Conformity assessment for machine graded timber by using output control

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SP Technical Research Institute of Sweden

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Abstract

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In the Nordic countries machine strength grading of structural timber is becoming increasingly important. A new standard, EN 14081, which allows CE-marking of strength graded structural timber was recently accepted. This standard allows both machine control and output control as methods for controlling the graded timber. Machine control is most commonly used in Europe. The project reported here deals with output control. This method is commonly used in for example USA.

Theoretical studies carried out within this project show that applying output control gives higher yield, especially in high strength classes. A document describing the implementation of the output control procedure is written and given in Appendix 1 of this report.

Key words: machine strength grading, timber, output control

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Preface

This report describes the project ”Conformity assessment for machine graded timber by using output control” funded by Nordisk InnovationsCenter (project no. 04142). The project has been carried out by:
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Charlotte Bengtsson

Sammanfattning

I de nordiska länderna hållfasthetssorteras alltmer konstruktionsvirke med hjälp av olika sorteringsmaskiner. En ny europeisk standard EN14081 ”Timber structures – Strength graded structural timber with rectangular cross section” har nyligen accepterats.

I de nordiska länderna (också i övriga Europa) använder man sig av s.k. maskinkontroll. Detta innebär att man godkänner och etablerar inställningsvärden för sorteringsmaskiner med en statistisk procedur baserat på provning av tusentals virkesstycken. Maskinsorteringsstandarden EN14081 möjliggör också användande av sk output control. Denna metodik används regelmässigt i t.ex. USA men i Europa har denna metodik inte fått något genomslag.

Detta projekt har via datorsimuleringar visat att, så som väntat, output control ger en fördel för de företag som önskar sortera virke i högre hållfasthetsklasser. Genom att använda output control kan utbytet ökas. Ett dokument som beskriver införandet av output control på ett företag har tagits fram. Detta dokument finns i rapportens Appendix 1.

1 Introduction

1.1 Background

The European standard EN 14081 "Timber structures - Strength graded structural timber with rectangular cross section" has been approved. This standard harmonises the procedures for determination of grading machine settings in all European countries. Furthermore, it gives the technical specifications for CE-marking of strength graded structural timber. The standard consists of four parts:

- Part 1: General requirements
- Part 2: Machine grading; additional requirements for initial type testing
- Part 3: Machine grading; additional requirements for factory production control
- Part 4: Machine grading - Grading machine settings for machine controlled systems

There are basically two systems for machine strength grading. These systems are referred to as "output control" and "machine control". The output-controlled system is suitable when the machine is used to grade limited timber sizes, species and grades or when settings adapted to a certain raw material is wanted. The machine is controlled by testing timber specimens from the daily output. Based on these test results the timber sample is accepted or rejected for the intended grade. The machine settings shall, when necessary, be adjusted to maintain the required strength properties. It is also permissible to adjust the settings to increase the yield as far as the required strength properties are met. The output-controlled system is so far not or very rarely used in Europe.

The general methods to derive initial settings for output-controlled grading machines are given in Part 2 of EN 14081 while the general methods to control and adjust these settings are given in Part 3 of the same standard. These settings are valid only for one single and specified machine installation.

The machine controlled system was developed in Europe to handle the grading of a large number of timber sizes, species and grades. This system relies on the machine being strictly assessed and controlled and on considerable efforts to derive the machine settings. Timber specimens are only control tested for grades with a characteristic bending strength above 30 N/mm^2. For other grades, covering almost all structural timber used in Europe, no testing is carried out on the daily output.

The general methods to derive settings for machine-controlled grading are given in Part 2 of EN 14081 while the specific settings for different machine types are given in Part 4 of the same standard. These settings are given for different species, or group of species, from a specified growth area.

1.2 Aim of the project

The project has the following main aims:

- Document when “output control” is advantageous compared to “machine control”
- Produce a document describing how output control can be implemented in the industry

Only those topics specific for output-controlled systems are presented in this paper. All other topics, as for example the required visual override inspection of machine graded timber, related to the certification procedure, are not handled. For the complete certification process reference is made to EN 14081 and any possible supporting

documents prepared by the notified bodies and SG 18 (notified bodies Sector group 18 “Structural timber products”).

2 Output control method

A document describing the implementation of output control in the industry is given in Appendix 1. This document will be presented to SG 18.

3 Simulation study

3.1 Data

The material used for this simulation is a part of the material used for establishing the machine settings of EN 14081-4. The wood material used was 700 timber pieces taken from four different locations in Sweden and Finland. Both spruce and pine wood was used. The nominal dimensions of the timber pieces varied, the widths ranged from 138 to 145 mm and thicknesses from 43-45 mm. From the previous work, the IP-values from a Dynagrade strength grading machine was known, together with bending strength and MOE, determined according to EN 408. An overview of all these characteristics is shown in the four diagrams of Figure 1.

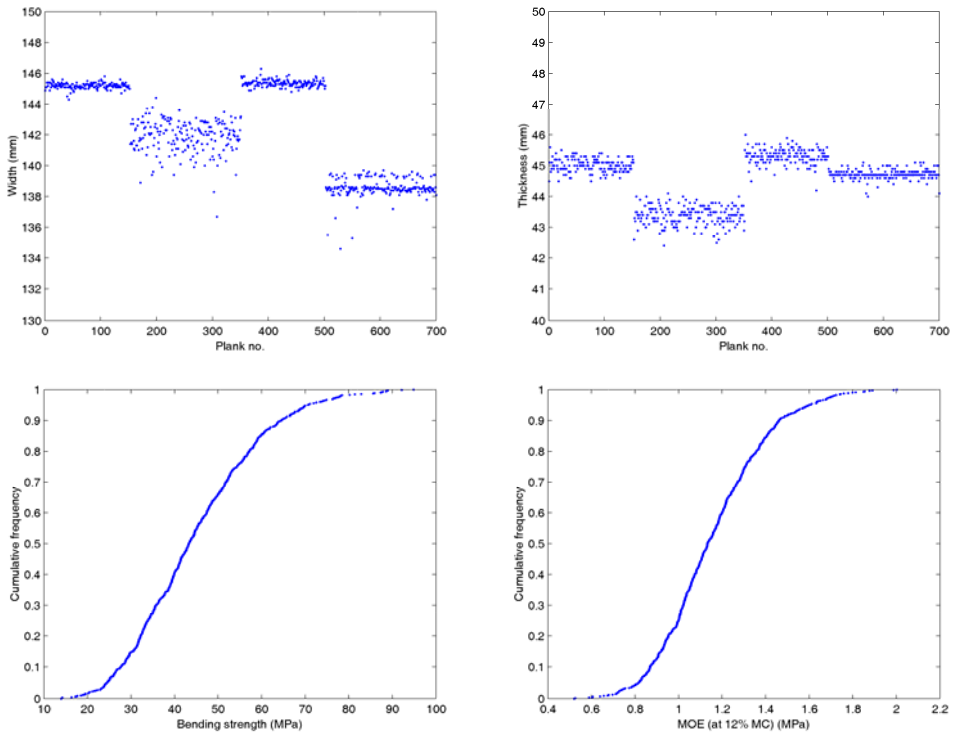

Figure 1. Overview of characteristics of the material used in the simulations. Strength data and MOE data are corrected to be valid at 12%MC and for 150 mm width**.**

3.2 Theoretical and IP yields

The material used gives theoretical yields in C24, C27 and C30 according to Table 1. By theoretical yield is meant the yield calculated from the tested bending strengths and MOEs, and fulfilling the requirements of class determining strength/1,12 and MOE*0.95. It should be mentioned here, that the mean MOE of the material (of all 700 timber pieces) is 11585 MPa, which means that the material fulfils the requirements of MOE up to C30 (0.95*12000=11400). In Table 1, the yield based on the IP(indicating property)-values is also given. The difference between the theoretical yield and the IP-yield is a measure of

the uncertainty of the stress grading due to the level of correlation. The correlation is typically between 0.5 and 0.6 for a machine grading using frequency. For the C30 class, the density is the class determining property. It must be noted that the theoretical yield is not the same as the result of the optimum grading according to EN 14081.

Table 1. Theoretical and IP yields when C24, C27 and C30 are graded separately.

Class	C24	C27	C30
Theoretical yield [% (No. of timber pieces)]	100 (700)	100 (700)	95.6 (669)
Yield from IP-values [% (No. of timber pieces)]	99.9 (699)	97.0 (679)	60.7 (425)

It is thus clear, that there should be a significant potential for increasing the yield for the C30 grade, the upper limit being, 95.6%. This will however require a perfect grading machine which does not exist. The figure is just a theoretical upper limit.

