Influence of the carbon dioxide emissions on selected mechanical properties of wood

Jozsef Garab, Zsolt Karacsonyi, Antal Kannar
University of West Hungary, Faculty of Wood Sciences, Institute for Applied Mechanics and Structures
garabj@fmk.nyme.hu

ABSTRACT. The relationship between the carbon dioxide concentration and selected mechanical properties were investigated on solid wood specimens. The carbon footprint is showing increasing tendency in the region where the examined trees were grown. Hence, the goal was to find any contact between this effect and selected mechanical properties of wood. The samples in this preliminary study were taken only from Norway spruce *(Picea abies)* and English oak *(Quercus robur)* trees, which were grown in Hungary. Compressive strength and hardness were determined from the pith to the bark in order to find any changes in the mechanical properties, which can be contact with the increased carbon dioxide concentration. The experiment shows that just in case of English oak has any relationship between the compression strength and the sample position in the stem. This connection can be explained with anatomical features, too. Therefore, added investigations are necessary (e.g. radial density profile determination).

Introduction

In the atmosphere of the Earth, the CO_2 concentration increases fast due to the industrial production, other human activity and natural processes like the release of CO_2 from melting ice. The measured CO_2 concentration was 280 ppm in 1900 while it is 380 ppm these days. The trees as CO_2 fixed biological system react to the changed condition. The goal of this study was to find any differences in the mechanical properties of wood due to the change of CO_2 concentration. In the scientific literature, many publications can be found in this topic.

Kretschmann et al. [1] has bred Sour orange trees (*Citrus aurantium* L.) in plastic-wall chambers. The trees were planted in 1987 and harvested in 2005. The elevated CO_2 concentration was 670 ppm (part per million). A control group was also planted in normal CO_2 concentration. They found that the specific gravity and modulus of elasticity values of CO_2 exposed samples and those of control samples did not show any statistically significant differences. Exposure to CO_2 seemed to influence micro-fibril angle development by reducing the length of juvenility.

Kilpelainen et al. [2] examined a 15 year old Scots pine *(Pinus sylvestris)* plantation where the elevated CO_2 concentration was 550 ppm. The temperature was increased by 2°C compared to the mean environment temperature, too. Neither the increased CO_2 nor the elevated temperature (combined or separately) had any statistically significant effect on radial growth over the entire 3-year treatment period except for the normal temperature-elevated CO_2 concentration samples where the radial growth increase was 54% over the entire treatment period.

Kostiainen [3] has found that the elevated CO_2 concentration increased the annual ring width in silver birch, in two clones of 3-year-old aspen and in 5-year-old aspen clones, but the radial growth increment did not lead to any changes in the wood anatomy.

In two studies with 40-year-old Norway spruce *(Picea abies)*, the elevated CO_2 did not affect the mean ring density and had no constant increasing effect on ring width, although some within-ring alterations in wood anatomy were observed. Cell wall thickness and tracheid lumen diameter in earlywood decreased and tracheid diameter in latewood increased under

elevated CO_2. These changes may be controlled by the processes of tracheid differentiation: growth in the radial and longitudinal directions or secondary wall formation.
Beismann et al. [4] have studied the biomechanical responses of stems of 6- to 7-year-old spruce and beech trees after 4 years of growth in elevated atmospheric CO_2 in combination with nitrogen treatment and on two different soil types. Spruce wood produced under elevated CO_2 was tougher on both soil types. In contrast, the beech wood samples did not show any significant reaction to CO_2 but were significantly tougher under high nitrogen depositions on acidic soil. Effects on wood density of both CO_2 and N treatments were not significant but wood density was higher in acidic soil and so were rigidity and toughness in CO_2 and N.
Based on the above mentioned, it can be stated that the effect of the elevated CO_2 depends on the wood species and other environment parameters as well. The caused effect is usually not significant but demonstrable. The diverse results are hard to generalise, additional experiments are necessary to understand the effect of CO_2. In our experiments we tested wood samples for compression tests and hardness tests especially for the wood species grown in Hungary.

MATERIAL AND METHODS

Since, it was a preliminary study to investigate the CO2 emission and mechanical properties only two species were investigated during compression and the hardness tests. Previous investigations were focused on Norway spruce *(Picea abies)*, therefore it was obviously to examine this wood species. In addition, the English oak (*Quercus robur)* was investigated. The Norway spruce tree was 65 years old, the English oak was 76 years old at tree felling.

Specimen preparation

100 mm thick discs were cut from each stem at 4 meter high. Specimens were prepared from the same discs both for compression and hardness tests. Specimens contain the pith, and wood defects were omitted. Samples in dimension 20mm x 20mm x 50mm (rad. x tang. x long.) were made from the section of the disk for compression specimen (Fig.1). The index of the specimens is the vintage of the annual ring in the centre of the specimen. Each specimen consists of 8-10 annual rings approximately. Therefore, the measured mechanical properties were average values of these growth year rings. By hardness measurements, specimens were taken from the cross shaped area of the discs cut in 5 cm height parts (Fig. 1). After a hardness measurement, the fractured area was cut out and new test was carried out on the rest of the material.

