Hide Soaking Controlled by Microcontroller with Ethernet Interface

PETR DOLEŽEL, VLADIMÍR VAŠEK, KAREL KOLOMAZNÍK, DAGMAR JANÁČOVÁ

Tomas Bata University in Zlin, Faculty of Applied Informatics,
nám. T. G. Masaryka 5555, 760 01 Zlín, Czech Republic
vasek@fai.utb.cz http://web.fai.utb.cz

Abstract: - The paper deals with utilization of Ethernet interface of microcontroller MC9S12NE64 in automatic control of hide soaking process. Microcontrollers are widely used in small or medium size technological processes. Microcontroller is usable for controlling the process described in this paper. The presented algorithm was developed to optimize the soaking process and prevent structural damage of hides that occurs while the hide is sunk and washed in plain water. Such damage is caused by large osmotic pressure that tears the fine structure of the hide. The algorithm was fully implemented into the microcontroller which controls the whole process. The Ethernet interface was used for interconnection with a computer. Web server is also part of the microcontroller so that the whole application is saved in the microcontroller`s flash memory. The computer only requires installation of a common web browser to provide successful communication with the microcontroller.

Key-Words: - Manufacturing technology, system mathematical model, measuring and control microcomputer system, simulation, Ethernet, webserver.

1 Introduction

Embedded systems are widely used for controlling small or medium sized technological processes [Axelson, 2003]. The utilization of microcontrollers has many advantages compared to common computers. Microcontrollers are cheap, small and have many useful functions prepared for direct use in technological processes. In addition there are microcontrollers equipped with built-in Ethernet interface that provides communication. Ethernet offers better options in data transfer compared to common serial communication (RS232, RS485, USB,…) used so far.

The goal of this paper is to show one of the possible applications of the microcontroller's Ethernet interface for controlling technological process of raw hide soaking.

Raw hides have to be conserved before they are used in tanning industry. There are several ways of conservation. It might be done by solid crystal salt, in salt solution or by pickling (salt solution with sulfur acid). Hides are delivered to tanneries in dry condition. There are many wet operations that change such dry hides to flexible and usable intermediate product. The soaking and desalting are included in these operations. The goal of this process among others is salt removal from the hide.

This process is usually done in large drums where hides are washed in plain water. There are several ways of washing [Covington, 2009]:

1) Flow system, where plain water is continuously brought to rotating drums. The increase in the water level is compensated by the outflow of waste water.
2) Decantation washing, where hide is washed with plain water in several steps. In this case it is always necessary to wait until the salt concentrations in the hide and washing bath equalize.
1) The last way consists in waste water utilization in the subsequent steps of the washing process. The only waste then is water saturated with salt from the last step of decantation washing.

Hide tanning, soaking and desalting belong to the most water-consuming industrial processes [Kaul et al., 2005]. Approximately 15-80m^3 of water is consumed per one ton of raw hide, giving in the outcome about 250kg of usable leather [Orhon, 2009].

Usually the hide is sunk into plain water. In such system the salt concentration rapidly decreases on the hide surface and then rises again. This rapid fall of concentration can be seen in Figure 1 and causes large osmotic pressure that can damage the fine surface structure of the hide [Kolomaznik et al., 2006]. This is more obvious in soft hides such as goatskin or sheepskin.

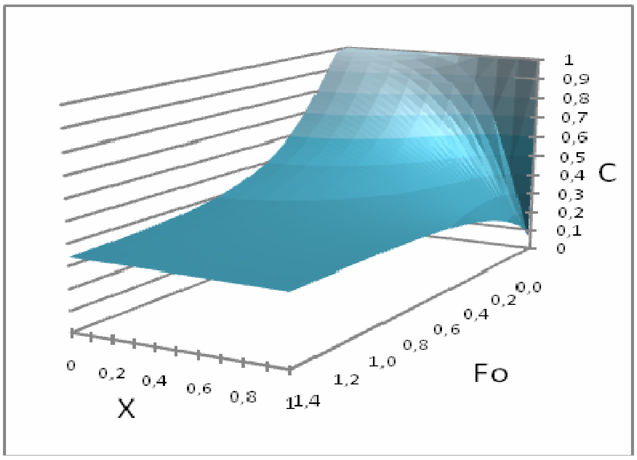


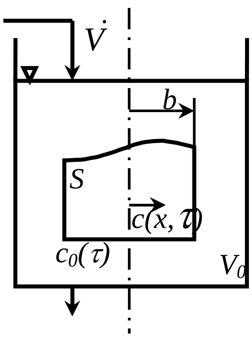
Fig. 1 Concentration shock on the surface

