Robust H∝ Controller of a nonlinear unstable system: Robotics wrist

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***Abstract*— The paper presents a new multi-controllers approach with H∝ control applied to control a manipulator robot wrist (Staubli RX-90). A brief description of process and linear mathematical modeling of the process. Principle of multi-controllers approach of control is briefly presented. Our new proposals concerning the type of the controllers used in the multi-controller approach of control and which are one controller based on H∝ control for nonlinear system and linear local models around each operating points. The principal of H∝ control has been described and finally the simulation results obtained approve the efficiency of our design control followed by a conclusion and some perspectives for future work.**

Keywords—Modeling, Manipulateur robot, H∝ Control, multi-model approach.

I. INTRODUCTION

Precise, optimal and robust control of manipulators arm in the face of uncertainties and variations in their environments is a prerequisite to feasible application of robot manipulators to complex handling and assembly problems in industry and space [1]. An important step toward achieving such control can be taken by providing manipulator hands with sensors that provide information about the progress of interactions with the environment. But more important is the lack of adequate controller architectures and computing techniques needed to take advantage of such sensory information, where it available.

Different architectures and techniques are used to control the manipulator arms [1], like multi-controller approach developed by Narandra & balakrishnan [2] base in RST controller or fuzzy controller with frank switching system and fuzzy switching system [3].

Other approach of control used same approach with PID controller, Fractional order PID controller and PSO-PID controller [4-6]. Other approach in litterateur, used nonlinear controller [5], adaptive controller [6].

The mechanical design of the manipulator arm has an influence on the choice of control type. The physical process (robot arm) behavior has generally many non-linearity [5] that are not taken into account in the modeling process. In the each operating point (equilibrium point) of the physical process we can develop a local linear model. In this work we used multi-model approach [2].

Then the objective of this approach [1] is to control the process in operational space using the local information [2][3].

We have proposed same modification in this approach and the diagram block of the multi-controllers approach modified is represented as follows:

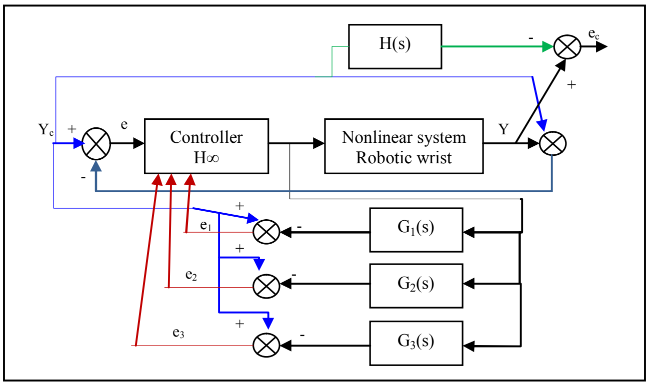

Fig.1. Structure of multi-model approach of control.

In our work, we have chosen the use one optimal H∝ controller works in all in operational space with three linear local models around each operating point.

II. PROCESSUS MODELING

The manipulator Stâubli Robot Rx-90 has coupling between axis 5 and 6. The actuators are brushless motors and the engine control uses the rotor position to magnetic flux rotate to achieve desired torque value and generally this motor as a DC motor behave[5]. Our process corresponds to a robot wrist (axis 6) can be represented by the following figure:

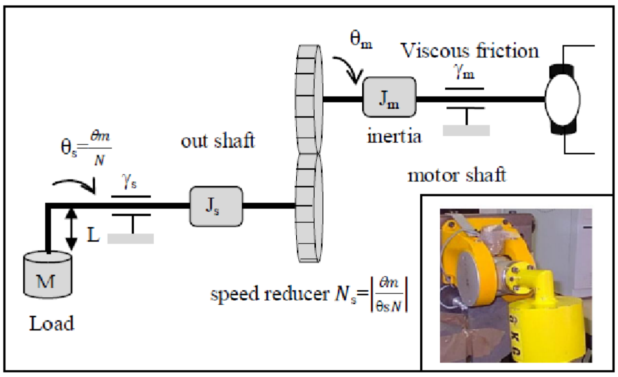

Fig.2. Process (Robot wrist) model.

frequencies, which means a high disturbance at low frequencies (the steady state).

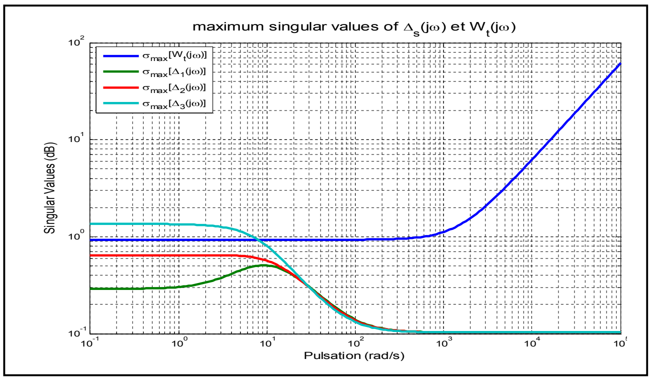

Fig.8. The maximum singular values of the system uncertainties $\Delta_s(j\omega)$ and of the stability specification $W_t(j\omega)$

