Control System Design by Frequency Response Using Matlab

Riyadh Nazar Ali AL-Gburi,Ali Saleh Aziz

Abstract—In frequency response methods, we vary the frequency of the input signal over a certain range and study the resulting response. Although the frequency response of the control system presents a qualitative picture of the transient response, correlation between frequency and transient response is indirect, except for the case of second order system in designing a closed loop system. We adjust the frequency response characteristic of the open loop transfer function by using several design criteria in order to obtain acceptable transient response characteristics for the system.

Index Terms— Lead-Lag, Bode plot, Gain Margin, Phase Margin.

I. INTRODUCTION

Automatic control has played a vital role in the advance of engineering and science. In addition to its extreme importance in space vehicle systems missile guidance systems robotic systems and the like automatic control has become an important and integral part of modern manufacturing and industrial processes For example automatic control is essential in the numerical control of machine tools in the manufacturing industries in the design of autopilot system in the aerospace industries and in the design of cars and trucks in the automobile industries It is also essential in such industrial operations as controlling pressure, temperature, humidity, viscosity, and flow in the process industries. Since advances in the theory and practice of automatic control provide the means for attaining optimal performance of dynamic systems, improving productivity. Relieving the drudgery of many routine repetitive manual operation, and more, most engineers and scientists must now have a good understanding of this filed. The controlled variable is the quantity or condition that is measured and controlled the manipulated variable is the quantity or condition that is varied by the controller so as to affect the value of the controlled variable .Normally, the controlled variable is the output of the system. Control means measuring the value of the controlled variable of the system and applying the manipulated variable to the system to correct or limit deviation of the measured value from a desired value In studying control engineering, we need to define addition terms that are necessary to describe control systems [1].

II. THEORY

It should be emphasized that for system in which the inputs are known ahead of time and in which there are no disturbances it is advisable to use open-loop control. Closed-loop control systems have advantages only when unpredictable disturbances and/or unpredictable variations in system components are present. Note that the output power rating partially determines the cost, weight, and size of a control system. The number of components used in a closed-loop control system is more than that for a corresponding open-loop control system. Thus, the closed-loop control system is generally higher in cost and power. To decrease the required power of a system, open-loop control may be used where applicable. A proper combination of open-loop and closed-loop controls is usually less expensive and will give satisfactory overall system performance [2].

A.Lead Compensation

We shall first examine the frequency characteristics of the lead Compensator. Then we present a design technique for the lead Compensator by use of the bode diagram. Consider of lead compensator having the following transfer function.

$$K_c \alpha \frac{T_S + 1}{\alpha T_S + 1} = K_C \frac{S + \frac{1}{T}}{S + \frac{1}{\alpha T}} \quad (0 < \alpha < 1) \qquad (1)$$

It has zero at S=- 1/T and a pole at S=-1/ (αT) Sine 0<α< 1 We see that the zero is always located to the right of the pole in the complex plane. Note that for small value of α pole is located far to left .the minimum value of α is limited by the physical construction of the lead compensator.

The minimum value of α is usually taken to be about 0.05. (This means that the maximum phase lead that may be produced by a lead compensator is about 65 degree). Fig.1shows the polar plot of

$$K_C \alpha \frac{J\omega T + 1}{J\omega \alpha T + 1} \quad (0 < \alpha < 1) \qquad (2)$$

With Kc=1.For a given value of α, the angle between the positive real axis and the tangent line drawn from the origin to the semicircle gives the maximum phase lead angle Ø$_m$ We shall call the frequency at the tangent point ω m

From Fig.2 the phase angle at ω=ω$_m$ is Ø$_m$, where Equation (3) relates the maximum phase lead angle and the value of α Fig.2 shows the bode diagram of a lead compensator when Kc=1 and α=0.1

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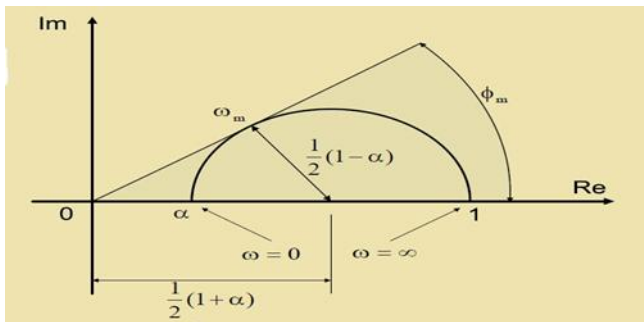
Fig.1 Polar plot of a lead compensator α(jωT+1)/(jωT+1) where 0<α<1

$$\sin \emptyset \mu = \frac{\frac{1-\alpha}{2}}{\frac{1+\alpha}{2}} = \frac{1-\alpha}{1+\alpha} \qquad (3)$$

