Indisputable key – a research and demonstration project aiming at an improved quality through traceability systems

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ABSTRACT

A large EU project – Indisputable key –started in October 2006 and is focused on traceability in the production chain from the forest to the end user. The objective of this project is to develop methodologies and advanced technologies that can improve the use of wood and optimize the forestry-wood production line through the chain of transformations while minimizing environmental impact. The magnitude of the problem, based on an estimation of the total production of sawn wood in Europe 2002, is that approximately 25 million m^3 of wood raw material is going to waste, worth billions of €. A major reason is that important information regarding the raw material, the process or the final use is not available throughout the process.

Making information available on-line, for process steering as well as for process evaluation, at different stages along the forestry-wood production chain requires automatic traceability systems. The developed systems will be based on the Individual Associated Data (IAD) concept. The logs, boards and packages are individually marked with unique numbers and data added to a database, reachable through the whole production chain. Each time a measurement is made or a decision is taken the data is added to the database. The log is marked in the harvesting process and read when forwarding, when the logs are measured and when sawn. The boards are marked after sawing and read in green sorting as well as after final sorting and at the end customer. For log marking especially the use of RFID transponders is investigated, including applicator and reader system development. Readers are installed at selected points in the sawmill production chain so that the piece can be detected and additional information obtained in the process connected to it in the database. Decision-making at different points (sawing pattern, selection of processing parameters and product) is based on all data gathered up to that point.

This paper describes the project in more detail, the benefits expected and some preliminary results obtained.

INTRODUCTION

Today wood is treated as a bulk material, while in reality wood is an inhomogeneous biological material having individual quality and property attributes, depending on geographical origin, growing conditions, age etc. Also the wood material itself is inhomogeneous; heartwood and sapwood, butt logs and top logs, density, moisture content, all these factors will have an influence on the final product appearance, durability, strength etc. As a consequence of the lack of information about individual property aspects, end products have to be graded in the final stages of the process to be able to satisfy customer demands. However, accurate data such as origin of logs, location in stem, treatments at different stages of the production chain, are collected in different process steps and are available during each step, but most of the data are lost later in the process as illustrated in Figure 1.

The core problem is to, more or less automatically, acquire the required data, i.e. product and production parameters for individual items, and to keep them throughout the production chain. The basis for having the necessary parameters at hand when needed is to have data associated with each specific item – log, board or package – data that can be followed through all steps of the production chain. The ultimate target is an unbroken traceability chain from the tree in the forest to the end user of the wooden product.

The main objective of the EU-project 'Indisputable key' is to develop methodology and technology needed for the implementation of traceability in the forestry-wood chain. The project aims also to demonstrate that the technology developed has the potential to improve material utilization, to select the optimal raw material for each product and to introduce a more holistic approach to environmental and economic issues. Not to forget the possibility to use all data collected for an item for the local optimisation of the procedure in each unit operation based on a global knowledge.

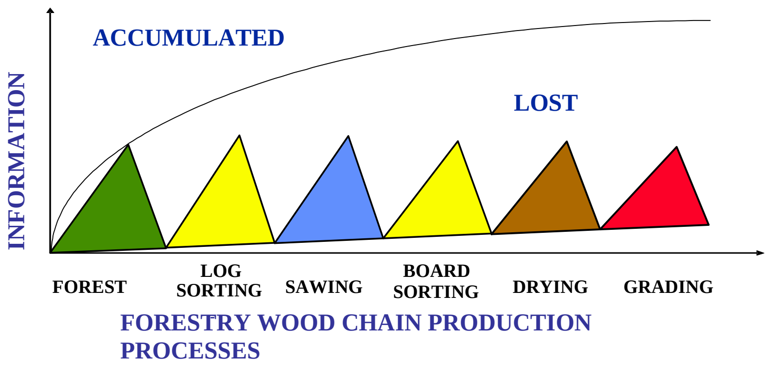

Figure 1. In traditional production, valuable data are produced, used and then lost. Information is created or recreated where it is needed in different locations: in the forest, in the sawmill's different production processes and at the end manufacturer or user. With traceability and IAD it is possible to retrieve and use all accumulated data instead of only the data produced at each stage.

Table 1. Participants in Indisputable key.

