Design of Portable Medical Cooler with Artificial Intelligent Control

Ismail Saritas, and Mehmet Okay

Abstract**—**The fact that technology and industry develop day by day whereas the energy sources gradually decrease led mankind to find new recyclable energy sources in today's modern era of information. Scientists began to study on sunlight, wind, river (hydro-power), biological processes and geothermal as a means of providing more energy. Throughout the development of technology there has been great advance in the cooling techniques. With the help of these advanced techniques some special coolers are now being produced. Mankind has started cooling and got rid of the need of cooling in years of about 1000 BC. The very early electric cooler was invented in 1914 and from that time on man has covered a remarkable distance on this way. As in every field of life coolers are needed in the field of medical. Coolers designed to be used in medical areas are far more sophisticated and of great importance for this sector. Some medical elements as vaccine, blood, serum and organ (during the donation of human organs) show how important a duty is to transport these items on time and without deforming. The aim of this thesis study is to design a portable medical hybrid cooler by assembling peltier, solar battery and dry accumulator in order to protect and transport some medical elements such as; vaccine, blood, serum and organ.

Keywords**—** Artificial Intelligence and Control, Blood, Organ, Peltiyer, Portable Medical Cooler, Serum, Solar Battery, Vaccine

I. Introduction

THERE is a great need for cooling systems in medical field as in all other fields. Cooling systems for medical field is of great importance due to their usage for storage and transportation stages of medical entities such as medicines, vaccines and blood etc. In recent years, as well as these entities, organ preservation and transportation increase the use of medical cooling systems. Storage and transportation conditions for each entity show changes such as temperature, duration, etc. Especially, the timely and intact delivery of these entities has become one of the major problems. Various studies have been conducted and medical cooling systems are developed in this field.

In addition to food deterioration as a result of exposition to the sun and radiation from the sun, continuation of life and human population is also an issue. Vaccines can be maintained in an environment from the temperature of (-3) °C to 8°C if the environment is devoid of external temperature effects. Also to avoid deterioration of certain foods a temperature between 0°C and 10°C is needed. There are mechanical refrigerators with conventional energy sources but it is not sufficient [1]. Vasiliev et all. [2] have designed and tested a new solar-powered electric refrigerators according to solid absorption phenomenon. Studies have been conducted with solar model of a solid absorption refrigeration system [3] amplified by using activated carbon/methanol adsorbent pair. This study was used as a model for calculations of subsequent studies. Dai et all. [4] have designed a thermoelectric refrigeration system by performing analytical and experimental studies about a subject on solar cells. Cold chain is a distribution system responsible for the care and prevention of primary health elements. Vaccines have to be maintained between specific temperatures for long distance storage and transportation purposes. For these purposes, Chatterjee et all. [5] have designed a portable refrigerator. Solar energy refrigeration systems have been designed for people living in desert for storage of perishable foods or transportation of biological materials and medicines that can preserve their effectiveness at low temperatures [6]. Blood cells, vaccines, other medical and biological products should be maintained at specific temperatures [7]. For this purpose, a portable medical cooling system has been achieved and thus, it is provided that the medical entities are maintained from temperature 6°C to 10°C [7]. Vian and Astrtain [8] have designed thermoelectric refrigerator. The developed thermoelectric refrigerator which maintains the temperature of 5 °C has a single compartment with a capacity of 0.223 m3 food storage.

From the research results, it has been seen that medical and biological products (vaccines, blood bags, serum, medicine, etc.) are transported with insulated carrying bags cooled with ice batteries. Nowadays, there are different types and sizes of carry bags and ice batteries are used as cooling. These products have many disadvantages such as coming into contact with ice batteries, transportation to long distances, reduction of transportation time due to a very hot environment [9].

These are;

- Deterioration in vaccines and blood products due to a power failure.
- The possibility of deterioration in vaccines and blood products is very high during transportation in a non-electric environment (e.g. desert).
- Ice batteries used for cooling are required to be checked frequently due to their uncontrolled cooling characteristic.

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• The direct contact of ice batteries with vaccines and blood bags is harmful. This is big problem in transportation.

• Transportation of vaccines and blood bags with uncontrolled cooling systems, for which we cannot control the temperature range, is difficult and problematic.

