Cascade Control

Dr. Ir. Yeffry Handoko Putra, M.T

Session Outlines & Objectives

Outlines

- A process challenge - improve performance
- Cascade design rules
- Good features and application guidelines
- Several process examples

Objectives

- Identify situations for which cascade is a good control enhancement
- Design cascade control using the five design rules
- Apply the tuning procedure to cascade control

Cascade Control Motivations

- The feedback controller can respond only after some changes appear in measurement of PV
- If a secondary measurement can recognize the disturbance and have causal relationship with actuator, then the disturbance can be handled more efficiently

Feedback Control of Jacketed Tank Reactor (JTR)

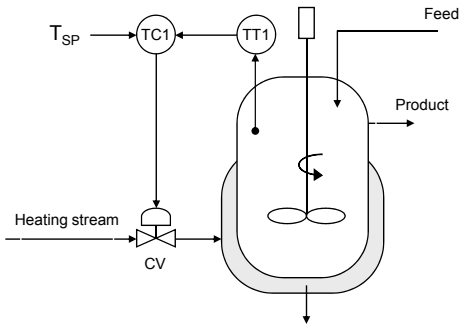
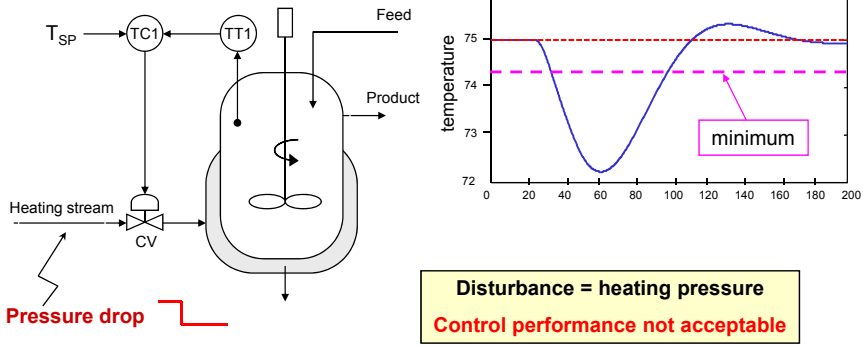


Fig. Direct feedback control of temperature in a jacketed tank reactor

Feedback Control Response of JTR Due to the Pressure Drop



Disturbance = heating pressure

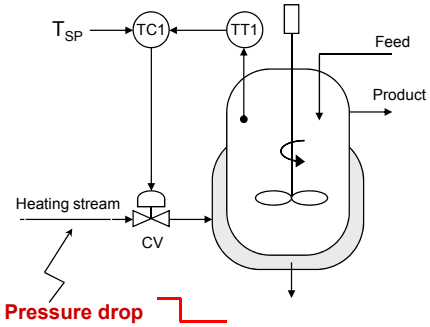
Control performance not acceptable

Fig. Direct feedback control response of temperature in a jacketed tank reactor in the present of pressure drop of the heating stream

More on JTR (1)

Let's think about the process behavior…

- Causal relationship from P disturbance to T (without control)
- What measurable effect always occurs when P changes?



v (valve) → ??? → Q → TC

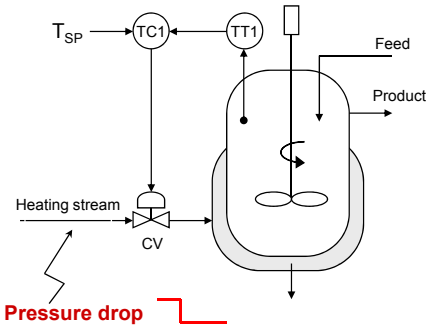
↑

P

More on JTR (2)

Let's think about the process behavior…

If we can maintain this variable approximately constant, can we reduce the effect of the disturbance?



