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Effect of Viscous Friction Coefficient Variation on Robot's Joint PID Control

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Abstract

Friction is the example of a complex result of an interaction between two contacting surfaces. The friction, also can be static models which depend only on the relative speed of interacting surface. Friction can be affected by other factors. This paper investigates the effects of friction and viscosity on the robot arm. Different values of the friction coefficient were tested with a DC motor robot joint. The stability and output performance were tested to determine the best performance of the robot in the presence of the friction.

Keywords: *Robot Arm, Friction, Viscosity, PID, Stability.*

1. Introduction

Friction is found in all mechanical systems to some degree. It can be explained as tangential reaction force interacting between two surfaces. This is considered as a nonlinear occurrence and it depends physically on contact geometry, topology, materials properties, relative velocity, lubricant, etc. [1]. In this research paper, friction has been studied using experiments on an industrial robot. The only reason for interest in friction of manipulator joints is the need to make friction models for control purposes [2], provided that accurate friction modeling can improve the overall performance of the manipulator with respect to accuracy and control stability. Wearing down process of mechanical systems can be clearly related to friction [3]. Friction modeling is also critical for robot condition monitoring and fault detection. A friction modeling which is synced with real experiments is needed to maintain successful simulation, design and evaluation.This research paper studies the friction and its impact on the robot arm according to five samples having different friction values. The responses were firstly measured without the PID controller. Consequently, the system was found unstable according to all friction value. It is found that when using the PID controller, the system becomes more stable especially when the friction values are increased. The proper selection of the arm robot friction value is critical to measure the arm lifetime and maintenance.

2. Friction Modeling

Friction is presented in power transmission elements such as gears and screws as well as in bearings, seals, hydraulic components and electric motors. Friction behavior in each of these is a complex phenomenon. For example, friction in rolling-element bearings is a function of bearing size, type and design. Additional factors include speed, load type and magnitude as well as lubricant viscosity and flow. While friction can be a function of many variables, it has been shown to be highly repeatable, thus friction modeling and parameter identification are applicable goals. Some researchers and manufacturers have developed theoretical or empirical friction models as well as typical values of the model parameters. These parameter values provide only rough estimations of the behavior in a particular system. While it may be possible to use them to identify the dominant sources of friction in a system, the actual parameter values should be identified by the experiments [4].

3. Methodology

The methodology followed in this paper could be stated as first, presenting the modeling of the robot system which includes: setting of the robot equations of the Friction modeling is also critical for robot condition monitoring and fault detection of the transfer function, then stating the setting of the requirements and testing the controller with different gains and analyzing the results to obtain the final desired controller.

3.1 Transfer Function of the robot arm friction

Dynamical stability analysis is performed in the following section using Matlab software for examining the roots of the characteristic equation. Transfer function in matlab as in the following manner: H=TF(system). Some examples for transfer function of arm robot frictions:

$$1\backslash TF = \frac{0.5}{s^3+2.5s^2+2.5s} \qquad (1)$$

$$2\backslash TF = \frac{0.5}{s^3+4.5s^2+5.5s} \qquad (2)$$

$$3\backslash TF = \frac{0.5}{s^3+4.5s^2+14.5s} \qquad (3)$$

The resulting step response of arm robot friction for the three transfer functions using Matlab are shown in Figure 1,2 and 3.

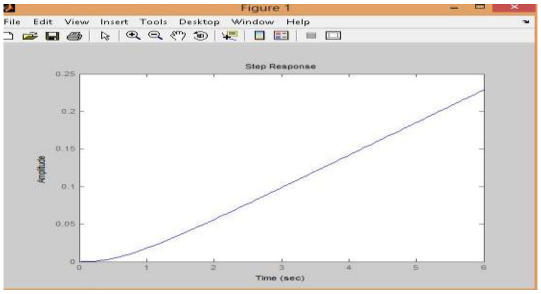

Figure 1: Step response of transfer function1

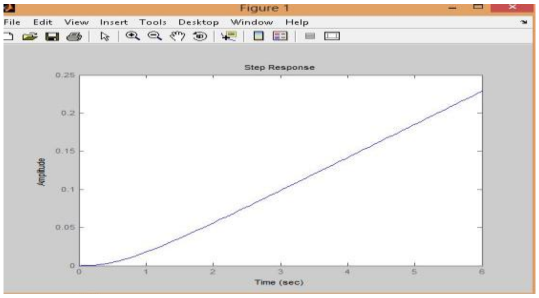

Figure 2: Step response of transfer function 2

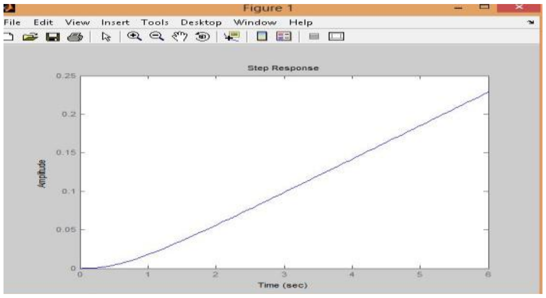

Figure 3: Step response of transfer function 3

3.2 The transfer function of the PID controller

The transfer function of the PID controller is stated as below: [5]

$$G(S) = \frac{\mathrm{U}(S)}{E(S)} \qquad (4)$$

$$G(S) = K_P + \frac{K_I}{S} + K_D S = \frac{K_D S^2 + K_P S + K_I}{S} \qquad (5)$$

3.3Proportional-Integral-Derivative (PID) Control

The PID algorithm consists of three basic modes, the Proportional mode, the Integral and the Derivative modes. When utilizing this algorithm, it is necessary to decide which mode to be used (P, I or D) and then specify the parameters (or settings) for each mode used. Generally, three basic algorithms are used P, PI or PID [5]. PID control logic is widely used in the process control industry. They are controllers which have been traditionally chosen by control system engineers due to their flexibility and reliability. Where KP represents the proportional gain, Ki represents the integral gain, and KD represents the derivative gain, respectively. By tuning these PID controller gains, the controller can provide control action designed for specific process requirements.) [6].