3.3 Simulation method

Three different single-grade simulations have been performed for the strength classes C24, C27 and C30. For each single-grade simulation the following algorithm was used:

1. Determine which of the 700 planks that belong to the desired strength class, based on the IP-value. Denote these planks by N_i.
2. Select, at random, 5 planks from N_i. Repeat this M_i number of times, always choosing from all N_i planks.
3. Determine, for each of the M_i groups of 5 planks, if the process is in control or not. If not, determine also whether MOE, bending strength or both is the reason for coming out of control.
4. Calculate number of out-of-control events. Three types of out-of-control events are possible: [MOE], [f_m], [MOE AND f_m].
5. For each case where the cusum-chart indicates the process being out-of control, draw new samples and calculate cusums according to the out-of-control charts. If the charts indicate the process not coming back in-control within 6 five-specimen samples being tested, a production-stop event is registered.
6. Calculate statistics for out-of-control events and production-stop events.
7. In order to estimate whether the number M_i is large enough to produce reliable results, steps 2-4 are repeated several times, increasing M_i until the standard deviation of the mean number of out-of-control events is small enough.

3.4 Results

3.4.1 Out-of-control events – original IP-settings

The frequency of the out-of-control events for the three strength classes is given in Table 2. Note that these frequencies relate to the frequency at which the out-of-control charts must be filled in and not to the frequency at which any measures must be taken with the machine settings. The numbers indicated are based on 10 000 simulations repeated 100 times (M_i=10 000).

Table 2. Results from simulations, out-of-control events.

Class	C24	C27	C30
Out of control (E AND f_m) [%]	0.49	1.1	0.13
Out of control (E) [%]	0.81	2.3	0.51
Out of control (f_m) [%]	9.85	11.5	5.61
In control [%]	88.85	85.1	93.8

3.4.2 Production stop events – original IP-settings

In Table 3 the production-stop statistics are given. The no-production-stop statistics is also depicted in Figure 2-Figure 4. From Table 3, it is clear that the output control method gives production stops with a frequency of 0.3-2.3% of the shifts, and this for the material which *fulfills* the requirements for the respective strength classes. Assuming three shifts per 24h-day, this means that the graded material will be held pending adjustments or additional tests, on average approximately once every 15 (C27) –110 days (C30). Thus, for the C30 material there seems again to be a potential of changing the initial IP-settings in order to increase the yield, and still keeping the number of productions stops within acceptable limits. If the number of production stops is acceptable must of course be judged from case to case, depending on number och shifts and grade combinations.

It is worth to note that, according to EN 14081-3 clause 7.2.7 b, settings may be adjusted by maximum 5% if the production is out of control. If the testing after that tells in control, the production can continue.

Table 3. Results from simulations, production-stop events.

Class	C24	C27	C30
Production stop (E AND f_m) [%]	0	0	0
Production stop (E) [%]	0	0	0
Production stop (f_m) [%]	1.4	2.3	0.3
No production stop [%]	98.6	97.7	99.7

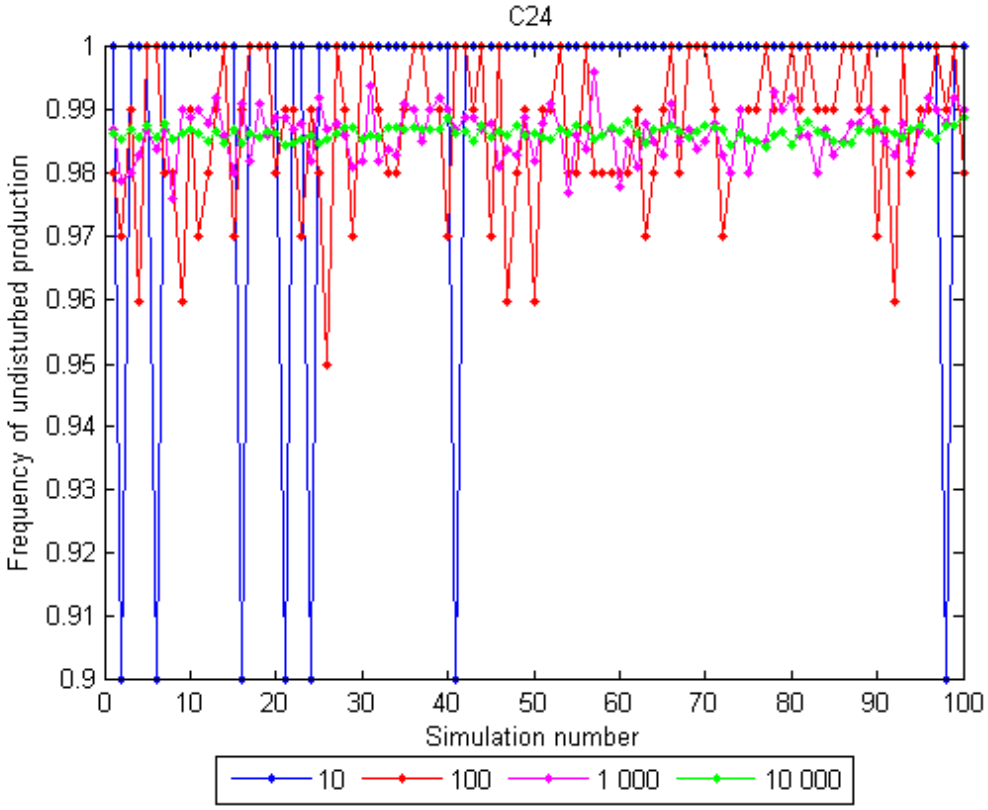

Figure 2. Simulation results. Frequency of production without stop for different sample size in simulations ranging from 10 to 10 000. C24 timber.

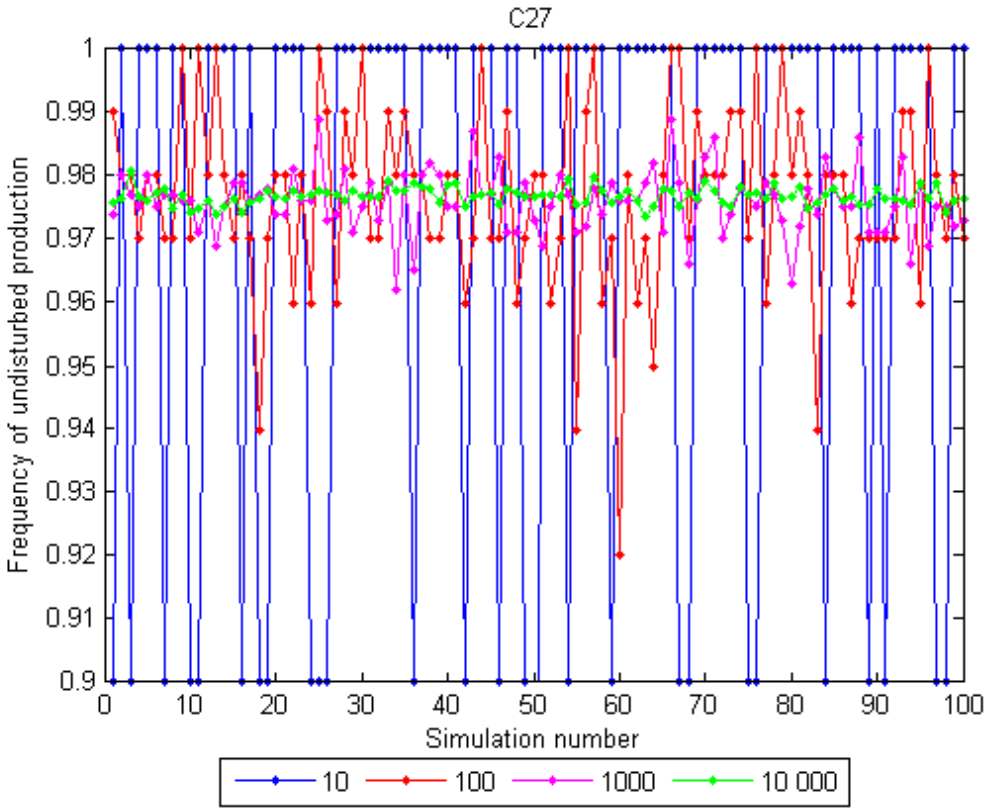

Figure 3. Simulation results. Frequency of production without stop for different sample size in simulations ranging from 10 to 10 000. C27 timber.

