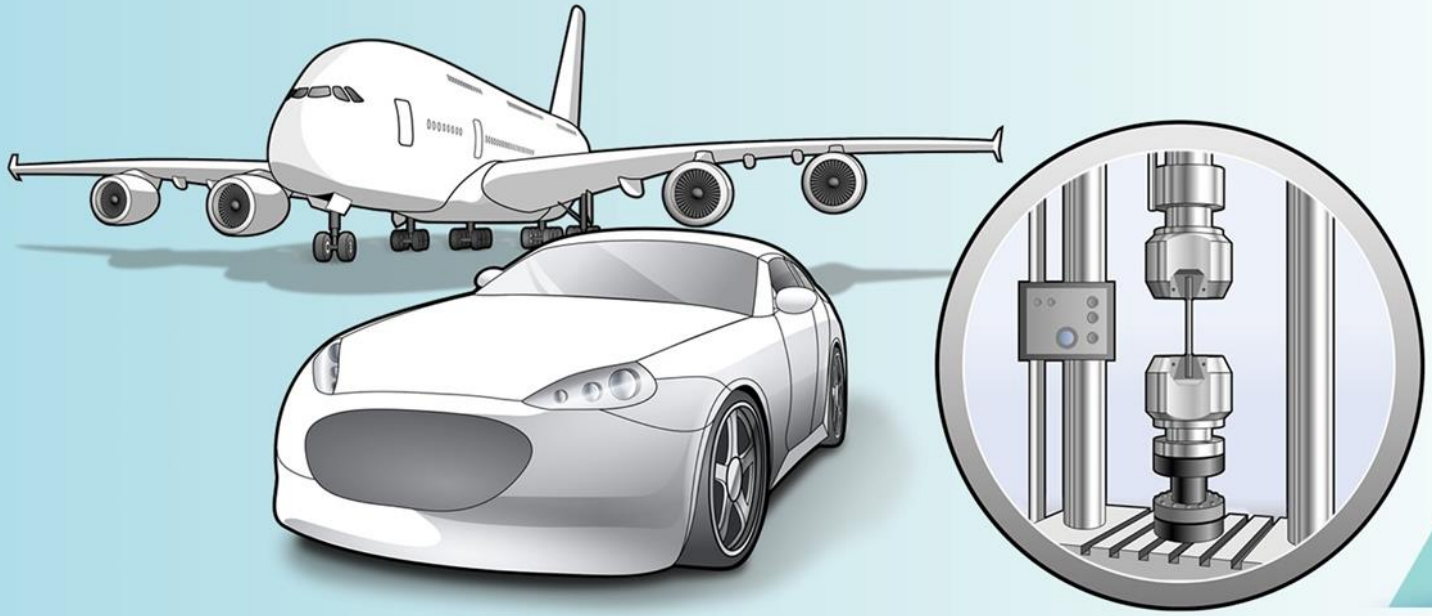
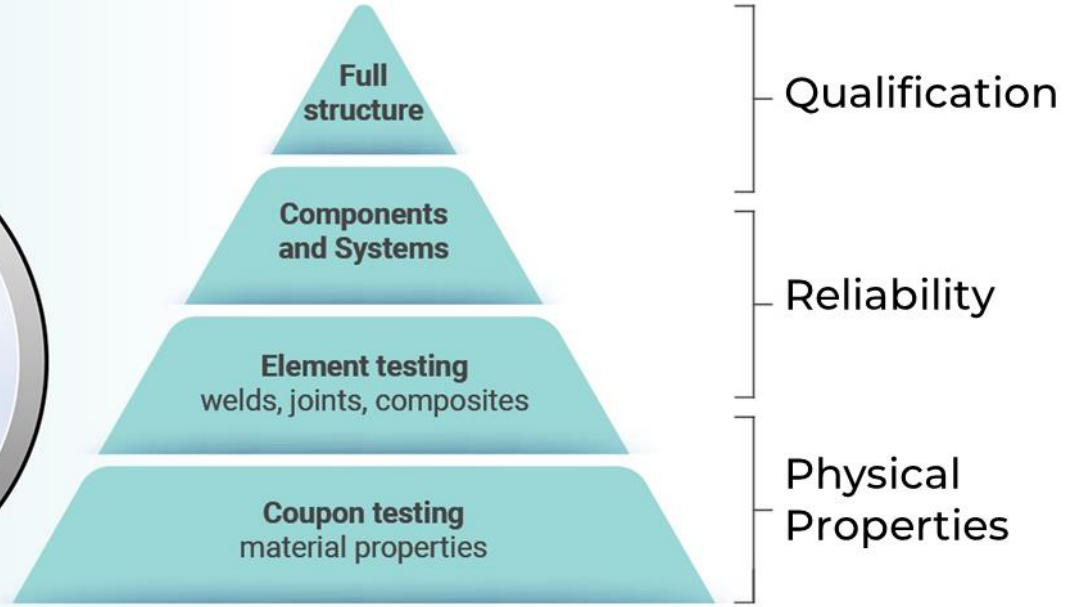
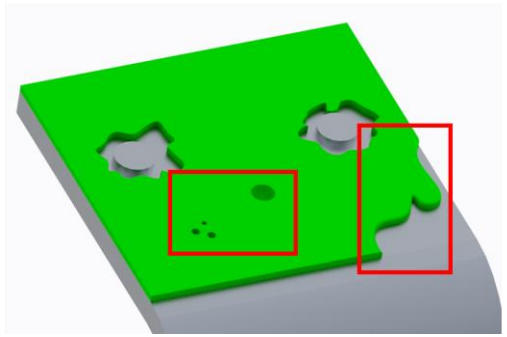


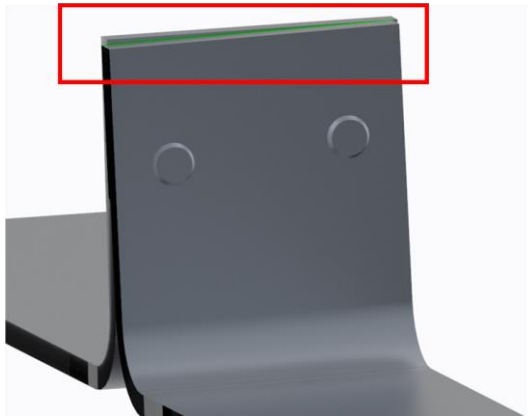


2023 HBK Technology Days

21 November 2023

Specimen inspection





- **A methodology for the fatigue testing of adhesive and hybrid joints**

Alex Pierpoint,
Materials Test Engineer, HBK

A methodology for the fatigue testing of adhesive and hybrid joints

Abstract

- This work presents how the HBK methodology for fatigue testing of welded joints has been extended to adhesive and hybrid joints. The method has been successfully implemented by HBK's Advanced Materials Characterisation and Testing (AMCT) facility in the UK. The results from testing are used to derive parameters for use in nCode DesignLife fatigue analysis.
- The presentation details the impact that defects in the joints can have on the amount of scatter present in the load-life data and how identifying these issues early, through a thorough pre-test inspection of the specimens, can help understand the test data. The possibility of selecting a more representative failure criterion can sometimes aid in reducing the amount of scatter present in the load-life data when compared with using specimen separation. This is achieved through the implementation of cameras to monitor crack initiation and propagation and displacement transducers for calculating stiffness drops.
- This approach enables the generation of high quality load-life data sets with low scatter. This has a beneficial impact on the quality of the fatigue parameters generated through reverse engineering the test data using finite element stress analysis results.

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A methodology for the fatigue testing of adhesive and hybrid joints

- About the presenter, Alex Pierpoint, Materials Test Engineer, HBK
  - Mr Alex Pierpoint joined HBK in September 2018 as an apprentice materials test engineer. He studied to gain a Bachelor's Degree in Maintenance Engineering from the University of Sheffield whilst simultaneously working at HBK's Advanced Materials Characterisation and Testing (AMCT) facility. Alex's degree dissertation focussed on creating a methodology for the fatigue testing of welded joints to develop and standardise the testing process. This work enabled the AMCT to adopt a standardised process for testing welded joints. He has since adapted this methodology from welded joints to fatigue testing a broader range of joining methods including adhesive and hybrid joints.

  - Alex is continuing his career development with a part time and remote Master's Degree in Advanced Mechanical Engineering at the University of Strathclyde, to be completed over the next three years whilst continuing his testing work in the AMCT at HBK.

