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LETTERS TO THE EDITOR

COMMENTS ON "COMPUTING CRITICAL SPEEDS FOR ROTATING MACHINES WITH SPEED DEPENDENT BEARING PROPERTIES"

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The writers found the title paper by Friswell *et al.* [1] interesting. The proposed "fictitious system", which has a set of dummy freedoms to incorporate the speed dependent properties of bearings, is surely of great use for critical speed and unbalance response analysis of rotor-bearing systems. However, the purpose of this letter is to mention several important papers that must have been inadvertently missed by the authors of the title paper.

It is quite surprising to the writers that the authors do not refer at all to the papers that have dealt with exactly the same topic as the title paper. Reference [2] presented an efficient unbalance response and critical speed computation technique for rotor-bearing systems with rotational speed dependent parameters. It is believed that the formulation proposed in reference [2] is a generalization of the formulation presented by the authors. In reference [2], it was shown that the rotational speed dependent eigenvalue problem can be transformed into the rotational speed independent eigenvalue problem by introducing a lambda matrix, assuming the bearing dynamic coefficients are well approximated by polynomial functions of rotational speed.

The theory developed in reference [2] contains the fundamental ideas of the title paper: for example, "polynomial fits of bearing parameters" and "dummy freedoms". Indeed, not only polynomial fits for bearings were employed but also the increase of the size of the eigenvalue problem with increasing the orders of polynomials for bearings was extensively discussed in reference [2]. In addition, the formulation in reference [2] is more general than that in reference [1]: it does not confine itself to specific orders of polynomials for bearings. Reference [2] highlighted a generalized modal analysis procedure as well for unbalance response analysis of rotor-bearing systems with the eigensolutions from the aforementioned eigenvalue problem. However, the unbalance response analysis

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method by using a modal decomposition was not developed in the title paper. The method proposed in reference [2] has been further extended in references [3, 4] to account for general, harmonic response analysis of rotor-bearing systems with rotational speed dependent parameters. In particular, one chapter in reference [4] is dedicated to treatment of the topic of interest in a systematic way. Moreover, it was shown in reference reference [5] that a similar approach could easily be applied for the analysis of *frequency dependent parameter* systems.

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AUTHORS' REPLY

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The authors thank Dr Hong and Professor Lee for their comments and for bringing their references to our attention. In our original paper we indicated our impression that the approach of fitting a polynomial to speed dependent bearing coefficients was not new, but that we were not aware of any suitable references. That omission has now been corrected. However, the polynomial fitting approach was not central to the argument in our paper but was used as an introduction to our method and also as a baseline for a comparison of the effectiveness of our proposed method.

The view of Dr Hong and Professor Lee that their method is a generalization of ours is, in fact, incorrect. Indeed if the mass, damping and stiffness properties of our "fictitious" degrees of freedom are chosen suitably then the polynomial approximation to the bearing coefficients is recovered. Thus, our approach is a generalization of their's. Although the polynomial fitting approach does introduce extra degrees of freedom, these extra degrees of freedom are constrained to be derivatives of the physical degrees of freedom. Hence, the properties of these degrees of freedom may not be fully utilized to obtain a good fit to the bearing characteristics. In our approach, the extra freedom in the curve fitting process means that the bearing coefficients are curve fit to a rational polynomial function. Often a polynomial of high degree is required to fit bearing coefficients accurately, as demonstrated in our paper, whereas a low degree rational polynomial usually fits well. Furthermore, our paper showed that polynomial approximations can produce spurious (or numerical) critical speeds within the running range. We believe that the better fit to the bearing coefficients and the associated computational savings, together with the lack of spurious critical speeds introduced, make our method a significant generalization and improvement on the polynomial fit approach.

Dr Hong and Professor Lee also mention the use of the expanded system with extra "fictitious" degrees of freedom to calculate the unbalance response via the eigenvalue decomposition. As stated in the introduction to our paper, this calculation is straightforward once the expanded system matrices have been set up. We did not think, and still do not think, that this extension is sufficiently great to warrant detailed consideration.