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STRESS DEVELOPMENT IN DEPENDENCE OF THE WOOD DRYING RATE

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ABSTRACT

The study investigated deformations, stresses and the character of changes induced by the non-free shrinkage of beech timber specimens (*Fagus sylvatica* L.) in the radial direction, in the conditions of varied drying intensity. During the experiments, the program of intense drying (T=60°C, EMC=10%) and the program of moderate drying (T=40°C, EMC=15%) have been taken into consideration, and the values of the accepted timber shrinkage have been differentiated. The varied efficiency of the mechanical restraint of the timber specimens deformations has been obtained due to the use of dynamometers of various characteristics. The research results prove the relationship between the values of durable deformation and the values of accepted shrinkage

Key words: shrinkage, drying, drying gradient, drying stress, deformations, timber.

INTRODUCTION

The desorption stresses in the convection-dried timber result from the moisture gradient in the cross-section of the material. In the initial period of the drying process, the outer layers are the first to reach the moisture content that makes the desorption drying possible. Therefore, the higher moisture content of the centre layers restricts the shrinkage of the outer layers. The efficiency of this restraint depends upon the difference in the moisture content of the layers. As a consequence of the restraining action of the more moist layers of the section, the tensile stresses are generated in the drier layers and deformations occur that have the form of extensions of two components: elastic – reversible and plastic – irreversible. The results of research made by Kawai et al. [6] show that presumably, the value and characteristic of the deformation are mostly affected by the drying dynamics, which depends on the values of the basic process parameters: drying air temperature *T* and equilibrium moisture content *EMC*. The fraction of the durable deformations of the outer layers of the section increased as a result of growing drying intensity. Moreover, the mentioned authors claim that the character of the deformations in these layers is mostly affected by the initial period of the drying process when the layers are stretched. This period of drying is the most risky since that is when the greatest number of exterior checks occur in the dried timber. The elimination of this risk is the basic purpose of the studies on the state of stress and strain, when the maximum value of the stress is considered the major reason for the destruction of the xylem [2, 8, 10]. The acceptable value of the desorption stress, calculated on the basis of a program simulation is also the main leading factor in the control systems for convection driers. According to Bernatowicz [1], simulation programs used in the technical scale calculate too high values of desorption stresses, since after reaching 80% of the assumed tensile stress visible checks on the surface of the dried material are recorded. Moreover, the value of transverse tensile strength accepted for the calculations is too high. So far, however, the researchers have not been able to unambiguously decide whether the reasons for the destruction should be ascribed to the presence of the stress of the determined, critical value or to the character and value of the deformation. Kass [5] observed a very close relationship between the number of checks on the timber surface and the value of the durable deformations. These results prove the supposition that the destruction of xylem results from the character and the value of the deformation, not from the value of the stress. The results of research made by Widłak [12] also confirm the theory by Kass about the decisive role of deformation in the possibility of appearing checks in the xylem. Widłak claims that the destructive stress in the experiments with the non-free shrinkage of the tangential specimens of beech timber is smaller by half than the immediate strength determined in the short-term tension test, and the deformation leading to the destruction is approximately 10 times grater than in case of an analogical value in a conventional destroying test.

