Modernization of Control System for Enzymatic Hydrolysis

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Abstract: - This paper describes new computer system for measurement and control for laboratory system for recycling chromium from tannery waste. The system is used for research and verification of unique chromium-recycling technology based on enzymatic hydrolysis developed at our institute. As the original control equipment became outdated, it was necessary to rebuild the technology with modern means of automatic control. This paper introduces the whole system for chromium recycling with focus on the control structure of the most important parts of the technology. The development and implementation of a new computer control system is described, from choosing the devices to final activation.

Key-Words: - Tannery waste, Chromium, Advantech, Control Web, Saia, Hydrolysis

1 Introduction

Chromium still remains the most used agent for hide-tanning in tanning industry even though one of its variants – hexavalent chromium - is highly toxic and is proved to cause cancer. Attempts to find substitute that would give comparable results as to the quality of the product and production costs were not successful so far and thus it seems unlikely, that in the near future chromium in tanning industry would be replaced [10]. Therefore it is important to develop methods for disposing of the waste containing chromium.

The amount of waste in tanning industry is very high. Only about 20 per-cent of raw hide is transformed into the final product; the rest being waste in various forms. The portion of this waste which contains chromium presents great burden for the environment and in the result, due to the cost of disposal, significantly affects the effectiveness of the production. As already mentioned, it seems unlikely that chromium in the tanning process will be replaced and therefore it is useful to look for options of effective disposal of chromium containing waste or, even better, methods for recycling chromium from this waste. The main problem nowadays is not the technological solution to recycling chromium from the tannery waste, but the economical side of the problem. It is required that the process is as effective as possible. At our institute a method was proposed for hydrolyzing chromium waste which produces relatively expensive protein hydrolyzates and also chromes sludge [1, 7]. 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. Recently, when the laboratory was moved into a new building it was it decided to completely upgrade the equipment of this laboratory with new control system.

2 Problem Formulation

Enzymatic hydrolysis 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.

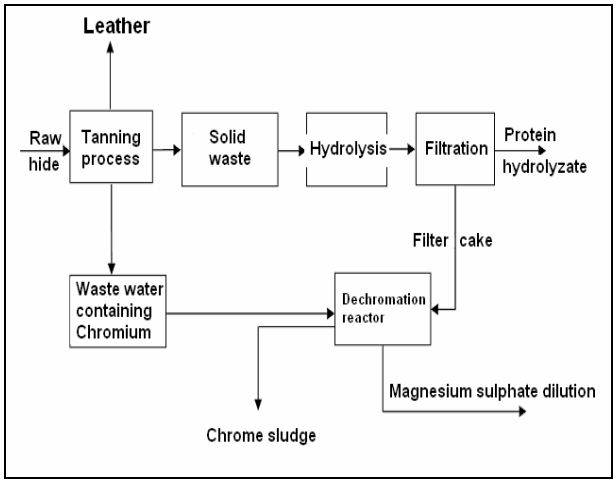

Fig. 1 Principle of the technology

Technology for this process is realized in our laboratory. The complete process for tannery waste recycling can be divided into four workplaces that we named as follows: fermentation, filtration, evaporator and dechromation. The principle of the method can be seen in Fig. 1.
First step of the process is chemical reaction in bioreactor (fermenter) – hydrolysis [2]. Product of this reaction is then filtered and the resulting filtrate (which is valuable protein hydrolyzate) is dried in under-pressure evaporator. Filter cake which contains magnesium hydroxide (material used in enzymatic hydrolysis), reacts in the dechromation reactor with tannery waste water (spent liquor) which contains chromium. As a result the waste water is freed of chromium and moreover the chromium thus obtained can be used in other industrial applications.
In this article we will focus on the new control system for this technology.
Because the equipment in the laboratory has been built over a period of years and many of the original devices became outdated, it was decided to rebuild the laboratory with new means of automatic control.
The aim of the modernization was to equip the laboratory with modern computer systems and other means of automatic control. The equipment was to be chosen not only with regard to technology but also so that it can be helpful for demonstrating automatic control equipment to students of our university. The aims for modernization were defined as follows:

- Modern computer technology for the computers that control the technology
- Intelligent sensors whereas useful
- Connect components using industrial buses
- Connect the technology with supervising system
- Use modern programming equipment with visualization

In the following text the solution we implemented will be described.

