INFRARED DRYING: A LEATHER FINISHING APPLICATION*

by

S. JÖNS, S. ALONSO**, F. TARACENA-SANZ[1], AND R. ZITZUMBO-GUZMÁN
CIATEC A.C. Omega 201
FRACCIONAMIENTO INDUSTRIAL DELTA
C.P. 37545, LEÓN, GTO., MEXICO

ABSTRACT

In leather finishing, alternative technologies such as infrared radiation can provide fast and efficient heat transfer for drying water-based films compared to conventional convection processes. In this investigation, an infrared dryer was designed and parameters such as heater distance to substrate, number and spacing of heaters, and leather transport speed were evaluated by using response surface methodology. From an experimental array, it was found that heater spacing is not statistically significant. However, other variables can be manipulated to improve overall dryer performance. A statistical model predicting the film drying in the infrared dryer was derived which can be used to choose suitable operating conditions for a particular finishing formulation. Furthermore, if the equipment is properly tuned, IR radiation can reduce both dryer length and residence time of the substrate during the drying process.

ABSTRACTO

En el acabado del cuero tecnologías alternativas, tales como radiación infrarroja, pueden suministrar más eficiente y rápida transferencia de calor para secar capas acuosas en comparación con procesos convencionales convectivos. En esta investigación, un secador infrarrojo fue diseñado y los parámetros tal como la distancia al substrato, número y separación entre calentadores, velocidad de transporte del cuero fueron evaluados por medio de la metodología de respuesta superficial. Por medio de un conjunto experimental, se encontró que la separación entre calentadores no juega significancia estadística. Sin embargo, otras variables pueden ser manipuladas para incrementar el rendimiento general del secadero. Un modelo estadístico que predice el secado de la película en el secador infrarrojo fue derivado con el cual se puede seleccionar las condiciones de operación aptas para alguna formulación específica de acabado. Más aun, sí el equipo se encuentra apropiadamente sincronizado, la radiación infrarroja permite reducir tanto la longitud del secadero como el tiempo de residencia del substrato durante el proceso de secado.

INTRODUCTION

Leather is finished to improve its characteristics of aesthetics and protection. Leather finishing formulations are based on different ingredients depending on desired properties of the finish. For example, garment leather needs abrasion and water protection, automotive leather must fulfill high fog and heat resistance standards, and shoe upper leather is required to withstand a standard number of Bally flexes (DIN 53340), as well as attain specific friction (DIN 53273) and adhesion (DIN 53339) values. As a consequence, finishing formulas are designed to meet the desired properties of the leather article being produced.

Three main techniques are commonly used to finish leather. The first one is named "curtain coating", where a curtain of coating is formed and applied to the leather by gravity. The second one is "roller coating", where the leather is in contact with a roller impregnated with finishing liquid. The third one is "spray coating" and is performed by utilizing spray guns that apply the finish by atomization. Since all three processes utilize totally different machines, each one requires different formulation properties.[1] The spray coating application requires a low viscosity fluid to facilitate flow through the nozzle. In the roll coating process, viscosity must be controlled to prevent the formulation from sagging on the roll.[2] The curtain coating technique requires a specific balance between surface tension and viscosity to avoid bubble formation and facilitate adequate penetration of the formulation into the leather since this coating method is primarily used in leather impregnation.[1]

*A **Technical Paper** based on a presentation at the 101st annual meeting of the American Leather Chemists Association at the Skytop Resort, Skytop, PA on June 23 - 26, 2005
[1]Instituto Technologico de Queretaro, Postgraduate and Research Division
**Corresponding author - Email: salonso@ciatec.mx
Manuscript received June 16, 2005, accepted for publication September 2, 2005