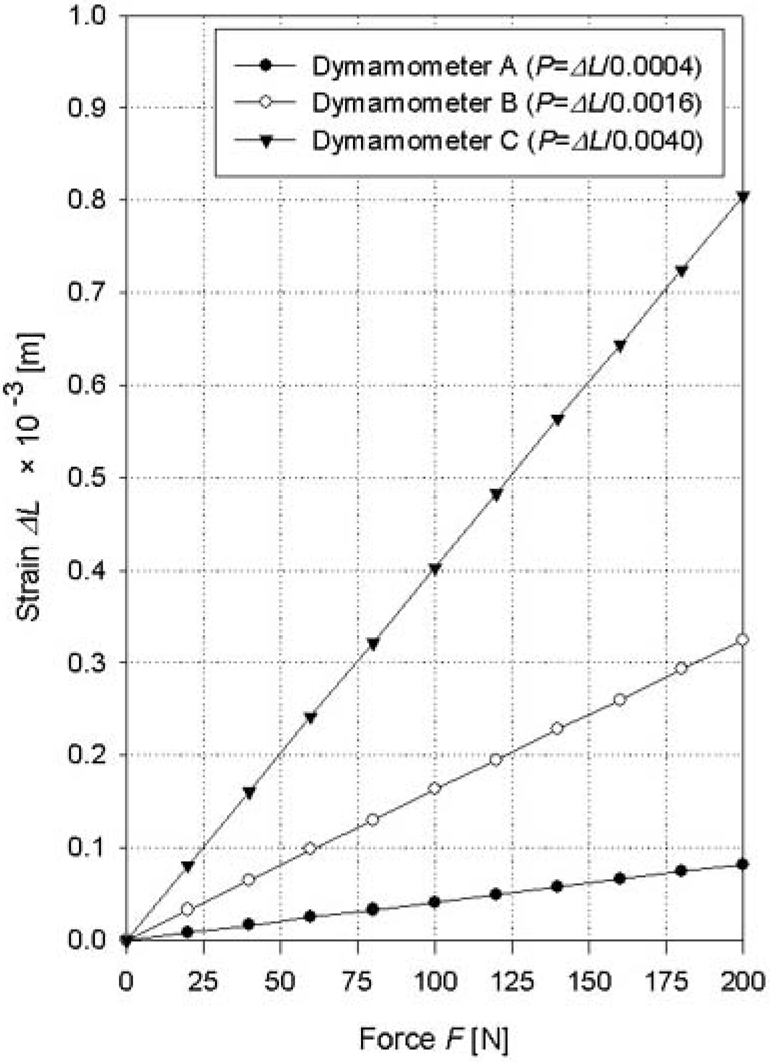
It ought to be emphasized that in most research made so far, in order to map the real drying conditions, the shrinkage of timber specimens is restrained using the tensile force that makes the shrinkage impossible [3, 7, 11, 12]. An experiment of this kind reflects an extreme situation, the probability of which, in the conditions of drying timber, can be described as theoretically possible. However, it seems reasonable to assume that the restraining action of the more humid layers is not efficient enough to totally constrain the phenomenon. Therefore, the tensions observed in the timber do not make the shrinkage impossible, but they occur along the non-free shrinkage. That is why the conditions in which the experiments are carried out, should allow for the changes of process parameters (due to their undeniable influence on the state of stress and tension in the dried timber) as well as the differences in the shrinkage restraint degree (various value of the accepted deformation). It is worth mentioning that Perkitny [9] discerned differences in the shrinkage values of xylem which dried at various rate. He found out that greater drying intensity resulted in smaller shrinkage of the xylem. This observation may prove the significance of the dynamics of tension decrease for the value and character of the deformation.

MATERIALS AND METHODS

The research was made with use of beech timber (*Fagus sylvatica* L.). This kind of timber is most frequently used in the studies on desorption stresses due to the small diversification of its anatomic structure, high values of desorption stresses and special susceptibility for checks in the drying process. That suggests great significance of the stress values and, therefore, their influence on the value of the durable deformation of timber in the context of drying quality.

A series of experiments was carried out, with three efficiency levels of restraining the desorption shrinkage: level A – high efficiency, level B – medium efficiency, level C – low efficiency. The varied efficiency of shrinkage restraint was obtained by means of using dynamometers of different characteristics, as shown in Figure 1.

