Is it necessary to perform a controlled cooling phase at the end of a conventional kiln drying process?

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ABSTRACT

A conventional wood drying process performed in a batch kiln chamber, normally includes a controlled cooling phase at the end. The climate in the cooling phase shall correspond to the desired moisture content of the wood product (EMC is equal to the desired MC in the wood). It is normal that the cooling phase has a duration of 5-8 hours, and that the dry bulb temperature in the kiln is about 40 °C at the end of this phase.

Traditional arguments for performing a controlled cooling phase is to avoid undesired drying of the outer layer when warm wood is taken out into cold climate, especially a Nordic winter climate. When exposed to such dry climate, there is a possible risk for cracks/micro cracks to form in the wood surface. For conditioned sawn timber, there is a possible risk for new development of casehardening. In addition, a controlled cooling phase can contribute to reducing the variation in moisture content between planks/boards.

It is, however, more and more important to reduce the drying costs at the sawmills, and the question is then if it is advisable to cut the controlled cooling phase to save some drying time.

Several experiments in a laboratory kiln were performed. The development of moisture content and casehardening during cooling phases performed in various ways was measured. In addition, some microscopic studies were performed to detect possible micro cracks.

The results indicate that the performance of the cooling phase has no significant consequence for the casehardening after drying. There has not been found any cracks or micro cracks in the test material either. However, the number of pieces in the performed tests is rather low, and therefore it is necessary to perform more tests before final conclusions are taken.

INTRODUCTION

A conventional wood drying process performed in a batch kiln chamber, normally includes a controlled cooling phase at the end. The climate in the cooling phase shall correspond to the desired moisture content of the wood product (EMC is equal to the desired MC in the wood). It is normal that the cooling phase has a duration of 5-8 hours, and that the dry bulb temperature in the kiln is about 40 °C at the end of this phase.

Traditional arguments for performing a controlled cooling phase is to avoid undesired drying of the outer layer when warm wood is taken out into cold climate, especially a Nordic winter climate. When exposed to such dry climate, there is a possible risk for cracks/micro cracks to form in the wood surface. For conditioned sawn timber, there is a possible risk for new development of casehardening. In addition, a controlled cooling phase can contribute to reducing the variation in moisture content between planks/boards.

It is, however, more and more important to reduce the drying costs at the sawmills, and the question is then if it is advisable to cut the controlled cooling phase, and then save some drying time.
The aim of this investigation was therefore to detect possible consequences of the drying stresses that can occur in the outer layer of sawn timber in cooling phases performed in various ways. The development of casehardening and possible cracks/micro cracks were the most important result parameters.
An important aspect was to expose the sawn timber to the similar climate as will occur through a sawn timber package when it is coming directly from a warm kiln and out into a cold climate. The first part of the work was therefore to perform measurements to describe the climate in warm sawn timber packages exposed to winter climate.

MATERIAL AND METHODS

Test material

Five main planks with a cross section dimension of 44 mm x 150 mm were each cut into smaller test pieces, with a length of approximate 1 m. Three test runs were performed in the laboratory kiln at Norsk Treteknisk Institutt (NTI), and in each kiln run, one test piece from each main plank was used, i.e. five test pieces in each run.

Kiln drying

The kiln drying runs were performed by having a constant dry bulb temperature of 75 °C, with a decreasing wet bulb temperature. After the drying phase, an equalising phase of 24 hours was performed, and the target MC in the three runs was 16 %, 14 % and 12 %, respectively.

Cooling phases

After the equalising phase, the test pieces were exposed for cooling processes of four types:

Type 1

Traditional cooling phase in the kiln, down to about 40 °C.
In this phase, the kiln tries to maintain an EMC in the kiln that corresponds to the target MC. Fig. 1 shows dry and wet bulb temperature during the cooling process in the kiln.

