International Journal of Engineering Innovation & Research
Volume 2, Issue 1, ISSN: 2277 – 5668

Design and Development of Direct Resistance Heating Device for Liquid Food Processing and its Monitoring

M. Hossein Mehraban Jahromi
Department of Electrical Engineering,
neyriz branch, Islamic azad University,
neyriz, Iran,
hmehraban82@gmail.com

Hamidreza Gharehchahi
Department of Mechanical Engineering,
neyriz branch, Islamic azad University,
neyriz, Iran,
gharehchahi@chmail.ir

Mohsen Gavahian
Department of Food Science and
Technology, School of Agriculture, Fasa
university, Fasa, Iran.
gavahian@fasau.ac.ir

***Abstract* – An experimental batch ohmic heating unit was designed and fabricated for thermal processing of liquid foods. The unit was supported by a data acquisition system for sensing the liquid temperature distribution, voltage and current with time. The data acquisition system performed well and could record temperatures, voltage and current at intervals of one second. The performance of the ohmic heating unit was evaluated based on experiments. Tests with 2, 4 and 6 w/v% aqueous sodium chloride solutions showed the ohmic heating to be fast. Results indicated that fabricated ohmic system can heat the samples faster than traditional heating system and also increasing of applied voltage will increase heating rate in ohmic system.**

***Keywords* — Ohmic Heating, Food Processing, Design and Fabrication.**

I. INTRODUCTION

Direct resistance heating of foods by passing of electrical current has been applied in the food industry for a long time (de Alwis and Fryer, 1990). The heating occurs in the form of internal energy transformation (from electric to thermal which is due to Joule effect) within the material (Sastry and Barach, 2000). Ohmic processing enables to heat materials at extremely rapid rates (generally, from a few seconds to a few minutes) (Sastry, 2005). Electrical conductivity is the main parameter determining the heating rate of an ohmic heating treatment. Distilled water is an excellent electrical insulator so in many studies on ohmic technology, salted water is used as the liquid phase for ohmic treatments (Goullieux and Pain, 2005). In the nineteenth century, several patents were filled for the use of direct resistance heating for the sterilization of static liquid foods (Jones, 1897; Roberts, 1900). In 1993, with the Food and Drug Administration (FDA) approval, process of stable low acid foods at ambient temperature became legal.

Commercial ohmic heating systems are already being used for continuous processing of food materials (Striling, 1987; Skudder, 1991). However, such applications provide little information on the design and performance aspects of the ohmic heating systems (Biss et al., 1989; Stirling, 1987). The use of static heaters has been reported in several studies for the measurement of electrical conductivity of foods during ohmic heating (Halden et al., 1990; Palaniappan and Sastry, 1991 a,b). Despite huge progress in ohmic heating science and commercialization in many countries, the deficiency of application and researches on this technology in developing countries (like Iran) is noticeable. So the objective of this study was to design and fabricate experimental ohmic heating units along with the necessary data acquisition system.

II. DESIGN OF THE OHMIC HEATING SYSTEM

Power supply system The experimental ohmic heating system consisted of three major parts: power supply, heating units, and data acquisition system (Fig. 1).

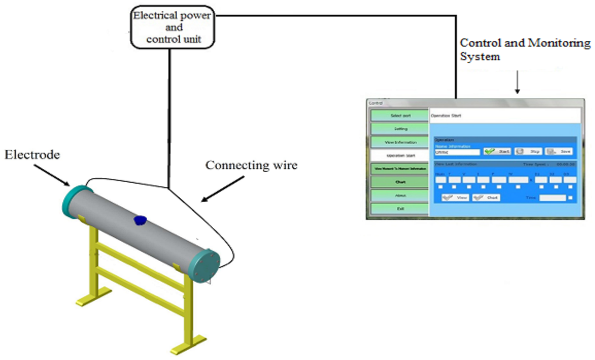

Fig.1. Schematic diagram of developed ohmic heating system

The schematic diagram of the power supply system is shown in Fig. 2. The power supply system included an isolation transformer, variable transformer, safety cut-out, circuit breaker, step-down and current transformers. The single phase power supply from the AC mains (220 V, 50 Hz) was used in the experimental set-up. An important consideration in the designing of the power supply system was personal and equipment safety to avoid unforeseen accidents. An isolation transformer was specifically used for this purpose. The various components and their specifications are shown in Fig. 2.

