Dtouch – drying has never been so easy

O. Allegretti [1], I. Cuccui[1], S. Ferrari[1] & A. Sione[2]

Abstract

The paper reports experience about an in progress project for the develop of a new control for kiln wood drying process.
The control contains a database of standard and special drying schedules and other technological parameters for more than 400 temperate and tropical species. These data, coming from different sources, allow to generate a suitable initial drying schedule for a given species and thickness. A series of functions and algorithms implemented in the control allow to customize the initial schedule by defining the best parameters to obtain a final specific result priority (colour, internal stresses, drying time).
The control has auto learning functions for the optimisation of the drying schedule. The expert system is based on the analysis of data process automatically acquired by the control during drying and on input data inserted by the operator at the end of the process answering to a questionnaire related to drying quality and drying kinetic.
At the present stage of the project, the debugged beta version of the control is installed in kilns of selected industrial operators involved in the project.

1 Introduction

A kiln dryer control system keeps the parameters of air within the kiln (Temperature, Relative Humidity, and occasionally air speed) on a set-up values defined by the drying schedule (DS). MC-DS in which change of air conditions occurs depending on current value of lumber MC loaded in the kiln are the most used in the industry. They have a multistage structure with a rising temperature and a decreasing RH. The initial and final values of air parameters of the DS depends on wood species on the thickness and on the initial MC. The past information from different sources and existing DS for similar woods are usually utilised in developing schedules.

Even in the best conditions (i.e. good control of air parameters, homogeneous distributions of air, correct stacking) the results of drying in term of quality and time is usually unpredictable, unreliable and non-repeatable. This due to:

- Complexity and non-linearity of the drying process;
- Heterogeneity of the wood;

[1] LABESS (Wood Drying Lab) of CNR-IVALSA Italian Research Council – Timber and Trees Institute, S. Michele all'Adige, Trento - ITALY, allegretti@ivalsa.cnr.it
[2] LOGICA H&S- Drying process and moisture testing, Udine - ITALY, www.logica-hs.com, sione@logica-hs.com

- Inaccuracy of the quality/quantity of input data, i.e. the MC of the lumbers in the stack.
- Unattended operations and events.

The research activity in the last 30 years in the field of wood drying has contributed to a better understanding of the drying process and many works were focused of the improvement of control systems. In particular numerical modelling techniques and adaptative/intelligent control techniques were the most explored and they are currently investigated in industrial applications.

Numerical Models had a huge development in the last 10 years, also thank to the increasing power/cost ratio of commercial PC. Nevertheless they are only sporadically applied on commercial on-line controls. One of the reason is the high number of variable and constants of constituent equations involved and the high range of variability of their value. By this point of view, the variability of the stack in the kiln drying process make difficult the control of the drying process by means of an average calculated value.

Intelligent controls based on fuzzy-logic or on other statistical analysis were successfully developed and implemented in the automation of industrial system above all for on line control of drying parameters based on the existing input data. However, the input data, above all concerning the drying quality evaluation, are still nowadays one of the main problem for their full application.

For those reason kiln drying process still requires a constant presence of a kiln operator for frequent monitoring and appropriate parameter adjustment. By this point of view, the kiln operator's skill and experience is still nowadays one of the most important capital of companies, especially the ones involved in drying of hardwood.

This paper describes a project for the develop of a new control system for the wood drying process carried out by the author's affiliations.

Logica H&S has been founded in 1991, it provides services and products for industrial process controls, for test and measurement devices in industrial, consumer and automotive applications, wood drying and wood moisture measuring fields. Initially the production was directed only to Italian KD producers, then the commercialization has been extended to all over the world, with special attention to the East Europe and Asian markets. In almost 19 years of activity, its products have been installed in over 50 Countries.

The project concerns the develop of the software, firmware and part of the hardware design. It started about one and half year ago and at the present the beta version of the control is at a testing stage in drying kilns of some factories in Italy.