Participant name	Country
SP Technical Research Institute of Sweden	SE
Association Forêt Cellulose	FR
Royal Institute of Technology	SE
Centre Technique du Bois et de l'Ameublement	FR
CIRIS Engineering	FR
IVL Swedish Environmental Research Institute	SE
Rottne Industri AB	SE
Technical Research Centre of Finland	FI
TietoEnator Forest & Energy Oy	FI
Confidex Ltd.	FI
Idesco Oy	FI
Tampere University of Technology	FI
Lappeenranta University of Technology	FI
Tallinn University of Technology	EE
Oskando OÜ	EE
AS Hekotek	EE
Skog-Data AS	NO
Norwegian Forest Research Institute	NO
Norsk Treteknisk Institutt	NO
Forestry Research Institute of Sweden	SE
Sveaskog Förvaltnings AB	SE
Ducerf Scierie	FR
Raunion Saha Oy	FI
Eidskog-Stangeskovene AS	NO
Scanpole AS	NO
Etablissements Pierre Mauchamp S.A.	FR
SETRA Group	SE
Norsjöfönster AB	SE
Rolpin	FR

There are 29 partners from five countries – Estonia, Finland; France. Norway and Sweden – involved in the project. These are listed in Table 1.

The partner list includes both universities, research institutes, equipment developers, software suppliers and companies in the forest-wood-chain.

SP Technical Research Institute of Sweden is the co-ordinating partner for the whole project. There are several wood related production units represented in the list, where demonstrations of certain parts of traceability chains will be implemented. The main demonstration site is the Malå Sawmill (SETRA Group) in the northern part of Sweden. A part of their production is further used for window manufacturing at Norsjöfönster AB – also a partner. Other sawmills participating are Raunio sawmill in Finland and ESAS sawmill in Norway.

Not only softwood sawmills are involved as production units: also an oak sawmill and a plywood factory in France and a pole factory in Norway are places for traceability installations.

The project started in October 2006 and is scheduled for three years. The total budget for the project is about 12 million euros.

OBJECT IDENTIFICATION BY MARKING AND READING

The Individual Associated Data (IAD) concept requires of course that the object to which data is associated is marked in some way so that a unique coupling between data and the object is created and maintained throughout the production process. It is equally important that the mark can be read later on in the chain so that new data can be added to the list of properties for that object in the database. It is obvious that both the marking and reading procedures should preferably be as automatic as possible. There is a multitude of marking methods used for very different purposes and different items – we are all familiar with some of them in every day life; bar codes, printed numerical identifications, colour markings etc.

A special attention is in this project paid to Radio Frequency Identification (RFID) transponders, especially for marking of logs, i.e. from the forest to the saw intake. Popularly described gives an RFID transponder an "echo" when subjected to an electro-magnetic pulse with a predetermined frequency. This echo is modulated according to the transponder identity, i.e. it gives a unique number to the object to which the transponder is attached. Transponders are today available in many different forms – from the size of a short match to thin labels – and the cheapest versions cost 10 – 20 euro cents when produced in large amounts. The realization depends on the frequency used, which in turn influences the reading distance.

Development of transponders suitable for softwood logs (Nordic countries) is a very demanding challenge. The harvester is using about 20 seconds per tree for felling, delimbing and cutting, and produces generally two to four logs (butt, middle and top logs). In order not to decrease the productivity, the application of a transponder should be finished in seconds. Further, as a lot of transponders will end up at a pulp mill – either directly or with chips from the sawmill – no plastics can be tolerated. In addition the harsh harvester environment – rough handling, dirt, snow and ice – will cause problems. It will be interesting to see the result from the project in this respect. For hardwoods the situation is quite different. An oak sawmill in France is one of the industrial partners in the project and oak trees are normally harvested manually (chainsaw) and forwarded as a single long log to the mill. Due to the high value of each oak log, a much more individual procedure is found all the way and application of a transponder should be a relatively easy task.

If the transponder marking concept fails, there are other options such as colour marking etc. An interesting method is to use nanoparticle inks that exposed to IR light will fluoresce in a way that can be detected through a reasonably thick layer of ice or dirt.

Another challenge regarding marking is the transfer of the log identity to the boards sawn from the log. The same problem may occur when boards are divided into smaller pieces in a secondary manufacturing. In some cases the boards from the saw are brought forward in a linear, unmixed way and the transfer of identity is easy. In other cases boards from several logs are mixed before marking is possible and this requires some additional information – as an example matching of log length and board lengths, maybe complemented by some other parameters like knot structure. In this project only centre boards are included in the traceability system.

Boards are preferably marked by printing a machine readable digital code or bar code, not by a transponder as these probably are too expensive. An example is seen in Figure 2.

Figure 2. Code marked board ends.