A Methodology for the Fatigue Testing of Adhesive and Hybrid Joints

HBK TECHNOLOGY DAY 3

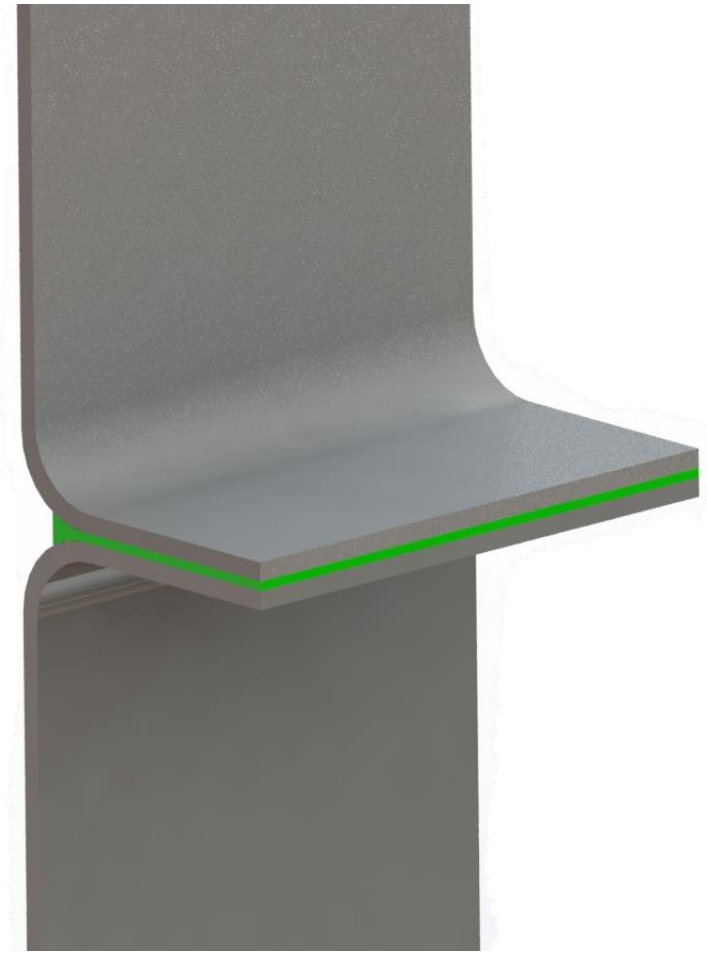
Alex Pierpoint
Materials Test Engineer, HBK

Agenda

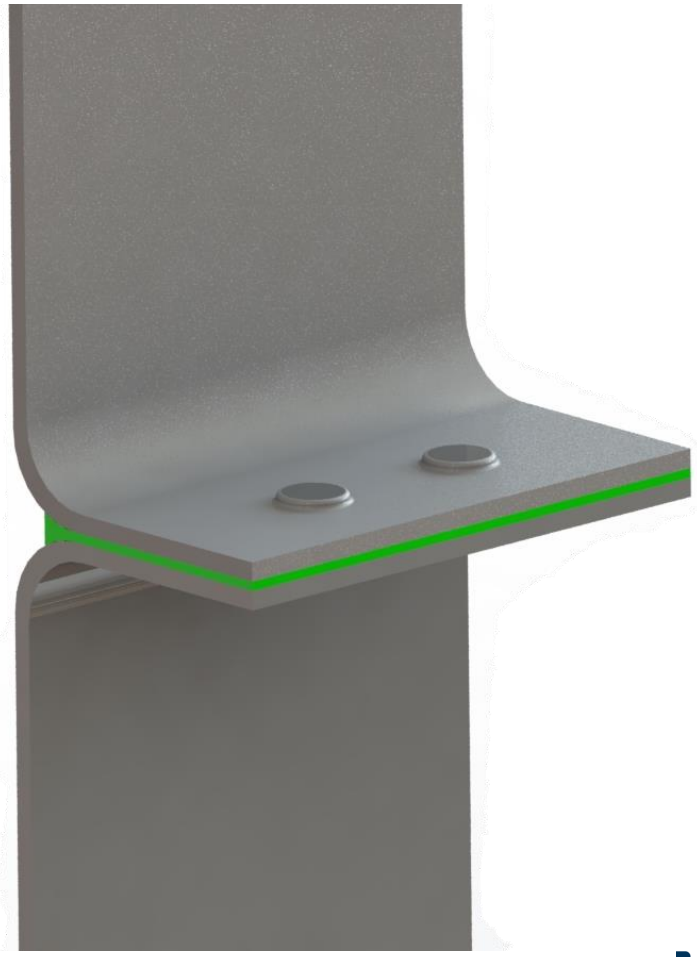
1. A brief overview of adhesive and hybrid joints
2. The methodology developed for the testing of welded joints
3. How the methodology has been adapted for adhesive and hybrid joints
4. Conclusions & Future work