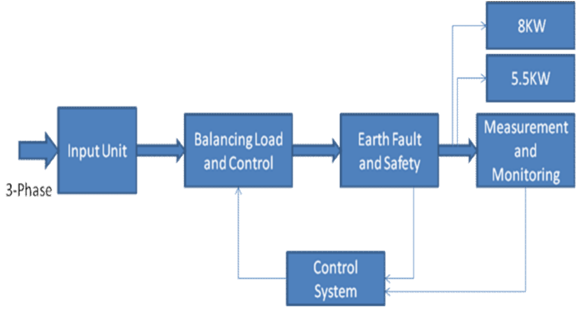

Fig.2. Diagram of ohmic power supply and controlling system

The static unit consisted of Pyrex cylinder, 9 cm in diameter and 51 cm long. Stainless steel (AISI 304) electrodes were positioned at each end of the cylinders. The electrodes were tightly held in position using rubber rings and specific flange system. The unit could be held in horizontal position. Three thermocouples were placed in the unit for monitoring the temperatures distribution. Special glass tubes used to fix the thermocouples in the cylinder.

III. DATA MEASUREMENT AND MONITORING SYSTEM

It is very useful to measure the internal parameters of electrical system under various operating conditions. The parameters like voltage, current, flux, power factor are usually measured & considered parameters to study the performance characteristics of the system to study its efficiency and power for different applications. But it is also important to measure & monitor one more parameter which is also important. Vibrations of machine for the considerations of performance, efficiency, reliability & life of system. It is usually complicated to have constant monitoring & recording & storing results of these parameters using the traditional measuring apparatus like meters. Hence a system is designed to have a constant monitoring & storing results of these parameters using sensor technology along with microcontroller. Also control of parameters can be achieved using relays. In this project to achieve monitoring of Resistance Heating device .specific ratings the circuit is to be designed. The vibration are sensed and then this signal is conditioned into suitable format. Then the analog signals are converted to digital and then they are given to the microcontroller and further to personal computer so as to achieve monitoring. The data is collected for different conditions of system such as temperature, power, voltage, current, total energy, unbalanced load etc. And hence this data can be analyzed and stored for future references. The system proposed in this dissertation is based on sensor technology & microcontroller. A sensitive real time monitoring can be achieved by this system and hence the performance characteristics and life of the system can be improved. The sensors will sense the parameter under study .Since the output signals of sensors cannot be directly processed by the electronic system a signal conditioning circuit is used for each sensor to condition the signal. This is an analog signal and it is converted to digital signal by using analog to digital converter. The signals are further given to microcontroller to convert it in decimal form. The output of microcontroller is given to level converter to manipulate between high and low levels of personal computer and microcontroller. The level converter interface with personal computer which will display real time results and these can also be stored & retrieved for future references and can also be used for the comparison purposes in the form of graphs, charts and tables by processing it using personal computers.

The data acquisition system measured the temperature distribution, applied voltage and current with time. A 16-channel amplifier/multiplexer (EXP-16) and A/D board (DAS-8) were used for logging the data with a PC.

PT-type thermocouples were inserted into 0.3 cm diameter thin glass tubes filled with UH-102 Silicone heat-conductive material. One end of the tubes was sealed by melting the glass, and the other with epoxy resin. Thermocouples placed in middle and near both sides of cylinder andwere connected to the A/D board through an expander board (EXP- 16) using a gain of 1000.

