**PID Control for Single-Heater Temperature System**

Group No.8, Obinna Ndubuisi

Mechanical and Mechatronics Engineering Department

Southern Illinois University Edwardsville

Edwardsville, IL, USA

**Introduction**

This project focuses on developing a temperature control system using a PID controller. The system utilizes a heater to regulate temperature in a thermal system. The key objectives include:

* Characterizing the system in open-loop mode.
* Developing a mathematical model.
* Designing and implementing a PID controller to improve performance.

MATLAB's Control System Designer was employed for controller tuning and performance evaluation.

**Open-loop Characterization**

**Experimental Results**

An open-loop step test was conducted with the heater input set to 80% power. The temperature response was recorded, and the following parameters were determined:

* **Initial Temperature (T0)**: 21.75°C
* **Steady-State Temperature (Tf)**: 32.06°C
* **Dead Time (θ)**: 2 seconds
* **Time Constant (τ)**: 42.2 seconds
* **System Gain (K)**:

**Open-Loop Graph**

A graph of a graph of a number of data

Description automatically generated with medium confidence

**Modeling**

**Governing Equations**

The system dynamics are modeled as a first-order plus dead time (FOPDT) system:

**Parameter Validation**

The experimental data was compared with the FOPDT model, showing good alignment.

**Simulation**

The FOPDT model was validated by comparing its response to experimental data. MATLAB was used to simulate the step response, and the results matched closely with the observed behavior, confirming the accuracy of the derived parameters.

A graph showing the temperature of a person

Description automatically generated with medium confidence

**Control Design and Implementation**

* **Steady-State Error**: 1 – 0.913 = 0.087

A screenshot of a computer

Description automatically generated

**Controller Design**

Using MATLAB's Control System Designer, a PID controller was designed to achieve:

* Fast response.
* Minimal overshoot.
* Steady-state error elimination.

**Controller Transfer Function**

**Closed-Loop System**

clc; clear all; close all;

% System parameters

K = 0.132625 \* 80; % Gain (from experimental data)

tau = 42.2; % Time constant (s)

theta = 2; % Dead time (s)

% Transfer function without delay (approximate for Control Designer)

num = [K];

den = [tau, 1];

Gs = tf(num, den);

controlSystemDesigner(Gs);

The closed-loop transfer function is:

**Performance Metrics**

The closed-loop step response was evaluated:

* **Rise Time**: 0.5014 seconds
* **Settling Time**: 3.1598 seconds
* **Overshoot**: 17.93%
* **Steady-State Error**: 0%

A screenshot of a computer

Description automatically generated

A screenshot of a computer

Description automatically generated

A close-up of a person

Description automatically generated

**Future Directions**

This platform can be adapted for various applications, including:

1. Real-time process control in manufacturing.
2. Advanced control strategies, such as adaptive or model predictive control.
3. Educational purposes for studying system dynamics and control.