Software Implementation of the Control System for Dechromation of Tannery Waste Water

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Abstract: This paper focuses on description of software system which controls the process of removing chromium from tannery waste-water. The system is implemented as a part of laboratory equipment for recycling chromium from tannery waste. The laboratory serves for research and improvement of unique chromium-recycling technology based on enzymatic hydrolysis developed at our institute and the described system is the main control component of a part of the technology. The concept of the whole technology is briefly summarized first, and then the paper focuses on the dechromation control system.

Key-Words: - Control Web, control software, tannery waste, chromium, Advantech.

1 Introduction

Computer-based systems are nowadays becoming the standard for controlling technological processes. Especially if the process requires complicated evaluation of several inputs and computation of results based on these inputs it is hardly possible to control such a process without computer and appropriate software. One of the areas where such relatively complicated control systems are used is in the modern processes which are required to achieve the best efficiency and environment-friendliness. This article focuses on tannery industry which produces huge amount of waste. In tanneries, only about 20 per-cent of raw hide is transformed into the final product; the rest is waste in various forms. Big portion of this waste contains chromium which is still the most-used agent for hide-tanning in the industry. Despite the fact, that one of its variants, hexavalent chromium, is highly toxic and is proved to cause cancer. As the attempts to find a substitute that would give comparable results as to the quality of the product and production costs were not successful so far, it seems unlikely, that in the near future chromium in tanning industry would be replaced. This makes it important to develop methods for dealing with the waste containing chromium. The best option is to recycle the chromium and return it into the tanning process or use it in other industrial processes. A method for hydrolyzing chromium waste was developed at our institute, which produces relatively expensive protein hydrolyzates and also chromes sludge [1]. But if any new method is to be successfully implemented in industry, it needs to be optimized in the means of investment and operating costs. For this reason the method is realized in small scale in our laboratory. The main problem now is not the technological solution to recycling chromium from the tannery waste, but the economical part of the problem. It is required that the process is as effective as possible to allow its implementation in the tanneries. For this a computer-based control system is required which can process the inputs and control the system in real time.

2 Problem Formulation

This section will briefly introduce the whole technology and then focus on the part which deals with removing chromium from waste water controlled by the described system.

The base of the technology is enzymatic hydrolysis, which appears to be the best method for processing chromium-containing tannery waste both from the economic and ecologic point of view. This technology yields protein hydrolyzates that contain virtually no chromium while the dose of expensive enzyme is less than 1% and the filter cake can be recycled. The complete process is in our laboratory divided into four workplaces called: fermentation, filtration, evaporator and dechromation. First step of the process is chemical reaction in fermenter – hydrolysis [2]. Product of this reaction is then filtered and the resulting filtrate (valuable protein hydrolyzate) is dried in evaporator. At the last workplace, the filter cake containing magnesium hydroxide reacts in dechromation reactor with tannery waste water (spent liquor), which needs to be cleared of chromium. The waste water is freed of chromium and the chromium caught in the filter cake can be used in other industrial applications or returned to the tanning process. This article focuses on the control system for this last workplace. The principle of the technology controlled by described system can be seen in fig. 1. Suspended filter cake obtained at filtration workplace is transported from tank S3 into filter press FP. The tank M is filled with waste water which is then circulated through the filter press until concentration of the chromium in this water drops below the level at which further circulation would not be economically advantageous – it is cheaper to precipitate the residual chromium using alkali. The necessary amount of alkali is then measured from tank S2 into M and the process is ended.