The core concepts at the basis of the control are :

- state of the art of the scientific knowledge about drying process of many wood species already codified in the memory of the control for a safety starting point;
- an integration between human and machine through a friendly interface towards a cross-learning path;
- a structure of data storage and data mining which allows an accumulation of knowledge and a reduction of the variability effect of the drying process factors.

The goal of the project is to make available on the market a control system that can be used worldwide on every type of conventional kiln drying for every species, temperate and tropical, softwood and hardwood, easy to install to configure and to use and flexible enough to ensure a good and safe starting point towards an optimised drying schedule whatever the operative condition and the operator's training level is.

2 The drying schedule creation

dTOUCH aims to be a step ahead in the control systems for kiln dryers, since it combines an advanced and flexible control system with the know-how of international experts in the timber drying field. It includes a wide range of base drying programs for over 400 timber species, including also some special DS to maintaining/changing the natural colour of the wood, for fast drying and so on. It uses this data base, together with the information received from the sensors and the inputs from the user (such as thickness, required quality, priority to time or to quality, particular requirements..) to create the program suitable to drying the wood according to the specific needs of the user. The system can automatically identify some critical conditions (like frozen wood, possible casehardened wood etc.) and modify the base drying program in order to include the most suitable remedy for the identified problem.

The creation of a customized program using dTOUCH does not require the operator to learn about drying methods and programming details (temperature, humidity, time, etc..); it is enough to "explain" to the system what are the special requirements by answering to some questions.

2.1 The database

At the moment, the control system contains a database with about 500 records corresponding to the same number of basic drying schedules for about 400 wood species. Every species is identified by the botanical name or by the commercial name in different languages. Some species have more than one record for different proveniences or for special drying schedules. For example the beech (*Fagus sylvatica*) has standard schedule as well as special schedule for different final colours.

Others information are associated to each records. Basically they concern technological information (density, shrinkages…), information on possible defects that could influence the drying quality (collapses, water pockets…) and, when available comments, prescriptions and warnings that, displayed on the screen, could help the user to get a better results (air pre-drying suggested, end coat suggested, tendency to warp…). Some of those information are used by the system for different purposes such as for the optimisation process or for some other calculation.

2.2 The drying schedule

The drying schedule system used in the control has been developed assembling, modifying and simplifying different systems already existing. The main kiln drying schedule sources are the *Dry Kiln Operator's Manual* by *USDA*, the *Timber Drying Manual* by *BRE* and the *Cividini's Conventional Drying of lumber* (Essiccazione convenzionale dei Legnami). Further information comes from the internal LABESS database, a collection of data from drying tests during '60s and '70's by Prof. Cividini and Giordano at IVALSA.

Specifications of the dTouch drying schedule system (dT DS) implemented in the control are:

1. The input data to create the basic drying schedule is species and thickness of lumber. For some of these species/thickness combination there are more options such as different final colour or special end product request.
2. Like in the USDA system the schedules are identified by a code of three numbers (ID-Code): the first identifies the temperature profile, the second the critical MC (MC_{cr}) at which there is the first change of the EMC and the third the EMC profile.
3. A ID-Code corresponding to a given dT DS is assigned to each record (wood species) of the database. The combination of species/ drying schedule is done on the basis of the existing DS systems.
4. There are 14 temperature (T) profiles MC dependents. T start to increase when the MC is 35% and linearly increase up 15% MC. Each profile is characterised by a minimum and maximum T.
5. There are 12 EMC profiles MC dependents. EMC is usually directly measured by the cellulose plates but it can be also calculated from RH or dry/wet bulb by mean of the *Hailwood Horrobin* equation. Each EMC profiles is identified by a nominal drying Gradient (G) = MC/EMC. Each EMC profile is characterised by a constant EMC (varying G) during the 1st drying stage and constant G (decreasing EMC) starting from MC_{cr} and during all the 2nd and 3rd drying stage.
6. Depending of the thickness (th) of lumber the nominal G is transformed in the real G. A two parameters first degree function G =f(th) is used to calculate real G as a function of thickness. T does not vary with lumber thickness.

