PhD POSITION

«OPTIMAL DESIGN OF LOW ENERGY CONSUMPTION ROBOTS»

Scientific field and context

Global energy consumption has increased by a factor of 26.5 per capita over the past two centuries [1]. Therefore, the EU and a number of non-governmental organizations have set themselves the goal in the coming years to increase the efficiency of the resources used industry. With growing concerns about this excessive consumption, new optimal methods of machine design need to be developed. Obviously, more energy-efficient robots will immediately lead to significant reductions in industrial energy consumption. In robot design, the reduction of energy consumption can be achieved in different ways. However, within the framework of this doctoral thesis, the methods of reducing the energy consumption of robots based only on the optimal redistribution of the mobile masses and the control of the movement will be considered. In low-speed operating mode, an effective solution is the balancing of gravitational forces, which leads to the minimization of input torques [4]-[9]. However, with the increase in the accelerations of the mobile elements of robots, the forces of inertia become important and the compensation of the gravitational forces in dynamic mode cannot be optimal. In this context, it would be necessary to find such a distribution of the mobile masses or shapes of elements, which makes it possible to minimize the input torques in dynamic mode [10]-[18]. It is also important to note that the balancing of the robots, which reduces the vibrations on the frame often leads to the increase of the moving masses and consequently to the increase of input torques. From this point of view, a compromise is possible to find a partial solution allowing these two objectives to be achieved simultaneously.

Objectives and scientific problems. The aim of the proposed research project is to develop a new technique to reduce the energy consumption of robots. To achieve the goal, a symbiosis of different approaches should be used: *a*) The development of a new robot design or its improvement by modifying the initial structure. Therefore, this thesis will address various points. First, synthesis of mechanisms will have to be carried out in order to find one or more optimal structures, which will make it possible to generate the reduced input torques. Once this has been achieved, it will be necessary to express the geometric, kinematic and dynamic models, which will be used for the optimal design and control of the system. The optimal design problem will then be posed as a multi-criteria optimization problem for which constraints and objectives will have to be set, mainly in terms of the dynamic capacity of the system with the simultaneous study of the efforts necessary for the cancellation (or reduction) of the reactions on the robot's frame. *b*) Optimization of the trajectory of the robot's center of gravity in order to reduce its potential energy; *c*) optimal redistribution of moving masses; *d*) study and optimization of robot motion laws. The influence of friction forces and backlashes in the joints on the energy consumption of robots can also be included in the problems considered. Numerical simulations and experimental tests will illustrate the effectiveness of the proposed solutions.

Start date and duration

The doctoral thesis will begin before 2024 for a period of 36 months.

Remuneration

26,4 k€ annual gross salary.

Place of work

The PhD student will carry out his research at the INSA Rennes (building 11, office 133), with possible displacements to Nantes. He will benefit from the support of the LS2N and the INSA Rennes.

Required skills

Candidates must have good skills in mechanics of linkages and robots. It is also desirable that they will be familiar with the Adams and Catia or SolidWorks software, as well as Matlab.

Deadlines

The candidate must submit his application on the «Thèse Bretagne Loire» website: https://theses.doctorat-bretagneloire.fr/spi.bzh

before **Friday, April 7, 2023**

Applicants must provide a CV, cover letter, master's grades and ranking as well as recommendations (if you have them).

Please send a copy of the application file to the address: **vigen.arakelyan@insa-rennes.fr**

Ranking of successful applications: **May 5, 2023**

The auditions will be organized between **May 16 and May 26, 2023** (for foreign candidates, these auditions may take place via videoconference). The duration of the interview is 30 min (15 min presentation and 15 min questions).

Supervisor

Vigen ARAKELYAN (100%)

Full Professor, Researcher in the teams ROMAS (LS2N) and MECAPROCE (INSA Rennes)

If you are interested, please contact:

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References

[1] C. Wilson, A. Grubler , Lessons from the history of technological change for clean energy scenarios and policies, Natura Resources Forum, 35(3), pp. 165–184 (2011).

[2] CM Gosselin, Adaptive Robotic Mechanical Systems: A Design Paradigm, ASME Journal of Mech. Des., 128(1), p. 192–198 (2006).

[3] M. Arsenault and CM Gosselin, Static balancing of Tensegrity mechanisms, ASME Trans. J.Mech. Design , 129(3), p. 295–300 (2007).

[4] CM Gosselin, Gravity Compensation, Static balancing and dynamic balancing of parallel mechanisms. In: Wang, L., Xi, J. (eds.) Smart Devices and Machines for Advanced Manufacturing. Springer, London, pp. 27-48 (2008).

[5] V. Arakelian . Gravity compensation in robotics. Advanced Robotics, 30(2), p. 79-96 (2016).

[6] A. Alamdari , R. Haghighi , V. Krovi . Gravity-balancing of elastic articulated-cable leg-orthosis emulator author links open overlay pane. Mechanism and Machine Theory, Volume 131, January, Pages 351-370 (2019).

[7] VL Nguyen. A design approach for gravity compensators using planar four-bar mechanisms and a linear spring. Mechanism and Machine Theory, Volume 172, June 2022, 104770 (2022).

[8] V. Arakelian (ed.), Gravity compensation in robotics, Series: Mechanism and Machine Sciences, Springer Nature Switzerland, 281p. (2022).

[9] C.-H. Kuo , Y.-X. Wu. Perfect static balancing using Cardan-gear spring mechanisms. Mechanism and Machine Theory, Volume 181, March, 105229 (2023).

[10] R.-C. Soong, Minimization of the Driving Torque of Full Force Balanced Four-bar Linkages, Journal of Kao Yuan Institute of Technology, pp. 591-594 (2001).

[11] H. Chaudhary, Balancing of four-bar linkages using maximum recursive dynamic algorithm, Mech. and Mach. Theory, 42, pp.216–232 (2007).

[12] C. Baradat , V. Arakelian , S. Briot , S. Guegan , Design and prototyping of a new balancing mechanism for spatial parallel manipulators, ASME J. Mech. Of the. 130(7), (2008).

[13] S. Briot , V. Arakelian , S. Guegan, S., PAMINSA: A new family of partially decoupled parallel manipulators. Mech. and Mach. Theory, 44(2), pp. 425-444 (2009).

[14] V. Arakelian , J.-P. Le Baron, P. Mottu , Torque minimization of the 2-DOF serial manipulators based on minimum energy consideration and optimum mass redistribution, Mechatronics, 21(1), pp. 310-314 (2011).

[15] C. Cho, W. Lee, J. Lee, S. Kang, S., A 2-dof gravity compensator with bevel gears, J. Mech. Science. Technology. 26(9), p. 2913–2919 (2012).

[16] V. Gupta, H. Chaudhary, SK Saha , Dynamics and actuating torque optimization of planar robots," Journal of Mechanical Science and Technology, 29(7), pp. 2699–2704 (2015).

[17] V. Arakelian , S. Briot , Balancing of linkages and robot manipulators. Advanced methods with illustrative examples. Springer, Switzerland, 308p. (2015).

[18] V. Arakelian , J.-P. Le Baron, M. Mkrtchyan , Design of Scotch yoke mechanisms with improved driving dynamics. Proceedings of the Institution of Mechanical Engineers, Part K: Journal of Multi-body Dynamics, Vol. 230, No. 4, pp. 379-386 (2016).