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Technical Comments

Comment on "Active Control Technology for Large Space Structures"

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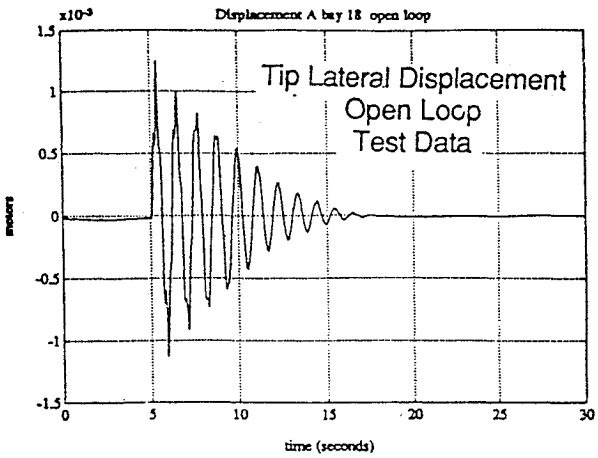
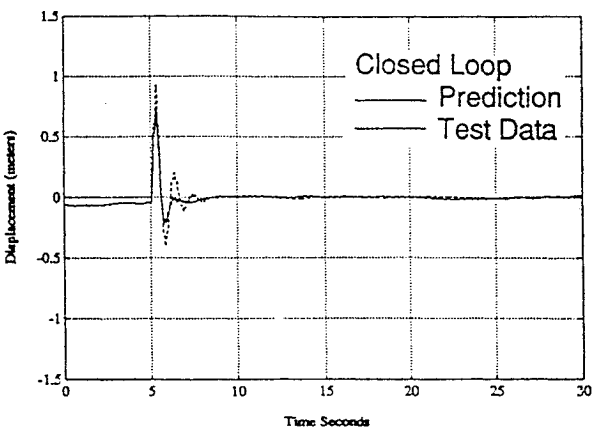
REFERENCE 1 is a survey paper on active control technology for large space structures. Figures 1 and 2 were used to illustrate the power and effectiveness of advanced system identification and a particular state-space control design method for controlling large space structures. For example, it is stated in Ref. 1 that "Figure 1 ... illustrates the efficacy of advanced active control methods. ..." It was also stated that "Figure 2 ... illustrates the effectiveness of advanced control methods. ..."

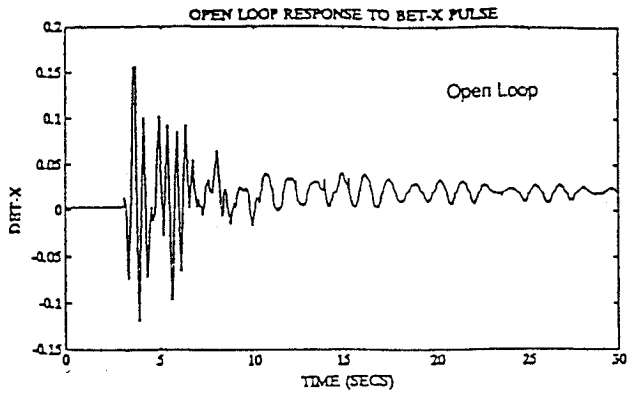


a)



b)

Fig. 1 Mini-MAST: open- vs closed-loop performance: a) tip lateral displacement, open-loop test data; b) closed-loop prediction vs test data. In both cases, excitation is a shaker pulse disturbance.[1]



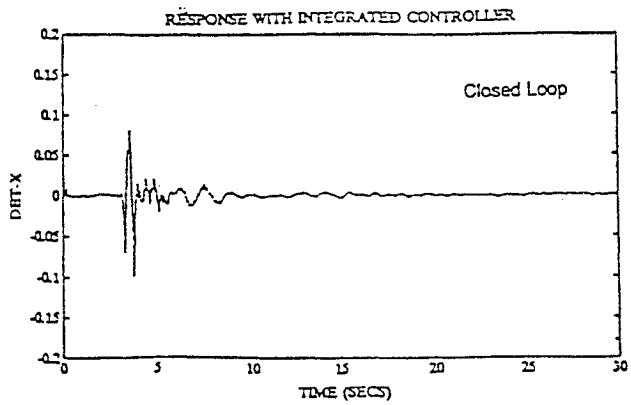


Fig. 2 Example results for ACES test bed: open- vs closed-loop LOS-*X* performance with controller.[1]

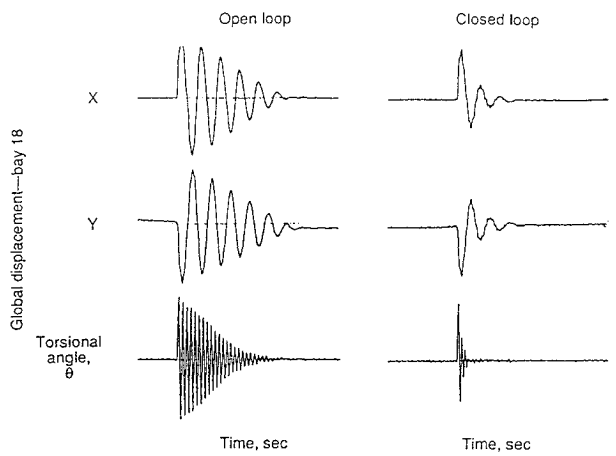


Fig. 3 Open- and closed-loop responses of Mini-MAST collocated controller at bay 18.

The purpose of this Technical Comment is to inform the readers of this journal that similar experimental results have been obtained by this author by simply employing a classical PID (proportional-integral-derivative) controller. These results are documented in Refs. 2–4 and are reproduced here as Figs. 3 and 4 for the purpose of direct comparison with Figs. 1 and 2 from Ref. 1.