3 Control System

Scheme of the complete technology from the point of view of the control equipment can be seen in figure 2. The whole technology in the laboratory is divided into five workplaces, four of which are directly connected with the technology and one is supervising. The conception is based on distributed structure with a supervising computer on top, connected with the workplaces by industrial Ethernet and alternatively also using Wi-Fi or GSM.
The main components of the system are based on devices manufactured by Advantech [4]. At the top level an industrial personal computer is used. This computer should work as a supervising place from which it is possible to watch all the technology in the lab. However, it should also be able to control any of the workplaces directly [5].
The supervising computer is connected with the workplaces via Ethernet network which is implemented using Industrial switch Advantech ADAM 6520-B.

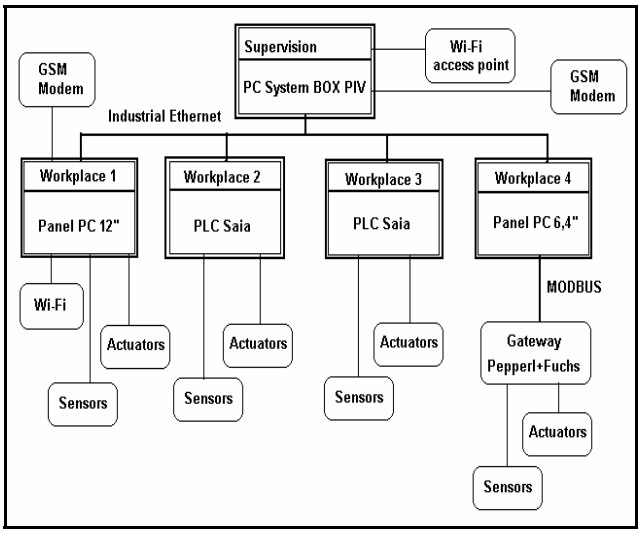

Fig. 2 Scheme of the whole control system

The dechromation workplace is also connected via wireless network – the central computer creates access point and the workplace can connect to this access point. The computer at the dechromation workplace as well as the central computer are further equipped with GSM modem, so that it is possible to demonstrate also this communication option in practical application. In the following sections the equipment of each workplace will be described in details.

3.1 Fermentation workplace control system

For the control of the fermentation workplace we use programmable logic controller (PLC) SAIA PCD2 manufactured by SAIA-Burgess Controls. It is compact controller with central unit and up to 8 input/output modules. For the control of the fermenter the following three modules are used:

- PCD2.A400 – binary output module with 8 outputs with transistors.
- PCD2.W200 – analogue input module with 8 channels, 0-10V, with 10-bit resolution.

- PCD2.W315 – analogue output module with 7 channels, 0(4) - 20 mA, with 12-bit resolution.

Temperature sensor from the old version of the equipment was retained, which is a Pt100 platinum sensor. The pH sensor is new, with 4-20 mA output connected directly to the PLC.
The PLC is connected with the supervising computer via RS232-Ethernet converter ADAM 4571. This converter allows the PLC to communicate using RS232 serial line as if it was connected directly to the serial port of the PC even though it is in fact connected via Ethernet. The principle of this can be seen in figure 3.

