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INVESTIGATION OF SOLAR AIR HEATER INTEGRATED WITH DATA ACQUISITION USING LAB VIEW

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ABSTRACT

A detailed categorization of the performance and energetic behaviour of solar air heating systems have been done in many of the researches, Ample monitoring and analyzing of solar air heating systems plays an important role in augmenting the efficiency of solar air heating systems by collecting the process parameters in the system. Application of solar air heating system is space heating and drying agro products. The usage of the LabVIEW real-time interface system helped in integrating several types of instruments into a single system which offered an online measurement of all data sources and compares the simulation results with monitored data in real-time. The DAQ system could realize the real-time data acquisition of temperature, air velocity, wind velocity, humidity, weight of the drying product and intensity of solar as well as data transmission, processing, and display, in addition provides users with significant data inquire. The single glass double-pass introduced in this study was proposed for aiming to strengthen the convective heat transfer coefficient and increase the heat transfer area. Based on both theoretical and experimental results of the collector efficiency of the charcoal and rock bed porous medium under different mass flow rates were compared. The proposed approach provides fast, secure and reliable system by making the system database-ready for performance analysis of solar air heating systems.

KEYWORDS: Solar air heater, Data Acquisition, LabVIEW

INTRODUCTION

Solar drying is the process of drying or removing the moisture content of a substance by exposing them to the solar heat either directly or indirectly. As stated by Sunil Chamoli et.al [1], the solar radiation provides an infinite and non polluting reservoir of fuel. The easiest way to utilize solar energy for heating applications is to convert it into thermal energy by using solar collectors. Solar water heaters and solar air heaters are for example flat plate collectors which are used mostly for heating of water and air respectively. In the solar air heating, the airflow can be generated by either natural or forced convection. The heating procedure can involve the passage of pre-heated air through the product by convective mode or by directly exposing the product to solar radiation or a combination of both. The transfer of heat to the moist product is facilitated by convection from the surrounding air mass at temperatures above that of the product or by radiation. The evaluation of the air heater is a tedious work as the recording and analysis of the various parameters have to be real time. But in most cases its usually an average of the performance parameters which is unlikely to yield a effective real time result and can also be biased. H.P. Garg et. al. [2], evaluated the performance of various conventional air heater and criticized its performance. The research performed on the thermal capacitance and conductivity, as it can be studied easily with the conventional system. Considering just two parameters in the case of air heater will lead to biased results, there can be serious effect of other parameters of the air heaters which would be neglected. Ram Chandra and M.S. Sodha [3] discussed about testing procedure for solar air heater, but they considered the testing procedures that are indoor test only. As the outdoor testing involves the interaction of various other parameters and thus there still was a requirement of carrying out an effective outdoor testing procedure. Lin Wang et.al. [4] wanted to enhance the coefficient of performance of solar absorption refrigerator and analyze the system performance. This brought about the requirement of combining the technique of visual instrument and the characteristics of the solar absorption of the solar absorption refrigerator using the LabVIEW software for an effective data acquisition (DAQ) system. The use of LabVIEW could save a lot of labor power and material resources, further made the measurement more convenient and fast. Weilin Wang et.al. [5], found the data acquisition to be a major challenge in the case of blurred imaging and thus required an efficient data acquisition software. Weilin Wang et.al [5], used the LabVIEW software and found it useful as a data acquisition tool for the filter based image acquisition. Based on the efficient performance of the LabVIEW software in the case of many practical data acquisition, the LabVIEW has been considered to study its effectiveness of data acquisition for a solar air heater under natural conditions.

The solar air heater performance improvement has been under study in many research areas, and many modifications has been suggested by researchers. The basic design of a flat-plate solar air heater consists of one or more glass (or transparent) covers located above an absorbing plate with air flowing upward type were done by Tan HM et. al. and Whillier A [6, 7] and air flowing below the absorber plate were done by Liu CH et. al. and Seluck MK et. al. [8, 9]. Various approaches have been proposed to improve the collector efficiency, such as allowing air flowing both over and under the absorbing plate simultaneously were done by Kreith F et. al. [10], enhancing the convective heat-transfer coefficient were done by Duffie JA et. al. [11], enlarging heat-transfer area were done by Gao W et. al. [12] and Verma SK et. al. [13] were discussed about increasing flow turbulence. Moreover, the feasibility of recycling operation for enhancing transfer rates in heat transfer processes and reactors has been confirmed by several investigators [14-18]. In terms of the collector configuration, double-pass design has been proposed, which plays an important role in influencing the fluid velocity, and thus, the forced convection strength, as well as in increasing the heat transfer area [19, 20].