$$\log \omega_\mu = \frac{1}{2}(\log \frac{1}{T} + \log \frac{1}{\alpha T}) \qquad Hence \ \omega_\mu = \frac{1}{\sqrt{\alpha T}} (4)$$
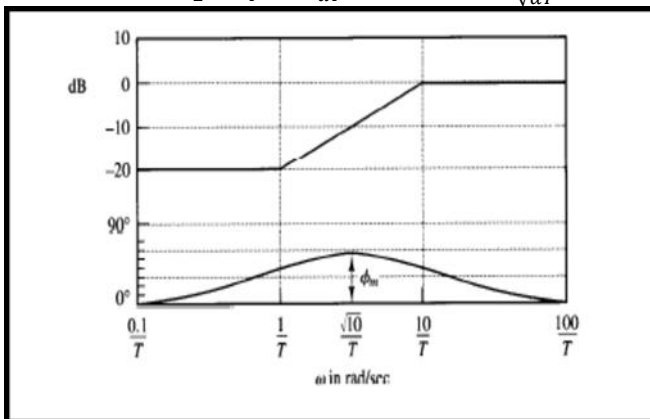

Fig.2 Bode diagram of a lead compensatorα(j ω T+1)/(j ω T+1), where α=0.1

The corner frequencies for the lead compensator are ω=1/T and ω=1/ (αT) = 10/T. By examining Fig.2, we see that ω_m is the geometric mean of the two corner frequencies, or As seen from Fig.2 the lead compensator is basically a high – pass filter. (The high frequencies are passed, but low frequencies are attenuated)

The primary function of the lead compensator is to reshape the frequency response curve to provide sufficient phase lead angle to offset the excessive phase lag associated with the components of the fixed system. Consider the system shown in Fig.3. Assume that the performance specifications are given in terms of phase margin, gain margin, static velocity error constants, and so on. The procedure for designing a lead compensator by the frequency response approach may be stated as follows
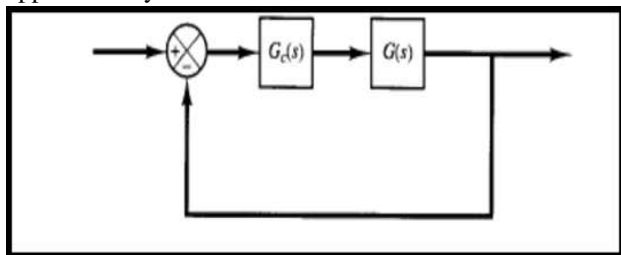

Fig.3 Control system

1-Assume the following lead compensator

$$G_C(S) = K_C \alpha \frac{T_S+1}{\alpha T_S+1} = K_C \frac{S+\frac{1}{T}}{S+\frac{1}{\alpha T}} (0 < \alpha < 1) \qquad (5)$$

$DefineK_C\alpha = K ThenG_C(S) = K \frac{T_S+1}{\alpha T_S+1}$

The open-loop transfer function of the compensated system is

$$G_C(S)G(S) = K \frac{T_S+1}{\alpha T_S+1} G(S) = \frac{T_S+1}{\alpha T_S+1} KG(S) = \frac{T_S+1}{\alpha T_S+1} G_1(S)$$

Where

$$G_1(S) = KG(S)$$

Determine gain K to satisfy the requirement on the given static error constant.

2-Using the gain K thus determined, draw a Bode diagram of G1 (jω), the gain-adjusted but uncompensated system. Evaluate the phase margin.

3-Determine the necessary phase lead angle Ø to be added to the system.

4- Determine the attenuation factor α by use of equation (3). Determine the frequency where the magnitude of the uncompensated system G1 (jω) is equal to -20 log (1/√α). Select this frequency as the new gain crossover frequency. This frequency corresponds to ωμ=1/ (√αT), and the maximum phase shift ωμ Occurs at this frequency.

5- Determine the corner frequencies of the lead compensator as follows: Zero of lead compensator: ω= 1/T
    Pole of lead compensator: ω =1/αT

6-Using the value of K determined in step 1 and that ofα determined in step 4, calculate constant KC from.KC=K/α

7-Check the gain margin to be sure it is satisfactory. If not, repeat the design process by modifying the pole-zero location of the compensator until a satisfactory result is obtained [3].

B. Lag Compensation

We present lag compensator techniques based on the frequency response approach.

Consider a lag compensator having the following transfer function

$$G_C(S) = K_C \beta \frac{T_S+1}{\beta T_S+1} = K_C \frac{S+\frac{1}{T}}{S+\frac{1}{\beta T}} (\beta > 1) \qquad (6)$$

Sections In the complex plane, a lag compensator has a zero at S=-1/T and a pole at S=-1/ (βT). The pole is located to the right of the zero. Fig.4 shows a polar plot of the lag compensator. Fig.5shows a bode diagram of the compensator, where K_C=1 and β=10.

