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Robust Control Design of Dispenser Table using Quantitative Feedback (QFT) Theory Method

Eatidal Ahmed Abdelgadir Abdallah[1] and Dr. Muawia Mohamed Ahmed Mohamed[2]

[1]P.G Student, Control Engineer, AlNeelain University, Khartoum, Sudan
eatidal_ahmed@yahoo.com

[2]Assoc. Prof., AlNeelain University, Khartoum, Sudan
amuawiamohamed@yahoo.com

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Abstract

Robustness is of crucial importance in control system design because real engineering systems are vulnerable to external disturbance and measurement noise and there are always differences between mathematical models used for design and the actual system.

A successfully designed control system should be always able to maintain stability and performance level inspite of uncertainties in system dynamics and/or in working environment to a certain degree.

Designing robust controllers involve looking for linear compensators that ensure satisfactory performance for all possible model variations not only for the nominal plant but also for the actual plant.

This paper outlines and depicts one of position control applications; it is robust control design of dispenser table using quantitative feedback theory (QFT) method.

Keywords: *Quantitative Feed Back (QFT), Dispenser Table.*

1. Introduction

Robustness is very important in control engineering.

To design a robust system , a control engineer is required to design a controller that will stabilize a plant ,if it is not stable originally, and satisfy certain performance levels in the presence of disturbance signals, noise interference, un-modeled plant dynamics and plant –parameter variations. These design objectives are best realized via the feedback control mechanism, although it introduces in the issues of high cost (the use of sensors), system complexity (implementation and safety), and more concerns on stability (thus internal stability and stabilizing controllers).

This paper will require the reader to have a solid background in frequency-domain concepts.

2. Quantitative Feedback Theory (QFT)

2.1 QFT Method

In the 1960's , as a result of pioneering work of Bode, Isaac Horowitz introduce a frequency domain design methodology that was refined in 1970's to its present form, commonly referred to as the Quantitative Feedback Theory (QFT).

The QFT is engineering method devoted to practical design of feedback systems.

QFT is a frequency domain technique utilizing Nicolas Chart (NC) in order to achieve a desired robust design over a specified region of plant uncertainty. Desired time responses are translated into frequency domain tolerances, which lead to bounds (or constraints) on the loop transmission function. The design process is highly transparent, allowing a designer to see what trade-off is necessary to achieve a desired performance level.

2.2 Plant Templates

Usually any system can be represented by its transfer function (Laplace in continuous time domain), after getting the model of a system. As a result of experimental measurement, values of coefficients in the Transform Function have a range of uncertainty, therefore in QFT every parameter of this function is included into an interval of possible values, and the system may be a family of plants rather than by standalone expression.

2.3 QFT Objectives

One of the main objectives in QFT is to design a simple, low-order controller with minimum bandwidth. Minimum bandwidth controllers are a natural requirement in practice in order to avoid problems with noise amplification, resonance and un-modeled high frequency dynamics. In most practical design situations iterations are inevitable, and QFT offers direct insight into the available trade-off between controller complexity and specifications during such iterations. QFT can be considered as a natural extension of classical frequency-domain design approaches.

2.4 Characteristics of QFT

- The amount of feedback is tuned to the amount of plant and disturbance uncertainty and to the performance specifications.
- Design trade-offs at each frequency are highly transparent between stability, performance, disturbance level and controller complexity and bandwidth.
- The method extends highly intuitive classical frequency-domain loop shaping concepts to cope with simultaneous specifications and the plants with uncertainties.

3. Dispenser Table using QFT

3.1 Robust Design of Dispenser Table

The QFT design, performed in the frequency domain, follows very closely classical designs using Bode plots. The model for the open loop dynamics can either be fixed or include uncertainty. The design of dispenser table will be described in some details in this paper. The dispenser table is depicted in figure(1)
As shown in figure (1) two motors are used for X-Y position of the table which contain vails.