What are adhesive and hybrid joints

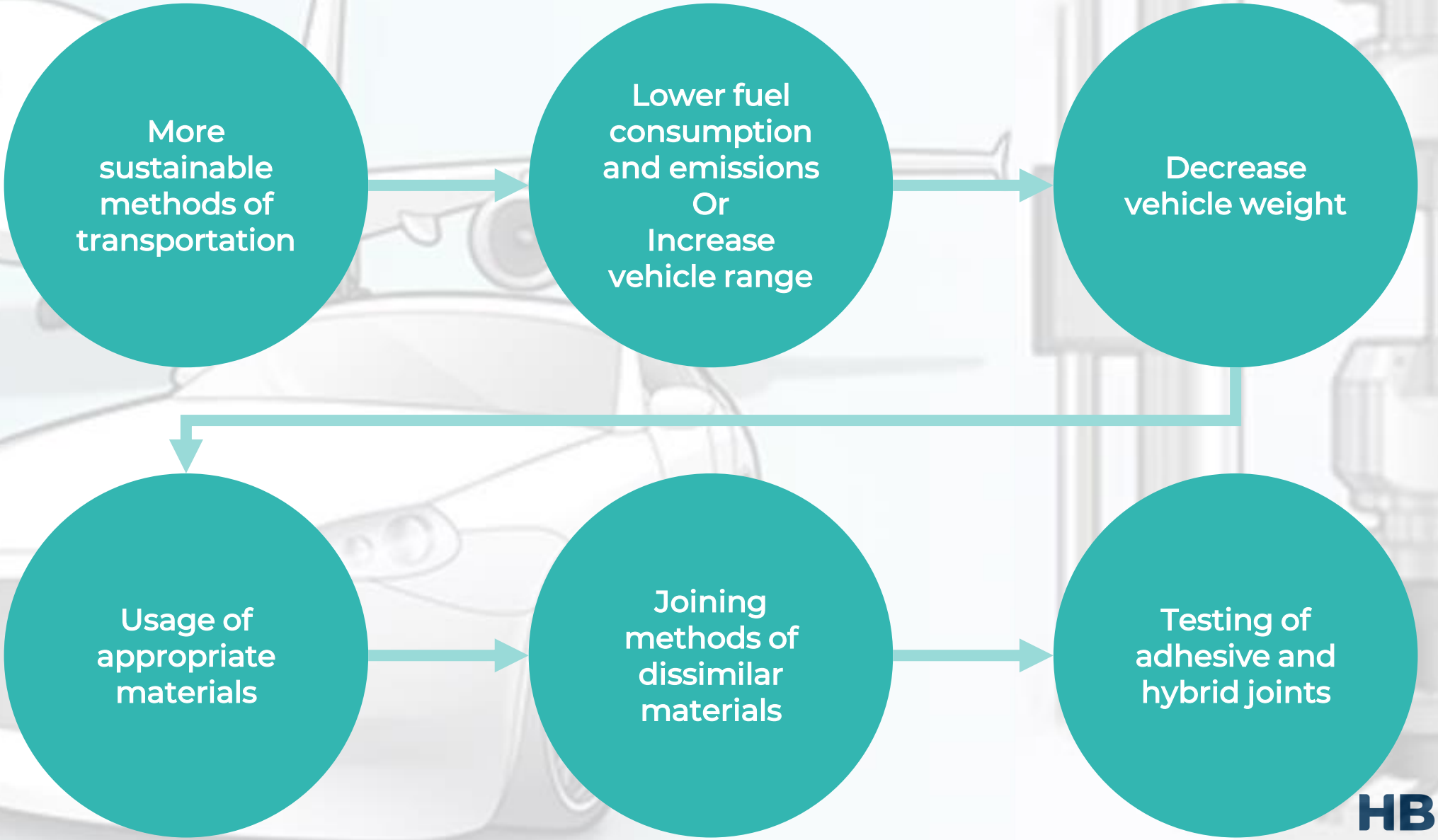
- Adhesive coach peel specimen



- Adhesive + SPR coach peel specimen



Motivation for the testing adhesive and hybrid joints



Agenda

1. A brief overview of adhesive and hybrid joints
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3. How the methodology has been adapted for adhesive and hybrid joints
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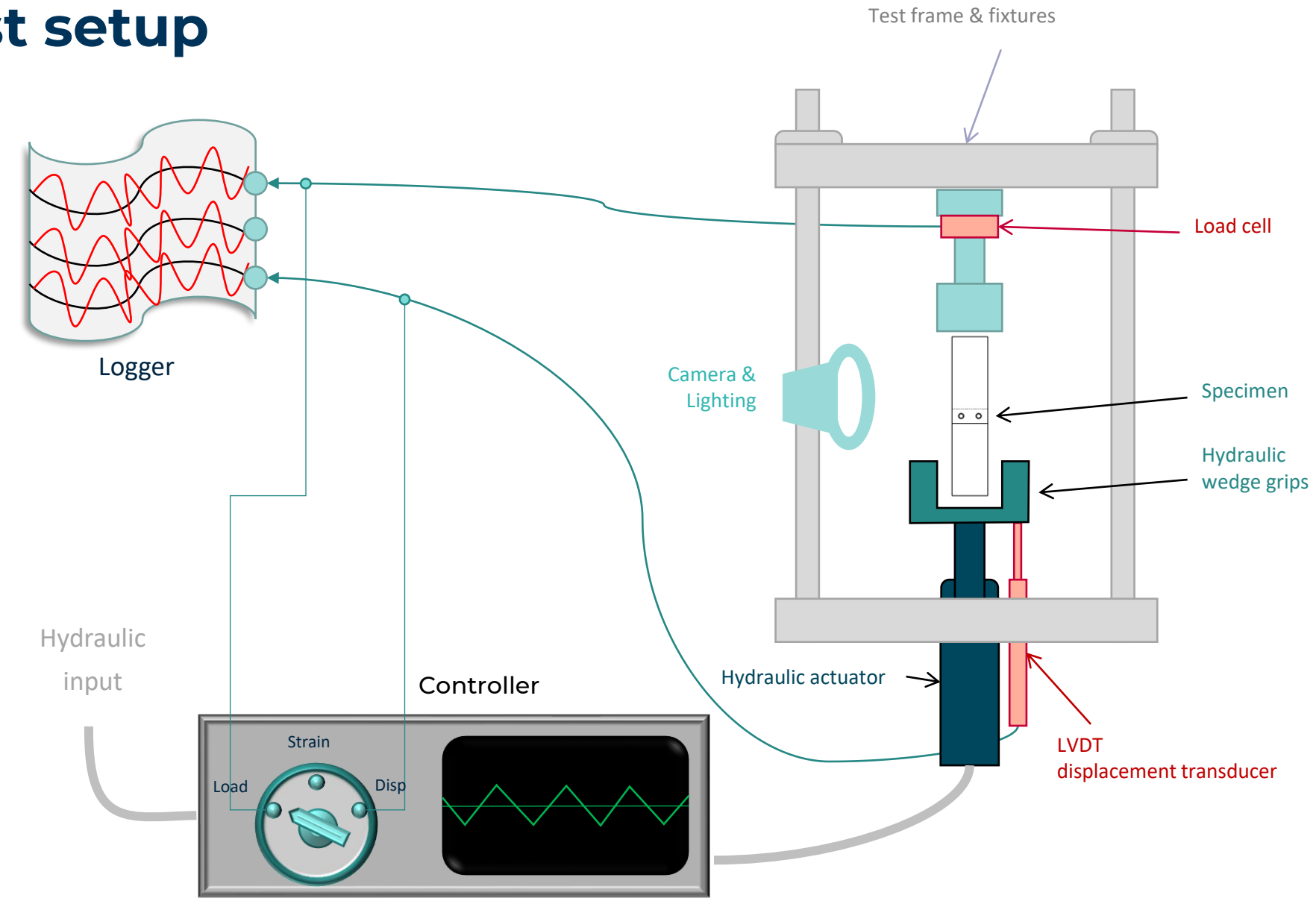
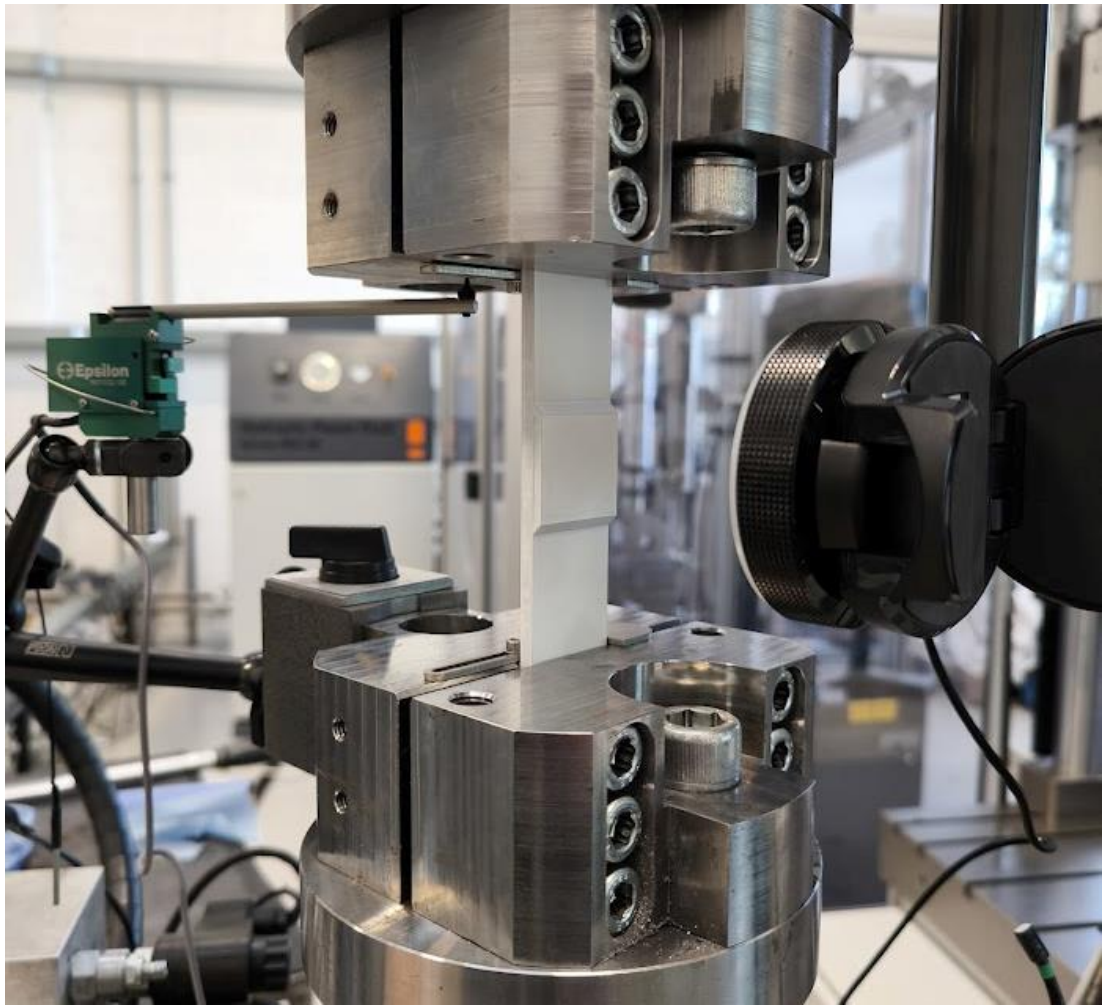
Test setup



Test setup for welded joints

- Modular grips
  - Allow for testing of different size specimens
- Camera
  - Take pictures of the specimen during testing
- Deflectometer
  - Measuring displacement of the specimen



This specimen has been manufactured by 3D printing for the purpose of illustration and is not a real welded specimen