The corner frequencies of the lag compensator, are at ω=1/T and ω= (1/βT). As seen Fig.5, where the values of Kc and β are set equal to 1 and 10, respectively, the magnitude of the lag compensator becomes

(10 or 20 db.) at low frequencies and unit (or 0 dB) at high frequencies. Thus, the lag compensator is essentially low pass filter [4].
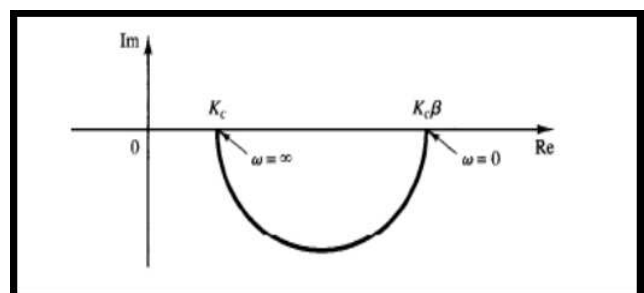

Fig.4Polar plot of a lag compensator Kcβ (jωT+1)/(jωβT+1).

The primary function of lag compensator is to provide attenuation in the high–frequency range to give a system sufficient phase margin. The phase lag characteristic is of no consequence in lag compensation the procedure for designing lag compensators for the system shown in Fig.5 by the frequency-response approach may be stated as follows:

1-Assume the following lag compensator

$$Gc(S) = Kc\beta \frac{TS+1}{\beta TS+1} = Kc \frac{S+\frac{1}{T}}{S+\frac{1}{\beta T}} \qquad (\beta>1)\text{Define}$$
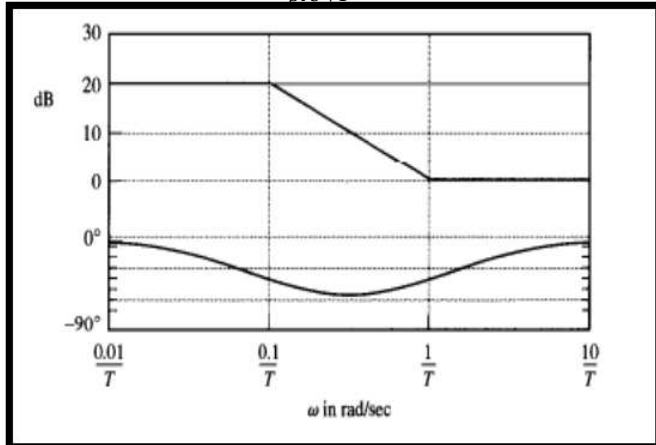
$Kc\beta=K$ Then $Gc(S) =K\frac{TS+1}{\beta TS+1}$

Fig.5 Bode diagram of a lag compensator β(jωT+1)/(jωβT+1), with β=10.

The open-loop transfer function of the compensated system is
$Gc(S) \; G(S) = K\frac{TS+1}{\beta TS+1} G(S) = \frac{TS+1}{\beta TS+1} KG(S) = \frac{TS+1}{\beta TS+1} G1(S)$
Where G1(S) =KG(S).
Determine gain K to satisfy the requirement on the given static error constant.

2-If the uncompensated system G1(S)=KG(jω) does not satisfy the specifications on the phase and gain margins, then find the frequency point where the phase angle of the open-loop transfer function is equal to -180° plus the required phase margin. The required phase margin is the specified phase margin plus 5° to 12°. (The addition of 5° to 12° compensates for the phase lag of the lag compensator). Choose this frequency as the new gain crossover frequency.

3-To prevent detrimental effects of phase lag due to the lag compensator, the pole and zero of the lag compensator mustbe located substantially lower than the new gain crossover frequency. Therefore, choose the corner frequency ω=1/T (corresponding to the zero of the lag compensator) 1 octave to 1 decade below the new gain crossover frequency. (If the time constants of the lag compensator do not become too large, the corner frequency ω=1/T may be chosen 1 decade below the new gain crossover frequency).

4-Determine the attenuation necessary to bring the magnitude curve down to 0 dB at the new gain crossover frequency. Noting that this attenuation is -20 log β, determine the value of β. Then the other corner frequency (corresponding to the pole of the lag compensator) is determined from ω=1/ (βT).

5-Using the value of K determined in step 1 and that of β determined in step 5, calculate constant Kc from

$Kc=\frac{k}{\beta}$

C. Lag–Lead Compensation

We shall first examine the frequency-response characteristics of the lag-lead compensator then we present the lag – lead compensation technique based on the frequency- response approach.Consider the lag – lead compensator given by

$$G_C(S) = K_C \left(\frac{S+\frac{1}{T_1}}{S+\frac{\gamma}{T_1}} \right) \left(\frac{S+\frac{1}{T_2}}{S+\frac{1}{\beta T_2}} \right) \qquad (7)$$

Where y > 1 and β > 1 the term

$$\frac{S+\frac{1}{T_1}}{S+\frac{\gamma}{T_1}} = \frac{1}{\gamma} \left(\frac{T_1 S+1}{\frac{T_1}{\gamma} S+1} \right) \qquad (\gamma > 1)$$

Produces the effect of the lead network, and the term

$$\frac{S+\frac{1}{T_2}}{S+\frac{1}{\beta T_2}} = \beta \left(\frac{T_2 S+1}{\beta T_2 S+1} \right) \qquad (\beta > 1)$$

Produces the effect of the lag network. In designing a lag–lead compensator, we frequently chose y= β. (this is not necessary. we can, of course, choose y ≠ β) in what follows, we shall consider the case where y = β. The polar plot of the lag–lead compensator with Kc = 1 and y = β becomes as shown in Fig.6. It can be seen that, for 0< ω< ω1, the compensator acts as a lag [5].

