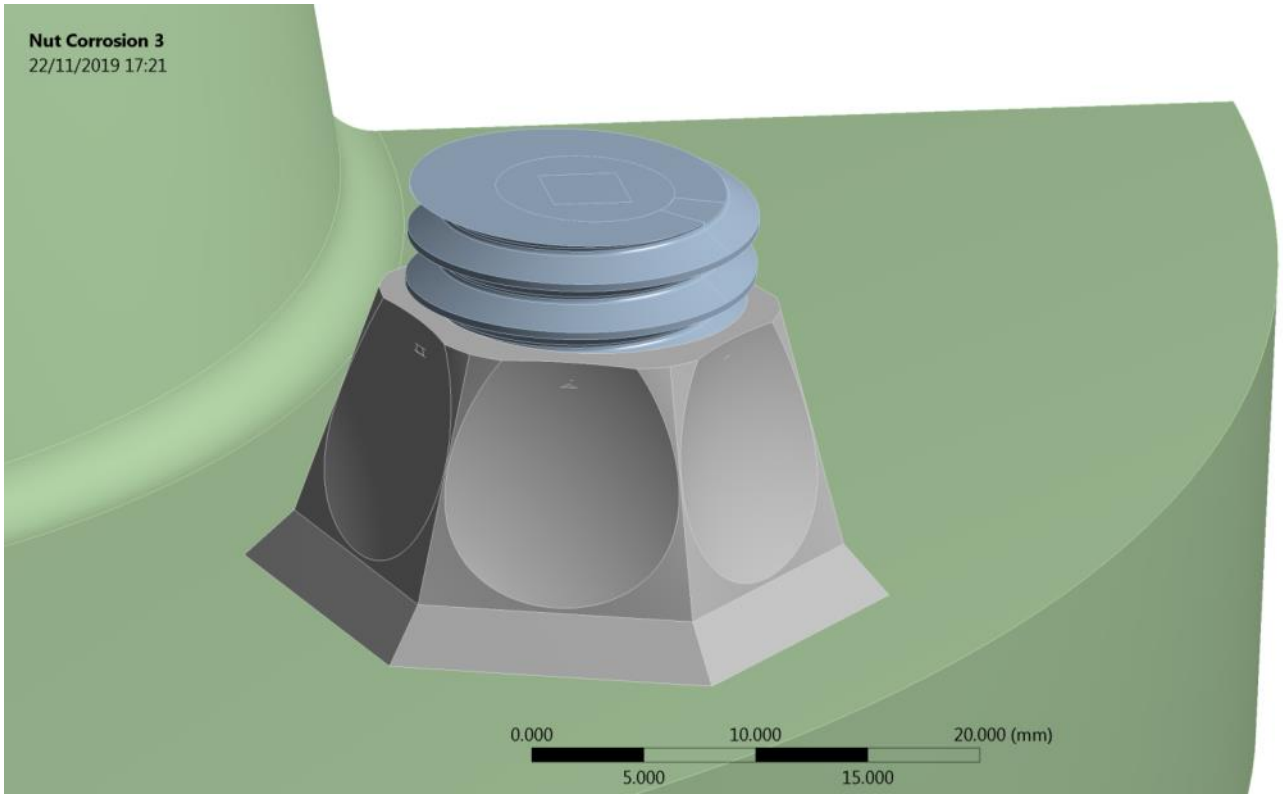
Modelling – Full nut



