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INTEGRATED USE OF PRODUCT DATA FOR IMPROVED WOOD MATERIAL UTILIZATION IN FURNITURE AND JOINERY PRODUCTION

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Abstract:

Quality communication from customer to supplier is crucial for the effectiveness of a value chain. In the forest products industry, a mutual understanding of quality requirements between customer and supplier in relation to material characteristics and production conditions is important if the material is to be utilized effectively.

In the mechanical wood industry, hardwood has normally been quality graded manually. This has been a work-intensive operation and a problematic working environment. Automatic grading equipment based mainly on camera and laser technology is therefore gradually replacing the manual grading operation which relies on the human eye. The cross-cutting of sawn wood into shorter components with well-defined quality parameters is a process which needs to be automated. This makes it possible for the sawmill to redefine the quality grading process with e.g. more complex grading rules. To gain full benefits from the new technology, however, the grading process must be redefined in cooperation with the customers. There is also an expressed need for tools to communicate the quality of products produced by sawmills.

In this study, three case studies were therefore performed where the communication of requirements between sawmills and customers was studied with regard to three different components delivered from two sawmills. In one sawmill, two products were studied; one intended for a furniture producer and one for a joinery producer. In the other sawmill, the studied product was intended for a producer of solid wood panels. The idea has been to study the need for product information expressed by both the customer and supplier through the automatic grading process and to utilise this equipment for data collection and visualisation.

The requirements for a communication and data exchange tool have been derived. There is often an expressed need to measure how different raw materials affect the volume yield in a process and how different quality requirements affect the volume yield. Sharing this information between customer and supplier has been shown to yield a mutual understanding of how and why deviations occur. Visualisation possibilities are a prerequisite for a mutual understanding of quality conceptions.

Key words: *products development; customer requirements; quality; automatic grading; scanning technique.*

INTRODUCTION

An increasing trend in the furniture and joinery industry is for the industry to purchase the wood raw material in pre-produced cross-cut components (Johansson and Sandberg 2010a). From being delivered in an un-edged and often air-dried condition, the sawn wood is today usually delivered with dimensions, qualities and moisture content according to well-defined specifications. In some cases, the customer even demands components ready for assembly with products from their own production. In practice, this change leads to a need to transfer the trained human eye for quality grading and yield optimisation from the furniture and joinery industry to the preceding production steps, i.e. to the sawmill or a component producer (Johansson 2008). This means that there is a need for investment in technology and competence. For the furniture and joinery industry, the possibility of purchasing components instead of boards means less material loss and greater possibilities of making the production more rational. On the other hand, the producer of the components may use the raw material more effectively than a single joinery. Components with different requirements with regard to dimensions and quality may be processed from the same raw material and meet the needs of several customers.

The natural characteristics of hardwood are very complex to describe in terms of quality, and it is challenging to translate the visual perception into a written and measurable form. The interpretation of quality is subjective and to analyse where and why quality deviations occur in the process becomes complex. In the customer supplier perspective, a matching of the quality conception is necessary. This has usually been handled through test deliveries until both parties have been satisfied. This procedure is time-consuming and does not give the partners an insight into each other’s processing and its challenges.

The use of digital quality data from different sensor and camera devices in production is becoming more and more common in the wood industry (Johansson 2011). Nowadays several commercially available systems are available for the automatic grading of wood. These are based on different setups of mainly cameras, lasers and x-ray technology. Different technologies are combined depending on the detection needs for different wood products (e.g. dimensions, colour, surface characteristics and internal defects). Scanner technology decreases through-put-time without increasing the need of labour, permits the use of more complex grading rules than are managed by a human-being, and makes it easier to monitor the process, while it facilitating the communication of quality and product data between customer and deliverer.

OBJECTIVE

In this study, the objective has been to derive requirements for communication and data exchange between customer and supplier in order to support the development of tools for use in the for communication of product and process data.

MATERIAL AND METHOD

Three different case studies have been conducted, focused on cross-cut operations controlled by scanner equipment. In each case study, the aim has also been to optimize the cross-cut process for a specific product to ensure quality grading meeting the specification demands. Birch wood (*Betula pendula and Betula pubescens)* has been used in all cases.