It is of course important that the code can be correctly and automatically read so that the object can be identified later on in the chain. In some special cases all codes need not to be read; a pile of logs is identified (truck driver in the forest) by identifying one or a few logs in the pile. A stickered kiln package can be identified from a few boards even if the package mark is missing. However, it has to be accepted that some marks will not be read correctly, and the corresponding objects will then cause some problems in databases etc. On the other hand, it should be mentioned that even if the mark is not read correctly, there are some methods to reconstruct the information. If a 10 digit numerical code is used then there are 10^{10} possible combinations. But consider that only a subset is used where each combination differs from all other combinations in the subset, in at least three positions. Then even if there is a reading error in one position, the original combination can be determined with a high probability, as there is only one combination in the subset that differs in one position from the combination read (error correcting code principle). The most important thing in this case is that all numbers put in the database are correct. If a reader is uncertain of a number, that number will not be stored.

BENEFITS WITH TRACEABILITY FROM THE FOREST AND WITHIN A SAWMILL

The public may conceive traceability as a possibility to check whether a wooden product origins from a certified forest or not, and other similar issues. A much more important benefit, however, is the possibility to use traceability for optimisation of production procedures, product quality improvement, waste minimisation etc.

The traceability makes it possible to calibrate the measurement systems used in the forest to the ones used at the sawmill. As the logs are cut to length in the forest, and the wanted log lengths are depending on log diameter and log quality, it is necessary that the harvester’s measurement system is correct and maintained. With feed-back built on traceability it is a simple task to compare, log by log, the measurements made in the forest with the ones in the sawmill.

One problem for most sawmills is to measure the log diameter correct, as the measurement and sorting is performed on logs where the bark is still on (some sawmills debark the logs before sorting). The interesting measure is the diameter under bark, and that is calculated from measurement above bark using a bark function, which is empirically established. By knowing the logs’ diameters when sorting (above bark) and comparing them with the diameter in the saw intake (under bark), it is possible to improve the bark functions both at the log sorting station and in the harvester which will make the sorting more efficient and improve the yield.

When marking logs, either in the forest or at the sawmill’s log sorting station, it is possible to compare log quality with the quality of the final board. A comparison could also be made between the green sorter and the final grading. This makes it possible to calibrate quality models to help grade and sort the logs and the boards to better fit the final products.

Some features are more easily detected in green (undried) condition than they are in dry. That is the case with some knot types where resin complicates the definition of the knot’s type and size after drying. A tracing between green sorting and final grading, where each grading system looks for features visible best at that place improves the overall grading.

One major board quality problem is twist, especially regarding studs for building purposes. It is well known that the basic reason for twist is spiral grain, i.e. the fibres in the log are not aligned completely in the direction of the log but form a helix around the pith. As the shrinkage properties are quite different in the fibre direction compared to the transverse direction, the grain angle will cause twist when the board is dried. For many species – like Norway spruce (*Picea abies*) – the spiral grain angle is highest close to the pith and decreases with the radial distance from the pith. The boards most prone to twist are thus those sawn close to the pith.

If the grain angle is measured then a rather good estimate of the twist development is obtained. In an industrial environment the grain angle can be measured using laser. If a circular laser beam is pointed at a wooden surface, the light spot will be elongated in the direction of the fibres (tracheid effect).

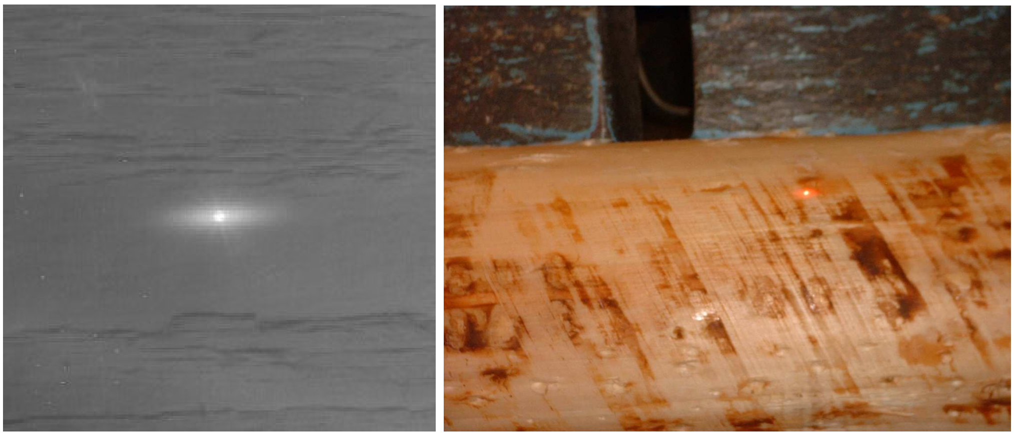

Figure 3. The tracheid effect is shown in the pictures, where the laser point is elongated into an ellipse, following the fibre direction when lit on a wooden surface, to the left of a board and to the right of a log.