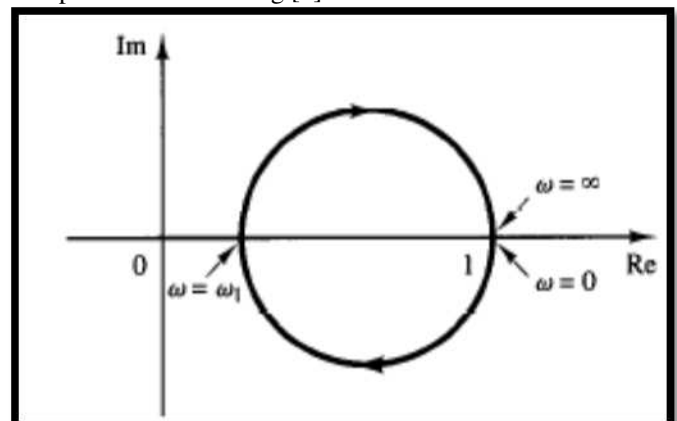Fig.6 Polar plot of a lag- lead compensator given by equation (7) with Kc =1 and y= β .

Compensator, for ω1<ω<∞, acts as a lead compensator. The frequency ω1 is the frequency at which the phase angle is zero. It is given by $\omega_1 = \frac{1}{\sqrt{T_1 T_2}}$
Fig.7 shows the Bode diagram of a lag- lead compensator when Kc=1 y=β = 10 and T2 =10T1.Notice that the magnitude curve has the value 0 dB at the low and high frequency regions.

The design of a lag – lead compensator by the frequency response approach is based on the combination of the design techniques discussed under lead compensation and lag compensation. Let us assume that the lag- lead compensator is of the following form [6].

$$G_C(S) = K_C \frac{(T_1 S+1)(T_2 S+1)}{\left(\frac{T_1}{\beta}S+1\right)(\beta T_2 S+1)} = K_C \frac{\left(S+\frac{1}{T_1}\right)\left(S+\frac{1}{T_2}\right)}{\left(S+\frac{\beta}{T_1}\right)\left(S+\frac{1}{\beta T_2}\right)} \qquad (8)$$

Where β> 1. The phase lead portion of the lag–lead compensator (the portion involving T1) alters the frequency

response curve by adding phase lead angle and increasing the phase margin at the gain crossover frequency. The phase lag portion (the portion involving T2) provides attenuation near and above the gain crossover frequency and there by allows an increase of gain at the low-frequency range to improve the steady state performance. We shall illustrate the details of the procedures for designing a lag–lead compensator by an example [7].
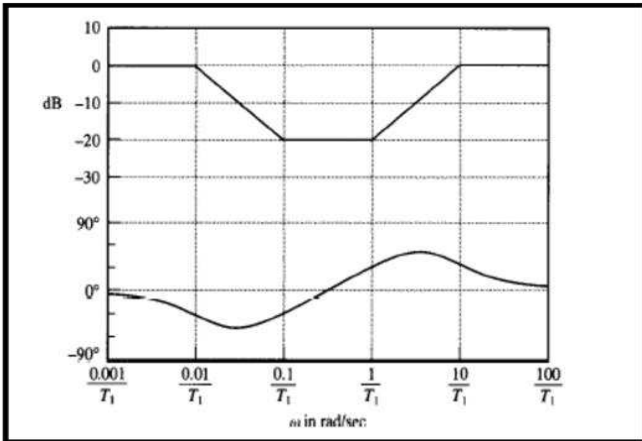

Fig.7 Bode diagram of a lag–lead compensator given by equation (8) with Kc =1, y = β = 10, and T2=10T1

III. SIMULATION MODEL & PROGRAM

Lead compensation essentially yields an appreciable improvement in transient response and a small change in steady-state accuracy. It may accentuate high-frequency noise effects. Lag compensation on the other hand, yields an appreciable improvement in steady-state accuracy at the expense of increasing the transient-response time. Lag compensation will suppress the effects of high-frequency noise singles. Lead-Lag compensation combines the characteristics of both lead compensation and lag compensation. The use of a lead or lag compensator raises the order of the system by (unless cancellation occurs between the zero of the compensator and a pole of the uncompensated open-loop transfer function). The use of a lead-lag compensator raises the order of the system by (unless cancellation occurs between zeros of the lead-lag compensator and poles of the uncompensated open-loop transfer function), which means that the system becomes more complex and it is more difficult to control the transient response behavior [8].

