Reaction mechanisms of modified wood
Modifioidun puun reaktiomekanismit

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Total project budget / Wood Wisdom funding
Kokonaiskustannus / Wood Wisdom -rahoitus
€ 812 516 / 504 564

1) Thermal modification of wood
Puun lämpömodifiointi
VTT
Saila Jämsä
8/1998–6/2001
Tekes € 281 345

1.1) Study of thermally modified wood by spectroscopic methods
Lämpömodifioidun puun spektroskooppisia tutkimuksia
Helsinki University of Technology
Teknillinen korkeakoulu
Tapani Vuorinen
10/1999–6/2001
Tekes € 69 462

1.2) NMR studies of thermally modified wood
Lämpömodifioidun puun NMR-tutkimuksia
University of Helsinki
Helsingin yliopisto
Franciska Sundholm
10/1999–6/2001
Tekes € 56 679

1.3) Study of nano- and microstructure by X-ray scattering methods and by light and electron microscope
Nano- ja mikrorakenteen tutkimus röntgensironta-menetelmillä sekä valo- ja elektronimikroskopialla
University of Helsinki
Helsingin yliopisto
Timo Paakkari
10/1999–6/2001
Tekes 21 865

2) Tall oil
Mäntyöljy
VTT
Leena Paajanen
8/1998–6/2001
Tekes € 75 180

Abstract

In this project wood was thermally modified by heating and steaming. The effects of the treatment on the properties and the structure were studied. With the aid of experimental design and statistical analysis the results were modelled as a function of temperature. The change of the properties was dependent upon the treatment temperature. Significant correlations were found. Classification and quality control methods can be developed on the basis of the results.

Cooperation between wood mechanists, wood chemists, polymer chemists and physicists has been established over the course of the project. This group of applied wood scientists had in its use the best research instrumentation, such as ^{13}CPMAS NMR, FTIR, ESR, UV-Raman, X-ray scattering, GC and HPLC.

When the heat treatment temperature was increased, the degradation of wood hemicelluloses began. The process accelerated parallel to the increase in temperature. The content of amorphous materials in the wood was decreased and the porosity of the wood was increased. The crystallinity and the average thickness of the cellulose crystallites were increased. As a consequence of lignin demethoxylation and free radical formation, the increase in the cross-linking of the material was achieved.

The improvement of dimensional stability is based on the degradation of wood hemicelluloses. The degradation of hemicelluloses and lignin had an essential effect on the improvement of decay resistance. As a result of the increase of cellulose crystallinity and the thickness of the crystallities together with the degradation of wood hemicelluloses the wood lost its strength and toughness.

Wood extractives were found to move toward the surface, which caused the water-based coating not to work properly. In high temperatures exceeding 200°C the extractives polymerized and they were no longer harmful to curing. Instead at these

temperatures the surface of heat-treated wood became water repellent and the absorption time of water-based coatings and glues was increased.

The process parameters and their influence on penetration and the uptake of crude tall oil (CTO) were studied with the help of a pilot plant. On the basis of pilot scale trials, the best treatment schedules were selected and two batches of railway sleepers (altogether 200), transmission poles and sawn timber were successfully treated with an industrial-sized creosote oil treatment plant. Exterior service trials with treated products have been initiated in order to study the long-term performance of CTO impregnated wood.

A decay test comprised of 32 weeks in un-sterilized natural soil showed that crude tall oil efficiently prevents wood against decay. The influence of CTO on mycelia growth was insignificant. Together with reduced water uptake, these properties suggest that CTO should not be classified as a fungicide. The preventive effect is more or less related to the hydrophobicity of the CTO treated wood.

The obtained results facilitate the continuation and specification of the research. By keeping in mind the effect of the phenomena on the usability of wood, it may be possible to find new unforeseen methods for developing new wood products or wood protection methods.