v (valve) → ??? → Q → TC

↑

P

Control of Heating Water Flow of JTR

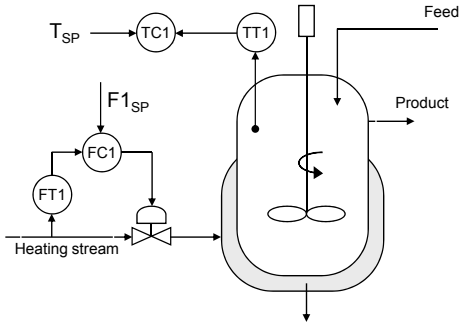


Fig. Control of heating water flow

Cascade Control I of JTR

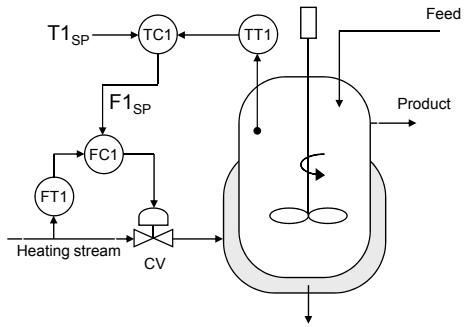


Fig. Cascade control of temperature using flow control loop as the inner loop

Block Diagram of Cascade Control I of JTR

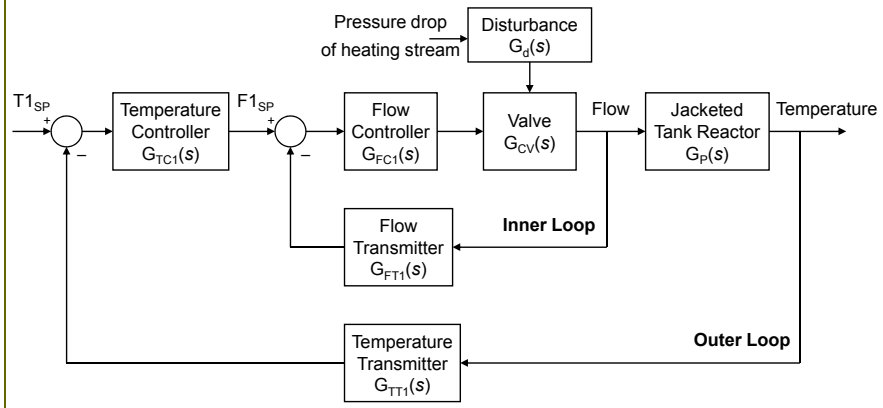
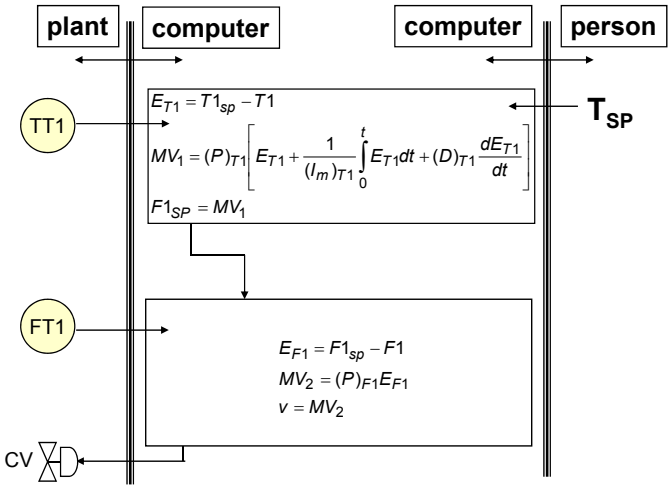
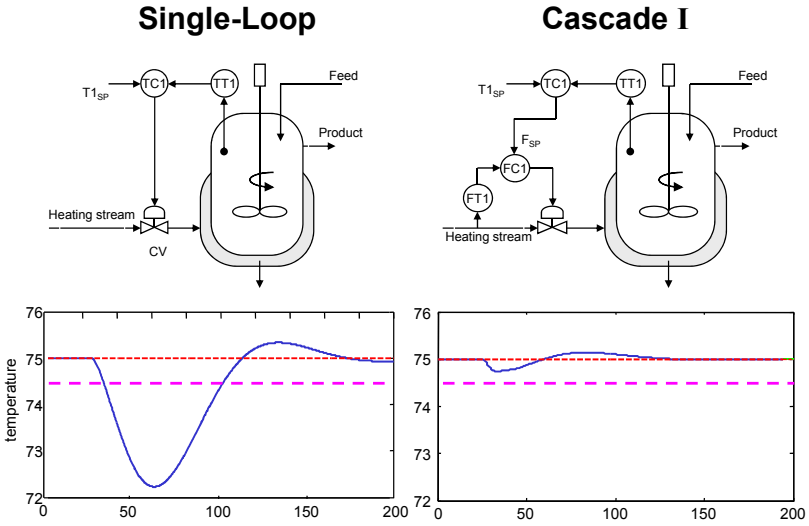