7. the USDA system has 6 MC_{cr} values from 30% to 70%. The dTouch drying schedule system was simplified to only three value from 30% to 45%. The reason of this simplification is that the electrical MC measure is not accurate for value higher than about 45%.
8. An air velocity profile (V) wood density and thickness dependent is also generated.
9. Complementary phases such as warm-up, equalisation and conditioning is also generated by the system. Other supplementary phases such as re-conditioning for collapse or defrost are suggested when appropriate.
10. supplementary outputs are information such as estimated partial and total drying time and energy consumption.

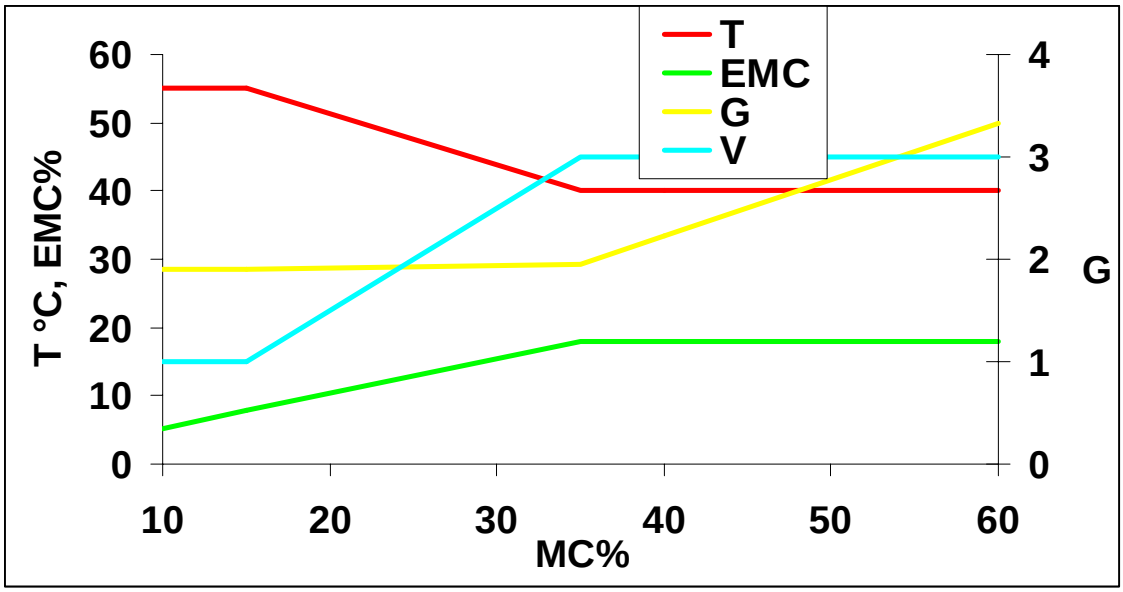

Figure 1: example of Drying schedule profile.

3 An evolving system

dTOUCH is a control system with a great potential, which is now at the first stage of its development and which will be expanded in the next future, thanks to already running validation tests on pilot plants. An automatic upgrade function (available when connected to a PC running XYLON software) allow the system to be upgraded.

The system has self-learning features: the *Drying cycle evaluation* function - especially useful in case of repeated drying cycles in homogeneous conditions- allows to optimise the drying cycles according to the specific kiln characteristics and to the user's specific requirements. At the end of the cycle, the user has the opportunity to answer to a few questions on the touch screen and to give an evaluation about the completed cycle in terms of drying speed and drying quality. The questionnaire is structured on different levels for different operator profiles. Some levels are access-free only to expert operators. This structure

allows to filter bad data due to inexperience or to some psychological behaviour that could lead the operator to force the system. The multi-level structure also allows to separate the learning procedure in two stages: a first testing stage (already running) and a second optimisation stage during the working service. Questions about quality allows graded answers according to standards to the wood drying quality. As a consequence some answers requires specific measurement or test such as for the measure of internal stress.

Outputs concerning the drying process parameters automatically recorded from the sensors and the additional information from the questionnaire are codified in a report file. The report file is stored in the internal database (single level) and, when Internet connected, to the shared database on the server (central level).

