MULTIVARIABLE CONTROL FOR A FLEXIBLE ROTOR: A CASE STUDY

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Abstract

In this paper the control system for a magnetically supported flexible rotor is studied. Only the three first vibration modes are considered in the design process. The third mode is called here as "flexible mode" (the first bending mode).

Although the experimental set-up is a rotating system, previous studies had shown that the coupling between orthogonal bearings could be neglected. The same is valid for the coupling between "axial" (thrust) and "radial" bearings. So, the rotor can be simply considered as a single "bar", and the coupling between "upper" and "lower" bearing systems is the only one taken into account.

A Linear Quadratic Gaussian (LQG) controller was designed. The criteria used for the choice of weighting matrices parameters, either for the state feedback matrix design or for the observer gain design, were based on pole placement specifications. The state weighting matrix was intentionally designed in order to achieve no actuation in the frequency range nearby the ressonance ("flexible mode") of the plant.

Some special characteristics could be observed in the designed controller: in particular, a right-half-plane zero is present at the controller cross (upper/lower and v.v.) transfer functions, that characterize the multivariable nature of this controller. It is interesting to note that such a transfer function could hardly be synthesized by the use of classical techniques of control design.

The implementation of the multivariable controller was preceeded by several computer simulations studying the behaviour of the system under high frequency disturbance. The effectiveness of the controller could be put in evidence when the coupling terms at the transfer function were arbitrarilly eliminated.

The results can be summarized as follows:

i) when the original controller is used, although the plant presents high frequency oscillations, the controller outputs do not present such components, i.e., there is no high frequency actuation;

ii) when the cross transfer function terms are eliminated, the controller presents actuation at high frequencies; nevertheless, the plant vibration at such frequencies is not attenuated.

So we conclude that the multivariable nature of the control allows higher gains at high frequencies; in other words, no high-frequency actuation could be obtained not through low overall gain, but by the cancelation of "cross" and "direct" signals, due to multivariable control.

Finally, the controller was implemented and tested in a laboratory experimental set-up with good agreement of the results.

We conclude that the possibility of using higher overall gain (beginning from DC), when compared with conventional SISO controllers, without causing instabilities, was the most outstanding feature of this controller that could be observed during the experiments.

All the experiments showed no actuation of the controller at frequencies close to ressonance ("flexible mode") of the system, resulting in energy saving.

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