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Temperature and Water Level Controlled Steam Therapy Equipment

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***Abstract*— Steam Therapy is a treatment method used extensively in the healthcare industry. Steam has numerous benefits which is why it is used in the healthcare industry. With the context of our project, we are focusing on the steam therapy used mainly by the physiotherapist for the treatment. There exists a steam therapy equipment which is used for the treatment, but is not user friendly. The current equipment does not consist of temperature control, water level indication and auto power on and off, because of which one needs to manually look after it. To make it more user friendly with less human intervention, we propose to develop a steam therapy equipment. We plan on adding various features to the existing model. The features are temperature control and water level indication. Our focus is to mainly remove human intervention as much as possible and make the equipment as smart as possible. To implement the prototyping of the above we have considered the ATmega328p microcontroller, DS18B20 as the temperature sensor and a Force sensor. Hence, to tackle the issues faced by the physiotherapist we plan to devise this model.**

***Keywords*—temperature control, water level indicator, microcontroller, force sensor**

I. Introduction

Steam has been one of the oldest remedies for many health issues. Steam bathing is a very old custom that is practiced by many cultures throughout the world. Steam baths and hot springs were popular among ancient Greeks and Romans. In India, steam therapy has become a very common practice. Workout recover, lowering the join stiffness and relaxation are few of many health benefits of Steam Therapy. The existing Steam Therapy Equipment has a few issues which keeps it below par from becoming more efficient and user friendly.

In the modern wellness landscape, the increasing popularity of steam therapy has led to a diverse range of materials and products in the market, enhancing the overall experience. Steam rooms and saunas, constructed with materials like ceramic tiles, glass, and specialty woods such as cedar, are readily available. These materials not only enhance the space aesthetically but also contribute to maintaining optimal temperature and humidity levels. For those seeking therapeutic benefits at home, portable steam generators offer a cost-effective solution, allowing individuals to create their own steam environment. Additionally, the market offers various essential oils, herbal blends, and aroma-infused steam tablets that can be added to the steam, enhancing the therapeutic experience and catering to individual preferences. As the demand for steam therapy continues to grow, innovations in materials and products contribute to making this ancient practice accessible and customizable for individuals seeking relaxation, respiratory relief, and overall well-being.

The growing interest in steam therapy has led to the development of diverse approaches and techniques, providing individuals with a range of options to meet specific needs and preferences. Traditional steam rooms and saunas are widely acknowledged, with dry saunas using heated rocks to generate steam, creating a dry and intense heat, while wet saunas maintain a milder experience with lower temperature and higher humidity. Infrared saunas, using infrared light for deeper heat penetration, have gained popularity.

For a portable and personalized experience, steam showers and steam cabinets are available, allowing individuals to enjoy steam therapy in the comfort of their homes. These units often come equipped with adjustable temperature controls, timers, and built-in aromatherapy options.

In the realm of DIY home remedies, steam inhalation remains a simple and effective method. Individuals can inhale steam by leaning over a bowl of hot water infused with essential oils or herbs, providing respiratory relief and relaxation. Steam therapy also extends to facial steamers designed to cleanse the skin and open up pores for a healthy complexion.

As the understanding of the therapeutic benefits of steam grows, the market responds with a diverse array of steam therapy options, offering individuals flexibility in choosing methods that best suit their preferences and lifestyle.

In the expanding market for steam therapy, various specialized equipment caters to different preferences and budgets. Traditional steam rooms and saunas can be installed with varying levels of sophistication, ranging from home kits to custom-built spa installations. The cost of these setups can vary based on factors such as size, materials, and additional features.

For a more accessible at-home experience, portable steam generators provide a cost-effective solution, ranging in price from $100 to $500. Infrared saunas come in different sizes and designs, with prices starting from around $500 for compact models to several thousand dollars for larger, advanced units. Steam showers, combining regular showers with steam therapy, vary in cost based on features, starting at around $1,000 and increasing for more advanced models. For budget-friendly options, facial steamers and handheld steam inhalers are available, ranging from $20 to $100.

