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Information transfer to kiln operators in the form of drying simulation models

Paper presented at the European COST Action E15 Workshop, Helsinki, Finland, June 11–13, 2001

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Sammanfattning

Datorbaserade simuleringsmodeller för virkestorkningsprocessen har utvecklats under många år. Idag existerar en mångfald modeller, från mycket enkla till ganska sofistikerade i två eller t.o.m. tre dimensioner, som också inkluderar virkesdeformationer inducerade av krympning och krypning. Dessa modeller innehåller teoretisk kunskap, samlad av många forskare under en lång tid. Användaren av sådana datorprogram behöver emellertid inte nödvändigtvis förstå eller känna till teorin bakom de beräknade resultaten. Detta innebär att, om procedurerna för data inmatning och –utmatning hålls på en enkel nivå, så kan t.ex. torkskötare ha en stor nytta av sådana hjälpmedel.

Denna artikel beskriver erfarenheter med en modell som distribuerats till nära 100 användare i Sverige och Norge, av vilka de flesta är torkskötare vid sågverk eller ansvariga för torkprocessen. Egenskaper som diskuteras är val av modellens komplexitetsnivå, sätt för distribution via användarkurser, huvudsakliga användningsområden i praktiken, inklusive undervisningsaspekter och användarrespons.

INFORMATION TRANSFER TO KILN OPERATORS IN THE FORM OF DRYING SIMULATION MODELS

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ABSTRACT

Computer based simulation models for the wood drying process have been developed for many years. Today a multitude of models exist, from very simple to rather sophisticated in two or even three dimensions that also include wood deformations induced by shrinkage and creep. These models comprise theoretical knowledge gathered by many researchers for a long time. However, the user of such computer programs does not necessarily need to understand or know the theory behind the calculated results. This implies that if the program input and output procedures are kept on a simple level, then for instance kiln operators could benefit a lot from such tools.

This paper describes experience from a model that has been distributed to almost 100 users in Sweden and Norway, most of which are sawmill kiln operators or responsible for the kilning process. Features discussed are selection of model complexity, mode of distribution through user courses, main application area in practise including educational aspects and feedback from users.

1. INTRODUCTION

Wood drying is a complex process, involving coupled heat and mass transfer phenomena. Mathematical modelling of the process was enormously improved when modern computers became available for this task. Numerical solutions of the diffusion equation became possible in practise also for more realistic cases, and not only for those simplified situations for which analytical solutions existed.

In the beginning the computer models were mostly used to check whether the model could reflect the phenomena observed in real drying processes. I.e. whether the descriptions of physical relationships included in the model were correct and whether associated material parameters were given correct values. Gradually models reached a level where they could be used for prediction of the outcome of a drying process, for instance final MC. This development can be viewed as a transition from "curve fitting" models to fully predictive models.

In 1994 twelve different models were compared and the results were presented at a IUFRO wood drying conference (Kamke, Vanek 1994). About 70 % of the models could fairly correctly predict the final MC measured in a drying test with a given climate. The internal moisture distribution was fairly correctly predicted by only about 60 % of the models. A correct moisture profile is a necessity for a reliable stress calculation, but this calculation was not included in the investigation. There are certainly understandable reasons why some models failed, perhaps simple misunderstandings regarding some features in the test. Anyway, it is quite clear that it would have been very risky to give such a model to a kiln operator for drying schedule improvement in full-scale operation.

On the other hand, every model that predicts the evolution and outcome of the drying process with acceptable accuracy contains a tremendous amount of valuable information, gathered not only by the developer of the specific model, but gathered by many researchers in different parts of the world during a long time. So, if it is thoroughly verified that model predictions are numerically reliable, then that model would be a valuable tool for a kiln operator and would at least partly bring all the information into practical use.

2. TRANSFER OF INFORMATION

A model can be viewed as an algorithm that from certain input data (wood species and dimension, type of equipment, drying schedule etc., etc.) produces estimates for some output data (final MC, MC profile, amount of checking and other quality values etc., etc.). Researchers are interested in this algorithm, its details and further development. But the kiln operator, or the person responsible for kilning operations, is interested in the relationship between input and output data and not in the algorithm itself. This simple fact is often forgotten among us researchers.

It should also be remembered that one main reason for advanced research work in this field is the existence of a wood working industry that asks for results and directly or indirectly finances that research work. Today, finding money for research seems to be an important part of daily work. In the efforts to convince the financiers of the importance of a specific research project, it is most often argued that industry will benefit a lot from that project. But afterwards, how often are the results actively transferred to industry in a form that easily and directly can be adapted and will improve operations? Are we too much focusing on the algorithm itself, instead of how the algorithm could be used in practise? There are probably several simulation models that were created with much effort – for instance in doctoral thesis works – but that were never used for solution of real sawmill kiln problems. This notwithstanding that the model surely included a lot of valuable information and ideas.

In conclusion, more attention should be paid to an active transfer of information to the industry. Computer simulation models have the potential for this transfer and should be put into use, despite possible problems. The following describes experience from distribution of a model – named TORKSIM – to kiln operators and persons responsible for the timber drying operation. In total some 100 licenses are given in Sweden and Norway.