METHODOLOGY

The Solar air heater is used to dry items such as the Agro products, paper, tea, textiles and space heating as well. In our case a double pass solar air heater of 2000mm length, 1000mm width and 125mm height is fabricated using 1.2mm thick mild steel plate. A zinc matte black coated copper sheet of 0.8mm thickness is used as an absorber plate. The sole purpose of the absorber plate is to convert the energy from solar radiation into heat energy. The maximum capacity of the drying product of 50kg can be loaded. The orientation of the heater is set face south and tilted with an angle of 30 degree with respect to the horizontal for maximizing the solar radiation received by the glass covers throughout the year. In order to reduce the heat losses to the ambient, the collector bottom and lateral sides are insulated with 25mm thick glass wool and to reduce convective losses, the collector top side is covered with a 5mm glass plate. Turbo ventilator is used to increase the mass flow rate and facilitates an effective forced convection heat transfer mode by natural wind. The total system parameters such as the temperature, air velocity, wind velocity, humidity and weight of the drying product and intensity of solar are monitored and recorded in real time by Data Acquisition system using LabVIEW.

The Solar Air Heater System Description

In this section, the description of the solar air heater unit utilized in this research is presented firstly and the DAQ system to collect the experimental data based on LabVIEW is then described. Finally, the approach of the experiment performed to collect the experimental data is shown and criticised. The solar-assisted air heater consists of a series of inter connected components which are the solar air heater unit, a flat plate solar collector and test section. Figure 1 shows a photograph of the solar air heater used for this research.

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Fig1 Photograph of the solar air heater.

Data Acquisition System

The research and development process of the solar air heater requires a series of experiments to be conducted for improving the efficiency of the solar air heater. There are many parameters that affect the overall performance of the solar air heater system, which are to be collected and analysed. The main component for the hardware configuration consists of an NI cDAQ-9174 data acquisition control unit, a personal computer and sensors. Figure 2 shows a block diagram of the DAQ system set up for this research.

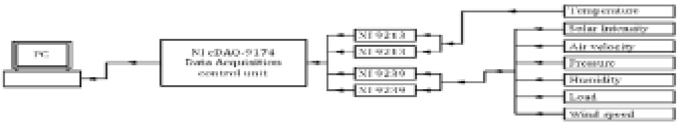

Fig 2 Block diagram of the DAQ system.

The NI cDAQ-9174 data acquisition control unit combines precision measurement capability with flexible signal connections for the production and development test systems. Four module slots are built into the rear of the instrument to accept any combination of data acquisition or switching modules. For temperature measurements two blocks NI 9213 16-Channel module are fixed to the NI cDAQ-9174 data acquisition control unit. Two blocks NI 9239 4-Channel module are fixed to the NI cDAQ-9174 data acquisition control unit.

Different parameters of solar intensity, wind speed, inlet and exit velocity, pressure, humidity, load and period could be measured by NI cDAQ-9174 data acquisition control unit directly. In Table 1 shows the specifications of sensors is being used in this research,

Table. Specifications of sensor

Sensor	Specification	Description
Pyranometer	0-3V (0-1800W/m^2) direct current signal	Intensity of solar radiation
wind-cup sand	0-5V (0-32m/s) direct current signal	Wind speed

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pressure sensor	0.5-4.5V (0-50 bar) standard direct current voltage signal	Inlet and exit pressure of drying chamber
Thermocouple	K Type	There are 20 temperature measuring points which includes absorber inlet and outlet air, test section inlet and outlet air temperature, top and bottom side of the absorber and test section temperature distribution
HD403TS1-Active hotwire air speed	4-20mA (0.05–40m/s) direct current signal	Inlet and exit Air velocity of drying chamber
humidity sensor module SY-HS-230	0.5-5V (10-90% RH) standard direct current voltage signal	Three humidity measuring point in drying chamber where humidity was collected

LabVIEW itself is a graphical development environment for creating flexible and scalable test, measurement, and control applications. Figure 3 shows the source code used in this measurement system. Hundreds of functional blocks for analysis, signal processing, and mathematics are built-in to the environment, making LabVIEW a smart choice for manipulating raw data collected with the NI cDAQ-9174 data acquisition control unit. The driver includes a full set of functional building blocks that can be used to create a completely custom NI cDAQ-9174 data acquisition control unit.

