Robot identification for dynamic simulation

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Robotized laser welding is an application, which requires high speed combined with high precision. Realistic Dynamic Simulations combined with Off-line Programming, significantly enhances the a priori prediction of the weldability of a specific product. Obviously, realistic dynamic simulations require realistic models of the robot and controller.

A 3DOF robot model has been formulated which includes lumped inertia parameters, stiffness parameters of the gravity compensation spring and a -three parameter- friction model to describe joint friction. The equations of motion are expressed in the vector of generalized coordinates \( q \) and the vector of model parameters \( p \):

\[
\ddot{z} = M(q, p)\ddot{q} + C(q, \dot{q}, p)\dot{q} + g(q, p)
\]

where \( M(q, p) \) is the reduced mass matrix, \( C(q, \dot{q}, p) \) represents the Coriolis and the centrifugal forces as well as the friction model, \( g(q, p) \) is the vector which includes stiffness properties and external nodal forces, including gravity, and the driving torques are expressed by \( \ddot{z} \). The model parameters \( p \) are estimated using experimental parameter identification. The set of model parameters is found using a linear least squares method. This linear least squares method requires that the robot dynamic model is rewritten in a parameter linear form:

\[
\ddot{z} = \Phi(q, \dot{q}, \ddot{q}) p
\]

where \( \Phi(q, \dot{q}, \ddot{q}) \) is known as the regression matrix. The quality of the least squares fit depends strongly on the condition of the regression matrix. Using excitation trajectories \( (q, \dot{q}, \ddot{q}) \) consisting of a Fourier series with 5 frequencies, this condition can be manipulated by choosing the phase and amplitude. Non-linear optimization techniques are used to find the best phase and amplitude combination while obeying motion constraints. The simulations are performed using SPACAR [1] and MATLAB.

Parameter estimation for a 3DOF model has been performed. The torques are obtained by measuring the servo currents and transforming them to joint torques. The trajectories are programmed in the robot control software. All experiments are done without modifications to the original industrial robot.

Simulation of the 3DOF robot model shows good agreement with the experimental results. Friction plays an important role in the dynamics of an industrial robot. The goal is a realistic 6DOF robot model, which enables the accurate and realistic simulations needed with off-line programming for laser welding.

Reference