Quantity and quality of information are different at the two levels. The auto - learning efficiency of the control is different as well.

The expert system analysis the report file and it proposes possible modification in the drying parameters.

The modification process requires:

1. Homogeneous Conditions (same initial and boundary conditions, same species and thickness. If possible same or similar secondary conditions such as provenience, period of the year);
2. Sufficient feedback given by input data related to the process parameters, process kinetic; results of the process in terms of quality/time;
3. A consistent statistical population of data (data from several homogenous drying process);
4. an input/output model.

Single and central levels have different data analysis procedures and different input/output models.

The rate of modification of some parameters can be adjusted according to presets corresponding to different operator's profiles (risk attitude). At the end of the modified drying process the expert system start to analyse the history of changes and to collect information about the variability and the error. An increasing quantity of data (increasing experience) increases the probability to reach an effective and stable optimisation.

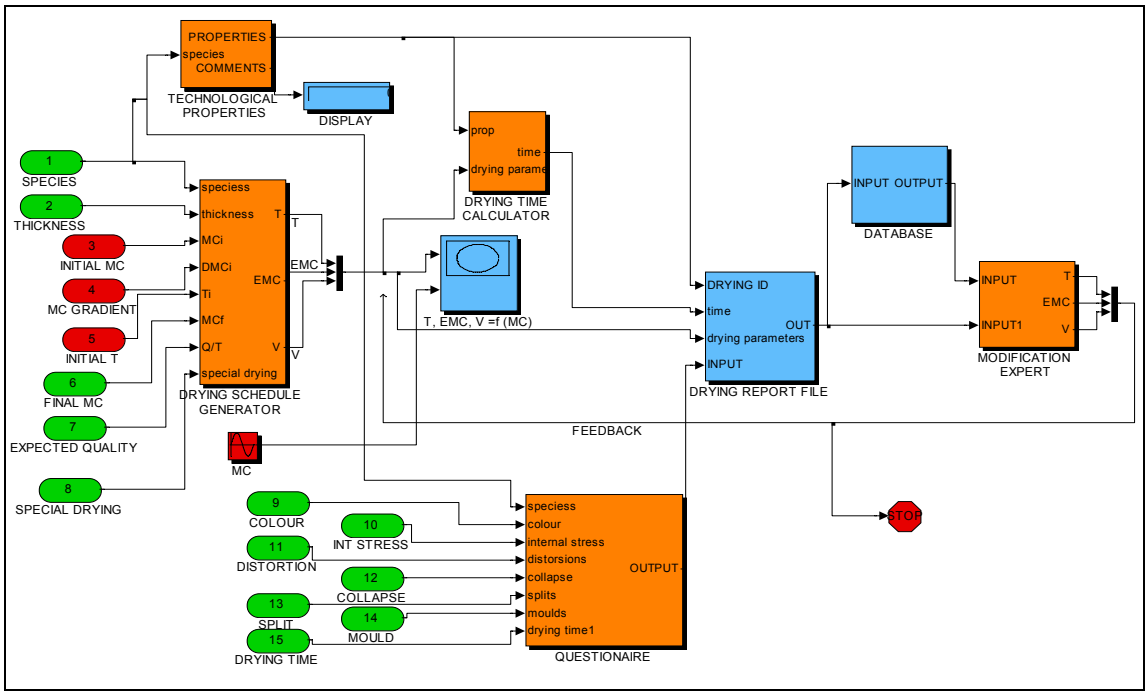

Figure 2. Diagram of control system: green: input from users; red: input from sensors; orange: elaboration units; blue: output.

4 The friendly expert

A big effort has been accomplished to provide dTOUCH with a friendly interface. The system is based on a colour LCD screen, touch sensitive. Whenever possible, every function is identified by a icon, while the menu are available in several languages. All the selectable functions are identified by buttons or blue colour. In any moment is possible to switch from the most complete automatic management to the simplest semi-automatic mode.

