Chemical Engineering Applications on Unit Operations of Tanning Industry–Case Studies

Rames C Panda and P G Rao

Abstract—**Tanning industries still follow primitive methods to handle chemicals and raw materials that give rise to spill over of costly chemicals, health hazards and hence incur losses. Computerized dosing systems are needed to reduce spillage and wastage of costly chemicals in tanning operations. The unit operations in leather making are made into modules. Engineering inputs through automation (using PLC) must be brought into picture to improve the working atmosphere and to reduce losses. The results show improved quality control and healthy work atmosphere in the industry can be achieved by use of computer aided dosing systems (CADS).**

Index Terms—**PLC, Automation, Leather process, Tanning**

I. Introduction

Tanning is a process by which the putrescible skins / hides of animals, involving stabilization of the cross linking of collage nous proteins against microbial attack, are converted to non-putrescible leathers that is strong, flexible, able to resist decay and spoilage. These tanned leathers can be used for making different leather goods. The skins and hides, having their own characteristic grain surface pattern due to different biological factors, contain water, proteins (Keratin, collagen, elastin, albumin, globulin and mucin), fat, mineral and coloring pigments out of which proteins and fats get transferred to several products in operation. In the process of making leather, raw materials are passed through different chemical and mechanical operations before it comes to finished leathers. In most of the tanneries, water and chemicals are added manually in the tanning drum and also adjust pH of the float / leather in the drum manually. Addition of correct amount of process water and chemicals are necessary for better processing of the hides. Moreover, gradual addition of chemicals and close monitoring of pH in the drum operation promise better quality leather with required properties. The processing of hides and skins into finished leather involves about 45 chemical and physical operations of long durations. Introduction of controls at number of points yields a better result in producing consistency in leather quality. Both local and supervisory control stations are employed to accurately manage the operations. The first area considered for automation of tannery-wet operations is the control of volume and temperature of water. In the second stage, weighing & mixing of different chemical solutions and addition of these mixtures gradually into the tanning drum can be included in the automation module (Purushotam et. al., 1990). Huang and Liu (1996), Hitchingham and Thomas (2007), Li and Shitao (2009) have presented their designs for automated dosing systems for different other applications but not for leathers.

The objective of this work is to develop process control technology and to implement that to minimize rejects and batch to batch variation of wet blue quality through improved in-process control measurements. This aims at consistency in quality of leathers. To achieve this, entire work is divided into following segments:

Secton1 gives a brief introduction of unit operations in wet tanning section of leather processing. Schematic and pictorial views of tannery wet section are shown in section2. Limitations of existing microprocessor-controlled automated system are highlighted in section3. The present computer aided dosing system (CADS) is explained in section 4. At the end, in section 5, techno economic assessment of this scheme is discussed.

Implementation of cleaner production technology is essential for the sustained growth and development of leather industry. Chemical engineering concepts are needed to minimize water usage, toxic chemical load in tannery waste, wastage of chemicals and to increase production capacity. Engineering inputs can give better & safe material handling, process control and provides environmentally cleaner and healthier working atmosphere. Implementation of the developed technologies has been carried out in one of the Indian tanneries.

II. Leather Manufacturing

The traditional process of leather manufacturing from raw to wet blue and to crust comprises the following steps:

1) Soaking and Washing – The hides are soaked to remove dirt and are washed thoroughly in water. These hides are then taken in a paddle and further soaked using wetting agent and preservatives. Then the hides become ready for un-hairing operations.
2) Liming – Lime and sulphides are added along with water in the paddle containing hides. After unloading they are processed as follows:
3) De-liming and Bating – Chemicals are added in drum containing water and hides for de-liming. Then the hides are treated for bating after which the liquid effluent is discarded from the drum.
4) Pickling – De-limed hides are treated with water, salts and chemicals for pickling in acidic conditions. Liquid float is discarded and the pickled hides are treated for chrome tanning.
5) Chrome Tanning – This is an important step in leather processing in which, chemicals are allowed to diffuse through the pores of hides in consequence of which the hides turn towards leathers. The tanned hides get the properties of leather.
6) Neutralization – After performing chroming and re-chroming in acidic conditions in drum, the hides

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are neutralized using soft alkaline solutions. Then the hides are processed for re-tanning, dyeing and fat-liquoring to produce wet blue. For producing crust and finished leathers, some more steps like, piling, setting, drying, staking, toggling, trimming, buffing and de-dusting etc. are necessary.

