Analysis and Control of Damped Flexible Structures

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ABSTRACT

Spatially continuous flexible structures appear in diverse engineering applications, ranging from MEMS actuators and sensors on the small scale to cranes, robotic arms and even bridges and buildings on the large scale. Due to their light weight, flexible structures are also widely used in air and space systems. It should be kept in mind that flexible is a relative term, depending both on the excitation bandwidth and the accepted level of vibration. Higher performance (faster maneuvers, better accuracy) requires therefore acknowledging the flexibility in systems that could otherwise be considered as rigid.

Feedback control has two important tasks in flexible structure design: adding ”artificial rigidity” for tracking systems, and absorbing energy. A flexible, light weight, system with carefully designed controller can exhibit the same behavior as a rigid system with larger and heavier damping devices.

The control method used in this paper is Absolute Vibration Suppression (AVS). In physical terms, it is based on a traveling wave approach and not on approximated or modal models as most methods do. In mathematical terms the key point is deriving infinite dimension transfer functions. In a series of publications by the author, e.g. [1]-[2] these transfer functions, consisting of delays and low order rational terms, were used to design a dedicated control law (with boundary actuation) that stops the wave reflections, thus achieving absolute vibration suppression (AVS) in the system. This approach, which uses the physical properties of flexible structures, is in contrast with the one of generic mathematical control laws that in theory can be applied to all dynamic systems, regardless of their physical origin.

The classical models of flexible structures are energy conservative, and this is the basic assumption of the comprehensive modal theory where the notions of natural frequencies and modeshapes are central to the analysis of the time domain behavior. The same is true for the traveling wave approach. However, in practice, the free vibration decays with time due to the presence of damping, both at the supports, and internal throughout the structure. The latter poses serious theoretical problems. The transfer functions consist then of fractional order exponents [3], which represent non-pure time delays and describe the special manner of wave propagation in the system. This requires the extension of the AVS method and of standard dead time compensation algorithms to the fractional order case.

REFERENCES

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