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Agenda

1. A brief overview of adhesive and hybrid joints
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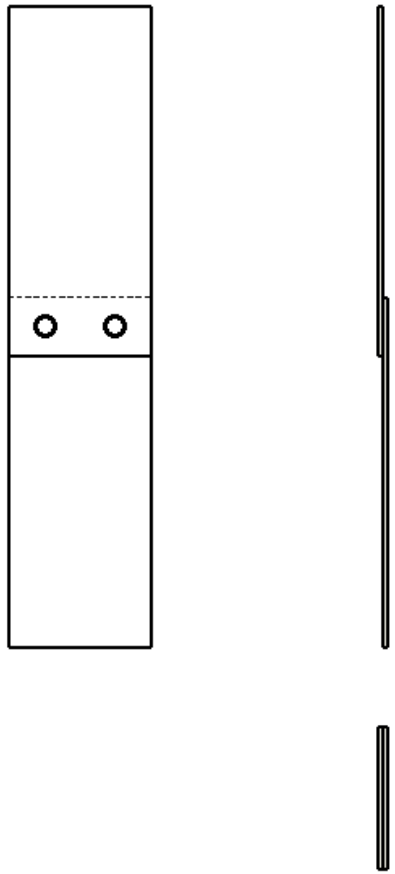
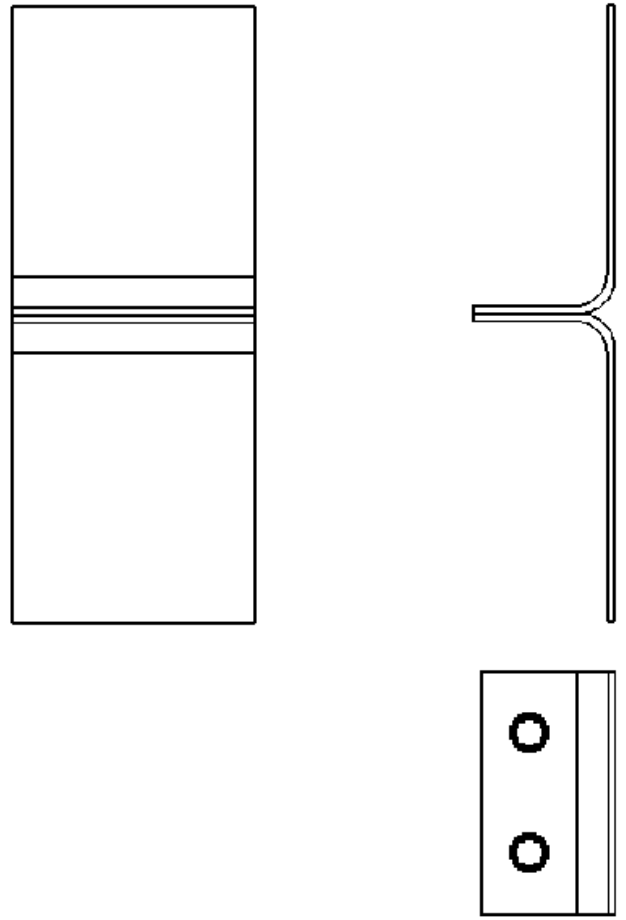
Specimen geometries

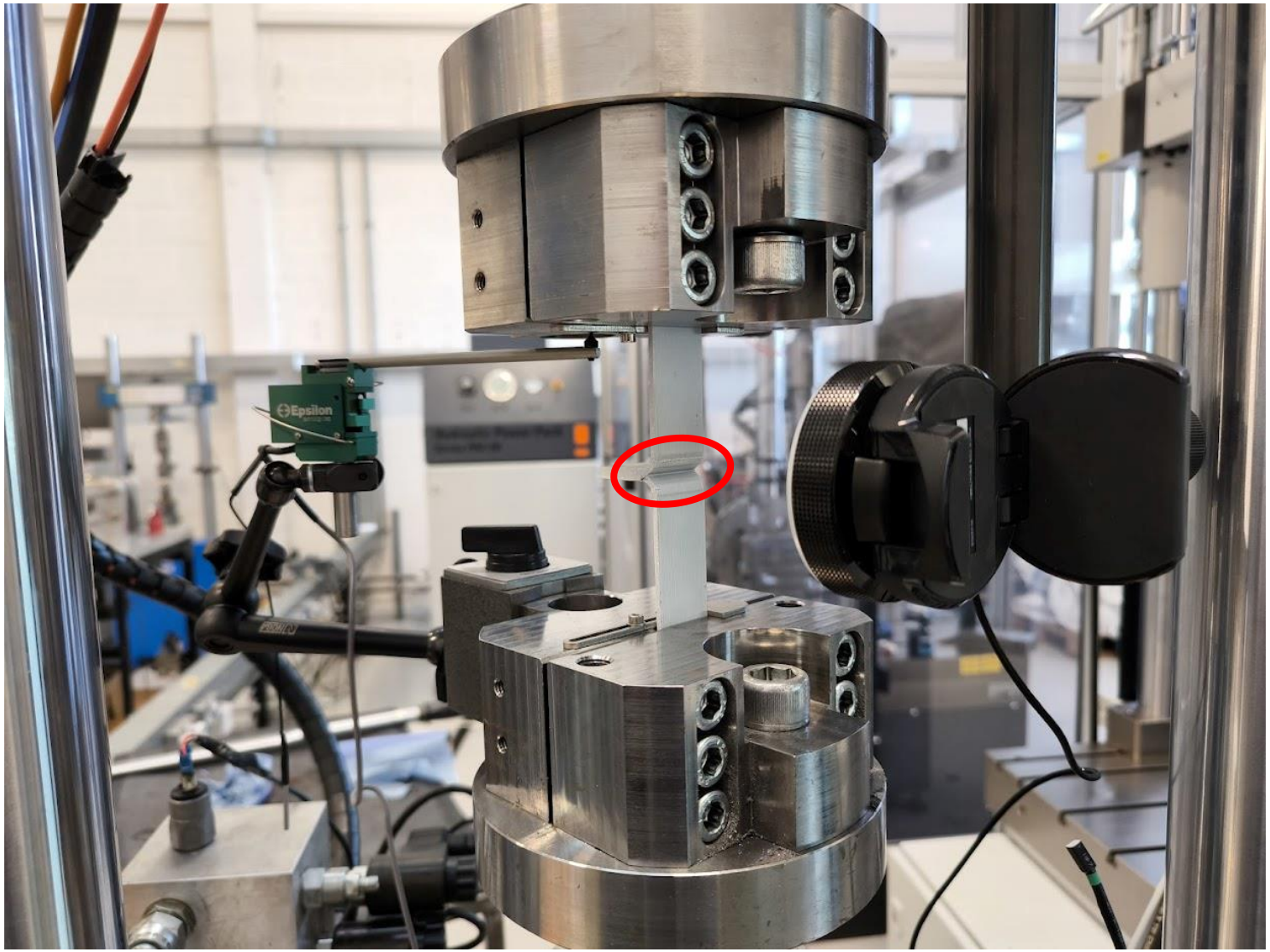
- Lap Shear
  - Predominantly shear loading



- Coach Peel
  - Predominantly peel loading



Test setup for adhesive / hybrid joints



- Camera is orientated to take images of the adhesive
- Failure should initiate at the bond line
- In hybrid joints the adhesive should fail first

This specimen has been manufactured by 3D printing for the purpose of illustration and is not a real adhesive specimen