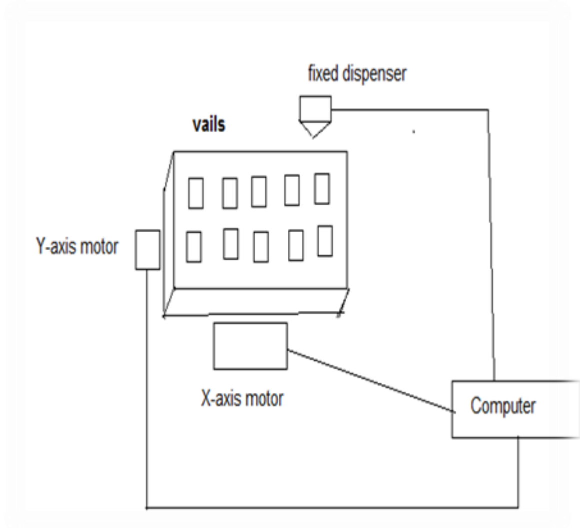

Fig. (1) Dispenser Table

A table is used to position vails under a dispenser as shown in figure (1).
The objective speed, accuracy, and smooth motion in order to eliminate spilling.
The location of the dot or bead being dispensed on the work piece relies on positioning equipment that controls the X-Y position of a work piece or manual abilities with dispensing gun.

3.2 The control system

A control system or plant or process is an interconnection of components to perform certain tasks and to yield a desired response, i.e. to generate desired signal (the output) when it is driven by manipulating signal (the input).
The position control block diagram is shown in figure (2)
Robust controller should guarantee closed loop stability and acceptable performance not only for the nominal plant model but also for the actual plant.

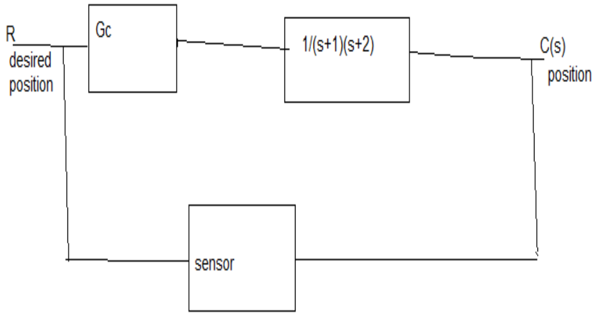

Fig. (2) Block Diagram of Control System

A motor is used to reduce the effect of disturbances

$$G(s)=1/(s+1)(s+2) \qquad (1)$$

The plant set include tow cases:
P1 = -1 , p2 = -2 (are nominal)

With variation + 50% variation from its nominal value.

QFT work directly with such uncertainties and does not require any particular representation.
The controller should meet specifications inspite of variation in parameters of the plant model.

The worse case with p1= -0.5 and p2= -1

$$Gc=[(s+z1)(s+z2)]/s \qquad (2)$$

Closed loop performance meets the required specifications with quite simple transfer functions with proportional, Integral and derivative (PID) controller to eliminate steady state errors caused by a constant disturbance.

3.3 QFT uses Graphical and Numerical Method

QFT uses graphical and numerical methods follows these steps:

1- Place the poles and zeros of G(s) in the s-plane
2- Starting near the origin place the zeros of G(s) immediately to the left of each of (n-1) poles on the left–hand s-plane (one pole is left)
3- Increase the gain k so that the poles of closed loop transfer function are close to zeros of Gc(s).

4. Results

When plotting Locus for kGcG(s):

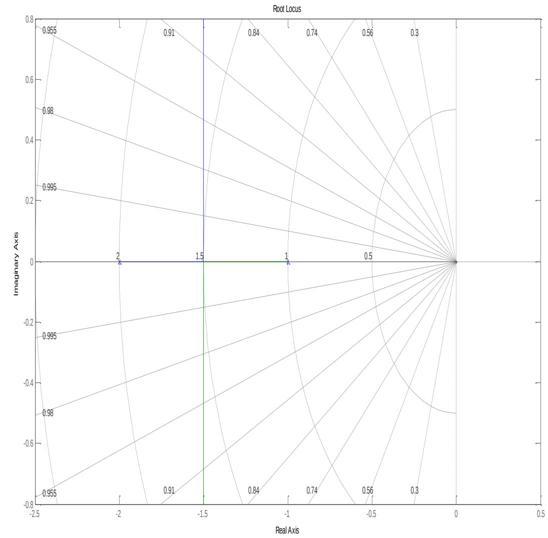

Fig.(3) locus plot for KGsG(s)

After adding Gc using QFT
Nominal G(s) 0.01% overshoot
40mS setting time
For worse case of G(s) 0.97% over shoot
40mS setting time

5. Conclusions

Quantitative feedback Theory(QFT) is frequency domain technique utilizing the Nicolas Chart(NC)in order to achieve a desired robust design over a specified region of plant uncertainty, other words about the suitability of QFT to different classes of problems, originally QFT method developed for uncertain linear Time Invariant systems single-loop system, has been extended to cascaded loop systems and multi-loop systems using a sequential loop closure approach .
This paper discussed one of applications of this technique; it is robust control design of dispenser table.

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