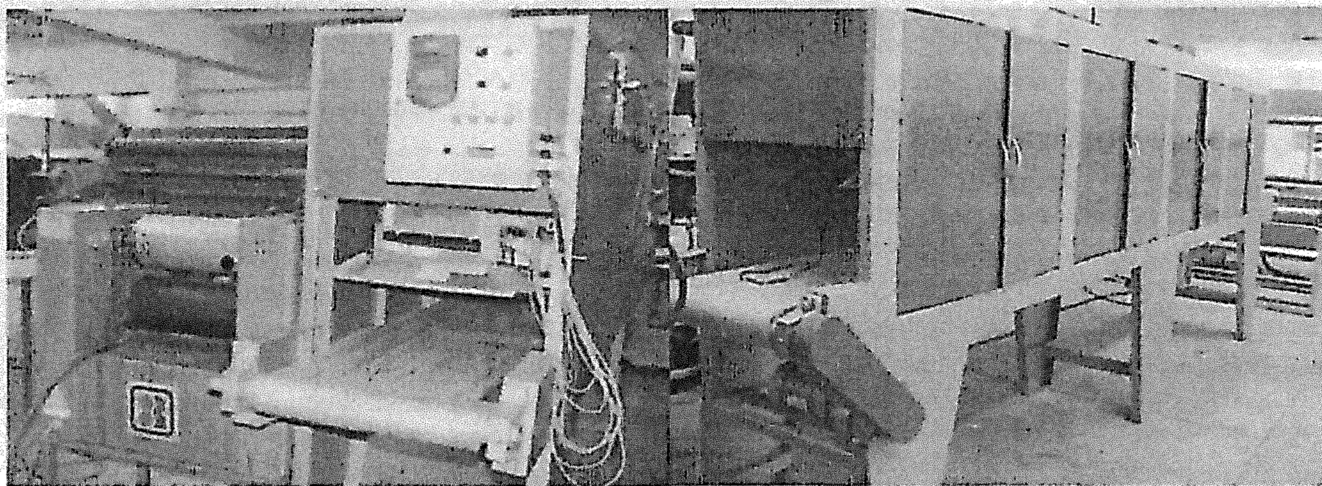

Figure 1. - Leather finishing experimental equipment

The primary objective of the drying process after the finish application is to evaporate the carrier agent (either water or organic solvent) from the formulation. Since each application process requires a different formulation viscosity, a distinctive film thickness is provided which leaves behind different amounts of carrier on the leather. Common sense says that the drying requirements should agree with the amount of formulation being applied but there are no references to confirm this. Only one reference about finish drying could be found: Wenzel[4] suggests that drying based on convective heat transfer should progress from a hot zone through an intermediate temperature and end with cooling, but lacks measurements or suggested temperature values. The majority of the literature only contains information about leather drying after the retanning-dyeing-greasing process. For instance, alternative technologies such as microwaves have been applied to the leather drying process with limited success.[5,6] In an experimental evaluation of the microwave drying process, Skansi et. al.,[5] developed a mathematical model to study drying speed, temperature variation and dielectric properties of leather. The results[5] lead to the conclusion that microwaves reduce the amount of energy necessary to dry the leather, but the technique does not seem to be commercially feasible. Monzó-Cabrera *et al.*[6] combined microwaves with a hot-air current, achieving significant savings of energy. Another technology is infrared radiation; it has been proven in paper drying instead of using rollers heated with superheated vapor.[7] In the paper making process, it is more efficient to use infrared drying to fulfill increasing speed demands since the use of heated rollers does not provide needed versatility.

Infrared energy is very versatile. By manipulating the infrared source temperature, the emission wavelength can be adjusted to the specific wavelength absorption of the substrate. Therefore, many materials can be heated. Heating efficiency is highest when both source emission and substrate absorption wavelengths are coupled.[8] Thus, infrared radiation can be used to dry both organic solvent and water-based formulations. Water-based formulations, in accordance with environmental considerations, were selected in this investigation (solvent-based formulations could be dried but require a costly flameless infrared heater). Gas-fired infrared sources were preferred as electrical sources generate radiation primarily in the short-wavelength infrared spectrum far from the absorption wavelength peaks of water, and because gas, as energy source, is cheaper than electricity in Mexico. Water has two peaks of absorption, the first one at ~ 2.95 µm (~ 708°C) and the second one at ~ 6 µm.[9] Following Plank's Law,[8] the higher the temperature the greater the emitted heat. Therefore, it is more efficient to emit at the lower wavelength peak of absorption of water, which also corresponds to the higher source temperature and higher heat generation.