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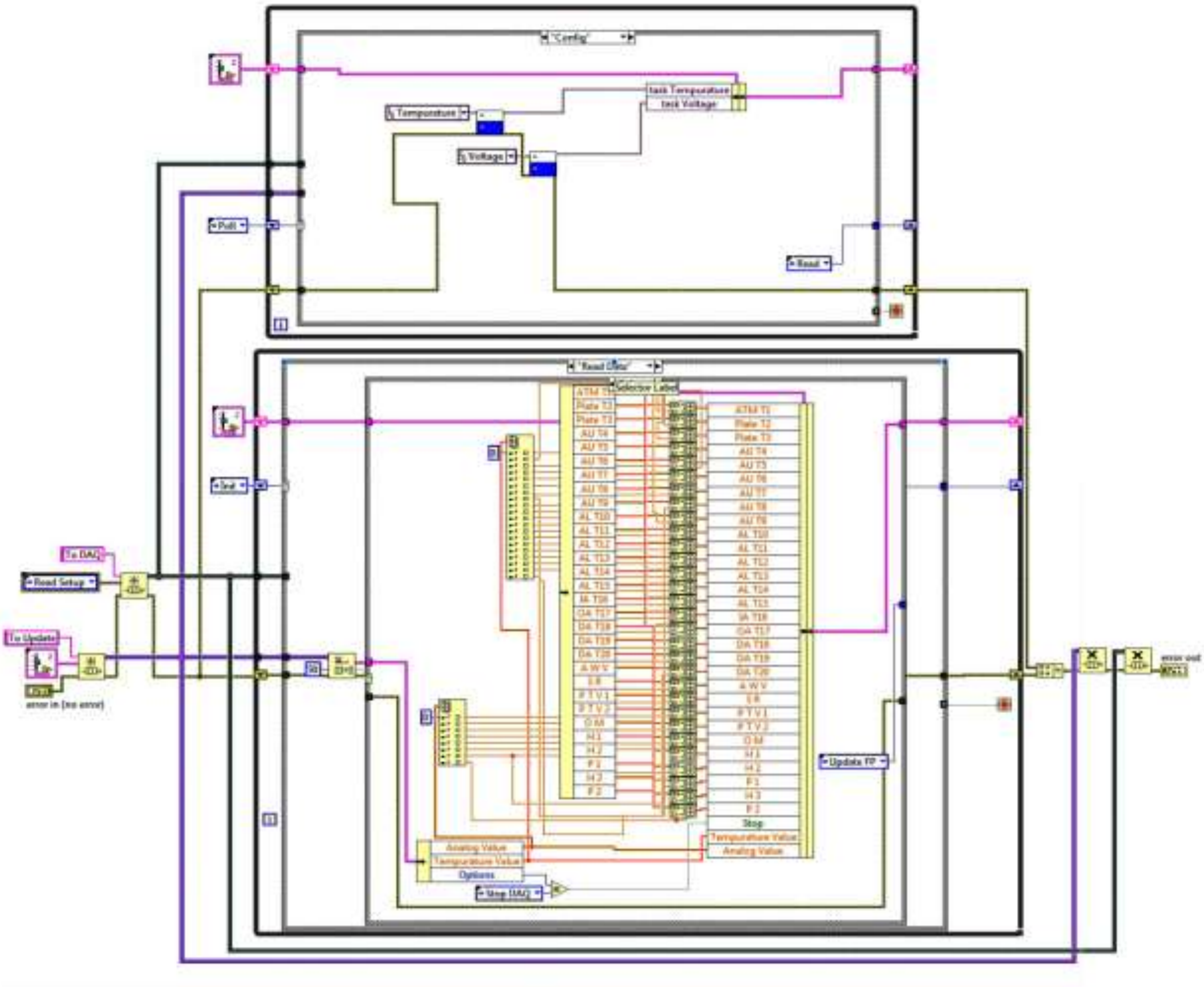

Fig 3 The program source code of DAQ modular

In LabVIEW, each of these programmatic building blocks is called a Virtual Instrument (VI). Any custom LabVIEW application is composed of two sections: one section is a front panel, which is the graphical user interface (GUI), on which the parameters required to the study ways to enhance the performance of the solar air heater is displayed. As mentioned above, the parameters considered are solar intensity, temperature, wind speed, inlet and exit velocity, pressure, humidity, load and period signals. Figure 4, 5 and 6 shows the front panel of the LabVIEW Graphical User Interface (GUI) developed for this DAQ system. As shown in fig. 4, the front panel not only shows all the important parameters instantly but also has provision for setting the sampling interval. DAQ is simply the process of measuring a real-world signal, such as a voltage, and bringing that information into the computer for processing, analysis, storage, or other data manipulation.

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Fig 4 The front panel of the LabVIEW for Atmospheric condition monitoring.

Fig 5 The front panel of the LabVIEW for the temperature distribution of the flat plate solar collector condition monitoring.

Fig 6 The front panel of the LabVIEW for the test section condition monitoring.