A. Lead Compensator

In order to examine the transient-response characteristics of the designed system, we shall obtain the unit-step and unit-ramp response curves of the compensated and uncompensated system with MATLABNote that the closed-loop transfer functions of the uncompensated and compensated system are given, respectively,

by$\frac{C(s)}{R(s)} = \frac{4}{s^2+2s+4}$ and

$$\frac{C(s)}{R(s)} = \frac{166.8s + 735.588}{s^3 + 20.4s^2 + 203.6s + 735.588}$$

MATLAB program for obtaining the unit-step response

```
*****Unit-Step Responses*****
num=[0 0 4];
den=[1 2 4];
numc=[0 0 166.8 735.588];
denc=[1 20.4 203.6 735.588];
t=0:0.2:6;
[c1,x1,t]=step(num,den,t);
[c2,x2,t]=step(numc,denc,t);
plot(t,c1,'*',t,c2,'+')
grid
title('Unit-Step Responses of Compensated
and Uncompensated Systems')
xlabel('t Sec')
ylabel('Outputs')
text(0.4,1.31,'Compensated System')
text(1.55,0.88,'Uncompensated System')
```

and unit-ramp response curves are given in MATLAB Program

```
*****Unit-Ramp Responses*****
num1=[0 0 0 4];
den1=[1 2 4 0];
num1c=[0 0 0 166.8 735.588];
den1c=[1 20.4 203.6 735.588 0];
t=0:0.05:5;
[y1,z1,t]=step(num1,den1,t);
[y2,z2,t]=step(num1c,den1c,t);
plot(t,y1,'*',t,y2,'+',t,t,'--')
grid
title('Unit-Ramp Responses of Compensated
and Uncompensated Systems')
xlabel('t Sec')
ylabel('Outputs')
text(0.89,3.7,'Compensated System')
text(2.25,1.1,'Uncompensated System'
```

B. Lag Compensator

In order to examine the unit-step response and unit-ramp response of the compensated system and the original uncompensated system, the closed-loop transfer functions of the compensated and uncompensated system are used as follow:

$$\frac{C(s)}{R(s)} = \frac{50s + 5}{50s^4 + 150.5s^3 + 101.5s^2 + 51s + 5}$$

And

$$\frac{C(s)}{R(s)} = \frac{1}{0.5s^3 + 1.5s^2 + s + 1}$$

MATLAB program for obtaining unit-step response

```
%****unit-step response***%
num=[0 0 0 1];
den=[0.5 1.5 1 1 ];
numc=[0 0 0 50 5 ];
denc=[50 150.5 101.5 51 5];
t=0:0.1:40;
[c1,x1,t]=step(num,den,t);
[c2,x2,t]=step(numc,denc,t);
plot(t,c1,'.',t,c2,'-')
grid
title('unit-step response of compensated an uncompensated
```

```
system')
xlabel('t sec')
ylabel('output')
text(12.2,1.27,'compensated system')
text(12.2,0.7,'uncompensated')
```

And unit-ramp response curves are given in MATLAB program

```
***unit-ramp response***
num1=[0 0 0 1];
den1=[0.5 1.5 1 1 0];
num2c=[0 0 0 0 50 5];
den2c=[50 150.5 101.5 51 5 0];
t=0:0.1:20;
[y1,z1,t]=step(num1,den1,t);
[y2,z2,t]=step(num2c,den2c,t);
plot(t,y1,'.',t,y2,'-',t,t,'*');
grid
title('unit-ramp response of compensated and
uncompensated system')
xlabel('t sec')
ylabel('output')
text(8.4,3,'compensated system')
trxt(8.4,5,'uncompenesated system')
```

C. Lag-Lead Compensator

In order to examine the transient-response characteristics of the compensated system.(the uncompensated system is unstable), the closed-loop transfer function of the compensated system is used as follow.

$$\frac{C(S)}{R(S)} = \frac{95.381S^2 + 81S + 10}{4.7691S^5 + 47.7287S^4 + 110.3026S^3 + 163.724S^2 + 82S + 10}$$

And

$$\frac{C(S)}{R(S)} = \frac{10}{0.5S^3 + 1.5S^2 + S}$$

MATLAB program for obtaining unit-step response

```
****Unit-Step Response****
num=[0 0 0 10];
den=[0.5 1.5 1 0];
num1=[95.38 81 10];
den1=[4.7691 47.7287 110.3026 163.724 82 10];
t=0:0.02:6;
[c1,x1,t]=step(num,den,t);
[c2,x2,t]=step(num1,den1,t);
plot(t,c1,'.',t,c2,'+')
grid
title('unit-step response of compensated and uncompensated
system')
xlabel('tsec')
ylabel('outputs')
text(0.4,1.31,'compensated system')
text(1.55,0.88,'uncompensated system')
```

and unit-ramp response curves are given in MATLAB program

```
****Unit-Ramp Response****
num=[0 0 0 10];
den=[0.5 1.5 1 0];
num1=[95.381 81 10];
den1=[4.7691 47.7287 110.3026 163.724 82 10];
t=0:0.02:5;
[y1,z1,t]=step(num,den,t);
```

```
[y2,z2,t]=step(num1,den1,t);
plot(t,y1,'-',t,y2,'*')
grid
title('unit-ramp response of compensated and uncompensated
system')
xlabel('tsec')
ylabel('outputs')
text(0.89,3.7,'compensated system')
text(2.25,1.1,'uncompensated system')
```