In view of that, we tested infrared heating technology in the leather finishing drying process. To carry out the investigation, a drying tunnel was designed and built. Infrared panels were selected from a commercial supplier and adapted for the application. Experimental design tools were used in order to assess the effect of different operating variables on dryer performance and a statistical model was developed to predict the behavior of the drying equipment. Finally, the benefits of using infrared technology in the finishing film drying process are presented. The associated efficiency gain can benefit both productivity and competitiveness of the tannery industry.

Experimental

From a brain storm, drying equipment variables were carefully identified to differentiate process, response, and noise variables. Four process variables were recognized as key factors: grams of applied film or film grammage (A), transport speed (B), distance from all panels to substrate (C), and number of panels in operation (D). The response variables identified were evaporation percentage, shrinkage, and exit temperature. In additions, noise variables such as ambient temperature (average 23°C) and relative humidity (average 45 %) were measured.

The experimental infrared dryer is shown in Fig. 1. The front panel and lab roller machine used to apply the finish are found on the left and the tunnel is at the right. Four LP gas-fired infrared panels were installed along the tunnel of 4 m long and 70 cm wide. According to the manufacturer, the temperature at the surface of the infrared panel is ~ 982 °C.

The experimental procedure was as follows:

1. Area measurement via digital image processing.
2. Weighing of the leather sample.
3. Application of the finish film via roller machine.
4. Weighing immediately after application.
5. Sample temperature measurement at the entrance of the tunnel.
6. Drying in the infrared tunnel.
7. Sample temperature measurement at the exit of the tunnel.
8. Weighing of the finish-dried leather sampl immediately after exiting the tunnel.
9. Area measurement via digital image processing

The repeatability and reproducibility of the procedures o weighing the samples and measuring the area wer considered in order to obtain reliable data (a Gauge R & F study[10,11] was followed).

Samples of chrome tanned leather for an automotiv application were used that were identified as Black Dakot by the supplier. The aqueous finishing formulatio (provided by Together for Leather) contained two acryli resins, black pigment, filler, and a viscosity modifier a 28 % of solids.

Though several experimental arrays were experimente with, the two ones that were key in optimizing drye performance are presented in Tables I and V. It is importan to mention that from the three initial experimental array carried out, it was found that the variable, heater spacing was not significant so that it was not considered in th experimental sets presented here. It was also discovere that the grams of formulation applied, or film grammage was very important (although at the beginning it was no even considered in the experimental arrays); thus, it wa taken into account as an additional main factor.

TABLE I
Experimental Array Used to Explore the Response Surface

EXP	A	B	C	D
1	-1	-1	-1	-1
2	-1	-1	-1	1
3	-1	1	-1	-1
4	-1	1	-1	1
5	-1	-1	1	-1
6	-1	-1	1	1
7	-1	1	1	-1
8	-1	1	1	1
9	1	-1	-1	-1
10	1	-1	-1	1
11	1	1	-1	-1
12	1	1	-1	1
13	1	-1	1	-1
14	1	-1	1	1
15	1	1	1	-1
16	1	1	1	1
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0

A = Film grammage (3.32, 6.14, 8.18 gr)
B = Transport speed (4, 7.5, 11 m/min)
C = Panel-substrate distance (12, 17.5, 23 cm)
D = Number of panels in operation (2, 3, 4)

TABLE II
Resulting Data from the Experimental Array in Table I

EXP	% Evaporation	% Shrinkage	Exit temp. (°C)
1	159.26	1.07	46.6
2	255.80	2.84	77.6
3	57.56	0.00	49.6
4	95.44	0.00	73.6
5	85.68	0.00	42.6
6	188.51	0.61	70.4
7	46.39	0.00	43.2
8	77.62	0.00	67.4
9	72.60	0.29	52.2
10	116.03	1.78	78.2
11	30.66	0.00	39.4
12	62.18	0.00	62.2
13	58.75	0.06	42
14	101.37	0.76	68
15	28.80	0.00	36.4
16	44.09	0.12	47.8
17	64.55	0.03	59.8
18	74.33	0.26	59.4
19	64.77	0.24	56
20	58.62	0.32	57.6
21	58.34	0.24	60.4