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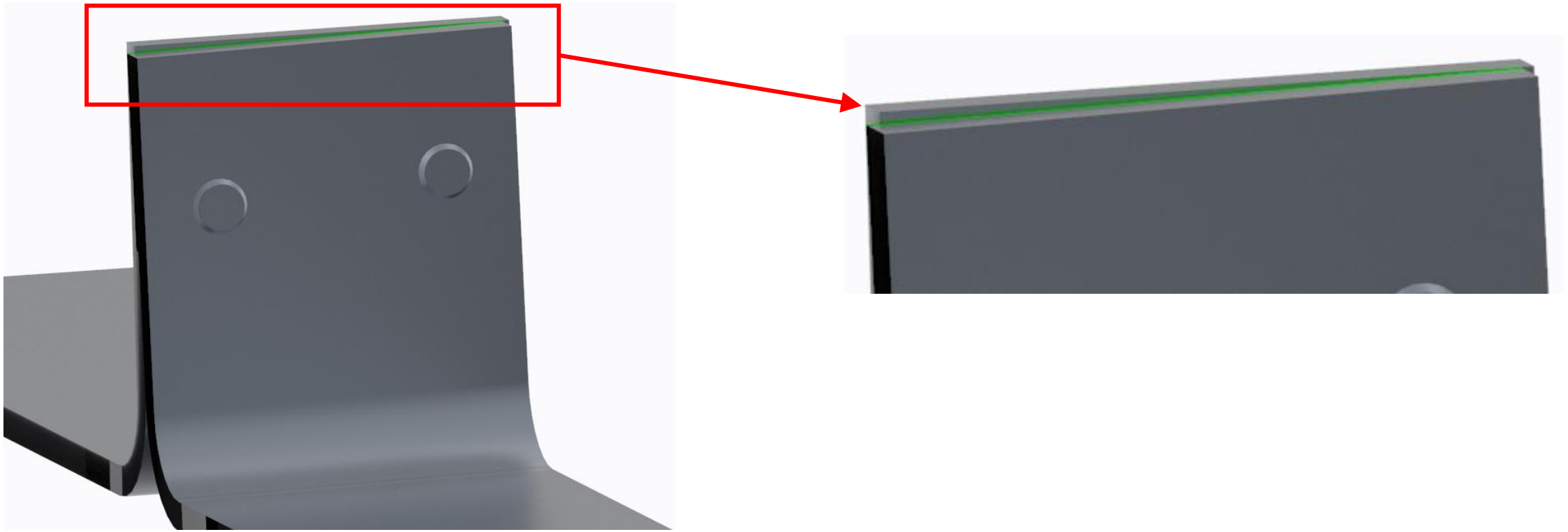
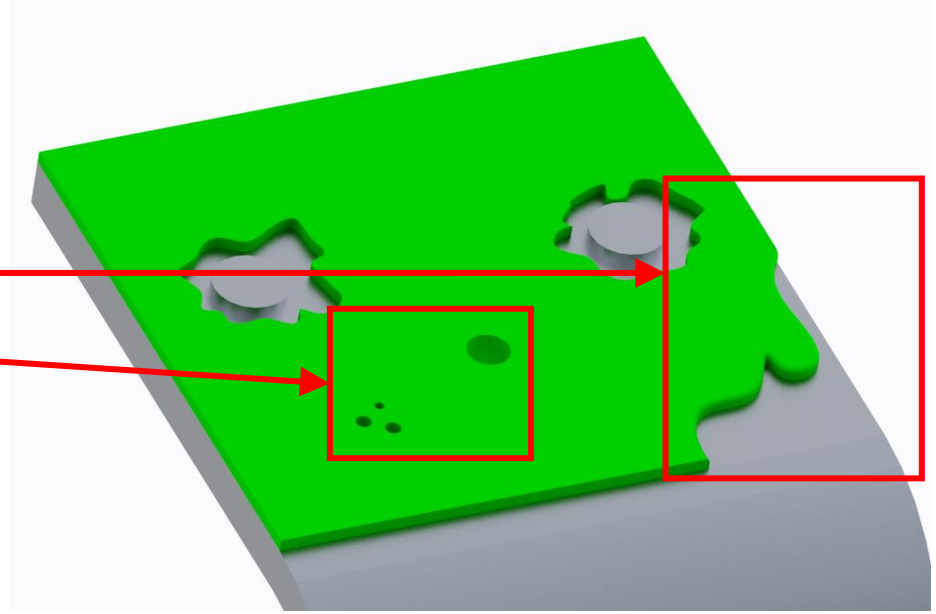
Specimen inspection

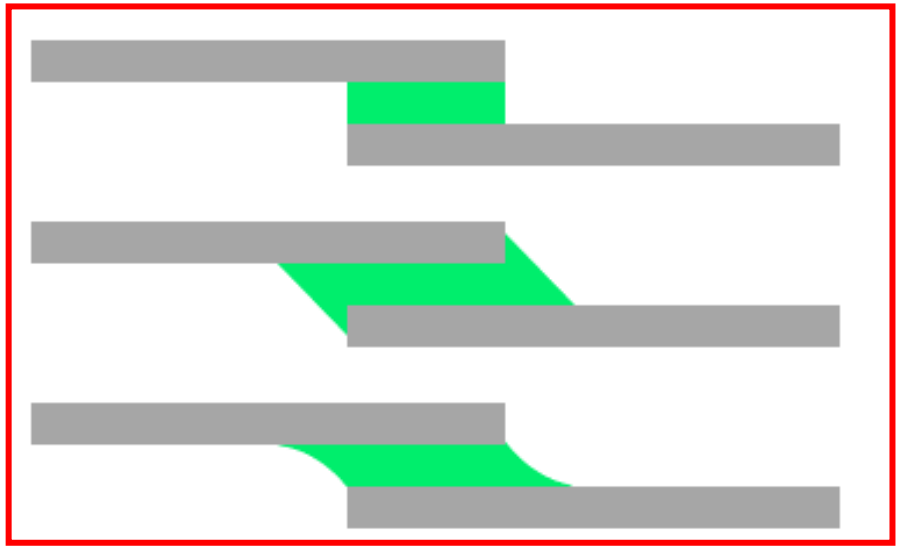
- Issues with the substrate
  - Misalignment of the substrate sheets
  - Defects in the substrate sheets



Specimen inspection

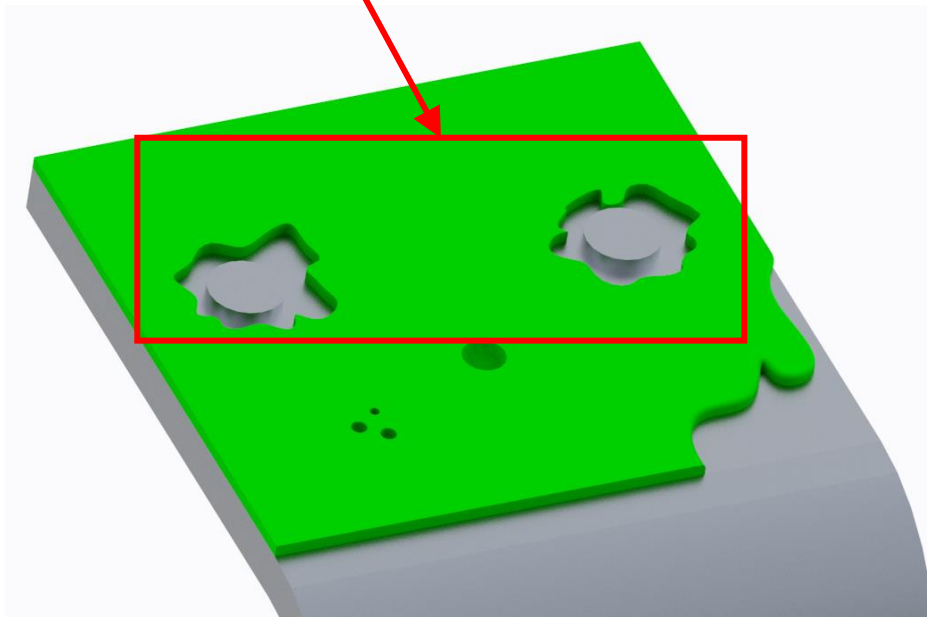
- Issues with the adhesive
  - Lack of adhesive bonding
  - Macro-voids and micro-voids
  - Contamination in the bonding area
  - Incorrect adhesive thickness
  - Incorrect curing of the adhesive
  - Adhesive spew

