MULTI-AXIAL REAL-TIME HYBRID TESTING WITH HIGH-PRECISION CONTROL

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1. INTRODUCTION

Hybrid testing is a sub component testing method where one part of a structure is modeled numerically and the remainder tested experimentally. A substructure of special interest displaying e.g. viscoelasticity, buckling, residual stresses etc. is tested in an experiment. The remainder of the structure is assumed to have a well-defined response and for this reason simulated in a numerical model. The coupling between the experimental- and numerical substructure is imposed through a shared boundary. The technique has previously been applied to structures in earthquake engineering [1, 2, 3], shock absorber in automobiles [4] etc. In these efforts the structures have been multicomponent structures where the shared boundary has been simple with few DOFs. In this paper, the real-time hybrid test is performed on a single component structure, in this case a composite beam structure with more complex boundary between the experimental and numerical structure with multiple DOFs. The aim is to develop a platform for real-time hybrid testing on more complex single component structures e.g. wind turbine blades, aircraft fuselage, boat hulls etc.

2. HYBRID TESTING ARCHITECTURE

The hybrid test is controlled by a LabVIEW program with an overall architecture as seen in figure 1. The hybrid test has two components: a finite element simulation and a physical test specimen loaded by hydraulic actuators. In order to run the test in real-time, and thereby include dynamic effects, both processes must run simultaneously. This is performed in the configuration presented in figure 1.

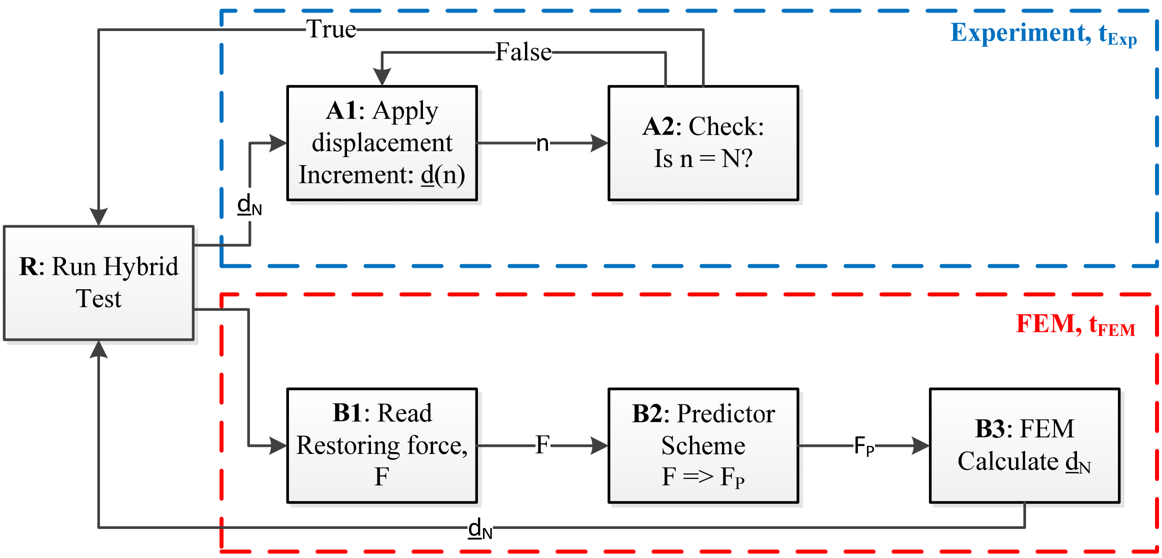

Figure 1. The data flow of the real-time hybrid communication program.

In the hybrid test, the finite element calculation is run simultaneously with the experiment. The displacement of the finite element model is calculated in **B3** and a displacement vector d_N is sent to the actuator in **A1** which is applied gradually in a loop between **A1** and **A2**. In the meantime, the restoring force in the experiment is read in **B1** and a predictor scheme calculates the restoring force in the next load step **B2** in order to perform a new finite element calculation **B3**. Here the time of the FEM: **B1**, **B2** and **B3** must be less than for the Experiment **A1** and **A2**, e.g. $t_{FEM} < t_{Exp}$. This ensures that the Experiment runs at all times thereby simulation the dynamic effects correctly.

3. EXPERIMENTAL SETUP

The real-time hybrid testing program is tested on a simple composite structure presented in Figure 2. The full structure consists of an 800mm long box profile composite beam (HxWxT = 60x140x5mm^3) clamped in both ends. The emulated structure is separated in a numerical- and experimental substructure presented in figure 2. The coupling between the substructures is defined by a discrete point with three degrees of freedom. The numerical substructure exhibits linear elastic behavior and is defined by a FE-model using plane elements. The experimental substructure includes geometric non-linearity and is loaded by three hydraulic actuators controlled through a MTS FlexTest 60 PID controller cf. figure 3. The test is controlled by measurements performed directly on the specimen in order to neglect the effect of slack and deformations in the test rig.

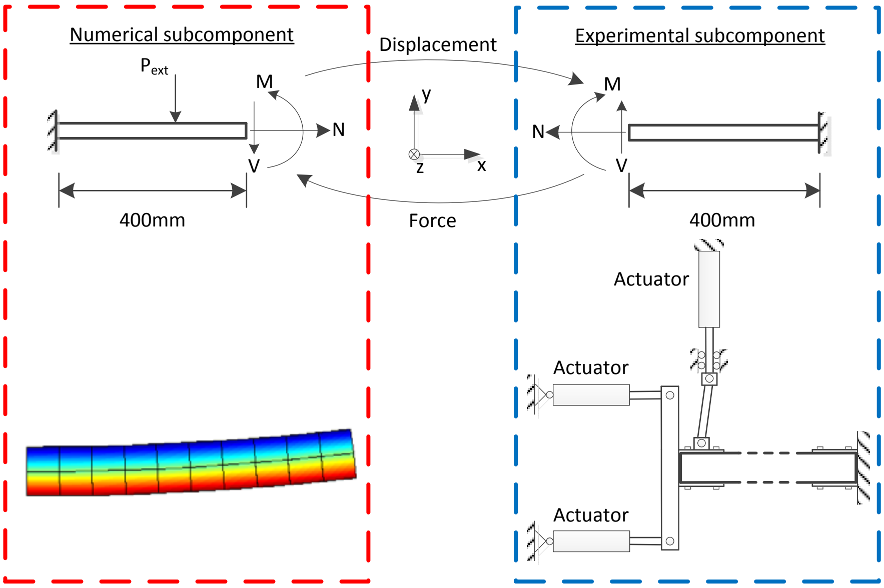

Figure 2. The full structure with the numerical substructure to the left and experimental to the right.

4. DISCUSSION AND CONCLUSION

The benefit of the hybrid testing real-time setup is it can be used on single component structures where the boundary between the numerical and physical structure is complex i.e. high number of DOFs. However the system needs improvements before it is fully useful on real structures. For one thing the iteration speed can be improved by optimizing the FEM calculation [5] or handling the actuator delay [6]. Extrapolating the restoring force to next load step from previously reactions could also been done to increase accuracy of the test.

The real-time single component hybrid test was performed at low frequency of 0.56 Hz on a composite structure. The program operates at low frequency and is thereby only suitable for applications where the load and natural frequency of the structures are equally low. However, further improvements in finite element calculation speed will enable higher frequency applications e.g. earthquake simulation.

References

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