Advanced Process Control

CBEg 6142

School of Chemical and Bio-Engineering
Addis Ababa Institute of Technology
Addis Ababa University

Chapter 7

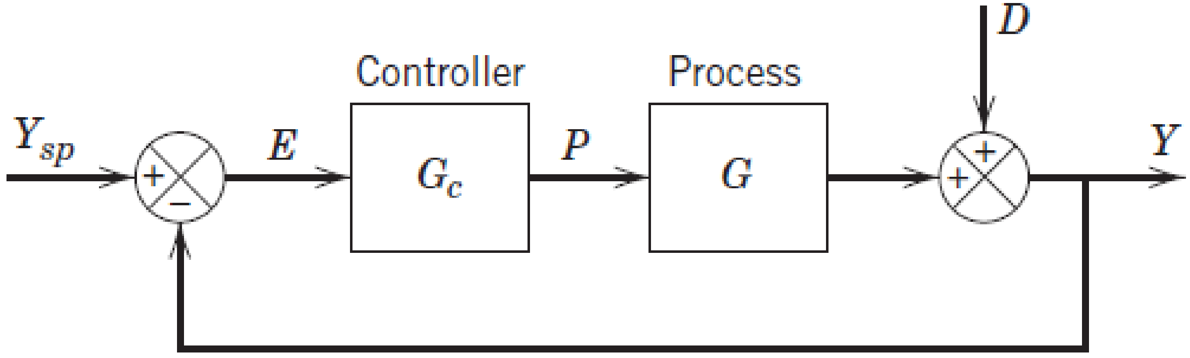
Internal Model Control

- A more comprehensive model-based design method, *Internal Model Control* (*IMC*), was developed by Morari and coworkers (Garcia and Morari, 1982; Rivera et al., 1986).
- The IMC method, like the DS method, is based on an assumed process model and leads to analytical expressions for the controller settings.

- These two design methods are closely related and produce identical controllers if the design parameters are specified in a consistent manner.
- However, the IMC approach has the advantage that it allows model uncertainty and tradeoffs between performance and robustness to be considered in a more systematic fashion.

Internal Model Control (IMC)

Consider the conventional FBC with unmeasured disturbance



It is observed from the block diagram

$$Y = PG + D \qquad (7.5)$$

Internal Model Control (IMC)

- If the plant model $\tilde{G}$ is available, the unmeasured disturbance can be estimated from

$$\tilde{D} = Y - P\tilde{G} \qquad (7.6)$$

- Rearranging (7.6)

$$P = \frac{1}{\tilde{G}}\left(Y - \tilde{D}\right) \qquad (7.7)$$

- Assuming ideal controller where $Y = Y_{sp}$

$$P = \frac{1}{\tilde{G}}\left(Y_{sp} - \tilde{D}\right) \qquad (7.8)$$

Internal Model Control (IMC)