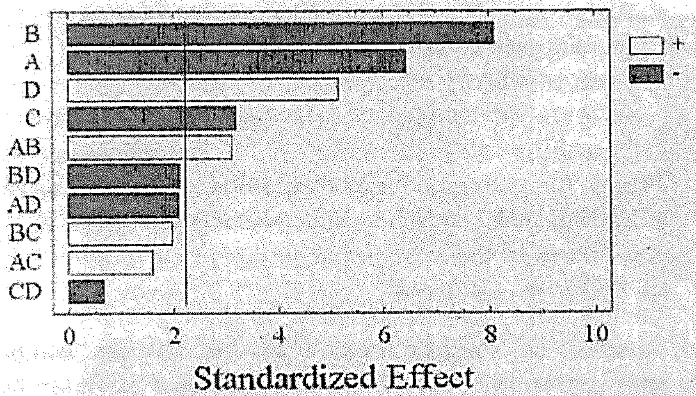

Figure 2. - Pareto diagram for the experimental array in Table I.

In order to determine the conditions or levels that best optimize the drying process, the response surface methodology[11,12,13] was followed. This technique[11,12,13] is particularly useful where several input variables potentially influence some performance measure or quality characteristic of either a product or process. A response surface model is developed from experiments instead of using a mechanistic model underlain on not fully understood process mechanisms. Furthermore, ignoring the shrinkage, the desirability function technique popularized by Derringer and Suich[15] was used. The general approach is to first convert each response y_i into an individual desirability function d_i that varies over the range $0 \leq d_i \leq 1$. If the response y_i is at its setpoint, then $d_i = 1$, but if the response is outside an acceptable region $d_i = 0$. The design variables are then chosen to maximize the overall desirability $D = (d_1 d_2 ... d_m)^{1/m}$ where there are m responses.[14] To facilitate the statistical analysis, all levels are presented in the usual statistics code mode (-1 at low level, 0 at mid-level, and 1 at high level). In the first array (Table I) it may be noted that a factorial set of 16 runs with 5 center points, i.e., 21 total runs with 10 degrees of freedom to estimate the random error.

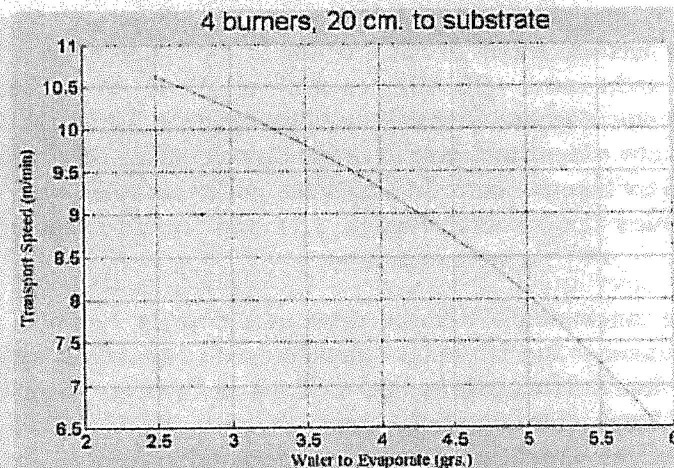

Figure 3. - Nomogram of optimal drying for the water-based finish.

Results and Discussion

The resulting data from the experimental array shown in Table I is found in Table II. Of the three output variables, the most important is the evaporation percentage which ranges from 28 percent to 255 percent (the target is 100 percent). This wide range of evaporation observed is due to the operating conditions established in the experimental array. The objective was to explore different circumstances (response surface) which are used to deduct an experimental model. It is also observed that the higher the evaporation percentage, the higher the shrinkage (negative values were considered as zero shrinkage). Hence, it is strongly advisable to avoid evaporating more than 100 percent of the water applied. In terms of temperature, the leather sample

TABLE III
Anova for the % Evaporation in Table II

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-ratio	p-value
A: Film grammage	13720.8	1	13720.8	37.86	0.0000
B: Transport Speed	21600.7	1	21600.7	59.60	0.0000
C: Panel-substrate distance	3410.57	1	3410.57	9.41	0.0098
D:# of burners	8607.3	1	8607.3	23.75	0.0004
AB	3420.84	1	3420.84	9.44	0.0097
AD	1545.18	1	1545.18	4.26	0.0613
BC	1308.41	1	1308.41	3.61	0.0817
BD	1308.63	1	1308.63	3.61	0.0817
Total error	4349.28	12	362.44		
Total (corr.)	60523.7	20			