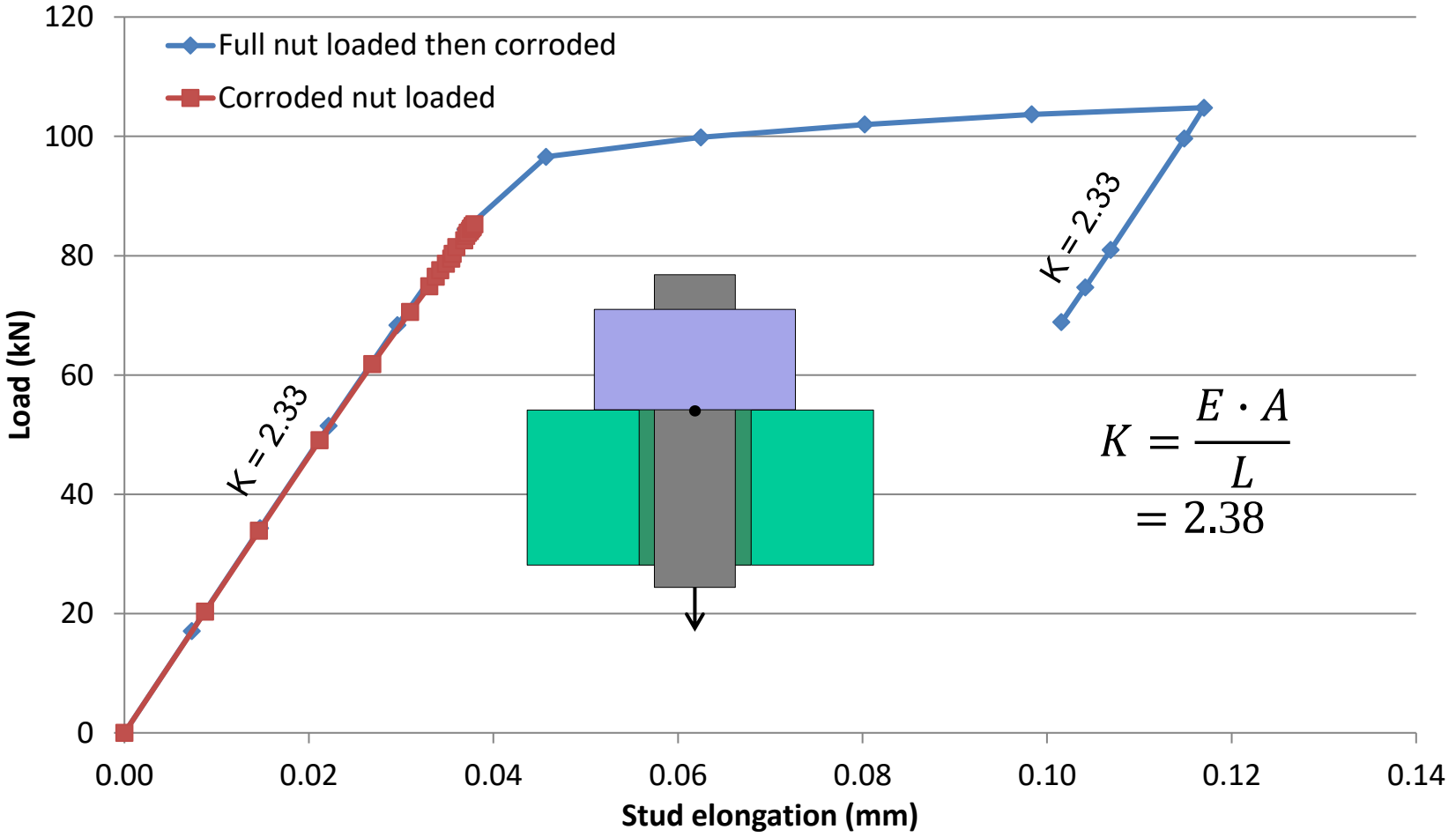
Modelling – Mid corrosion (50 %)