- Defining an internal model control (G_{IMC}) by

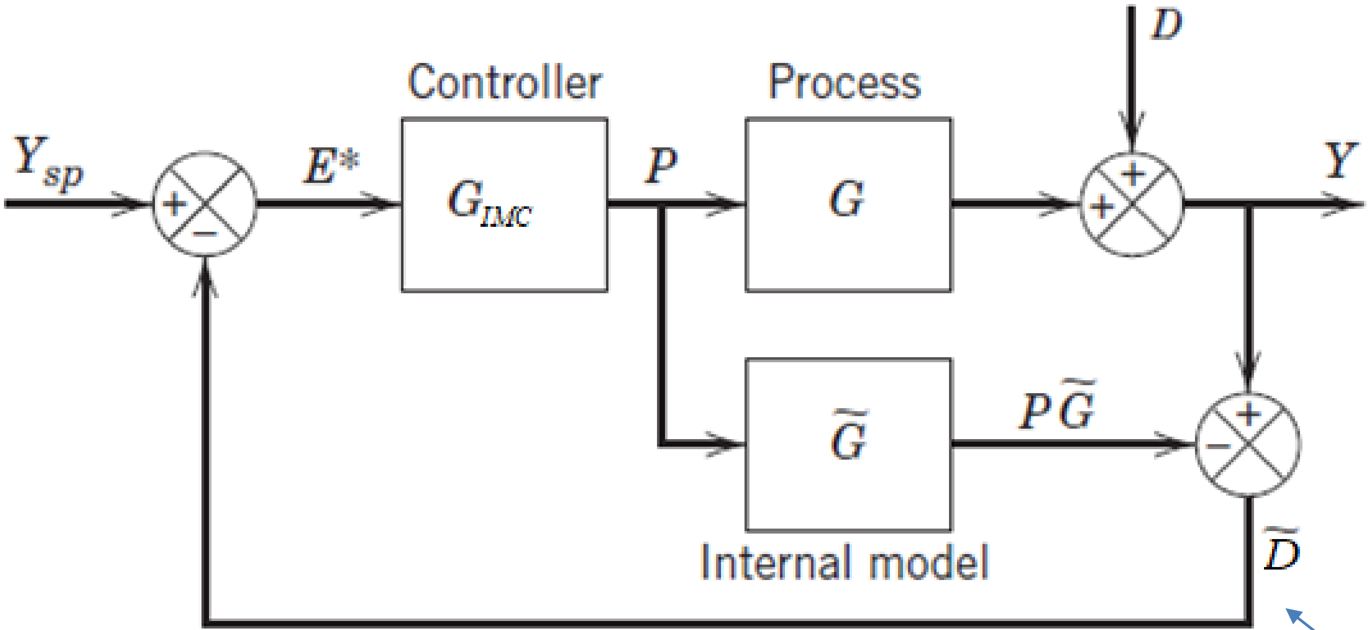
$$G_{IMC} = \frac{1}{\tilde{\tilde{G}}} \qquad (7.9)$$

- Using (7.9) in (7.8)

$$\boxed{P = G_{IMC}\left(Y_{sp} - \tilde{D}\right)} \qquad (7.10)$$

Internal Model Control (IMC)

- The internal model control can be implemented as shown by the block diagram below



See Eq. (7.6)

