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Research Article

A Low Cost Effective Contrast Therapy Using Controlled Peltier Effect

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Abstract

The main objective of this work is to develop an IoT enabled low cost contrast water therapy module, the work make use of the peltier effect to generate the hot and cold water that is stored in the containers, accurate temperature, rapid attainment of the specific temperature and retention of the specific temperature are the most important requirements for the contrast water therapy, these requirements are fulfilled through the reliable sensors and the optimized code in the controller, For different injuries different level of temperatures are maintained through the controller , The use of internet of things makes the module smarter and the history of the treatment gives more inferences to treat the patient better.

Keywords: *Internet of Things, Contrast therapy, Sensors , Peltier Module*

Introduction

In the ancient culture hydrotherapy is one of the basic treatments used in natural medicines which is also called water therapy. The use of water in various forms and in various temperatures can produce different effects on the body system. Contrast Water Therapy (CWT), widely used for the sporting community which is offered to athletes as alternating cold and warm water immersion instead of cryotherapy. Its proof that CWT reduces edema by alternative peripheral vasoconstriction and vasodilation. Other effective CWT treatments may assist athletic recovery from reduced muscle spasm, inflammation, and improved range of motion. However, the exact mechanisms by which CWT may improve athletic recovery have yet to be established effectively by devices. With athletes often having limited time between training and competition, their ability to recover quickly is becoming increasingly important. In recent years development and research of CWT devices have been made to accomplish flexible, streamlined, and treatment options for different users, injuries, surgeries, and diverse stages of rehabilitation. At the same time cost of devices and treatments has higher. Because of this, there is a necessity to develop a low-cost CWT device with effective sustainability, flexible and usage of different treatments.

Existing Methodology

Ice bag and hot bag are widely used treatment tools to changing quickly tissue temperature from hot to cold and back again. This treatment usually achieved with hot and cold water by immersing the whole body or dunking the limbs [1], but the sustainability of hot and cold duration is lesser. Contrast therapy is more effective than thermotherapy and cryotherapy, commonly, flexible hot and cold bags used for contrast water therapy (CWT) treatments [2]. David Schaefer and Richard smith designed a thermal contrast therapy device to provide a sequence of alternating cooling and heating periods to one or more areas of the patient's body through fluid circulating pads. A TCT device consists of a hot fluid source, a cold fluid source, and pumps to circulate treatment pads [3]. The innovative (Med4 elite) dual user recovery system consists of cold, controllable heat, contrast, and compression therapy techniques. This technique tool helps to decrease pain and swelling, reducing opioid consumption, reducing joint and muscle stiffness, and increasing blood flow to the treatment part [4]. Using Equine contrast therapy device, achieve therapeutic tissue temperatures lesser than 15°C and greater than 40°C at different tissue depths relative to the digital flexor tendons and evaluate the time temperature describes during serial heating and cooling cycles [5].

Proposed Methodology

Our proposed method consist of peltier coil which is used as heater and cooler at same time. Due the Peltier effect, electrical current flows through two dissimilar conductors; depending on the direction of current flow, the junction of the two conductors will either absorb or release heat. When the DC source applied to the peltier it act as a heater at one surface and simultaneously act as a cooler in other surface. A typical TEC module comprises of two highly thermally conductive substrates ($A1_2O_3$, AlN, BeO) that serve as Hot/Cold plates. The device is normally attached to the cold side of the TEC module, and a heat sink which is required for enhanced heat dissipation is attached to the hot side. The maximum level of cool and hot is assigned by formula which is given below,

$$Q_1 = (\alpha_p - \alpha_n)\, T_1 - (T_2 - T_1) * (K_p + K_n) - I^2(R_p + R_n)/2$$

Based on this equation, when current rises in Peltier as rises in cooling linearly, but the rise of Joule heating depends on I^2 value. So there is a necessity to analyse the cold and hot water temperature through an experimental setup. The following table gives detailed analyse of cold and hot water temperature with the interval of 10 minutes.

