C.R.C. Cell Rotaring Conditioning system

New drying and conditioning unit working with indipendent cells

by

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Abstract

C.R.C. is the new drying and conditioning system suitable for both chrome and non-chrome / metal-free leathers.
The layout includes a conditioning unit at the end of the tunnel whereas the drying chamber is split into independent sections.
Temperature, humidity, airflow and strain can be individually set for each section or cell according to the leathers characteristics like thickness, re-tanning, desired softness etc.
A machine engineered with independent cells allows the conditioning of different leather articles at the same time in sequence granting each lot a specific condition with no contamination from batch to batch.
The peculiar airflow ensures a smooth drying and a consistent conditioning across the cells thus avoiding the typical downsides of the current techniques (dark/burst edges, colour shade change, uncontrolled loose grain).
As a matter of fact a machine made up by individually programmable sections has a clear edge over the rotary or continuous traditional systems for the sake of the repeatability of all drying & conditioning cycles with particular regard to the critical phases of changeover of articles, pauses and shift change.

Introduction

Drying is one of the key mechanical operations in tannery process and is one of the key steps governing leather quality. Leather physical properties, such as area retention and softness, were affected by the drying method and dry condition. There are many predictive drying models and mathematical relation for toggling, vacuum and enviromental leather drying. Toggling and vacuum drying are today the most import method applied in tannery. Observation showed better toughness and softness for vacuum drying and higher area yield and stiffer leather for toggling. A laboratory scale composite drying with simultaneous vacuum and toggling was presented [1] in order to maximise the advantages of each technologies. Others authors proposed in the past ten years a steps drying [2].

For the CRC's design we have considered all these things and the physico-chemical connection beetween water and leather. Komanowsky's publications are the most quoted publication on this subject [3]. To understand the drying it is necessary to know the fibre structure of the leather and the interactions of collagen with water.

A wet leather contains different kind of water usually divided up in three main groups:

- Bulk water: liquid-like, can form ice at 0°C
- Bound water: structure between solid and liquid
- Structural water: part of the fibre structure

Each portion of the three kind of water may be different and depends upon the process and the chemical products that have been used. The relation between the water molecules and collagen fibres is paramount to the leather properties. The drying rate through evaporation of a wet leather was discussed by Friedrich. He defines three main stages:

〈: costant rate period: water between fibres removal
®: first falling rate period: water between fibrils removal
|: second falling rate period: water within the fibrils removal
Usually the costant rate period ends at 50% and the first falling rate at 30% moisture (expressed on dry leather basis).

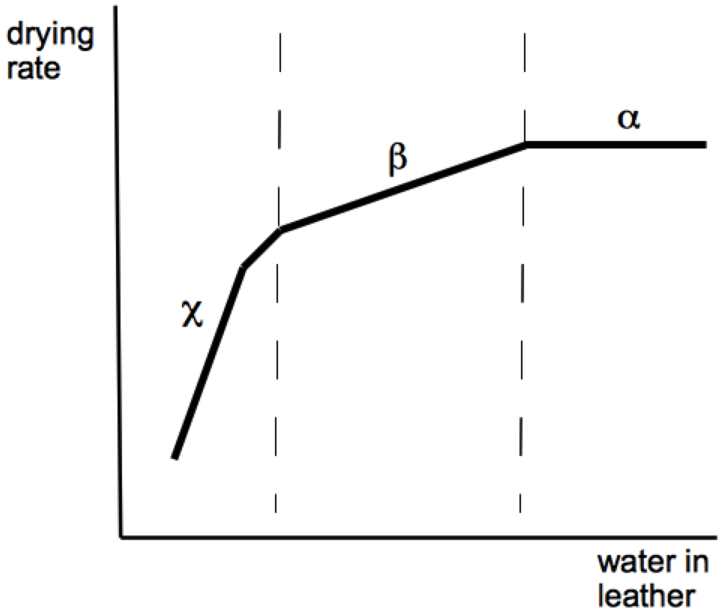

Figure 1 Rate of drying vs water in leather [2]

Leather is a viscoelastic material and the water content changes its properties like a plasticizer. It is also a microporous material where water is evaporated from its surface and is constantly replaced by other water from inside. The water diffusion is regulated by the capillary force and the evaporation occurs a constant rate. The mathematical model of the leather drying examined [6] shows that the drying rate is a function of four main parameters: water content, leather thickness (with exponent -2), drying time (with exponent -2), air velocity (with exponent -0,6).

