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# Comments on Response Errors of Non-proportionally Lightly Damped Structures

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## AUTHORS' REPLY

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The authors wish to thank Dr Shahruz for his comments [1] on the authors' letter [2], in which he questioned: (1) that the assumptions of  $|b_k|/|b_i| = 1$  and  $|\xi_k|/|\xi_i| = 1$  lead to the erroneous conclusions regarding the output error; (2) that the two-norm was mistakenly used for the step response; and (3) that the error can exceed the output, as shown in the example of [1].

Regarding the first question. In our letter [2] we did not explain that the assumption  $|b_k|/|b_i| = 1$  denotes the worst case of equation (7). Indeed, consider  $|b_k|/|b_i| \ll 1$ . In this case the  $k$ th mode is excited lightly, and the  $k$ th error is negligible at the output. Similarly, the ratio  $|\xi_k|/|\xi_i| = 1$  denotes the worst case in equation (7) of reference [2]. Certainly, for  $|\xi_k|/|\xi_i| \ll 1$  the  $i$ th mode is excited lightly, and the  $i$ th error is negligible at the output.

In order to explain the second question, note that the two-norm was finite in our example. We used the two-norm of the step response in a limited time segment, up to the moment when the motion is stationary. In our case it was from 0 to 10 s in Example 1, and from 0 to 50 s in Example 2, as in Figure 4 of reference [2].

Now we turn to the last question. The example of reference [1] shows that errors under specific conditions are substantial. The magnitude of the error could be considered small or large, depending on the signal it is compared to. In the discussed example, the frequency of the harmonic excitation was equal to the first resonance frequency (of 1 rad/s). Therefore the first mode response is dominant (of amplitude 250), while the responses of the remaining modes are negligible (of amplitudes 0.25 and 0.1). The output as a combination of all modal responses is dominated by the first mode response in the example. The errors of the first mode, as well as the errors of the remaining modes, are negligible when compared to the output (less than 0.1%).

Finally, the claim in reference [1] that "the error in modal co-ordinates does not provide a definitive measure of size in the physical co-ordinates" is not true if the output error is considered: output does not depend on a choice of co-ordinates.

In conclusion, we consider an output error as a measure of the system performance. We thank Dr Shahruz for pointing out the inconsistencies in explaining the problem assumptions and in conditions of norm computation.

### REFERENCES

1. S. M. SHAHRUZ 1998 *Journal of Sound and Vibration* **210**, 279–284. Comments on "Response errors of non-proportionally lightly damped structures".
2. W. GAWRONSKI and J. T. SAWICKI 1997 *Journal of Sound and Vibration* **200**, 543–550. Response errors of non-proportionally lightly damped structures.