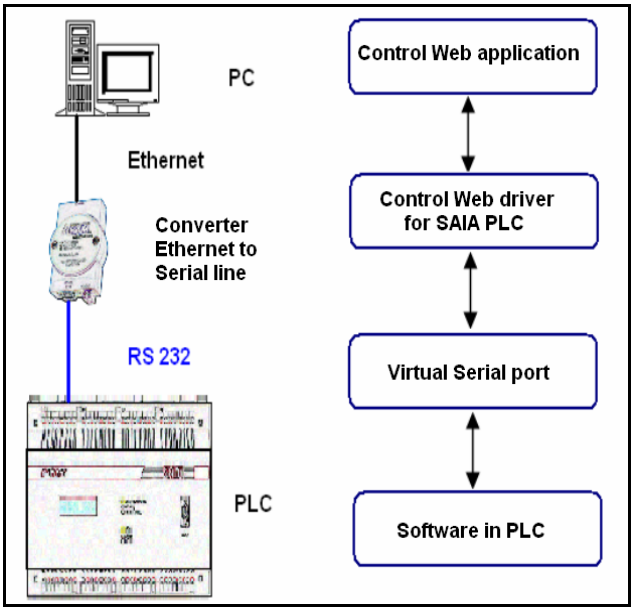

Fig. 3 Principle of connection between PLC and PC

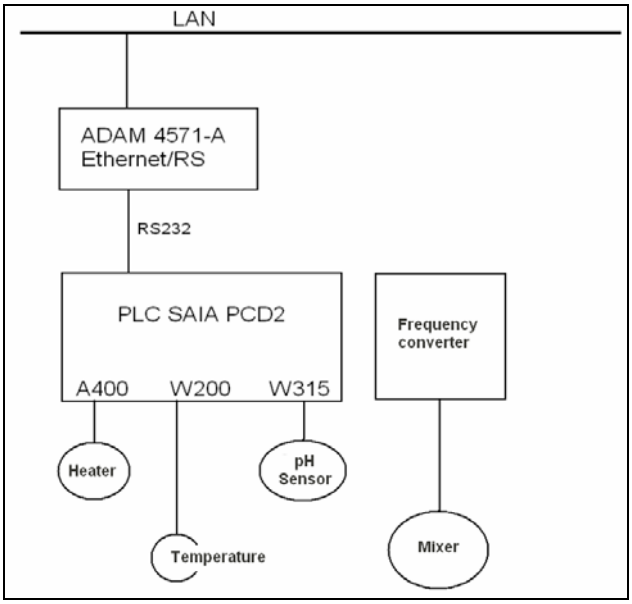

Fig. 4 Scheme of the fermentation control system

Simplified scheme of the control system can be seen in figure 4. Figures 5 and 6 then depict the control board with PLC and converter and the whole workplace respectively.
For the temperature sensor and output (heater control) there is a converter box which performs necessary conversions of voltage and power levels and also allows basic manual control of the process.
The PLC can work as a stand-alone control unit or it is possible to control the workplace from the supervisor computer where the PLC acts only as an input-output unit.

Fig. 5. Board for fermentation workplace


Fig. 6. The fermentation workplace

3.2 Filtration workplace control system

The control system for filtration workplace is very similar to the system used for fermentation. It also uses SAIA PCD2 PLC which is connected to the Ethernet via Serial-To-Ethernet converter ADAM 4571. Scheme of the control system can be seen in fig 7.

At this workplace the original temperature sensors which are built-in into the filtration funnel were retained but a new converter was created which converts the signal levels from sensors to unified 0-10V signal required by the PLC input modules and also provides power output for heater in the funnel. The stirrer is currently controlled manually but the converter box includes simple D/A converter which will be used to control the speed of the stirrer in 8 steps using three binary outputs from the PLC.

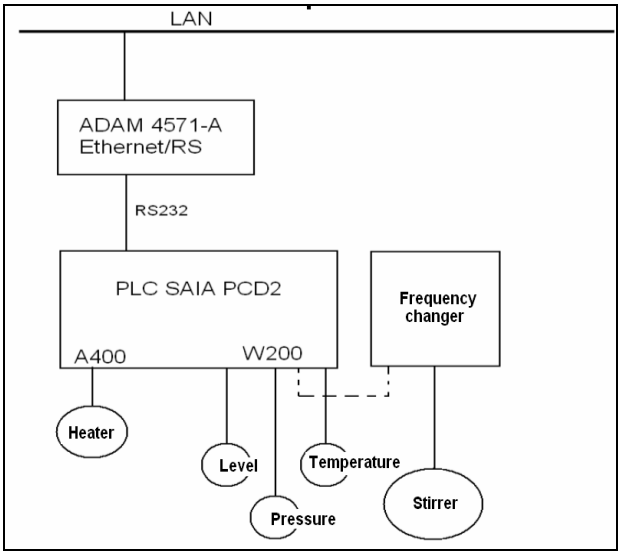

Fig. 7 Scheme of the filtration control system

3.3 Evaporator workplace control system

Workplace 4, evaporator, is controlled by Advantech TPC650T–CE panel PC with 5.7-inch touch screen and Windows CE operating system. Main features of the panel PC include Intel Pentium 266 MMX CPU with 32 MB DRAM, touch screen and support for Compact flash memory cards. For communication the computer is equipped with one PC/104 slot, Ethernet port, PS/2 port for mouse and keyboard and 2 serial ports, one of which can be configured to run in RS422 or RS485 mode.

