



Robotics and Vibration Mechanics

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1. Robotics and Vibration Mechanics

Robotics and vibration mechanics are among the main research areas in mechanical engineering. Robotics includes the design, construction, control, operation, and trajectory planning of autonomous and automatic machines that can substitute or help humans in several tasks in manufacturing processes, dangerous situations, and even in the domestic environment. On the other hand, vibration mechanics investigates the dynamic effects that can arise when flexible mechanical systems are excited by an external time-varying disturbance, or set in motion with an initial input and allowed to vibrate freely.

The growing interest and development of lightweight robots and mechanisms have led to the study and investigation of several aspects of both robotic systems and mechanical vibrations strictly related between them. Indeed, flexibility may lead to undesired mechanical vibrations, especially when lightweight systems performing high-speed operations are considered [1]. Therefore, proper structural design, modelling, and control are required to correctly steer the system during operation.

Compliant mechanisms and robots are characterized by the bending of flexible members. The advantages of this kind of mechanism include, for instance, low weight, low friction, compactness, and reduced power consumption. On the other hand, challenges are mainly related to their nonlinear motion, complex modelling and control.

When dealing with compliant mechanisms, dynamic models become fundamental to predict not only the motion, but also forces and torques acting on the system and those required by the actuators. Several approaches for the dynamic modelling of flexible multibody systems have been developed over the years. Notable formulations include the Floating Frame of Reference [2], the Absolute Coordinate Formulation [3], the Absolute Nodal Coordinate Formulation [4], and the Equivalent Rigid-Link System [5–7].

Compliant mechanism design methods encompass finite element analysis, topology optimization, and pseudo-rigid-body model methods [8]. Design methods can include, for instance, the modal modification of a predefined mechanical system [9], the assignment of proper eigenfrequencies [10], as well as vibration absorption techniques [11]. A further approach that exploits the elastic behavior of a mechanism is the natural motion [12,13], which allows for energy saving in cyclic tasks by properly designing compliant elements [14], and by considering the free vibration response of the system [15].

When dealing with robotic systems and mechanisms in which flexibility cannot be neglected, control is certainly an important and challenging aspect, since a clever control strategy is needed to avoid potential vibration-induced issues [16,17]. Several control strategies have been developed over the years, for instance, adaptive control, feedforward control, model-based control, nonlinear control, optimal control, and PID, among others. However, the problem of control of flexible multibody systems is still an open and challenging field of investigation.

This Special Issue invited researchers to present recent advances and technologies in the fields of robotics and vibration mechanics. Suitable topics included, but were not limited to, the following: robotics and autonomous systems, mechanical vibrations and



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noise, kinematic and dynamic modeling of robotic systems, path and trajectory planning, automatic control systems, flexible multibody systems, collaborative robotics, design and optimization of robotic and mechatronic systems, mechanisms design, and manufacturing systems.

2. Special Issue

This Special Issue collects papers in open-access format on a broad number of aspects of robotics and vibration mechanics introduced above. The call for the Special Issue *Robotics and Vibration Mechanics* was open from 8 May 2020 to 27 November 2021, and received 13 manuscript, 9 of which were accepted for publication, with a 69% approval rate. In most of the papers, numerical simulations are corroborated by experimental results. These articles are described in the following in order of publication.

The paper in [18] analyzes the flexible multibody dynamics of a non-symmetric planar parallel manipulator with three degrees of freedom using the Floating Frame of Reference formulation. Numerical simulations are carried out to compare the Rayleigh–Ritz and the finite element approximations, and a sensitivity analysis is performed to investigate how to better increase the rigidity of the links.

The authors of [19] present a multi-criteria motion planning optimization strategy for combining smoothness and speed in collaborative robotics. Thanks to the variational formalism, optimal trajectories are tested with simulations and experiments, by keeping safety requirements for human–robot collaboration into account.

In [20], a vision-based model predictive control for a Schunk PowerCube serial robot is designed with a structured step-by-step procedure. The proposed control allows the robot to sense the environment and to be controlled with visual feedback in real-time. This approach can be suitable for multi-link flexible multibody systems, where joint angles are not sufficient to describe the state of the system due to the elasticity of the links.

The work in [21] investigates the influence of the approach direction on the repeatability of a real industrial robot, namely an ABB IRB 1200. High-speed cameras are used to measure the range of directional deviations and determine the repeatability of the robot end-effector.

The authors of [22] analyze the effects of end-effector compliance on impacts and collisions in robotic teleoperation. An elastic system based on a bi-stable mechanism is proposed to decouple the inertia of the tool from the inertia of the robot and mitigate the effects of potential impacts. Numerical simulations show the effectiveness of the proposed approach.

A non-linear control strategy for flexible-link mechanisms is illustrated in [23]. The described controller is model-free and, therefore, does not require the measurement of the elastic deformation of the mechanism. The closed-loop stability of the control approach is evaluated with the Lyapunov theory, and its performance is shown with numerical simulations on a four-bar flexible robotic system.

The paper in [24] reports the design, modelling and experimental evaluation of an amphibious robot that can move both on land and water thanks to a vibration-based mechanism, composed of a micro-DC motor with eccentric mass. Different excitation frequencies are tested on the prototype of the robot, and a good agreement between the numerical model and experimental results is found.

In [25], the authors present a mathematical model for a Formula Student car to investigate the performance of a hydraulically interconnected suspension system with respect to a traditional one. The motion response of the vehicle is tested in simulation using a dynamic model with seven degrees of freedom for each of the two suspension architectures.

The authors of the paper [26] analyze the performance of a reconfigurable spherical parallel mechanism dedicated to craniotomy surgery. Motion capture and force experiments are performed by a neurosurgeon to analyze the kinematic and force interaction between the robot tool and the cranium in surgery with highly real conditions.

3. Final Remarks

This Special Issue collects valuable articles on the topics of robotics and vibration mechanics, spanning several theoretical aspects and applications. In most of the papers collected in the Special Issue, both numerical and experimental results are presented. This Special Issue *Robotics and Vibration Mechanics* demonstrates the importance and actuality of these topics and provides hints and suggestions for possible future developments.

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