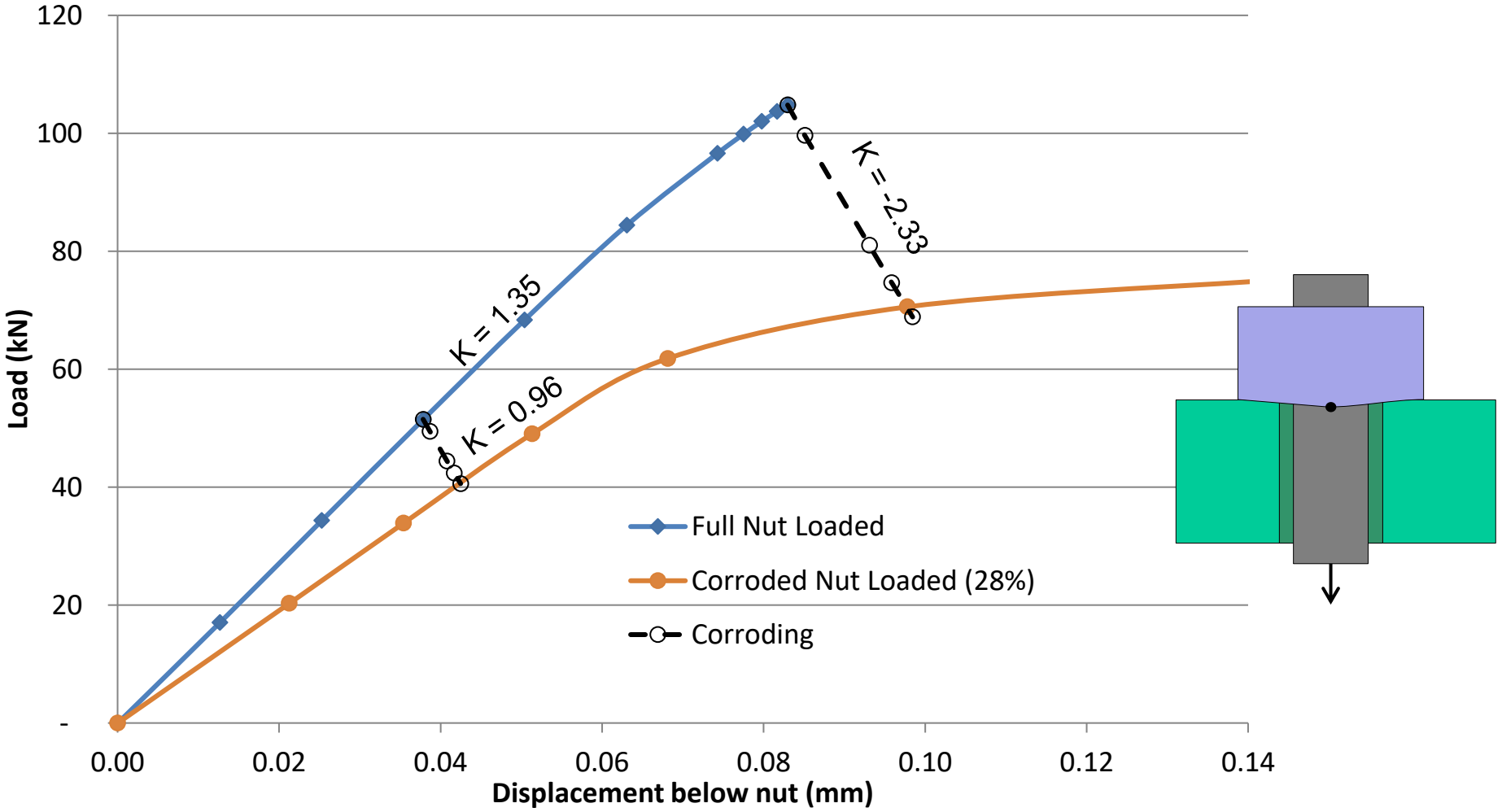
Modelling – High corrosion (28 %)



Stud elongation



Nut displacement



Spring model

- Knowing all stiffnesses, deflections/forces can be calculated
- Effect of reduction of nut (and/or stud) stiffnesses can be estimated

Spring model

	Original Stiffness		Changed Stiffness	
Stud	1.20	kN/µm	1.05	kN/µm
Nut	1.36	kN/µm	0.95	kN/µm
Gasket and flange	0.11	kN/µm	0.53	kN/µm

Stud Stiffness		
Length	24.0	mm
E	200	GPa
Radius	6.35	mm
Area	127	mm^2
Stiffness	**1.05**	kN/µm