Tiivistelmä

Tutkimuksessa käsiteltiin puuta lämmön ja vesihöyryn avulla ja tutkittiin tämän käsittelyn vaikutusta puun rakenteeseen ja ominaisuuksiin. Koesuunnittelun ja tilastollisten analyysien avulla puun ominaisuudet mallinnettiin lämpötilan funktiona. Ominaisuuksien muuttuminen riippui käsittelylämpötilasta. Ominaisuuksien ja käsittelylämpötilan välillä oli tilastollisesti merkittäviä riippuvuuksia. Saatujen tulosten perusteella voidaan kehittää puun lämpökäsittelyn luokitus- ja laadunvarmistusmenetelmiä.

Projektissa luotiin toimiva yhteistyö puumekanistien, puukemistien, polymeerikemistien ja fyysikoiden välille. Tällä soveltavan puutieteen ryhmällä on käytettävissään alan parhaimmat tutkimuslaitteet kuten ^{13}CPMAS NMR, FTIR, ESR, UV-Raman, röntgen, GC ja HPLC.

Puun lämpötilan kohotessa alkaa hemiselluloosien hajoaminen. Prosessi kiihtyy lämpötilan noustessa. Amorfisen aineen massaosuus pieneni ja puumateriaalin huokoisuus kasvoivat lämpökäsittelyssä. Sekä selluloosan kidekoko että kiteisyys kasvoivat lämpötilan kasvaessa. Ligniinin demetoksyloituminen ja ligniinistä peräisin olevien vapaiden radikaalien määrä lisäsi puumateriaalin ristisilloittumista.

Hemiselluloosien hajoamisen seurauksena puun kosteuseläminen pieneni. Hemiselluloosien ja ligniinin hajoamisella oli oleellinen merkitys lahonkestävyyden paranemisessa. Selluloosan kiteisyysasteen ja kidekoon kasvu yhdessä hemiselluloosien hajoamisen kanssa alensi puun lujuutta ja sitkeyttä.

Uuteaineiden todettiin nousevan kohti pintaa haitaten vesiohenteisten pinnoitteiden kovettumista. Yli 200 °C:een lämpötilassa uuteaineet polymeroituivat eivätkä enää muodosta ongelmaa. Sen sijaan näissä lämpötiloissa puun pinta muodostui vettä hylkiväksi hidastaen vesiohenteisten pinnoitteiden ja liimojen imeytymistä.

Prosessimuuttujien vaikutusta raakamäntyöljyn (crude tall oil, CTO) tunkeumaan ja imeytymään tutkittiin pilot-laitteistolla. Tulosten perusteella valittiin parhaat kyllästysohjelmat teollisuuskokeisiin, joissa kreosoottikyllästyslaitteistolla kyllästettiin onnistuneesti kaksi erää ratapölkkyjä, pylväitä ja sahatavaraa. Raakamäntyöljyllä kyllästetyllä materiaalilla on aloitettu käytännön pitkäaikaiskestävyyskokeet, joissa on muun muassa asennettu 200 ratapölkkyä liikennöitävään rataan.

Steriloimattomassa mullassa tehty 32 viikon lahotuskoe osoitti, että raakamäntyöljy estää hyvin puun lahoamista. Raakamäntyöljyn vaikutus sienirihmaston kasvuun on hyvin pieni ja toisaalta se pienentää veden imeytymistä. Näiden ominaisuuksien perusteella raakamäntyöljyä ei tulisi luokitella fungisidiksi vaan lahoamista estävä vaikutus perustuu pääasiassa puun kostumisen estoon.

Saadut tulokset antavat mahdollisuuden jatkaa ja täsmentää tutkimusta. Kun pidetään mielessä ilmiöiden merkitys puun käytettävyyteen on löydettävissä uusia ennalta arvaamattomia menetelmiä kehitettäessä uusia puutuotteita tai puun käyttöön liittyviä suojausmenetelmiä.