R-squared = 92.8139 percent
R-squared (adjusted for d.f.) = 88.0232 percent
Standard Error of Est. = 19.0379
Mean absolute error = 12.1061

TABLE IV
Validation of Equation 1

Speed, m/min	Film grammage, gr	# Burners	Eq. 1, %	Exp. Measurements, %
10.09	4.32	4	100	93.54
9.52	5.15	4	100	87.71
9.76	4.81	4	100	91.36
10.89	4.37	4	85	87.17
10.95	4.26	4	85	86.23
11.00	4.17	4	85	87.44
11.08	4.01	4	85	87.88
9.25	4.40	3	90	75.45
9.22	4.45	3	90	82.55
9.62	4.31	3	85	74.50

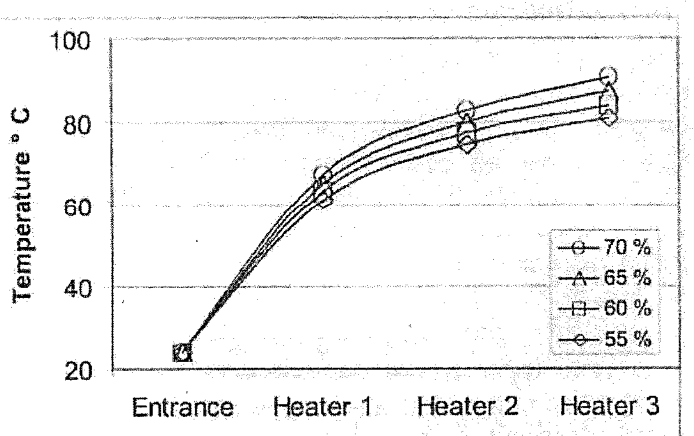

Figure 4. - Temperature profile for several evaporation percentages.

cools very rapidly so that the exit temperature, taken 30 cm after the fourth heater panel, is maintained within acceptable values. From the higher values of temperature observed, one might suspect that the film may be overheated inside the tunnel.

The Pareto diagram of Fig. 2 illustrates the effect of the main variables and the interactions for the experimental array shown in Table I. There are four main variables and one interaction statistically significant at a 95 percent confidence level. The R-squared statistic indicates that the model as fitted explains 92.81 percent of the variability in the evaporation percentage, as presented in the Anova of Table III. According to the Pareto diagram (Fig. 2), the interactions AD, BC, BD are not statistically significant; however, due to the magnitude of each coefficient and their effects on the mean absolute error of 12.11, they are taken into account in Equation 1 (developed by using least squares):

$$\%\ evaporation = 86.397 - 28.6976A - 36.755B - 14.6144C + 23.2312D - 14.448AB - 9.76644AD + 9.07311BC - 9.05896BD \quad (1)$$

TABLE V
Experimental Array for Contrast versus Convection Dryer

EXP	A	B	C2	C3
1	-1	-1	-1	-1
2	-1	1	-1	-1
3	-1	-1	1	-1
4	-1	1	1	-1
5	-1	-1	-1	1
6	-1	1	-1	1
7	-1	-1	1	1
8	-1	1	1	1
9	1	-1	-1	-1
10	1	1	-1	-1
11	1	-1	1	-1
12	1	1	1	-1
13	1	-1	-1	1
14	1	1	-1	1
15	1	-1	1	1
16	1	1	1	1
17	0	0	0	0
18	0	0	0	0
19	0	0	0	0
20	0	0	0	0
21	0	0	0	0

A = Film grammage (3.9075, 5.608, 9.19125 gr)
B = Transport speed (5.76, 9.6, 13.44 m/min)
C2 = Distance from panel 2 to substrate (14,20,26 cm)
C3 = Distance from panel 3 to substrate (14,20,26 cm)

This statistical model can be used to build nomograms as depicted in Fig. 3. It has been calculated for 100 percent of the water applied to be evaporated, and it works within the abscissa values shown in the plot which permits to select the adequate transport speed. Equation 1 can also be manipulated to choose the suitable transport speed for a particular percentage of water evaporation; it works with any solids percentage and, as a consequence, with any form of application: roller, curtain, or spray coating. Although we worked with a black formulation, any other color may alter the drying behavior of the infrared system.

