International Master's Programs of Chemical Engineering in the Graduate School of Engineering, Kyushu University (Academic Year from October, 2025)

Subject： Process Control（1 sheet）

1. (50 points)

Consider the liquid-level control in which a liquid is supplied to the tank at a volumetric flow rate F_1 and flows out from the tank at a constant volumetric flow rate F_2 as shown in Fig.1. The cross-sectional area of the tank A is 2 m^2. As the manipulated variable we can use the inlet flow rate F_1. Initially, the system is at steady state with rate $F_1 = F_2 = 1$ m^3 min^{-1} and liquid level L at 2 m. Assume a proportional controller with $K_c = 4$ and that the transfer functions for the measuring device and control valve are equal to unity. Also, time is denoted by t [min], and the liquid density ρ [kg m^{-3}] is constant. Answer the following questions.

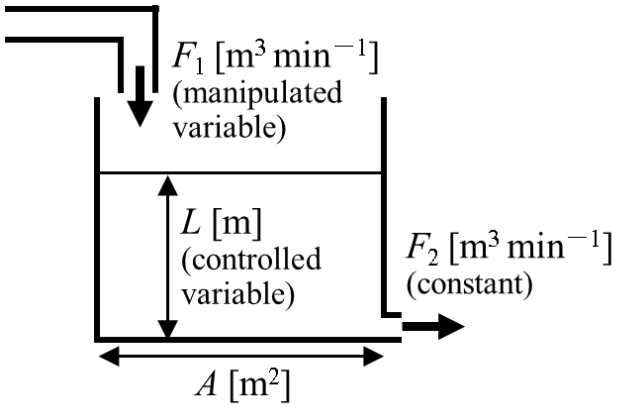

Fig.1 Target system with liquid-level control

(1.1) Derive the differential equation that expresses the dynamic characteristics of the storage tank.

(1.2) Derive the transfer function G_p (s) between F_1 and L.

(1.3) Show the block diagram for the liquid-level control system. Also, derive the loop transfer function of the feedback control system.

(1.4) Prove this feedback control system has stability.

(1.5) Compute the closed-loop response to a unit step increase in the desired set point.

(1.6) At $t = 0$, the desired set point of L is changed from 2 m to 4 m. Draw the graph of the relationship between time and L.

(1.7) This feedback control system has proportional controller (P-controller). Describe advantage and disadvantage of this P-controller. Also, describe the difference between the proportional controller and the proportional-integral control.