Preload	50	kN	**44.4** kN
Reduction			**11.2** %
X	**520.9**	µm	**520.9** µm

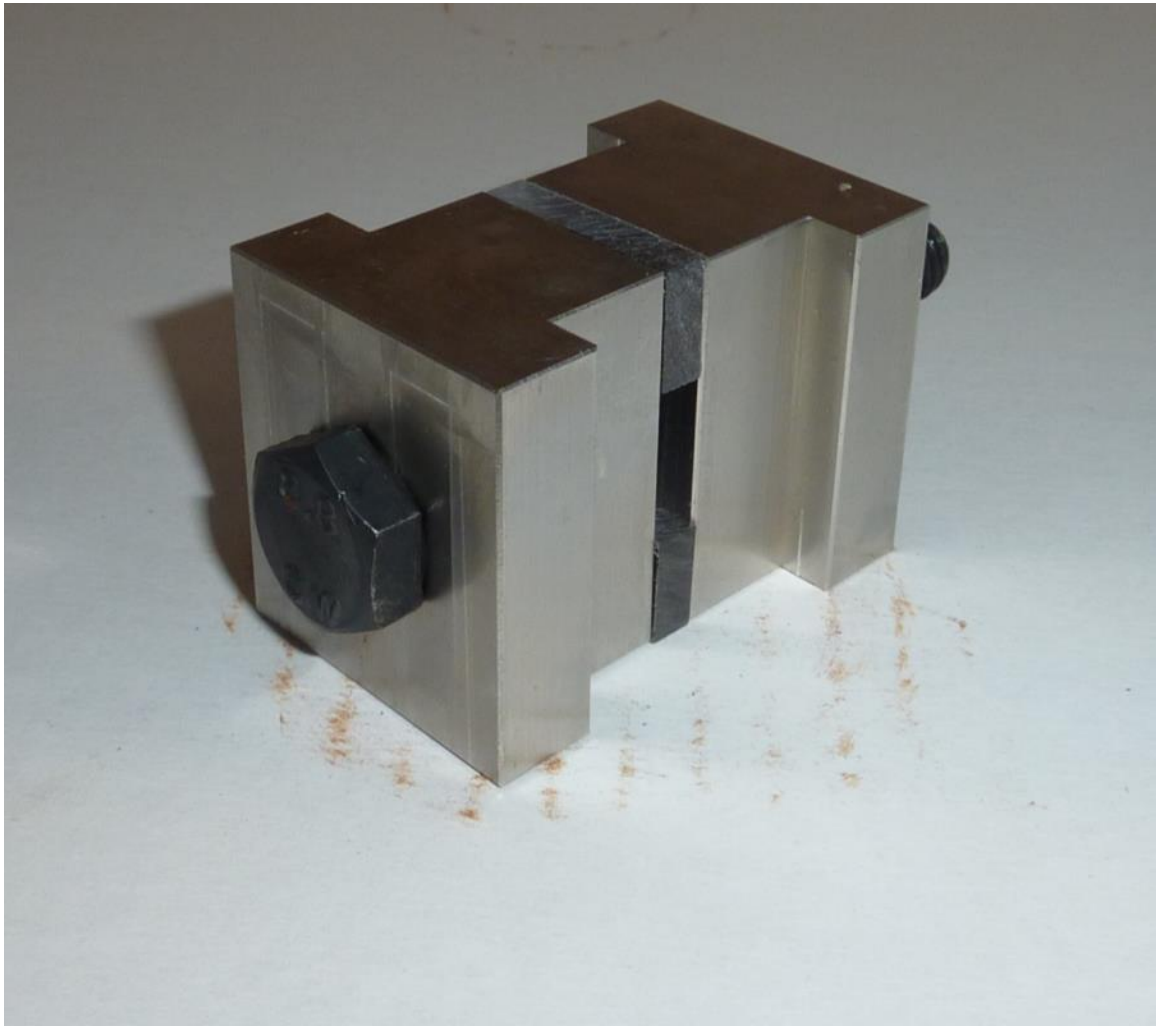
Spring model

Corrosion Stage	Model Loss	Predicted Loss
1		
2	1.5%	1.5%
3	6.7%	5.6%
4	8.7%	7.5%
5	10.5%	9.2%

Testing

- Accelerated Corrosion testing
- Samples exposed to corrosive environment for 3 to 9 months
- Different orientations and material combinations
- Tensile tested

