Readers' Forum

Brief discussions of previous investigations in the aerospace sciences and technical comments on papers published in the AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

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Comment on "Proportional Optimal Orthogonalization of Measured Modes"

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RESEARCH in structural system identification continues to be characterized by wishful thinking. The most recent wish[1] is that a "practicing engineer" would review experiments and obtain the experience to "teach us what the proper values are of the credibility matrix" to make Prof. Baruch's orthogonalization method meaningful. This practicing engineer has reviewed some experiments[2] and the experience gained suggests that Baruch's recent proposal is as wishful as Targoff's earlier proposal.[3,4]

The data of Ref. 2 were analyzed in Refs. 5 and 6. They have been reanalyzed for this Comment using Baruch's Eqs. (15) and (17) to obtain orthogonal modes and the procedure of Ref. 5 to obtain the structural influence coefficients (SIC's). Three sets of credibility factors α_i were investigated: the first was constant, $\alpha_i = 1$; the second was inversely proportional to the modal frequency f, $\alpha_i = f_l/f_i$; and the third was inversely proportional to the square of the frequency, $\alpha_i = (f_l/f_i)^2$. Space does not permit showing all four of the orthogonal modes for all three choices of credibility factors; however, the second and fourth modes are regarded as representative and the various solutions are shown in Tables 1 and 2. The three Baruch solutions are compared in Tables 1 and 2 with the experimental modes and the results of Refs. 5 and 6. Comparison of the modes in these tables reveals very little to recommend any choice of credibility factor, and this experiment and experience have taught us nothing about proportional optimal orthogonalization.

Representative SIC's are compared in Table 3; they are diagonal elements from the influence coefficient matrices. In addition to the experimental data and the results from Refs. 1, 5, and 6, results from the method of Berman[7] are given. Berman's method modifies the mass matrix to achieve orthogonality† while preserving the modes, frequencies, and rigid body inertial properties. A perusal of Table 3 again shows no basis for selection of Baruch's credibility factors.

Unfortunately, Table 3 in its entirety suggests that orthogonality has very little to do with system identification. It is now obvious that the truncation error from only four modes dominates the results. What is needed is a systematic method for modifying the element stiffnesses and/or masses in a finite element model of the structure to obtain agreement with the incomplete set of experimental modes and

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†Note that an argument in favor of Berman's method can be made from Tables 1 and 2: Many of the modal elements are modified more than the probable errors in the modal measurements, so, since the theoretical mass matrix does not possess a high degree of accuracy, it is also an eligible candidate for modification. In the example considered here, the theoretical mass matrix is quite accurate for translation but rotary inertia effects have not been included.

Table 1 Second symmetric mode, $f_2 = 88.8$ Hz

Load station[a]	Test	Ref. 1 $\alpha_i = 1$	Ref. 1 $\alpha_i = f_l/f_i$	Ref. 1 $\alpha_i = (f_l/f_i)^2$	Ref. 5	Ref. 6
2	0.613	0.626	0.623	0.623	0.632	0.614
4	0.243	0.221	0.226	0.228	0.226	0.236
6	−0.033	−0.058	−0.056	−0.056	−0.057	−0.053
8	0.037	0.005	0.013	0.016	0.009	0.031
10	−0.312	−0.340	−0.340	−0.340	−0.344	−0.337
12	−0.655	−0.650	−0.667	−0.672	−0.667	−0.700
14	0.072	0.071	0.073	0.074	0.070	0.077
16	−0.170	−0.184	−0.183	−0.182	−0.185	−0.180
18	−0.426	−0.425	−0.436	−0.439	−0.433	−0.457
20	−0.474	−0.439	−0.466	−0.474	−0.459	−0.520
22	0.278	0.321	0.315	0.314	0.318	0.302
24	0.170	0.177	0.180	0.180	0.181	0.183
26	0.154	0.116	0.129	0.132	0.130	0.153
28	0.513	0.462	0.478	0.482	0.478	0.510
30	1.000	1.000	1.000	1.000	1.000	1.000