Fig. Block diagram of cascade control of temperature using flow control loop as the inner loop

Computation of Cascade Control I



Single-loop vs. Cascade Control I



Cascade Design Criteria

Cascade is desired when

1. Single-loop performance unacceptable
2. A measured variable is available

A secondary variable must

3. Indicate the occurrence of an important disturbance
4. Have a causal relationship from valve to secondary
5. Have a faster response than the primary (3 times or greater)

Feedback Control Response of JTR Due to the Temperature Drop

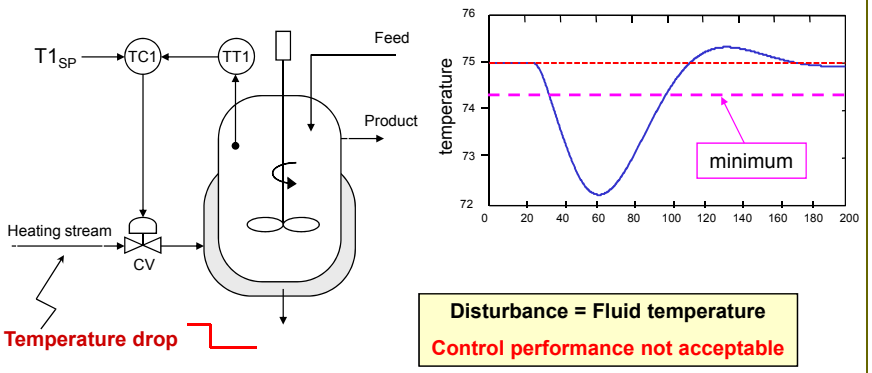
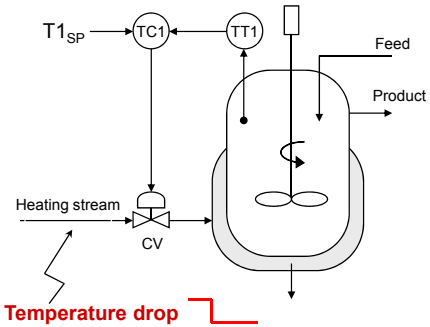


Fig. Direct feedback control response of temperature in a jacketed tank reactor in the present of fluid temperature drop of the heating stream

More on JTR (3)

Let's think about the process behavior…

- Causal relationship from T disturbance to T (without control)
- What measurable effect always occurs when T changes?



v (valve) → ??? → Q → TC

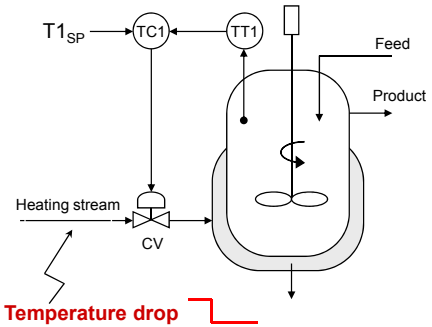
↑

T

More on JTR (4)

Let's think about the process behavior…

If we can maintain this variable approximately constant, can we reduce the effect of the disturbance?



