Design of Intelligent Soft Arm Control

Arindam Banerjee[1], Amarnath Sanyal[2], Dr. Sourish Sanyal[3], *Raju Basak[4]

***Abstract*— Robots are of tremendous use in many fields of industrial automation, now-a-days. They are also increasingly being used in medical field. Remote robotic surgery is the best example. Now robots are also being used to assist disabled and handicapped persons. Proper design of one automated robotic actuator to feed a disable person has been the main topic of this paper. The original work of A. Kara et al in this field lacked in certain obvious design specifications. So, it need be modified. In this paper, design specifications and constraints have been specified at first. Then the design has been made to conform to such specs. The original design has been modified by adding compensation for this purpose. MATLAB-tools have been used for design computation.**

***Index Terms*— loop control, forward path gain, stability margins, ISAC robot arm, disable person**

I. INTRODUCTION

Intelligent Soft Arm control (ISAC) is the design of a robotic arm which is properly adjusted for feeding food to disabled persons. The cotrol system guides the spoon to the foodand then to a position near to the mouth of the disabled person. The arm contains a special pneumatically controlled actuator called rubbertuator. This actuator consists of rubber tubes covered with fiver cord. The actuator contracts in length when pneumatic pressure is increased and expands in length when pressure is dcreased. This expansion/contraction can drivea pulley or other device. A video camera gives sight for the robot and the tracking loop [1,2]. Block diagram has been used to represent the system [3]. The simplified block of

the mouth is shown in fig. 1. diagram for regulating the spoon at a distance from

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II. MATHEMATICAL MODEL

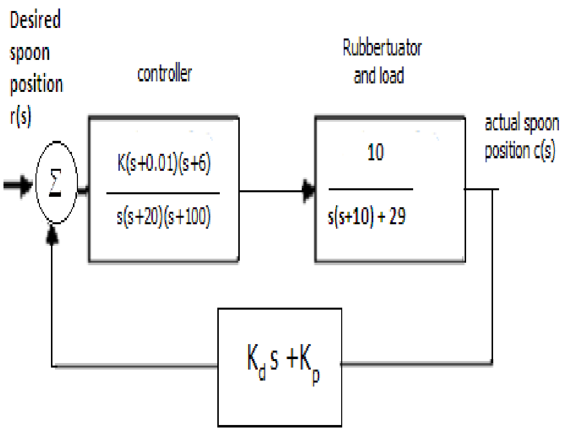

Fig.1. Block diagram representation of the system

From the block diagram of the system, we find that the transfer function of the forward and the feedback path [4,5] are given as:

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$$G(s)=\frac{K(s+0.01)(s+6)}{s(s+20)(s+100)}\times\frac{10}{s^2+10s+29};\; H(s)=1$$

The characteristic equation for the closed loop system is given as:

$$x^5+130x^4+3229x^3+(23480+10K)x^2+(58000+60.1K)s+0.6K=0$$

This equation is of a linear system. It fixes up the limits on gain to ensure stability.

III. RANGE OF GAIN K FOR STABILITY

It can be found out from Routh's array tabulation [6] of the characteristic equation

s^5	1	3229	$58000+60.1K$
s^4	130	$23480+10K$	$0.6K$
s^3	$\frac{396290-10K}{130}$	$\frac{7540000+7812.4K}{130}$	$\times$
s^2	$\frac{357710+7822.4K}{130}$	$0.6K$	$\times$

Which shows that $-0.022\le K\le 39629$ is the condition for stability.

IV. STEADY STATE ERROR AND STABLITY

The position error constant for the system [7,8]is given as:

$$K_p=\frac{Lim}{s\to 0}\frac{K(s+0.01)(s+6)}{s(s+20)(s+100)}\times\frac{10}{s^2+10s+29}=\infty$$

$$K_v=Lim(s\to 0)\frac{K(s+0.01)(s+6)}{(s+20)(s+100)}\times\frac{10}{s^2+10s+29}=0.1;\therefore K=96667$$

Settling time and percent overshoot: $t_s\le 1\ s$; $OS\le 1\%$

V. THE DESIGN PROCEDURE

To match the requirement for this dynamic response, we set (by trial and error in MATLAB-environment)[9,10], $K_d=0.02$ The response to step input for this modified system (along with rate feedback) is given in fig. 2.

