SAFETY OF TIMBER – AN ANALYSIS OF QUALITY CONTROL OPTIONS

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1 INTRODUCTION

For the construction purposes the mechanical properties of timber such as density, modulus of elasticity and strength are of interest. These so called characteristic values are defined in a strength class system that lists mean values or 5th percentiles of certain material properties for a population.

Through grading a piece of timber is assigned to a specific grade. To ensure that these timber pieces reveal the actual timber properties quality control procedures are necessary. In Europe the machine controlled method is broadly used. The machine settings are determined prior to the production and remain constant during the entire production [1]. An alternative option defined in the European grading standard EN 14081 is the output controlled method. Samples of the daily production are used to control and adjust the production settings. Additionally, methods of “real-time” production control are available but not included in standards so far. These methods are based on information gathered non-destructively during the grading process [2].

All production control methods are limited to timber from certain growth regions, assuming constant ratios between material properties and prediction parameters. With growing interest in extension of the growth regions the question arises whether the declared timber properties are achieved for timber originating from multiple growth regions. Whereas the on-going research in Europe, e.g. GRADEWOOD project, aims to define such growth regions with special regard to machine control, no analysis of a real production process with joint settings has been carried out.

In the current study the capability to produce timber with guaranteed characteristic values independent of the growth region is studied. Three production control methods are applied to real production data for which the timber properties were simulated.

2 MATERIALS AND METHODS

The dataset used to assess the performance of different production control methods includes the measurements of indicating properties - dynamic modulus of elasticity and density - of 279,235 boards recorded during production. The strength and stiffness values for each single piece were simulated based on this information. The simulation algorithm assumed a log-normal probability distribution of tensile strength, dynamic and static modulus of elasticity and the same relationship between variables (coefficient of correlation) as in real (laboratory) data.

Three different production control methods were applied to grade 279,235 timber pieces over multiple growth regions. The machine control method was simulated using the requirements on initial type testing defined in EN 14081-2. The estimated settings remained constant during the production.

The output control was simulated in accordance with EN 14081-2 and EN 14081-3. For each production shift samples (10 specimens) were taken and control charts were applied as required in the standard. Additionally, the option to maximize yield was included in study. Due to probabilistic nature of output control the simulation was repeated 100 times to cover the different reaction patterns of the system.

By non-destructive output control the variable CUSUM control chart was established to observe the indicating property $E_{\text{dyn}}$ of the graded timber. It was assumed that by maintaining the process on the specific level (of $E_{\text{dyn,mean}}$) the characteristic properties of a specific grade are fulfilled.

For each production control system the achieved characteristic properties, as well as yield, were observed in intervals of 10,000 specimens.

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3 RESULTS

3.1 MACHINE CONTROL

In the present study the possibility for using joint settings, estimated on 1,400 specimens from different growth regions, was studied. Depending on the chosen strength class combination the method worked. This is caused by differences in material properties and their relationship by timber pieces of different origin sampled to estimate the initial settings. For the combination L40-L25 the higher proportion of timber with lower quality but higher strength prediction in a sample leads to low characteristic values, for L30-rej the lowest characteristic values were near to the required ones.

3.2 OUTPUT CONTROL

The results include the reaction patterns of output control over multiple growth regions. The overall capability to react on too low settings could be observed during the phase of initial settings “verification”, as well as during the production. Such reaction leads to increment of settings and more satisfying timber properties. Furthermore, as already concluded in previous investigations [3, 4] the low reactivity of attribute chart could be shown. For L40 the 5% lower initial settings (85.7% of periods below the requirements) are adjusted every 2.6 months. The higher the sampling rate, the lower is the reaction time.

The probabilistic approach leads to a case where the settings are adjusted, although the characteristic properties are fulfilled. Thus, the yield maximization – reduction of settings - is a necessary step.

In figure 1 the different possible reaction patterns of output control (incl. yield maximization) are brought in connection with characteristic strength achieved in 100 simulations. The grey scaled polygon shows the broad interval possible on the values of achieved characteristic strength with minima (reduced settings due to yield maximization) and maxima (increased settings). The mean over 100 simulations remains above the requirements (26 N/mm²).

Figure 1: Output control performed with yield maximization: time series of characteristic strength for L40 (combination L40-25)

3.3 NON-DESTRUCTIVE OUTPUT CONTROL

The results for non-destructive output control indicated that its application over multiple growth regions is not possible. First, the detection of quality shift was limited due to changes in the coefficients of determination between the source countries. Whereas the coefficient of determination between E dyn and f Δam increased from 52.4% to 60.4% the mean value of ungraded timber decreased. As a result during the grading the control procedure for L40 indicated the decrease of E dyn, mean - a signal for falling characteristic strength, which was not the case. For L25 and L30, which was graded separately, no such issues occurred. Second, the single control parameter for all growth regions could not be found, as these were estimated on the sample basis and the descriptive statistic differed markedly.

4 CONCLUSIONS

Timber can be produced safely over multiple growth regions using both machine and output controlled system. In order to achieve this, using the machine controlled system graded with E dyn as indicating property, conservative settings must be selected because different ratios between E dyn and tensile strength (f t) are different depending on the growth region.

Also the use of output control over multiple growth regions is possible. The system can detect too low quality independent of the growth regions. However, the output control shows low sensitivity to quality shifts, which is caused by a low performance of the attribute chart. Therefore, a higher sampling rate is needed. Also, for output control the option to optimize the yield is essential.

The application of non-destructive output control for graded timber does not function if applied for multiple growth regions, especially due to changes in the coefficients of determination which affects the detection of quality shift. Additionally, the single control parameters for all growth regions cannot be found due to different descriptive statistic.

REFERENCES