• Because ice batteries occupy extra space, the number of medical products to be transported is reduced and the volume of the carry bag becomes larger [9].

In this study, medical cooling systems used for transportation and storage of medical samples such as vaccines, blood, organs, serum, etc., are expressed. Considering the storage and transportation problems that are occurring or likely to occur, a portable cooling system is designed and realized with a hybrid structure as a solution.

II. Material And Methods

Stainless Steel for medical refrigerator, Styrofoam for insulation, thermostat for sensor, a fan to provide cooling, dry battery for power supply, connection apparatus, aluminum plate and electronic circuit elements for solar panels and these supplies are used [9].

Control Unit is carried out as shown in the Fig. 1.

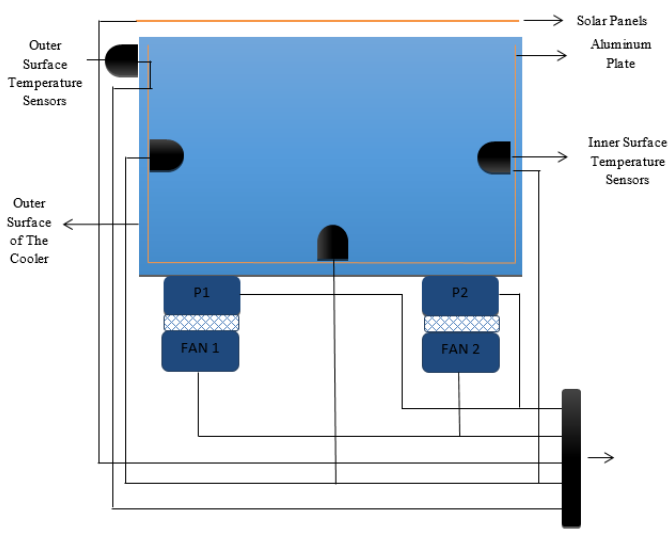

Fig. 1 Cooling System

Portable medical cooler is designed to have hybrid structure. As seen in the Fig. 1, solar panels, three temperature sensors on the inner surface of the cooler, one temperature sensor on the outer surface of the cooler, one peltier and two cooling fan were used [9].

The digital data from the temperature sensors is interpreted with fuzzy modeling and the results are transferred to duty value of PWM inside the PIC. MOSFET's are driven according to the duty value. As demonstrated by Fig. 2, by the status of MOSFET's, fans and peltiers starts working [9].

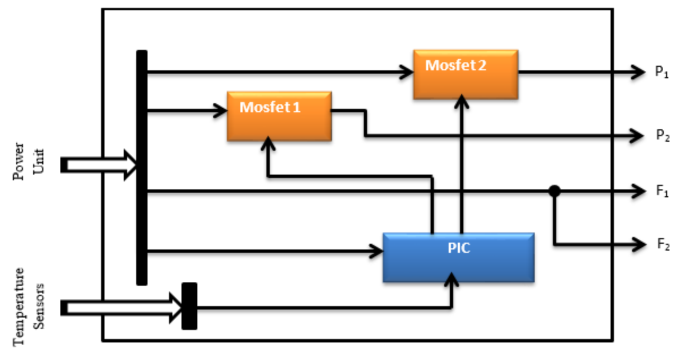

Fig. 2 Control Unit

A. Working Principle Diagram

Portable Medical Cooling System has a hybrid structure. It combines three different power sources namely; 12V DC power source from solar panel, 12V DC power source from car cigarette lighter and 12V DC power source from adapter that is connected to city network. This combination takes place in Charging Regulator and finally goes to the 12V 12A 20H dry battery to charge it.as shown in the Fig. 3. Dry Battery supplies the generated power to the system.