1 Introduction

1.1 Background

1.1.1 Thermal modification of wood

Over the past few years, VTT Building and Transport has been actively engaged in work to develop and improve the properties of wood in response to the requirements imposed by its intended use. Though a vast amount of knowledge has been produced on the influence of the different modifying techniques on wood properties, the basis of the changes in the properties is not properly known or understood.

1.1.2 Tall oil

Crude tall oil (CTO) is a novel chemical collected from forest industries. A total of 260 tons is collected annually in Finland as a by-product of sulphate pulping. Typically CTO contains 60% rosins, 20–25% fatty acids and 10% neutral hydrocarbons.

Since 1989, VTT Building and Transport has studied CTO as an agent that protects wood from decay. The initial trials were positive, although the mode of action was not investigated. Since then, tall oil rosins have also been studied in a European programme aimed at the protection of wood. The goal of this study was to complete the understanding of the mode of action and to investigate the suitability of CTO for use in industrial processes.

1.2 Objectives

1.2.1 Thermal modification of wood

The object of this research was to find out how thermal modification affects chemical, morphological and physical wood properties and the behaviour of wood. The wood was treated with heat and moisture and the mechanisms of degradation were analysed and the effects of degradation on the behaviour of wood were clarified.

1.2.2 Tall oil

The aims of this consortium were to study the suitability of CTO for the impregnation of wood, to locate the process parameters for industrial scale impregnation, to begin the exterior trial with treated products and investigate the mode of action of CTO.

2 Results and discussion

2.1 Thermal modification of wood

Pine was heat-treated in saturated steam ranging between 100–240°C at 20°C intervals for a period of 3 hours. In order to perform a statistical analysis, a sufficient amount of timber in each temperature was treated in order to discover the relationships between different properties and treatment temperatures.

The changes in properties began in practice at temperatures over 180°C and increased significantly when the temperatures exceeded 200°C.

When the heat treatment temperature exceeded 180°C, the increase of dimensional stability was significant. Equilibrium moisture content decreased linearly as treatment temperature increased. The increase in the moisture content in water immersion tests was lower when the heat treatment temperature was increased. The absorption of water from the treated wood was greater in heat-treated wood than in normal wood in water immersion.

A significant improvement in biological durability was reached when the heat treatment temperature exceeded 200°C. In soil contact wood lost its strength even though the fungi were not able to decay it.

In thermal modification bending and torsion strength and toughness of wood were reduced. In order to avoid these reactions, temperatures should not exceed 180–190°C. The temperature had no significant effect on Brinell hardness.

The colour of the wood darkened as a result of heat treatment. The correlation between the heat treatment temperature and the colour component L (black-white) was statistically significant at the level of 0.1%.

The surface of thermal modified wood became grey and began to crack as normal wood would do in outdoor exposure. In spite of the surface changes, the heat-treated wood material under the surface remained in good condition.

In high temperatures exceeding 200°C the surface of heat-treated wood was water repellent and the absorption of water-based coatings and glues was slower than with untreated wood.

The phenomena presented above are clarified with the following chemical analysis results. The factors affecting the properties of wood are presented in Figure 1.

As a result of lignin degradation, stable free radicals were formed. Their prevalence had a clear connection to the heat treatment temperature.

The carbohydrate composition changed. Arabinose and galactose completely disappeared from the samples that were heat-treated at 230°C, and the amounts of xylose and mannose also decreased.

Subproject 1. Study of thermally modified wood by spectroscopic methods

The movements of extractives in softwood during the heat treatment could be detected with FTIR spectroscopic methods. Resin acids were seen as resinous spots in heartwood and a typical absorption band (1695 cm^{-1}) of these spots was detected in the temperature range of 70 to 180°C. At 200°C the resinous spots disappeared from the middle of the heat-treated battens and appeared as large dark regions in sapwood at distances ranging from 600 to 700 mm from the middle of the battens. At higher temperatures the resin acids disappeared from the wood. Characteristic absorption bands of fats and waxes (1740 cm^{-1}) were recorded on the edges of the sapwood of battens that were treated at lower temperatures (70–160°C), and they appeared as dark rings on the sapwood edges. At elevated temperatures (above 180°C), fats and waxes were removed from the sapwood surface and were no longer detected with FTIR spectroscopy.