v (valve) → ??? → Q → TC

↑

T

Control of Jacket Temperature of JTR

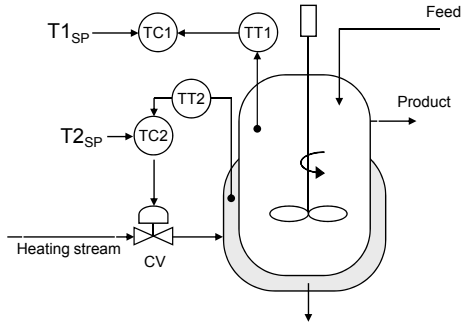


Fig. Control of jacket temperature

Cascade Control II of JTR

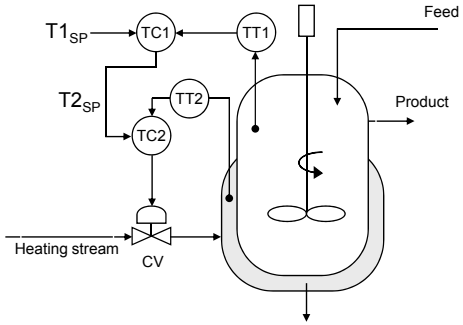


Fig. Cascade control of temperature using jacket temperature control loop as the inner loop

Block Diagram of Cascade Control II of JTR

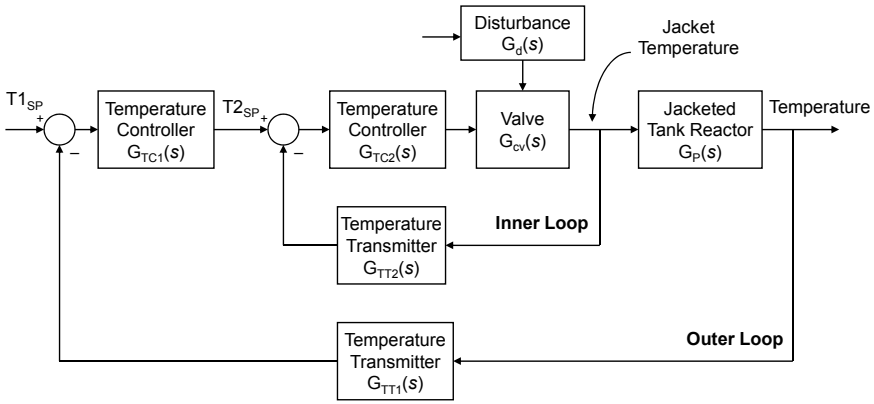
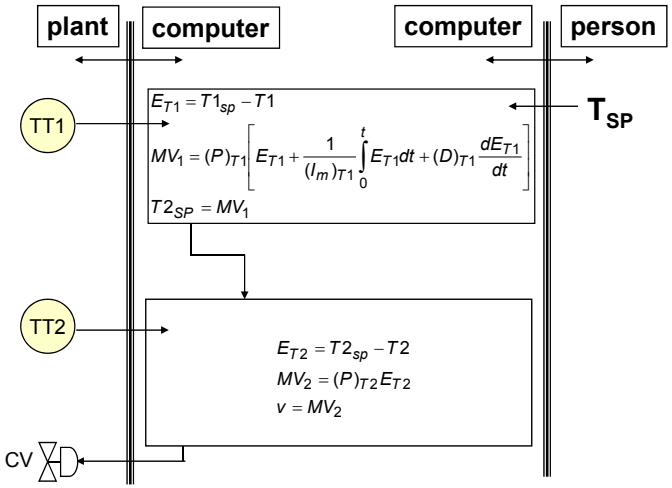


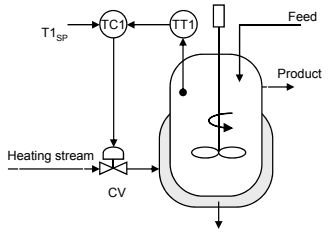
Fig. Block diagram of cascade control of temperature using jacket temperature control loop as the inner loop