From Fig. 8 it is possible to determine the transfer function of $W_t(s)$ by identification, one obtains:

$$W_t(s) = 0{,}93\,\frac{(1+6{,}667.10^{-5}s)}{(1+0{,}5.10^{-6}s)} \quad (36)$$

To guarantee the stability of the system perturbed by the H_∞ controller, the following robust stability condition must first be ensured [16-17] and from the relation (32) we can write:

$$\bar{\sigma}[T(s).W_t(s)] < 1 \quad (37)$$

Where it comes from: $\bar{\sigma}[T(s)] < \bar{\sigma}[W_t(s)]^{-1}$ (38)

Thus, in order to ensure the performance robustness, i.e. to satisfy the desired performances, a gentle response without overshoot, zero steady-state and an acceptable settling time, for the perturbed system in closed loop, it is necessary to guarantee the following performance robustness condition, [16-17]:

$$\bar{\sigma}[S(s).W_p(s)] < 1 \text{ or } \bar{\sigma}[S(s)] < \bar{\sigma}[W_p(s)]^{-1} \quad (39)$$

Where: W_p is a weighting function chosen to satisfy the requirements of the previous desired performance specifications, see Fig. 9, there is also a high gain in low frequencies, integrator action, therefore we choose the weighting function of the following form:

$$W_p(s) = 0{,}6\,\frac{(1+1{,}165.10^{-3}s)}{(5.10^{-6}+1{,}165.10^{-3}s)} \quad (40)$$

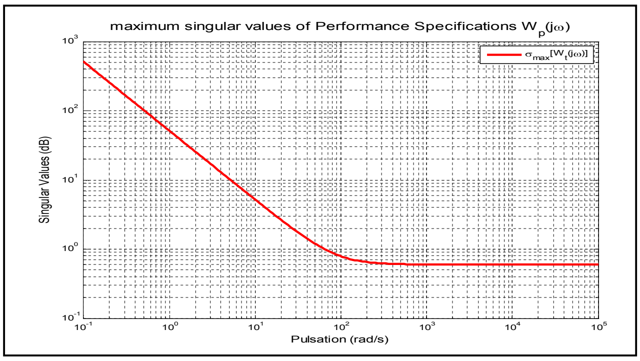

Fig.9. The maximum singular values of the Performance specifications $W_p(j\omega)$

After all, the robustness conditions for robotics wrist are represented in Fig. 10:

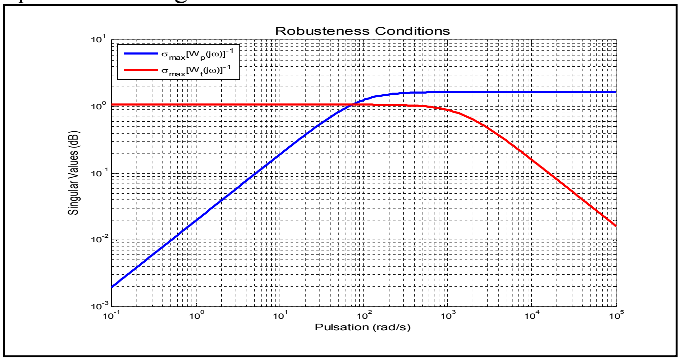

Fig.10. Robustness Conditions

According to Fig. 11, it can be said that the stability and performances robustness conditions are guaranteed (38) and (39) respectively.

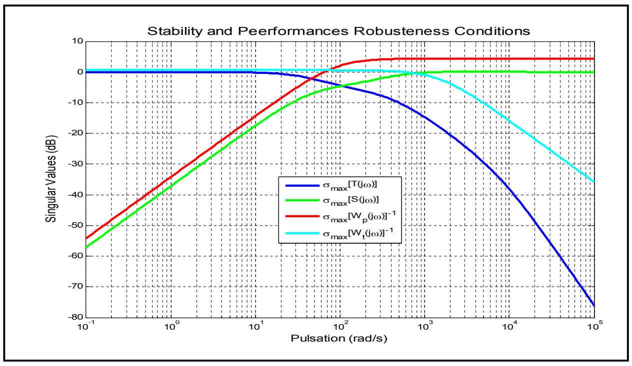

Fig.11. Singular Values of the Stability and Performances Robustness Conditions

In the following, the results are illustrated in the time domain. By applying a sinusoidal signal to the input of the closed-loop control system:

$$y_c = \left(\frac{\pi}{3}\right)\sin(5.t) \quad (41)$$

Where the sampling period is defined T = 0,001 sec .