Starting with a wet leather, experimental data were obtained measuring the elastic bending modulus (E) during the time at different air temperature. The elastic bending modulus indicating the stiffness of the leather, increases from wet to dry leather but the curve obtained shows two inflection points. Different tanned leather shows the same curve's shape in a diagram E vs time (fig.2) with two characteristic inflections.

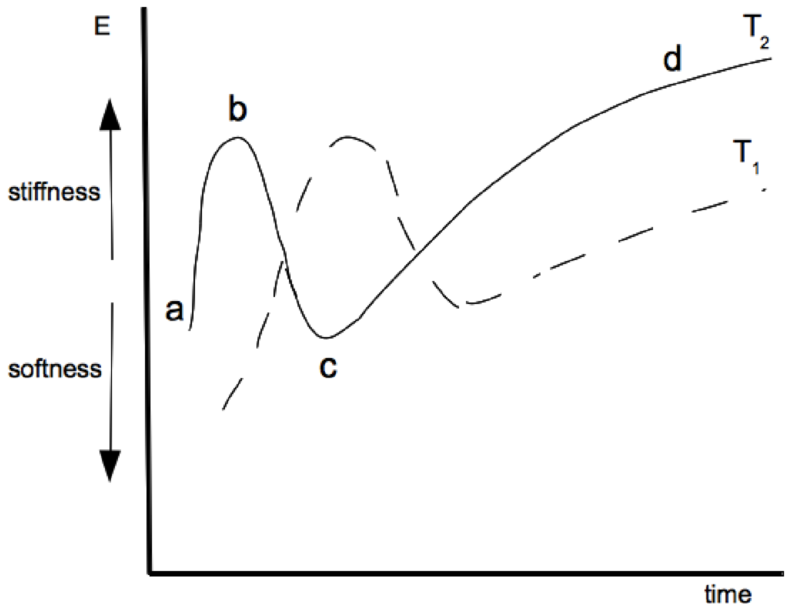

Figure 2 – Bending modulus vs time for same leather at different temperature (T_1<T_2) [2]

The critical points are around 60 and 30% moisture (water weight / dry weight) for a chrome tanned leather and around 10% less for an organic tanned leather. This value may be influenced by the chemical used and is very similar, for chrome and chrome-free tanning, if the water content is calculated on the dry collagen basis.

Increasing the temperature the drying rate is higher and curve shifts to the left, the inflection point compress to the ordinate axis (T_2).

For the three stages of the curves:
a → b removal of the freezable water. The molecular packing increases and so the bending modulus
b → c the fibrils dimension changes and allow more freedom of movement
c → d the water lose in this stage is bound to the side chains, the fibrils dimension decreases and reduces the volume

Many experimental data obtained on chrome and organic tannned leather prove that the softness is independent of the drying condition (temperature and humidity) reached in the first step of the process (point “c” in Fig.2) [2]. Only the loose of the structural water may change the leather softness so in the past ten years authoritative research suggests a two steps drying like the best way [5]: a first step to remove moisture until approximately 30% and a second step to give the final moisture.

Also the toggling tension was experimentally investigated [4]. There are evidences that during drying, collagen fibres become adhered to each other and this explains why the stress-strain curves for the dried leather are different in shape from wet leather.

The stress-strain curve of the dried leather is different with the stress applied (%) during the water evaporation. This is a measurable properties of the leather fibre allignment produced by the forced strain.