The three partners, a sawmill, a customer and researchers from Linnæus University (LNU), met at the start of each case study. Each study had a unique customer, but in studies 2 and 3 the partner sawmill was the same. At the sawmill in case study 1, the site manager, the production manager, the technical manager and one operator were involved in the study. The customer representatives were a project leader and a purchase manager. In case study 2 and 3, the sawmill staff involved were the managing director, the purchase manager and the production leader. The production leader was also the cross-cutting equipment operator. In case study 2 the customer was represented by the production manager and in case study 3 by the purchase manager and production manager.

At each meeting, the sawmill partner and the customer discussed the product requirements in relation to quality parameters controlling the grading specification. Thereafter, each sawmill prepared raw material for the tests and the staff of LNU planned the experiments, defined grading specifications and implemented these in the equipment at the different sites. Each case study was performed as described below. During the case studies, the researcher observed the dialogue between customer and sawmill.

Quality grading of the sawn boards and components was in all studies made as indicated in Table 1.

The following quality criteria (grades) were used for the components in the different studies:

Case study 1: For the produced components, only grade C was used but separated into two levels grade C1 and grade C2. Grade C1 allowed a smaller amount and size of the mentioned defects than grade C2.

Case study 2: Grade A was used for one component and the other components were grade according to grade B1 and grade B2. Grade B1 and grade B2 allowed respectively one side and two sides of the products to meet grade B while the other side(s) had to fulfil grade A.

Case study 3: Grade A together with a requirement of deviation of fibre orientation of not more than 11 degrees from the longitudinal axis of the board.

Table 1

Basic grading rules for the sawn boards and components of birch in the studies

Grade	Description
A	4-sides clear*, straight-grained, no red-heartwood
B	2-3 sides clear*, mineral streaks allowed, narrow streaks of red-heartwood allowed
C	Fresh knots allowed, single black knot allowed, red-heartwood allowed, wavy grain allowed

* Free from knots and other defects

In case study 1, the customer asked for a quotation from the sawmill for a component specified with regard to volume, dimensions and quality. The thickness was 32mm, the width was 100 or 125mm and the length was 150-3,000mm. The sawmill had previously only supplied edged full-length boards of a certain width and thickness. The mill had no knowledge of volume yield in a cross-cutting process for the specified quality. The sawmill had, however, access to crosscut equipment controlled by a scanning unit. With an initial specification of the quality in the scanner equipment, a test run was performed with two different raw materials, one of mixed grade A/B and one of grade C, as defined in Table 1. The sawmill staff and the customer together then assessed the output. The scanner was adjusted and new test runs were made until the customer and sawmill staff were agreed that the product corresponded to the specifications. Thereafter, a larger test was performed based on the two raw materials. From the results the sawmill was able to calculate the product cost and submit a quotation to the customer.

Case study 2 concerned the continuous development of a component to a furniture company. The products were specified regarding volume, dimensions and quality. The products were intended for the same piece of furniture and the dimensions were 45x45mm in four different lengths between 450 and 500mm. The grading specification had low tolerances to deviation in knottiness, colour and textural effects. The price of the component was therefore high and there was a mutual interest from the sawmill and the customer in developing the product to allow quality variations for specified sides of the product e.g. visible or not visible surfaces in the furniture. Initial tests were performed where the raw material was processed with a scanner-supported cross-cut equipment. Simulation studies were performed on the data with different grading rules, and the results were used by the sawmill for discussions with the customers.

In case study 3, a sawmill was delivering a product specified with regard to volume, dimensions and quality to a joinery producer. The product was 21mm thick, 66mm wide and 250mm long. The product had strict requirements where the most challenging was the fibre orientation. The sawmill possessed a scanner-controlled cross-cut equipment, but for this specific product a manual working station had been used since it had been judged that it was only possible to measure the fibre orientation on a planed surface. For sawn wood coming directly from the kiln dryer, the surface was judged to be non-gradable by the scanner equipment with regard to fibre orientation. However, after sawing the boards to lamellae in accordance with the thickness and width of the component, two of the surfaces were considered to be smooth and it was of interest to study whether these surfaces could be used for the detection of fibre orientation by the scanner. A test was performed to study the performance of the scanner and to compare the results with the manually graded wood.