S.NO	Time(minutes)	Cold Water Temperature (T_1)	Hot Water Temperature (T_2)
1	10	30	35
2	20	26	37
3	30	22	41

4	40	18	44
5	50	10	48
6	60	7	50

Table.1. experimental values of hot and cold water temperature.

In this low cost CWT device comprises data processing part of controller, data acquisition part of sensors, peltier, IOT layer with cloud, pumping motors with driver circuit and display unit given in figure 1.

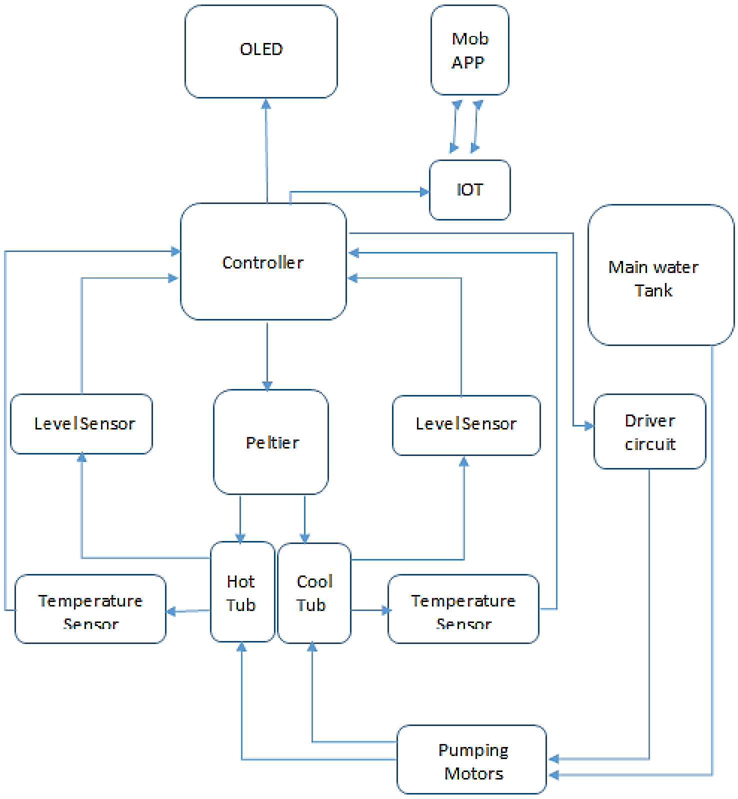


Fig.1. block diagram of proposed method.

At first start with data processing unit of controller connects level sensors and temperature sensors of corresponding hot and cold tub via input ports. Similarly, Peltier, display unit, IOT module and driver circuit connected via output ports.

Level sensors like ultrasonic sensors fixed at the top of both tubs, used to notify the water level and send the information to controller as 8 bit data. Controller sets the water level of tubs through 12volt pumping motors which drains the water from main water tank. Based on this data controller operates the driver circuit to switch on or off the pumping motors.

LM 35 temperature sensor has the range of 0 to 5 volt to measures the temperature of hot and cold water. Controller receives this Analog data to manipulate the temperature of hot and cold water for to increase or to sustain.

Peltier is a thermoelectric module – solid state device need 12 volt nominal voltage to make the one side of module cold while the other side is hot, because, the current flow through the module is reversed the cold side will become the hot side vice versa. Through this property, the specified hot/cold temperature was attained easily in short time period.

Finally controller connected with IOT (internet of things) module ESP 8266 used to upload the analysed information about water level, hot/cold temperature, sustaining period, total duration of therapy into IOT cloud. ESP 8266 is a Wi-Fi module with networking capability has self-contained SOC with an integrated TCP/IP protocol stack, it can give microcontroller access to the Wi-Fi network. Information’s not only shared with IOT and also to OLED (Organic Light Emitting Diode).