Figure 3: Touch screen of the control unit: main page

Being based on "Kiln Bus" protocol, the system is compatible with all the most recent sensors and interfaces developed by Logica. The number of probes and their typology can be configured as required to satisfy whatever control need, including interfacing to non conventional sensor or sensors for special uses like ISPM15 compliant heat treatment.

The top configuration has wireless EMC and MC sensors. Each MC unit - named "Moisture Mouse"- measures MC at two different deep (surface and core) and the wood temperature (figure 2).

The system has a relays output unit, to drive proportionally flaps, heating valve and sprayers (by pulses) and to manage the fans inversion and speed (through a 0-10 analog output). Several different configurations are available either to add further outputs or to connect additional sensors.

Figure 4: Moisture Mouse- wireless unit

5 Conclusion

Based on simple cause/effect assumptions and on a machine-human interaction, the dTouch wood drying control system is designed to grow up with the aid of the scientific community and together with the users. By this point of view we can say that inside this control there is a little of 20 years of IUFRO wood drying conferences and of the work of the COST Actions E53 and E15.

At the present stage of the project, the control is installed in kilns of selected industrial operators for the first operative tests and the first results will be available soon. The project is open to new operators and partners that wants to cooperate to develop the control. The conference is the occasion to welcome new possible partners interested to interact with dTouch and contribute to the project.

References

Boone S.R., Kozlik C. J., Bois P.J., Wengert E.M. 1993. Dry Kiln Schedules for Commercial Woods. Temperate and Tropical. General Technical Report. USDA.

Cenerini M., Edlmann Abbate M. 1984. Usi e proprietà tecnologiche di legni di latifoglie americane. Contributi scientifico-pratici. CNR/ ITL Firenze, Italy.

Cenerini M., Edlmann Abbate M. 1988. Legni. Asiatici-Americani-Africani. Conoscenza e Utilizzazione. Edagricole, Firenze, Italy.

Cenerini M., Edlmann Abbate M. 1996. Usi e proprietà tecnologiche di legni di conifere. Contributi scientifico-pratici. CNR/ ITL Firenze, Italy.

Cividini R., Travan L. 2000. Conventional Drying of lumbers - Essiccazione Convenzionale dei Legnami. Compendio. Nardi ed., Verona, Italy

Denig J., Wengert E.M., Simpson W.T. 2000. Drying Hardwood Lumber. General Technical Report USDA.

Drenier K., J. Welling, (1992), " Self-Tuning controllerws for the kiln drying process" proceedings of the 3rd Int. IUFRO Wood Drying Conf., Vienna, Austria, pp 205-216

F. M. Chevalier, J-M. Frayret, (1996), «A fuzzy logic application to kiln dryer regulatuion », proceedings of the 5th Int. IUFRO Wood Drying Conf., Quebec City, Canada, pp 221-229

Gann. Table of Timber Species. GANN und Regeltechnik GmbH, Stuttgart.

Giordano G. 1980. I Legnami del mondo. Dizionario Enciclopedico. Il Cerilo Editrice.

Giordano G. 1988. Tecnologia del Legno – I legnami del commercio. Volume III: Parte seconda. UTET.

Pratt, G. H., Timber drying manual; 1997, BRE, Watword, GB.

Rijsdijk J.F. and Laming P.B. 1994. Physical and Related Properties of 145 Timbers. Information for Practice. TNO Kluwer Academic Publishers.

Simpson W. T. 1996. Method to Estimate Dry-Kiln Schedules and Species Groupings. Tropical and Temperate Hardwoods. Res. Pap. USDA.

Simpson W.T. 1991. Dry Kiln Operator's Manual. USDA Agricultural Handbook.

Skuratov N. V., (2005) "Schedules and Quality Control at Kiln Drying", proceedings of the 9th Int. IUFRO Wood Drying Conf., Nanjing, China, pp 308-311

Wang X. G.. W. Liu, L. Gu, C. J. Sun, C. E. Gu, C. W. de Silva, (2001), „Development of an Intelligent control system for wood drying processes" IEEE/ASME Intern. Conf. On Advanced Intelligent Mechatronichs Proceedings, Como, Italy, pp 371-376;