This effect might be eliminated by sinking the hide into the salt solution. In this case there is no longer such rapid concentration fall and only small osmotic pressure. The control algorithm described in this paper eliminates large osmotic pressure and reduces the concentration differences between the hide surface and its inner structure.

The algorithm was implemented in a microcontroller with an Ethernet interface. The Ethernet was used to connect the microcontroller to a PC and to obtain data from the microcontroller and display them in graphical environment on the computer screen.

2 Mathematical Model

The control of soaking process is based on a mathematical model. The system of desalting is shown in Figure 2.



τ – time

b – maximal sample thickness

x – variable sample thickness

S – sample surface area

c – salt concentration in sample

c_0 – salt concentration on the sample surface

Fig. 2 Model of the flow system

Raw hide is sunk into the solution with specific salt concentration and then the plain water is driven into this system while the waste water is flowing out.

The system is described by Fick's second law of diffusion [Kolomaznik et al., 2006]:

$$\frac{D\partial^2 c(b,\tau)}{\partial x^2}=\frac{\partial c(b,\tau)}{\partial \tau}$$

By introducing dimensionless variables we get

$$-\frac{\partial C(X,F_0)}{\partial X}=L[C_0(F_0)+1]+\frac{N_a}{\varepsilon}\frac{\partial C_0(F_0)}{\partial F_0}$$

where the dimensionless quantities have the form:

$$X=\frac{x}{b}\qquad F_0=\frac{D\cdot\tau}{b^2}\qquad N_a=\frac{V_0}{S\cdot b}\qquad L=\frac{\dot{V}\cdot b}{S\cdot D\cdot\varepsilon}$$

$$C=\frac{c-\varepsilon\cdot c_{0p}}{c_p}\qquad C_0=\frac{\varepsilon(c_0-c_{0p})}{c_p}$$

The initial concentration value is $C(X,0)=0$. The solution for the through-flow systems is :

$$C(X,F_0)=-1+2L\cdot$$
$$\cdot\sum_{n=1}^{\infty}\frac{\cos(X\cdot q_n)e^{(-F_0\cdot q_n^2)}}{q_n\sin(q_n)+q_n^2\cos(q_n)+q_nL\sin(q_n)+\frac{2N_aq_n^2\cos(q_n)}{\varepsilon}-\frac{q_n^3N_a\sin(q_n)}{\varepsilon}}$$

The roots q can be calculated from the transcendent equation:

$$tg(q)=\frac{L}{q}-\frac{N_a}{\varepsilon}q$$

The control algorithm was developed according to this mathematical model. The goal of this algorithm is to eliminate the concentration shock and change the salt concentration decrease from exponential to a linear character.

This behavior is achieved by implementation of the following algorithm:

$$\mathrm{u}_k=\frac{w\cdot u_{k-1}}{y_k}\cdot K$$

The u in the equation is the controlled value (flow rate of plain water), w is a set point (required gradient of the concentration degression) and y is the measured value (conductivity which is proportional to the salt concentration in the solution). The constant K is used for delay elimination and usually varies between values from 1 to 1.6.

ISBN: 978-1-61804-004-6

The desalting process depends on measuring of concentration, plain water flow or controlling the basic peripheries (valves, motors or pumps). The A/D converter, inputs and outputs are essential parts of any microcontroller. That's why microcontroller was used for controlling this process.

However, it is useful to visualize the process on the screen in an interactive way. This can be done by an additional application that runs on the computer and communicates with the microcontroller. This application has only interactive function and does not contain any control algorithm.

There are several options to accomplish the interconnection. It might be done by serial communication such is RS232 or RS485, by CAN interface or by Ethernet. In this work Ethernet was chosen because of its widespread utilization. Ethernet interface has been used only in desktop computers or laptops for years. Now there are already lots of embedded systems with this interface. It is easy to use and usually does not require any special device.