Computation of Cascade Control II

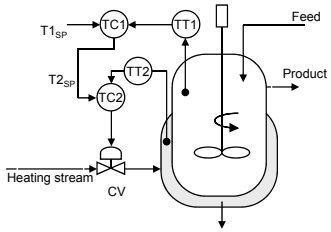


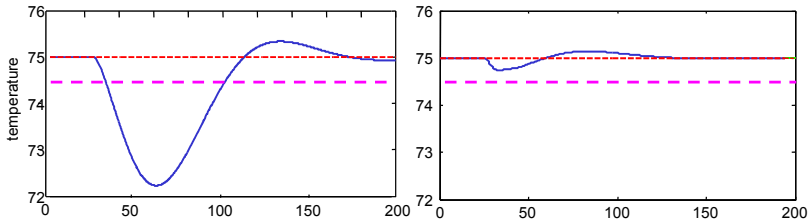
Single-loop vs. Cascade Control II

Single-Loop



Cascade II





Cascade Control III of JTR

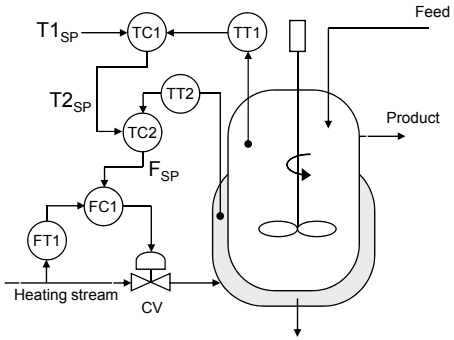


Fig. Double cascade control with flow control as the innermost controller and JTR temperature loop as the outermost controller

Cascade Advantages & Disadvantages

Advantages

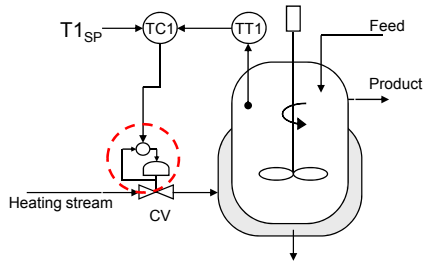
- Large improvement in performance when the secondary is much faster than primary
- Simple technology with PID algorithms
- Use of feedback at all levels. Primary has zero offset for "step-like" disturbance

Disadvantages

- Requires more instrumentation than the equivalent single-loop control
- More complex structure

Special Note on Cascade Control

- Does cascade apply to instrumentation? Yes, a valve positioner is a <u>secondary</u> that reduces effects of friction!!



Valve positioner: Measures the stem position and adjusts the air pressure to (closely) achieve the desired position. This is located at the valve

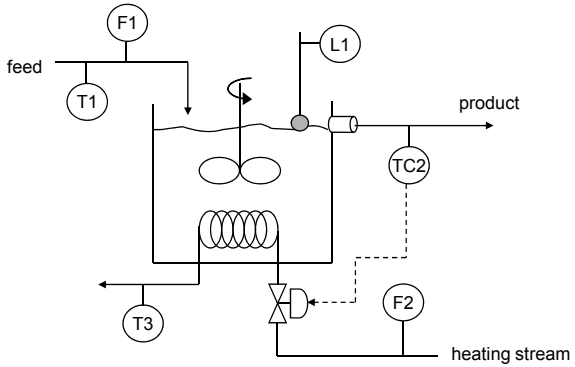
Fig. Cascade control of valve stem position using valve positioner

Tuning of Cascade Controller

- Tune the innermost loop first. Set the above loops to manual
  - Conduct test and tune it
    - Remove integral and derivative actions from the innermost and tune it, aiming for tight control
      - Absence of derivative avoids excessive activity of the **slave loop**
      - Overall integral action to remove offset in the tank temperature is already provided by the master controller
- …
- When tuning the master loop, place the inner loops in automatic, and tune in the normal way
  - Note that the slave loop now becomes part of the master loop that you are tuning at the outermost loop
  - Conduct test and tune it
    - Use integral action to remove offset
    - Use derivative action if necessary

Classroom Exercise

- Evaluate cascade control for every possible disturbances in the heating medium inlet temperature. You may add sensors but make no other changes to the equipment



Session Summary

- Cascade control can be used to improve control system performance due to disturbance
- Some precautions must be carefully handled to implemented cascade control successfully