Enabling Qualification of Hybrid Structures for Lightweight and Safe Maritime Transport

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Motivation

The drivers to reduce weight in ship construction demands the development of durable, lightweight solutions that can withstand severe mechanical loads in a marine environment. Combining steels and composites in adhesively bonded structures can reduce weight while preserving strength, leading to lighter and stronger ships. 10% weight reduction could trigger a reduction of up to 7% in fuel consumption. The potential savings, along with the manufacturing advantages, have motivated the shipbuilding industry to explore the use of adhesively bonded hybrid joints in primary structures, capable to withstand high loads and guaranteeing safety.

Currently, no certification guidelines exist to orient the naval industry when certifying new designs using such hybrid assemblies, which limits their application to secondary structures. In QUALIFY, a multi-scale testing and simulation approach is implemented by a consortium of 11 international partners, to provide reliable insights into the long-term performance of hybrid joints operating in demanding marine environments. This will ultimately enable the increased use of adhesively bonded hybrid structures in primary structures in shipbuilding and will also generate spin-offs to other industries.

Objectives

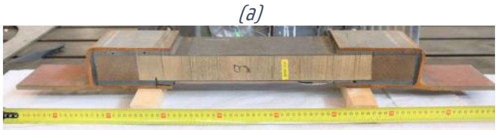
The QUALIFY project aims to remove the technological and regulatory barriers that currently prevent the widespread application of hybrid structures (metal-to-composite) in the marine and offshore industry. It will deliver the knowledge and the guidelines that the industry needs to pursue certification of adhesively bonded hybrid joints for primary structures in marine applications.

The objectives of the project are:

1. To evaluate the long-term structural performance of an adhesively bonded multi-material joint under representative operational and environmental conditions.
2. To develop a reliable inspection and maintenance methodology for adhesively bonded hybrid joints.
3. To develop guidelines for the qualification of adhesively bonded hybrid joints in primary marine structures.

Of which Soete Laboratory is tasked with the development of an accelerated ageing methodology suitable for multi-material adhesive joints at various scales (Figure 1) and evaluating the effect of ageing on the long-term mechanical performance. There is also a need to evaluate the service life of these joints, for which the development of an S-N curve and fatigue crack growth rate curve are paramount.

(a)



(b)

Figure 1: Small scale (a) and large scale (b) multi-material adhesive joints

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APPROACH

A testing methodology is developed for evaluating the service life and fatigue damage evolution at various scales. At the coupon level, steel-CFRP double strap joints (DSJ) and steel to steel bonded double cantilever beam (DCB) specimens with thick adhesive bondlines are tested under quasi-static and fatigue loading in both unaged and aged conditions. The goals are to develop an S-N curve (DSJ) and to quantify the fatigue crack growth rate (DCB). Experimental data will also serve as input to the project partners involved in modelling. During testing, joints are monitored using digital image correlation (DIC) and infrared thermography (IRT), figure 2 shows these techniques being implemented on DSJ specimens. These advanced inspection techniques allow to identify various damage mechanisms which occur during fatigue loading.

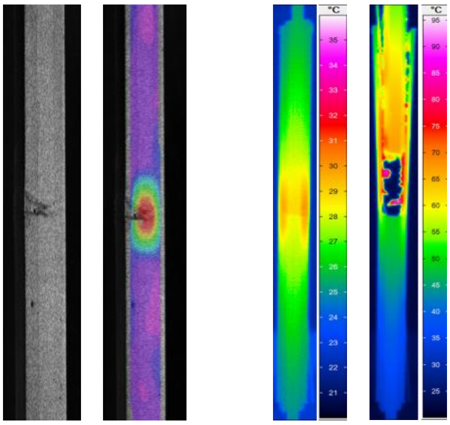
DIC images IRT images

Figure 2: DIC and IRT images used for analysing damage mechanisms

In order to study the behaviour of the multi-material thick adhesive joint when subjected to the harsh marine environment, in accordance with the ASTM B117 standard some specimens have been placed in a salt-spray chamber. Besides this ageing technique two additional accelerated techniques are developed; a) electrochemical corrosion and b) immersion in salt water at an elevated temperature. Each technique has been developed keeping in mind the various scales of testing.

Electrochemical corrosion is primarily used for coupon level DSJ specimens to study what effect the corrosion of the steel at the steel-adhesive interface has on the quasi-static strength of the test specimens.

Figure 3: Large scale specimen (01) submerged in heated saltwater for corrosion ageing.

A series of large scale specimens are manufactured by Damen Naval and BAE Systems under shipyard conditions. These will be subjected to quasi-static and fatigue loading till failure; half of which are after immersion in a saltwater bath (Figure 3) maintained at elevated temperature for 10 weeks. This technique of ageing allows to evaluate the long-term effects of water diffusion into the adhesive and corrosion at the adhesive-adherend interfaces on the mechanical performance of the joint. During these tests, the global deformation of the joint and local strain distributions will be monitored using digital image correlation (DIC). In a few tests, Fibre Bragg grating (FBG) sensors are used for local strain measurement and the potential of acoustic emission (AE) and ultrasound inspection techniques for damage detection within the joint are evaluated.

Project website: https://www.qualify-euproject.com/

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