The sensors and actuators are connected with the computer via modular system made by Pepperl+Fuchs which includes gateway KSD2-GW2, relay modules KSD2-GW2 and analog input modules KSD2-CI-2. The analog modules can be used to connect sensors with current output 4-20 mA or smart sensors which support HART protocol. The gateway communicates with the computer via RS 485 line using MODBUS protocol and with the input/output modules using CAN protocol.

Figure 8 shows the schematics of the control system of the evaporator workplace. As can be seen in the figure, the technology requires measurement of pressure and temperature and control of a heater and a small engine for rotating the ballon. These requirements dictated the number and types of the modules connected to the gateway. Of course other modules can be easily added. At the lowest level we use sensors with 4-20mA output.

Figure 9 shows the real control system and figure 10 then a test program running on the panel PC.

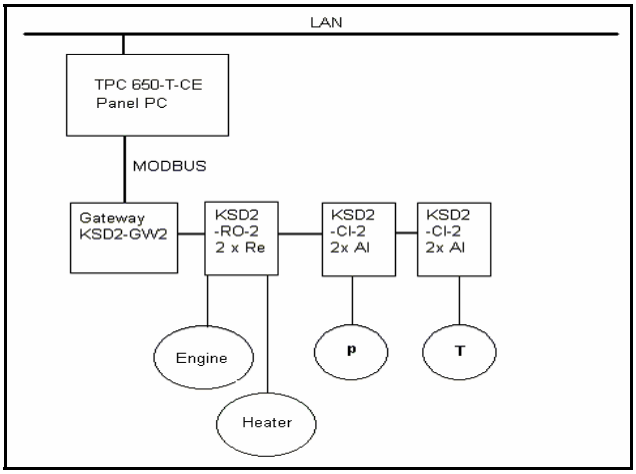

Fig. 8 Scheme of the evaporator control system

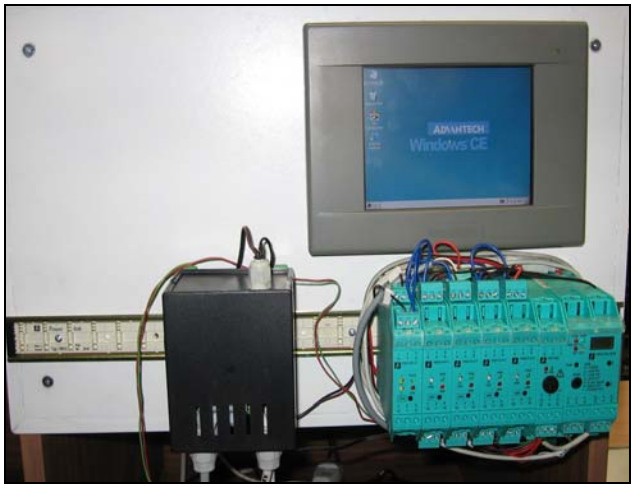

Fig. 9 The evaporator control system

Fig. 10 Main window of a test program running on the TPC-650 panel PC.

3.4 Dechromation workplace control system

In Fig. 11 the technological schema of the dechromation workplace can be seen. The process works as follows. Suspended filter cake obtained at filtration workplace is transported from tank S3 to filter press FP. After filling it, the tank M is filled with waste water. The water is then circulated through the filter press until concentration of the chromium in the waste water drops below level where it is cheaper to precipitate the residual chromium using alkali. The necessary amount of alkali is then measured from tank S2.

