High precision tracking compensator for single component hybrid simulation

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Abstract. Accuracy and stability within single-component hybrid simulation (HS) is compromised by experimental errors induced at the partitioning between the numerical and experimental substructure such as inconsistencies between the achieved and desired displacement. In this paper, a high precision tracking compensator is presented, capable of reducing the discrepancy between the desired and achieved displacement at the experimental substructure.

Introduction

Structural assessment through single-component HS introduces a cost-effective substructural technique by combining the advantages of numerical modelling with those of experimental testing [1,2]. Here the experimental substructure represents the portion of special interest and is therefore physically replicated to reveal the structural response when exposed to e.g. viscoelasticity, buckling, crack propagation, delamination, rate dependent properties, etc. The remaining portion – referred to here as the numerical substructure – typically covers the majority of the emulated structure representing either predictable mechanical behavior or is considered uncritical for the analysis conducted. The coupling governed through the interface between the numerical and experimental substructure – referred to here as the shared boundary – is achieved by maintaining the compatibility and equilibrium at the partitioning. Consequently, the fidelity of the HS is dependent on the level of consistency between the desired and achieved displacement at the shared boundary [3]. Within single-component HS, the shared boundary of the experimental substructure typically comprise multiple degrees-of-freedom (dofs) operated by a servo-hydraulic transfer system through multiple unidirectional hydraulic actuators connected by a test rig [4]. Due to slack and deformations in joints and bearings, a high precision tracking compensator is presented capable of operating the experimental substructure from a feedback signal acquired directly on the shared boundary.

High precision tracking compensator

Through a cascade control loop, each dof in the transfer system is operated using two PID controllers and two sensors. From figure 1, the outline of the dataflow is separated in five units labelled **(1)** through **(5)**.

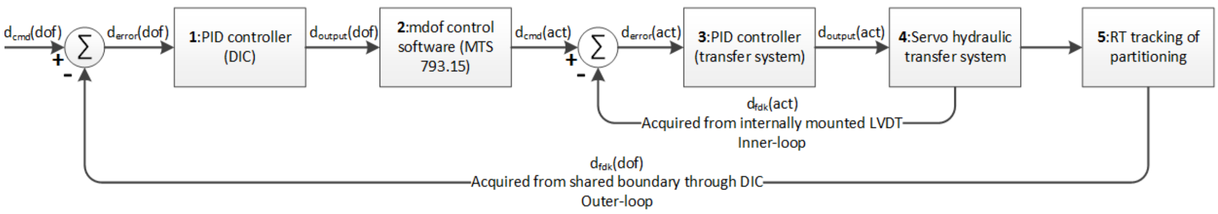

Figure 1: schematic block diagram representing the cascade control loop algorithm

Here the outer-loop in turns adjust d_{output}(dof) in **(1)** based on the set point d_{cmd}(dof) defined by the numerical model and the active feedback signal d_{fdk}(dof) acquired on the shared boundary through digital image correlation (DIC) in **(5)**. Through a coupling matrix in **(2)**, d_{output}(dof) is converted to the corresponding displacement of each actuator d_{cmd}(act) which serves as the set point for the inner-loop. The inner-loop serves as a traditional feedback control system where the transfer system in **(4)** in turns is operated by **(3)** based on the set point d_{cmd}(act) and the active feedback signal acquired from the internally mounted LVDT.

Test setup

The test setup consist of a cantilever GFRP beam loaded by three servo-hydraulic actuators labelled A, B and C cf. figure 2. Real-time tracking of the shared boundary is enabled through a DIC system of the type: ARAMIS 12M by Gesellschaft für Optische Messtechnik mbH (GOM GmbH). Through five measurement points, the equivalent three-dof displacement is derived including: translation in the x and y direction along with rotation φ around the z-axis – referred to here as d_x, d_y and r_φ. With a measurement area of 140x175mm, the system achieve a sampling frequency of 0.25 kHz with a frequency and amplitude independent time delay of 13ms. The standard uncertainty of the repeatability offered by the system is given by d_x = 9.94e-4mm, d_y = 1.20e-3mm and r_φ = 6.57e-5rad.

