State-of-the-Art Kebony Factory and its Main Products

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ABSTRACT

Kebony ASA has commissioned a new factory for manufacturing Kebony wood. The factory is designed with the newest knowledge generated by Kebony ASA for the kebonation of various wood species, and has several distinct design features that will allow large scale production of Kebony wood in a manner that ensures minimal impact on the external environment, high production throughput, assured product quality and product mix flexibility combined with optimal occupational hygiene. Kebony has been through a rapid commercialisation process during the last years. Products with total revenue of more than € 10 million have been supplied to a variety of projects and applications areas from the first semi-industrial production plant. The new factory is planned for serving Kebony's main segments and will enable the company to enter a new growth phase, based on the main Kebony product lines.

INTRODUCTION

The demand for Kebony wood has increased sharply since the first semi-industrial Kebony production was started in Porsgrunn, Norway, in 2004. This operation was based on furfurylation processes invented for water borne impregnation mixes of furfuryl alcohol (Schneider 2001, 2002). Already in 2005 the first decisions were made to build a dedicated commercial scale factory for the production of Kebony wood. Besides meeting the demands on safety and environmental criteria, it was important that the factory should be both streamlined for high throughput and at the same time flexible enough for producing different types of high quality Kebony products. The planning of the new plant started in 2006, and the plant was commissioned November 2008. The total investment is € 22 million.

INITIAL REQUIREMENTS

The start-up factory

The first Kebony factory - 'Kebony Products' - was constructed at Norsk Hydro's large Heröya industrial site in 2004. The most important reasons for selecting this site were incentives and motivation to start new enterprises, both from local authorities and the business community; a well suited industrial infrastructure with easy access to steam, electrical power and water, as well as available buildings, offices and even some process equipment. However, this set-up was not designed as a long-lasting facility, but rather as a semi-industrial start-up. A lot of the equipment was sub-optimal for Kebony's use - several elements of the plant were based on second-hand equipment with a limited lifetime. Furthermore, the production capacity was less than 3000 m^3/year.

Originally the plant only consisted of an impregnation autoclave and a steam curing chamber, with the necessary tanks, pumps and piping *etc*. After a short while a Nardi drying kiln was installed, and in 2006 a vacuum drying kiln from WTT A/S was added.

Market Needs

From the initial marketing began in 2004, cladding and decking boards of Kebony Pine, previously branded "VisorWood", have been the most demanded of the Kebony products in the Norwegian home market. In addition, there is increasing demand for a range of other products based on different wood species. Examples are decking boards from kebonized southern yellow pine (Kebony SYP), solid wood flooring of kebonized ash and beech and special teak substitutes from Kebony Maple. With its semi-industrial setup Kebony Products was able to produce a variety of products, but demand outgrew capacity already a couple of years after the initial start-up. Simultaneously the interest for special products grew rapidly in several European continental markets. Consequently, the need for a larger and better adapted production plant became apparent already in 2005.

Initial requirements for new production capacity

Based on the experience from the first years of operation of the Kebony Products plant, and the market responses, the following main requirements were set for the new production capacity:

- Annual output capacity above 20 000 m^3 Kebony
- Flexible production technology that could produce both softwood and hardwood based Kebony
- Production technology that could deliver products suited for both outdoor and indoor applications
- A production layout with a high level of automation.
- Flexibility in wood raw materials.
- Post-processing of finished products

The combination and balancing of these requirements, into a result that gave an economical, robust and flexible production system contained serious challenges, since this plant is the first commercial scale production of furfurylated wood.

Project Organisation

The design and construction of the new Kebony plant was done in two main project phases: The pre-study, which had as its main goal to determine feasibility and cost estimates of alternative solutions to production layout, site selection, equipment alternatives, utilities etc., and the main project following the "decision gate" from the pre-study. The main project was organised with a steering group, a project team and suppliers and contractors managed by the project team. The steering group was Kebony ASA management, while the project team was responsible for the planning, progress and follow-up, and consisted of both external and internal staff.