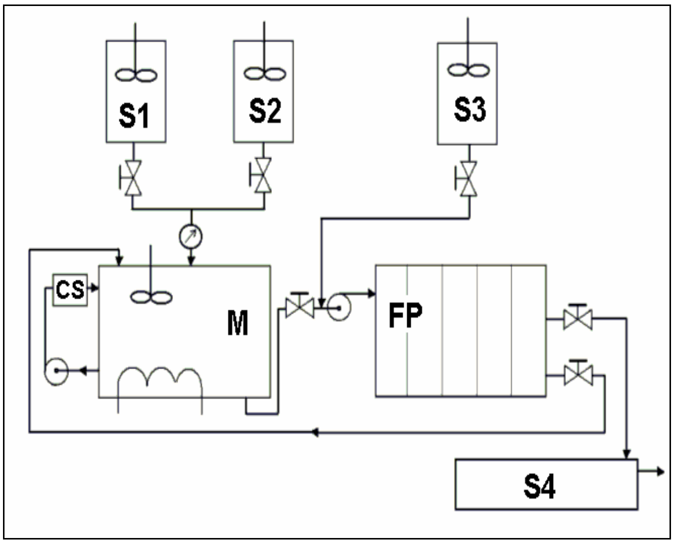

Fig. 1 Principle of the technology for dechromation

The task of the control system for this technology can be defined as continuously monitoring the concentration of the chromium in the waste water circulating through the filter press and computing the time required to reach the point, where it is cheaper to stop the circulation and remove the remaining chromium with alkali. This computation is based on equations published in [1]. The resulting optimal time for circulating the water through filter press is:

$$t_{opt} = \sqrt{\frac{V\beta K_A}{K_p k}} - \frac{1}{kc_p} \quad (1)$$

Where V is the volume of the water circulating through the filter press, β is stoechiometric coefficient of the reaction (which is 3 in this case), K_A is the price for unit amount of alkali, K_p is the price for running the pump for 1 second, k is the speed constant of the reaction of the chromium in the waste water with the magnesium hydroxide contained in the filter press and c_p is the starting concentration of chromium in the water.

When the control system finds out that the time of circulation already exceeded this optimum time, it will stop the cycle.

3 Control System

This section describes the control system developed for controlling the dechromation reaction. The description is divided into 2 main categories - hardware and software - but the focus is on the software implementation. The hardware has been already described in [4].

3.1 Hardware part of the control system

The control system for the dechromation workplace is depicted in Fig. 2.

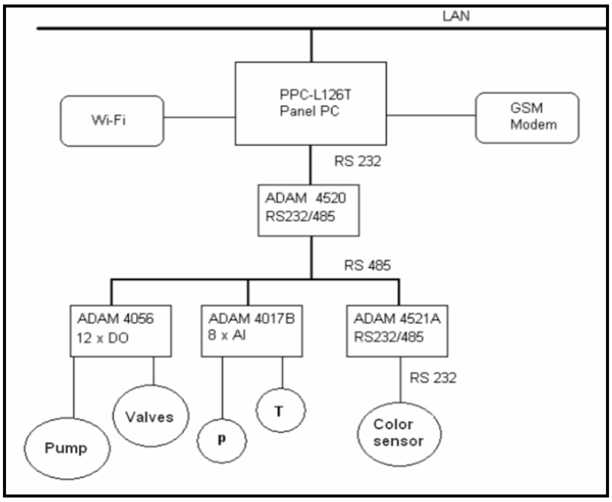

Fig. 2 Schema of the components of the control system

The central part is industrial panel PC Advantech PPC-L126T-R70 with 12” touch screen and Windows XP operating system. It allows comfortable control and visualization of the technology directly at the workplace. The computer is equipped with Via processor at 667 MHz with low power consumption and passive cooling which allows maintenance free operation for long time. To connect the computer with the technology, we used Advantech ADAM modules. These modules are connected via RS 485 bus which is connected to the RS323 port of the panel PC through RS 232/485 converter ADAM 4520. The following ADAM modules are used:

- Digital output module ADAM 4056S – to control the actuators (solenoid valves and pump). The module provides 12 outputs with open collector only, so there is a relay box between the module and the actuators.
- Analog-input module ADAM 4017B – used for sensors with current or voltage output.

For measuring temperature in the tank and pressure in the filter press sensors with current outputs (4 to 20 mA) are used. The concentration of the chromium in the water is measured by color sensor HDSC16 which communicates with the computer via serial line and reports the color as RGB values [3].

3.2 Software part of the system

As the main platform for programming the control systems for the technology we used Control Web. It is Rapid Application Development (RAD) system which allows easy development of control systems running in real time including visualization. It supports many devices and basically all Windows platforms, including Windows CE used in one of the workplaces. For the control system for dechromation workplace described here, Control Web version 5 is used with Advantech Adam 4000 driver.