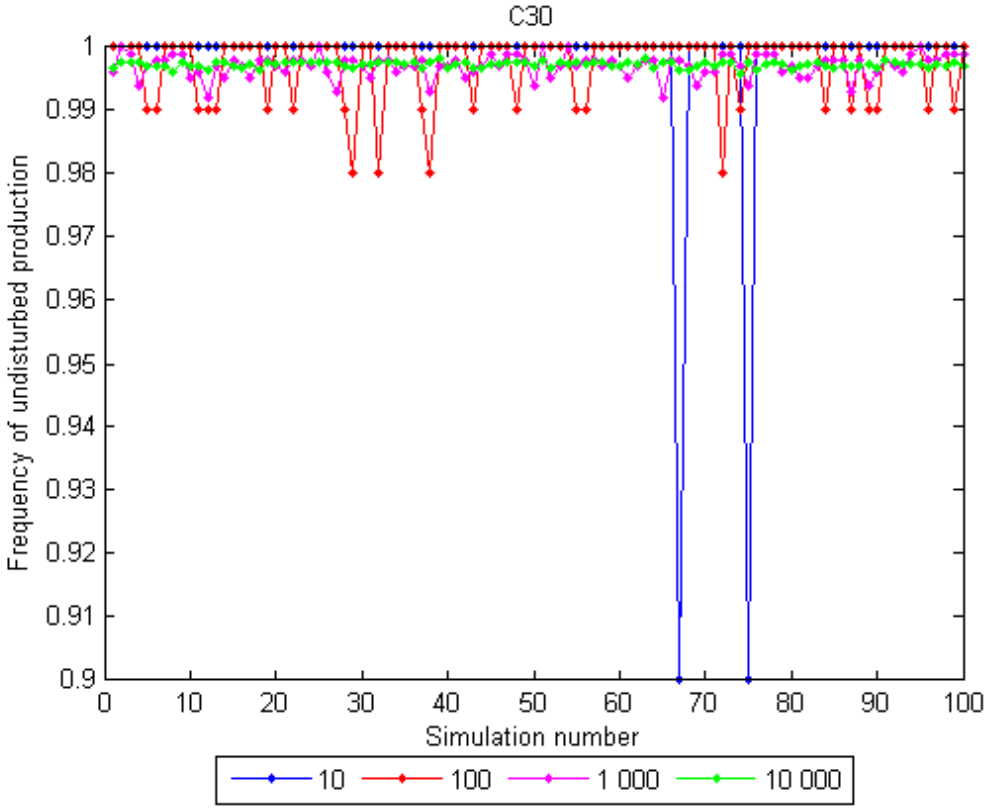

Figure 4. Simulation results. Frequency of production without stop for different sample size in simulations ranging from 10 to 10 000. C30 timber.

3.4.3 Revised IP-settings for maximised yield

According to EN 14081-3, it is possible to change the IP-settings with 5% increments in order to maximise the yield. Here, the results from such simulations are presented, all being based on 10 000 simulations run once. The outcome is presented in Table 4 for a 5% decrease and in Table 5 for a 10% decrease Since the material fulfils the requirement for the MOE, it is only the bending strength that is of interest. Finally, an overview of the yield, the characteristic strength of the material and the frequency of undisturbed production, after grading with new IP-settings reduced 0-10 % is shown in Figure 5, Figure 6 and Figure 7 respectively.

Table 4. Results from simulations, production-stop events for 5% decrease of initial IP-settings.

Class	C24	C27	C30
Yield [%]	100	98.4	76.3
f_{mk}	27.2	28.0	32.3
$E_{mean,0}$			
Production stop (E AND f_m) [%]	0	0	0
Production stop (E) [%]	0	0	0
Production stop (f_m) [%]	1.6	2.6	2.7
No production stop [%]	98.4	97.4	97.3

Table 5. Results from simulations, production-stop events for 10% decrease of initial IP-settings.

Class	C24	C27	C30
Yield [%]	100	99.4	86.7
Production stop (E AND f_m) [%]	0	0	0
Production stop (E) [%]	0	0	0
Production stop (f_m) [%]	1.6	4.0	7.3
No production stop [%]	98.4	96.0	92.7

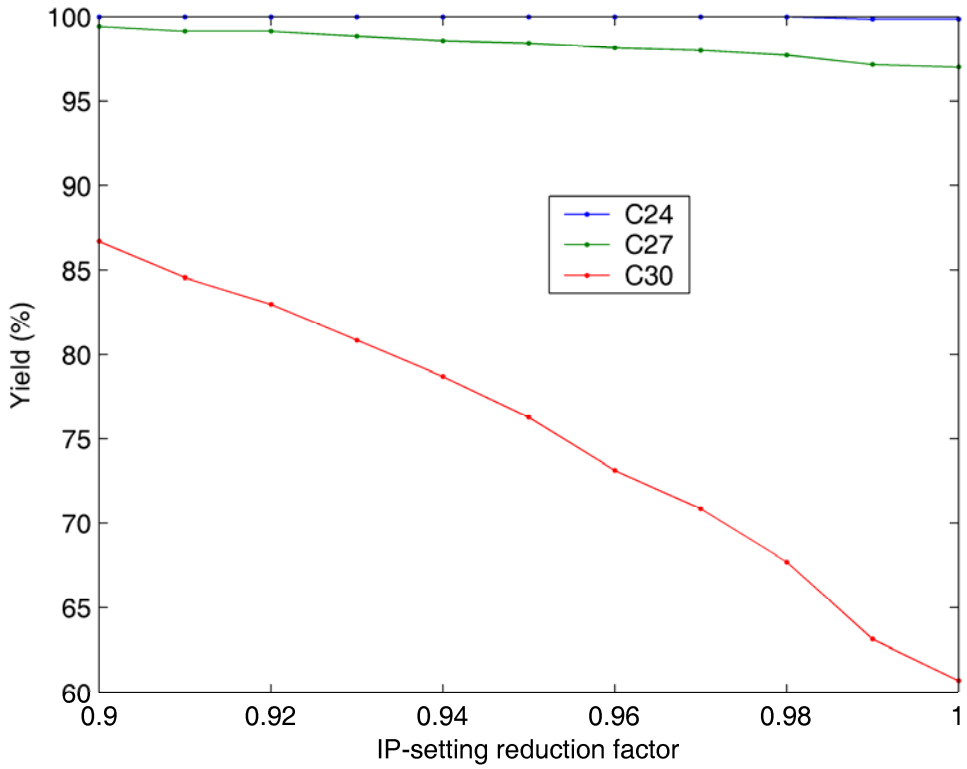

Figure 5. Influence of the reduction of IP-settings on yield.

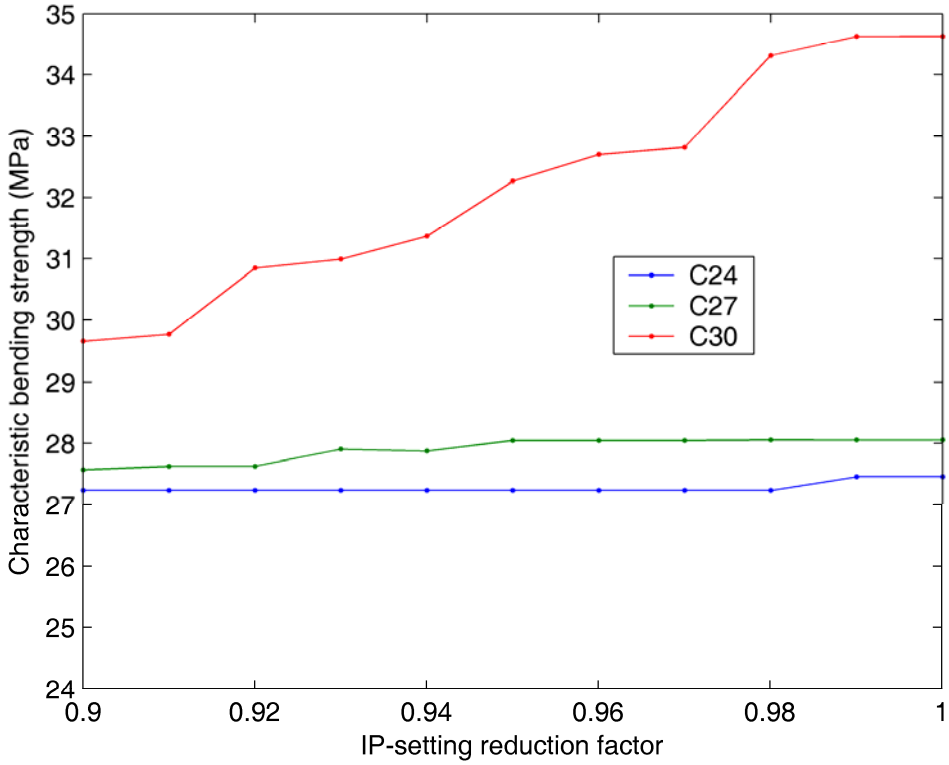

Figure 6. Influence of the reduction of IP-settings on the characteristic bending strength.