Most of the above operations till wet-blue product are done in drums where chemical, water additions and pH adjustments are done manually. Hence, much process water, chemicals spill over and other utilities go as waste. In order to minimize the losses and improving the consistency of leather a strategy is to be undertaken to produce good leather in terms of color and finish. The solution is to adopt the benefits of recent advances in process monitoring, measurement and control. Strict control guarantees leather quality, consistency and insures the diversity of leathers and offers greater efficiency. Control of volume and temperature of water in dyeing & fat-liquoring, control of weighing, mixing, diluting of chemicals and addition of these chemicals into tanning drums are to be brought under automation.

III. Limitations of Existing Microprocessor Based Partial Automated System (PAS) –

PAS provides a dedicated system for a tannery processing specific products. It has following limitations:

1) This system cannot survive in rugged condition of environment / working atmosphere and hence is not robust.
2) Number of chemicals is limited and change in recipe according to managerial decision is not possible.
3) In case of failure of PAS the entire process cannot run independently and hence it does not provide redundancy.
4) This system is less flexible and less fault tolerant to operators.
5) The system efficiency and performance must be improved.
6) Start-up, shut down and maintenance is difficult for this system.

Hence in order to improve over all the above short comings, the present CADS (using programmable logic controllers, PLC) is designed to partially automate the wet operations.

IV. Computer Aided Dosing System (CADS)

Employing process computer will help in achieving the following

1) Reducing toxic discharges in effluent
2) Reducing BOD and COD levels to an extent of 50%
3) Improving grain characteristics and rejects of leathers
4) Easy handling and minimizing the losses of materials

In the present system, the critical and bulk chemicals are stored in bulk storage tanks (one for sulphuric acid, one for formic acid, one for alkali and two for fat liquors) and are drawn into the load cell as per process requirements or recipe. From the load cell, chemicals are fed into the drums through auxiliary tanks either in feeds or continuously. The float recycle system comprises of tube assembly that collects the process liquor during lower half cycle of rotation of drum and delivers into collector fitted inside the manhole during upper half cycle of rotation of drum. The process liquor flows back to the drum through the pH chamber that houses the electrode for pH monitoring. The pH indicator transmitter continuously monitors the process liquor. The pH control system controls addition of critical chemicals that indicates automatic end point. In order to create a better working environment improved drainage systems are provided in this package. The system helps in segregating the spent liquors to avoid mutual precipitation & subsequent clogging of drains apart from removing solid materials through appropriate screening. The flooring of the drum yard has been altered to prevent spill over in the pathway and to collect the liquors in the drains easily.

The entire process control operation is designed with following five modules:

1) Water addition module
2) Chemical preparation and dosing system
3) pH control and float recycle system
4) Drum rotation module
5) Odor reduction module

The proposed system is an integrated process computer with necessary field instrument and Programmable Logic Controller (PLC) connected in Distributed Control System (DCS) manner.

1) Water Addition Module (WAM): Hot/normal water is added in the drums as per process recipe. Water is also added in load cell tank for dilution of chemicals or is added to batch / bulk chemical tanks for ringing purpose. In case of hot water option, water is heated at 65 0C using steam in a heat exchanger. All the sequence of works are controlled by real time software for WAM through PC/PLC. The PC/PLC and field instruments/ controllers exchange data between them. Sequences and schedules of operation written using Laddar logic diagram are loaded into PC/PLC memory. The hot water storage tank is linked with the receiving units / equipments by header and branch pipelines as shown in figure 4. Based on the requirements of types of water hot/normal, water is added to respective drums through this module and pumps.
2) Chemical Dosing Module (CDM) – The P & I diagram for this module is shown in Figure 5. Chemicals required for a week's time can be unloaded into bulk storage tanks (T1 to T8). The local level indicators in each bulk tank show the actual level of chemicals inside the tank. For daily use, required amount of chemicals are drawn from these tanks to load cell by pumps (P3 to P10). These pumps can be switched on/off from the console / mimic panel. An interlock system between respective pumps and level indicators / switches of bulk tanks are set up to trip the pumps on/off. According to the recipe program loaded in the PLC, chemicals are drawn from batch tanks to

load cell. After mixing, required chemicals in exact amount, in the weighing cell for a particular time, the bottom valve of load cell can. be energized to open where by chemical mixture can be pumped to batch tank. There is an interlock between load cell bottom valve and pump. After filling up selected batch tanks, the drum operation modules starts. The gradual addition of chemicals starts with air operated solenoid valves. The time of operation or addition is programmable after which the respective valves are closed.

