Technical Comments

Comment on "Orthogonality Check and Correction of Measured Modes"

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AT some point (usually quite early) in the career of every Structural Systems Identifier, he indulges in some wishful thinking. "Wouldn't it be nice if the eigenvalues of the nonorthogonal generalized mass matrix were really the generalized masses and the eigenvectors would lead to the real vibration modes?" He soon dismisses this mathematical novelty because it is obviously irrelevant to the physics of the Ground Vibration Test (GVT). However, we have just seen a strange variation of this mathematical curiosity advanced in Ref. 1 as a serious proposal for correcting measured modes. Rather than using the eigenvectors of the generalized mass matrix as a postmultiplying correction matrix to the measured modes, Targoff suggests the inverse square root of the generalized matrix as the correction matrix. Targoff observes that, "unfortunately, an infinitude of modal sets can be found, each of which will satisfy the orthogonality check perfectly." This, of course, is true, but there is more to System Identification than that (see, e.g., the survey by Flannelly and Berman[2]). If Targoff had attempted an experimental correlation with the data correlated by McGrew,[3] rather than merely criticizing McGrew's choice of the Gram-Schmidt method for mathematical rather than physical reasons ("the assumption that all of the modal errors occur with the same signum disturbs our concepts of the randomness of the errors in the experimental process,") he would have discovered the wishfulness of his mathematics. McGrew's data[4] had two rigid body modes and four vibration modes. Here is the dilemma in Targoff's hypothesis: shall we "corrupt" the rigid body modes by making all of the modes orthogonal, or shall we orthogonalize the vibration modes among themselves and accept the nonorthogonality with the rigid body modes? Since there is no escaping between the horns of the dilemma, Targoff's hypothesis is reduced to absurdity.

Taking the latter horn of the dilemma, i.e., using the correct rigid body modes with the vibration modes made orthogonal among themselves, a calculation was made based on the data of Ref. 4. The deflection influence coefficient at the wing-tip was found to be 784×10^{-6} in./lb by Targoff's hypothesis, which compares unfavorably to McGrew's 798×10^{-6} in./lb by the Gram-Schmidt method and the experimental value of 875×10^{-6} in./lb. In an earlier calculation Rodden[5] had obtained a value of 788×10^{-6} using Gravitz'[6] influence coefficient averaging procedure, and he noted that much of the discrepancy arises from the truncation error from having only four measured modes. Clearly, Targoff's proposal does not lead to any improvement in the correlations obtained to date.† There is no need to make the calculation‡ impaled on the first horn of the dilemma; it must be agreed that GVT crews can determine rigid body modes without "corrupting" them.

Since Targoff did not refute McGrew's physical argument for the Gram-Schmidt method, the justification bears repeating[3]: "The method is based on the following assumptions: 1) measured frequencies constitute the most accurate test data, 2) modal amplitude and phasing errors increase with increasing frequency, and 3) structural damping effects are small, but tend to cause higher modes to excite lower modes. Therefore, each successively higher-frequency mode shape consists of the "true" modes plus a linear combination of all preceding modes, including rigid-body modes in the case of free-free vibration." The correlation McGrew achieved is a point in favor of the Gram-Schmidt method and, perhaps, it is to be preferred for the physical reasons stated, but it also achieves the required orthogonlity among the rigid and flexible modes.

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†There is a slight improvement over our original wishful thinking: the eigenvectors of the generalized mass matrix lead to an influence coefficient of 776×10^{-6} in./lb.

‡How can we? The calculation is *not* invariant with the choice of coordinate system!

References

[1]Targoff, W. P., "Orthogonality Check and Correction of Measured Modes," *AIAA Journal*, Vol. 14, Feb. 1976, pp. 164-167.

[2]Flannelly, W. G. and Berman, A., "The State of the Art of System Identification of Aerospace Structures," *System Identification of Vibrating Structures*, Reprints of Papers Presented at ASME Winter Meeting, 1972, pp. 121-131.

[3]McGrew, J., "Orthogonalization of Measured Modes and Calculation of Influence Coefficients," *AIAA Journal*, Vol. 7, April 1969, pp. 774-776.

[4]Kordes, E. E., Kruszewski, E. T., and Weidman, D. J., "Experimental Influence Coefficients and Vibration Modes of a Built-Up 45° Delta-Wing Specimen," NACA TN-3999, May 1957.

[5]Rodden, W. P., "A Method for Deriving Structural Influence Coefficients from Ground Vibration Tests," *AIAA Journal*, Vol. 5, May 1967, pp. 991-1000.

[6]Gravitz, S. I., "An Analytical Procedure for Orthogonalization of Experimentally Measured Modes," *Journal of the Aerospace Sciences*, Vol. 25, Nov. 1958, pp. 721-722.

Reply by Author to W. P. Rodden

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TO any serious reader of Targoff's paper,[1] Rodden's remarks must seem strange indeed. He completely disregards the main thrust of the paper, setting up his own straw men which he proceeds to attack with great vigor. Let us list the points he tries to make: 1) a simple alternative to a complex method is obviously wrong; 2) modal survey tests of "free-free" structures are always performed with *perfectly* unconstrained end conditions; 3) Targoff[1] did not attempt to refute McGrew's[4] argument; ergo, it is correct; 4) two (or more) processes may be evaluated comparatively to the order of 1% using an inaccurate data basis, by passing their results through an unproven filter. Response will be made to each of these points, in turn.

1) Rodden makes derisive reference to the fact that the assumption of only-symmetric errors leads to use of "the inverse square root of the generalized matrix as the correction

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