IV. VOLTAGE AND CURRENT MEASUREMENT

The output of voltage transformer (220/380 V) is further reduced using two resistors R2 and R3 as a voltage divider. A precision metal film resistor (R1) of about 1 12, 10 W rating converted the output current from the current transformer into a voltage. The AC voltage and current signals could not be measured without first converting them into DC at intervals less than 1 s due to the low processing speed of the computer. Two precision rectifier circuits were employed for this purpose. After installation of the EXP- 16 and DAS-8 boards, calibration was carried out. The program was written in BASIC using the I/O driver routine provided with the DAS-8 board. The program included the following steps:

a) Initialize DAS-8 and load the standard thermocouple output data.
b) Define the arrays for call statement in every mode and for storing the real data.
c) Measure the voltage and current signal outputs.
d) Measure the output of CJC and temperatures through the EXP- 16 board.
e) Convert the recorded data into temperature, voltage and current.
f) Display the measured data at set time intervals.

V. EXPERIMENTAL PROCEDURE

Aqueous sodium chloride solution of 2, 4 and 6 w/v% concentration were used in the experimental tests.

The unit (cell length 104 cm) was used in static or batch heating experiments in the horizontal position.

All mentioned concentrations of NaCl solutions were heated using voltage gradients of 220 and 380 (V). All tests were replicated at least three times.

The temperature profiles along the axis of the heating unit and at three points in a radial plane near the center of unit were recorded with time during test.

The thermocouples were calibrated using a constant temperature water bath and a precision thermometer. The temperatures recorded by the microcomputer were then automatically corrected based on the developed relationship.

A digital multi meter was used to read the AC voltage and current at the electrodes and to compare the respective values displayed by the data acquisition system for calibration purposes.

VI. RESULTS AND DISCUSSION

6.1 Performance of data acquisition system

The data acquisition system performed satisfactorily and measured the temperature, voltage and current of an AC field without safety problems. The voltage and current could be varied from 220 to 380 V and from 0.1 to more than 30 A, respectively. The system needed about 1 s for sampling when nine channels of EXP- 16 board (for temperature measurement) and three channels of DAS-8 (for CJC, voltage and current measurement) were used. It measured temperatures alone within 1 s. These intervals were based on data display on the screen. If the data were stored only in the computer, the system took less than 1 s for each test run. The maximum error in temperature measurement was determined to be 0.3°C in the range of 20-90°C. The maximum error in both voltage and current measurements was less than 3% in the range of test conditions. The actual value of error was 2.93%. For example, there was a difference of about 4.38 V at 187.7 V with a maximum error of 2.34%.

6.2 Performance of ohmic heating units

During heating tests, the temperature difference in the ohmic unit ranged from 1 °C to 3 °C. In order to indicate the speed of ohmic heating, the relationships between the required times, voltage gradient and current density for heating the 2% solution from 20°C to 80°C. When the voltage gradient was varied from 220 to 380 V/cm, the required heating time decreased exponentially from approximately 180 to 30 s with the increase in the voltage gradient. Also the voltage gradient and current density appeared to be linearly related.

In comparison with traditional heating system, it was observes that the heating rate in ohmic system was dramatically higher as shown in Fig.3.

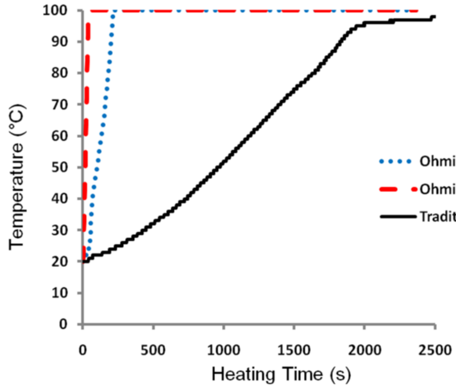

Fig.3. Temperature profile during heating by ohmic and traditional heating

Formation of bubbles was observed during the heating process, especially when the solution temperature reached around 50°C. The reason for this could be the release of gas in the liquid due to some electro-chemical reactions, corrosion indeed. The bubbles occurred much more quickly in high voltage gradient operations. Therefore releasing the bubbles needs serious consideration in designing static ohmic heaters.

VI. CONCLUSIONS

The experimental ohmic heating units and the data acquisition system showed good general performance. In developed system, the liquid foods could be heated from 20°C to 80°C in about 20 s at a voltage gradient of 380 V/cm. The heating was uniform for all practical purposes. The releasing of the bubbles formed during ohmic heating should be given seriously consideration, especially when the liquid temperature exceeds above 50°C.