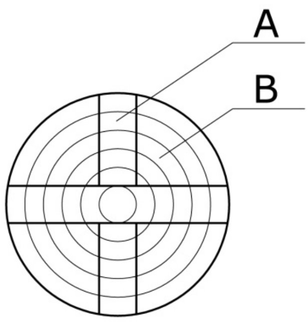

Figure 1: Specimen preparation from the disc. A: Specimens for hardness measurements.
B: Specimens for compression specimens

Compression tests

Compression tests were carried out on the prepared specimens from the section of the discs. Instron 4208 universal testing machine was applied. The loading rate was chosen with the assumption that the fracture of the specimens should occur in 90 ± 30 seconds. The applied loading rate was 5 mm/min. Within the scope of this study, load was applied until fracture. Compression strength was defined when the specimen crushed 2% in the load direction.

Hardness tests

Samples for hardness tests were taken from the cross shaped parts of the discs. Hardness was measured according to Brinnel [5] in the radial direction. All measurements were done using a steel ball of 10 mm diameter and load of approximately 500 N in the Instron 4208 universal testing machine.

Results and discussion

The results of the measurements are shown on the Fig.2-5.

In case of the English oak there are strong correlation between the age and the investigated mechanical properties. For the Norway spruce this connection is not significant. The compressive strength is higher by the Norway spruce in older years. The situation is opposite by the English oak. These results are open to speculation: what is the major reason of the determined properties. More investigations are needed to decide that the anatomical influence (e.g. the oak has bigger vessels at older age which can decrease the compressive strength) or the environmental influence (e.g. carbon dioxide emission) has more significance. Impact of the local capability cannot be neglect. It is obvious that the global carbon dioxide emission is decreasing. But regions where are factories which damaged more the environment, the effect of the carbon dioxide is higher than in other regions.

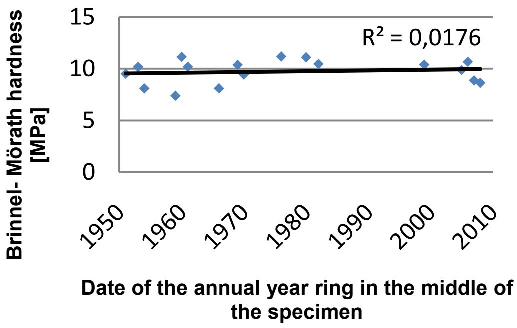

Figure 2: Hardness of Norway spruce samples in different ages.

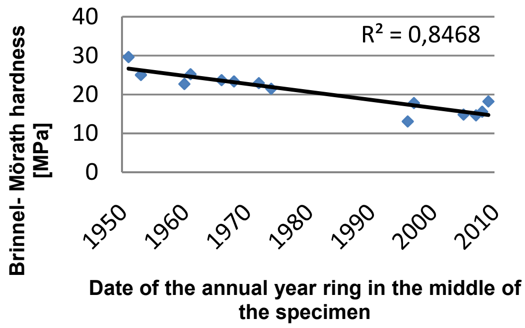

Figure 3: Hardness of English oak samples in different ages.

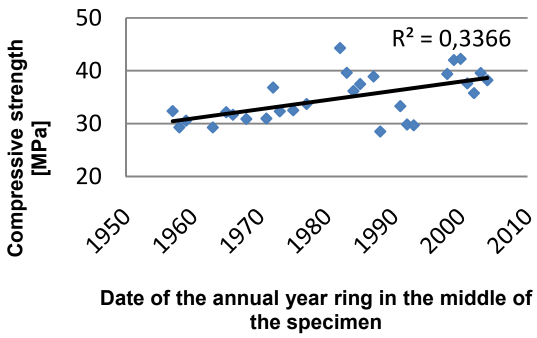

Figure 4: Compressive strength of Norway spruce samples in different ages.

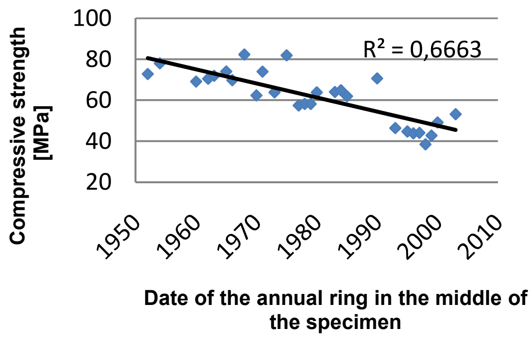

Figure 5: Compressive strength of English oak samples in different ages.

Conclusion

The performed investigations show that the influence of the carbon dioxide on the compressive strength and the hardness is not confirmed clearly. The English oak shows correlation between the mechanical properties and the sample position in the stem. However wood anatomical reason can be in the background. Therefore, other mechanical tests are necessary (e.g. radial density profile).

Acknowledgement

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