[a] See Ref. 5, Fig. 3, for station locations

Table 2 Fourth symmetric mode, $f_4 = 164.2$ Hz

Load station[a]	Test	Ref. 1 $\alpha_i = 1$	Ref. 1 $\alpha_i = f_l/f_i$	Ref. 1 $\alpha_i = (f_l/f_i)^2$	Ref. 5	Ref. 6
2	0.616	0.645	0.637	0.657	0.653	0.685
4	−0.142	−0.125	−0.119	−0.112	−0.119	−0.103
6	−0.166	−0.159	−0.152	−0.152	−0.157	−0.155
8	−0.416	−0.412	−0.409	−0.412	−0.412	−0.412
10	−0.314	−0.321	−0.316	−0.326	−0.325	−0.343
12	0.413	0.394	0.386	0.370	0.382	0.346
14	0.127	0.123	0.102	0.096	0.113	0.107
16	−0.163	−0.172	−0.177	−0.187	−0.180	−0.203
18	0.160	0.148	0.150	0.139	0.141	0.113
20	1.000	1.000	1.000	1.000	1.000	0.999
22	0.900	0.893	0.841	0.838	0.873	0.855
24	0.082	0.076	0.058	0.054	0.066	0.046
26	−0.858	−0.847	−0.815	−0.810	−0.835	−0.831
28	−0.904	−0.852	−0.784	−0.750	−0.807	−0.719
30	0.627	0.729	0.788	0.857	0.799	1.000

[a] See Ref. 5, Fig. 3, for station locations.

Table 3 Diagonal elements of symmetrical structural influence coefficient matrix, in./lb × 10⁶

Load station[a]	Test	Ref. 1 $\alpha_i = 1$	Ref. 1 $\alpha_i = f_l/f_i$	Ref. 1 $\alpha_i = (f_l/f_i)^2$	Ref. 5	Ref. 6	Ref. 7
4	59	33	35	37	34	38	38
6	254	220	235	249	231	257	260
8	875	786	791	795	788	798	803
11	28	14	14	13	14	13	13
13	34	22	23	23	22	22	21
15	107	94	96	97	95	97	95
17	265	240	237	235	238	233	230
21	50	30	29	29	29	28	27
23	58	46	46	46	45	45	43
25	129	97	97	97	97	96	94
32	42	16	16	16	16	16	15
34	73	34	34	34	33	33	32
42	27	0	0	0	0	2	0

[a] See Ref. 5, Fig. 4, for station locations.

frequencies. Continued research along the lines recently proposed by Chen and Garba[8] would appear to be appropriate if any further progress is to be made in structural system identification. Orthogonality exercises seem to have led us nowhere.

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Reply by Author to W.P. Rodden

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RODDEN puts the wagon in front of the horses. The choice of credibility factors has nothing to do with the orthogonalization procedure itself. The credibility factors must be determined in connection with the method of measurement. and not by comparison among different methods[1,2,3] as Rodden tries to do using his carefully performed caleulations. Let us assume, for example, that in some given method of measurement the error in the measured amplitude does not depend on the magnitude of the amplitude itself. Clearly, in this case, the credibility factors must be proportional to the magnitude of the amplitude. Here it seems natural to make the credibility factors proportional to the mean value of the given measured mode,

$$\alpha_i = \beta\sqrt{\tilde{T}_i^t M \tilde{T}_i} \tag{1}$$

where α_i is the credibility factor, β is some common multiplier, M is the mass matrix and $\tilde{T}_i$ is the measured mode shape which must be given in the same units for all measured modes.

In some other methods of measurement the errors in the measured modes can be some function of the modal frequencies and then, the credibility factors will be chosen in connection with this function. This is the reason why the assignment of the credibility matrix was left in Ref. 1 to the discretion and intuition of the practicing engineer. Note that the method of measurement is not mentioned in the comment.

It must be added that the orthogonalized modes are needed to calculate the corrected stiffness matrix.[1,4,5,6] Only then is the stuctural system identification completed.

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