3) pH Monitoring Module (pHCM) – For pH control (Figure 6), the pH of float is monitored and sampled. The control valves (solenoid) work on error proportional mode and are guided by the positioner of control valves. Local pH controller (redundant) and indicators are available. In case of PLC failure, the local pH controllers can take up their respective jobs. The entire drumming operation runs as per the control module loaded in PLC
4) Odor Control Module (OCM) –
5) The sources of odor in tannery are mainly from H2S, NH3 and VOC generated due to putrefaction of protinacious material, collagen etc of hide/skin in pre tanning sections. These gases contaminate process liquor and air. The emission standards are shown in following Table I.

TABLE I. STANDARD LIMITS OF EMISSION

species	in water (mg/lit)	in air (mg/lit)
sulphide	1.0	0.14
ammonia	0.025	0.0006

The contaminated air inside the tannery is sucked and passed through blower and then through bio-filter. The filtration process is based on the principle that VOCs (in the order of 5-500 ppm) and odors can be biologically oxidized into carbon dioxide and water by naturally occurring microbes. The control parameters are: moisture in the bed and uniformity of media (contaminated air or process liquor). The humidity and temperature of inlet media is controlled and contact time with microbes is 10-30 secs. Moisture is controlled to maintain microbial population.

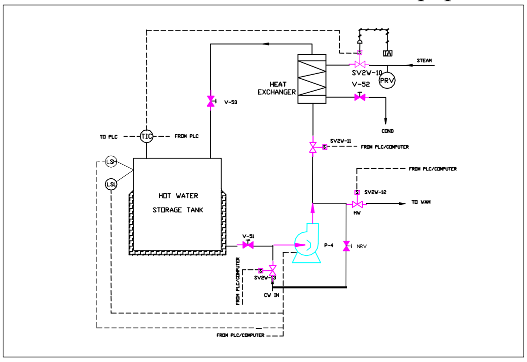


Figure 1. Schematic Representation Of Water Addition Module

V. FEATURES OF THE CADS

The proposed control system is envisaged to do the control and monitoring functions of the drums. Number of drums that can be linked to control system can vary from one to many. Since the system is modular, the facility can be expanded for any number of drums. Under the control modules, the sequences of opening and closing of valves, the mixing of chemicals & transferring operations are carried out through proper logic. The PLC system enables the operator to

1) Recipe management (download parameters based on selected recipe)
2) Monitor & Control of the process status
3) Monitor & report operator's intervention
4) Time tagging of all functions
5) Positioning of the drum in any position
6) Speed control of the drum via variable frequency drives
7) Control & Monitoring of the barrier & float & float temperature
8) All color coded multiple level alarm functionality along with time tagging
9) Interacts with Chemical feed and Water feed system
10) Control with both manual & auto modes of all the drum operations
11) Operate each drum independently & effectively
12) Initiate each drum with any tanning operation
13) De-initiate any of the initiated drum at any stage of the operation
14) Option to extend any of the operation
15) Wash the mixing tank, storage tanks independently
16) Data logging and printing
17) Digital indication of all process variables

Additional Features of the CADS / PLC system are

1) Alarm : Audio-visual indications for the convenience of the operator
2) Overall-Drum Status: Can be viewed on the custom graphic screens on the MMI
3) Hard copies of the detail can be obtained
4) Mimic panel board: to operate motors (MCB), pumps switches and AC/DC drives

Process Operating Conditions under the present system

A. *Water Addition Module (WAM):(Figure 1)*

1) Drum handling capacity: 1 to 8 per Satellite / PLC
2) Number of operating modules: 5
3) Operating pressure (WAM): Min: 2 atm
   Max: 4 atm
4) Allowable pressure fluctuations: ±30%
5) Water flow rate: Min: 600 LPM
   Max: 1200 LPM
6) Temperature: Max: 800C
7) Mixing arrangement: Heat-exchanger with hot water storage tank or 3 way mixing valve for hot and normal water mixing

B. *Chemical Dosing System (CDS):(Figure 2)*

1) Drum handling capacity: 1 to 8 per Satellite / PLC
2) Number of operating modules: 5
3) Automatic dosable bulk chemicals: 30
4) Manually addable products: 1 to 999 or powdery products in load cell

5) Mixing component per batch: 10
6) Mixing tank charge volume: 500 Lit
7) Accuracy of weighing: ±100 gms
8) Liquid pumping rate: 80 – 150 LPM

C. Drum Rotation Module (DRS):

1) Pneumatic door opening / variable frequency drives
2) Electronic speed adjustment: 8 and 16 RPM
3) Manually operated side/liquid drain valve
4) Side axle opening for entry of pneumatic piping/ over pressure control adjustment

D. Odor Control Module (OCM):

1) Online monitoring of bad odors generated from process & emissions
2) Control of operating process variables of bio-scrubbers
3) Microbial feeding and regeneration of filter/ packed bed

Figure 1 shows schematic diagram of water addition module, The chemical Dosing system is shown in Figure 2 and pH monitoring module is schematized in Figure 3.