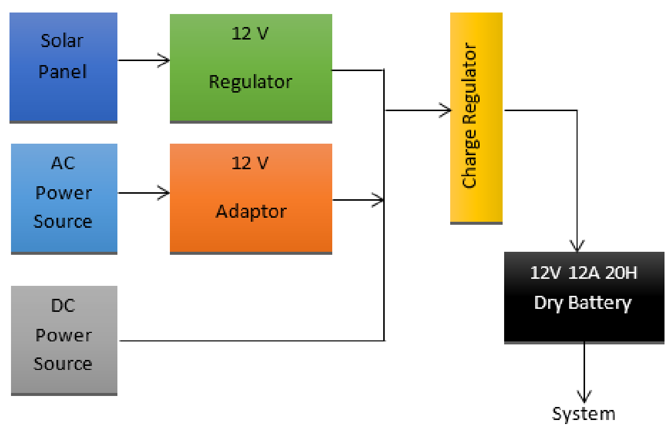

Fig. 3 Power Unit

The drawings of the designed prototype are performed on AutoCAD and these drawings are shown in Fig. 4 [9].

Fig. 4 Design and realized of the Prototype

B. Fuzzy Control of Portable Medical Cooling System

B.1 Input and Output Parameters

According to the values obtained from the three sensors within the cooling system and the sensor outside the cooling system, how the PWM will operate is determined by interpretation of the input parameters obtained which are inside temperature of the cooling system (ITCS) and outside temperature of the cooling system [9].

Membership functions for fuzzy control are determined as follows (Eq. 1, Eq. 2, Eq.3);

S_{IC}= {CS, S, N, SI, CSI} (1)
S_{DIS}= {SO, NO, SO} (2)
PWM= {CCCD, CCD, CD, D, N, Y, CY, CCY} (3)

The definitions of membership functions' abbreviations, which are used for fuzzification of the information from the sensors inside the cooling systems, are as follows;

CS: Very Cold, S: Cold, N: Normal, SI: Hot, CSI: Very Hot

The definitions of membership functions' abbreviations, which are used for fuzzification of the information from the sensors outside the cooling systems, are as follows;

SO: Cold, NO: Normal, SO: Hot

The definition of PWM output parameters' abbreviations obtained from the interpretation of the input parameters are as follows;

CCCD: Very Very Very Low, CCD: Very Very Low CD: Very Low, D: Low

N: Normal, Y: High, CY: Very High, CCY: Very Very High

TABLE I
FUZZY CONTROL USED IN THE COOLING SYSTEM

S_{IC}	S_{DIS}	PWM
CS	SO	CCCD
CS	NO	CCD
CS	SI	CD
S	SO	CD
S	NO	CD
S	SI	D
N	SO	CD
N	NO	D
N	SI	N
SI	SO	N
SI	NO	Y
SI	SI	CY
CSI	SO	CY
CSI	NO	CCY
CSI	SI	CCY

Fuzzy set of the cooling system's internal temperature (SIC) corresponds to CS, S, N, SI, CSI membership functions. Fuzzy set of the cooling system's outer temperature (SDIS) corresponds to SO, NO, SO membership functions. PWM fuzzy set corresponds to CCCD, CCD, CD, D, N, Y, CY, CCY membership functions (Table I).

Function equations on these sets are shown below (Eq.4-6).

µSİÇ = [µÇS, µS, µN, µSI, µÇSI] (4)
µSDIŞ = [µSO, µNO, µSI] (5)
µPWM=[µÇÇÇD, µÇÇD, µÇD, µD, µN, µY, µÇY,µÇÇY] (6)

C.2. Determination of Fuzzy Sets of Input and Output Parameters

The fuzzy set of input parameters is shown in Table II.

TABLE II
FUZZY SET FOR INPUT PARAMETERS

Input Parameters	Fuzzy Sets	Interval
Inside Temperature of the Cooler(SIC)	Very Cold, Cold, Normal, Hot, Very Hot	0-36
Outside Temperature of the Cooler (SDIS)	Cold, Normal, Hot	(-10)-40

The fuzzy set of output parameters is shown in Table III.

TABLE III
FUZZY SET FOR OUTPUT PARAMETERS

Output Parameter	Fuzzy Sets	Interval
PWM Reference Voltage	Very Very Very Low, Very Very Low, Very Low, Low, Normal, High, Very High, Very Very High	0-5

Fuzzy sets of the input parameters and their ranges of values are shown in Table I. Fuzzy sets of the output parameters corresponding to the input parameters and their ranges of values are shown in Table 2.

The Fig. for the membership functions and their fuzzy sets of inside and outside temperature of the cooling system (Fig.5-6) and the membership function and fuzzy set of PWM (Fig. 7) is shown below.