3.2.1 Overview of the control system

The user interface of the software consists of full-screen window with tab selector on the right side, see fig. 3. There are tabs for manual control of the workplace, for semi-automatic and automatic control and for archiving the process. Each tab then displays its content in the left part of the window. Besides the tab selector there is also information about the current temperature, pressure and water color displayed all the time, for all tabs. There is also central stop button for emergency shut down of the actuators.

Most of the application code in Control Web is bound to graphical components on the screen (so called virtual instruments) and the following description of the system is therefore organized according to the tabs and their virtual instruments.

3.2.2 Manual control tab

This tab provides GUI for controlling the technology on the level of individual elements, such as solenoid valves. The scheme of the workplace is shown on the screen and the user can simply control the elements by touching the screen. The controls in this tab are Control Web "switch" instruments which have their "output" property set to the appropriate channel of ADAM 4000 driver.

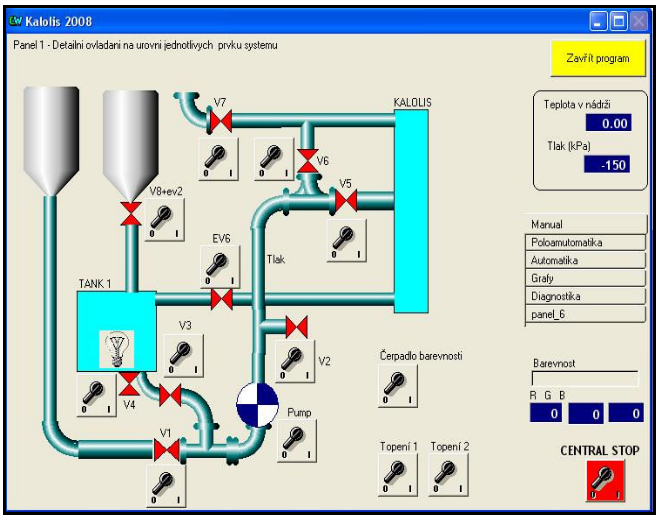

Fig. 3 Control program – manual control tab

3.2.3 Semi-auto control tab

In this tab the user can select a phase of the technological process, e.g. filling the filter press, and start this phase by single command instead of manually switching the required valves one by one. The main control in this tab is a combo box containing available phases. User selects a phase and then starts it by the switch. The implementation is as follows: when user activates the switch, its procedure OnOutput detects the selected item in the combo box and calls custom procedure "ActivateAction" which sets the outputs according to given action code. The interaction with the ADAM I/O modules is performed through a "program" instrument named "programAdvantechIO", which serves as an interface between various parts of the program and the actuators.

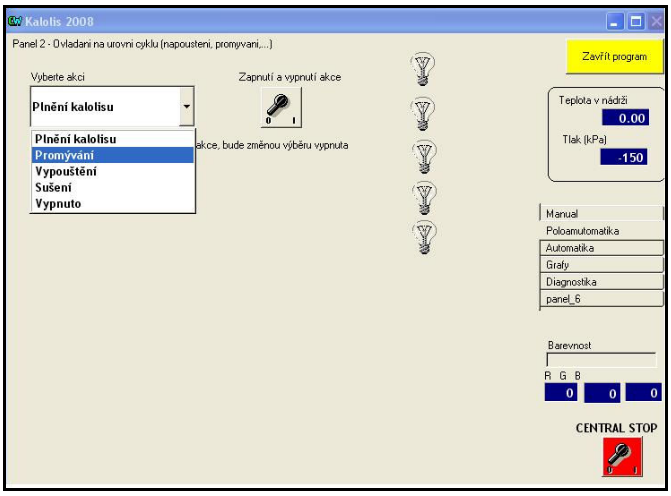

Fig. 4 Control program – semi-automatic control tab

3.2.3 Automatic control tab

This tab is used to control automatic dechromation of the waste water. The user enters the input parameters and then can start the dechromation. The input parameters include: volume of the waste water, price for 1 second of pump operation, price for 1 g of alkali and required concentration of the chromium at the end of the cycle. Once the dechromation is started it will be automatically ended when one of two conditions is met: either if the operation is already running longer than the optimal time, or if required concentration of the chromium is reached. The process can also be stopped at any time by the user. During dechromation, this tab displays the time from the start, optimum dechromation time as currently computed, chromium concentration etc.