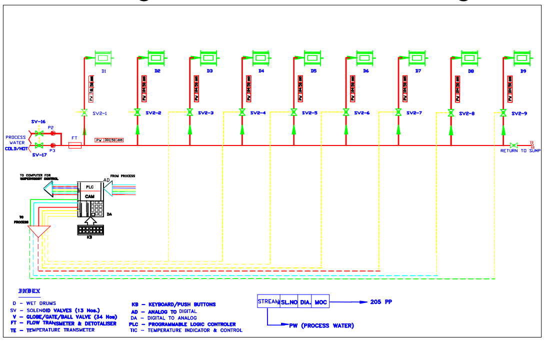


Figure 2. P&I diagram of Chemical Dosing Module

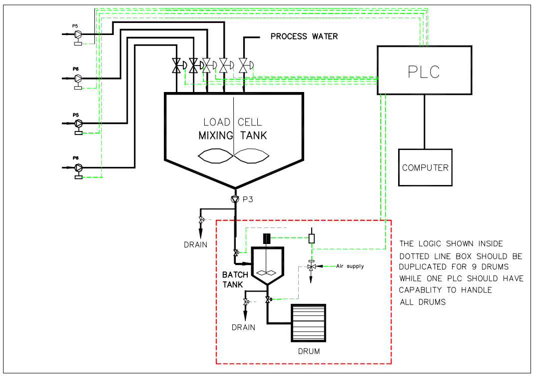


Figure 3. P&I diagram of pH Monitoring and Control (float) module

VI. Techno-Economic Benefits

The present technology is implemented in Tannery X (capacity- 400 hides/day) and technical feasibility report was made based on following processes –

1) Raw to wet blue
2) Wet blue to crust

Six batches of hides are processed under 3 batches with conventional and other 3 batches with modified. Wet blue & crust quality assessment have been made on the product. Effluent streams are also analyzed for composition.

Calculation is done for a particular tannery (say X) processing raw to wet blue. It is done in two sections. In the first section, only wet blue product is considered and pay-back period is calculated, and in the second section, savings in crust operations are also added to gross savings to calculate pay-back period. The gross savings (amount saved through chemicals, power, time saving and reduced wastage of water) play important role in these calculations. By working 300 days per year, the gross profit is calculated to be Rs. 8.63 lakhs per one shift basis or Rs. 17.25 lakhs per two shifts basis. Based on the 4 drums connected to automation system, percent of net return on additional investment comes to be 34%. Hence the pay-back period comes to be 4 years. The following benefits are observed on the modified process:

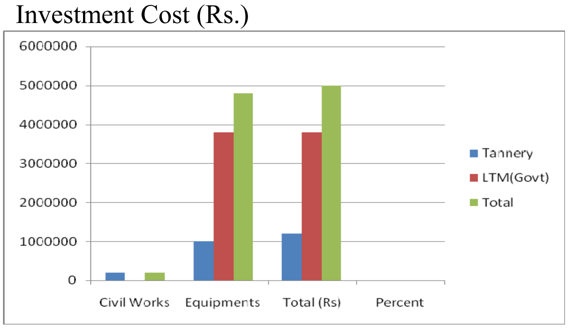
1) Quality consistency was improved to a minimum of 3%
2) Existing capacities can be significantly enhanced by changing over to 3 shift schedules. This is mainly due to saving in process time and hence manpower and power consumptions are reduced.
3) Strong economic incentives exist for accepting a higher level of investment of automation system. More attractive returns can be realized on investment than hitherto possible with the conventional systems.
4) The work culture in a tannery wet section with automation system can be changed for the better occupational health and safety. Production teams can be kept well informed of the operation sequences and drudgery can be reduced in various repetitive operations. Work procedures can be systematized to a great extent.