To corroborate the reliability of the statistical model, new runs in the drying tunnel were carried out (Table IV). Three different evaporation percentages were defined in Equation 1: 100, 90, and 85 percent. We found a very good correlation between the model and the experimental observations, especially when 85 percent of evaporation is defined. Inside the tunnel and on the samples, temperature profiles were also measured. The measurements confirmed the suspicion since the temperature after the heater 3 was above 80°C for a 70 percent evaporation (Fig. 4). This means that, in the runs of first experimental array (Tables I

TABLE VI
Results of the Experimental Design in Table V

EXP	% Evaporation (experimental)	% Evaporation (model)
1	93.78	88.26
2	48.24	41.33
3	92.44	88.85
4	43.24	41.90
5	92.28	91.50
6	42.95	41.24
7	88.75	88.91
8	40.02	40.99
9	62.22	59.01
10	30.75	29.35
11	57.29	59.77
12	33.35	31.10
13	62.75	59.59
14	31.36	30.93
15	57.35	57.59
16	30.28	29.98
17	53.32	57.86
18	58.52	59.50
19	50.30	59.90
20	52.98	59.66
21	53.66	58.62

and II) where the evaporation was above 70 percent, the temperature of the sample inside the tunnel reached at least 80°C. Although not presented in images, the samples which were overheated suffered a relatively high degree of shrinkage and deformation i.e., the removal of any degree of natural water of the leather sample is undesirable in terms of flexibility and smoothness.

To compare results with industry operating conditions, a tannery was visited to carry out measurements in a typical convection oven of 12 m length for leather finishing. From 12 experimental tests, the measurements showed an average of 68 % of evaporation (standard deviation of 6 percent) and an exit temperature around 55°C at 18 m/min for a formulation with the same solids percentage as the one used in the infrared dryer (28 percent). Thus, in the tannery visited, the operating conditions of the convection dryer did not achieve 100 percent evaporation.

TABLE VIII
Levels of the Operating Variables Required to Evaporate the Specified Amount of Water in the Film.

Factors	% Evaporation 65	% Evaporation 100
A: Film grammage	5 gr/ft^2	5 gr/ft^2
B: Transport speed	9 m/min	9.6 m/min
Number of panels in operation	3	4
Distance from panel to substrate	20 cm	20 cm

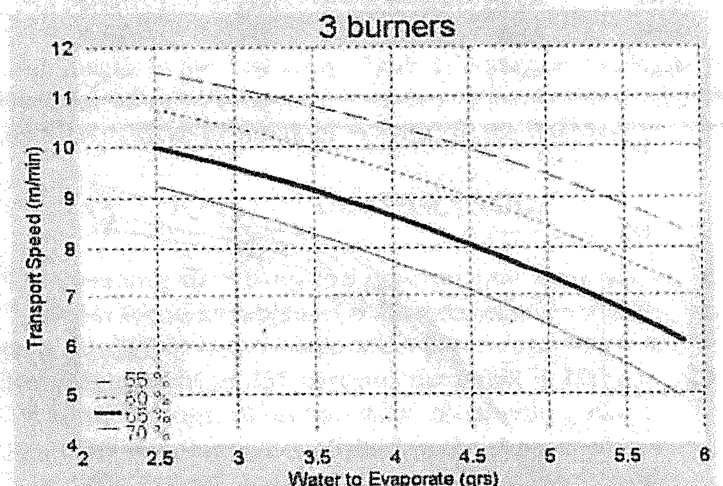

Figure 5. - Nomogram for several percentages of evaporation.