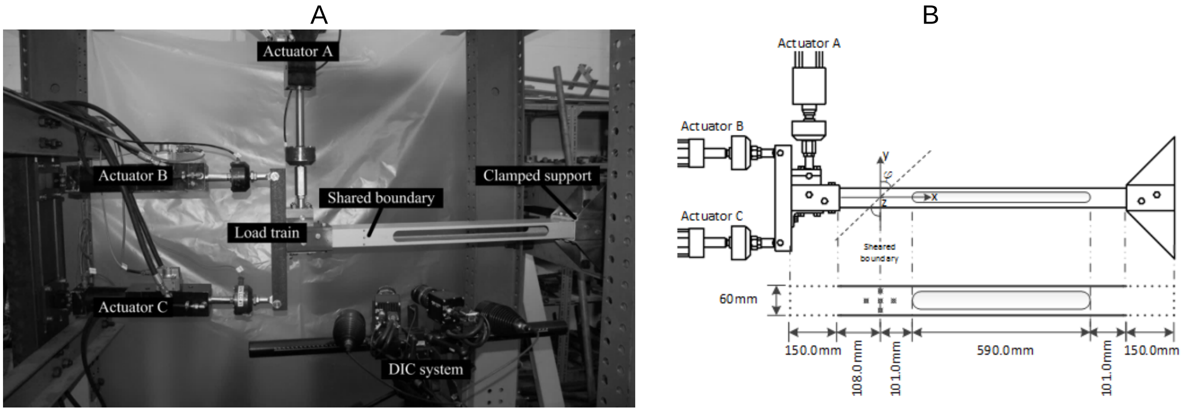

Figure 2: Test rig: a) overall test setup including load train, DIC system, etc. and b) overall dimensions

Generated through a MTS FT100 controller the cascade control loop is defined through the MTS 793 software. Here each dof is operated by the outer-loop with a clock frequency of 1 kHz. The active feedback signal from the DIC system is fed into the outer-loop through an analogue input channel. Each servo-hydraulic actuator in the transfer system is operated by the inner-loop with a clock frequency of 3 kHz to allow enough time to compensate for disturbances before affecting the outer-loop.

Results

Through a chirped sine wave in the domain 0-2Hz, system performance is evaluated in the y-direction. For a duration of 250 seconds and constant amplitude of 7.5mm, the desired and achieved displacement along with error between the two signals is represented in figure 3.

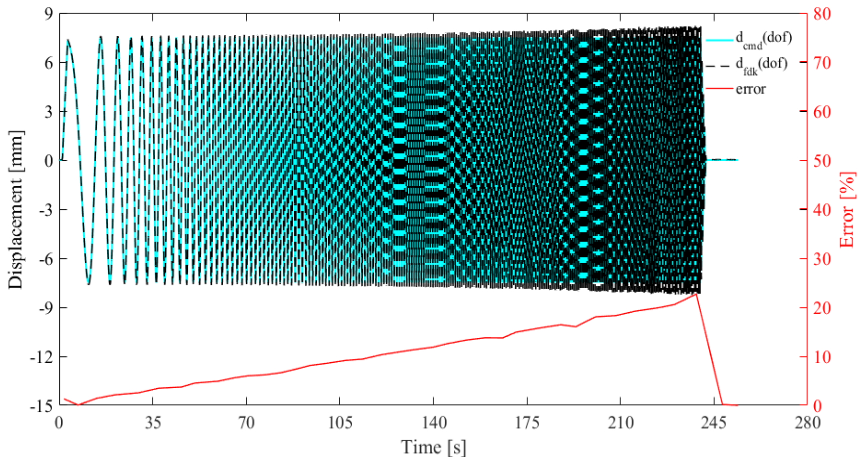

Figure 3: compensator performance with a chirped sine wave in the domain 0-2Hz

Here the error is defined as the relative deviation between the achieved and desired signal. To smooth the error output, only the peak error within each displacement input is presented. It is observed that the error is increasing as a function of the frequency, mainly governed by the time shift between the desired and achieved displacement.

Conclusion

The high precision tracking compensator has proven to significantly reduce the error between the desired and achieved displacement in both the static and dynamic regime, enhancing the accuracy and stability within single component HS.

References

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