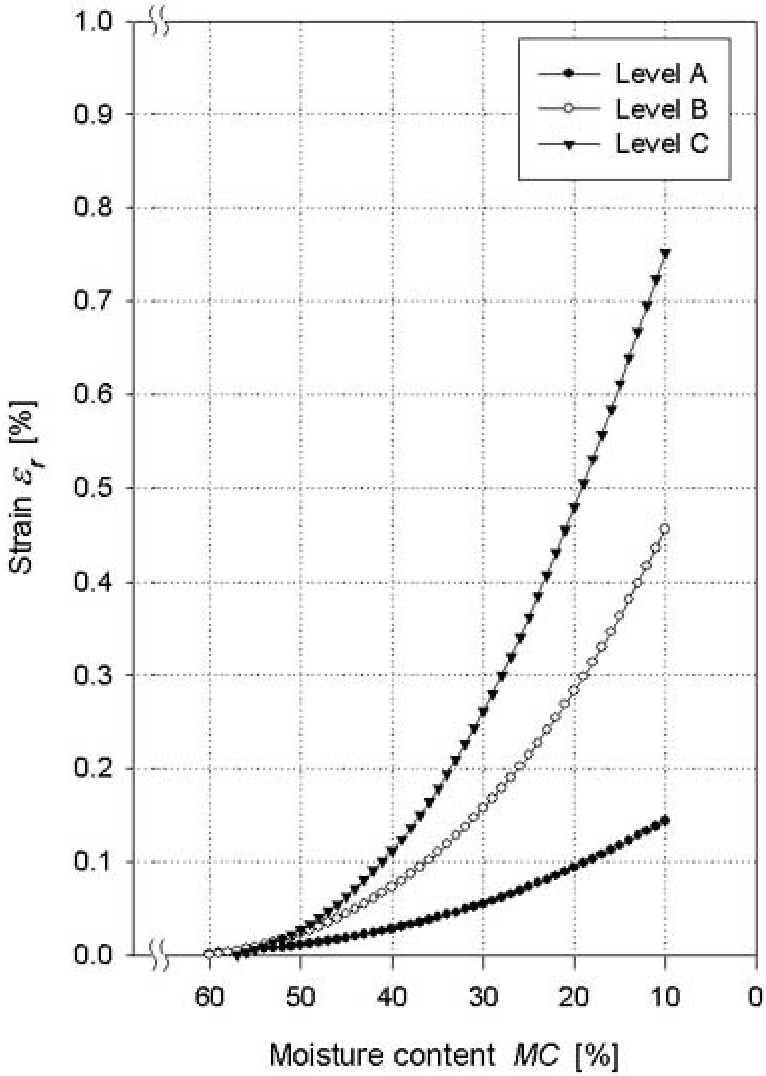
Figure 1. Characteristics of dynamometers used in experiments



In the course of the study, various drying conditions characteristic for conventional programs for drying beech in convection driers were taken into account: intense drying (Schedule 1; T = 60°C, EMC=10%), and mild drying (Schedule 2; T = 40°C, EMC = 15%). An assumption was made that, with varied efficiency of shrinkage restraint and various process parameters, the intense drying is accompanied by high efficiency of shrinkage restraint (level A) and the mild drying is accompanied by low efficiency of shrinkage restraint (level C). During experiments, the deformations of a freely shrinking specimen and decrease in the moisture content of a twin specimen were observed simultaneously in a laboratory drier with a forced air-cycle (air rate v = 3m/s).

The character of the timber deformations induced by the non-free shrinkage was determined in an extra experiment: the dried specimens were moistened again over the water solution of potassium sulfate (K_2SO_4). The vapor pressure over the solution in the temperature of 20°C made it possible to achieve the hygroscopic equilibrium of 28% [4]. The durable deformation of the specimens was determined as the difference in the values of the repeated swelling of the specimens which shrank freely during the drying and the specimens that shrank non-freely.

Figure 2. Strain curve for specimens dried at temperature *T*=60°C; equilibrum moisture content *EMC*=10%



RESULTS AND ANALYSIS OF EXPERIMENTS

Based on the results of experiments (Table 1) we can conclude that, due to the use of dynamometers of various characteristics, a significant differentiation of the accepted deformation value was obtained. The dependence of the stress value in the axial tension test upon the susceptibility of the applied dynamometer can be treated as the dependence of stress upon the value of accepted shrinkage. A similar assumption was made by Svensson [10]. The experiments show that, as in the experiments made by Svensson, the lower value of the accepted shrinkage is accompanied by a greater value of the generated tension.

Table 1. Streses and set-strain for specimens of beech (radial direction) in different efficiency of restraining the shrinkage (*T*=60°C; *EMC*=10%)

Restraint efficiency		Level A	Level B	Level C
Restrained strain ε_r	[%]	0.14	0.46	0.75
Stress σ	[MPa]	3.65	2.72	1.82
Set-strain ε_s	[%]	64.0	55.2	43.9