3. SELECTION OF MODEL COMPLEXITY

Researchers are aiming for the utmost final complete model – and the goal is perhaps never reached. The kiln operator wants a tool that predicts the output data that he is interested in, with an acceptable accuracy, but that still is simple enough to be understood on a general level. That is a much simpler goal, but should be given a thorough consideration before the complexity and completeness of the model is decided.

In the COST E15 workshop in Edinburgh (Perré 1999) presented a model classification scheme based on two criteria, number of state variables (moisture, temperature and internal pressure) and number of spatial dimensions (1,2 or 3). In Scandinavia low temperature drying (below about 80°C) is still the totally dominating process. Because of that the internal pressure field is of minor importance and can be neglected. According to (Perré 1999) a model with only the moisture field calculated is unusable, which is certainly true. This implies that both moisture and temperature should be calculated, but an important simplification, not mentioned in (Perré 1999), could be done. In most cases the drying schedule used represent rather slow changes in temperature levels. Thus the temperature gradient inside the board can very well be neglected. TORKSIM thus calculates the moisture profile only, the *average* wood temperature is calculated from an energy balance, which equals assuming infinite thermal diffusivity. This selection simplifies the computational work considerably.

Another computationally important decision is the selection of the number of spatial dimensions. As boards are stacked in the kiln close to each other in layers, it is natural to view these layers as infinite plates, i.e. a one-dimensional model is selected. There is, however, a problem regarding this selection. In Scandinavian practise almost all boards contain both sapwood and heartwood in the same board cross section (Scots pine and Norway spruce). Thus the "infinite plate" is not homogeneous in the direction perpendicular to the principal direction. So a correct handling of this feature would require a two-dimensional model. But as the location of the heartwood portion of the cross section varies from board to board, simulation of a single (2-D) board would still not be a complete solution. Thus a simplification admitting use of a one-dimensional model would be preferred. In the TORKSIM case a homogenisation procedure for the cross section pattern has been chosen. Some more details are found in (Salin 1999).

The simulation performed by TORKSIM thus comprises the solution of the moisture diffusion equation for a single homogeneous board (infinite plate) with appropriate external heat and mass transfer boundary conditions. This single board then represents the whole kiln load. If average values for the kiln load (initial MC and temperature, density, heartwood content etc.) are used in the simulation, then the calculated results will reflect the behaviour of the kiln load as a whole. Normally two additional parallel simulations are made, one for pure heartwood and one for pure sapwood. This gives an idea of the influence of heartwood content on the result and is especially important in the stress calculation.

A tool that can predict the final MC is of course valuable, but not sufficient for a kiln operator who wants to improve the drying process, for instance by drying schedule modifications. There has to be additional output information that is related to the quality of the dried timber. The risk of checking is certainly one of the most important features that restrict the selection of drying schedules in practise. This requires that the simulation is extended with a stress calculation, based on the moisture profile calculated. It is important that this calculation includes the mechano-sorptive creep behaviour (Salin 1999). By presenting the calculated stress in relation to wood rupture strength, the kiln operator gets an idea of the risk of checking and in which part of the schedule this risk is at its highest.
It should be pointed out that this stress calculation is possible only due to a vast amount of international research work in this area. But the kiln operator is not at all interested in the constitutive equations, only in the resulting timber quality prediction and its reliability. A simulation model is by far the best way to transfer the results of this research work to the sawmill.

The simulation model can, and should, be extended with other important subroutines such as slicing test gap prediction, energy demand (instantaneous and total), cost (capital, energy, quality), discoloration, longitudinal deformations etc. Some of these are rather easy to implement, other require extensive research work, such as the two last mentioned features. Cost calculations are discussed in another paper presented at this workshop (Salin 2001).

The simulation model requires a set of input data that have to be given by the kiln operator. For obvious reasons this set should only include values that the kiln operator knows and understands. For instance select wood species from a list, not the value of a diffusion coefficient; and air velocity between board layers, not the external mass transfer coefficient, etc. The number of input values should be minimised to those absolutely needed. The model will probably be used as a basis for decisions that may have substantial economic consequences and all possibilities for misunderstandings should be carefully avoided. TORKSIM includes the following input data:

- wood species
- board thickness (real, not nominal)
- initial MC
- initial temperature
- density
- heartwood content
- air velocity (not necessarily constant)
- drying time
- drying schedule

The drying schedule is given as dry bulb and wet bulb temperatures for arbitrarily chosen points on the time scale. Temperatures are assumed to change linearly between points. Instead of dry/wet bulb, optional alternatives are dry bulb/RH and dry bulb/wet bulb depression. The schedule can also be in the form of a computer file (from a data acquisition system).

As can hopefully be seen from the description above, there is a multitude of alternatives regarding selection of model complexity and completeness. The best choice depends on many factors and is certainly also dependent on geographic area. The situation is simpler in Scandinavia with only two wood species of major commercial importance (Scots pine and Norway spruce). Thus "only" two sets of material parameter values are needed. For a researcher the most difficult point is perhaps to realise that a very simple model is the best choice to begin with. More complete models can wait until the first step has been accepted and kiln operators start asking for more.