It's important to note that these price ranges are approximate, and actual costs may vary based on factors such as brand, features, and local market conditions. As the demand for steam therapy grows, a variety of equipment at different price points ensures individuals can find a suitable option for incorporating this therapeutic practice into their lifestyles.

The technical aspects of steam therapy equipment play a crucial role in ensuring a safe, effective, and enjoyable experience for users. Considerations for steam rooms or saunas include heating elements, ventilation systems, and control mechanisms. High-quality heating elements made of stainless steel ensure durability and efficient heat distribution. Advanced ventilation systems regulate humidity levels and air circulation, preventing discomfort. Temperature and humidity control mechanisms in modern steam rooms and saunas often feature digital control panels for a personalized experience. Steam showers may include digital controls, built-in seating, and aromatherapy dispensers. Facial steamers and handheld inhalers are designed for simplicity, typically with water reservoirs and heating elements, allowing users to customize settings for specific therapeutic benefits.

As consumers explore the market for steam therapy equipment, understanding these technical aspects becomes crucial in making informed choices aligned with individual preferences, budget considerations, and desired health outcomes.

The existing steam therapy equipment device does not have temperature control, water level indicator is not available resulting in the dry running, system does not support auto switching on water level or temperature settings, no system power on and heater on indication, no system display and cannot be operated remotely. Hence, we propose to prototype a system to tackle the issues of the existing steam therapy equipment, in order to reduce the human intervention as much as possible.

We propose to present a model that is temperature and water level controlled, which would further reduce the human intervention for operating the steam therapy equipment.

II. Literature Survey

To design a microcontroller-based temperature controller, was our primary aim, for we which we had to find a temperature sensor, that had high resistivity to heat.

The temperature controller is a system that monitors and controls the temperature of a room or any place under consideration such that if the temperature is higher than required, the system brings the temperature down. Similarly, if the temperature is lower, the system makes it high as required. Temperature controller can be manual or automatic. The former requires full human intervention to operate, while the latter requires little or not at all [1]. The physical and chemical reactions are sensitive to temperature and consequently, temperature control is important in several industrial processes. Using RTD as a sensor, a wide temperature span, ranging from -180°C to 600 °C can be controlled [2]. The Microcontroller-based temperature control has become so important that it acts as benchmark for testing and simulation of sensors for detection and monitoring of temperature automatically [3]. A comprehensive temperature controller for enclosed spaces such as chambers can be implemented by a device that uses pulse width modulation to control independent cooling and heating elements over a broad range of amperages, which minimizes or eliminates temperature overshoot and ensures precise and accurate temperature control [4].

To encapsulate all the sensors used, we decided to create a 3D printed base. The 3D printing materials, PLA or polylactic acid, PETG and ABS were shortlisted for the base case. These were some of the most widely used and easily available filaments. However, just because they are widely available does not imply that they are equally appropriate to every printing task, so we had to choose one single material which fulfilled the specifications required. PLA is one of the easiest materials to print with. When improved durability in a part is demanded, ABS is frequently utilized, but it can be stinky. PETG is a popular material choice for food safety and has excellent material qualities. Printing it, on the other hand, can be a task.