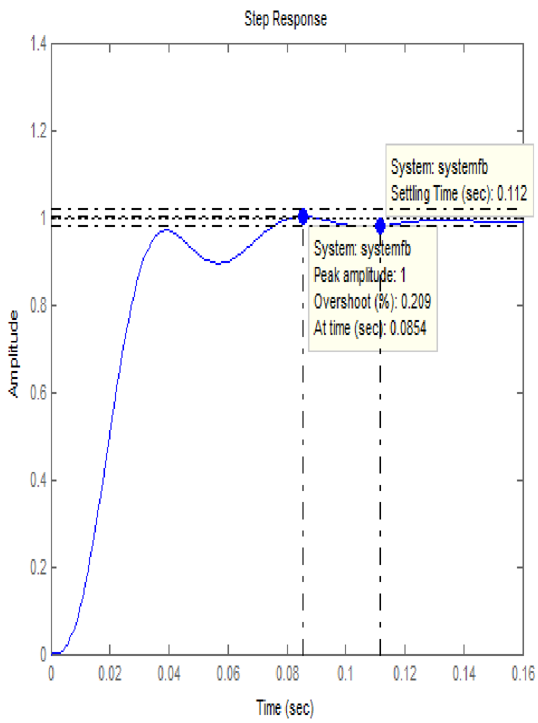

Fig.2 time-domain response to unit step for system with P-D feedback

We find that the settling time and the peak response are well within limits. The f-domain response (Bode plot) is given in fig. 3.

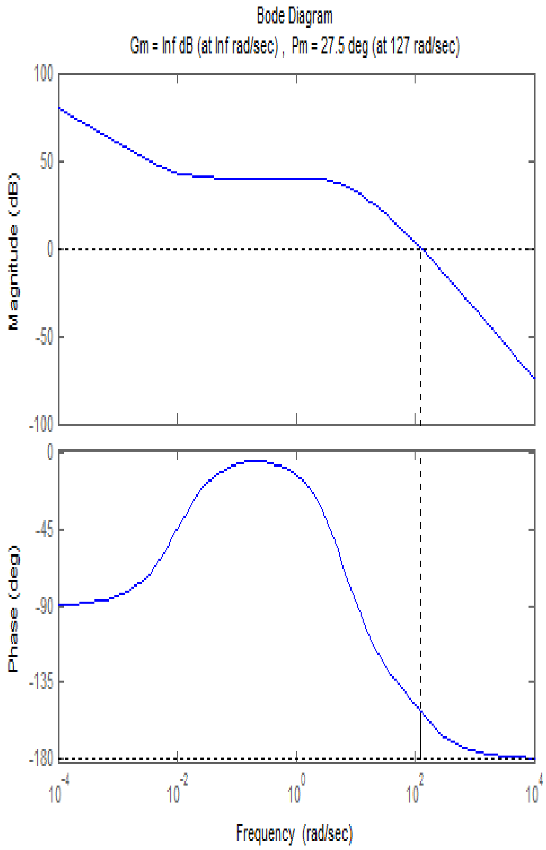

Fig.3 Bode diagram of the system for system with P-D feedback

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The system is now stable. The gain margin is infinity. However the phase margin is only 27.5^{o}, which is less than specified. If more phase has to be added to increase the phase margin and consequently the robustness of the system, a lag-type compensator will be suitable.

VI. ADDITION OF LAG COMPENSATOR

By following a cut and try procedure we select a lag-type compensator of the following transfer function [3, 10, 11]:

$$G_c(s) = \frac{1+s}{1+3.8s}$$

6

The time domain response to a step input with lag compensator is given in fig. 4. The system is slightly over damped almost critical. Hence the overshoot is nil. The settling time is less than 1 s as specified.