The Ethernet interface is a part of OSI (Open Systems Interconnection) standard. This standard is divided into several layers: physical, data link, network, transport, session, presentation and application layer. Each layer has its own function. The Ethernet represents the data link layer. The network layer is usually represented by IP protocol and the transport layer is usually represented by TCP protocol. The session, presentation and application layers might be joined into a single layer that is represented by any application.

3 Implementation

The algorithm was verified also on an experimental device created by modification of an old washing machine. This machine was equipped with two flow meters, a valve and secondary water circulation for a conductivity sensor. The whole device is controlled by a control unit.

Fig. 3 Ethernet module with microcontroller

The Freescale microcontroller MC9S12NE64 [8] is a part of the control unit that contains a mainboard and an Ethernet core unit (Figure 3). The Ethernet core unit is inserted into two slots located on the mainboard.

The mainboard is powered by a power module that transforms the input voltage of 24V into 12V, 5V and 3.3V. The conductivity sensor is powered by 24V, flow meters by 12V and the microcontroller itself is powered by 3.3V. The 5V is used for the controlling action elements (motor, pumps, valve etc.).

The output signal of the conductivity sensor is between 4 to 20 mA. This is transformed to 0-5V and read by an AD converter of the microcontroller.

The flow meters have impulse output that is processed by interrupts of the H port of the microcontroller. The impulse counter also provides information about direct water consumption.

The microcontroller and its Ethernet core unit were delivered with OpenTCP library. This library was developed by Viola Systems and is written completely in C language and might be used with different microcontrollers and not only Freescale.

The MC9S12NE64 contains also a simple web server. Files with web pages and applications are saved on a 1 MB flash memory. The server has a few limitations. Any web page on the server may contain only three external objects (CSS file, image, javascript etc.). This is the number of simultaneously served requests which the microcontroller is capable to process. This is the reason why the serving application is limited to java applet or flash animation; however, the total number might be changed in the configuration file.

In this paper, flash animation (Figure 4) was used for its easy visual implementation of the whole process. The communication between the microcontroller and computer is similar with the same communication in java applet.

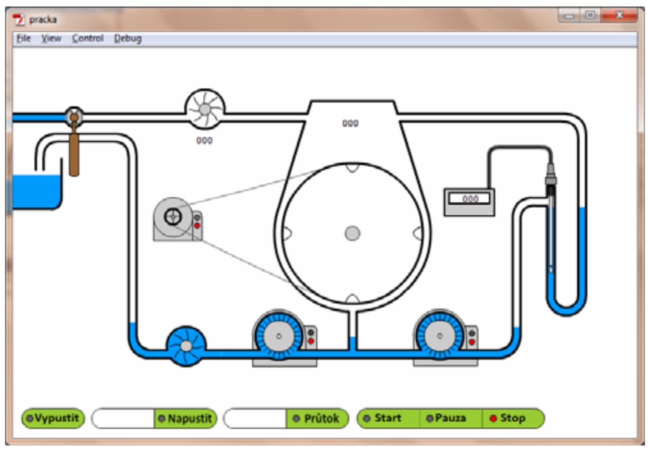


Fig. 4 Flash visualization

The communication process is based on requests that are run periodically in a specific time span. When the flash application is loaded in the web browser, the

ISBN: 978-1-61804-004-6

request of the current system state is sent. The result contains all information about the control process state (concentration, water consumption, time of process control etc.). After this initial step only the basic state is requested repeatedly because the state might be changed directly on the control unit by pushing the buttons. The action elements might be switched on or off also from the application by clicking on interactive elements in the flash animation.

4 Results

Figure 5 shows measurements of constant plain water flow for different flow rates. As can be seen the hide is sunk into a solution with specific salt concentration and no concentration shock occurs. The concentration decreases in exponential manner. It resulted in high differences between salt concentration inside the hide and on its surface.

