

Advances in Mechanical Systems Dynamics

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1. Introduction

Modern dynamics was established many centuries ago by Galileo and Newton before the beginning of the industrial era. Presently, we are in the presence of the fourth industrial revolution, and mechanical systems are increasingly integrated with electronic, electrical, and fluidic systems. This trend is present not only in the industrial environment, which will soon be characterized by the cyber-physical systems of industry 4.0 [1,2], but also in other environments like mobility, health and bio-engineering, food and natural resources, safety, and sustainable living. In this context, purely mechanical systems with a quasi-static behavior will become less common and the state-of-the-art will soon be represented by integrated mechanical systems, which need accurate dynamic models to predict their behavior. Therefore, mechanical systems dynamics is going to play an increasingly central role. Significant research efforts are needed to improve the identification of the mechanical properties of systems in order to develop models which take non-linearity into account, and to develop efficient simulation tools. This Special Issue aims at disseminating the latest research achievements, findings, and ideas in mechanical systems dynamics, with particular emphasis on the applications which are strongly integrated with other systems and require a multi-physical approach.

2. Advances in Mechanical Systems Dynamics

The papers collected in this Special Issue can be grouped into some topical areas of dynamics, as follows: Trajectory and motion planning, dynamic stability, vibration control and damping, control, modelling, and simulation. Most of them deal with multi-physical systems applications, including robotics, turbomachinery, vehicles, agricultural, and industrial machinery.

2.1. Trajectory and Motion Planning

Trajectory and motion planning are increasingly relevant in robotics and in other mechanical systems [3,4]. Indeed, the goal of achieving ever higher speeds is extending into all fields of mechanics. In order to preserve accuracy and repeatability, proper strategies should be adopted in order to generate trajectories that could be executed at high speed, while avoiding excessive motor accelerations and mechanical structure vibrations.

In Reference [5], a single leg platform for quadruped robots is designed in order to achieve high-speed locomotion. For this purpose, the foot-end trajectory for quadruped robots with a high-speed trot gait is proposed. The gait trajectory is planned for swing and stance phases. These phases are separately designed with position control and impedance control, while guaranteeing continuous and smooth transitions. Such an approach allows avoiding great rigid impact and achieving stable walking or running.

In Reference [6], a classification and a discussion of several approaches that adopt the concept of natural motion to enhance the energetic performance in robotic and mechatronic systems is presented.

In the first part of the paper, the physical requirements that a system has to fulfill in order to exploit the natural motion are identified. While in the second part, the approaches related to natural motion are classified by trajectory types, as follows: Given trajectory, optimized trajectory, free-vibration response, and periodic trajectory learning. In the end, the methods which are able to reduce energy consumption while preserving task flexibility are highlighted.

2.2. Dynamic Stability

Dynamic stability is a classic topic of dynamics that, presently, has important applications in many fields of engineering, including manned and unmanned aircraft [7,8], ground vehicles [9,10], and walking robots [11,12]. In recent years, there have been important research developments in the field of light vehicles for urban mobility, for example, electric scooters, Segways, electrical bicycles, three-wheeled vehicles, and motorcycles [13]. In the Special Issue there are two papers which address vehicle stability.

In the first paper [14], a three-wheeled vehicle with double front wheels and single rear wheel and an active tilting mechanism is studied. A comprehensive analysis including stability, obstacle avoidance, and energy management is carried out considering the effect of both mechanical and control parameters. Results show that the developed vehicle has good handling and stability properties and is more efficient than a standard car.

The second paper [15] deals with the low speed stability of a scooter-type motorcycle. This problem is closely related to urban mobility, since congested traffic conditions limit vehicle speed, generating stability problems that require the continuous effort of the rider to stabilize the vehicle. A theoretical model is developed and validated by means of road tests. The validated model is able to predict regions of low speed stability and will be used for developing a controller.

2.3. Vibration Control and Damping

In recent years the interest in vibration has increased, owing to the rapid development of vibration energy harvesting technologies [16]. However, vibrations are also a potential problem for any application that includes moving components [17]. Thus, control and damping of the dynamic response is a very relevant topic. In the Special Issue there are three papers which deal with vibration control and damping in three very different fields, as follows: Electric motors, turbines, and agricultural machines.

In Reference [18], the problem of prediction of vibrations in switched reluctance motors (SRMs) is tackled with a multi-physics approach. The comparison between the numerical and experimental data shows that the method is accurate. Therefore, it can be applied to the structural and control design optimization of SRMs.

In Reference [19], the vibrations of turbine blades are considered, while removing one the assumptions often employed, i.e., the bladed disc's rotation. The work contributes to a better understanding of the dynamics contributions to be considered when designing under-platform dampers.

In Reference [20], the dynamic behavior of a No-Till Coulter Assembly is analyzed, with a focus on the effect of magneto-rheological (MR) dampers, aimed at giving a consistent seeding depth. The comparison between the simulated and measured vertical dynamics shows good agreement with the numerical model developed. Therefore, the model can be used for the optimization of the MR dampers.

2.4. Control

Presently, more and more mechanical systems are being controlled, with the aim of adjusting their dynamics, e.g., pantograph/catenary [21], suspension bridges [22], gas turbines [23], motorcycles [24], etc. In this issue two challenging scenarios are considered. The first is related to laser communication, while the second is related to the control of flow separation in axial compressors. In the first paper [25], the design of a sliding mode controller to solve the nonlinear disturbance problem of a ground-based

laser communication turntable is discussed—indeed, the alignment of the platform is a key issue in this field. Experimental results on the pitch closed-loop behavior show a better performance of the proposed (chatter-free) controller when compared to the traditional proportional, integrative, derivative (PID) and existing sliding mode.

In the second paper [26], the flow separation in axial compressors is controlled by the unsteady (pressure) excitation, not only at the shredding vortex frequency (traditional method), but also at other frequencies, demonstrating the impact on the structure of shredding vortices.

2.5. Modelling and Simulation

Mechanisms, gears, and transmissions are still key elements of advanced industrial systems [27]. To improve the performance of the system, detailed models of machine elements, taking into account non-linearities or time-variant properties, are needed [28,29]. This Special Issue includes three papers that cover the modeling and simulation of machine elements. The first paper [30] investigates the dynamics of thin walled gears and takes into account time-variant properties due to gear meshing. The method of multiple scales [31] is adopted to solve the equations of motion in the frequency domain. This method requires shorter calculation times than direct time integration methods. The results presented in this paper are important for aeronautical applications.

The second paper [32] covers a variable compression ratio engine and presents a non-linear model which includes both mechanical and hydraulic equations, similar to the models adopted for studying vehicle suspensions and shock absorbers [33]. Results show that the proposed system can achieve a continuous variation in the compression ratio of an engine, with advantages in terms of efficiency and pollution.

The third paper [34] addresses the problem of the emergency extension of nose landing gear. An interesting combination of mechanism analysis methods and statistical methods for reliability analysis is presented. The most important failure factors of an existing mechanism for emergency extension are highlighted and a more reliable mechanism is designed.

3. Final Remarks

In summary, this Special Issue contains a series of interesting research works focused on advances in mechanical systems dynamics, covering a wide area of applications. This collection shows the actuality of this topic and sheds light on future developments.

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