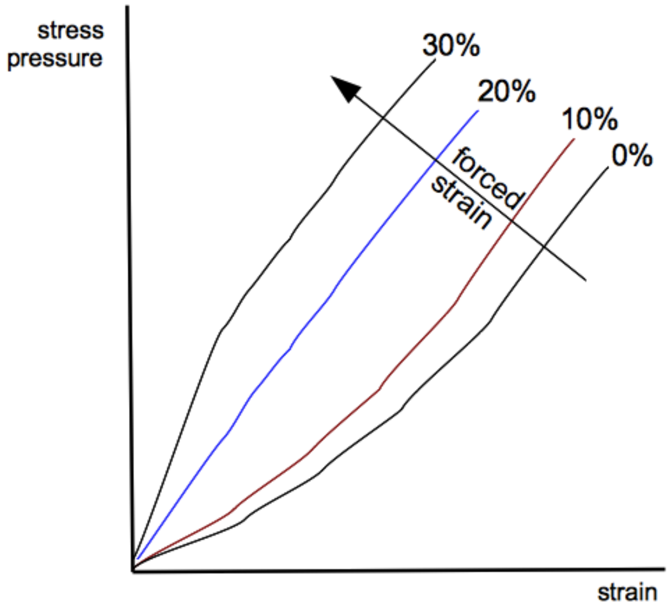

Figure 3. Stress vs strain curve of dried leather at different stress applied during the water evaporation [4]

The fixed strain affect with the microstructure of the collagen fibres and many properties like: tensile resistance and elogantion, area yield, loose grain. Considering the importance of the strain, CRC allows tensile control of each element during the drying: the expansion can be controlled and changed according to the leather size, article type and softness desired.

Results and discussion

A new system suitable for the drying and conditioning of leathers for furnishing and automotive interiors has been engineered and built as a result of both the investigations on the theory of drying and the long-time experience in the making of traditional tunnel driers.

Some distinctive features implemented as a consequence of the research are set forth below:
- Independent sections engineering: each cell counts on twenty frames that stay in according to the working cycle that has been programmed. A block of frame is simultaneously shifted from one cell to the next and the last module allows for a conditioning stage at near ambient temperature with possibility of increasing the humidification by means of water atomizers.

The leathers and the frames eventually get to the unloading station at near-room temperature bringing the double advantage of cooling down both the leathers and the frames before the unloading operation and also being able to keep the ambient standard conditions for longer periods of time;

- Airflow: there is heating system for each cell that can be individually regulated. Optionally the airflow can be either recycled inside the section or exchanged with the one coming from either the previous or the next cell;

- Airflow distribution: the airflow is drawn from the ceiling and blown downwards along the sides giving a bottom/top movement therefore crossing the leathers belly to belly and opposing the water that percolates down owing to the gravity. The centrifugal fans run at different speed for the sake of a better air mixing and in order to prevent the stratification of moisture. The pitch between frames is wider than normal so as to grant a better ventilation and thus enhancing the evaporation of water;

- Strain control: a sequence of devices provide the first extension to the wet leather and to the strain control system section by section in order to prevent any excessive stretch that may damage the leather. The strain control can be individually achieved on both the butt and the neck side so as to get a differentiated elongation in case of need;

- Drying programs: the drying management is done through working recipes set in accordance with the article being processed. Typically the anticipated drying pattern is individually performed in every cell and the block of twenty frames is sequentially moved from one cell to the next. When there is a change of shift or a pause any single cell will modify its working condition so as to carry out the process according to the anticipated cycle even without moving the frames. The actual air parameters (temperature and relative humidity %) are continuously monitored as time goes by in order to make sure that the set schedule is abode by.

Figure 4. Independent sections engineering

Figure 5. Airflow distribution

As for the power consumption the systematic use of centrifugal fans means a flat saving of 15% compared to the traditional axial fans whilst the air recycling among the cells grants a considerable saving of energy depending on the leathers being processed and the general working conditions.

A further saving of energy estimated in 10÷15% can be obtained if an air/air heat exchanger making up an efficient heat recovery system using the exausted is added to the plant.
The savings of energy and the working conditions are dramatically influenced by the type/origin of the hides. However, based on the previous experience acquired and the research works already examined and illustrated in the introduction it has been possible to pinpoint some general rules for the drying process to shape an ideal three-stages “drying profile” in the attempt to follow the ideal pattern of Fig.1 keeping into consideration the alteration of softness as a function of the moisture shown in Fig.2.