IV. RESULT AND DISCUSSION

A. Lead Compensator

Fig.8 shows the lead compensation for unit-step [R(s) =1/s] response of the closed-loop transfer functions (uncompensated):

$$\frac{C(s)}{R(s)} = \frac{4}{s^2 + 2s + 4}$$

But for lead compensation we have:

$$Gc(s) = K_c \alpha \frac{T_{s+1}}{\alpha T_{s+1}}. \qquad (0 < \alpha < 1).$$

Then the compensated system

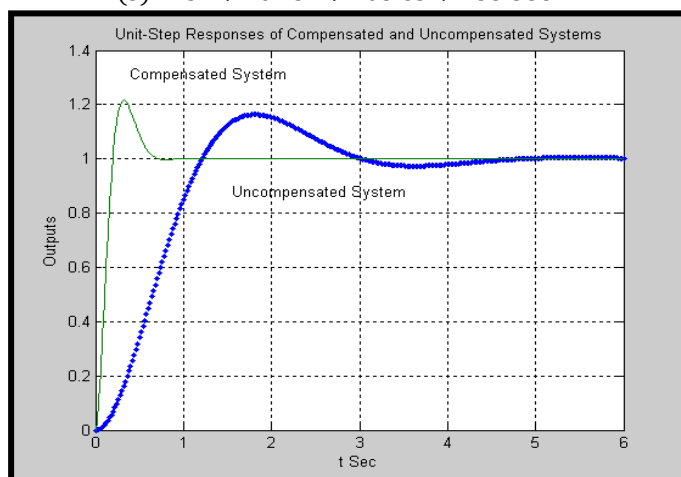$$\frac{C(s)}{R(s)} = \frac{166.8s + 735.588}{s^3 + 20.4s^2 + 203.6s + 735.588}$$

Fig.8   Unit-step   responses   of   compensated anduncompensated System.

Fig.9. shows the lead compensation for unit-ramp [R(s) =1/s^2] response of the closed-loop transfer functions (uncompensated):

$$\frac{C(s)}{R(s)} = \frac{4}{s^2 + 2s + 4}$$

But for lead compensation we have:

$$Gc(s) = K_c \alpha \frac{T_{s+1}}{\alpha T_{s+1}}. \qquad (0 < \alpha < 1)$$

Then the compensated system

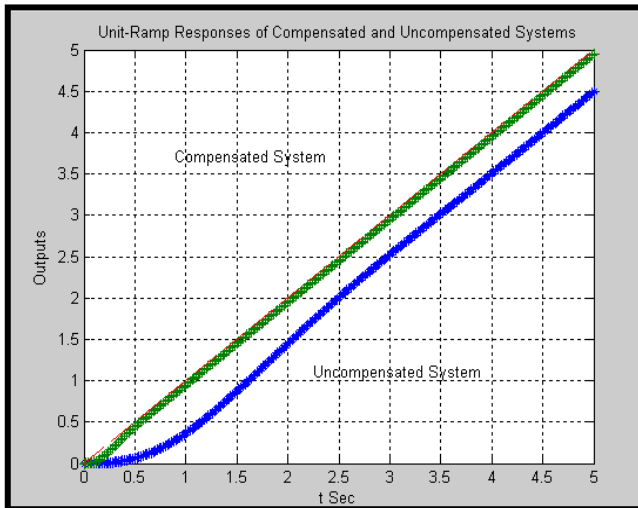$$\frac{C(s)}{R(s)} = \frac{166.8s + 735.588}{s^3 + 20.4s^2 + 203.6s + 735.588}$$

Fig.9 Unit-ramp responses of compensated and uncompensated System.

Fig.11 Unit-ramp responses of compensated and uncompensated System.