OLED is a self-light emitting technology incorporated with SSD1306 driver IC which is used connect the controller through I2C mode. It used to display the two temperature readings of hot and cold water continuously.

Computational Algorithms And Results

An analytical measurements taken between water level (in ml), hot/cold temperature, and time period (in minutes), given in table 2.

S.NO	**Water taken from each tank(ml)**	**Cold water Temp after 1 min T_{c1}**	**Cold water temp After 2 min T_{C2}**	**Cold water temp after 3 min T_{C3}**	**Cold water temp after 4 min T_{C4}**	**Cold water temp after 5 min T_{C5}**	**Hot water Temp after 1 min T_{h1}**	**Hot water temp After 2 min T_{h2}**	**Hot water temp after 3 min T_{h3}**	**Hot water temp after 4 min T_{h4}**	**Hot water temp after 5 min T_{h5}**
1	**50**	**30**	**26**	**22**	**17**	**10**	**35**	**41**	**44**	**48**	**53**
2	**100**	**31**	**26**	**22**	**17**	**12**	**35**	**40**	**43**	**47**	**50**
3	**150**	**33**	**29**	**26**	**19**	**15**	**35**	**39**	**44**	**45**	**47**
4	**200**	**35**	**31**	**28**	**22**	**18**	**35**	**37**	**39**	**43**	**46**
5	**250**	**35**	**32**	**30**	**26**	**21**	**35**	**37**	**40**	**42**	**43**
6	**300**	**35**	**32**	**27**	**25**	**24**	**35**	**37**	**39**	**40**	**42**
7	**350**	**35**	**33**	**31**	**28**	**25**	**35**	**36**	**38**	**39**	**40**
8	**400**	**35**	**32**	**29**	**28**	**27**	**35**	**36**	**36**	**38**	**39**
9	**450**	**35**	**33**	**31**	**30**	**28**	**35**	**36**	**37**	**38**	**38**

Table 2. Analysed values of hot/cold temperature readings for various water levels.

This analytical values are very much useful to find the time period to attain a assigned temperature level. In contrast water therapy treatments different temperatures assigned for different injuries, averagely for hot above 38°C and for cold below 14°C temperatures was assigned.

Initially, by algorithmically CWT treatment duration, hot and cold temperature, water level of both tubs was instructed to controller. Due to this instructions, hot and cold water tub filled by initiated level of water by turning ON the pump motors. Frequently the water level was monitored by level sensor whether the water in reserved level or in brim level and this information uploaded into cloud. Next, the peltier get operated and its timing was uploaded. For every minutes, temperature of both tubs monitored by controller and displayed through OLED and also uploaded into cloud. When the CWT treatment duration time exceeded, peltier get turned OFF by controller and gain the process will be continued for next CWT treatment.

Algorithm:

Step 1:

Initialize the sensors, establish the connections with the cloud

Step 2:

If (water level < reserved level)

{

Turn on the water pump through relay,

While (water level > brim level)

{

Upload the level of water in the tank to the IOT cloud;

}

Turn off the pump ( );

}

Else

Read water level and upload to cloud ( );

Step 3:

Turn on the peltier module
Step 4:
Measure the level of temperature in each tank & upload the same to cloud
Step 5:
Start timer and count the retention time and upload the same to the cloud
Step 6:
if time (= = upper extreme time)
Stop peltier ( );
Repeat step 2 to step 6

Results:

The status of peltier coil shown in figure. It indicates ON condition of peltire at particular time for CWT treatment.

Fig.2. ON status of peltier

The updated water level of both tubs is shown in figure 3 and 4. Type of treatment specifies the level of water which is fed to controller before starting the treatment.