The setting of the airflow parameters of any single cell should take into account and be in correlation with the actual trend of both the temperature and the moisture of the leather across the whole drying process. This rule must be strictly followed in every cell and for all the segments making up the anticipated working cycle.

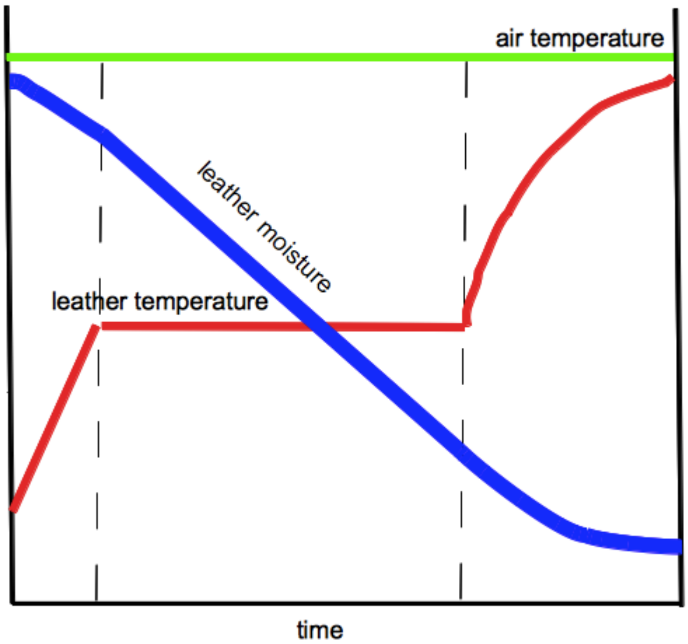

Figure 6. Leather temperature and moisture during drying

Graphically-wise the length of the individual segments and the slope of the ramps depend upon:
- Type of leather (tanning process and chemical products that have been used)
- Thickness and early moisture content of the leather
- Relative humidity of the air and its speed

In the real industrial environment the leather will not stand in a drying cell long enough to reach the airflow’s temperature and therefore the set for the air temperature can be higher than the theoretic limit temperature relative to the leather being processed.

Some crucial operational conditions that may do harm to the leather can be singled out through the working experience.

When it comes to non-chrome leathers this concept takes on a crucial weight and it is the main obstacle to the use of known technologies or practices for the drying as a dramatic shrinkage and a remarkable flattening of the fibres can be observed with a moisture content of 12-14% at temperature higher than 40-45°C.

Chrome-tanned leathers are less likely to shrink at high temperature and may show other defects when the leather is brought over 45-50°C with moisture as low as 10%. Amongst these side effects it is worth to mention: looseness on the flanks, diminished absorption of water, colour change.

Another essential contribution to the fulfilment of a drying recipe is the consistency of water content across the whole section of the leather and all over its surface. The critical conditions should not be met in any point of the leather so as to avoid defects here and there and grain burns.

The splitting of a drying process into sequential stages to be carried out within independent sections insures that potentially harmful conditions of either temperature or humidity that may turn into a damage of the leather, as mentioned above, are not reached. The consistency and the repeatability of the process is additionally achieved along with the necessary ductility of production granting different articles to be rotated without contamination between lots.

Conclusions

The research carried out has brought to building a plant on industrial scale which offers new possibilities of adjustment and a better control of the drying profiles.
Temperature, humidity, airflow and strain can be individually set for each section or cell according to the leathers characteristics like thickness, re-tanning, desired softness etc.
A machine engineered with independent cells allows the conditioning of different leather articles at the same time in sequence granting each lot a specific condition with no contamination from batch to batch.
As a matter of fact a machine made up by individually programmable sections has a clear edge over the rotary or continuous traditional systems for the sake of the repeatability of all drying & conditioning cycles with particular regard to the critical phases of changeover of articles, pauses and shift change.
Nevertheless the results achieved cannot be extended to all kind of leathers because there is a substantial influence of the tanning and re-tanning modes, no mention the raw material being processed. The trials have highlighted savings in electric power and heat ranging around 10-15% if compared to the traditional scheme.

References

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