To compare objectively both infrared and convective dryers,

TABLE VII
Anova for Evaporation Percent in Table VI

Source	Sum of Squares	Degrees of Freedom	Mean Square	F-Ratio	p-Value
A: Grammage	1800.15	1	1800.15	97.44	0.0000
B: Transport Speed	6064.29	1	6064.29	328.25	0.0000
AB	388.257	1	388.257	21.02	0.0003
Total error	314.066	17	18.4745		
Total (corr.)	8360.29	20			

R-squared = 96.2434 percent
R-squared (adjusted for d.f.) = 95.5804 percent
Standard Error of Est. = 4.29819
Mean absolute error = 2.91433

additional experiments were performed in the infrared dryer to dry 70 percent of the water applied in the formulation. Only three panels were used to avoid increasing the temperature of the finish film above 80°C. Four factors were considered: film grammage (A), transport speed (B), and heater-substrate distance for the last two panels (C2, C3). A distance of 20 cm was maintained between the first heater panel and the substrate while changing the position of the other two heaters. Table V shows the experimental array, and Table VI the resulting data with the corresponding Anova in Table VII. Two main factors were found statistically significant with an interaction between transport speed and film grammage. A new statistical model was developed (Equation 2) which can be used to predict the drying of the aqueous film in the infrared dryer and obtain a comparable product to one from a convection dryer.

$$\%\,Evaporation = 55.1652 - 10.3839A - 19.4767B + 4.90718AB \quad (2)$$

The nomogram in Fig. 5 shows four curves, each one for a specific evaporation percentage. Being compared, the length of the dryer can be reduced by using infrared technology and, at the same time, reduce the residence time of the substrate within the equipment. It this investigation, the infrared dryer was less than half of the length of the convection dryer, the former achieving similar evaporating efficiency with a lower residence time. For illustration purposes, Table VIII shows the operating conditions at which the infrared tunnel should be operated in order to achieve either 65 percent or 100 percent evaporation of the water in the film. The transport speed is almost the same, but an additional heater should be used to increase the evaporation efficiency.

Conclusions

The response surface methodology was used to conduct experiments and optimize the performance of an infrared dryer for leather finishing. A statistical model was developed that predicts the operating conditions of the dryer in terms of the main variables that can be manipulated: number of panels used, panel-substrate distance, transport speed, applied film grammage, and evaporation percentage. Mathematical models can be used to build drying nomograms to help the tanner to be more productive in the finishing process. The use of infrared radiation in drying the leather finishing film can reduce dryer length and residence time which may lead to higher productivity in the tannery.

Acknowledgements

The authors wish to thank Martin López Vela, MSc., and Martin López Torres for their valuable help in the configuration of the equipment and Francisco J. Ornelas, PhD., for the digital image processing technique to measure the area of leather samples. In addition, the financial contribution of CONCYTEG-Fondos Mixtos Guanajuato (CONACYT) and the leather chemicals supplier Together for Leather (TFL), primary user of the results presented here, was invaluable during the development of this project.

References

1. Alonso, S., Medina-Torres, L., and Brito de-la-Fuente, E.; Rheology Aspects of Leather Finishing Formulations. *Chem. Eng. Comm.* **192**, 839-854, 2005.
2. Biles, J.; Parameters in the application of water-based topcoats. *JALCA* **85**, 163, 1990.
3. Adzet, J. M.; Química-Técnica de Tenería (Romanya/Valls, Barcelona). Chap. Acabados, pp. 559 - 632, 1987.
4. Wenzel, W.; Ecología en el acabado del cuero. Memorias del XVIII Encuentro Nacional Técnico de Curtiduría. León, Gto. Marzo 14-15, 2001.
5. Skansi, D., Bajza, Z., and Arapovic, A.; Experimental evaluation of the microwave drying of leather. *JSLTC* **79**, 171, 1995.
6. Monzó-Cabrera, J., Díaz-Morcillo, A., Catalá-Civera, J. M., and De los Reyes, E.; Kinetics of combined microwave and hot air drying of leather. *JSLTC* **84**, 38, 2000.
7. Seyed-Jagoobi, J., Sikirica, S. J., and Counts, K. M.; Heating/drying of paper sheet with gas-fired infrared emitters Pilot machine trials. *Drying Technology* **19(3&4)**, 639, 2001.
8. Seyed-Jagoobi, J., and Wirtz, J. W.; An experimental study of Gas-Fired infrared drying of paper. *Drying Technology* **19(6)**, 1099, 2001.
9. Modest, M. F.; Radiative Heat Transfer. Academia Press, Chap. 1, 2, 3, 4, and 12, 2003.
10. Gutiérrez-Pulido, H., and De la Vara-Salazar, R.; Control Estadístico de Calidad y Seis Sigma. McGraw-Hill, México 2004.
11. Montgomery, D. C.; Design and Analysis of Experiments. 5th edition, John Wiley & Sons, New York, 2001.
12. Gutiérrez-Pulido, H., and De la Vara-Salazar, R.; Análisis y Diseño de Experimentos. McGraw-Hill, México 2004.
13. Myers, R. H., and Montgomery, D. C.; Response Surface Methodology: Process and Product Optimization Using designed Experiment. 2nd ed. Wiley, New York, pp. 281-283, 2002.
14. Derringer, G., and Suich, R.; Simultaneous optimization of several response variables. *Journal of Quality Technology* **12**, 214-219, 1980.