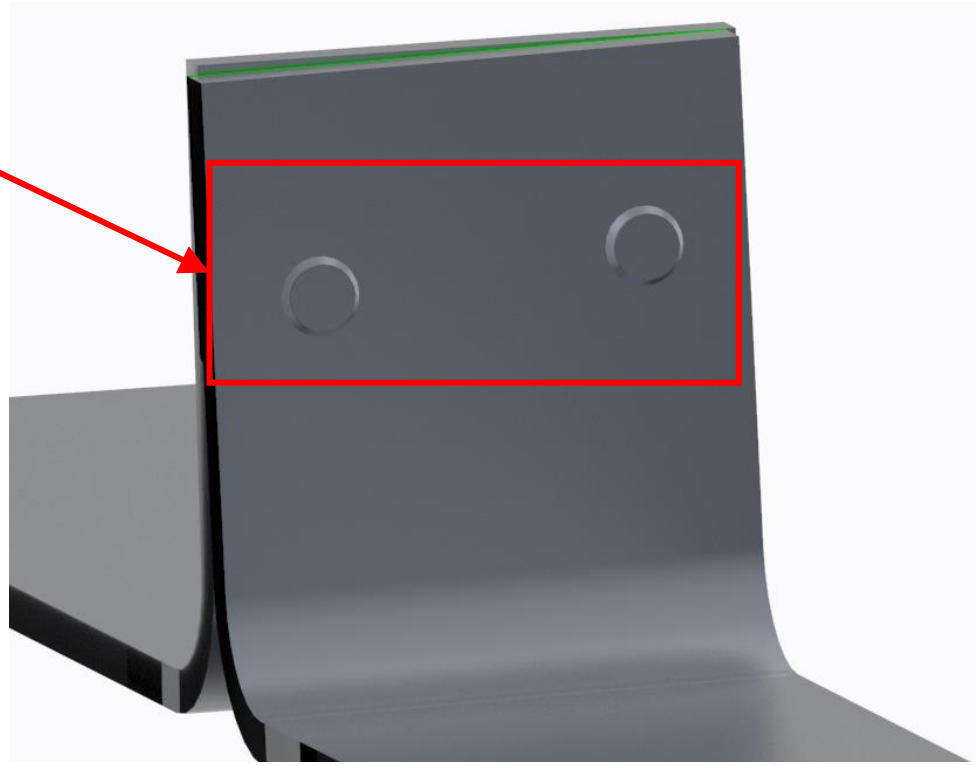




Specimen inspection

- Issues with the mechanical fasteners
  - Misalignment of the mechanical fasteners
  - Incorrect application of the mechanical fasteners





How stiffness is calculated

- Data is taken from the testing
  - Load
  - Displacement (deflectometer)

- Stiffness is calculated using the following equation:

$$K(N) = \frac{\Delta F}{\Delta u(N)}$$

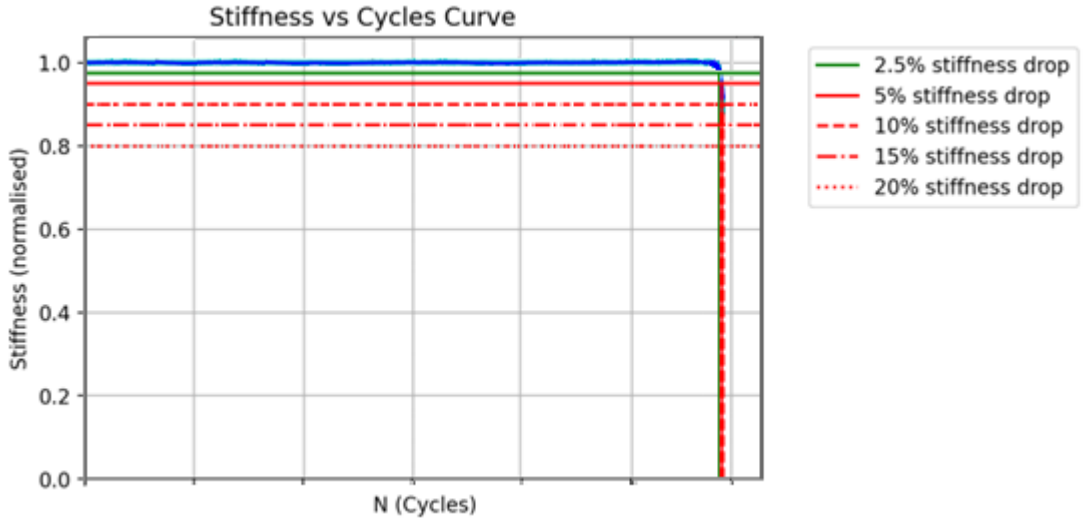
- The stiffness value is then normalised

$$K_n(N) = \frac{K(N)}{K(N_0)} \cdot 100[\%]$$

Difference between welded and adhesive / hybrid joints

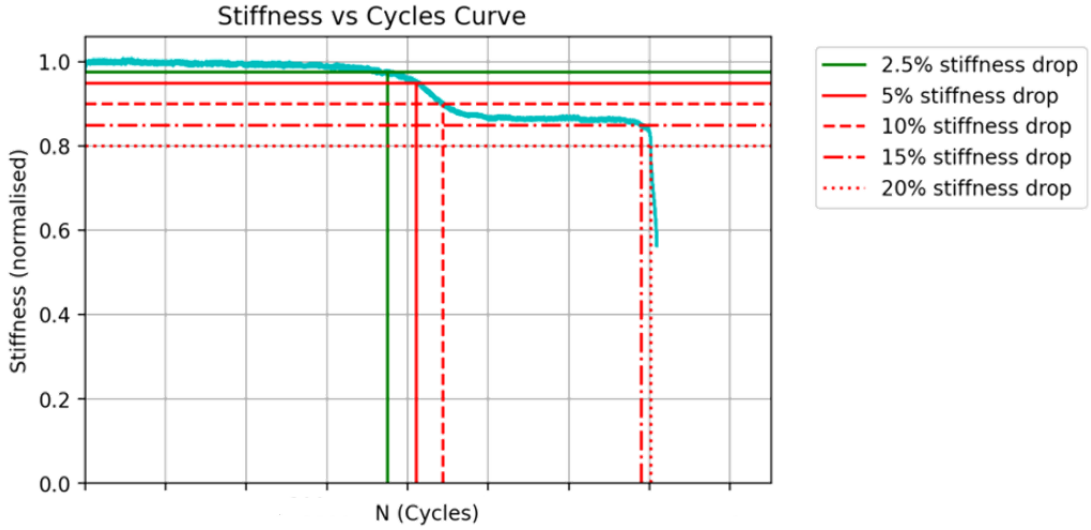
Welded joints – Single Stage Failure

- Stiffness begins stable
- Drop in stiffness on specimen failure
- Rate of stiffness drop is dependent on specimen and weld geometry



Hybrid joints – Double Stage Failure

- Stiffness begins stable
- Initial drop on adhesive failure
- Stiffness stabilises
- Final drop in stiffness on specimen failure