3D printing, unlike other manufacturing processes, being an additive process has emerged as a viable technology for the production of engineering components. The aspects associated with 3D printing such as less material wastage, ease of manufacturing, less human involvement, very less post processing and energy efficiency makes the process sustainable for industrial use [5]. The beginning of the emergence of 3D printing more than 10 years ago, contrary to what some think, however, the interest in it has begun to grow in recent years in a unique manner, in addition, the 3D printers were expensive at first, and could not be obtained easily [6]. 3D printing is an additive manufacturing process in which the entire part of a product is constructed using layer by layer deposition of materials that based on plastic and its derivatives [7]. One of the most popular polymer materials is polylactic acid (PLA); the material that rules the world of desktop 3D printing. The applications of PLA in 3D printing include prototyping, models, DIY projects, artistic objects, household items, low-wear toys, packaging, and biomedical applications. It offers advantages such as simple printing, a wide variety of colors and patterns, and being "biodegradable." It also has some drawbacks, such as being brittle and having weak mechanical properties. The most crucial characteristic of PLA (polylactic acid) material for 3D printing is its widespread use in FDM technology due to its low melting point, lack of toxicity, lack of irritation, and biocompatibility [8]. Another popular polymer for 3D printing is ABS, or acrylonitrile butadiene styrene. ABS is ideal for a variety of applications, including phone covers, high-wear toys, tool handles, automotive trim components, and electrical enclosures due to its good mechanical qualities, such as its impact, heat, chemical, and abrasion resistance. ABS must be printed on a heated print bed with bed glue since it is prone to warping [9]. An increasing popular material for 3D printing is polyethylene terephthalate glycol (PETG), a variation of polyethylene terephthalate (PET). PETG is appropriate for applications, including mechanical parts, printer parts, and protective components since it is flexible,

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strong, and simple to print. However, polyethylene terephthalate glycol (PETG) is prone to dampness and is easily scratched [10].

PLA was the material which we had decided to 3D print our base case with since it is one of the most extensively used materials in desktop 3D printing. Since it can be printed at low temperatures and does not require a heated bed, it is the default filament of choice for most extrusion-based 3D printers. PLA was an excellent choice for our model because it is easy to print, affordable, and produces fragments that can be utilized in a variety of applications. It is also one of the most environmentally friendly filaments available currently on the market. PLA is renewable and biodegradable, derived from crops such as corn and sugarcane, which allows the plastic to give off a sweet aroma during printing.

III. Field Survey

The steam therapy equipment that we were working on was more prevalent in the healthcare industry and was majorly used by the physiotherapist. So, we studied the issues that they were facing while treating their patients using the steam therapy equipment. The survey included questions revolving around the issues faced while operating the machine, how efficient the existing steam therapy equipment is, whether would they like to invest in steam therapy equipment with advanced features, and what would be the usual cost that they would like to incur for a basic steam therapy equipment. The survey was conducted among a few number of physiotherapists through interviews.

The observations from our analysis were that many physiotherapy doctors used steam therapy equipment for treating the patients, the already existing steam therapy equipment was not found to be efficient enough to use and 60% of the users wanted to invest in some advanced features in the equipment whereas the others chose to continue with the basic equipment.

IV. Methodology

Our project's main goal is to implement a microcontroller-based system to regulate and control the temperature during steam therapy sessions without much human intervention.

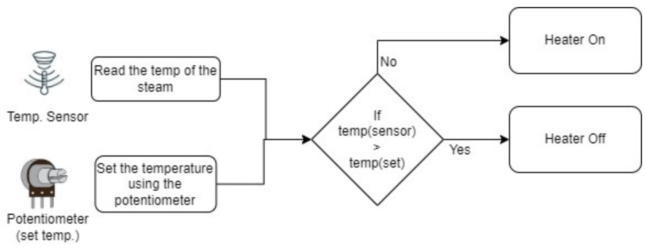

Fig. 1 Block diagram of equipment logic

To accomplish this, we have developed a logical flow (Figure 1) that outlines the steps required for implementing the control system on hardware. This flowchart provides a visual representation of the sequential process involved in achieving the desired temperature and water level regulation. By following this flowchart, we can effectively control the steamers within the steam therapy equipment. The flowchart serves as a guide, depicting the logical progression and decision points necessary to maintain the desired temperature and water level. It acts as a roadmap for the hardware implementation, ensuring that the necessary actions are taken at each stage to control and adjust the temperature and water level accurately. The flowchart aids in streamlining the implementation process and facilitates a clear understanding of the logical flow involved in achieving the project's objectives.

