On the Dynamic Stability Analysis for Compliant Gripper

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Abstract

The compliant grippers require special attention regarding their design, in order to improve the positioning accuracy. We have analyzed the dynamic stability conditions when a compliant self-centring gripper is actuated with electric stepper motor. A virtual instrument was designed to control the values of point coordinates along the imposed planar trajectory.

Keywords
Virtual instrument, transfer function, dynamic stability.

Introduction

From the classic point of view, we may design a grasping mechanism by using the analysis and synthesis methods where kinematic and dimensional parameters of joints and elements are the main parts of computation. Across the synthesis process for instance, we have to assume an imposed number of points along the trajectory and the element length is determined [1]. In such a case we do not take into account the gap between elements inside a joint as well as the friction forces, so that important errors may occur when the displacements have very low values.

During the last years, the mechatronic system development pointed out the advantages of compliant mechanisms [2], so that we may use them for high accuracy positioning. The compliant mechanisms may follow different trajectories of an element point, by using different motion control algorithms, which is a very important feature. On the other side, the disadvantage consists in some critical errors that appear during the dynamic regime computation due to the axis position movement. This is the reason why we have to impose a dynamic structure absolutely simply, in order to improving the control only by analyzing the final element kinematic parameters.

The paper concerns with the study of the accuracy positioning control of a compliant gripper with elastic joints. During the working period, it may occur some unpredictable errors generated even by the material properties. Because of the imposition of angular dimensions between elements, after the kinematic synthesis, we have applied the laser welding to the compliant joint couple. Therefore, the elastic properties were modified and some supplementary errors influence the positioning.

We aim to control the movement starting from the active surface of the gripper, paying attention to the contact points with the object. The transfer function of the system point out the stability of the system.

The actuator control system

In order to study the positioning accuracy of compliant grasping mechanism, we have started from the classical mechanism synthesis, by imposing a number of nine points across the trajectory of active surface for the grasping mechanism with the dimensional model presented in Fig. 1.[3] The dimensional constraint were determined after the synthesis, so the angle values are very well known for the entire model. Using an orthogonal coordinate system, we may establish the coordinates of point along the planar trajectory of a contact point between the object and the active surface of the gripper. The actuation is made by using an electrical stepper motor with four electrical phases, which may be controlled whether we compute an affordable LABVIEW virtual instrument.

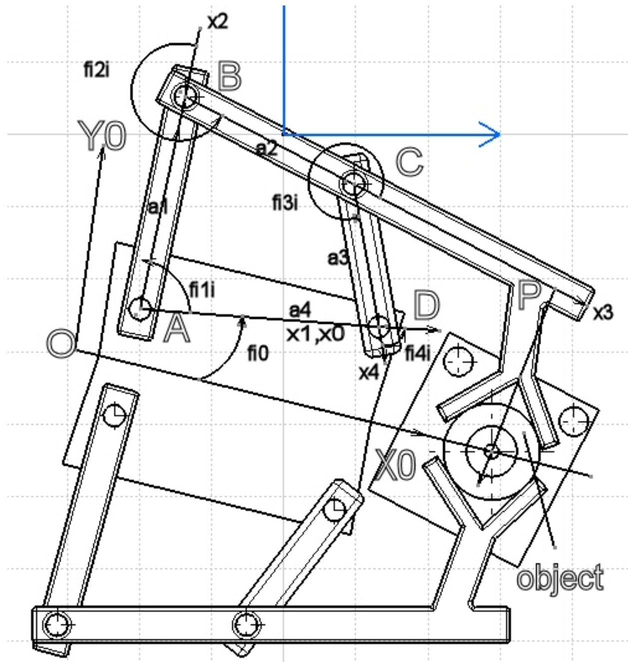

Fig. 1. The model of the compliant gripper.

The software application (Fig. 2., Fig. 3.) was designed in order to control the movement of compliant gripper active surface following complex trajectories in Cartesian coordinate systems.

At the beginning, the virtual instrument has to identify the axes attached to a planar vector. The imposed trajectory is defined by a numerical string of planar points having the X-Y values of coordinates. The spline interpolation will be used in order to find the point series the active surface of the gripper should pass through. The control could be extended for speed and acceleration values. The position will be set in absolute mode or in the relative one, depending on which criteria are required for initial and final point of movement to be set. This is an important condition whether we aim the trajectory to be a closed loop.

The next step is to set the correct value for the parameter named 'Requested Time Interval', meaning the time delay needed for a sequence of two points to get around. This means the time set for electrical motor command and it is on direct dependency with the parameter time of the PID controller. Finally, we have to compute the entire time interval value as a function of total point number set for trajectory definition and their corresponding coordinate values.

Because of limited memory dimension, all these values specified above will be written and read sequentially specifying the total number of points for one read/write operation. For each stage of this operation, it is necessary to verify whether the buffer capacity was overloaded or not. We have set the number of point at 300 for the movement parameters. The Front Panel has a Stop control, meaning a False or True operation in order to finish the motion.

The final step of the motion has to be done within a deceleration phase without modifying the elasticity of the joint.

