Nonlinear Modeling and Control Design of Tension-only Elements in Adaptive Structures

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ABSTRACT

The introduction of *adaptivity* in structural engineering enables a way to build lightweight and sustainable and therefore save material in the construction sector by actively influencing the structure. Adaptive engineering structures guarantee their structural stability by combining sensors and actuators with a control unit. Therein, a smart control algorithm processes sensor signals to provide actuator inputs for compensating static and dynamic loads and ensuring a comfortable usage and a secure functioning of the structure.

Civil engineering structures often make use of tension-only elements, which are used as bracings for example. In case of pressure loads on such an element, it gets slack, (temporarily) loses its load bearing behavior and therefore its function in the structure [1]. A high pretension of these elements can prevent the state of slackness. However, if high pretension forces are implied, additional stress is put on the structure, which is not desirable due to the increased material and construction costs. This is contrary to our goal of a sustainable and lightweight construction.

In a modelling process the effect of tension-only elements needs to be addressed, which results in piecewise linear model equations. This impedes the usage of classical workflows, in which linear finite element models are extracted from any preferred tool (e.g. ANSYS) and reduced for control design purposes. The mechanical model of adaptive engineering structures, e.g. of high-rise buildings, shows typically a high dimensionality and possibly a high number of tension-only elements. This complexes the model und results in a loss of linearity excluding the application of many control concepts.

A further aspect is the installation of an actuator in a tension-only element. In general, active elements can expose different realizations of how they are included in the whole structure. Actuation principles we can think of are, among others, a parallel or serial setup, which are both useful for various types of implementation and usage [2]. Here, a setup with an actuator in series with a passive tension-only element is considered. Reasoned in the design of this active element, it is only possible to actuate in the tension direction. Furthermore, the element must keep up its function of an element under pretension to guarantee the whole structure's safety, even when the system is not under power. Therefore, a mechanical stop is installed and the actuator has a bounded range of motion. These nonlinearities are incorporated in the dynamic model of the structure.

The discussed aspects of modelling are illustrated by a numerical example of an adaptive structure. The results show a strong impact of the described nonlinearities on the structure's behavior compared to strictly linear modeling approaches.

REFERENCES

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