The durable deformation fraction in the stretching of the specimen determined in the repeated moistening test is characterized by a similar dependence. The greatest fraction occurs in the specimens stretched with the smallest value of the accepted shrinkage (Table 1). Figure 3 shows the course of desorption stresses development corresponding to the levels of shrinkage restraint efficiency. The data indicate the dependence of the stress development dynamics upon the value of accepted shrinkage. The small value of accepted shrinkage – corresponding to the highest level of shrinkage restraint efficiency, results in a more rapid increase in the stress. It confirms the significant role that is ascribed to the shrinkage restraint level in the process of drying stresses development [5]. Table 2 illustrates the results of determining the stresses and durable deformations for the extreme conditions of intense drying. An assumption was made that in real drying conditions the increase in drying intensity is accompanied by the decrease in in the value of accepted shrinkage. That is why the highest efficiency of shrinkage restraint (level A) was associated with the conditions of intense drying (schedule 1), and the lowest efficiency (level C) with the mild conditions of drying (schedule 2).

Figure 3. Stress curve for specimens dried at temperature *T*=60°C; equilibrum moisture content *EMC*=10%

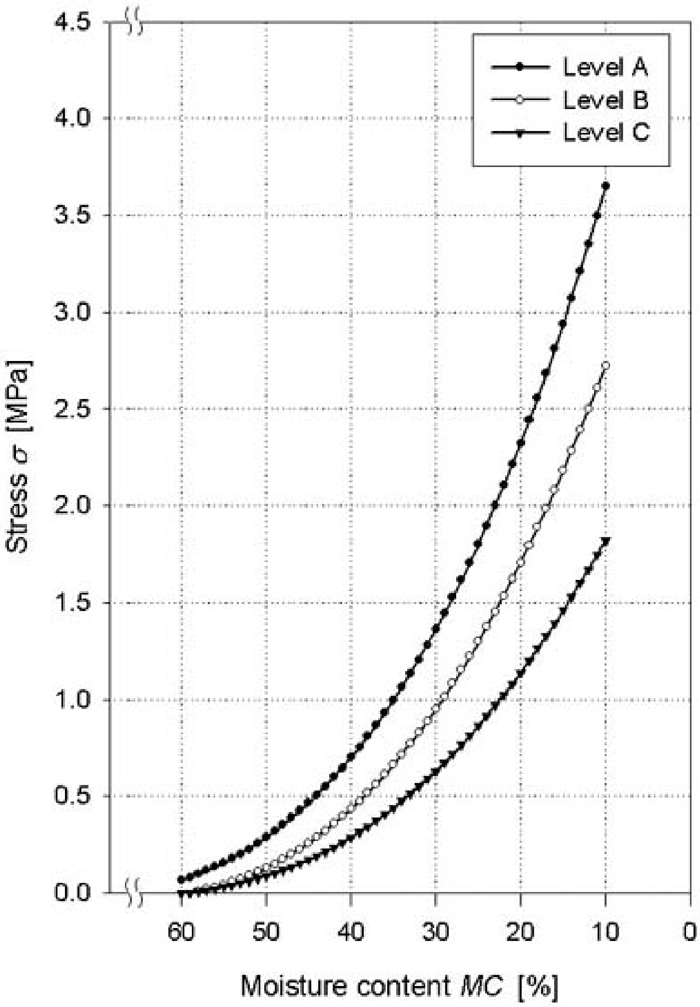


Table 2. Streses and set-strain for specimens of beech (radial direction) in different drying conditions

Drying conditions		Schedule 1 Level A	Schedule 2 Level C
Restrained strain ε_r	[%]	0.14	0.54
Stress σ	[MPA]	3.65	1.35
Set-strain ε_σ	[%]	64.0	31.7

Based on the results of experiments a conclusion can be drawn that the more intense drying of timber (in higher temperature, and lower equilibrium moisture content accompanied by greater efficiency of desorption shrinkage restraint) leads to the increase in the stress value as well as in the value of durable deformation that occurred during the non-free shrinkage of the stretched layers. It is manifested by the higher value of the stress and increasing fraction of the plastic component in the total deformation of the studied specimens, in comparison with the determination results of the specimens dried moderately (schedule 2). Therefore it is incorrect to suppose that the lower stress value in the specimens dried according to schedule 2, with the lowest efficiency level of shrinkage restraint (level C) may imply better conditions of stress relaxation than in case of the intense drying (schedule 2) and, therefore, greater stretching of the specimen. The experiments have however confirmed the supposition claimed by Perkitny [9], that a great intensity of drying is accompanied by lower shrinkage degree.

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