PROCESS PRINCIPLES

The basic principles of the Kebony process have been described previously (Lande *et al*. 2004), but a considerable amount of technical know-how is required to ensure a smooth and economical production. The process consists of the following main parts:

- Receiving and preparing wood starting material
- Preparation of impregnation mixture
- Full cell impregnation
- Curing and drying
- Post-processing of products
- Recycling of unspent mix and condensates

Experience from the first semi-industrial Kebony plant was that the vacuum drying technique provided a flexible way of drying, which could be made relatively gentle towards products that were sensitive to cracking and checking during conventional kiln drying. Production of Kebony based on hardwoods like beech and ash were thus much more robust using vacuum drying than kiln drying. And, since furfuryl alcohol, the main organic ingredient of the treatment mix, has a much higher boiling point (170 ^{o}C) than water, the water can be removed prior to curing when using vacuum drying - since drying temperatures then are well below curing temperatures. On the other hand, softwoods, especially Scots pine, can tolerate tougher drying schemes than the hardwoods, so for the Kebony Pine the vacuum drying is unnecessarily gentle. By using more rapid heating to a higher level, without using vacuum, the curing and drying can then be done in one step. This technique is much faster both in curing and drying, and consequently more economical for a high throughput of Kebony Pine. Thus, in designing the factory, both the rapid combined drying and curing of softwood based Kebony, as well as the vacuum drying technique had to be catered for.

PRODUCTION LAY-OUT

Impregnation

The impregnation autoclave is 13 m long by 3.25 meters in diameter. The impregnation liquid is introduced by pumping from the buffer tank containing the impregnation mix. The autoclave itself is designed for pressures ranging from 0.1 to 13 bar, enabling full-cell impregnation cycles. A special feature of the autoclave is that it can be tilted up to *ca* 5 degrees in longitudinal direction. This function removes excess of liquid on the surface of the boards and thus prevents unwanted layers of polymer formed on the board surfaces.

Curing and Drying

After impregnation, the products must be cured - that is the step of applying heat that actually brings about the in situ polymerisation of furfuryl alcohol to furan polymers in the impregnated wood fibres. The Kebony dryers are specially designed vacuum dryers where both the drying and curing steps are carried out. The dryers have side-mounted fans giving a rapid circulation of the atmosphere in the vessel. In addition there are heating batteries for regulating the temperature during curing and drying. A final, special feature is spray nozzles for water and steam spraying inside the dryers, enabling moisture conditioning after the curing step. The condensate formed in the dryers during

drying and curing is collected and re-used as process water in the dilution of new impregnation mix. Since the impregnation step is much faster than the curing and drying steps, the factory is equipped with much higher dryer volumes than the impregnation autoclave volume. There is one single autoclave taking six stickered packs of wood of 4.2 m by 1.2 m in one sideways row two packs high, while the dryers take two rows sideways which each is two packs high. The current setup thus uses four dryers with the one autoclave. Two of the four dryers are equipped with higher capacity heating batteries, which make a more rapid heating possible. These two dryers are dedicated to the rapid combined drying and curing of Kebony pine.

Internal Transportation

An automatic transportation system handles the wood starting materials and transports the wood during the process. The starting materials are off-loaded onto lateral conveyors and taken through a stacker system. From there the stickered packs are loaded on to the transport wagon that is shifting rows of packs between the autoclave and the dryers. After drying and curing the packs are pulled out from the dryer and off-loaded by forklifts to the conveyor where they go to the de-stacking system. From here the products can be packed for shipment or taken further to planing, profiling and finally to quality control by scanning and manual inspection before they are finally stacked and packed.

UTILITIES AND ADD-ON SYSTEMS

Utilities

Cooling water to the plant is delivered from the municipal water basin. Air compressors are installed in a separate compressor room and supply pressurized air to the plant.