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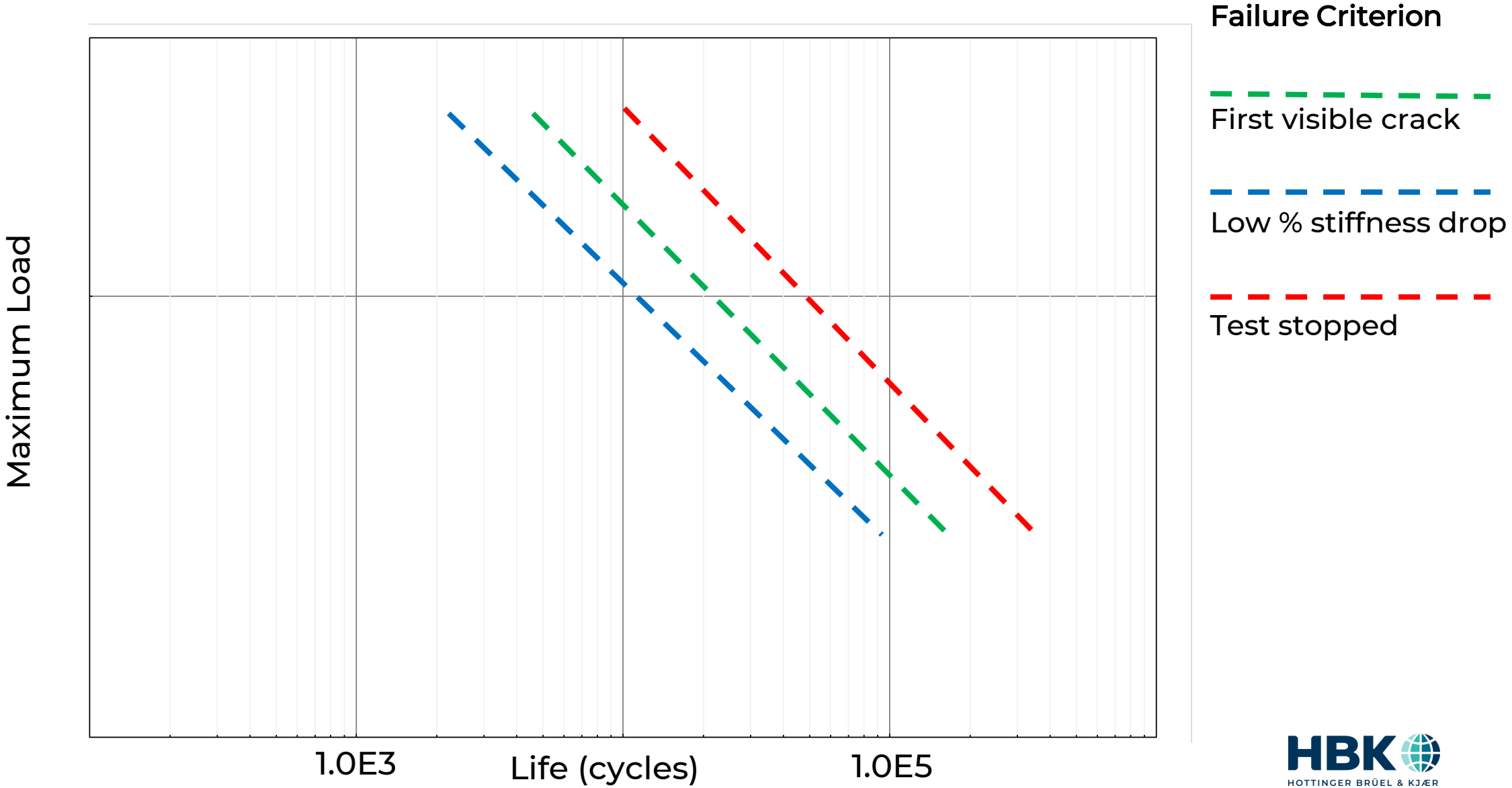
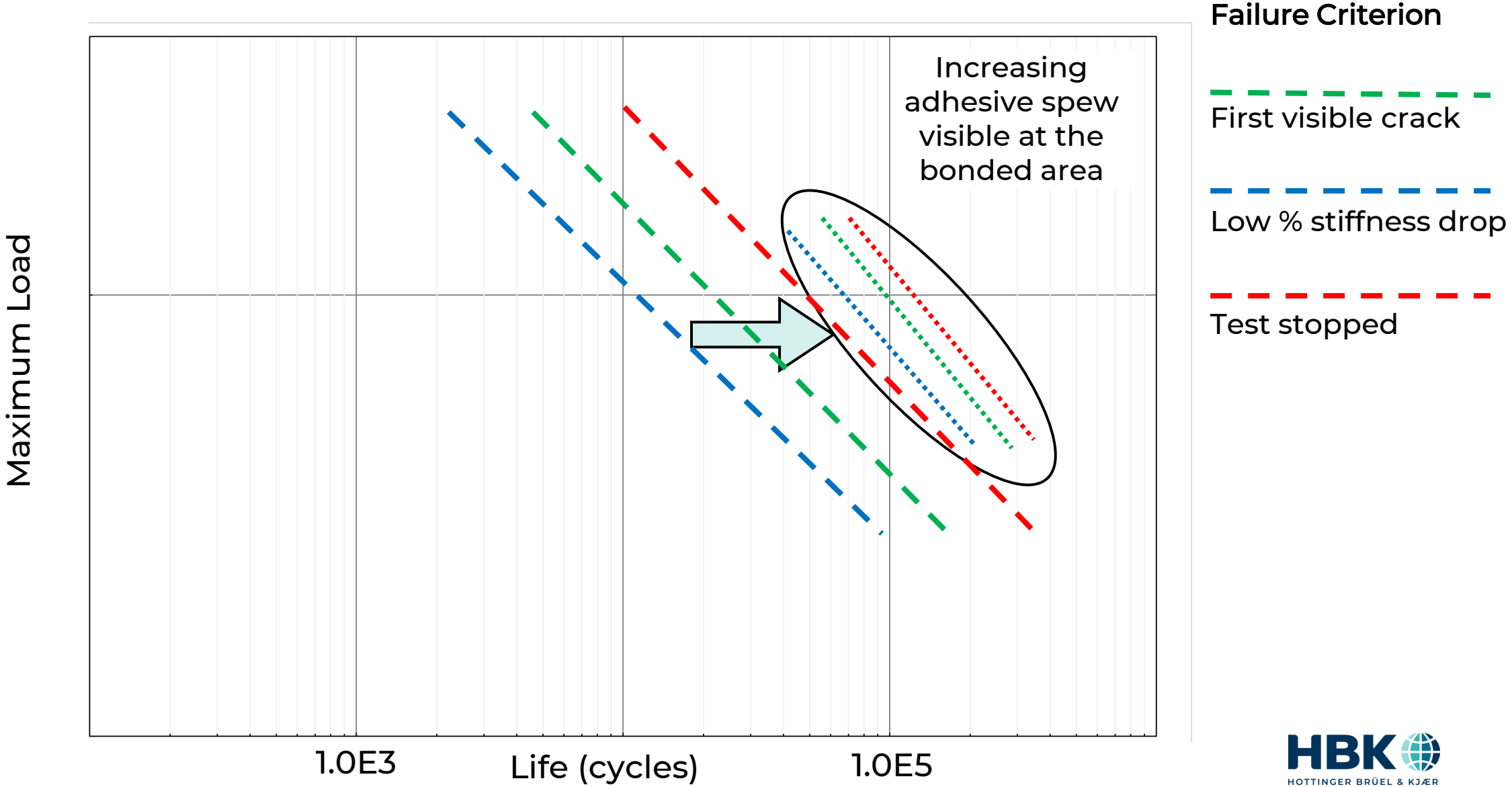
How this links to the analysis

- Possible failure criteria:
  - Specimen separation
  - Crack initiation
  - Stiffness drop
- The most appropriate failure criterion is selected
  - Customer requirements
  - Application
- Load-Life plots can be produced
  - Test load of specimen
  - Life to failure criterion