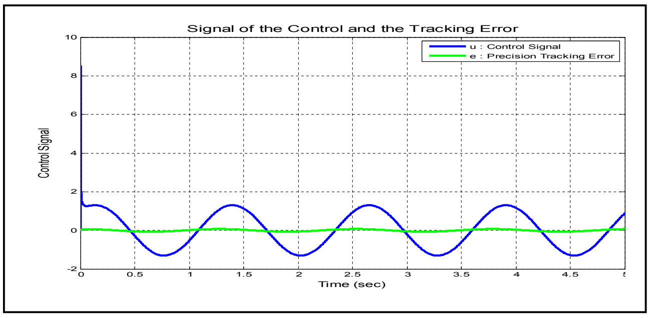

Fig.12. Signal of the Control and Tracking Error

In the figure above, a high precision tracking performance with a minimization of the energy is observed. The following figures illustrate the temporal response of the closed loop controlled system for the nominal and perturbed operating regimes.

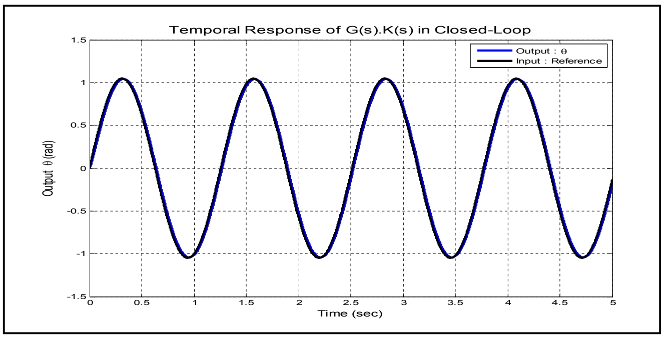

Fig.13. Temporal response of the controlled closed loop nominal system

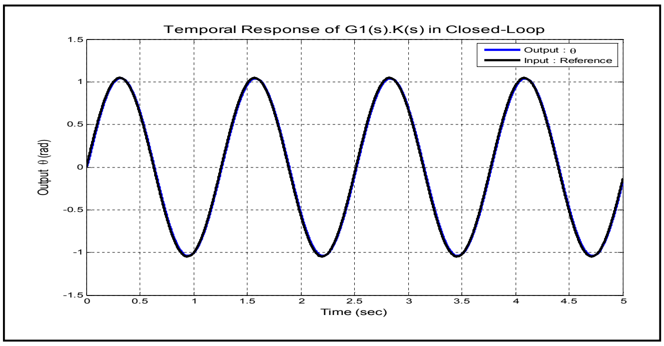

Fig.14. Temporal response of the controlled closed loop Perturbed system with first operating point

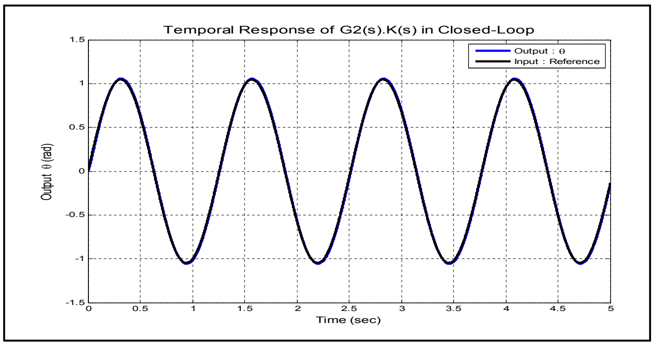

Fig.15. Temporal response of the controlled closed loop Perturbed system with second operating point

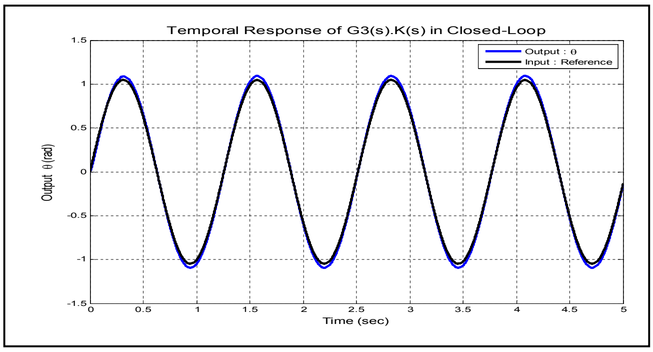

Fig.16. Temporal response of the controlled closed loop Perturbed system with third operating point

We can observe with obtained results illustrated in Fig.13 at Fig-16, the controller H∝ can be powerfully control nonlinear system and all locals linear models in the same time. We can observed too the high robustness and precision of our controller.

V. Conclusion

In this work, we have presented the modeling of nonlinear process (robotics wrist of RX90 Stâubli Robot). After that the local linear model near each considered operating points has been calculated. We have described the H∝ controller with our new design control of multi-control approach. Simulation we noted that the obtained results approve the high robustness and precision of our controller and design control approach. The results obtained allow concluding that we can control nonlinear system with one robust controller and this controller give good results in local linear model obtained around each operating points. Finally we will study at the future work other robust control approach with optimization with algorithm inspired in biologic like (PSO, GA,..).

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