B. Lag Compensator

Fig.10. shows the lag compensation for unit-step [R(s) =1/s] response of the closed-loop transfer functions (uncompensated):

$$\frac{C(S)}{R(S)} = \frac{1}{0.5S^3 + 1.5S^2 + S + 1}$$

But the lag compensation we have:

$$Gc(S) = K_C \beta \frac{T_S + 1}{\beta T_S + 1} \qquad (\beta > 1)$$

Then the compensation system:

$$\frac{C(S)}{R(S)} = \frac{50S + 5}{50S^4 + 150.5S^3 + 101.5S^2 + 51S + 5}$$
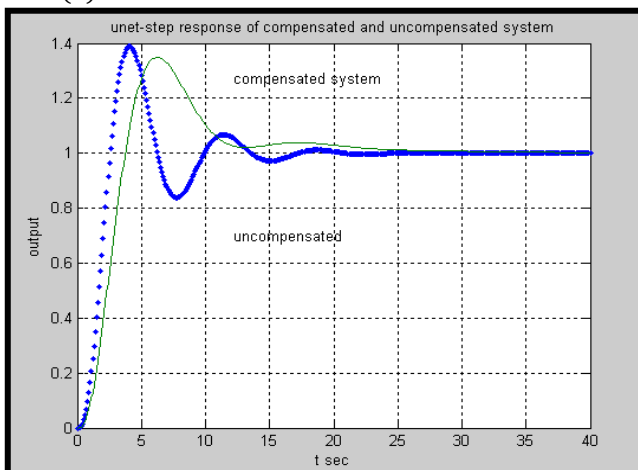

Fig.10. Unit-step responses of compensated and uncompensated system.

Fig.11 shows the lag compensation for unit-ramp [R(s) =1/s²] response of the closed-loop transfer functions (uncompensated):

$$\frac{C(S)}{R(S)} = \frac{1}{0.5S^3 + 1.5S^2 + S + 1}$$

But the lag compensation we have:

$$Gc(S) = K_C \beta \frac{T_S + 1}{\beta T_S + 1} \qquad (\beta > 1)$$

Then the compensation system:

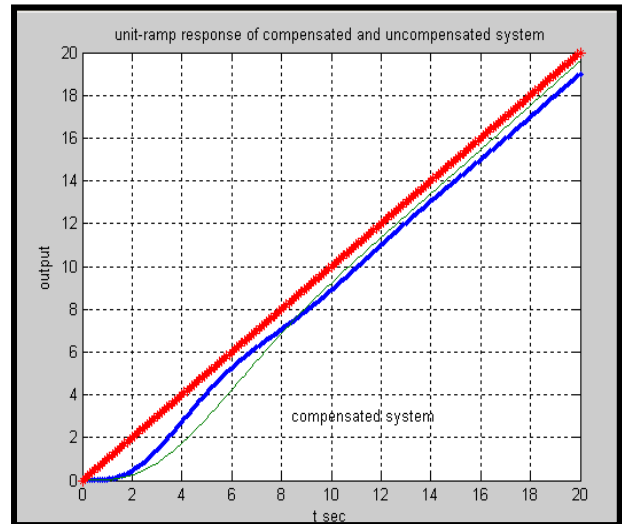$$\frac{C(S)}{R(S)} = \frac{50S + 5}{50S^4 + 150.5S^3 + 101.5S^2 + 51S + 5}$$

C. Lag-Lead Compensator

Fig.12 shows the lag-lead compensation for unit-step [R(s) =1/s] response of the closed-loop transfer functions (uncompensated):

$$\frac{C(S)}{R(S)} = \frac{10}{0.5S^3 + 1.5S^2 + S}$$

But the lag-lead compensation we have:

$$Gc(S) = K_C \left(\frac{S + \frac{1}{T_1}}{S + \frac{Y}{T_1}} \right) \left(\frac{S + \frac{1}{T_2}}{S + \frac{1}{\beta T_2}} \right) \qquad (Y>1) \text{ and } (\beta>1)$$

Then the lag-lead compensation system:

$$\frac{C(S)}{R(S)} = \frac{95.381S^2 + 81S + 10}{4.7691S^5 + 47.7287S^4 + 110.3026S^3 + 163.724S^2 + 82S + 10}$$

Fig.12 Unit-step responses of compensated and uncompensated System

Fig.13 shows the lag-lead compensation for unit-ramp [R(s)=1/s²] response of the closed-loop transfer functions (uncompensated):

$$\frac{C(S)}{R(S)} = \frac{10}{0.5S^3 + 1.5S^2 + S}$$

But the lag-lead compensation we have:

$$Gc(S) = K_C \left(\frac{S + \frac{1}{T_1}}{S + \frac{Y}{T_1}} \right) \left(\frac{S + \frac{1}{T_2}}{S + \frac{1}{\beta T_2}} \right) \qquad (Y>1) \text{ and } (\beta>1)$$