Finally, it should be heavily underlined that the accuracy and correctness of model predictions have to be thoroughly verified against a multitude of drying tests, before a kiln operator version is released. A substantial part of this testing should preferably be done in full scale. This tuning of parameter values is normally a heavier task than producing the model itself (physics, mathematics, programming). It is probable that part of the model failures reported by (Kamke, Vanek 1994) were due to neglecting this verification part.

4. USER COURSES

An important question is how the computer program should be given to the user. The simplest way, selling a diskette or a CD-ROM together with a user manual and giving the user no further assistance, is in our opinion not good. We have chosen to arrange 2-3 day courses for a small group of future users, during which the model background is described in general terms and the program demonstrated. One personal computer is made available for every 1-2 attendants and most of the time is devoted to computer exercises using very realistic drying problems.

The simulation model is typically used for modification of drying schedules towards a better over all drying result or for creation of completely new schedules for special purposes. These tasks require many simulations at which the model is used in an interactive way until a good final result is achieved. This process is discussed in detail during the course. In this process it is important to include the kiln operator's practical experience, so that reasonable schedules, that can be implemented at his sawmill, are created. In this sense there is seldom a single correct answer to an exercise. We also think it is important that the kiln operator feels that the final decision is his, and is not given by a computer program made by someone in a distant research laboratory. The model is a tool only, which supplements the kiln operator's practical experience.

Computer work during the course is preferably combined with other items, i.e. presentations of results from other research projects (technology transfer!), discussion of current issues in the sawmill industry, new equipment and so on, not to forget the social part. The information transferred in the opposite direction, from the sawmill people to the researchers, should not be underestimated either.

The aim of the course concept is to thoroughly introduce the model to the user and describe how it can be used in different situations, including limitations. Possible misunderstandings, wrong applications etc., should be detected during the course – not in the first "full scale" use at the sawmill.

Questionnaires circulated among course attendants have clearly shown that the simulation exercises and related discussions are highly appreciated, although the time devoted to this part may seem long.

5. MAIN MODEL APPLICATION AREAS

Questionnaires sent to TORKSIM users and discussions have shown that there are three main areas of application and that these are about equally important.

1. Too much checking. The situation is analysed by simulating the case in question and investigating the stress development curve. Modifying the drying schedule in those parts where the calculated relative stress level is high will solve this problem.
2. Too long drying time. The problem is solved by, for instance, increasing the wet bulb depression in those parts of the drying schedule where the calculated stress level is clearly below the critical limit.
3. General analysis of drying schedules, temperatures etc., for cases where there are no known problems. The aim is to find out if there is a potential for improvement.

Results indicate that in the first application at least 90% of the cases could be solved in a satisfactory way. For the second application the average reduction in drying time can be estimated to about 15%. The three areas above are of course the same applications that we primarily discuss during the user courses.

As the model is based on fairly correct descriptions of the physical phenomena involved in the drying process, it can be used also for cases outside the main area of application. Such questions are for instance "How long will it take for a low MC board to regain 1 %-unit moisture in a given storage climate?" or "Is there a risk of checking if this wooden plate is removed to a completely different environment?". The accuracy of the prediction in such cases is certainly not good, but even an order of magnitude answer is often a valuable information.

6. SOME EDUCATIONAL REMARKS

It is not necessary to understand the theory behind the simulation model in order to be able to use the model. However, this theory is presented in general terms, without any equations, during our courses and probably some parts of it will be adopted by the kiln operators on a more permanent basis. If the kiln operator accepts the model as a natural tool for solving drying problems, then this theoretical knowledge is perhaps gradually further established. Especially some aspects of stress calculation – as the mechano-sorptive creep behaviour – have considerably penetrated Swedish sawmills in this way.

The simulation model gives numerical information on how different variables and parameters are connected to each other. If for instance the temperature level during drying is increased by 5°C, how much is the drying time shortened due to faster moisture migration? How much is the stress level decreased due to enhanced mechano-sorptive creep and how much additional capacity is obtained if this is also transferred into a higher drying rate? How much will this increased creep influence the slicing test gap and will this require changes in the conditioning phase? Further, will the energy demand (both instantaneous and total) decrease or increase? And finally, will the drying cost decrease or increase? If the model is used regularly, the kiln operator will eventually better understand these interactions. This is most typical "Learning by doing". By the way, how many researchers in this field can directly give an answer to the last two questions?

As a final remark, it can be stated that a computer simulation model can very well be used for basic educational purposes for young people in the beginning of a career in the timber drying profession. The relative importance of different drying variables and interactions (simpler than those listed above) can be demonstrated and discussed by means of the model.

7. CONCLUSIONS

The general structure of a timber drying simulation model intended for use by kiln operators has been described and discussed. The distribution of this model has been a success as a whole. The purpose, however, is not to exaggerate the importance of this specific model, but to show that any carefully constructed model can in a very efficient way transfer information from advanced research into sawmill practice. This will not only benefit the sawmills but also the research community in the long run.

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