In order to understand the behaviour of hemicelluloses in heat treatment, components of hemicelluloses were removed with hydrochloric acid and sodium hydroxide. As a result of alkaline treatment, cleavage of acetyl groups of glucomannan was observed with FTIR spectroscopy. The removal of acetyl groups had no effect on the swelling of the wood. This could be due to the sodium acetate that remained in wood after the treatment. Hydrochloric acid hydrolyzed the arabinose and part of the glucuronoxylan, which reduced the tangential swelling of wood by 45% and bending strength by 45%.

Subproject 2. NMR studies of thermally modified wood

Liquid-state NMR measurements showed that the pore size of heat-treated wood (180 and 230°C) was increased to a level of around dozens of nanometers. The diffusion coefficient of water along the tracheid axis increased with the thermal treatment.

According to the solid-state NMR measurements, the crystallinity of the cellulose increased due to the preferred degradation of less ordered molecules. The deterioration of hemicelluloses began already at temperatures under 180°C, which indicated the depolymerization of the carbohydrates. The deacetylation of hemicelluloses was also observed. The intensity of the aromatic region increased during the treatment even though the demethoxylation of lignin occurred. As a consequence of demethoxylation, an increase in the cross-linking of the material was achieved. The ESR measurements proved the formation of stable free radicals during the heat treatment. These radicals were believed to have affected the condensation reactions leading to the cross-linking in the lignin and possibly between lignin and the other wood components. The changes in the structure of wood were the most remarkable in temperatures exceeding 200°C.

Soft-rot and brown-rot fungi selectively degraded the carbohydrate fraction of the wood while the aromatic lignin structure remained almost unchanged, with the exception of the formation of carboxylic acid structures as a consequence of the cleavage of $C\alpha$-$C\beta$ bond of the lignin side chain.

Differences were found between the untreated and heat-treated samples exposed to outdoor conditions for six years. The destruction of lignin aromaticity was not nearly as extensive for the heat-treated samples as it was for the untreated samples according to solid-state NMR.

Subproject 3. Study of the nano- and microstructure of thermally modified wood by X-ray scattering methods and by light and electron microscope

The crystallinity and the thickness of the crystallites increased in the thermal modification. The relaxation process occurred even in rather low temperatures.

The modification had no effect on the orientation of the cellulose microfibrils.

The increase in the specific surface was observed at the higher temperatures by USAXS measurements indicating an increase in porosity. The distance between the microfibrils increased from 7 nm to 8 nm in hydrated wood and a transition at 160°C was observed.

2.2 Tall oil

Pilot impregnation trials showed that typical processes developed for creosote oil were also usable for crude tall oil. Two batches of railway sleepers, transmission poles and sawn timber were successfully treated with industrial creosote oil impregnation plant. Long-term service trials have been started with the treated material.

Soil box test (ENV 807, part 2) showed that CTO was effective against decay fungi. The modulus of elasticity (MOE) of CTO-treated blocks reduced by 15%, which was much less than in the untreated controls, where the MOE reduction was 52%. Decay test (EN 252) in ground was established and after the first year, decay was observed only in untreated controls.

CTO affected, to some extent, the growing rate of fungal mycelia and was comparable to linseed oil. The growing rate was reduced to some degree depending on the fungus. The trials suggested that the mode of action is not based on the fungicidal effect of CTO but the hydrophobicity of CTO-treated wood.

3 Conclusions

3.1 Thermal modification of wood

Hypotheses were developed in order to illustrate the phenomena occurring in heat treatment. The hypotheses were verified by analysing the changes in the physical, biological and chemical properties of wood, which were caused by heat and moisture.

The carbohydrate composition changed and decreased in heat-treated samples and in decayed heat-treated samples. The amounts of arabinose and mannose were reduced in heat-treated wood to the same level as in decayed wood, to the extent that the fungi were unable to initiate the decaying reaction.