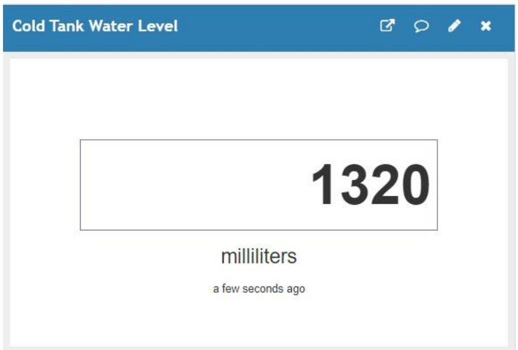


Fig.3 cold tub water level in ml

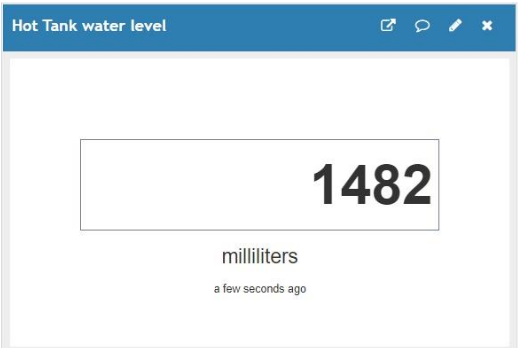


Fig.4 Hot tub water level in ml

A constant hot/cold water temperature duration result is shown in figure 5 & 6. Experimental output of hot and cold water temperature retention time in minutes is uploaded into cloud.

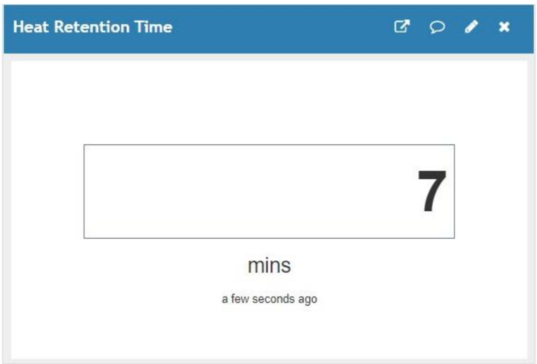


Fig.5 Duration of hot water temperature

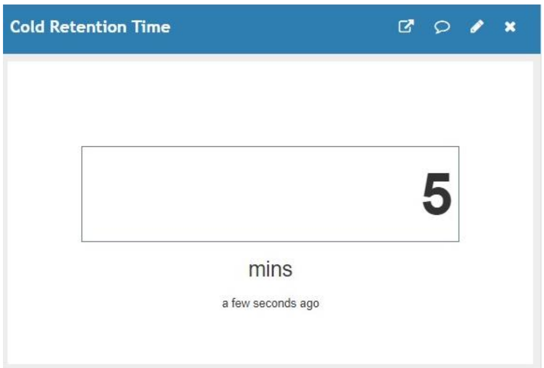


fig.6. Duration of cold water temperature

Figure 7 and 8 illustrates the readings of hot and cold temperatures with respect to the time.