Accelerated Corrosion



Accelerated Corrosion – 3 Months

Accelerated Corrosion – 6 Months

Accelerated Corrosion – 9 Months

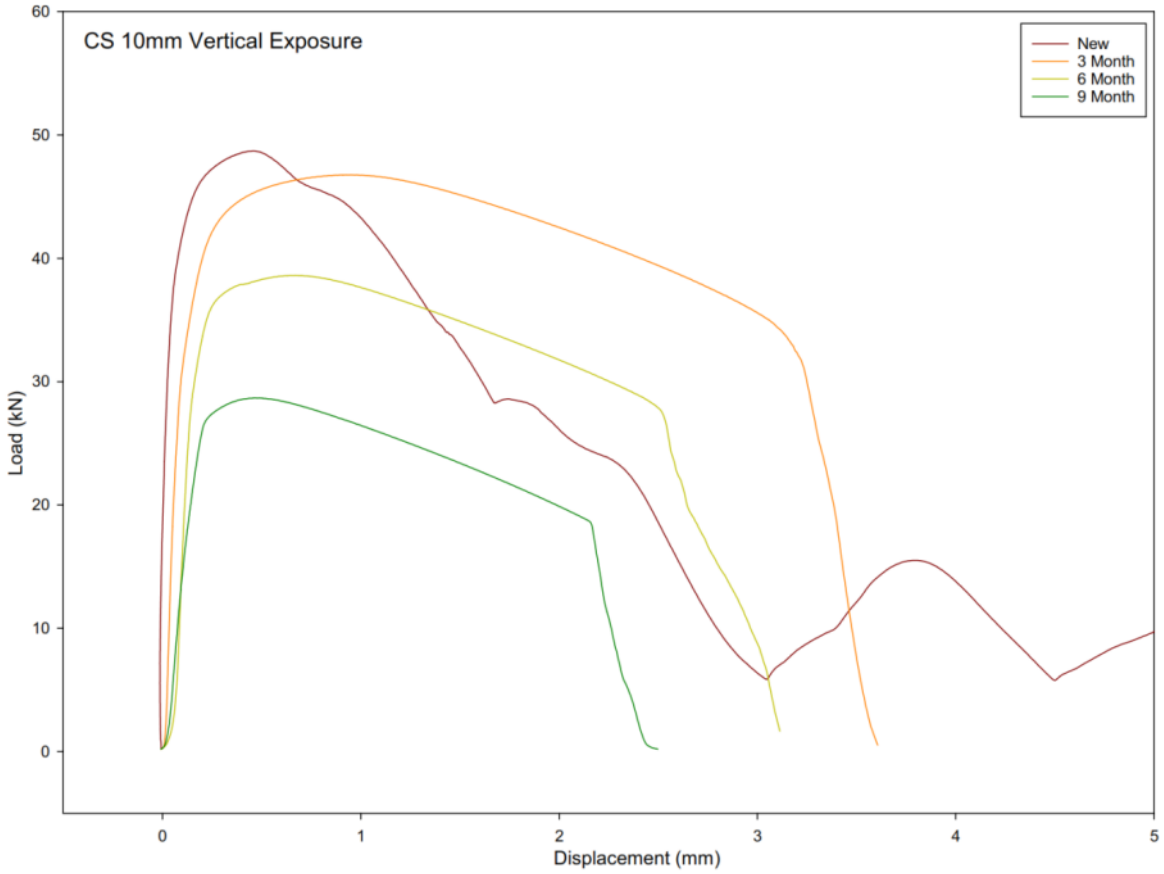
Accelerated Corrosion (M10)

Sample					
Exposure (Months)	Orientation	Size (Mxx)	Nut AF (mm)	Bolt head (mm)	
0	N/A	10	**16.84**	**16.88**	Original size
3	Horizontal	10	-0.19	-0.15	
	Diagonal	10	-0.09	-0.06	
	Vertical	10	-0.63	-0.02	
6	Horizontal	10	-1.29	-1.03	
	Diagonal	10	-1.50	-0.96	
	Vertical	10	-2.34	-1.07	
9	Horizontal	10	-1.60	-1.12	
	Diagonal	10	-2.18	-1.39	
	Vertical	10	-3.29	-1.09	