The direction of the main axis of this ellipse can be measured with camera technique. This makes it possible to determine on-line if a log will give prone to twist boards or not. The measurement can be made on the surface of the (barked) log, which together with the log diameter (log class) gives an estimate of the twist level. This log can then be used for products that are not sensitive to twist or even directed to a pulp mill. A better estimate of the twist level for the centre boards is obtained by measuring the grain angle on the surface of the block from the first saw. These centre boards may then be characterized as prone to twist if a high grain angle is found and this information is entered into the traceability system.

Later on in the production chain the boards prone to twist are directed to kiln packages that are placed as the bottom package in the kiln stack. Boards kept straight during drying will show a final twist level that is about half of the level found for boards free to move during the drying process. Almost all centre boards will twist in the same direction. Based on this fact an improvement is obtained if the prone to twist boards are dried in a pre-twisted position, i.e. twisted in the opposite direction compared to the inherent direction. Measures of this kind can be implemented only if the appropriate information is associated with the object in question and retrievable downstream.

The majority of customer complaints are directly or indirectly related to product moisture content and thus to the drying process. Traceability can be used for investigations regarding the reasons for such complains. If for instance too high moisture content is found, the history of that consignment can be analysed; dried in which type of kiln, kiln number, location in kiln, drying schedule used, time between stickering and loading into kiln, responsible kiln operator, disturbances in boiler operation etc. This kind of information will help to find and correct an accidental production flaw or to initiate new or improve existing procedures in the production chain.

Within the sawmill it is also possible to pinpoint kilns in need for repair, as if the boards dried are more cracked or distorted than boards dried in other kilns.

Boards with different features need different drying programs, and should be sorted accordingly; for instance do inner and outer boards contain different amount of heartwood, and should be dried with different drying programs. This could be solved with a marker direct after the saw and a reader in connection with the green sorting.

It is known to saw millers that some kinds of boards are causing problems in the production. There are, though, some discrepancies about which boards it is. With tracing of boards, from logs, it is easy to find out which type of boards, and from which type of logs they emanate. When the problem boards are mapped, it is possible to see to that the logs never enter the sawmill but are sorted out at the log sorting station. Problems might be caused, for instance, by twisted boards or boards with a large amount of reaction wood.

Special products, that need special treatment, or are aimed for certain customers, might be traced and steered to the right process fit for that product. One example is boards with long internode lengths. These boards are scanned, knots and other defects are cut off, and the remaining knot free pieces are finger jointed for making window frames. If the lengths between knots are increased, the number of cuts and joints are reduced and the yield is improved, both for production and material. Logs with long distance between knots, suitable for this product, might be traced all the way from the forest and kept track of through the sawmill process to the window maker. It is also possible for the window factory to know exactly the yield improvement, due to the “new” board quality.

The sawmill can keep thorough track of which forest is most suitable for which product, based on the final grading, and thereby direct felling crew and set time for felling based on collected empirical data from earlier volume and quality yield. The payment can be based on actual yield, as it is possible to know exactly from which supplier each log and board is bought.

Stock management and logistics can be much improved by efficient traceability of logs and packages within the sawmill’s gates. One important duty on sawmills is searching for “lost” packages. With an automatic package tracer, based on GPS or similar technology, every package movement is recorded and each package’s position is known to the system. The fork lifts are directed to the right storage place to pick up the package, whose number is read automatically to confirm picking up, and then the fork lift is directed to the right delivery position, be it a kiln, another temporary storage or another process. By this system the storage time before the dryer can be known and minimised, and cracks kept to a minimum. It is also possible to know exactly how much timber is in stock, where it is, at each process stage, as green packages, in the dryers, as dry packages and as packages ready for sale and shipping.

Each harvester and harvester operator has an operating level based on inner and outer conditions, such as training, forest type machine maintenance etc. With traceability system it is possible to locate where training level is low or machine maintenance is needed, as well as it is possible to see if certain forests are tougher to harvest than other, due to more damage to the logs.

CONCLUSIONS

According to the agreed plans for this EU project –Indisputable key – the strategic objective is to improve competitiveness and resource efficiency of the European wood industry by initiating and stimulating an industrial breakthrough of traceability systems for biological raw materials in general and for wood in particular. The project will specify, develop, introduce, evaluate and disseminate a powerful distributed and collaborative network-oriented system for improving the use of wood raw material and production resources. The project results will make it possible to extend the knowledge about the usability potential of wood for different products, greatly beyond what is realistic today with traditional production feed-back systems.

A webpage www.indisputablekey.com is established where more information can be found and progress followed up on how successful the fulfilling of the strategic objectives will be, during the two remaining years.