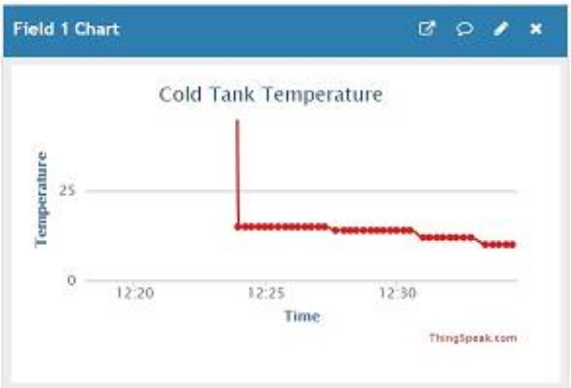


Fig.7. Temperature level of cold tub

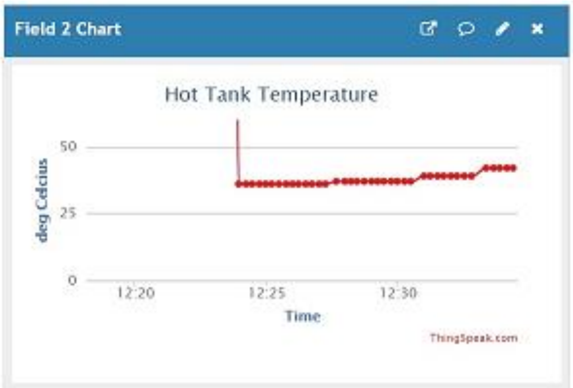


Fig.8. Temperature level of hot tub

Figure 9a, 9b, 9c and 9d shows the series of cold temperature readings of every degree Celsius with respect to the time.

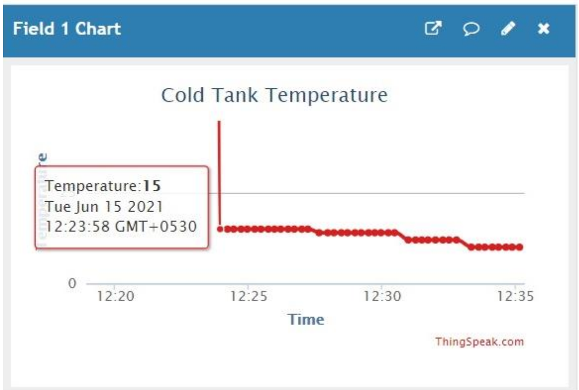


Fig.9.a. cold temperature at 15°C

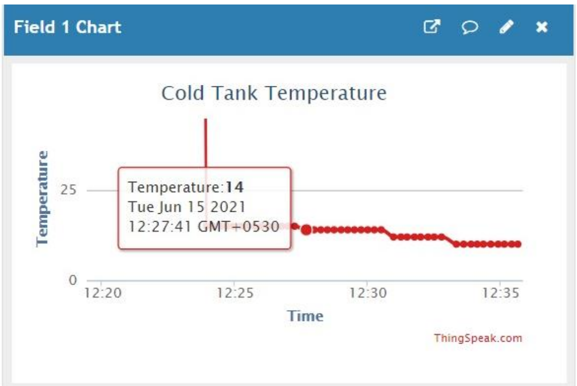
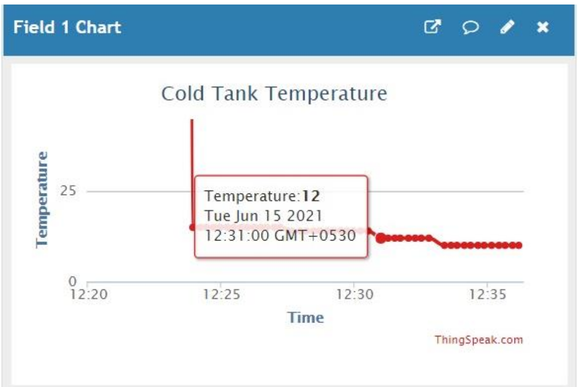


Fig.9.b cold temperature at 14°C

In this experiment the feeded cold temperature is 10°C, so that the proof of this was shown in figure 9d.



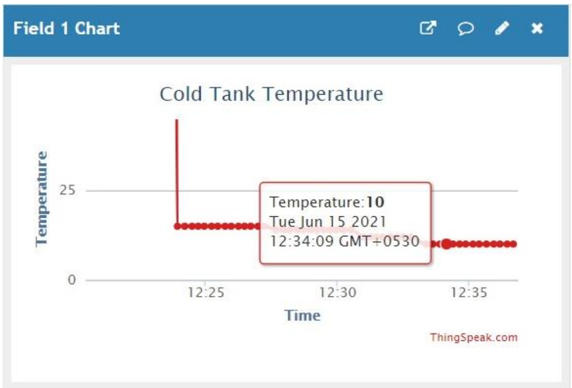
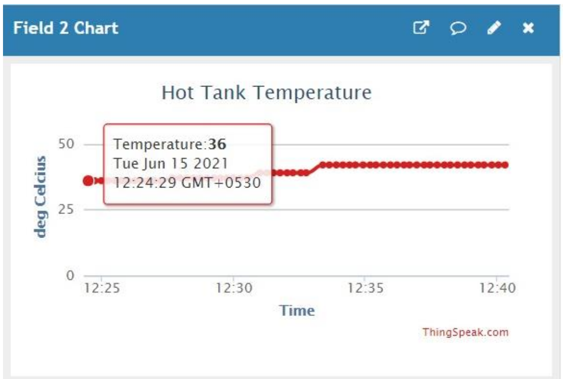