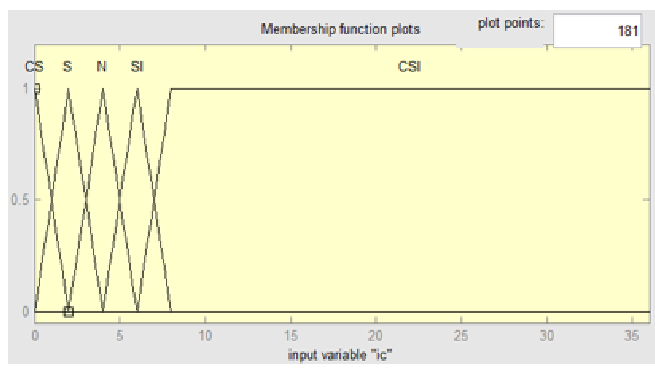

Fig. 5 Membership function and fuzzy set for inside temperature of the cooling system

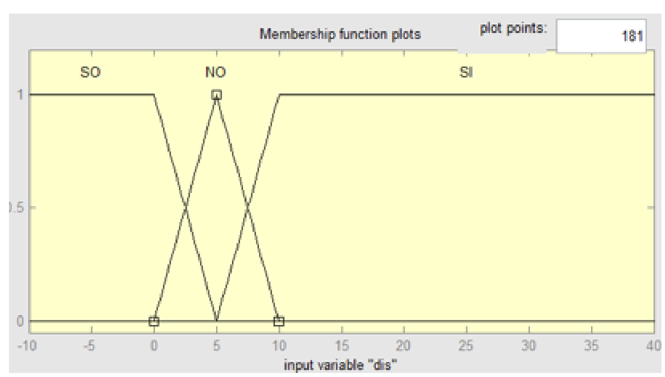

Fig. 6 Membership function and fuzzy set for outside temperature of the cooling system

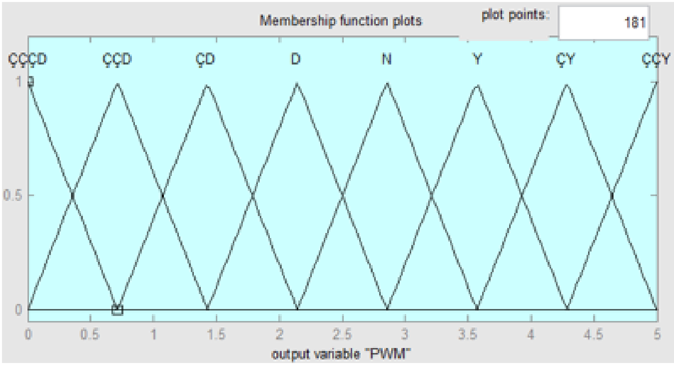

Fig. 7 Membership function and fuzzy set for outside temperature of the cooling system

B.3 Establishment of Fuzzy Rules

In this section, the rules are determined by taking into account of all different variables and all possible differences. These rules are designed to include different possibilities.

The basic elements considered in the creation of fuzzy rules are for the cooling system to be extremely accurate and to be able to be transported as soon as possible. Also, the internal temperature of the cooling system has to be kept between 0°C and 4°C and the minimization of the system's use of power for saving energy.

The effects of input values on output values are evaluated by overlapping both input and output terms plus indicating both input and output spaces as graphically. The interaction of these parameters with each other is important for evaluation and contributes to development stage of the rules.

Data from the fuzzy system becomes ready to be processed. Then, according to the rules installed in the fuzzy rule base which are defined as "if-then", they are handled by the inference mechanism.

Fuzzy results are obtained by using membership functions coming from the fuzzification unit with stored information sets founded on the database.

Here is the information about the membership functions of the system;

S_{IC}= {CS, S, N, SI, CSI}

S_{DIS}= {SO, NO, SO}

that includes conditional statements which have "if-then-else" structure. Each of the conditional statements is defined as a rule. Below, some of the generated rules are shown.