Machining

A separate stacking/de-stacking line handle stacking and de-stacking of mainly Kebony Pine materials. This line has also 4 cross cutting saws installed to produce short lengths. The main line contain a de-stacker system, a resaw for splitting boards, a four-side moulder with the possibility of using up to 9 spindles. After the moulder, an automatic WoodEye wood scanner (http://www.ivab.se/en/) grades the boards into different quality categories, which again automatically can be directed to sorting bins or further cutting (for example for removal of cracked board ends). There is also automatic dimension measurement of the boards. The line also contains two packing machines including a foil machine and a labelling and wrapping station.

Quality Control

The wood scanner can grade both the starting materials and finished products on parameters like knots, cracks and colour deviation. There is also grading stations for manual control of the materials. The final products are analyzed for moisture content and chemical residuals by in-house laboratory tests.

Energy supply

The drying/curing chambers use saturated steam at 5 bar as heat source. The steam is produced in a boiler system based on propane gas as fuel. The boiler is installed in a separate boiler house. A propane tank and an evaporator were installed for supply of gas to both the boiler and the regenerative thermal oxidizer.

Ventilation and Off-gases

All tanks and other vented equipment are connected to a process ventilation system to avoid odours and diffuse gases in the plant. All off-gases from the process are pumped to a thermal regenerative oxidizer where they are converted to CO_2 at 800 ºC.

THE PRODUCTS

Outdoor applications

The main volume of exterior products is made from Scots pine, the Kebony Pine product. The treatment level that is used on these products give a long durability against rot, and an even tar-brown colour and increased dimensional stability to the products.

Cladding and decking account for roughly 80% of the produced volumes. All these products are profiled and planed before the kebonation treatment, since planing or profiling after treatment obviously will expose un-treated heartwood and create unwanted colour contrasts. Outdoor products based on other species cover a range of different applications, and the machining is done *after* the kebonation process, in order to ensure a good finish and high dimensional accuracy. This is a good solution since the products consist solely of treated sapwood:

Kebony SYP - Kebony based on southern yellow pine with treated sapwood on three or four sides - is used for more exclusive decks and claddings than the products based on Scots pine. Kebony SYP has also been used for windows.

Kebony Beech - a homogeneous product with high durability, high hardness and a deep brown look - as an alternative to tropical timber for decks, handrails, stairs *etc*.

Kebony Maple - another product with high durability, hardness and slightly lighter colour than Kebony Beech. This product is made from American hard maple sapwood, and has been in demand as an alternative to Burma teak on pleasure boats, decks and some special exclusive building parts - even as cladding on a few occasions. All the outdoor products produced by Kebony today are treated with the same furfuryl alcohol solution, and the actual solution gives a durability class 1 or class 2 according to EN-350 (Lande *et al*. 2004, Alfredsen and Westin 2009).

Indoor applications

Kebony products for solid wood indoor floors may be varied in treatment levels since resistance to microbial decay can be ignored. The main features of Kebony floors are hardness, appearance like tropical hardwoods and dimensional stability. Important parameters of floor boards from different Kebony products with different surface treatment systems have been tested, and the conclusion is that also when subjected to rigorous technical tests the Kebony floors perform very well (Tjeerdsma 2008). Kebony floors can be made from a range of wood species: Beech, maple, ash, radiata pine and southern yellow pine. After kebonation the boards are planed, profiled and packed in Kebony's own plant. The moisture content of the Kebony products from the vacuum drying process is very near the theoretical moisture content that is ideal for indoor wood

flooring, so no special conditioning is required after production. Moisture proof packing immediately after production is protecting the boards from additional moisture uptake.

CONCLUSION

The new Kebony factory is the first commercial scale production of furfurylated wood, and its design is based on Kebony's patened technology and the know-how developed by Kebony during the operation of the semi-industrial plant that was started in 2004. The layout of the factory has the flexibility to produce products based on different wood species and for different applications, while at the same time the equipment has sufficient size and automation to produce large series of standardized products.

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