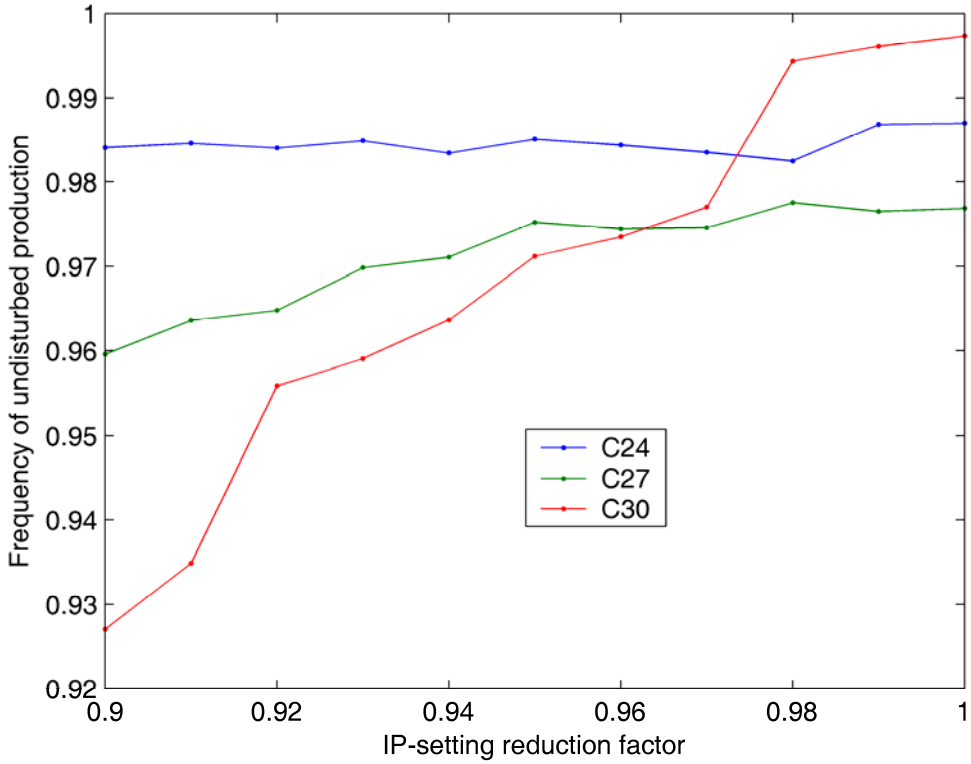

Figure 7. Influence of the reduction of IP-settings on the frequency of undisturbed production.

3.5 Discussion

The method used to perform simulations of the possible yield and optimisation of IP-values in an output control system, relies on the input data used. It was assumed that this data (700 timber pieces from Sweden and Finland) are representative of timber from the Nordic countries, as defined in EN 14081-4. The simulations were performed using random picking of the planks, always choosing from the original 700. This approach is appropriate if the 700 timber pieces are representative for an indefinitely large sample size. Another approach could be to use the data from the 700 timber pieces to fit e.g. log-normal distributions for the strength, MOE and IP-values, respecting the correlation between these quantities.

The results from this theoretical study show that there is a potential of using the output control method in order to obtain higher yields, especially for high strength classes. It should be noted that, for the C30-class, the low yield using standard strength grading is due to the density becoming the class determining property. In the output control method, the density is not measured.

To quantify the results, it can be concluded, that the yield for the C30 class can be improved. By adjusting the IP-setting by a factor of 0.92 the initial yield of approximately 60% can be increased to about 80%, maintaining a reasonable frequency of undisturbed production (95%), and still fulfilling the strength and MOE requirements (cf. Figure 5, Figure 6 and Figure 7). This means a 33% increase in yield.

4 Case studies

4.1 Raute Timgrader - C35

4.1.1 Data

The data used to derive settings for machine control for Raute Timgrader was re-analysed. From the total sample size of 1216 timber pieces only the timber size of 42 x 147 mm was included. All these 580 pieces were of spruce (*Picea abies*) material grown in Finland. A summary of the machine controlled results for the grade combination C35-C27-C18 is given in Table 6.

Table 6. Summary of machine controlled results for C35-C27-C18.

	C35	C27	C18	Reject
Indicating property F in kP	551	438	332	-
Yield, number of specimens	357	205	15	3
Yield in %	61	35	3	1
Char. bend. strength, N/mm^2	35,3	26,2	18,5	-
Mean mod. of elasticity, N/mm^2	14300	11200	9100	-
Char. density, kg/m^3	414	372	326	-
Req. for grade fulfilled	OK	OK	OK	-

4.1.2 Initial settings for C35, day 0

The initial setting for the grade C35 was estimated to be 583. Timber was graded using this setting and 60 specimens were proof loaded. The results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 7.

Table 7. Summary of assessment of initial settings for C35.

	C35
Estimated initial settings F in kP	583
Proof load F_p in kN, eq (1)	11,6
Number of failures	2
Number of failures less than 3	Yes
Proof load E_p in N/mm^2	14500
E_p exceeds 95 % of $E_{0,mean}$	Yes
Assessment	OK

4.1.3 Production control for C35, days 1 - 3

The initial setting of 583 was used to grade timber to the strength class C35. During the first three working days 2 x 5 specimens were proof loaded per day. Twice each day the results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 8.

Table 8. Production control during the first 3 days using the initial setting of 583 for the strength class C35.

IN CONTROL CHART First 3 days 2 x 5 specimens per day				Grade F_p F	C35 11,6 583	Control constants Mean E Bending strength	K 12005 1	Y 1791 1	Z 3309 6
Day	1	1	2	2	3	3	-	-	-
E_{p1}	17700	16400	13400	10700	17000	14200	-	-	-
E_{p2}	14600	15200	14800	13300	14000	17200	-	-	-
E_{p3}	15100	14600	14800	15100	16500	14600	-	-	-
E_{p4}	19000	17200	16000	14500	13400	15400	-	-	-
E_{p5}	14700	18300	15100	14800	14400	15000	-	-	-
$E_{p,mean}$	16200	16300	14800	13700	15100	15300	-	-	-
Last cusum	0	0	0	0	0	0	-	-	-
Previous + K	12005	12005	12005	12005	12005	12005	-	-	-
Prev. - $E_{p,me}$	-4195	-4295	-2795	-1695	-3095	-3295	-	-	-
Cusum	0	0	0	0	0	0	-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-
Broken 1	No	No	No	10,7	No	No	-	-	-
Broken 2	No	No	No	No	No	No	-	-	-
Broken 3	No	No	No	No	No	No	-	-	-
Broken 4	No	No	No	No	No	No	-	-	-
Broken 5	No	No	No	No	No	No	-	-	-
∑ Broken	0	0	0	1	0	0	-	-	-
Last cusum	0	0	0	0	0	0	-	-	-
Prev. + ∑ Brok	0	0	0	1	0	0	-	-	-
Previous - K	-1	-1	-1	0	-1	-1	-	-	-
Cusum	0	0	0	0	0	0	-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-

IN CONTROL

4.1.4 Adjusted settings for C35, day 4

To maximize the yield the initial setting of 583 was adjusted to 522. However, this adjustment is more than 5 % but carried out in one step to speed up the analysis in this case study. During the fourth working day 12 x 5 specimens were proof loaded to verify that the grading using the adjusted setting is in control A summary of the results is given in Table 9.

Table 9. Production control during the 4th day using the adjusted setting of 522 for the strength class C35.

