39th Solid Mechanics Conference
Zakopane, Poland, September 1–5, 2014

P028

ON REAL-TIME DISTRIBUTED ADAPTATION OF STRUCTURES SUBJECTED TO TRAVELLING LOADS

D. Pisarski

French National Institute for Research in Computer Science and Control, Grenoble, France

Institute of Fundamental Technological Research, Warsaw, Poland

1. The subject and the goals of the study

Problems of structures subjected to loads travelling with high velocity are of a special interest for practicing engineers. Numerous of analytical and numerical solutions are applied to solve the problems of transportation and robotic systems with a single or multi-point interactions such as train-track, vehicle-bridge or effector-guideway. These problems concern high vibration levels of both structures and travelling objects due to permanently increasing speed and load carrying capacity requirements.

The construction of new railway tracks or bridges with sufficiently higher load carrying capacity and ability to withstand dynamical stresses and strains is usually limited by costs. On the other hand, a static strengthening increases structure mass and often is restricted for technological reasons. To face undesired vibration effects a variety of control systems acting on both vehicle suspensions and structures have been proposed and put into practice. Active vehicle suspension systems are based on controlled rheological dampers that tend to improve the travelling comfort by keeping the passage trajectory as smooth and straight as possible [1]. For structural control, the objective is usually centered on a structure itself. Heavy and high power consumed force actuators are attached to a structure to stabilize it in the case of dangerous external excitations that occur, for instance, during earthquakes. A recent trend is to replace force actuators with semi-active rheological dampers. These solutions attract the engineers' interest due to significantly less power consumption. They are also safer in the case of a control system failure.

The use of semi-active supports for the structure subjected to a moving load was first proposed in [2]. By means of numerical simulations the authors demonstrated that for a wide range of travel velocity the switching damping strategies outperform standard passive solution. The idea was later extended in [3] and [4], where by introducing rigorous analysis and optimization techniques the authors concluded that even one switching action for each damper can provide very smooth load passages. The total deflection of the load trajectory from the straight line was reduced up to 50%.

The goal of this study is to design an efficient and easy for implementation feedback control system based on change of both damping and stiffness of structure supports. The system will be split into modules (often identified as "plug and play" tools). The functionality and incorporated computational procedures for every module will be the same. It will compute its optimal decision by using local state information and necessary information arriving from other controllers. The global time consuming optimization problem will be then divided into local problems of reduced size that can be solved on-line. A distributed control architecture is also convenient for system assembling and maintenance. In the case of failure, only the malfunctioning module needs to be replaced. In addition, a decentralization plays an important role for safety. Suppose a malfunction of the central computer computing the optimal decision for every controller. An incorrect signal is then sent to the whole control system that may drive the structure to dangerous states. In distributed control architecture this risk is reduced to local failures.

2. Research methodology

In the study, we consider the system as depicted in Fig. 1. The carrying structure or railway track is represented by one or two parallel spans. For the spans, the Euler-Bernoulli beam model is adapted.

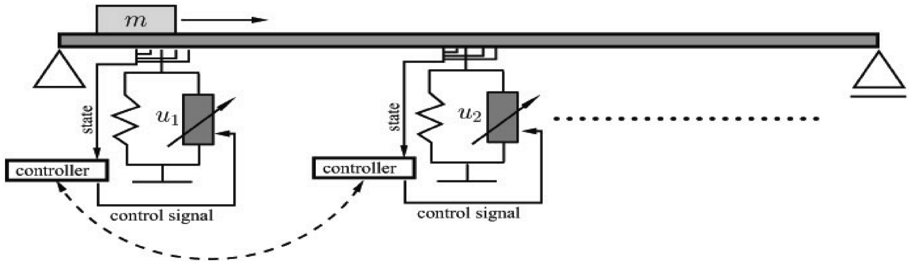

Fig. 1. A span supported by a distributed semi-active control architecture.

The beam is supported by a set of controlled supports (perceived as a set of modules). For control objective, we combine the smooth passage with reduced beam deflections. For control parameters we assume both damping and stiffness parameters. Eventually, the variable stiffness are meant to be approximately realized by relevant non-linear springs. Each of the supports is equipped with a controller that receives the information of its local state. It is also allowed to communicate with other controller or controllers under a relevant minimal communication topology (to be determined). Thus, the optimal controller decision is based on its local state and also on the information provided by the other controller (or controllers). The information arriving from one of the previous modules will be also triggering the controller to update his optimal decision. This must be done in advance, since the process of optimization takes some time and the optimal decision is supposed to be applied at the right time, i.e. when a load is passing the section corresponding to the controller. Therefore, at this stage two major problems are addressed. The first one is to find a proper controller communication topology taking into account performance, but also computational capabilities and simplicity in practical realization. The second one is to design a feedback structure for each of the controllers and a method that allows them to update the optimal decision in a reasonably short time. To solve these problems, analysis of controllability of distributed systems is performed and the methods of real-time optimization (based on the receding horizon control [5]) are applied. The analyzed model is represented by the following bilinear system of ODEs:

$$\dot{x} = A(t)x + \sum_{i=1}^{m} u_i B_i(t)x + F(t), \tag{1}$$

where x, u and F stands for the state, the set of control input and the travelling load excitation, respectively. The experimental validation of the proposed control method will be carried out by using the test stand operating in the Institute of Fundamental Technological Research.

References

1. Sh.J. Dyke, D. Giraldo (2002). Control of an elastic continuum when traversed by a moving oscillator, *Journal of Structural Control and Health Monitoring*, **14**, 197–217.
2. D. Pisarski, C. Bajer (2010). Semi-active control of 1D continuum vibrations under a travelling load, *Journal of Sound and Vibration*, **329**, 140–149.
3. D. Pisarski, C. Bajer (2010). Smart suspension system for linear guideways, *Journal of Intelligent and Robotic Systems*, **62**, 451–466.
4. C. Bajer, R. Bogacz (2000). Active control of beams under moving load, *Journal of Theoretical and Applied Mechanics*, **8**, 523–530.
5. Y. Wang, S. Boyd (2010). Fast Model Predictive Control Using Online Optimization, *IEEE Transactions on Control Systems Technology*, **18**, 267–278.