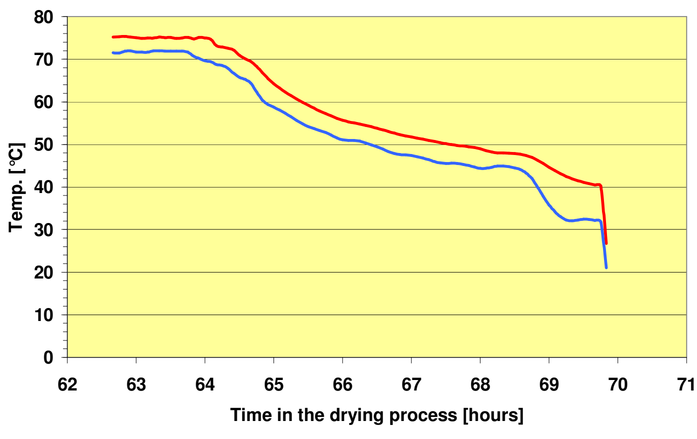

Fig. 1: Dry (red line) and wet (blue line) bulb temperature during the cooling process in the kiln.

After the controlled cooling phase in the kiln of about six hours, the test pieces were thereafter exposed to outdoor climate (temp.: 0-4 °C, RH: 75-90 %).
One test piece from each kiln run was exposed to this type of cooling phase.

Type 2

Conditions comparable to what is the situation in the middle of a package that is coming out into cold climate directly from the drying/equalising phase in the kiln (no cooling phase is performed in the kiln).

To find the climate that is representative for this situation, the temperature and relative humidity were measured and logged in one timber package at a sawmill. The drying temperature was 70 °C at the end of the drying process, and the timber was taken directly out into the cold climate without any cooling phase in the kiln. The climate in the middle of the package is shown in Fig. 2. The target MC was 17 %.

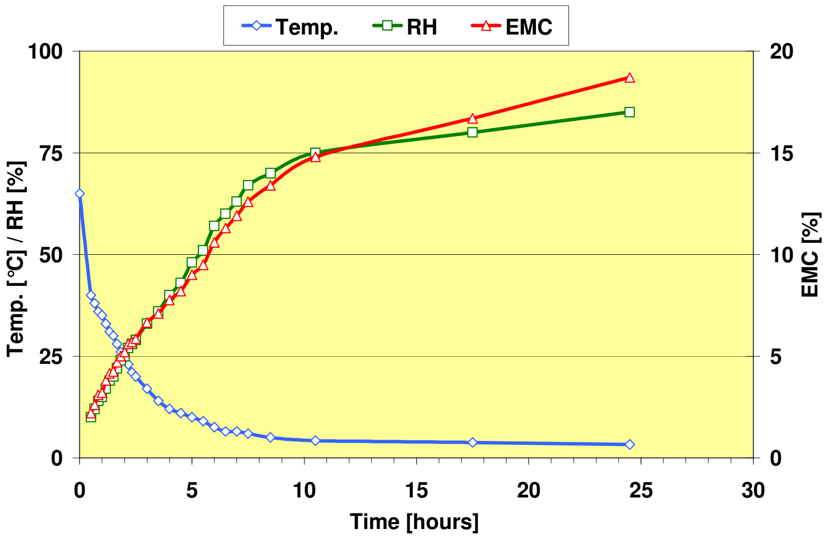

Fig. 2: Logged climate in the middle of a sawn timber package that is taken directly out from a kiln, without any cooling phase, at a sawmill.

Fig. 2 shows that the sawn timber in the middle of the package is exposed to climatic conditions which will give a drying potential for several hours. The length of this period will of course also depend on the wind conditions (and then the potential air speed in the packages). The air speed was not measured, but the wind was very low when the measurements were performed.

The sawn timber in the outer layer in the package will be exposed to the normal outdoor climate the whole time, while it will be a gradual change from these two conditions from the outer to the inner layer in the sawn timber packages. However, concerning the undesired drying effect, it is the layers in the middle of the packages that are most exposed to this risk.

In the experiments, a climate chamber was used to attain the climate shown in Fig. 2.

Two test pieces from each kiln run were exposed to this type of cooling phase.

Type 3

Directly into a freezer at -18 °C after the drying and equalising phase in the kiln.

This represents timber in the outer layer of sawn timber packages that are taken directly out into very cold climate, without any cooling phase in the kiln.

One test piece from each kiln run was exposed to this type of cooling phase.

Type 4

Directly out into outdoor climate.

The climate during the test days varied from 0-4 °C, and RH of 75-90 %. This represents timber in the outer layer of sawn timber packages that are taken directly out into outdoor climate, without any extreme coldness, and without any cooling phase in the kiln.
One test piece from each kiln run was exposed to this type of cooling phase.