As a result of lignin degradation, stable free radicals were formed. Their amount had a correlation with the decay resistance of wood.

As a result of the increase of cellulose crystallinity and thickness of the crystallites together with the degradation of wood hemicelluloses wood lost its strength and toughness.

The mutual dependence of the factors affecting the properties of thermally modified wood are presented in Figure 1.

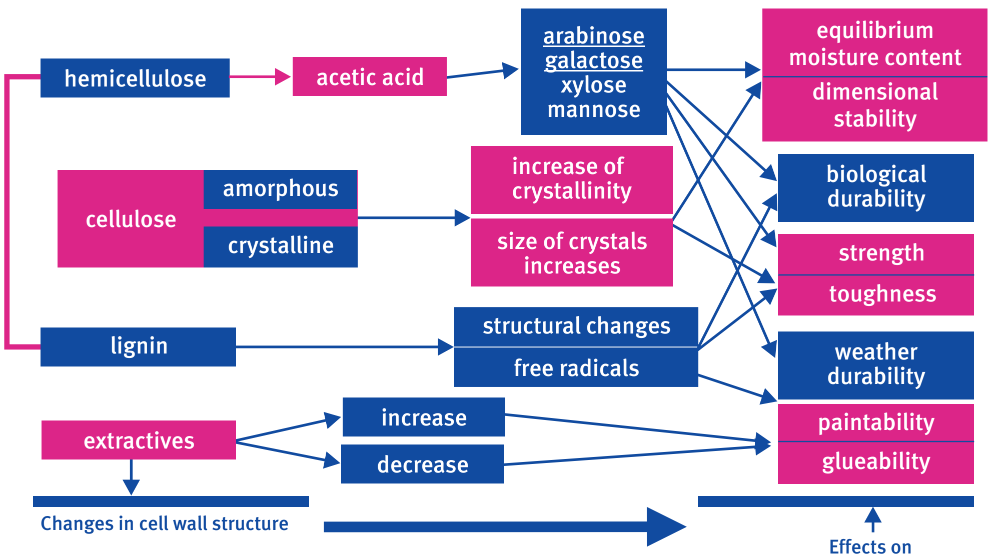

Figure 1. Factors affecting the properties of thermally modified wood.

3.2 Tall oil

Wood can be treated with hot CTO in a creosote oil treatment plant. Long-term service trials will show whether CTO can sufficiently protect wood in and above ground end-use areas. The results of the growing test of mycelia suggested that CTO should not be regarded as a biocidal product and, therefore, should not be included in the Biocidal Products Directive.

4 a) Capabilities generated

The research inspired a strong basis for the exploitation of wood chemistry, polymer chemistry and physical phenomena to meet the needs of wood mechanists. This group of applied wood scientists has found a common language, which is a basic requirement for transferring the knowledge and experiences over research area borders.

The group has helped to educate the research scientists on the needs of the industry. The group has visited the wood industry and all of the members of the research group have attended the advisory board meetings.

New methods were developed in order to measure the chemical properties directly from solid wood samples instead of milled wood samples.

Patent application

Patent application FI 20000101. Menetelmä lämpömodifioidun puun modifiointiasteen toteamiseksi. VTT, Finland (Viitaniemi, P., Jämsä, S. ja Sundholm, F.). Appl. 20000101, 18.1.2000. 13 p. (Method for identifying the modification degree of heat-treated wood)

Degrees

Four PhD degrees to be earned.

b) Utilisation of results

The results are already being exploited in the development of the classification and quality control methods for heat-treated wood. In addition to the national project, an EU project is being planned.

Another item of exploitation is wood surface finishing. A project on the surface finishing of heat-treated wood is already underway. A project focusing on the surface finishing of fast-dried wood is in the planning stage. The project will concentrate on the resins coming to the surface and how they can be utilised in curing acrylate-based coatings.

