Progress in hybrid testing of composite structures

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Abstract

Hybrid testing is explored as a virtually augmented substructure testing technique for the validation of composite structures. Progress on the development of a multiaxial loading platform with hybrid testing capability for the 'Large Structures Testing Laboratory (LSTL)' at the University of Southampton, UK is reported. The results of an initial test to commission the new platform are presented, and the application of hybrid testing to a composite wind turbine blade substructure is discussed.

Introduction

Hybrid testing is a combined experimental and numerical technique that enables physical testing of a substructure while the remainder of the structure is modelled numerically as shown in Figure 1. During the hybrid test, displacement and force resultants are iteratively exchanged at the shared boundaries as shown in Figure 1 (b).

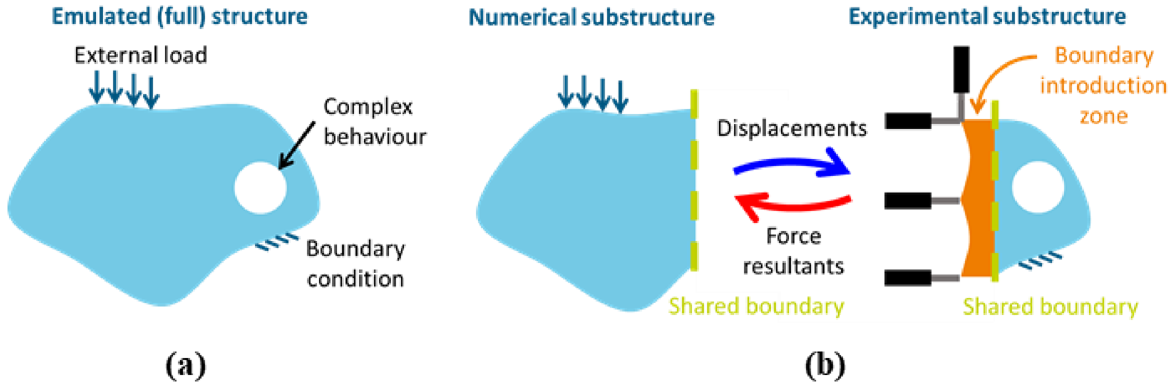
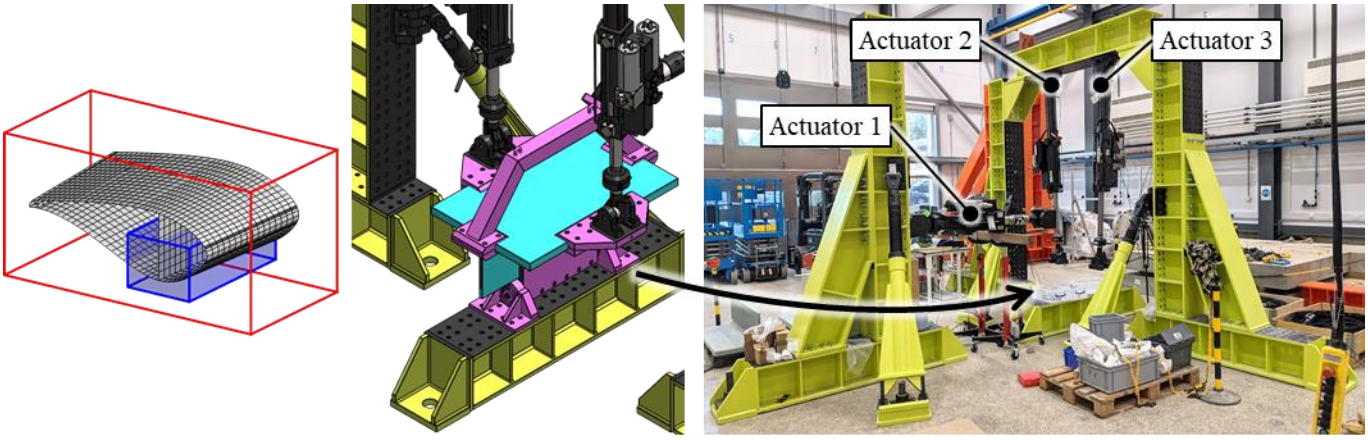


Fig. 1: Schematic of a 'continuous structure' hybrid test inspired by [1]: (a) emulated (full) structure with external loads applied, and (b) hybrid test set-up with numerical and experimental substructures with complex shared boundary.

The complex *continuous* shared boundaries shown in Fig 1b necessitate the use of multiaxial loading rigs and advanced experimental methods to control and monitor the tests. In the present work, a modular multiaxial hybrid testing platform is developed and commissioned for LSTL that enables testing of large substructures subjected to multiaxial loading conditions, informed by numerical models. The overarching aim is the development of virtually augmented testing techniques that will enable more efficient certification as well as rapid exploration of novel structural solutions not possible with the current pyramid-of-testing approach [2].

Methodology

The hybrid testing approach is developed for the wind turbine blade 'T-joint' substructure shown in Figure 2 (a). A tri-axial loading experimental set-up has been designed, as shown in Figure 2 (b), using reconfigurable reaction frames. This enables the T-joint substructure to be subjected to global blade bending induced shear loads via actuator 1 and cross-sectional loads, i.e. cross section compression, tension, and local bending effects, via actuators 2 and 3. To handle the complex shared boundaries arising from sub structuring, external LVDTs will be used within the hybrid test control loop. A digital twin of the hybrid test (or virtual hybrid test) is constructed using the commercial FE software Abaqus and Python to explore the experimental design space as well as to verify the set-up prior to physical testing. In the experiment, the linking between the physical and numerical substructure will be carried out via a bespoke LabVIEW code and National Instrument analogue input and output boxes. The experiment is also equipped with multiple digital image correlation (DIC) and thermal cameras to monitor full-field deformation and damage progression during the hybrid test.



(a) (b)

Fig. 2: Experimental set-up: (a) wind turbine blade ‘T-joint’ substructure, and (b) multiaxial reaction frames and actuator arrangement on the LSTL strong floor.

Future work

The intention is to demonstrate that hybrid testing can augment conventional substructure testing by accounting for the interaction between the physical substructure and the remainder of the structure (numerical substructure). Furthermore, it is the aim to integrate DIC displacement data from the shared boundary of the wind turbine blade substructure into the hybrid testing control loop. The approach will be to mimic the effect of defects in the numerical substructure on the different damage modes in the physical substructure as well as to account for the effect of damage in the physical structure on the global deformation of the numerical substructure.

Acknowledgements

The work has been funded through the EPSRC programme grant ‘CerTest’ EP/S017038/1, the EPSRC standard research grant ’Structures 2025’ EP/R008787/1, and by SIEMENS Gamesa renewable energy. The help of Dr Duncan Crump, LSTL principal experimental officer University of Southampton, Dr Sergey Kravchenko, University of British Columbia and of Dr Geir Olafsson, University of Bristol, in setting up hardware and software, is grateful acknowledged.

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