After acquiring the data in the DAQ modular, all the parameters are presented for analysis. LabVIEW is also capable of interfacing with a data management system, whether it consists of a simple spreadsheet file or a relational database.

RESULTS AND DISCUSSION

In this experiment the outlet temperature reaches 65°C with the inlet temperature of 30°C. The two different porous medium such as charcoal and rock bed has been used. By using turbo ventilator the mass flow rate is being increased maximum to 0.08kg/s. The size of the porous medium was approximately 0.0016m^2 were placed between the bottom of the absorber plate and back side insulated frame. Considering the arrangement of the experimental setup, the arrangement is placed with 30° inclination to achieve the best performance. The measurement is performed on different modifications with different conditions. The tracing methods for ambient conditions are illustrated in fig. 7. The output characteristics are taken under irradiance from 400 to 1020W/m^2

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where the maximum temperature gained is about 65°C. The first method outperforms the second one on the aspects of accuracy and tracing speed.

Fig 1 Characteristics of solar intensity, ambient temperature and wind speed with time period

Fig 2 Characteristics of solar flat plate collector temperature distribution with respect to time

Fig 3 Characteristics of drying chamber temperature distribution with respect to time

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Fig 4 Characteristics of drying chamber humidity and Inlet & Exit air temperature with respect to time

However, more ripples appeared due to high frequency and sampling rate. Temperature and irradiance variation observed across day is shown in fig. 8 where a maximum test section temperature of 57.2 °C was detected. In fig. 9 shows the characteristics of temperature distribution is recorded for the drying chamber and fig. 10 shows the characteristics of change in humidity and air temperature of the inlet and exit of drying chamber is illustrated.

Thermal Analysis

The mass flow rate has been described by Eq. (1). The efficiency of the flat plate collector has been described in Eq. (2). The heat gained by the flat plate collector based on mass flow rate has been illustrated in Eq. (3). To analyse thermal performance of solar air heating system, following equations were used,

$$\dot{m} = \rho A V \qquad (1)$$

$$\eta = \frac{Q_u}{G.A_c} \qquad (2)$$

$$Q_u = \dot{m} C_p (T_o - T_i) \qquad (3)$$

For thermal analysis of flat plate solar air heater, two different heat storage materials which are porous medium are used in this system. First, a rock bed is used as a porous medium of the flat plate collector and extracted the data from DAQ by using LabVIEW. Secondly, the charcoal used as a porous medium and data is acquired for the thermal analyze. The solar heater model with rock bed is found to be better than model with charcoal in the aspect of temperature of the exhaust air, while the output air velocities ranges from 0.31m/s to 0.34m/s for natural convection and 0.91m/s to 0.93m/s for forced convection in both the cases. The minimum and maximum temperature of charcoal is 46.7°C and 53.2°C while 50.1°C and 57.4°C for rock bed was precisely measured and a real time recording of the data was carried out using the LabVIEW software setup. It is also notable that all the modifications made in both the cases were similar and easy using this measuring technique.

CONCLUSIONS

Development of an instrumentation and data acquisition of a solar hybrid drying system LabVIEW was presented. This research work expresses the design and implementation of data acquisition software for flat plate solar air heating system. The usability of the system is enhanced by several advanced features, such as previewing group ratio images and live monitoring data. The projected method is based on precision electronic circuits and an easy to use graphical environment, for processing, displaying and storing the collected data. The system operator can easily process the measured parameters using any LabVIEW built-in function available. The design strategies and techniques presented in this paper can also be used to develop similar solar tracking data acquisition programs. For two different heat augmentation methods for drying process are tried, one with rock bed and second with charcoal. A good improvement is found in the thermal performance of both the heaters while performing on all new configurations on both rock bed and charcoal. The results show that there is a significant effect on rock bed with ambient conditions which could be effectively recorded and analyzed. Future development of this instrumentation research will include the solar tracking system to enhance the overall system performance. LabVIEW was identified ideal for carrying out the acquiring and analysis of data for the solar air heater. The software can be used in development environment for innovation, discovery and accelerated results.

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NOMENCLATURE

$\dot{m}\dot{m}$, mass flow rate of fluid in $kg/skg/s$

C_pC_p, specific heat of air in $KJ/kg.KKJ/kg.K$

$\rho\rho$, density of the fluid in $kg/m^3kg/m^3$

AA, flow area in m^2m^2

VV, velocity of air flow in $m/sm/s$

T_oT_o, temperature of exhaust air of the collector °C°C

T_iT_i, fluid inlet temperature to the collector °C°C

$\eta\eta$, efficiency of the collector or system in percentage

A_cA_c, collector surface area in m^2m^2

GG, solar radiation in $W/m^2W/m^2$

Q_uQ_u, heat gained

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