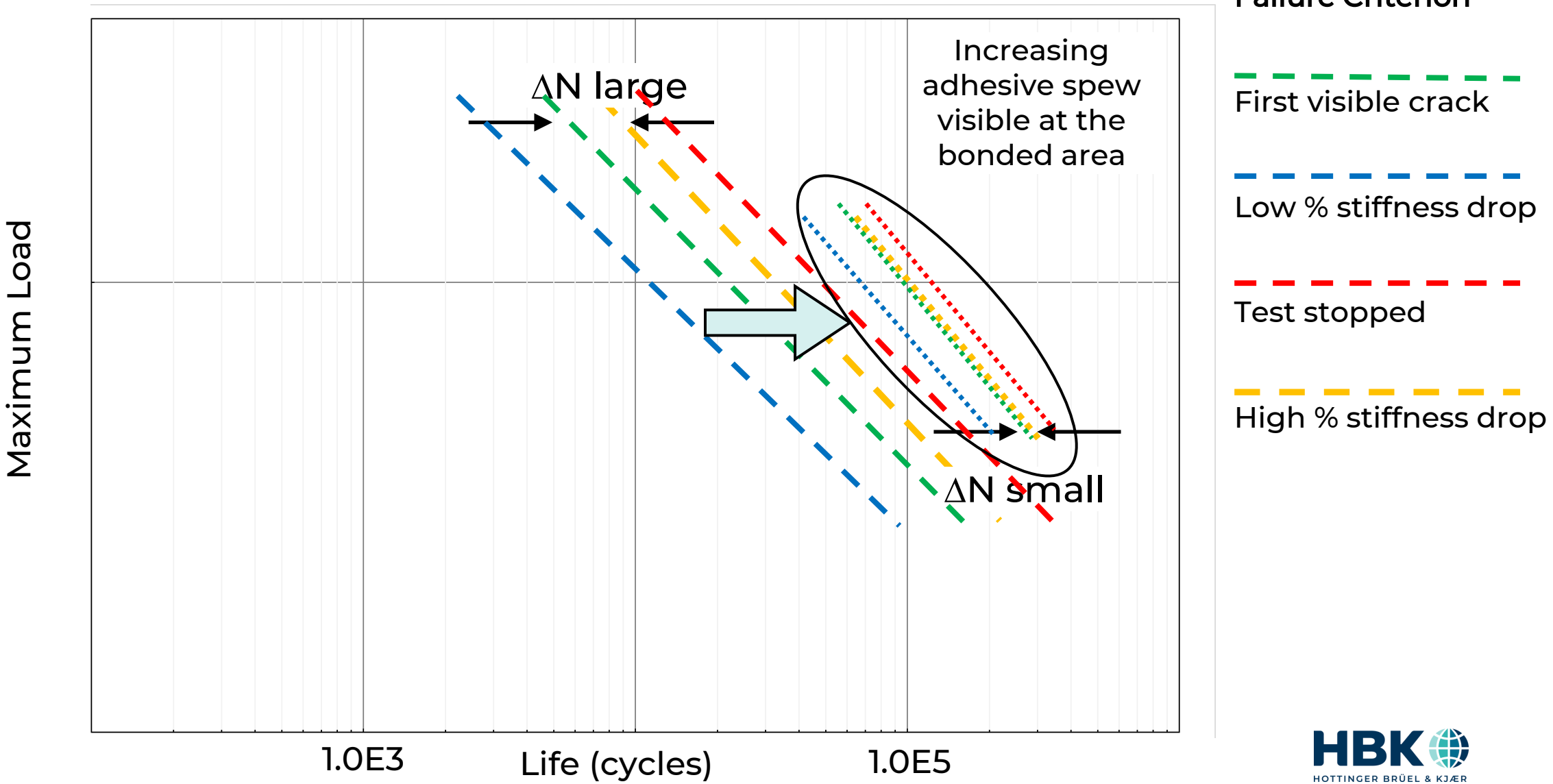
Example Load-Life plots



Example Load-Life plots



Example Load-Life plots



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Conclusions

- It is important that the specimens produced for testing are representative of the manufacturing methods and quality that is seen in production
  - Different types of defects can have different impacts on the performance of specimens
  - The influence of these defects should be captured
  - Different substrates, adhesives and mechanical fasteners can affect the behaviour of the specimens

- Load-Life plots can be generated through fatigue tests
  - The failure criteria used needs to be appropriate for the customer requirements and application of the joints
  - These can then be reverse engineered into Stress-Life plots for use in design

- HBK's Advanced Materials Testing and Characterisation facility, located in the UK, have a vast experience in fatigue testing

Future Work

1. Testing more substrate materials
   - Composites, polymers, ceramics, other metals
   - Dissimilar materials
2. Increasing the number of joint configurations tested
   - Different types of adhesives
   - Different types of mechanical fastening
3. Sub-element level testing

Thank you

Alex Pierpoint | Materials Test Engineer

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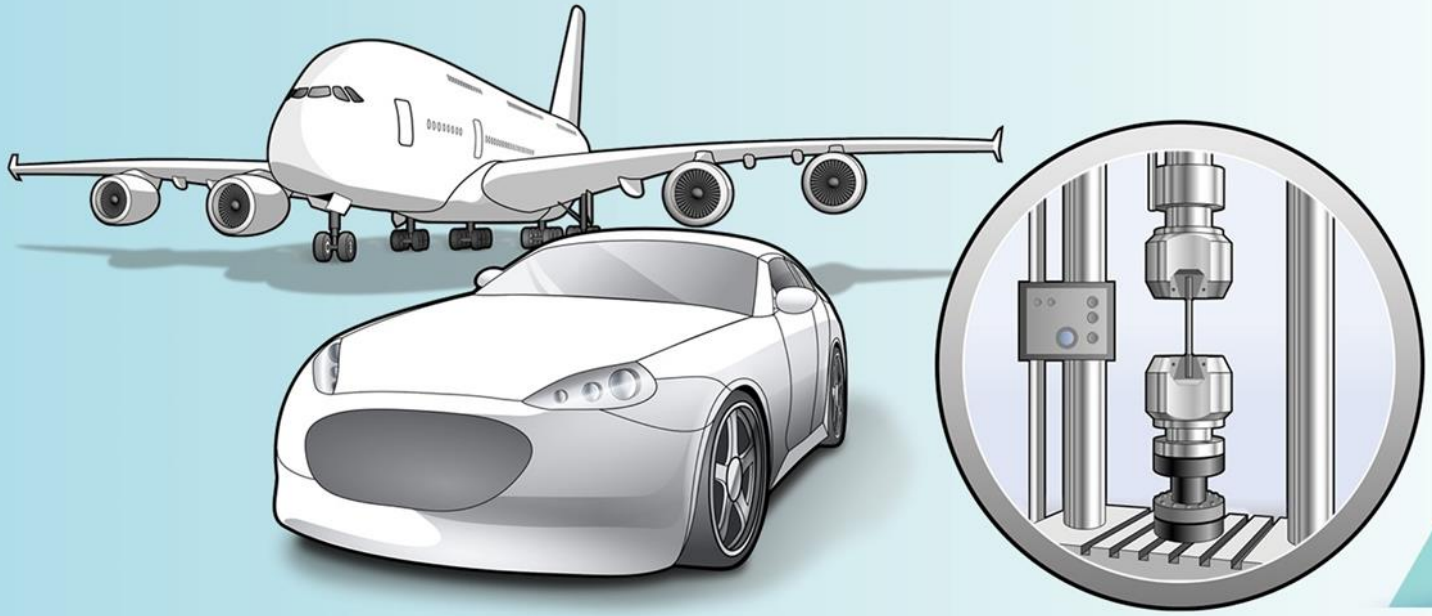

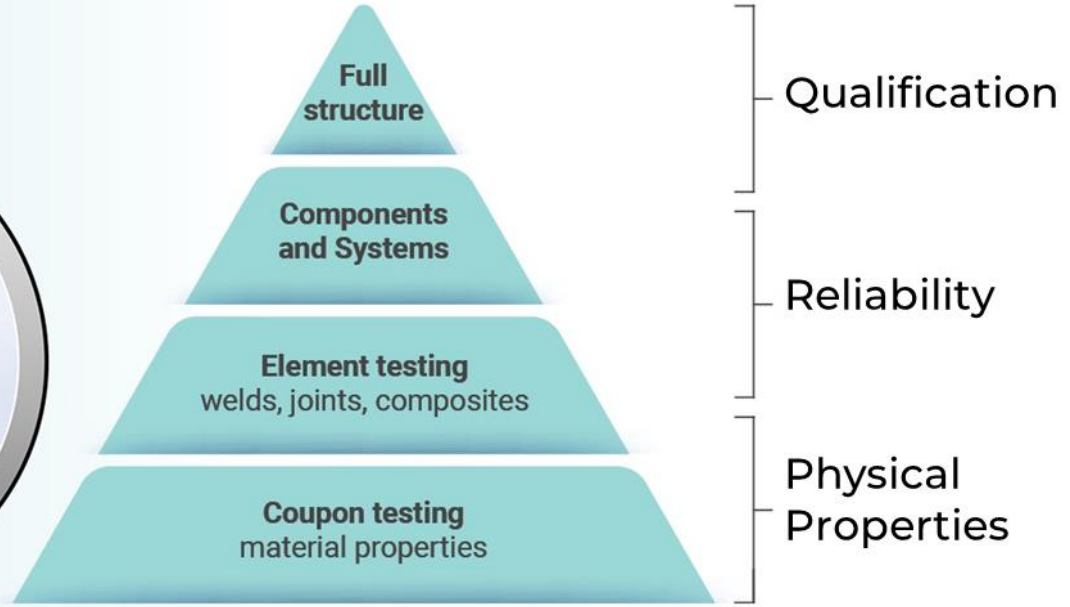

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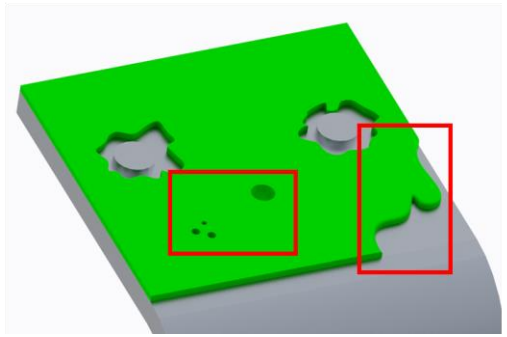

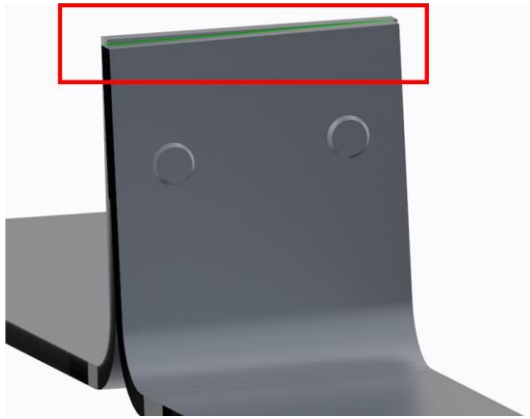

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