The results will be presented to the industry in a seminar in autumn 2001. A number of questions have arisen in the field concerning the use of heat-treated wood. As a result of this study we are able to answer most of these questions.

Results from the crude tall oil (CTO) study have been exploited by the industry. Industrial adoption is most likely to happen, if CTO can be classified as a non-biocidal wood protecting agent.

The obtained results facilitate the continuation and specification of the research. By keeping in mind the effect of the phenomena on the usability of wood it may be possible to find new unforeseen methods for developing new wood products or wood protection methods.

5 Publications

Articles in international scientific journals with referee practice

Hietala, S., Maunu, S.L., Sundholm, F., Jämsä, S. and Viitaniemi, P. Structure of Thermally Modified Wood Studied by Liquid State NMR Measurements. Holzforschung, submitted.

Sivonen, H., Maunu, S.L., Sundholm, F., Jämsä, S. and Viitaniemi, P. Magnetic Resonance Studies of Thermally Modified Wood. Holzforschung, submitted.

Nuopponen, M., Vuorinen, T., Jämsä, S., Viitaniemi, P. Effects of heat treatment on the behaviour of extractives in softwood. Wood Science and Technology, submitted.

Serimaa R., Andersson S., Väänänen T., Sarén M.-P., Paakkari T. and Viitaniemi P., The structure of thermally modified wood by x-ray scattering methods, manuscript.

Other scientific publications

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Andersson, S., R. Serimaa, M. Sarén, M. Peura, T. Paakkari, S. Maunu, S. Hietala, H. Sivonen and F. Sundholm. 2000. The Structure of Thermally Modified Wood by X-ray Scattering and NMR. Poster in Nordic Polymer Days. June 24-26, Helsinki, Finland.

Sivonen, H., S.L. Maunu, F. Sundholm, S. Jämsä and P. Viitaniemi. 2001. 13C CPMAS NMR Studies of Thermally Modified Wood. Proceedings and Poster of 11th International Symposium of Wood and Pulping Chemistry. June 11-14, Nice, France.

Väänänen T, Ikonen T, Sarén M, Andersson S, Torkkeli M, Serimaa R, Paakkari T. 2001. X-ray scattering studies on natural glucose polymers, The XXXV Annual Conference of the Finnish Physical Society, Jyväskylä, 22nd-24th March.

Oral presentations

Väänänen T, Workshop on The Nature of Fibre Bonds and Properties of Fibre Products, Helsinki, Finland 4th May 2001.

Väänänen T, COST Action E 20: Workshop on Wood Fibre Cell Wall Structure, Interaction Between Cell Wall Components, Uppsala, Sweden 26th-28th April 2001.

Jämsä, S. Thermowood:properties, applications and experiences. Eurowood Technical Workshop: Wood as exterior construction material for buildings: new products, coatings and applications. Brussels 30 - 31.10.2000.

Viitaniemi, P. Heat Treatment and the ThermoWood Process®. Workshop on Enviromentally Compatable Timber Treatments. September 27th, 2000. Coford, National Council for Research & Development. Ireland.

Hietala, S., Maunu, S. L. and Sundholm, F., Structure of Wood Studied by Liquid State NMR Measurements, Nordic Polymer Days 2000, 24.-26.05. 2000, Helsinki, Finland.

Other

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Publishing and dissemination of information outside the scientific community

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6 Cooperation

Advisory group, Thermal modification
Ismo Heinonen, Vapo Timber, chair
Aarni Metsä, Wood Focus
Olli Oksanen, Finnforest
Leena Paavilainen, Wood Wisdom
Eero Saarelainen, Honkarakenne
Jouko Silén, Stora Enso Timber
Heikki Sonninen, TekmaWood
Juha Vaajoensuu, Tekes

Cooperation and networking

- Thematic Network for Wood Modification
- Co-operation in wood modification with other European research scientists and industry
- COST Action E22 (Environmental optimization of wood protection)
- Preparation of an EU project concerning quality control methods for heat-treated wood
- COST Action E20 (Wood fiber cell wall structure), Working Group 2, Characterization and Ultrastructure (variation of cell wall structure and chemistry)