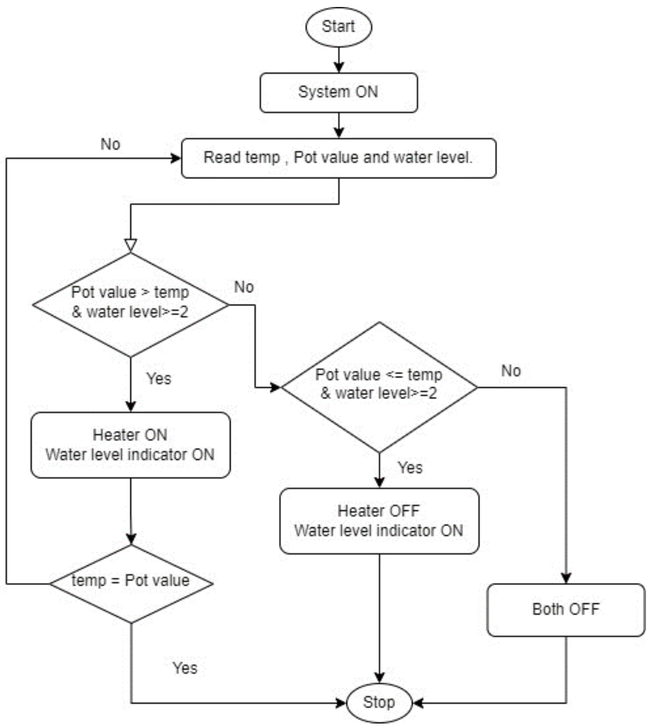

Fig. 2 Workflow diagram of hardware

Figure 2 indicates that upon system activation, a cut-off temperature (set temperature) is set using a potentiometer. The steamer's steam temperature is measured with a temperature sensor, while a pressure sensor is used to measure the water level of the system. Through a comparison of temperature values and water level monitoring, a determination is made regarding the activation or deactivation of the heater. If the heater is deactivated, the steamer's temperature gradually decreases until it falls below the predetermined temperature threshold, at which point the power to the heater is reactivated.

V. Hardware Implementation

The steam therapy apparatus has been enhanced with an automated monitoring and control system to ensure a consistent steam supply. Key features included:

1. Reduction of human involvement through the integration of sensors like the DS18B20 temperature sensor and force sensor.

2. Continuous and on-demand steam delivery facilitated by a proportional solid-state relay and PWM-based control.

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3. Enhanced safety measures against dry heating, achieved by incorporating a force sensor beneath the support legs.

4. The equipment is enclosed in a specially designed case to ensure safety and isolation.

The control system, employing an ATmega328P microcontroller, comprises various components such as a 16*2 LCD, DS18B20 temperature sensor, force sensor, water level indicator, 10k potentiometer for temperature adjustment, proportional solid-state relay, 1.5kW heating element load, control power supply, 230V AC power supply, and LEDs for status indications. These components are intricately interconnected and housed within a designated control box. Analog input is acquired by the microcontroller at regular 500-millisecond intervals.