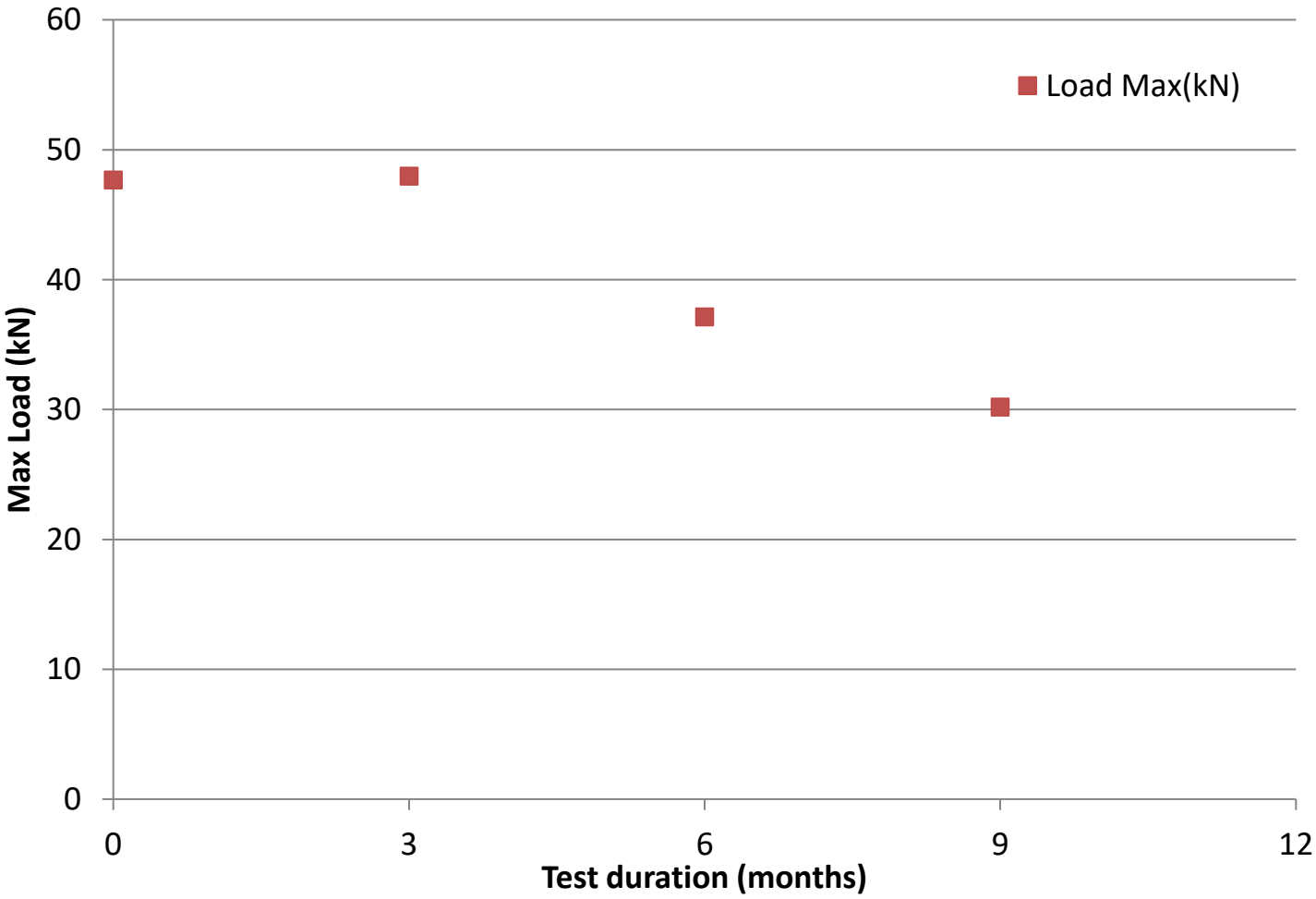
Accelerated Corrosion (M12)

Sample					
Exposure (Months)	Orientation	Size (Mxx)	Nut AF (mm)	Bolt head (mm)	
0	N/A	12	**18.78**	**18.76**	Original size
3	Horizontal	12	-0.05	-0.15	
	Diagonal	12	-0.06	-0.09	
	Vertical	12	-0.54	-0.04	
6	Horizontal	12	-1.18	-0.85	
	Diagonal	12	-2.04	-0.90	
	Vertical	12	-2.10	-0.85	
9	Horizontal	12	-2.59	-1.68	
	Diagonal	12	-2.60	-1.56	
	Vertical	12	-3.38	-1.52	