Measurement of casehardening
After drying and equalising in the kiln, test pieces for measurements of MC and casehardening were cut from the planks. Afterwards, the planks were end-sealed with silicone and exposed to the various cooling phases.
The casehardening level was measured by the two-cleave-method, described in ENV 14464 (CEN 2002). The average MC was determined by the oven dry method, based on a cross section test piece. In addition, a test piece was cleaved into nine lamellae (Fig. 3) to detect the gradient of MC in the cross section (the oven dry method was used for each lamella), and the deflection was inspected for each lamella to detect possible casehardening development.
The method used for measuring the development of MC and casehardening in the cross section is described earlier by Fløtaker, Tronstad & Sandland 1996 and Sandland 1999.

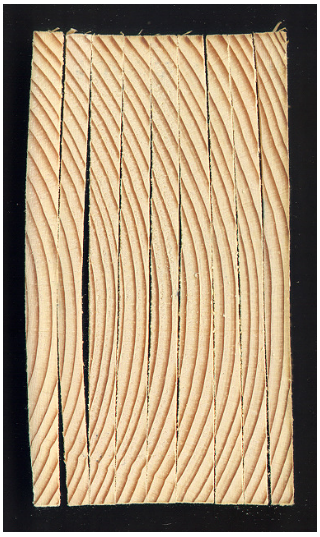

Fig. 3: Test piece cleaved into nine lamellae.

Detection of possible micro cracks
In the investigation, macroscopic and microscopic methods were used. A blue contrast fluid was introduced to the surface of the test pieces, and layers of 0.5-1.0 mm were gradually removed from the surface by sanding, to see if some kind of micro cracks occurred. Fig. 4. shows the test pieces.

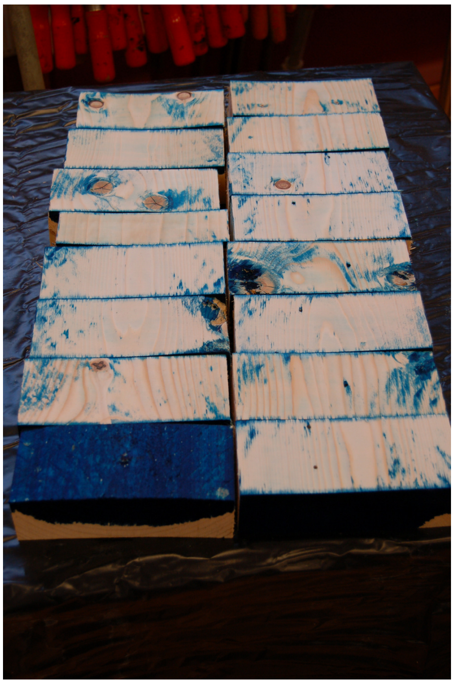

Fig. 4: Test pieces with blue contrast fluid. Test piece before sanding is shown at bottom on left side. The other test pieces were sanded after the blue contrast fluid has been introduced to the surface.

RESULTS

Casehardening

The development of casehardening for the four types of cooling procedures is shown in Fig. 5-8.