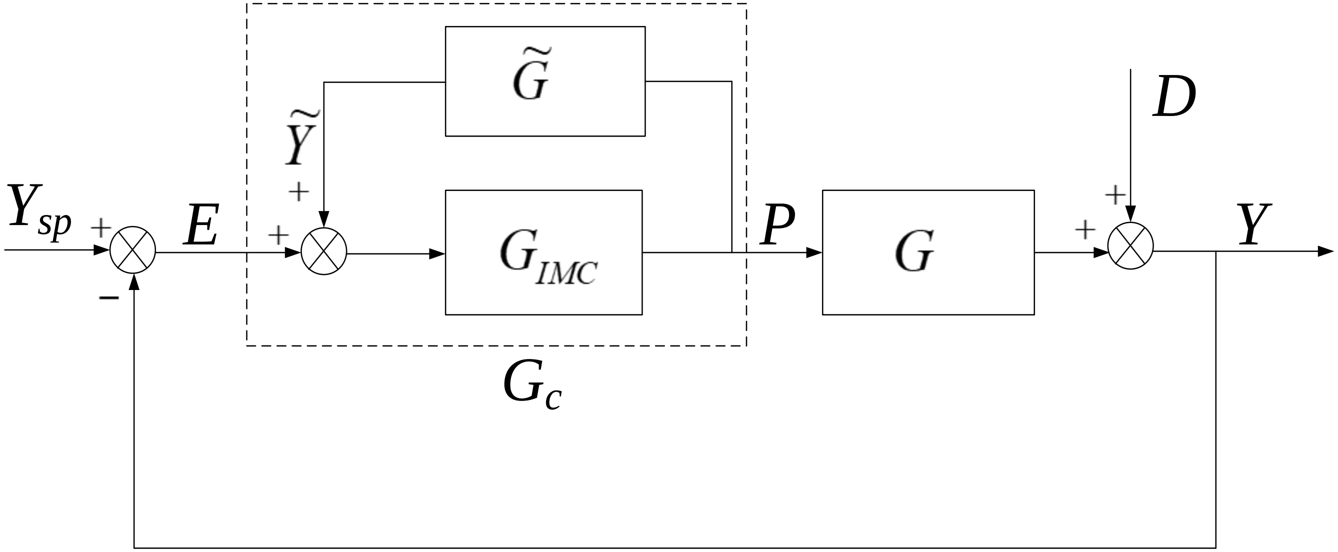
$$\tilde{D} = Y - P\tilde{G}$$

Internal Model Control (IMC)

- From the above block diagram we can derive

$$Y = \frac{G_{IMC}G}{1 + G_{IMC}G}Y_{sp} + \frac{G_{IMC}G}{1 + G_{IMC}G}\tilde{Y} + \frac{1}{1 + G_{IMC}G}D \qquad (7.11)$$

- Eq. (7.11) can be represented by the following equivalent block diagram



Internal Model Control (IMC)

- From the last block diagram the relationship between conventional FBC and IMC can be derived

$$EG_c = (E + P\tilde{G})G_{IMC}$$

$$P = EG_c$$

$$EG_c = (E + EG_c\tilde{G})G_{IMC}$$

$$G_c = \frac{G_{IMC}}{1 - G_{IMC}\tilde{G}}$$

Internal Model Control (IMC)

The IMC controller is designed in two steps:

Step 1. The process model is factored as

$$\tilde{G} = \tilde{G}_+ \tilde{G}_- \qquad (7.12)$$

Where $\tilde{G}_+$ contains any time delays and right-half plane zeros. In addition $\tilde{G}_+$ is required to have a steady-state gain equal to one in order to ensure that the two factors in Eq. (7.12) are unique.

Internal Model Control (IMC)

- **Step 2.** The IMC controller is specified as

$$G_{IMC} = \frac{1}{\tilde{G}_{-}} f$$

where *f* is a *low-pass filter* with a steady-state gain of one. It typically has the form

$$f = \frac{1}{(\tau_c s + 1)^n}$$

n is selected so that the controller is physically realizable and the desired response is obtained.

Example 7.3

For a general first order process and a first order filter derive the IMC controller and the equivalent FBC.

$$\tilde{G} = \frac{K}{\tau s + 1}$$

$$F = \frac{1}{\tau_c s + 1}$$ Filter

- Solution

$$G_{IMC} = \frac{(\tau s + 1)}{K}\left(\frac{1}{\tau_c s + 1}\right)$$

$$G_{IMC} = \frac{1}{K}\left(\frac{\tau s + 1}{\tau_c s + 1}\right)$$

- The equivalent FBC

$$G_c = \frac{G_{IMC}}{1 - G_{IMC}\tilde{G}}$$

Internal Model Control (IMC)

- The equivalent FBC is given by

$$G_C = \frac{\frac{1}{K}\left(\frac{\tau s + 1}{\tau_c s + 1}\right)}{1 - \frac{1}{K_p}\left(\frac{\tau s + 1}{\tau_c s + 1}\right)\left(\frac{K}{\tau s + 1}\right)}$$

- After simplification and rearranging we get

$$G_c = \frac{\tau}{K_p \tau_c s}\left(1 + \frac{1}{\tau s}\right)$$

- This is a PI controller with $K_c = \tau/(K_p \tau_c)$ and $\tau_I = \tau$

Internal Model Control (IMC)

Exercise 7.4

For a process that can be approximated a first order plus time delay model derive the IMC controller and the equivalent FBC. Use first order $\acute{P}$ade approximation.

$$\tilde{G} = \frac{Ke^{-\theta s}}{\tau s + 1}$$

$$f = \frac{1}{\tau_c s + 1}$$ Filter