RESULTS

At the time of the test, the two sawmills were in different phases concerning the use of scanner equipment. At the sawmill in case study 1, the technology was new and had only been used on softwood. At the sawmill in case studies 2 and 3, the technology had been used for approximately three years. The case studies therefore had different aims. For the sawmill not experienced with scanning for hardwood sorting, the idea was to replace the human eye and increase the speed of production without increasing the number of employees. For the sawmill which had used the equipment longer, the aim was to grade the wood in a different way by redefining the quality concept.

In the handling of the scanning equipment and utilisation of the information, the operator is important for a good result. In these studies, the operators said that it was difficult to develop the use of the equipment due to a production focus. If the machine was not in use, the operator usually had other operation activities.

Case study 1

After discussions, the customer requirements were defined as in Table 2. In the visual inspection of the material, both the customer and the sawmill gained new knowledge. The customer expressed a positive feeling concerning the quality of the material, saying that the quality was better than expected, while the sawmill found that the customer requirements allowed more defects in the material than was previously realised. The sawmill was interested in determining the volume yield of different products (Grade C1 and C2) based on different predefined raw materials. The amount of waste and unused material indicates how to develop the cross-cutting bill by finding new customers or products. For example, the cutting bill could be expanded with products allowing certain types of defects to reduce the amount of waste, or it could be expanded through new products with shorter lengths to reduce the amount of unused material. The unused material might also be used for e.g. finger-jointing. To obtain a complete understanding of the profitability of the cutting process, the price levels of different raw materials must be studied in relation to the prices of the products and the unused and waste materials. From the customer perspective, it was valuable to understand how different grading specifications affected the volume yield of the process.

Table 2

Customer requirements and product data generated from case study 1

Input raw material				
Width (mm):	125			
Thickness (mm)				
Quality (Table 1)	A/B			
No. of scanned boards	144			
Scanned volume (m³):	1.11			
Output products				
Product	Product length (mm)	Total produced length (m)	Volume (m³)	Volume yield (%)
Grade C1	200-3000	329.6	0.98	88.3
Grade C2	150-3000	13.9	0.04	3.6
Unused material*		8.5	0.03	2.7
Waste**		23.8	0.06	5.4

* *Unused material* is material approved in relation to the grading specification but not used because of length requirements.

** *Waste* is material not accepted due to quality deficiency.

Case study 2

Based on the results of the simulation, the numbers of components in different length classes were determined per 1,000m of lamellae run through the scanner. The results are presented in Figure. The cumulative proportions of components of different lengths in relation to the total scanned length are presented in Fig. 2, where it is possible to see how the total scanned length is distributed in freely chosen length intervals. Table 3 describes the volume yield and losses based on the grading specifications shown in Table 1.

The product in case study 2 is used in furniture production in both visible and partly hidden constructions. Different qualities could possibly be employed to obtain a higher volume yield. The lengths of the products were between 450 and 500mm. Fig. 2 shows that 16% of the wood was shorter than 500mm in grade A, 11% in grade B1, and 9% in grade B2. This means that if it is possible to use grade B1 or grade B2 instead of grade A, between 4 and 7 per cent more of the desired length can be obtained from the same raw material volume. In this study, the raw material was material of grade A, and the differences between grade A and grades B1 and B2 were considered to be relatively small.