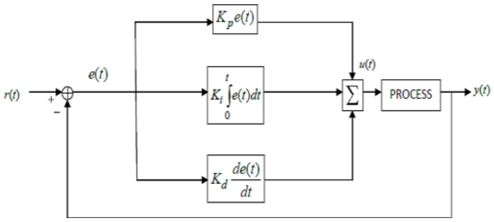

Figure 4: PID Control Logic

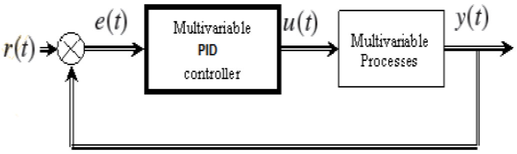

Figure 5: A structure of a PID control system[3]

4. Results and Discussions

If the system must remain online, one tuning method is to first set KI and KD values to zero. Increase the KP until the output of the loop oscillates, then the KP should be set to approximately half of that value for a "quarter amplitude decay" type response. Then increase KI until any offset is corrected in sufficient time for the process. However, too much increasing in the value of KI will cause instability. Finally, increase KD, if required, until the loop is acceptably quick to reach its reference after a load disturbance. However, higher values of KD will cause excessive response and overshoot. A fast PID loop tuning usually overshoots slightly to reach the set point more quickly; however, some systems cannot accept overshoot, in which case an over-damped closed-loop system is required, which will require a KP setting significantly less than half that of the KP setting that was causing oscillation. In proportional and integrative controller mode, the transfer function below was produced and added to system, reminding that adding P or I or D may improve some required response and but still cause an undesired response.

The simulations after adding PID controller are carried out in MATLAB environment and the results obtained are shown in Fig.6, Fig.7 andFig.8.

- At KP= 110, KI= 10 and KD=90

$$1\backslash\, TF = \frac{45s^2+55s+5}{s\char`^4+2.5s^3+47.5s^2+55s+5} \qquad (6)$$

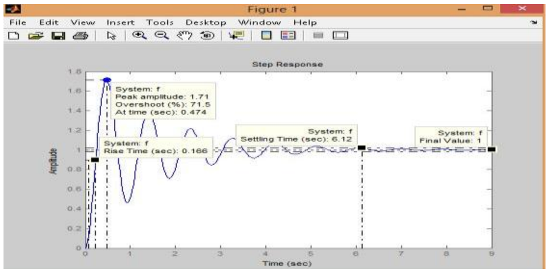

Figure 6: Step response of transfer function1 after adding PID controller

- At KP= 110, KI= 10 and KD=90

$$2\backslash\, TF = \frac{45s^2+55s+5}{s\char`^4+4.5s^3+50.5s^2+55s+5} \qquad (7)$$

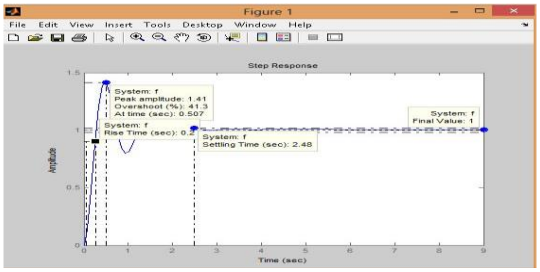

Figure 7: Step response of transfer function2 after adding PID controller

- At KP= 110, KI= 10 and KD=90

$$3\backslash\ TF = \frac{45s^2+55s+5}{s{}^\wedge 4+10.5s^3+59.5s^2+55s+5} \qquad (8)$$

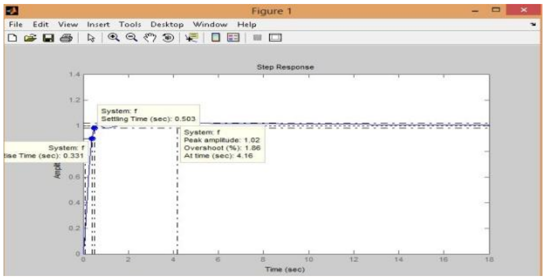

Figure 8: Step response of transfer function3 after adding PID controller

This figure below explains the difference between three samples

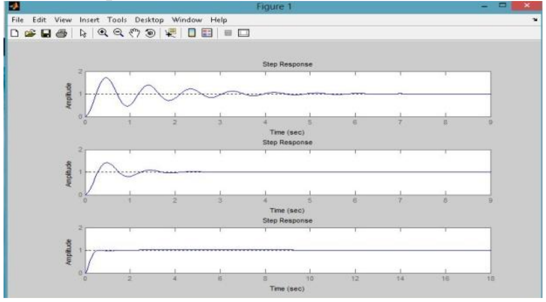

Figure 9: The figure showing the difference between the three samples

This transfer function is a PID controller with K_I, K_P and K_D.The resulting of step responses is shown inTable1.

Table 1: Resulting of step responses after adding PID control system

TF No	Rise time	Overshoot	Setting time	Steady state gain
1	0.166	71.5%	6.120	1
2	0.200	41.3%	2.480	1
3	0.331	1.86%	0.503	1

5. Conclusions

The accuracy of the performance of the robot arm depends on the value of the viscous friction. Deterioration of the robot joint may increase the friction, hence decrease the accuracy of doing required jobs. Many actions could be done to monitor and maintain the friction as low as possible to guarantee the required jobs of the robot arm. Choice three of table 1 shows the best performance of the robot arm.

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