IN CONTROL CHART				Grade	C35	Control constants		K	Y	Z		
Adjusted setting, 4th day 12 x 5 specimens				F_p	11,6	Mean E		12005	1791	3309		
				F	522	Bending strength		1	1	6		
Day	4	4	4	4	4	4	4	4	4	4	4	4
E_{p1}	15400	13100	14300	12900	18500	15400	13100	17600	16500	12200	17100	12300
E_{p2}	17200	15600	17300	10100	11100	14800	16900	10800	12900	15300	12400	13600
E_{p3}	15500	16100	14200	14600	16200	14300	10400	15300	14200	15400	17900	15900
E_{p4}	11300	14400	13500	12500	11700	14600	12400	15800	16100	12600	15500	14100
E_{p5}	11500	13500	13400	11200	15200	16500	13300	15500	13900	13700	13700	13500
$E_{p,mean}$	14200	14500	14500	12300	14500	15100	13200	15000	14700	13800	15300	13900
Last cusum	0	0	0	0	0	0	0	0	0	0	0	0
Previous + K	12005	12005	12005	12005	12005	12005	12005	12005	12005	12005	12005	12005
Prev. - $E_{p,me}$	-2195	-2495	-2495	-295	-2495	-3095	-1195	-2995	-2695	-1795	-3295	-1895
Cusum	0	0	0	0	0	0	0	0	0	0	0	0
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Broken 1	No	No	No	No	No	No	No	No	No	No	No	No
Broken 2	No	No	No	9,3	No	No	No	No	No	No	No	No
Broken 3	No	No	No	No	No	No	No	No	No	No	No	No
Broken 4	No	No	No	No	No	No	No	No	No	No	No	No
Broken 5	No	No	No	No	No	No	No	No	No	No	No	No
∑ Broken	0	0	0	1	0	0	0	0	0	0	0	0
Last cusum	0	0	0	0	0	0	0	0	0	0	0	0
Prev. + ∑ Brok	0	0	0	1	0	0	0	0	0	0	0	0
Previous - K	-1	-1	-1	0	-1	-1	-1	-1	-1	-1	-1	-1
Cusum	0	0	0	0	0	0	0	0	0	0	0	0
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4.1.5 Production control for C35, day 5

The adjusted setting of 522 was used to grade timber to the strength class C35. During the fifth working day 2 x 5 specimens were proof loaded. The results were compared to the requirements and due to the two broken timber specimens the grading was found to be out of control. After that the grading machine and test equipment were checked. The settings were adjusted from 522 to 548. Using the new setting 90 timber specimens were graded and 6 x 5 of them were sampled for confirmation tests. The results were compared to the requirements and due to the two broken specimens of the first fifteen the grading was confirmed to be out of control. The timber was not released for delivery as intended. A summary of the results is given in Table 10.

Table 10. Production control during the 5th day using the adjusted setting of 522 for the strength class C35. Additionally, the results of the confirmation tests are given in which the setting of 548 was used.

IN / OUT OF CONTROL CHART 5th day 2 x 5 + 3 x 5 specimens				Grade F_p F	C35 11,6 522/548	Control constants Mean E Bending strength	K 12005 1	Y 1791 1	Z 3309 6	
Day	5	5		5	5	5	5	5	5	
E_{p1}	16400	12000	OUT OF CONTROL	14000	13500	13500	-	-	-	OUT OF CONTROL CONFIRMED
E_{p2}	12400	12900		10900	11200	12000	-	-	-	
E_{p3}	20900	13700		13200	14800	15400	-	-	-	
E_{p4}	17800	12900		16500	17200	10900	-	-	-	
E_{p5}	14900	13800		13600	15500	10400	-	-	-	
$E_{p,mean}$	16500	13100		13600	14400	12400	-	-	-	
Last cusum	0	0		0	0	0	-	-	-	
Previous + K	12005	12005		12005	12005	12005	-	-	-	
Prev. - $E_{p,me}$	-4495	-1095		-1595	-2395	-395	-	-	-	
Cusum	0	0		0	0	0	-	-	-	
In control ?	Yes	Yes		Yes	Yes	Yes	-	-	-	
Broken 1	No	11,6		No	No	No	-	-	-	
Broken 2	No	9,5		11,3	No	No	-	-	-	
Broken 3	No	No		No	No	No	-	-	-	
Broken 4	No	No		No	No	11,1	-	-	-	
Broken 5	No	No		No	No	No	-	-	-	
∑ Broken	0	2		1	0	1	-	-	-	
Last cusum	0	0		6	6	5	-	-	-	
Prev. + ∑ Brok	0	2		7	6	6	-	-	-	
Previous - K	-1	1		6	5	5	-	-	-	
Cusum	0	6		6	5	5	≥ 4	≥ 3	≥ 2	
In control ?	Yes	No		No	No	No	No	No	No	

4.1.6 Adjusted settings for C35, day 6

Since the confirmation tests in which the setting of 522 was temporary adjusted to 548 confirmed the grading to be out of control a new adjustment was carried out. The new setting was 549. During the sixth working day 6 x 5 specimens were proof loaded to verify that the grading using the adjusted setting of 549 is in control A summary of the results is given in Table 11.

Table 11. Production control during the 6th day using the adjusted setting of 549 for the strength class C35.

IN CONTROL CHART Adjusted setting, 6th day 6 x 5 specimens				Grade F_p F	C35 11,6 549	Control constants Mean E Bending strength		K 12005 1	Y 1791 1	Z 3309 6
Day	6	6	6	6	6	6		-	-	-
E_{p1}	14100	13200	12200	13400	13400	15500	IN CONTROL	-	-	-
E_{p2}	13800	11400	14000	14700	13900	15100		-	-	-
E_{p3}	12200	17700	14300	17900	15100	14200		-	-	-
E_{p4}	14900	13600	13600	13400	14800	17400		-	-	-
E_{p5}	11600	12400	12100	17300	14200	14700		-	-	-
$E_{p,mean}$	13300	13700	13200	15300	14300	15400		-	-	-
Last cusum	0	0	0	0	0	0		-	-	-
Previous + K	12005	12005	12005	12005	12005	12005		-	-	-
Prev. - $E_{p,me}$	-1295	-1695	-1195	-3295	-2295	-3395		-	-	-
Cusum	0	0	0	0	0	0		-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes		-	-	-
Broken 1	No	No	No	No	No	No		-	-	-
Broken 2	No	No	No	No	No	No		-	-	-
Broken 3	No	No	No	No	No	No		-	-	-
Broken 4	No	No	9,3	No	No	No		-	-	-
Broken 5	No	No	No	No	No	No		-	-	-
∑ Broken	0	0	1	0	0	0		-	-	-
Last cusum	0	0	0	0	0	0		-	-	-
Prev. + ∑ Brok	0	0	1	0	0	0		-	-	-
Previous - K	-1	-1	0	-1	-1	-1		-	-	-
Cusum	0	0	0	0	0	0		-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes		-	-	-

4.1.7 Production control for C35, days 7 - 9

The adjusted setting of 549 was used to grade timber to the strength class C35. During the seventh, eight and ninth working days 2 x 5 specimens were proof loaded per day. Twice each day the results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 12.

Table 12. Production control during the 7th, 8th and 9th day using the adjusted setting of 549 for the strength class C35.

IN CONTROL CHART 7th - 9th day 2 x 5 specimens per day				Grade F_p F	C35 11,6 549	Control constants Mean E Bending strength		K 12005 1	Y 1791 1	Z 3309 6
Day	7	7	8	8	9	9		-	-	-
E_{p1}	12700	16800	18000	15100	16100	13100		-	-	-
E_{p2}	12400	12700	11200	14100	13200	13300		-	-	-
E_{p3}	17200	11300	13900	11800	14600	13200		-	-	-
E_{p4}	13100	15300	13900	11600	15500	12600		-	-	-
E_{p5}	13100	14600	16800	14300	17900	14600		-	-	-
$E_{p,mean}$	13700	14100	14800	13400	15500	13400		-	-	-
Last cusum	0	0	0	0	0	0		-	-	-
Previous + K	12005	12005	12005	12005	12005	12005		-	-	-
Prev. - $E_{p,me}$	-1695	-2095	-2795	-1395	-3495	-1395		-	-	-
Cusum	0	0	0	0	0	0		-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	IN CONTROL	-	-	-
Broken 1	No	No	No	No	No	No		-	-	-
Broken 2	No	No	No	No	No	No		-	-	-
Broken 3	No	No	No	No	No	No		-	-	-
Broken 4	No	No	No	No	No	No		-	-	-
Broken 5	No	No	No	No	No	No		-	-	-
∑ Broken	0	0	0	0	0	0		-	-	-
Last cusum	0	0	0	0	0	0		-	-	-
Prev. + ∑ Brok	0	0	0	0	0	0		-	-	-
Previous - K	-1	-1	-1	-1	-1	-1		-	-	-
Cusum	0	0	0	0	0	0		-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes		-	-	-

4.1.8 Production control for C35, days 10 - 32

The adjusted setting of 549 was used to grade timber to the strength class C35. During the 10th to 32nd working days 5 specimens were proof loaded per day. Each day the results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 13.

Table 13. Production control during the 10th to 32nd day using the adjusted setting of 549 for the strength class C35.