TABLE IV
SIC AND SDIS RULE

S_{IC}\\S_{DIS}	CS	S	N	SI	CSI
SO	CCCD	CCD	CD	N	CY
NO	CCD	CD	D	Y	CCY
SI	CD	D	N	CY	CCCY

A few examples of the rules from the fuzzy rule table (Table 4) which are used for portable medical cooling system prototype are shown below;

Rule 1: If CS and SO then CCCD else
Rule 2: If CS and NO then CCD else
.
.
Rule n: If CSI and SI then CCY else
.
.

Rules are realized by fuzzy sets. For each rule a fuzzy μ(z) output is obtained. Later, fuzzy outputs are converted to exact numbers by the defuzzification unit.

To indicate the logical degree of rules, each rule has an assigned degree of support. Logical factor of the support degree varies between 0 and 1.

III. Conclusion

In this study; a prototype has been designed and manufactured which eliminates the disadvantages of portable coolers using eutectic batteries. Peltier and aluminum plates have been used for the prototype of the designed cooler. Peltier has been used inside the portable cooling system to ensure the sufficient cooling with homogeneous distribution. For this purpose, 3 temperature sensors have been used and fuzzy controllers have been realized for temperature control of the sides needing interference. Also, the cooling processes of the designed prototype have been carried out in two different ways. Feeding of the peltiers has been provided directly from the network in the first method and from dry batteries in the second method. Dry batteries which are used as power sources has been provided to charge from vehicle cigarette lighters or network voltage, in the absence of these sources dry batteries are able to be charged with the energy supplied from solar panels.

This prototype of the cooler which can operate as a hybrid system has been tested while the inside is empty and with different products in it and the measurements taken during the test are shown below in a graphic chart.

The first experiment was run when the cooler was empty. During this experiment, while the outdoor air temperature was averagely 21 °C, how much time later the desired temperature was measured after the cooler lid was closed (Fig. 8) [9].

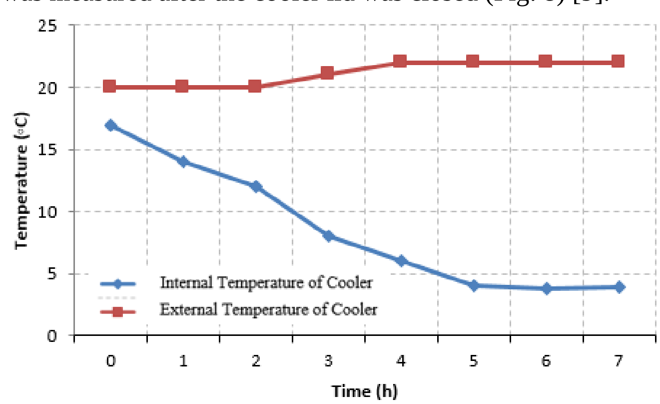

Fig. 8 First execution of the designed cooler

As shown in the Fig. 8, while the cooler was empty, the cooler has reached its desired temperature in a period of about 4 hours and it has maintained this value after the 5th hour.

In the second experiment, while the cooler was at the desired temperature level (4 °C) and the average external temperature was 20 °C, 2 units of 0.5 liter PET bottle with water having a temperature of 18 °C was placed inside the cooler. Inner temperature of the cooler started to rise but by increasing the current applied to peltier by the fuzzy controller, the cooler has maintained its initial temperature (Fig. 9) [9].

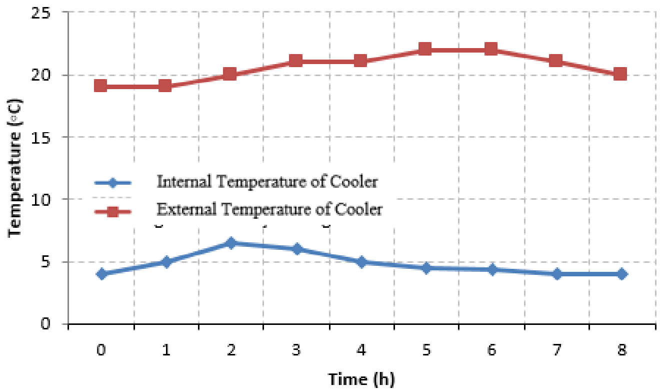

Fig. 9 Placing bottled water into the cooler

In the third experiment, while the average outdoor temperature was 20 °C and the internal temperature was 4 °C, bags, which are about 36 °C and prepared as suspension, representing blood bags were put into the empty working cooler. The result of the measurements were taken before and after the bags were put and the chart was obtained shown in the Fig. 10 [9].