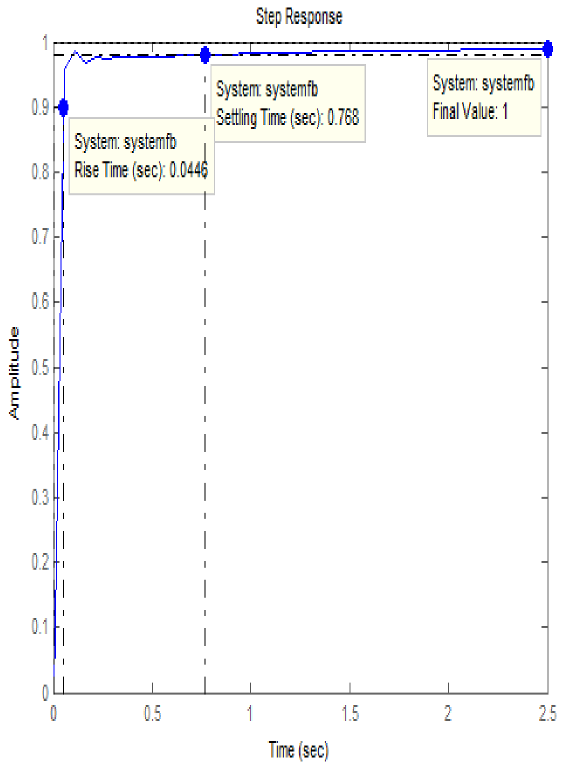

Fig. 4.Response of the compensated system against step input

The frequency-domain characteristic (Bode plot) is given in fig. 5. Now with addition of the compensator the phase margin is 42^{o} which is more than the specified minimum.

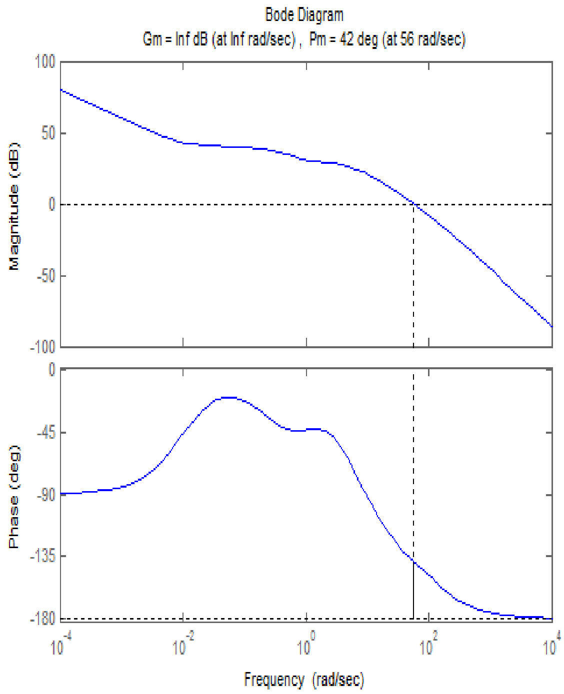

Fig. 5. Bode plot of system with lag compensator

VII. CONCLUSION

Robotic appliances are finding wide-spread application as automated devices to help the handicapped and disabled persons. As long back as in 1992, A. Kara et al proceeded design of such a device in one of their papers. The development was quite interesting but notice was not paid to its design aspects. The steady state error of a control system must be within specified limits to keep a certain accuracy level. His requirement fixes up the forward path gain. Kara's system becomes unstable for such a large gain. As such rate feedback compensation had to be added along with his original design with unity feedback. The time domain response to step input should be nearly critically damped. Also the settling time must be small. After specifying the requirements, addition of appropriate rate feedback was made. This could achieve desirable t-domain response along with the required amount of steady state accuracy. However, the phase margin of the system was less than the specified value of 40^{o}. To achieve the required amount of phase margin, a static lag compensator had to be inserted in the forward path which could fulfill all the specifications made beforehand.

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