IN CONTROL CHART 10th - 32nd day 5 specimens per day				Grade F_p F	C35 11,6 549	Control constants Mean E Bending strength		K 12005 1	Y 1791 1	Z 3309 6
Day	10	11-14	15	16	17-27	28	29	30	31	32
E_{p1}	15100	...	15700	10400	...	13800	15600	13400	14500	17200
E_{p2}	14900	...	11900	14100	...	17400	14000	13700	13500	13900
E_{p3}	14100	...	11900	15600	...	11200	12400	16000	19500	17700
E_{p4}	15000	...	15100	14700	...	12300	14400	13700	17000	15400
E_{p5}	14900	...	10300	13800	...	13200	15000	10800	15700	13900
$E_{p,mean}$	14800	> 12100	13000	13700	> 12100	13600	14300	13500	16000	15600
Last cusum	0	0	0	0	0	0	0	0	0	0
Previous + K	12005	12005	12005	12005	12005	12005	12005	12005	12005	12005
Prev. - $E_{p,me}$	-2795	< 0	-995	-1695	< 0	-1595	-2295	-1495	-3995	-3595
Cusum	0	0	0	0	0	0	0	0	0	0
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Broken 1	No	No	No	No	No	No	No	No	No	No
Broken 2	No	No	No	No	No	No	11,2	No	No	No
Broken 3	No	No	No	No	No	No	No	No	No	No
Broken 4	No	No	No	No	No	10,4	No	No	No	No
Broken 5	No	No	7,1	No	No	No	No	No	No	No
∑ Broken	0	0	1	0	0	1	1	0	0	0
Last cusum	0	0	0	0	0	0	0	0	0	0
Prev. + ∑ Brok	0	0	1	0	0	1	1	0	0	0
Previous - K	-1	-1	0	-1	-1	0	0	-1	-1	-1
Cusum	0	0	0	0	0	0	0	0	0	0
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4.1.9 Results

In the output controlled system the initial setting for the grade C35 was estimated and verified to be 583. This setting was used during the first 3 days and the grading was verified to be in control. To maximize the yield the setting was then during the 4th day adjusted and verified to be 522. The next day the grading was out of control which also was confirmed. During the 6th day the setting was adjusted and verified to be 549. This setting was then used between the 7th and 32nd day without any grading problems.

A summary of the machine controlled and output controlled results for the grade C35 is given in Table 14. The indicating properties are practically equal to each other, 551 and 549. Hence, the yield and the grade determining properties are also close to each other. However, the characteristic bending strength of the output controlled grade C35 is 33,7 MPa which is below the requirement.

Table 14. Summary of machine and output controlled results for C35.

	C35 Machine controlled	C35 Output controlled
Indicating property F in kP	551	549
Yield, number of specimens	357	362
Yield in %	61	62
Char. bend. strength, N/mm^2	35,3	33,7
Mean mod. of elasticity, N/mm^2	14300	14300
Char. density, kg/m^3	414	414
Req. for grade fulfilled	OK	NO

4.2 Case study - Raute Timgrader - C35 and C27

4.2.1 Data

The data used to derive settings for machine control for Raute Timgrader was re-analysed. From the total sample size of 1216 timber pieces only the timber size of 42 x 147 mm was included. Furthermore, the grade C35 defined as those specimens of which the indicating property was greater than or equal to 549, were creamed off. Hence, the number of pieces was 218. A summary of the machine controlled results for the grade combination C35-C27-C18 is given in Table 6.

4.2.2 Initial settings for C27, day 0

The initial setting for the grade C27 was estimated to be 366. Timber was graded using this setting and 60 specimens were proof loaded. The results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 14.

NOTE: *The estimated initial setting of 366 differs considerably from the setting of 438 obtained in the machine controlled system. The main reason for this is the requirement given by the global cost matrix. Furthermore, there are only 18 specimens of which the indicating property is less than 438.*

Table 15. Summary of assessment of initial settings for C27.

	C27
Estimated initial settings F in kP	366
Proof load F_p in kN, eq (1)	8,0
Number of failures	2
Number of failures less than 3	Yes
Proof load E_p in N/mm2	11200
E_p exceeds 95 % of $E_{0,mean}$	Yes
Assessment	OK

4.2.3 Production control for C27, days 1 - 3

The initial setting of 366 was used to grade timber to the strength class C27. During the first three working days 2 x 5 specimens were proof loaded per day. Twice each day the results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 15.

Table 16. Production control during the first 3 days using the initial setting of 366 for the strength class C27.

IN CONTROL CHART First 3 days 2 x 5 specimens per day				Grade F_p F	C27 8,0 366	Control constants Mean E Bending strength	K 10580 1	Y 1450 1	Z 2927 6
Day	1	1	2	2	3	3	-	-	-
E_{p1}	11300	10000	15200	10800	12400	12900	-	-	-
E_{p2}	11500	12000	12000	8900	9100	9800	-	-	-
E_{p3}	9600	11200	10400	12000	10000	14200	-	-	-
E_{p4}	13500	11100	10900	9700	10900	9300	-	-	-
E_{p5}	13300	11700	12400	12800	8000	9300	-	-	-
$E_{p,mean}$	11800	11200	12200	10800	10100	11100	-	-	-
Last cusum	0	0	0	0	0	480	-	-	-
Previous + K	10580	10580	10580	10580	10580	1106	-	-	-
Prev. - $E_{p,me}$	-1220	-620	-1620	-220	480	-40	-	-	-
Cusum	0	0	0	0	480	0	-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-
Broken 1	No	7,9	No	No	No	No	-	-	-
Broken 2	No	No	No	No	No	No	-	-	-
Broken 3	No	No	No	No	No	No	-	-	-
Broken 4	No	No	No	7,8	No	No	-	-	-
Broken 5	No	No	No	No	No	No	-	-	-
∑ Broken	0	1	0	1	0	0	-	-	-
Last cusum	0	0	0	0	0	0	-	-	-
Prev. + ∑ Brok	0	1	0	1	0	0	-	-	-
Previous - K	-1	0	-1	0	-1	-1	-	-	-
Cusum	0	0	0	0	0	0	-	-	-
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	-	-	-

IN CONTROL

4.2.4 Production control for C27, days 4 - 9

The initial setting of 366 was used to grade timber to the strength class C27. During the 4th to 8th working days 5 specimens were proof loaded per day. Each day the results were compared to the requirements and found to fulfil these. Due to the two broken timber specimens at the 9th working day the grading was found to be out of control. After that the grading machine and test equipment were checked. The setting was not adjusted. Using the unadjusted setting 90 timber specimens were graded and 6 x 5 of them were sampled for confirmation tests. The results were compared to the requirements and after the first 25 tested specimens the grading was confirmed to be back in control. All timber graded during the 9th day was released for delivery as intended. A summary of the results is given in Table 16.

Table 17. Production control during the 4th to 9th days using the initial setting of 366 for the strength class C27.

IN / OUT OF CONTROL CHART 4th -9th day 5 + 5 x 5 specimens				Grade F_p F	C27 8,0 366	Control constants Mean E Bending strength		K 10580 1	Y 1450 1	Z 2927 6		
Day	4	5	6	7	8	9		9	9	9	9	9
E_{p1}	10700	10800	7500	12000	11700	13100		10800	10700	9200	11700	9300
E_{p2}	9100	13200	11400	14000	11300	8800		9400	8200	12100	12000	12700
E_{p3}	12600	12100	10900	14400	9200	8900		10700	10000	11300	9300	11500
E_{p4}	12700	11000	8400	14600	8600	14200		8900	9700	10800	10800	11600
E_{p5}	10400	11900	12300	13600	10300	8200		9600	13000	10500	9500	12000
$E_{p,mean}$	11100	11800	10100	13700	10200	10600		9900	10300	10800	10700	11400
Last cusum	0	0	0	480	0	380		360	1040	1320	1100	980
Previous + K	10580	10580	10580	11060	10580	10960		10940	11620	11900	11680	11560
Prev. - $E_{p,me}$	-520	-1220	480	-2640	380	360		1040	1320	1100	980	160
Cusum	0	0	480	0	380	360		1040	1320	1100	980	160
In control ?	Yes	Yes	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes
Broken 1	No	No	No	No	No	No	OUT OF CONYTOL	No	No	No	No	No
Broken 2	No	No	No	No	No	No		No	No	No	No	No
Broken 3	No	No	No	No	No	6,9		No	No	No	No	No
Broken 4	No	No	No	No	No	No		No	No	No	No	No
Broken 5	No	No	No	No	No	7,2		No	No	No	No	No
∑ Broken	0	0	0	0	0	2		0	0	0	0	0
Last cusum	0	0	0	0	0	0		6	5	4	3	2
Prev. + ∑ Brok	0	0	0	0	0	2		6	5	4	3	2
Previous - K	-1	-1	-1	-1	-1	1		5	4	3	2	1
Cusum	0	0	0	0	0	6		5	4	3	2	0
In control ?	Yes	Yes	Yes	Yes	Yes	No		No	No	No	No	Yes

4.2.5 Production control for C27, days 10 - 22

The initial setting of 366 was used to grade timber to the strength class C27. During the 10th to22nd working days 5 specimens were proof loaded per day. Each day the results were compared to the requirements and found to fulfil these. A summary of the results is given in Table 17.

Table 18. Production control during the 9th to22nd days using the initial setting of 366 for the strength class C27.

