**DESIGN OF BALANCED MANIPULATORS WITH REDUCED CENTER OF MASS ACCELERATION**

Many industrial manipulators face the problem of frame vibrations during high-speed motion. Such a vibration can result from a number of conditions, acting alone or in combination. One of the main reasons is the unbalanced inertia forces leading to the increase of shaking force and shaking moment. It is known that a mechanical system with unbalance shaking force and shaking moment transmits substantial vibration to the frame. Thus, a primary objective of the balancing is to cancel or reduce the variable dynamic loads transmitted to the frame and surrounding structures. The balancing of manipulators is generally can be achieved in two steps: i) the cancellation (or reduction) of the shaking force and ii) the cancellation (or reduction) of the shaking moment.

One of the most simple and easily practicable methods is the balancing of manipulators by mass redistribution in order to keep the total centre of mass of moving links stationary. It is obvious that the adding of the supplementary mass due to the counterweights is not desirable because it leads to the increase of the total mass, the overall size of the robot-manipulator and the efforts in joints. That is why in many designs of industrial robots (for example, KUKA R360, PUMA 200), the masses of the motors are often used as counterweights. However, a wide application of this type of balancing is rather limited.

Different approaches have been developed in order to balance the shaking force by adding auxiliary structures. The aim is the same: to keep the total centre of mass of moving links stationary. However, in this case, the balancing is activated not by redistribution of the masses of the initial mechanism but through an auxiliary structure. The parallelogram and the pantograph have been used as auxiliary structures. However, such a balancing can be reached by creating relatively complex mechanical system and by an unavoidable increase of manipulator’s sizes.

The nature of the proposed research project is based on the optimal control of the robot-manipulator centre of masses. The aim of such a balancing consists in the fact that the manipulator is controlled by planning the displacements of the total mass centre of moving links. The trajectories of the total mass centre of moving links are defined as straight lines and are parameterized with “bang-bang” motion profiles. Such a control approach allows the reduction of the maximal value of the centre of mass acceleration and, consequently, leads to the reduction in the shaking force. It should be mentioned that such a solution is also very favourable for reduction of input torques and shaking moment because it is carried out without adding counterweights. Such an approach seems very promising.

It is well known that after shaking force balancing, the shaking moment applied on the base is constant relative to any point, i.e. for a given position of the manipulator it has the same value for any point of the base. Taking into account this property, in the present project,
the shaking balancing of designed manipulators will be carried out by adding an inertia flywheel rotating with a prescribed angular velocity.

The proposed design concept will be validated via demonstrators. The motion control system will include robust high precision control based on feedback linearization.

Related recent publications by members of research team:


Length of PhD student Position: 36 months

Contacts:

Prof. Vigen ARAKELYAN or Prof. Jean-Paul LE BARON  
Mail: vigen.arakelyan@insa-rennes.fr Mail: jean-paul.le-baron@insa-rennes.fr

Address:

Department of Mechanical and Control Systems Engineering  
I.N.S.A. Rennes, 20 av. des Buttes de Coësmes  
CS 70839, F-35708 Rennes  
France