Then the lag-lead compensation system:

$$\frac{C(S)}{R(S)} = \frac{95.381S^2 + 81S + 10}{4.7691S^5 + 47.7287S^4 + 110.3026S^3 + 163.724S^2 + 82S + 10}$$
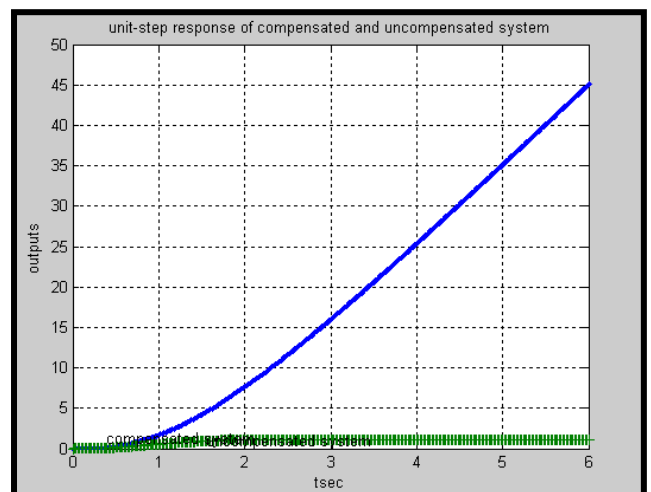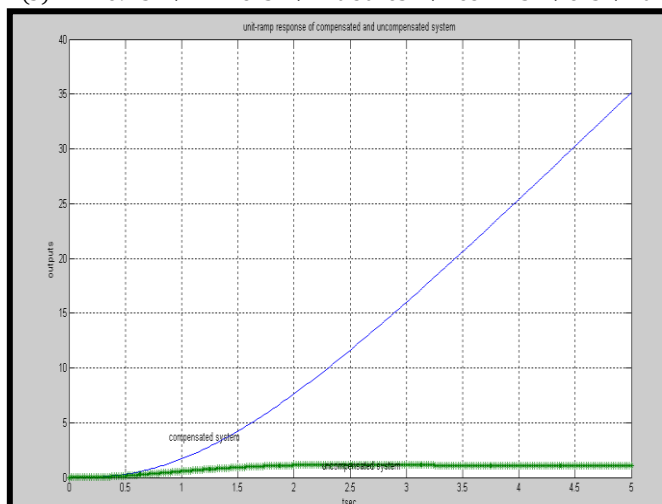

unit-ramp response of compensated and uncompensated system

Fig.13 Unit-ramp responses of compensated and uncompensated System

V. CONCLUSION

Lead compensation achieves the desired result through the merits of its phase–lead contribution, whereas lag compensation accomplishes the result through the merits of its attenuation property at high frequencies. Leadcompensation is commonly used for improving stability margins. Lead compensation yields a higher gain crossover frequency than is possible with lag compensation. The higher gain crossover frequency means larger band width. A large band width means reduction in the settling time. The band width of a system with lead compensation is always greater than that with lag compensation. Therefore, if a large band width or fast response is desired, lead compensation should be employed. If, however noise signals are present, then a large band width may not be desirable since it makes the system more susceptible to noise signals because of increase in the high frequency gain. Lead compensation requires an additional increase in gain to offset the attenuation inherent in the lead network. This means that lead compensation will require a larger gain than that required by lag compensation. A larger gain, in most cases, implies larger space, greater weight, and higher cost. Lag compensation reduces the system gain at higher frequencies without reducing the system gain at lower frequencies. Since the system band width is reduced, the system has a slower speed to respond. Because of the reduced high frequency gain, the total system gain can be increased, and there by low frequency gain can be increased and the steady state can be improved. Also, any high frequency noises involved in the system can be attenuated. If both fast responses and good static accuracy are desired, a lag –lead compensator may be employed. By use of the lag–lead compensator, the low–frequency gain can be increased (which means an improvement in steady- state accuracy), while at the same time the system band width and stability margins can be increased. Although a large number of practical compensation tasks can be accomplished with lead, lag –lead compensators, for complicated system simple compensation by use of these compensators may not yield satisfactory results. Then, different compensators having different pole-zero configurations must be employed.

REFERENCES

[1] Brogan, W.L, "*MODERN CONTROL THEORY*" upper saddle river, NJ: Prentice Hall, 1985.
[2] Dorf, R.C, "*MODERN CONTROL SYSTEM*" 6thed, Reading, MA: Addison-Wesley publishing company, Inc, 1992.
[3] Jayasuriya, S."*Frequency Domain Design for Robust Performance Under Parametric, Unstructured, or Maxed Uncertainties,*" ASMEJ. Dynamic System, Measurement, and Control,115 (1993), pp.439-51.
[4] Math Work, Inc, "*The Siudent Edition Of MATLAB, Version 4.0*", Upper Saddle River, NJ: Prentice Hall, 1995.
[5] Evans, W.R, "*The Use Of Zero And Pole For Frequency Response Or Transient Response*", ASMF. Trans, 76(1954), pp 1135- 44.
[6] Ogata. K, "*Designing Linear Control Systemwith MATLAB*". Upper Saddle River, NJ: Prentice Hall, 1994
[7] D. Antunes, W. Geelen, and W. Heemels, "Frequency-domain analysis of real-time and networked control systems with stochastic delays and drops," in European Control Conference (ECC), July 2015, pp. 934–940.
[8] Gaurav Verm, VikasVerma,SumitJhambhulkar and Himanshu "(Design of a Lead-Lag Compensator for PositionLoop Control of a Gimballed Payload)," 2015 2nd International Conference on Signal Processing and Integrated Networks (SPIN)

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