Advisory group, Tall oil
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Initiating research into the properties of solid wood
Mekaanisen puun mittaustekniikan tutkimuksen käynnistäminen (PUUMI)

Total project budget / Wood Wisdom funding
Kokonaiskustannus / Wood Wisdom -rahoitus
€ 780 392 / 620 613

University of Oulu
Oulun yliopisto
Jukka Räty
8/1999–4/2001
Tekes € 620 613

Abstract

The objective of the project was to establish research facilities for the study of solid wood properties. The activities will be focused on the evaluation and development of measurement methods based on, for example, optical, microwave and ultrasound technologies. The applications include the determination of the size, shape and structure (inner and outer) of wood logs and planks. In addition, changes within the microstructure of wood during the various drying and heat treatment processes will be examined.

Tiivistelmä

Hankkeella luotiin edellytykset mekaaniseen puuhun liittyvälle tutkimustoiminnalle Oulun yliopiston mittalaitelaboratoriossa. Tutkimustoiminta tulee kohdistumaan eri mittausmenetelmien evaluointiin ja kehittämiseen. Tutkimuslinjoiksi on valittu puun, koon, muodon ja rakenteen mittaustekniikan tutkimus sekä puun aineanalyysitutkimus sovelluskohteena lämpökäsitelty puu.

1 Introduction

1.1 Background

Mechanical wood industry is one of the key sectors in the development programmes of both the Kainuu region and the town of Kajaani. In order to increase the volume and versatility of mechanical wood production and to improve its operating environment, Kajaani started the Woodpolis project in 1998. One of its subprojects focuses on co-operation with the university and on product development support, with the goal of initiating mechanical wood research in the Measurement and Sensor Laboratory.

The Measurement and Sensor Laboratory is part of the Infotech laboratory network which includes the laboratories of the University of Oulu and some external parties, such as VTT Electronics. The laboratory also maintains close research contacts with the University of Joensuu, Department of Physics. The laboratory specialises in optical measurement technology and its economically viable applications in the measurement electronics and pulp and paper industries. It has also participated in research projects focusing on machine vision and image processing. Mechanical wood processing is a new field of application receiving a lot of attention in connection with the Woodpolis and Measurepolis projects.

The current state of solid wood measurements was at first evaluated. Measurement technologies utilising the visible light wavelengths have been extensively researched and various instruments suited for mechanical wood measurements are commercially available, but the other wavelength ranges are still largely in the experimental stage. X-ray technology is being tested and also microwave measurements have been studied, but as yet there are no commercial instruments that utilise these techniques. Reliable machine vision applications for the classification and assessment of sawn timber quality are available, particularly for moist raw material. Machine vision applications for dry sawn goods are also well underway and will probably reach the market in the next few years.

Sawmills and wood refining plants as well as measurement instrument manufacturers consider it very important to study the quality and possible defects of wood at the earliest possible process stage, and to preserve and complement the data throughout the process so that it is readily available at all times. This ensures that the timber can be sawn into optimum quality according to customer needs.

1.2 Objectives

The objective of the project was to initiate the study of technologies applicable to determine the size, shape and structure of wood at the Measurement and Sensor Laboratory. Optical, electromagnetic and acoustic measurement methods are applied. The measurement must be carried out at the earliest possible process stage. High accuracy is required, despite the fact that the measured objects are in constant motion, also with regard to the measurement bed. For this reason the present commercial instruments are very prone to errors.

Another goal is to start research into the material analysis of wood. The first application will be heat-treated wood and particularly the changes in the microstructure of wood during the thermal process. The material analysis will mainly rely on IR-spectrum measurements.