Due to reduction in chemical loads, the waste streams from the wet processing area are carrying less chemical loads

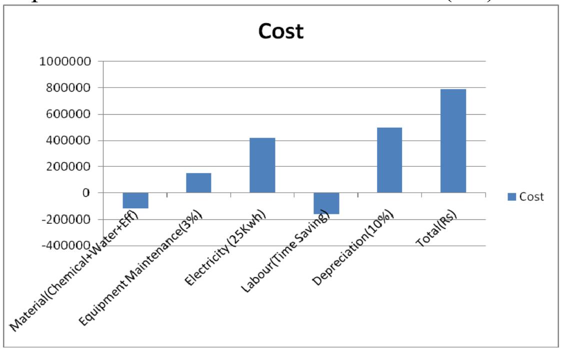
A. Achievements

Implementation of eco-friendly Process Control Systems in Tannery Wet Operations

1) Basic objectives are
   i) To reduce chromium and other toxic chemicals
   ii) To achieve better water management (water requirement = 17%) through
   iii) weighing exact amount of water feed and float recycles
   iv) To minimize the rejects of finished leather
   v) To create better working environment and improved house keeping in tannery
   vi) wet section
   vii) To provide adequate protective measures to the tannery personnel
   viii) To provide on-job training to the host tannery personnel
2) Investment Cost (Rs.)



3) Operation and Maintenance Cost / Year (Rs.)

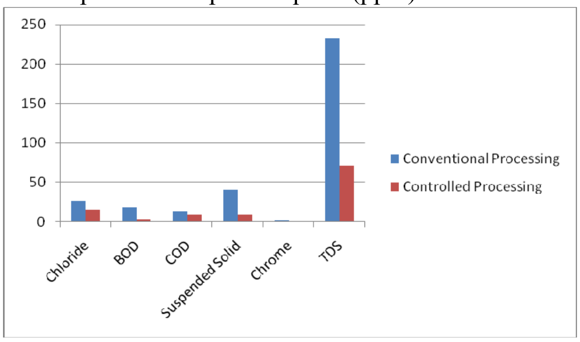


4) Training Provided
   i) Handling of eco-friendly systems including process control measures etc.
   ii) Safe handling of chemicals
   iii) Operation and maintenance of all the equipments
   iv) Time sequencing of unit operations

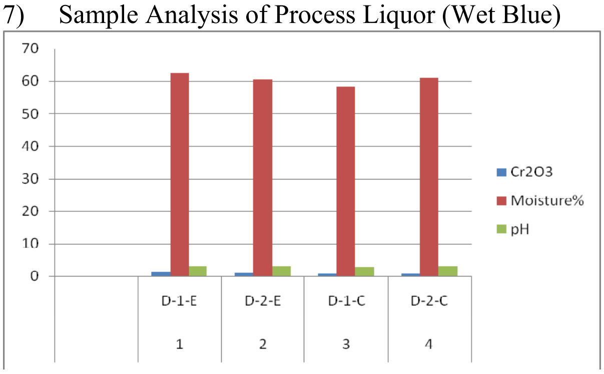
5) Cost Benefit Analysis (Rs)

Additional cost for cleaner technology implementation	50,00,000
Additional annual operating cost	19,70,000
Benefits through value addition (less rejects due to improved quality of product)	17,50,000
Pay-back period	**4 yrs**

6) Comparison of Spent Liquors (ppm)



7) Sample Analysis of Process Liquor (Wet Blue)

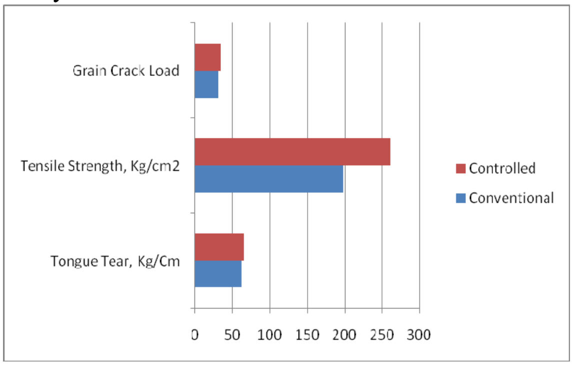


* E- for experimental and C- for control

8) Boil Test

B. Sample	**Conventional Processing**	**Controlled Processing**
Batch –1	Boil test failed	Boil test passed
Batch – 2	Boil test failed	Boil test passed
Batch - 3	Boil test failed	Boil test passed

9) Physical Test Date of Crust Leather



VII. Conclusion

Tannery wet operations are automated by implementing various process control measures that will help to yield more throughput, uniform quality product and build awareness on occupational safety. Comparison of products from processes & economic benefit analysis between conventional and PAS (partially automated system with CADS) reveals that the present technique can be implemented in more tanning units throughout the country.

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