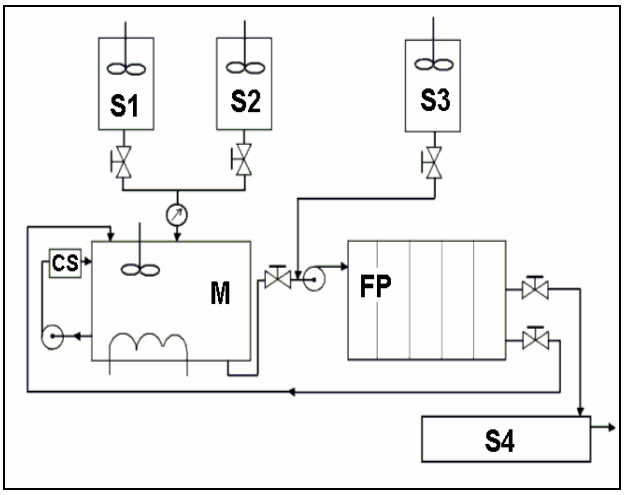

Fig. 11 Technological scheme of the dechromation

Fig. 12 shows the schematics of the control system of the dechromation workplace. At the heart industrial panel PC Advantech PPC-L126T-R70 is used. This computer with 12" touch screen and Windows XP operating system 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 promises maintenance free operation for long time. To connect the computer with the technology, we use Advantech ADAM modules. These modules form a RS 485 bus that is connected to the RS323 port of the panel PC through RS 232/485 converter ADAM 4520.

Based on requirements of the technology the following ADAM modules are used on the RS 485 bus:

- Digital output module ADAM 4056S – to control the actuators such as solenoid valves and pump. The module provides 12 outputs with open collector only, so the actuators are actually connected to a relay box controlled by the module.
- Analog-input module ADAM 4017B – used for sensors with current or voltage output.
- Input counter module ADAM 4080-D to connect flow meter.
- Converter module ADAM 4521-A (RS 232/485) used to connect intelligent color sensor to the RS 485 bus.

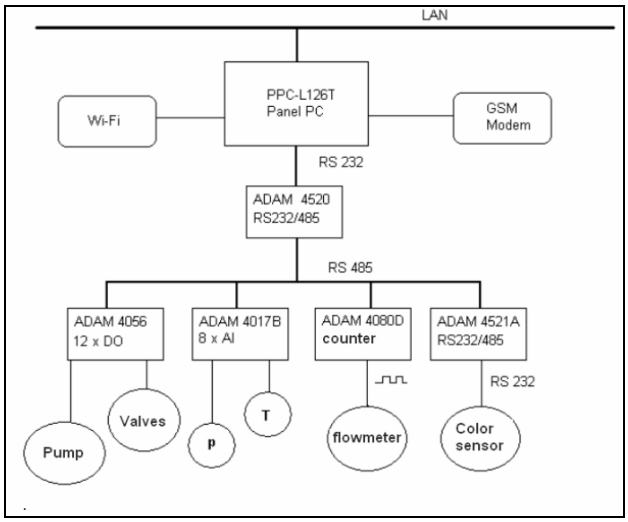

Fig. 12 Scheme of control system for dechromation

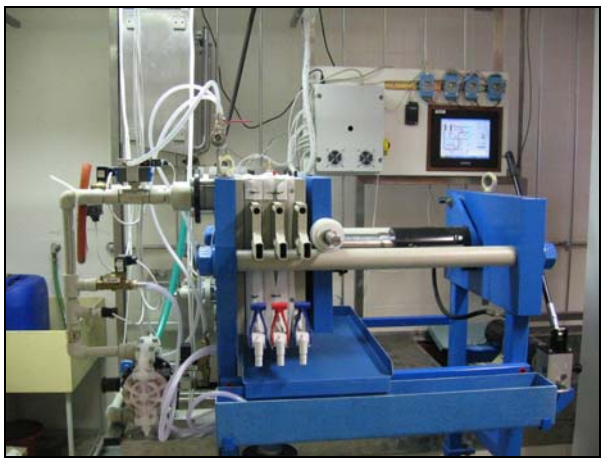

Fig. 13 Filter press workplace – side view

Fig. 14 Filter press workplace – front view