When a piece of wood is measured using different techniques, typically a very large amount of data is obtained. The data management is difficult because it requires a lot of memory and processing capacity. Our goal is to process the obtained measurement data by taking into account the later use. Only the data needed in the subsequent processes are stored. Such selective data processing will accelerate the measurement and data collecting. Moreover, the trend in mechanical wood industry to increasingly concentrate on customer-oriented harvesting and processing further facilitates the use of this technique.

2 Results and discussion

The purchased equipment and measurement systems were tested by applying commonly known methods, whereby the researchers had the opportunity to get acquainted with the different tests. The results were compared to data available in existing literature, and found to largely agree with earlier studies.

So far, wood planks in more than 20 batches have been heat treated. The main species is pine, dimensions maximum 50x150 mm. The planks were tested and measured both before and after the heat treatment for colour, cracks (internal and surface), deformation due to moisture, and mechanical strength. Some chemical analyses were also made.

NIR/DR-spectra of planks during the heat treatment were gathered. The results will be used for process control to produce high-quality heat-treated wood. The measurement method is further investigated in a recently started research project.

One of the objectives of the project is to study the wood structure. Two test benches were designed and constructed for this purpose: one for logs and timber, one for planks. Using the microwave and ultrasonic measurements 'images' of the inner structure of wood were produced. This information is obtained by exploiting the reflected and transmitted light or phase data.

Also a colour measurement for the observation of surface defects has been developed. The measurement setup consists of 16 sensors placed on a circular frame. Light reflected from the log surface is transmitted by optical fibres to a spectrograph that resolves the light into space and colour components. The measurement is quick and accurate.

Timber is usually measured and tested with various instruments and at different stages of the manufacturing process. Unfortunately, information is often lost or the data are not efficiently linked to other data. We are currently developing a system that combines the data obtained at laboratory and only preserves the essential knowledge.

3 Conclusions

During the project we have created a modern, versatile wood research laboratory in Kajaani. The measurement experts involved in this work have become familiar with a new field of application and established contacts with other Finnish wood research institutes.

The laboratory mainly concentrates on the development and application of measurement methods for the mechanical wood industry. The structure of wood (log or sawn timber) – not only the surface but also the internal properties of the material – is studied by using non-destructive measurements. The measurement methods utilise ultrasound and the visible and microwave ranges of the electromagnetic spectrum. So far the measurements are carried out in laboratory environment, with the studied timber placed in separate test benches.

Material analysis of wood – especially heat-treated timber – is another main line of research in the laboratory. Small batches of heat-treated wood for research purposes can be produced. Changes occurring in wood during the process are studied using, for example, IR-measurements. It is also worth noting that methods based on NIR/DR-measurement have been developed for monitoring the changes taking place during the process. Material analysis is supported by chemical analyses.

If required, wood can also be tested at the laboratory using traditional methods (e.g. standardised strength tests). The necessary apparatus and tools for wood machining are also available.

4 Capabilities generated and utilisation of results

See previous section.

5 Publications

Jorma Heikkinen, ”Tutkimuspenkki puun tutkimista varten” (Test bench for the study of wood), final paper in engineering, Kajaani Polytechnic, 2000 (in Finnish).

Marko Brilli, ”Software and motor controller card for an ultrasound measurement station”, final paper in engineering, Kajaani Polytechnic, 2001.

P. Eskelinen, H. Eskelinen, J. Räty and M. Sorjonen, ”A microwave measuring system for the analysis of trees and logs”, MIOP-2001 conference, 8-10 May 2001, pp. 182-185.

Intermediate and final reports of the project.

6 Cooperation

The project control group included representatives of:

- Municipalities and other authorities: Regional Council of Kainuu, town of Kajaani, town of Kuhmo, municipality of Suomussalmi, Tekes.
- Research institutes: Infotech Laboratories, Measurement and Sensor Laboratory.
- Enterprises: Kuhmo, Ponsse, PRT-Wood, Valutec, United Sawmills.

Cooperation (microwave measurements) with the Lappeenranta University of Technology and Helsinki University of Technology.

7 Research team

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