

Design a Temperature controller for Direct

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Melt Pool Temperature Control

Introduction
The input signal for the system is the temperature, which is regulated by the controller through voltage variation. To obtain real-time temperature information, we must subtract the desired voltage from the current temperature of the melt pool. Two types of pyrometers can be used to measure the current temperature.

Input Signal
One of the pyrometer types measures temperature by detecting the thermo-electric electromotive force generated by the temperature gradient at different ends, which is then converted into electrical signals for temperature measurement.

Non-Contact
The second pyrometer type uses infrared radiation to detect temperature. According to Planck's law, the energy emitted by a body can be expressed as follows:

$$L_{\lambda}(T_b, \lambda) = \frac{C_1}{\lambda^5 (e^{C_2/(\lambda T_b)} - 1)}$$

where C_1 is the spectral radiance of the body at wavelength λ and temperature T . C_2 is Planck's constant. λ is the speed of light. C_1 is Boltzmann's constant. By knowing the emissivity of the material (L_{λ}), we can calculate the thermal signal (T_b) using the measured radiance values from the pyrometer.

Output Signal
The output signal is voltage. After setting a desired temperature, starting from 0, the input voltage into this control system will start to modify itself generation by generation. Note that the voltage is the attribute that affects the temperature of the melt pool.

Control Parameters
The dynamic model is identified using second order state-space model with the form

$$\begin{aligned} x(k+1) &= Ax(k) + Bu(k) \\ y(k) &= Cx(k) + Du(k) \end{aligned}$$

-x: state vectors
-y: output, temperature
-u: input, driving voltage of laser power

-A, B, C, and D are the matrices defining the state space model, defined as

$$\begin{aligned} A &= \begin{bmatrix} 0.98587 & -0.01655 & 0.016227 & 0.00011625; \\ 0.019185 & 0.96187 & 0.21983 & 0.036113; \\ 0.021373 & 0.02255 & 0.33864 & -0.72384; \\ 0.0075648 & 0.028816 & -0.42782 & -0.65477 \end{bmatrix}; \\ B &= \begin{bmatrix} 0.0085367; \\ -0.015565; \\ 0.027322; \\ -0.022222 \end{bmatrix}; \\ C &= \begin{bmatrix} 1.647648 & 1.26713 & -330.72 & -17.855 \end{bmatrix}; \\ D &= 0; \end{aligned}$$

Control Process
The control system design is based on a feedforward control loop. The first step is to generate a voltage-temperature lookup table using the following design diagram.

Since every voltage has its unique temperature output, when we get a temperature output, we can inversely find the voltage input.

For example, when we have 1.42V, the temperature output is 2191.2°C, vice versa.

To start with temperature controller, we first need to set the temperature we desire into the control model. The initial voltage state is set as 0. The figure below is the control diagram we build.

Conclusion
DLD has a bright and wide application scenarios in the future. With feedforward control system, the DLD will self-correct and have less flaws and defects on the produced parts. This poster shows a possible method of achieving it.

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