IN / OUT OF CONTROL CHART				Grade	C27	Control constants		K	Y	Z			
10th 22nd day				F_p	8,0	Mean E		10580	1450	2927			
5 specimens per day				F	366	Bending strength		1	1	6			
Day	10	11	12	13	14	15	16	17	18	19	20	21	22
E_{p1}	10900	10700	11000	10500	7100	12300	13100	10400	11700	15000	10700	11400	12700
E_{p2}	9800	11500	9100	13300	10400	12300	11800	9200	11400	11900	11000	10600	8600
E_{p3}	12100	10500	10600	13000	9100	10200	11600	10400	12900	8500	10300	10100	11100
E_{p4}	11800	10900	11800	11400	11100	8500	12400	10100	11200	12100	12000	10200	10200
E_{p5}	11000	12400	16000	11000	9300	12700	12900	10500	11800	12900	8500	11900	6600
$E_{p,mean}$	11100	11200	11700	11800	9400	11200	12400	10100	11800	12100	10500	10800	9900
Last cusum	160	0	0	0	0	1180	560	0	480	0	0	80	0
Previous + K	10740	10580	10580	10580	10580	11760	11140	10580	11060	10580	10580	10660	10580
Prev. - $E_{p,me}$	-360	-620	-1120	-1220	1180	560	-1260	480	-740	-1520	80	-140	660
Cusum	0	0	0	0	1180	560	0	480	0	0	80	0	660
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Broken 1	No	No	No	No	No	No	No	No	No	No	No	No	No
Broken 2	No	No	No	No	No	No	No	No	No	No	No	No	No
Broken 3	No	No	No	No	No	No	No	No	No	7,0	No	No	No
Broken 4	No	No	No	No	No	No	No	No	No	No	No	No	No
Broken 5	No	No	No	No	No	No	No	No	No	No	No	No	6,7
∑ Broken	0	0	0	0	0	0	0	0	0	1	0	0	1
Last cusum	0	0	0	0	0	0	0	0	0	0	0	0	0
Prev. + ∑ Brok	0	0	0	0	0	0	0	0	0	1	0	0	1
Previous - K	-1	-1	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	0
Cusum	0	0	0	0	0	0	0	0	0	0	0	0	0
In control ?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

4.2.6 Results

In the output controlled system the initial setting for the grade C27 was estimated and verified to be 366 provided the grade C35 is creamed off. This setting was used between the 1st and 8th day without any grading problems. During the 9th day the grading was out of control but also verified to be back in control. Hence, the same setting 366 was used between the 10th and 22nd day without any grading problems.

A summary of the machine controlled and output controlled results for the grade C27 is given in Table 19. Although the indicating properties differ from each other, 438 and 366, the yield and the grade determining properties are close to each other. This is explained by the fact that only 4 % of the timber pieces have an indicating property below 438. The characteristic density of the output controlled grade C27 is 368 kg/m3 which is below the requirement.

In the machine controlled grading system the indicating property is affected by the requirement given in the cost matrix. This requirement is of no relevance in the output controlled grading system.

Table 19. Summary of machine and output controlled results for C27 when C35 is creamed off.

	C27 Machine controlled	C27 Output controlled
Indicating property F in kP	438	366
Yield, number of specimens	205	213
Yield in %	35	37
Char. bend. strength, N/mm^2	26,2	24,6
Mean mod. of elasticity, N/mm^2	11200	11100
Char. density, kg/m^3	372	368
Req. for grade fulfilled	OK	NO

5 Discussion and conclusions

The theoretical studies and the case studies have shown that there is a potential for increased yield for classes C27, C30 and above if using output control. The main reason for this is that the grade determining property density is not included in the evaluation when using output control.

It is worth to point out that the simulated examples are theoretical exercises showing the limit of how much can be achieved. Not only production stops are of importance but also out of control events may disturb the production and a closer analysis of actual conditions may be needed to make a better ground for choosing out put control or not. All possible cases were not possible to cover in this study.

A document describing the implementation of output control has been written. This document will be distributed to companies interested in applying output control for their grading.

The clauses in parts 2 and 3 of EN 14081 dealing with output-controlled grading machines are copied from relevant documents in the United States. These clauses should carefully be studied when EN 14081 is next time revised. At least the following should be discussed:

- Minor details in the standard should be updated based on the notes given in Appendix 1.
- The grade determining property, density, is not included in the output controlled system but included in the machine controlled system. Based on work carried out for machine controlled systems the density has shown to affect the indicating property for some grades, especially high grades.
- The cost matrix method has been introduced in the machine controlled system to decrease the amount of timber pieces wrongly upgraded. Based on work carried out for machine controlled systems the cost matrix has shown to affect the indicating property for some grades.
- When the initial settings are introduced in the output controlled system no more than 2 of 60 specimens are allowed to be broken. However, if the settings later on are adjusted to increase the yield then 12 of 60 specimens are allowed to be broken provided they are broken in an optimum order.
- When grading is out of control then new timber pieces shall be graded and tested to confirm that the grading is back in control or alternatively confirm that the grading is out of control. However, the new timber pieces can be graded with settings that are adjusted by 5 % to decrease the yield. It is difficult to defend this adjustment.

A manufacturer may consider to use the output controlled system for the following reasons:

- For machine controlled systems the machine settings shall be approved by CEN/TC124/TG1 and included in part 4 of EN 14081 before they can be used. The output controlled systems can be used without any involvement of CEN/TC124/TG1. In both systems a notified body shall be involved.
- Timber graded to a strength class of which the bending strength is better than 30 MPa shall daily be control tested. The step to introduce the output control system is smaller for these grades than for grades not exposed to daily control testing.
- For those grades where the density or the cost matrix have affected the indicating property the output controlled system may increase the yield.

6 References

EN 14081 Timber structures – Strength graded structural timber with rectangular cross section, part 1-4

Appendix 1

Document for implementation of output control

Paper to be presented for SG 18, CEN/TC124/TG1 and industry.

Machine graded timber - Output control

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Introduction

The European standard EN 14081 "Timber structures - Strength graded structural timber with rectangular cross section" has been approved. This standard harmonises the procedures for determination of grading machine settings in all European countries. Furthermore, it gives the technical specifications for CE-marking of strength graded structural timber. The standard consists of four parts:

- Part 1: General requirements
- Part 2: Machine grading; additional requirements for initial type testing
- Part 3: Machine grading; additional requirements for factory production control
- Part 4: Machine grading - Grading machine settings for machine controlled systems

There are basically two systems for machine strength grading. These systems are referred to as "output control" and "machine control". The output-controlled system is suitable when the machine is used to grade limited timber sizes, species and grades or when settings adapted to a certain raw material is wanted. The machine is controlled by testing timber specimens from the daily output. Based on these test results the timber sample is accepted or rejected for the intended grade. The machine settings shall, when necessary, be adjusted to maintain the required strength properties. It is also permissible to adjust the settings to increase the yield as far as the required strength properties are met. The output-controlled system is so far not or very rarely used in Europe.

The general methods to derive initial settings for output-controlled grading machines are given in Part 2 of EN 14081 while the general methods to control and adjust these settings are given in Part 3 of the same standard. These settings are valid only for one single and specified machine installation.

The machine controlled system was developed in Europe to handle the grading of a large number of timber sizes, species and grades. This system relies on the machine being strictly assessed and controlled and on considerable efforts to derive the machine settings. Timber specimens are only control tested for grades with a characteristic bending strength above 30 N/mm^2. For other grades, covering almost all structural timber used in Europe, no testing is carried out on the daily output.

The general methods to derive settings for machine-controlled grading are given in Part 2 of EN 14081 while the specific settings for different machine types are given in Part 4 of the same standard. These settings are given for different species, or group of species, from a specified growth area.

Method

Initial settings

Initial settings shall separately be derived for each timber grade or combination of grades, for each timber species or combination of species, for each timber size and for each timber growth area or combination of growth areas. The method for deriving and assessment of the initial settings prescribed by clause 7 of EN 14081-2 can be summarised as follows:

1. Introduce initial settings from any relevant available information between the indicating property and the grade determining properties.

   NOTE: *The standard uses the wording bending strength in stead of grade determining property. This is assumed to be a minor mistake.*

2. Use the introduced initial settings to grade timber to obtain at least 60 specimens in each grade.

3. Proof load each specimen in edgewise bending in accordance with clause 10 of EN 408. The tension edge shall randomly be selected while the weakest cross-section shall be positioned where possible between the loading points. The proof load F_p is given by

$$F_p = \frac{th^2}{3a} \cdot \frac{0.96 k_h f_{m,k}}{k_v} \tag{1}$$

   where t is the thickness, h is the width, a is the distance between the load point and the nearest support, k_h is the size effect factor given in clause 5.3.4.3 of EN 384, k_v is the 1,12 factor given in clause 5.4 of EN 384 and $f_{m,k}$ is the characteristic bending strength of the grade.