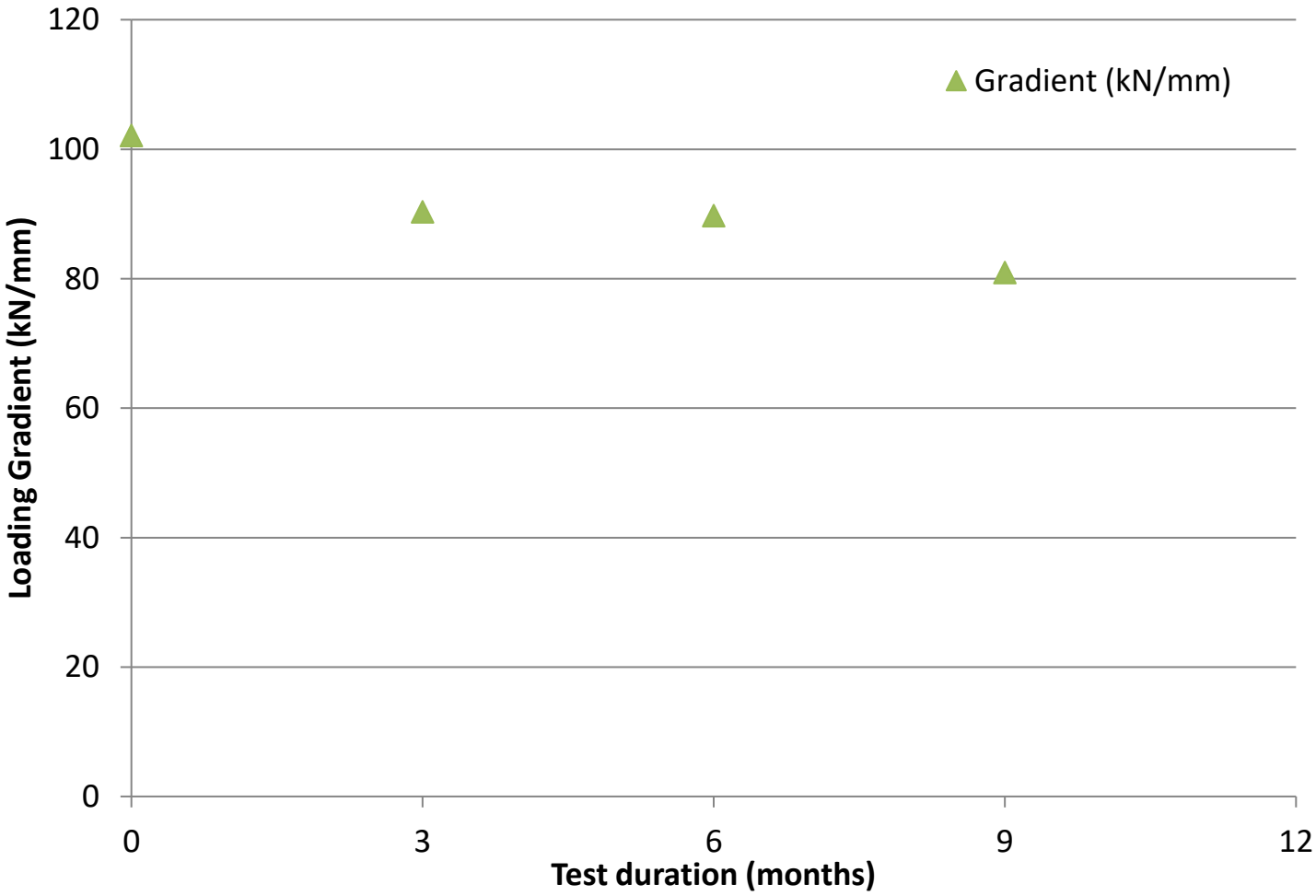
Testing – Vertical



Testing – Load results



Testing – Stiffness results



Conclusions

- Assessing levels of corrosion difficult
- Most nut corrosion occurs in less stressed part – resilient
- Some preload loss avoided due to relaxation of other components

Thank You