The dynamic control system

The system stability was studied following the dynamic conditions regarding the technical characteristic values: actuator couple and actuator electrical and mechanical characteristic constants; the value of resistant torque that occurs when the object should be moved over the planar surface, including the friction force and elastic forces of the joints [4].

$$H(s)=\frac{\theta_m(s)}{U_\alpha(s)}=\frac{M_m\left[s^2\left(L_{\alpha\alpha}L_{\beta\beta}-L_{\alpha\beta}^2\right)+s\left(L_{\alpha\alpha}R_\beta+L_{\beta\beta}R_\alpha\right)+R_\alpha R_\beta\right]}{sU_\alpha\left(D_r+J_{red}s\right)\left(R_\beta+L_{\beta\beta}s\right)} \quad \textbf{(1)}$$

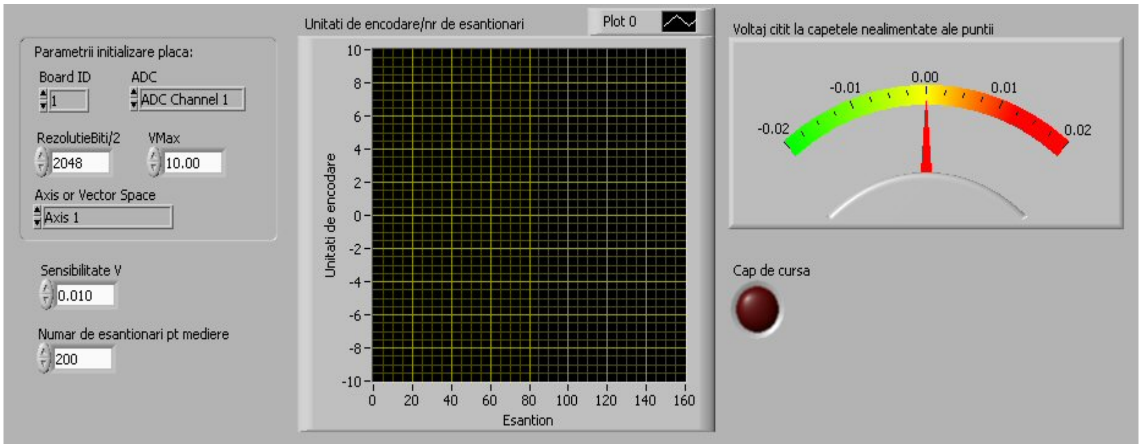

Fig. 2. The Frontal Panel of the virtual Instrument.

The transfer function for the system is given by the equation below, if we take into account the mathematical differential equation system of the electrical motor and of the compliant self-centring gripper too.

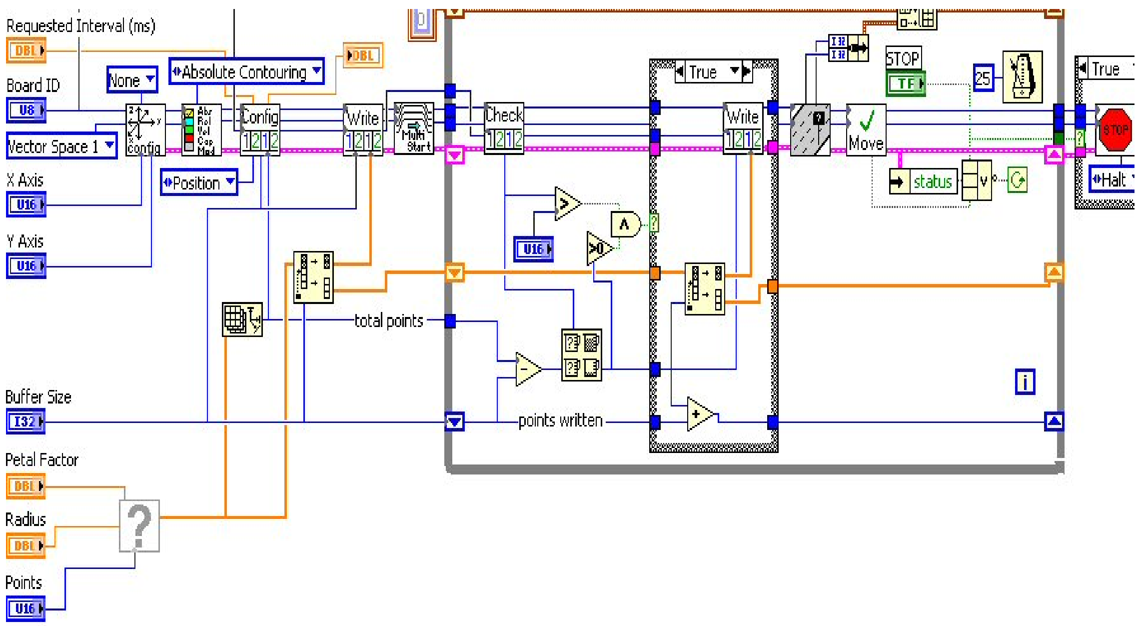

Fig. 3. The diagram of the virtual instrument.