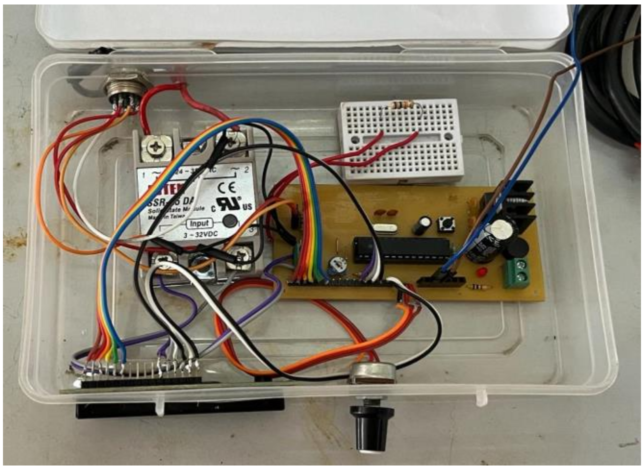

Fig. 3 Hardware implementation from inside

Users manually set the desired temperature within the prescribed range of 35 to 100 degrees Celsius using a 10k potentiometer. The control logic systematically compares the set temperature against the sensor data, thereby instigating temperature control operations. Two distinct cases are contemplated: Case I - where the set temperature exceeds the actual temperature, thereby initiating the steamer to commence heating the water; Case II - where the set temperature is lower, prompting the steamer to deactivate and cease water heating.

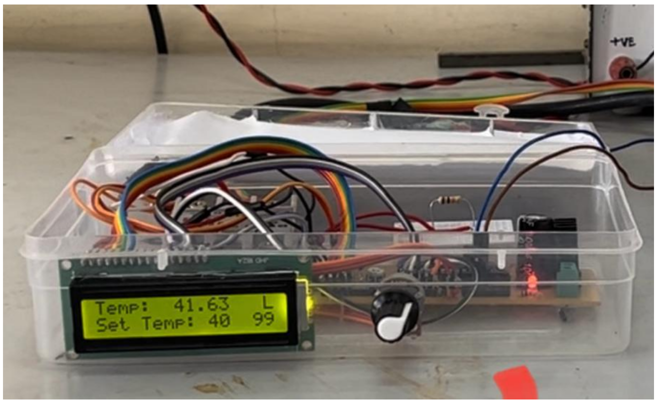

Fig. 4 Hardware implementation from outside

Furthermore, a safety mechanism has been instituted to deactivate power if the water level surpasses 20%, thereby averting potential dry running of the equipment. The LCD cyclically displays pertinent information such as the.

- Set temperature, denoted by variable *Set Temp*, as set by the user with potentiometer
- Current temperature, denoted by variable *Temp*, indicating the temperature of the equipment vessel and
- Water level data, denoted by variable *L*, indicated the water level inside the vessel

LEDs positioned on the control box indicate the water level status (whether it is within the acceptable range or low) and the operational status of the heater.

A Pulse Width Modulation (PWM) pulse output, contingent upon the differential between the set and current temperatures, is conveyed to a proportional solid-state relay (SSR). This SSR governs the power supplied to the heating element, proportionately enhancing power as the temperature differential increases. This design ensures a more expeditious and consistent supply of steam, provided the water level remains above 20%. In the interest of safety, heating operations cease if the water level falls below 20%, irrespective of whether the pre-set temperature has been attained.

VI. Results and Discussion

The project aimed at revamping steam therapy equipment, for steam therapy has yielded significant findings and opened avenues for substantial improvements in patient care and physiotherapy treatment. This section presents the crucial outcomes and delves into their implications for the medical physiotherapy domain.

The following results were observed basis the implementation as present in Figure 5:

a) Performance of Temperature Sensor, DS18B20: The integration of a temperature sensor (DS18B20) has proven highly effective, guaranteeing precise temperature control. The sensor consistently measured and maintained the desired temperature, significantly enhancing the safety and efficacy of treatments

b) Accuracy of Force Sensor for Water Level indication: The water level indicated using a Force Sensor, has successfully fulfilled its role of monitoring water levels inside the therapy equipment. It promptly alerts users when the water level falls below the recommended threshold, thus preventing equipment damage and ensuring a seamless flow of the therapy session

c) Functionality of LCD Screen: The incorporation of an LCD screen has provided real-time updates on temperature and water integrity, streamlining equipment operation for healthcare professionals and patients. This feature not only elevates the user experience but also significantly improves the overall safety and efficiency of the therapy

The results obtained from this project underscore the substantial advantages of the re-engineered therapy equipment.