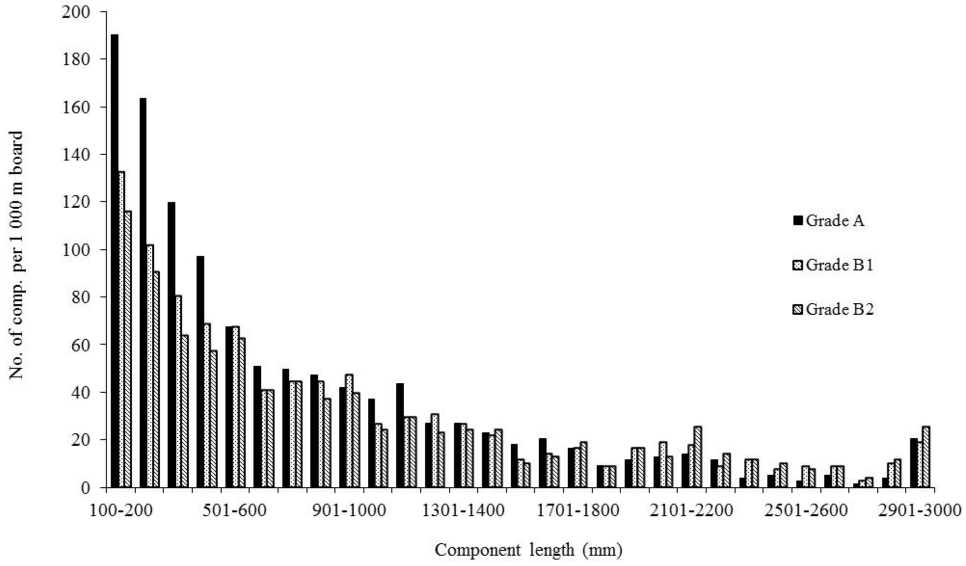

Fig. 1
Number of components of different qualities in different lengths normalized to 1 000 meters of scanned material based on simulated cross-cutting.

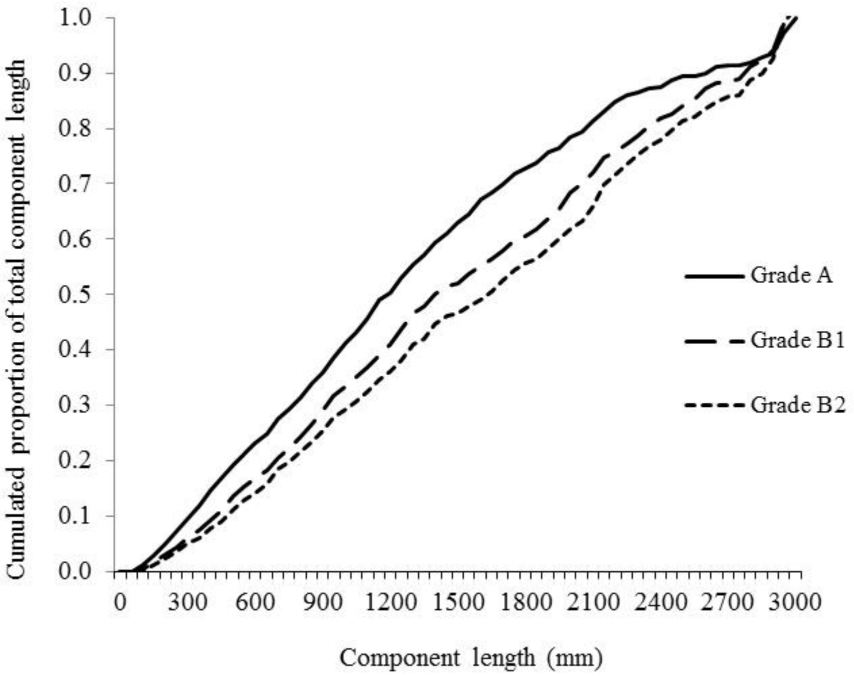

Fig. 2
Cumulative length distribution of components of different qualities.

Table 3

Volume yield and losses with different component quality settings in case study 2

Product	Total length	Volume yield	Un-used material		Waste material	
	(m)	(%)	(m)	(%)	(m)	(%)
Grad A	784	83	47.5	6	83.5	11
Grade B1	784	85	47.1	6	67.8	9
Grade B2	784	86	46.6	6	66.4	8

Case study 3

In case study 3, the initial setup of the qualities and adjustments was based on the customer requirements. The sawmill had long experience of the product and its requirements. The products were divided into full-width product and partial-width product, as shown in Fig. 3. The part containing grade C in the partial-width products was removed through rip-sawing in a later production step.

The result of the test was a volume yield of 78% of components compared to the volume of the lamellae. The distribution between the different products was 18% partial-width products and 82% full-width products based on volume.

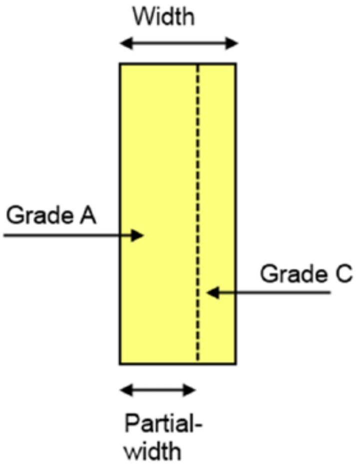

Fig. 3
Top surface of a cross cut product in case study 3. If the product had a quality not fulfilling grade A but at least fulfilling grade C (Table 1) in the marked area, the product was graded as a partial-width product.