REFERENCES

[1] Biss, C.H., Coombes, S.A. and Skudder, P.J., 1989. The development and application of ohmic heating for the continuous processing of paniculate foodstuffs. In: R.W. Field and J.A. Howell (Editors), Process Engineering in the Food Industry. Elsevier Applied Science, London.

[2] de Alwis, A.A.P. and Fryer, P.J., 1990. The use of direct resistance heating in heatfood industry. J. Food Eng., 11 (3): 3-27.

[3] Goullieux, A., and Pain, J. P. 2005. Ohmic Heating. In: Emerging Technologies for Food Processing (edited by D.W. Sun). London, UK: Elsevier Academic Press. pp. 469-505.

[4] Halden, K., de Alwis, A.A.P. and Fryer, P.J., 1990. Changes in the electrical conductivities of food during ohmic heating. Int. J. Food Sci. Technol., 25: 9-25.

[5] Jones, F., 1897. Apparatus for electrically treating liquids. US Patent No 592 735.

[6] Palaniappan, S. and Sastry, S.K., 1991a. Electrical conductivity of selected solid during ohmic heating. J. Food Proc. Eng. 14(3): 221-236.

[7] Palaniappan, S. and Sastry, S.K., 1991 b. Electrical conductivity of selected juices: influences of temperature solid, applied voltage, and particle size. J. Food Proc. Eng., 14 (3): 247-256.

[8] Roberts, I. L. 1900. Receptacle for sterilised perishable substance. US Patent No 645 569.

[9] Sastry, S. K., & Barach, J. T. 2000. Ohmic and inductive heating. J. Food Sci Sup, 65: 42-46.

[10] Sastry, S. K. 2005. Advances in ohmic heating and moderate electric field (MEF) processing. In: Novel Food Processing Technologies (edited by G. V. Barbosa-Ca´novas, M. S. Tapia, & M. P. Cano). Boca Raton, FL, USA: CRC Press. pp. 491-500.

[11] Skudder, P.J., 1991. Industrial application of the ohmic heating for the production of highadded value food products. In: R. Ahrenainen, T. Mattila-Sandholm and T. Ohlsson (Editors), News in Aseptic Processing and Packaging. VTT Symposium 119, Technical Research Center of Finland, Espoo, pp. 47-52.

[12] Stirling, R., 1987. Ohmic heating - a new process for the food industry. Power Eng. J., 6: 365-371.

AUTHOR'S PROFILE

Mohammad Hossein Mehraban Jahromi

Author was born In Jahrom, Iran. He received the B.Sc. degrees in Electronic Engineering, in 1999, at Islamic Azad university and M.S.E. degree in Power Engineering on Dec 2006 from Shiraz University. His research interests are in the Power Systems Operation, Modeling and Simulation, Identification, Monitoring and Control system, Solar Energy and solar Power Generation.

Hamidreza Gharehchahi was born at Isfahan, Iran in 26 April 1977. He graduated from Tabriz University on Mechanical Engineering in 2000, Tabriz, Iran. Then he passed the M.Sc. program at Iran University of Science and Technology on Mechanical Engineering in 2003, Tehran, Iran. Most of the time, he was very active at class and he got top marks in some courses. He has held positions on the Mechanical Engineering Department of the Islamic Azad University and he was the head of Mechanical Engineering Department for one year at Neyriz Branch. Now, he is a Full time Faculty Member and Student Deputy of Neyriz Branch, Islamic Azad University, Neyriz, Iran. His major fields of study are Manufacturing, CAD/CAM, Metal Forming, Advanced Manufacturing Technology.

Mohsen Gavahian was born in 1985 and received his B. Sc. and M. Sc. in Food Science and technology at Shiraz University (2008 and 2011, respectively). He is Ph.D. student in Food Science and technology (since 2011) at the Ferdowsi University of Mashhad (IR). . He is a Professor at the Department of Food Science and technology at the University of Fasa and also Department of Nutrition at Shiraz University of Medical science. He specializes in the areas of food engineering and technology, and in particular on ohmic heating systems.