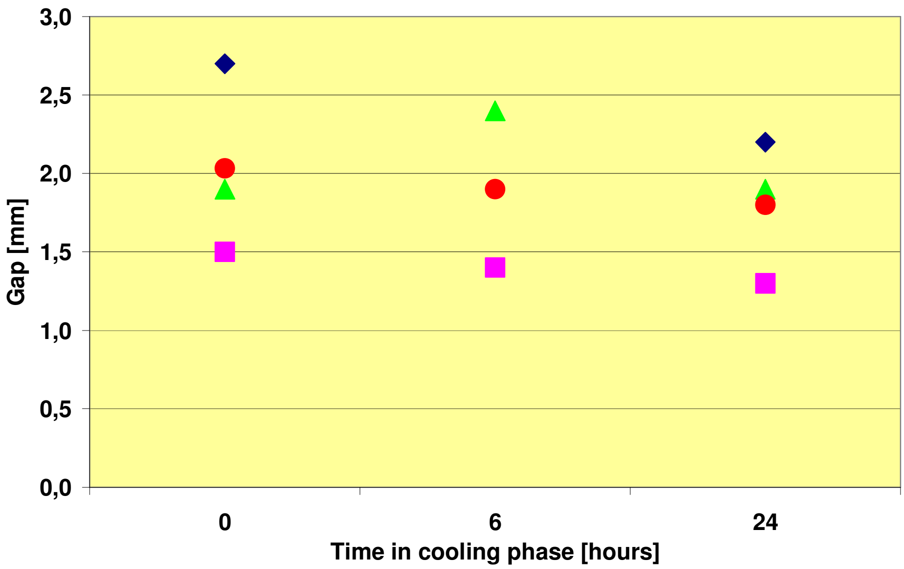

Fig. 5: Development of casehardening during the controlled cooling phase in the kiln (from 0-6 hours), and thereafter exposed to outdoor climate (from 6-24 hours) (Type 1). One type of indicator for each test plank. The red circles indicate the mean values.

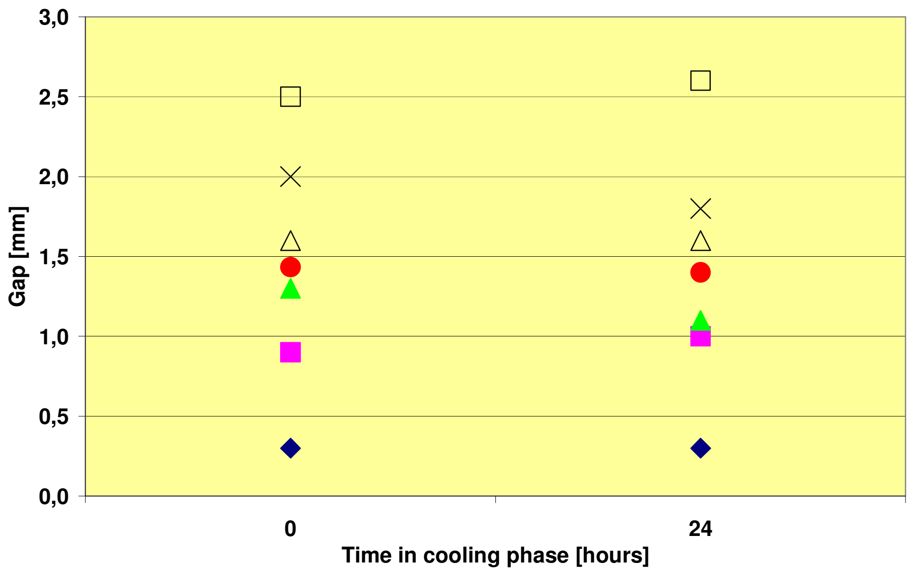

Fig. 6: Development of casehardening during a cooling phase that corresponds to the measured climate in the middle of a sawn timber package that is taken directly out into cold winter climate (Type 2). One type of indicator for each test plank. The red circles indicate the mean values.

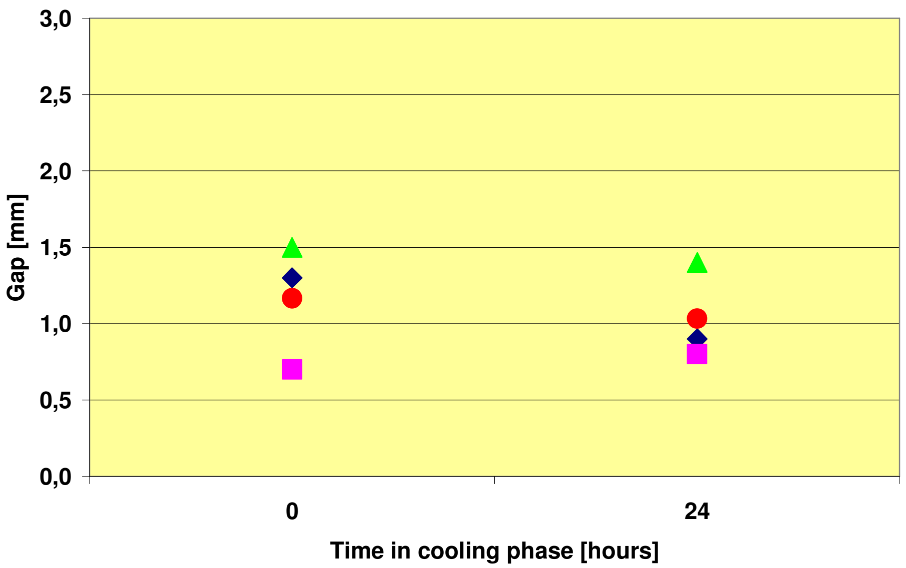

Fig. 7: Development of casehardening during a cooling phase in a freezer (Type 3). One type of indicator for each test plank. The red circles indicate the mean values.