As shown in the graph in Fig. 10, because of opening the cooler lid and filling the cooler with approximately 36 °C suspension bags, the inner temperature of the cooler has risen. For preventing the increasing temperature, the controller has become activated and started the cooling process. The desired temperature has been reached over a period of about 2 hours.

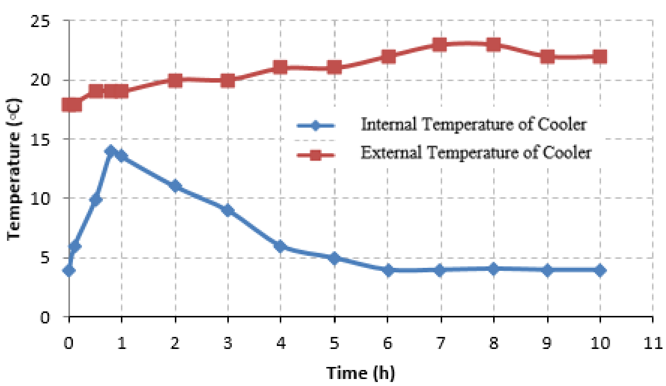

Fig. 10 The situation of working cooler with suspension at 36 °C

In the fourth and the final experiment, while the average outdoor temperature was 22 °C and the internal temperature was 4 °C, vaccine-like products were purchased from the pharmacy to be transported with coolers working with ice batteries. 250 mg / 3 ml 20 unit bulb (temperatures below 4 °C) purchased from the pharmacy were put into the empty cooler of which the internal temperature is 3 °C. The result of the measurements were taken before and after the bulbs were put and the chart was obtained shown in the Fig. 11 [9].

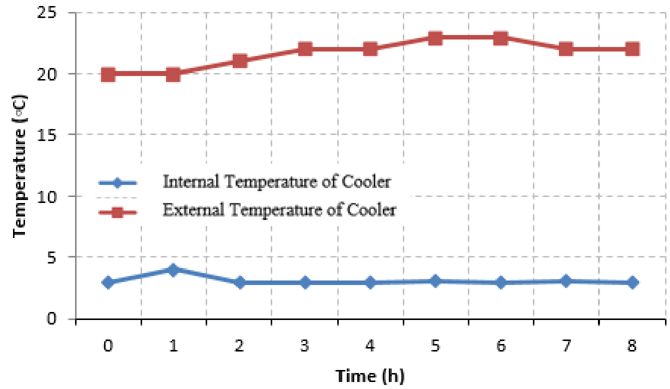

Fig. 11 The situation of working cooler with 250 mg / 3 ml 20 unit bulb

As shown in the graph in Fig. 11, with the opening of the cooler lid, the temperature has risen very little. Despite that, the controller has become activated and quickly started the cooling process. The desired temperature has been reached in about 15 minutes.

In the experiments conducted, the measurements were taken by feeding with dry batteries or from network power supply during the experiments. Dry batteries charges from solar panels or network supply voltage. In the fourth experiment, charging was achieved entirely from solar panels.

Because of the coolers for being inactive for a long time, solar panel charging provided dry batteries to produce power for long periods of time.

As a result of the studies, the results obtained have shown that; instead of coolers with ice batteries, cooling process using dry batteries, providing homogeneous temperature distribution, which can be charged from network power supply, solar panels or a car cigarette lighter is more efficient and long-lasting.

It is seen that a cooler with the realized fuzzy control is more reliable for blood, vaccine, serum or other medical supplies.

It is necessary to use more powerful and long-lasting dry batteries because of the excessive current drawn by peltiers. This situation may provide cooling with lower currents by increasing the number of the peltiers.

Fuzzy controller can be developed by increasing the linguistic expressions of or using hybrid artificial intelligence methods.

More efficient cooling can be achieved by using the materials that may absorb heat faster than aluminum plates(or sheet).

The weight of the portable cooler can be mitigated by using heat-insulated plastic materials.

Charging time can be reduced by using more efficient solar panels.

Acknowledgment

This study has been supported by Scientific Research Project of Selcuk University.

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