It is the opinion of this author that the excellent experimental results of Figs. 1 and 2 are not necessarily due to the "advanced" nature of the advanced control design methodology, since very comparable

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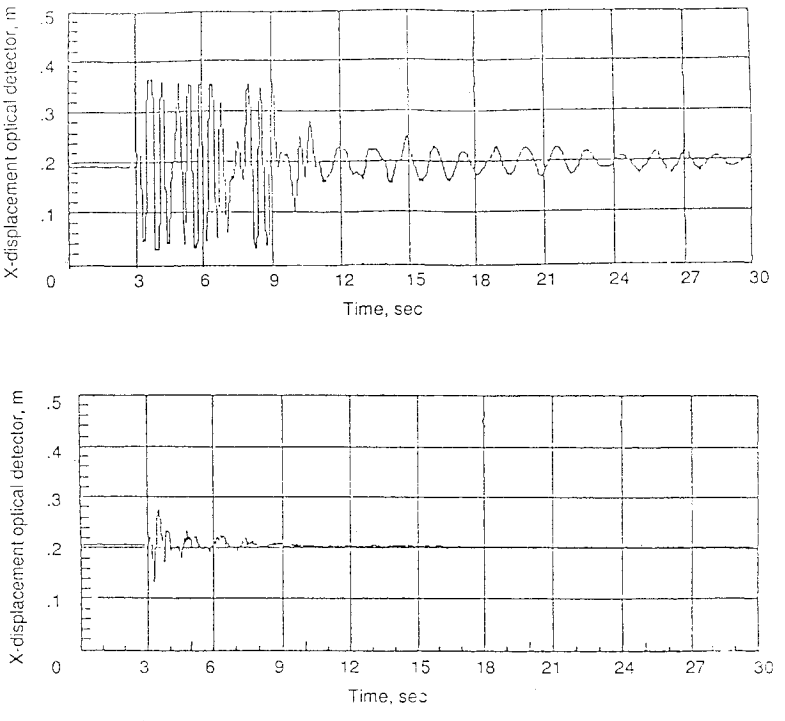

Fig. 4 ACES experimental data for DET-*X* responses to BET-*X* pulse: a) open-loop response and b) closed-loop response with integrated AGS (Advanced Gimbal System) and IMC (Image Motion Compensation) controllers.

results have been obtained by using a classical technique. In summary, this author feels that it is inappropriate to use Figs. 1 and 2 to advocate the power and effectiveness of advanced system identification and advanced state-space control design methods.

References

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[2]Wie, B., Horta, L., and Sulla, J., "Active Vibration Control Synthesis and Experiment for the Mini-MAST," *Journal of Guidance, Control, and Dynamics*, Vol. 14, No. 4, 1991, pp. 778–784.

[3]Wie, B., "Experimental Demonstration of a Classical Approach for Flexible Structure Control," *Journal of Guidance, Control, and Dynamics*, Vol. 15, No. 6, 1992, pp. 1327–1333.

[4]Smith-Taylor, R., and Tanner, S. E., "Controls-Structures Interaction Guest Investigator Program," NASA TM 4412, Feb. 1993.

Reply by the Author to Bong Wie

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THE "efficacy of advanced active control methods" is manifested in a number of ways: directly in the results they produce and indirectly due to the insight they provide for practical design.

First, the advantages of modern control design methods can be seen by a direct comparison of Figs. 1 and 3 of the Comment. We invite Dr. Wie and our readers to examine these two results more closely. Although in the classical design of Fig. 3 the closed-loop Mini-MAST takes nearly three cycles (of the primary mode vibration period) to decay to imperceptible levels, under the modern multi-input, multi-output (MIMO) design, illustrated in Fig. 1, the Mini-MAST tip motion damps out within one cycle. This is despite the fact that the open-loop response in Fig. 1 apparently persists for a larger number of cycles than the open-loop response in Fig. 3 (11–12 cycles are evident in Fig. 1, only 6 in Fig. 3).

This faster decay of the closed-loop impulse response does represent a distinct performance advantage. We attribute this advantage to the use of modern multivariable designs, as a result of an exhaustive study. As reported by Smith-Taylor and Tanner,[1] the Harris Guest Investigator (GI) team designed and tested, not one design only, but a sequence of distinct designs ranging from simple rate feedback to the advanced OPUS (Optimal Projection for Uncertain Systems) design illustrated in Fig. 1. This was done to assess the complexity/performance trade-offs associated with the use of modern versus classical single-input, single-output (SISO) design. The fact that, upon testing, all these designs worked the first time, as predicted, with no instabilities, is attributable to the professionalism of the GI team, not to modern design. Figure 1 of this reply compares the closed-loop tip responses of several of these distinct control designs. Figure 1c certainly shows that, given a talent for Bode-Nyquist methods, the design of one SISO loop at a time can be very effective. However, it was only upon the use of a modern control method that the closed-loop response was made to damp out (as shown in Fig. 1d) within one cycle. To our knowledge the only other GI team to obtain comparable results for the Mini-MAST tip response was that of the California Institute of Technology, using mu-synthesis (again, a modern MIMO technique).

But the value of advanced system identification and modern control design is also manifested indirectly. These modern methods serve as intellectual ladders that allow the designer to climb to higher levels of insight. Even when, on a given project, the final detailed design is obtained classically, the classical design benefits greatly from insights on the system dynamics and on the controls architecture that are afforded by automated identification and design methods. If, e.g., on the ACES testbed (Figs. 2 and 4 of Dr. Wie's comment) one had available accurate eigensystem realization algorithm (ERA) generated system models and modern control design results indicating the most appropriate decentralized control architecture, then one would be in an excellent position to execute a classical design quickly and confidently.

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