LIFE LINES

Hongru Wang received his B. Sc. degree in 1982 and a M. Sc. degree in 1987 from the Shaanxi University of Science and Technology. He has been with the Leather Engineering Department of Shaanxi University of Science and Technology (original Northwest Institute of Light Industry) since 1982. At present he is a Ph. D. candidate of Donghua University and a professor of Leather Engineering Department in Shaanxi University of Science and Technology. His research includes investigations in collagen modification, tanning agent synthesis, leather technology.

Xiang Zhou graduated from the Donghua University (original China Textile University) and has been with the College of Chemistry and Chemical Engineering of the Donghua University since 1960. At present she is a professor at the Donghua University and an academician for the Chinese Academy of Engineering. Her research includes investigations in chemical crosslinking of textile fibers, synthesis of textile chemicals, cleaner technology of dyeing and finishing of textile.

K. J. Sreeram, see *JALCA* **95,** 348, 2000

J. Raghava Rao, see *JALCA* **93,** 156, 1998

N. K. Chandrababu, see *JALCA* **100,** 243, 2005

Balachandran Unni Nair, see *JALCA* **93,** 156, 1998

T. Ramasami, see *JALCA* **93,** 156, 1998

Eser Eke Bayramoglu, see *JALCA* **101,** 74, 2006

Gürbüz Gülümser was born in Ankara-Turkey in 1954. He graduated in 1968 from the Agriculture Faculty of Ege University as a MSc in Agriculture Engineer. He completed his PhD from the Engineering Faculty, Department of Textiles at Ege University in 1983. He started to work as an Associate Professor for the Agricultural Faculty, Department of Leather Technology at the same university in 1991 and then became Professor in 2002. He has been the second head of the Leather Technology Department of Engineering Faculty at Ege University.

Ýsmail Karaboz graduated as a biologist from the Department of Botany, Faculty of Science of Ege University, Bornova-Ýzmir, Türkiye in 1977. He started his professional career in the Microbiology Section of Biology Department of Science, Faculty of Ege University in 1979. He finished the master program in Microbiology Section of Biology Department of same University in 1980. I finished a Ph.D. program in the Basic and Industrial Microbiology Section of Faculty of Science of Ege University, Bornova-Ýzmir, Türkiye. Now he is working as a professor at the same department. Dr. Karaboz is married and lives in Ýzmir, Türkiye.

S. Jöns is a PhD student at CIATEC León, Mexico. His research field is the mathematical modelling and process optimization via response surface methodology and genetic algorithms.

F. Taracena-Sanz is a Chemical Engineer from UNAM (Mexico) and got his PhD in Industrial Engineering from the University of Oregon in 1983. He has more than 20 years of professional experience in design and optimization of processes and products.

Sergio Alonso is a chemical engineer. He got his MSc degree from Universidad Autonoma Metropolitana in Mexico City in 1994. His PhD was accomplished in 2000 from Ecole Polytechnique of Montreal. He has worked at CIATEC since 2000. Currently, he is a coordinator of the Materials Area. During his job at CIATEC, he has worked on subjects related to the leather finishing process: roll and spray coating, drying, and rheology of leather finishing formulations. He has also worked with colleages from CIATEC on projects related to polymeric materials.

Roberto Zitzumbo-Guzman is a chemical engineer. He got his PhD from Universidad Autonoma de Coahuila in 2002. He has worked at CIATC since 1996. He works developing projects about polymer science, nanocompounds, and plastic processing on subjects mainly related to the shoe and leather industry.