KONTROL SUHU DAN KECEPATAN ALIRAN AIR PADA MESIN TERAPI KAKI BERBASIS PID DIGITAL

ABSTRAK

Sistem kendali suhu dan kecepatan aliran air pada mesin terapi kaki merupakan aspek penting untuk memastikan kenyamanan dan efektivitas terapi *hidrotermal*. Sistem ini dirancang untuk menjaga suhu dan aliran air tetap stabil pada nilai setpoint yang diinginkan. Salah satu metode efektif yang digunakan adalah kontroler *Proportional Integral Derivative* (PID) digital, yaitu algoritma umpan balik yang bekerja berdasarkan perhitungan error antara setpoint dan kondisi aktual guna menghasilkan sinyal kendali yang optimal. Penelitian ini membahas desain dan implementasi sistem kendali berbasis mikrokontroler Arduino Uno. Sistem menggunakan sensor DS18B20 untuk mengukur suhu air serta keypad ADC untuk memasukkan parameter PID (Kp, Ki, Kd). Tampilan LCD I2C digunakan sebagai antarmuka untuk menampilkan suhu, status sistem, dan laju aliran air secara real time. Pemanas air dikendalikan melalui driver mosfet IRF5305S, sedangkan kecepatan aliran diatur dengan sinyal PWM pada pompa air. Parameter awal PID diperoleh dengan metode *Ziegler-Nichols* (Kp = 12,96; Ti = 1,102 s; Td = 0,2755 s), namun belum menghasilkan kestabilan yang optimal sehingga dilakukan *fine tuning* manual melalui keypad ADC. Nilai hasil tuning ditetapkan Kp = 30,03; Ki = 6,51; Kd = 5,2779. Metode *Cohen-Coon* juga digunakan sebagai pembanding untuk mendapatkan karakteristik sistem yang lebih presisi. Hasil pengujian menunjukkan bahwa suhu air dapat dipertahankan pada setpoint 40°C dengan deviasi ±1,2°C dan laju aliran stabil pada 6,00 L/min. Sistem pemanas memiliki *rise time* 15 detik, *overshoot* 4%, dan *settling time* 30 detik, sedangkan aliran air mencatat *rise time* 83 detik, *overshoot* 2.86%, dan *settling time* 145 detik. Keseluruhan hasil membuktikan sistem bekerja stabil, efisien, dan berpotensi dikembangkan lebih lanjut dalam perangkat terapi digital berbasis mikrokontroler.

Kata Kunci: *Mesin Terapi Kaki, PID Digital, Suhu Air, Kecepatan Aliran, Arduino Uno, Keypad ADC.*

CONTROL OF TEMPERATURE AND WATER FLOW RATE IN A FOOT THERAPY MACHINE BASED ON DIGITAL PID

ABSTRACT

The temperature and water flow rate control system in a foot therapy machine is an essential aspect to ensure comfort and effectiveness during hydrothermal therapy. The system is designed to maintain both temperature and flow rate at the desired setpoint. One effective method employed is the Proportional Integral Derivative (PID) digital controller, a feedback algorithm that operates by calculating the error between the setpoint and the actual condition to generate optimal control signals. This study presents the design and implementation of a control system using an Arduino Uno microcontroller. The system utilizes a DS18B20 sensor to measure water temperature and an ADC keypad to manually input PID parameters (Kp, Ki, Kd). An I2C LCD serves as the interface to display real-time temperature, system status, and water flow rate. The water heater is regulated via an IRF5305S MOSFET driver, while flow rate control is achieved through PWM signals to the DC water pump. Initial PID parameters were determined using the Ziegler-Nichols method (Kp = 12.96; Ti = 1.102 s; Td = 0.2755 s). However, the results did not yield optimal stability; therefore, fine tuning was carried out manually via the ADC keypad. The final tuned values were Kp = 30.03, Ki = 6.51, and Kd = 5.2779. The Cohen-Coon method was also applied as a comparison to approach more precise system characteristics. Experimental results demonstrated that the system could maintain the water temperature at a 40°C setpoint with a ±1.2°C deviation, while stabilizing water flow at 6.00 L/min. The heating system achieved a rise time of 15 seconds, maximum overshoot of 4%, and settling time of 30 seconds. Meanwhile, the flow control system recorded a rise time of 83 seconds, overshoot of 2.86%, and settling time of 145 seconds. These findings confirm that the system operates stably and efficiently, and has strong potential for further development as a microcontroller-based digital therapy device.

Keywords: *Foot Therapy Machine, Digital PID, Water Temperature, Flow Rate, Arduino Uno, ADC Keypad.*