During the full test run with a larger volume, it was found that the limit for the deviation of fibre orientation was set too low, even if the initial testing were approved, the value for allowed wane was too high.

In the later evaluation of the test material in the customer's own production 12.5% of the products were rejected after the customer had processed the components to thinner lamellae followed by planing and milling. This was slightly higher than normal. Normally, approximately 9% of the products were rejected. Therefore further tests will be made smaller allowed deviations of the fibre orientation and of the size of the allowed wane. Even though the results were not comparable to normal manual grading, the customer and the sawmill agreed to continue evaluating the method based on a mutual understanding of the problem and of the potential benefits. Certain defects were found in the material in the customer´s production. Some of these were acknowledged to be internal defects encountered when the customer processed the material, which neither the scanner nor the human eye would have seen on the surface.

DISCUSSION

The information from case studies 1 and 2 may be used for production planning or sales, as well as for a product costing tool. Birch is rarely used in the form of long and wide boards in consumer products and information about the length distribution of components obtained in these studies was therefore valuable. The sawmill or the furniture manufacturer can now better predict the outcome of their processes. The mutual understanding of quality achieved through the visual inspection of the wood in the case studies was valuable for both customer and supplier. Particularly in case study 1, where the supplier and customer should agree on the quality of a new product, the visual inspection became important. In this case, written descriptions of the quality had been communicated between the customer and supplier before the test. Visualization aspects are clearly something to consider further. Woxblom and Palm (2011), for example describe visual grading cards for logs and an internet-based tool called WoodPicker where logs and boards of different qualities may be shared between partners in the value chain to describe qualities.

The raw material accessibility in product design is extremely important for product or manufacturing costs, as well as for avoiding problems with raw material flow. For the sawmill, the information generated by this study helps in balancing the cutting bill which, according to Maness and Wong (2002), is critical for the profitability of the cross-cutting process. If the producers add other products to the cutting bill, this will, however, affect the possibility or willingness to share information with the customers. In such cases simulation possibilities in production would be an advantage.

Johansson and Sandberg (2010b) indicate that different defects may become visible or disappear when the wood is planed. This was also observed in case study 3 in the customer´s own production. Acceptance of this by the customer is necessary. To take advantage of automatic grading, it is important to understand both processing practices and the wood material.

Understanding the possibilities of the techniques used is important to gain full benefits of process data. The operator of the scanner is important for the utilisation of the data and of the process. Organisational support and educational possibilities are probably important to aid these persons. Interaction between human and machine is something that the tools developed must consider.

Maness and Wong (2002) point out that the correlation between grading and grading rules is strongly dependent on the overall wood quality and on the complexity of the grading rules. The authors further show that there are large differences in the value yield of the component manufacturing practices of different companies, related to raw-material quality, the number of different products manufactured, and the lengths of different products produced. A large number of different lengths and a well-balanced list of demanded products were shown to be important (Maness and Wong 2002).

Trung and Leblon (2011) also imply that the process should be monitored from one end to the consumer product. The integrated use of information requires, however, sub-systems to communicate to eachother. This Electronic Data Interchange (EDI) is said by Marri *et al*. (2003) to give benefits concerning productivity and quality aspects. The case studies have also shown that the raw materials affect the cross-cutting process.

Through a system where product data in the sawmill is communicated between different production steps, the raw material resource could be used more efficiently and the product perhaps produced at a lower cost. This requires however, the possibility of controlling the process and steering specific wood qualities towards specific uses together with good communication between the sawmill and the final product manufacturer and an understanding of the requirements and demands of the different actors in the value chain.

CONCLUSIONS

Requirements regarding tools dealing with the communication of quality and product data in the wood industry have been derived from three case studies utilizing scanner data. The studies showed the importance of showing the natural wood characteristics in order to gain an understanding of the quality of wood. Yield data concerning dimensions, volumes and qualities are identified as being important. By processing these data, the tool may make it possible to calculate product prices and see how changes affect the system. Integration of the full system from log to product is an advantage. It is important to consider the operator and the implementation of technologies in relation to the provision of educational opportunities in the development of tools for data handling.

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