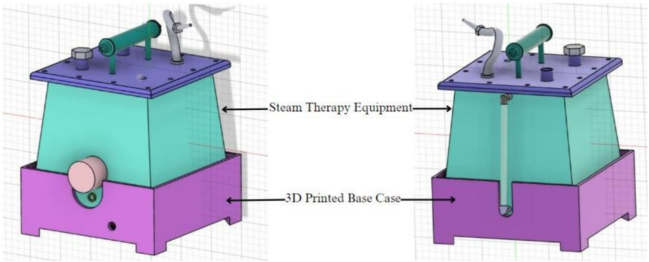

Fig 5. Animated front (image on right) and back (image on left) view of equipment with 3D-Case

The incorporation of a temperature sensor and water level indicator directly addresses critical concerns that pervade the administration of steam therapy.

Foremost among these benefits is the precision and consistency achieved in temperature control. The maintenance of a stable temperature throughout therapy is a paramount factor for ensuring patient safety and optimizing the desired therapeutic outcomes. The temperature sensor facilitates accurate monitoring and adjustments, substantially mitigating the risks of overheating or insufficient heating within the therapy environment. The force sensor used for indicating water level play pivotal role in equipment safety and functionality. By alerting users to low water levels, the equipment proactively safeguards against damage and prevents unwarranted disruptions during treatment. This significantly contributes to the longevity of the therapy equipment, while also guaranteeing that therapy sessions proceed according to plan. The introduction of an LCD screen adds to the overall user-friendliness of the equipment, making it simpler for healthcare professionals to monitor and fine-tune therapy parameters. This innovative feature enhances the overall usability of the equipment, thereby reducing the risk of errors that might arise during the treatment process.

Fig 6. Actual imlementation of equipment with 3D-Case

In summation, the results unequivocally establish that the redesigned therapy equipment introduces substantial advancements to the field of physiotherapy. By enhancing safety, accuracy, and usability, this equipment carries the potential to revolutionize the practice of steam therapy, with direct benefits for both patients and healthcare providers. Subsequent endeavors in this domain should be geared towards further refinements and exploring broader applications of this pioneering technology in the medical arena.

VII. Conclusion

In the ever-evolving landscape of the medical field, innovation is the driving force behind enhanced patient care and therapy modalities. Our project focused on redesigning therapy equipment, particularly in the realm of steam therapy, to ensure more efficient and user-friendly treatment. This endeavor has culminated in a product that not only advances the capabilities of therapy equipment but also improves patient experiences and outcomes.

The enhanced therapy equipment now incorporates critical features to better serve both patients and healthcare professionals. A temperature sensor allows precise temperature measurement, guaranteeing the safety and effectiveness of the treatment. Simultaneously, a water level indicator helps maintain the equipment's optimal performance by monitoring water levels. An LCD screen provides real-time temperature and water integrity updates, enhancing the usability of the equipment.

Our project unfolded across three meticulously executed phases. In Phase 1, we laid the foundation by conducting extensive research, encompassing project-related inquiries, field surveys, and market analysis. This phase provided a comprehensive understanding of the existing landscape and needs within the field of physiotherapy. Phase 2 saw the application of our knowledge as we delved into programming using Atmel Studio 7, connecting each sensor for rigorous testing via simulations. The final phase focused on hardware interfacing, essential modifications, and the creation of a custom 3D-printed casing to house the equipment. Extensive testing ensued to ensure the equipment's reliability and safety.

This project represents a significant step towards improved patient care in the medical field. The redesigned therapy equipment offers a more accurate, reliable, and user-friendly approach to steam therapy. By incorporating cutting-edge technology and adhering to a methodical development process, we've achieved a product that has the potential to transform how physiotherapy is administered, ultimately benefitting both patients and medical professionals. The future holds exciting possibilities as we continue to refine and expand upon this innovative therapy equipment, setting a new standard for the medical industry.

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