In the equation above the following notation were used: θ_m - angular displacement of the electrical motor rod; U_α - the electrical tension for the first electrical phase; M_m – the actuation couple; $L_{\alpha\alpha}$ - the own inductivity of the first electrical phase; $L_{\beta\beta}$ - the own inductivity of the second electrical phase; $L_{\alpha\beta}$ - the mutual inductivity between the two supplied electrical phases; R_α - the electrical resistance of the first supplied electrical phase; R_β - the electrical resistance of the second supplied electrical phase; D_r – the viscous friction coefficient; J_{red} – the masses inertial coefficient of the entire system and computed in relation with the electrical motor rod. We have computed the transfer function coefficients, so the dynamic stability may be studied by applying the Bode criteria. The results are presented in Fig. 4., so that we may infer a good dynamic stability at the beginning of the movement. At the end of the movement, some improvements are required, due to the elastic characteristics and some other error sources.

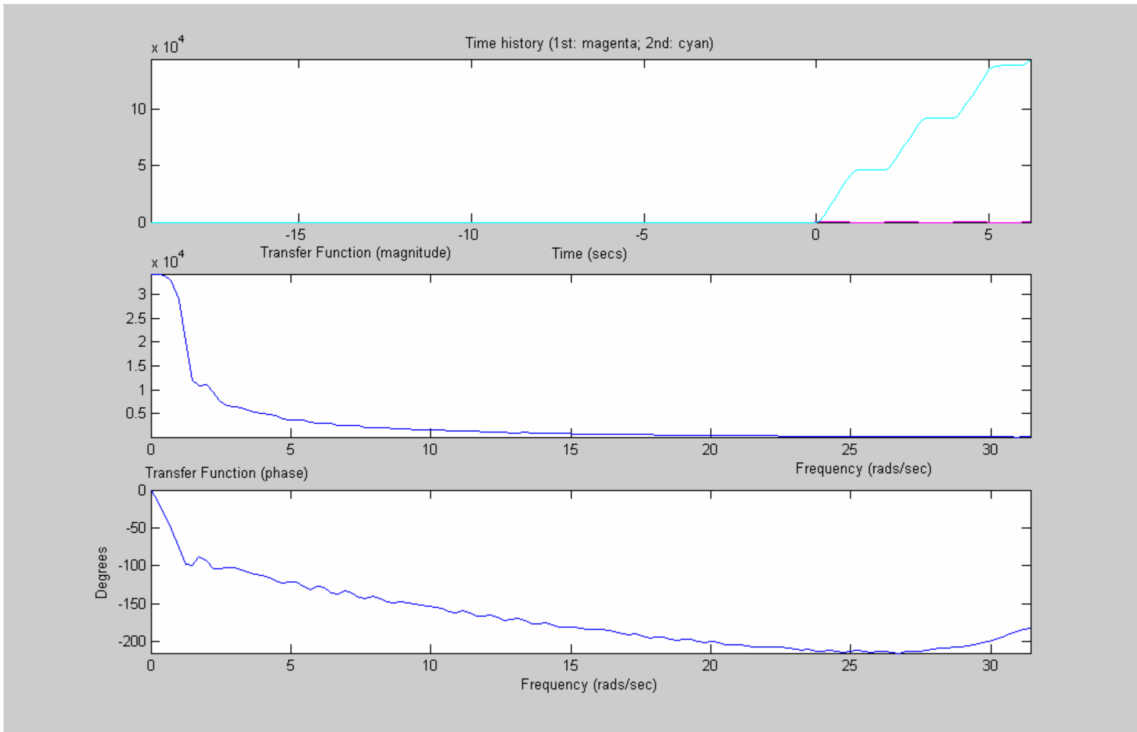

Fig. 4. The Bode criteria results for dynamic stability.

Conclusions

The dynamic phase conditions of the compliant mechanisms require very important improvements, because of the increasing positioning accuracy. Moreover, the self-centring gripper implies some initial constraints resulting from synthesis impositions. The control system, which has to be very well designed, has the main role during the working period, especially for choosing the correct trajectory points with adequate speed values. The errors caused by some unpredictable reasons should be removed during the last phase of the movement, when the speed and acceleration are very low.

As future work we will concern with the improving method for controlling the speed and acceleration in the same time with the trajectory. The real position during the movement will be taken from a sensor on the active surface of the finger.

References

[1]. Simionescu, I., Moise, V., Spanu, A. The Grasping Precision and Stability of Cylindrical Object in Self-Centering Grippers. Eight World Congress on the Theory of Machines and Mechanisms, Prague, Czechoslovakia, 1991.

[2]. Noveanu, S. Contributii privind studiul mecanismelor compliante specifice sistemelor mecatronice. Ph.D. Thesis, Technic University Cluj-Napoca, Romania, 2009.

[3]. Spanu, A., Besnea, D., Bacescu, D., Avram, M. Design Method for Self-Centering Grasping Mechanism. Annals of DAAAM for 2010 Proceedings Of The 21 ST International DAAAM Symposium Inteligent Manufacturing Automation Focus on Interdisciplinary Solutions, Zadar, Croatia, 20-23 October 2010.

[4]. Besnea D., Perfectionarea instalatiilor de prelucrare cu laser comandate numeric, teza doctorat, 2005