The implementation for this tab is based on "selector" instrument which allows branching of the execution according to logical expressions. Each branch has a name and if the condition of this branch is met, all instruments which have this branch name set as their "timer" parameter are activated. In our program these activated instruments are "program" instruments, each of which handles one phase of the process such as calibrating the color sensor, circulating the water or error handler. In the programs it is also ensured that once the execution reaches its end, it changes a state variable to activate the next program by the selector.

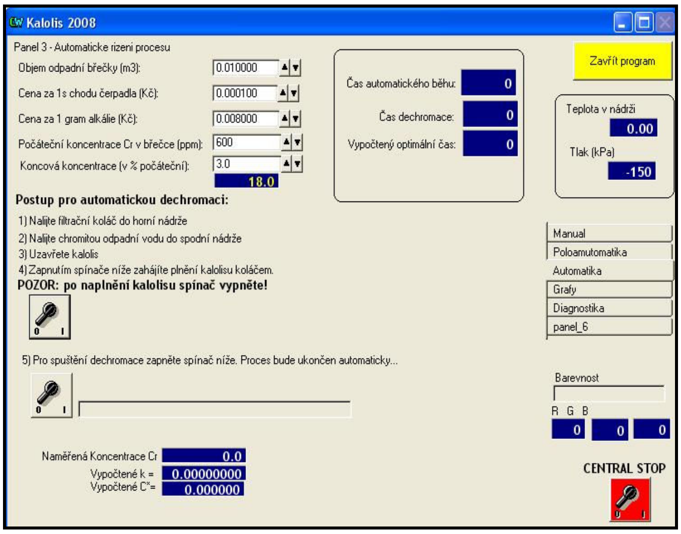

Fig. 5 Control program – automatic control tab

3.3 Verification of the system

For the verification of the system it was first necessary to determine the dependency of the output of the color sensor (RGB values) on the concentration of chromium in waste water. This was done using several samples of water with known concentration of chromium. Then an experiment was performed in which filter cake was prepared and then used in the filter press to clear waste water of chromium. The measured values were recorded and later used to compute the optimum time and verify the results of the program. It proved to be working correctly. Fig. 6 shows the record of change of the color of the water (RGB values) and pressure in the filter press.

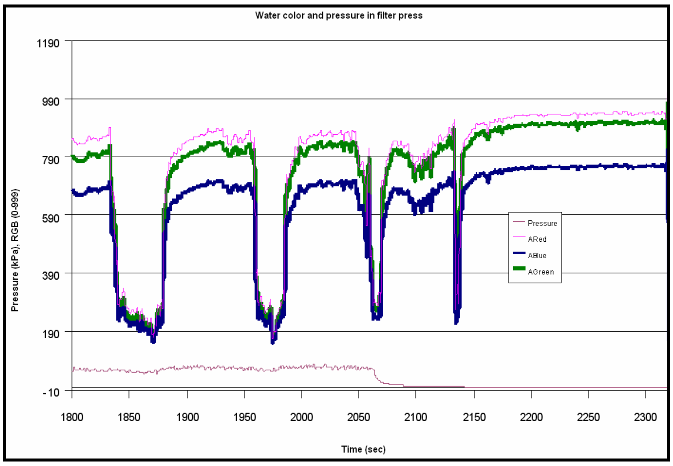

Fig. 6 Results of experimental dechromation

The drops in the color courses are caused by refilling the tank with the water leaked during the circulation, which caused turbulence and disturbed the color sensor.

4 Conclusion

This paper describes the software system for automatic control of the process of removing chromium from tannery waste-waters. The complete process of recycling chromium from both solid and liquid tannery waste is realized in laboratory scale at our institute and it consists of four workplaces. This paper focuses on one of these workplaces where the liquid waste is freed of chromium. It briefly describes the hardware and then concentrates on the software system which allows automatic dechromation of waste water. The system is implemented in Control Web development environment and running on the panel PC with Windows XP operating system equipped on the workplace. It consists of several windows selected by tab selector, which the user can control by touching the screen of the control computer. The software allows three modes of operation of the workplace: manual, with individual control of each element (e.g. solenoid valve); semi automatic mode with control of the phases of the technological process (e.g. filling the filter press); and automatic mode where the user only enters initial values and the system continuously measures process values and automatically decides when the dechromation should be stopped.

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