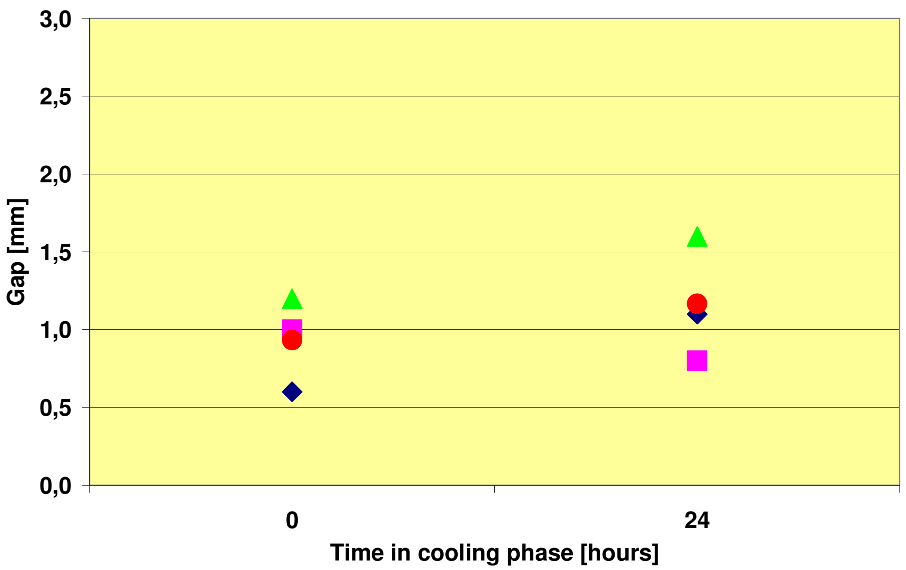

Fig. 8: Development of casehardening during a cooling phase in outdoor climate (Type 4). One type of indicator for each test plank. The red circles indicate the mean values.

As can be seen from the figures, the casehardening level during the cooling phases is quite stable for all the treatments. None of the cooling phases differs from the other ones in a significant way concerning casehardening level.

Micro cracks

It has not been possible to detect micro cracks in the test pieces. Bigger cracks have not occurred either.

DISCUSSION AND CONCLUSIONS

The results show that the casehardening level during the cooling phases is quite stable for all the treatments. Even for the cooling phase that included a very dry climate for several hours, corresponding to the situation in the middle of a sawn timber package, there has not been found any significant development of casehardening, nor cracks/micro-cracks. Based solely on these findings, it is not necessary to perform a controlled cooling phase in the kiln concerning casehardening or cracks/micro-cracks. However, in this investigation the outdoor temperature was about 0-4 °C. In colder climate than this, further research is necessary to make certain conclusions.

Some more reservations must be taken concerning this conclusion. It is a limited number of observations in the tests, and the results are not verified by industrial tests. However, it is not expected that more tests and/or industrial tests will change the main conclusion.

The possible positive effect of a controlled cooling process concerning equalising of the MC between planks/boards in a kiln is not investigated in this research work. If this is a motivation for a controlled cooling phase in the kiln, perhaps it will be better to replace it with longer duration of an equalising phase. However, to get clear answers of these questions, some industrial tests have to be performed.

ACKNOWLEDGEMENT

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REFERENCES

CEN (2002). Sawn timber – Method for assessment of case-hardening. ENV 14464, November 2002, European Committee for Standardization.

Fløtaker, S., Tronstad, S. & K. M. Sandland. (1996). Tørkespenninger – kondisjonering, bakgrunn, forsøk, metoder. Rapport 35, Norsk Treteknisk Institutt, Oslo, Norway.

Sandland, K. M. (1999). Deformations in wood – The influence of the wood drying process. Doctor scientiarum theses 1999:9, Agricultural University of Norway, Ås.