Fig.9.c cold temperature at 12°C **Fig.9.d cold temperature at 10°C**

Figure 10a, 10b, 10c and 10d shows the series of hot temperature readings of every degree Celsius with respect to the time.



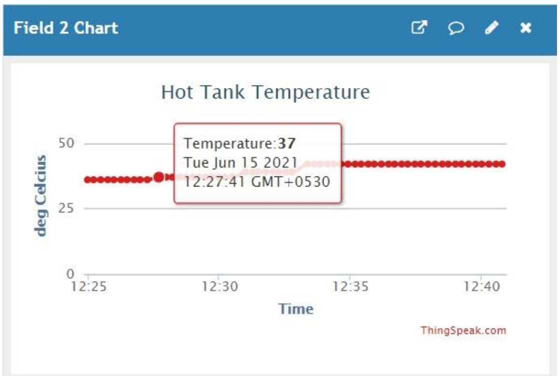
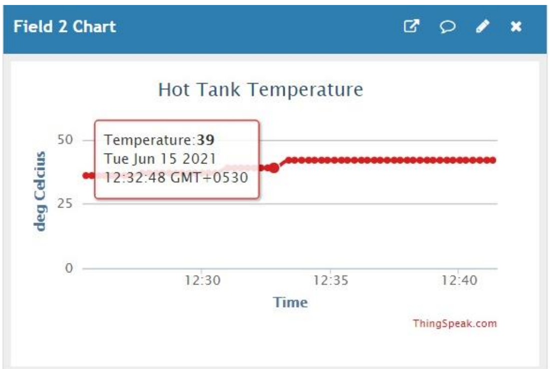


Fig.10.a. Hot temperature at 36°C **Fig.10.b. Hot temperature at 37°C**

Similarly as cold, here feeded hot temperature is 42°C shown in figure 10d as proof.



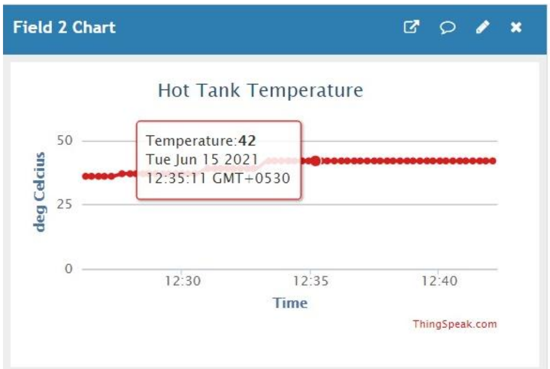


Fig.10.c. Hot temperature at 39°C **Fig.10.d. Hot temperature at 42°C**

Conclusion

The effectiveness of low cost CWT enhanced by providing a sequence of treatments that includes rapid transition between hot and cold periods. Use of this low-cost Peltier module with the controller makes the system cheaper and the inclusion of the internet of things make the system more powerful by getting the treatment pattern frequently, which helps in improving the treatment better, by including more sensors and the same module can be used as effective treatment for a number of different conditions of different injuries. With the help of the microcontroller, the Peltier modules are controlled and the retention of temperature at the hot and cold junction is possible, the challenge is that the independent controls are needed to retain the temperature separately.

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