   NOTE: *The standard does not make reference to the k_v factor given in clause 5.4 of EN 384. This is assumed to be a mistake.*

4. Calculate for each specimen the proof loaded local modulus of elasticity E_p considering the dependence between the local and global modulus of elasticity given in clause 5.3.2 of EN 384 as follows

$$E_p = 1.3 \cdot \left(\frac{23}{108} \cdot \frac{L^3}{th^3} \cdot \frac{\Delta F}{\Delta w} \right) - 2690 \tag{2}$$

   where L is the span length, ΔF is the increment in load and Δw is the corresponding increment in deflection measured at the span centre.

   NOTE: *The standard does not make reference to clause 5.3.2 of EN 384. This is assumed to be a mistake.*

5. Assess the results as follows:
   - The bending strength requirement of the grade is fulfilled only if the number of broken timber pieces is less or equal to 2.
   - The modulus of elasticity requirement of the grade is fulfilled only if the mean proof loaded local modulus of elasticity $E_{p,mean}$ is greater than or equal to 95 % of the mean modulus of elasticity $E_{0,mean}$ of the grade.

6. If the requirements on both bending strength and modulus of elasticity is satisfactory then the initial settings can be used.

   If the requirements are not fulfilled then the initial settings shall be adjusted and the procedure described in 1 - 6 shall be repeated for a new set of tested timber pieces.

   NOTE: *The standard does not assess the density, which also is a grade determining property and relevant at least for high grades.*

Production control

Production control shall separately be carried out for each timber grade or combination of grades, for each timber species or combination of species, for each timber size and for each timber growth area or combination of growth areas. The method for production control of each working shift prescribed by clause 7 of EN 14081-3 can be summarised as follows:

1. Use the initial or adjusted settings to grade timber.

2. Sample 5 specimens for each grade of one pass through the machine. This sampling procedure shall representatively be carried out for each working shift.

   NOTE: *The standard requires the sample size to be 2 x 5 specimens but only one 5 specimens set is used in the normal production control.*

   When initial or adjusted settings are first time used the sample size shall be increased from 5 to 10 for the first three working shifts.

3. Proof load each specimen in edgewise bending in accordance with clause 10 of EN 408. The tension edge shall be randomly selected while the weakest cross-section shall be positioned, when possible, between the loading points. The proof load F_p is given by Eq. (1).

4. Calculate for each specimen the proof loaded local modulus of elasticity E_p as given in Eq. (2).

5. Note the three cusum (cumulative sum) control constants *K*, *Y* and *Z*. For control of bending strength $K = 1$, $Y = 1$ and $Z = 6$. For control of mean modulus of elasticity *K*, *Y* and *Z* are given in Table 1.

Table 1. Cusum constants K, Y and Z for control of mean modulus of elasticity.

	C40	C35	C30	C27	C24	C18	C16
K	12955	12005	11055	10580	10105	8205	7255
Y	2027	1791	1541	1450	1336	883	672
Z	3531	3309	3054	2927	2774	2354	2148

NOTE: *In the example, Figure A1 of prEN14081-3 K is given as 10215. This means that $E_{0,mean}$ is 11116. The example is not in agreement with C-classed timber.*

6. Enter the test results in the cusum control chart given in Annex A of EN 14081-3 using the instructions given in the same appendix.

Assess the sum, row 11 for modulus of elasticity and row 23 for bending strength. If the sum is less than the cusum control constant *Y* then the grading is in control and the timber graded at the same shift representing the sampled grade, species, size and growth area can be released for delivery.

If the sum is greater than or equal to the cusum constant *Y* then the grading is out of control and the timber graded at the same shift representing the sampled grade, species, size and growth area shall be held pending until the results of the confirmation tests are carried out and assessed.

7. Check the grading machine as well as the proof loading machine and grade new timber specimens for the confirmation tests. These specimens shall be graded using either no setting adjustments or a maximum adjustment of 5 %. Select 6 sub-samples of 5 specimens each out of 15 graded timber specimens.

   Repeat the proof loading and assessment for the first one sub-sample, or if necessary for all other sub-samples. If the sum after the first one sub-sample, or second one, or third one etc, is less than the cusum control constant *Y* then the grading is back in control and the pending timber can be released for delivery. The grading can be continued using the same settings used before the confirmation tests were carried out.

   If the sum after all six sub-samples still is greater than or equal to the cusum constant *Y* then the grading is confirmed to be out of control and the timber shall not be released for delivery as intended. The grading can only be continued after the used settings are adjusted.

Adjustments of the settings

The settings shall always be adjusted when the result of the confirmation tests is that the grading is out of control. The adjusted settings shall separately be assessed for each timber grade or combination of grades, for each timber species or combination of species, for each timber size and for each timber growth area or combination of growth areas. The method for assessment of the settings prescribed by clause 7 of EN 14081-3 can be summarised as follows:

1. Use the settings adjusted more than 5 % to grade timber.

2. Select 6 sub-samples of 5 specimens each out of 15 graded timber specimens.

3. - 5. Proof load the 30 timber specimens, calculate and use the cusum control constants as described for production control.

6. Enter the test results in the cusum control chart given in Annex A of prEN 14081-3 using the instructions given in the same appendix.

   Assess the sum, row 11 for modulus of elasticity and row 23 for bending strength. If the sum is less than the cusum control constant *Y* then the grading is in control and the timber graded at the same shift representing the sampled grade, species, size and growth area can be released for delivery. The grading can be continued using the settings adjusted more than 5 %.

   If the sum is greater than or equal to the cusum constant *Y* then the grading is still out of control and the timber shall not be released for delivery as intended. The grading can only be continued after the adjusted settings are adjusted once again and the procedure described in 1 - 6 is repeated.

The settings may also be adjusted to maximise the yield. The adjusted settings shall separately be assessed for each timber grade or combination of grades, for each timber species or combination of species, for each timber size and for each timber growth area or combination of growth areas. The method for assessment of the settings prescribed by clause 7 of EN 14081-3 can be summarised as follows:

1. Use the adjusted settings to grade timber. Note that the settings shall not be adjusted more than 5 %.

2. Select 12 sub-samples of 5 specimens.

3. - 5. Proof load the 60 timber specimens, calculate and use the cusum control constants as described for production control.

6. Enter the test results in the cusum control chart given in Annex A of prEN 14081-3 using the instructions given in the same appendix.

   Assess the sum, row 11 for modulus of elasticity and row 23 for bending strength. If the sum is less than the cusum control constant *Y* then the grading is in control and the timber graded at the same shift representing the sampled grade, species, size and growth area can be released for delivery. The grading can be continued using the settings adjusted not more than 5 %.

   If the sum is greater than or equal to the cusum constant *Y* then the grading is out of control and the timber shall not be released for delivery as intended. The grading can only be continued with the settings used before the adjustments.

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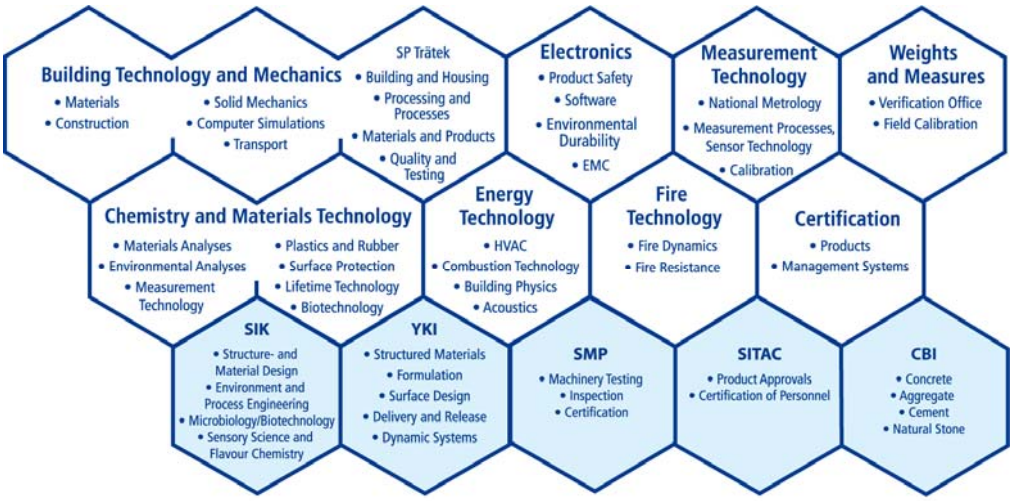

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