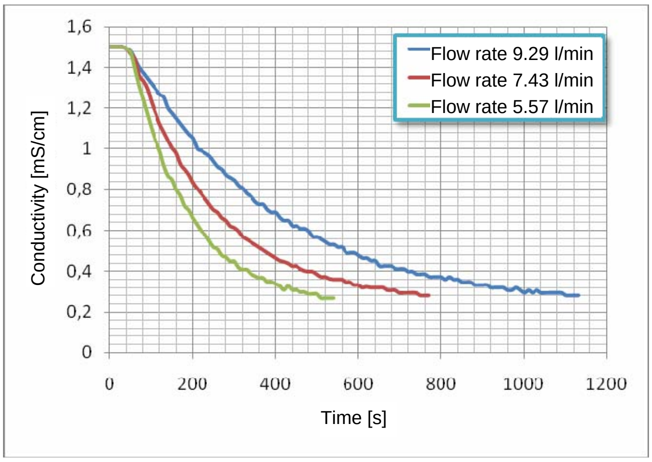


Fig. 5 Conductivity course for different flow rates

Changing the characteristic into linear behavior the differences between concentrations inside the hide and on the surface are much smaller. In Figure 6 is shown the controlled system. The flow rate is controlled by the algorithm described above.

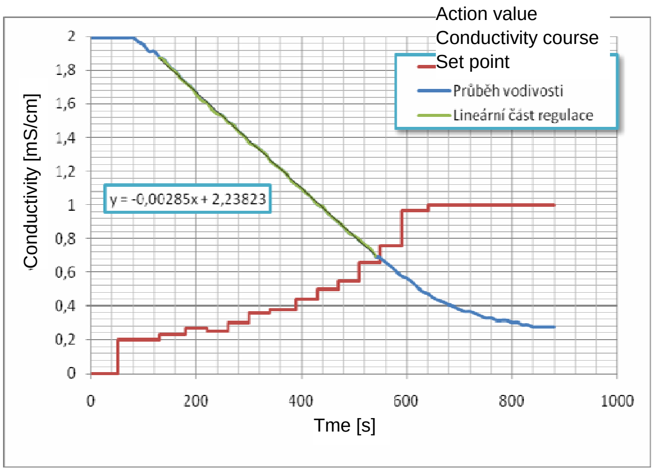


Fig. 6 Controlled flowrate

The data is repeatedly sent into the computer through the Ethernet for obtaining these characteristics.

5 Conclusion

The results show that linear behavior is achieved successfully by implementing the algorithm. It is also shown that utilization of a microcontroller is high enough for this purpose and the Ethernet interface is useful for visualization of such processes. It is easy to use as well as widespread and accesible in almost all computers or portable devices. The web server containing the visualization flash application ensures interportability. While communication based on USB, RS323 or CAN interface needs aditional software installation before it might be used, the Ethernet interface with web server and flash application (or java applet) ensures instantaneous use. The only required application is a common web browser that is a basic part of any operationg system.

Acknowledgement

This work was supported by research project MSM 7088352102 and ERDF Project CEBIA Tech No. CZ.1.05/2.1.00/03.0089. This support is very gratefully acknowledged.

***References*:**

[1] AXELSON, J. (2003). *Embedded Ethernet and Internet Complete*. Lakeview Research LLC, Madison, 2003. ISBN 1-931448-00-0

[2] COVINGTON, D. A., (2009). *Tanning Chemistry: The Science of Leather*. RSC Publishing, Cambridge, 2009. ISBN 978-0-85404-170-1

[3] KAUL, S. N., NANDY, T., SZPYRKOWICZ, L., GAUTAM, A., KHANNA, D. R. (2005). Waste Water Management With Special Reference to Tanneries. Discovery Publishing House, New Delhi, 2005. ISBN 81-7141-918-6

[4] KOLOMAZNÍK, K., PROKOPOVÁ, Z., VAŠEK. V., BAILEY, D. G. (2006) Development of a Control Algorithm for the Optimized Soaking of Cured Hides. The *Journal ot the American Leather Chemists Association*. Volume 101/9, 2006, pages 309-345.

[5] ORHON, D., BABUNA, F. G., KARAHAN, O. (2009). Industrial Wastewater Treatment by Activated Sludge. IWA Publishing, London, 2009. ISBN 1843391449

[6] Motorola. MC68HC11A8 HCMOS single-chip Microcontroller, 1996. Available from WWW: <www.freescale.com>