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THE METHODS OF IMPREGNATION AND THERMAL MODIFICATION OF WOOD

Solid materials are classified into a few main groups, such as, metals, ceramics, polymers, and composites. Naturally-occurring wood is classified into the composite group, and it is one the oldest materials utilized by human beings. Today, several different materials are available to meet the needs of the modern society, and selecting the right material may be a problem in many places. However, the economic point of view can be the deciding factor in the material selection. A material may contain an ideal set of properties but be prohibitively expensive (1).

In addition to the positive environmental impact, wood has a large number of favorable properties which contribute to its use in many applications. Favorable properties are, inter alia, easy workability, good insulation, and high strength compared to weight. However, some of the inherent properties of wood impair its competitiveness, such as vulnerability to moisture, biological organisms, and weathering. Due to its hygroscopic nature, several physical properties of wood become undesired with the moisture change. Wood starts to shrink when moisture is removed below the fibre saturation point (FSP), and contrarily, dry wood starts to swell with water contact. The shrinkage and swelling of wood varies between the growing directions due to its anisotropic nature (4). Depending on the temperature and moisture conditions, biological organisms may attack wood and degrade its quality (2). Environmental factors, such as solar radiation, can destroy the texture of the wood surface, which is reflected as a grey, cracked, or rough surface (3).These susceptibilities have led to the development of wood protection to enhance the qualities of wood. Several countries have made significant investments in the research of wood preservation (5).

The development towards urbanization and demographic evolution will affect the requirements of building products (1). The competing products can reduce the use of wood. The construction industry is a big user of wood products, and wood-frame buildings have become common in several European countries. Wood is a safe material under high stress conditions, but the challenge for wider utilization is national fire regulations, which restrict the use of wood in many countries. However, it should be remembered that a layer of char is created when wood burns, and this char layer ensures the structural integrity of wood, reducing the risk of collapsing concurrently. The opportunities relating to the use of wood in construction are not fully exploited. at the moment A positive building policy toward wooden multi-storey construction can lead to a larger use of wood, and using more wood in construction could save global carbon dioxide (CO2) emissions and fossil fuel consumption substantially (3).

Keywords: equilibrium moisture content; thermally modified wood; vacuum; thermally modified ash wood; thermo gravimetric, method; weight method.

Impregnation modification. The impregnation modification of wood results in filling of the wood substance with an inert material, providing a desired performance change. The presence of material in the wood cell wall can affect several properties of wood. The fixation of the impregnator within the cell wall of wood can take place by two main mechanisms: by monomer impregnation or by diffusion. Generally, a monomer (or oligomer) solution penetrates into the cell wall, followed by subsequent polymerization. In the other fixation mechanism, a soluble material is diffused into the cell wall so as to render the material insoluble afterward (3).The best known impregnation methods are full cell treatment Bethel and empty cell treatments. The initial vacuum in the full cell treatment method, which evacuates air from the wood, is the most noticeable difference to the empty cell methods. Full cell treatment is generally used for water-borne solutions, where maximum solution retention is desired. The empty cell treatment is often used with oilbornesolutions, whose requirement for net solution retention is much lower (3).

The chemical structure of wood components has an influence on wood penetration and reactivity. The hydroxyl group is the main chemical group in wood cell wall biopolymers, and it is mostly responsible for the chemical reactivity of wood (1). It should be mentioned in this context that the water content of wood is critical because the hydroxyl in water is more reactive than the hydroxyl groups available in wood components. The cell wall must be in a swollen state during the impregnation phase tonsure the accessibility of the impregnator. A catalyst or a workable co solvent may beaded to cause the wood to swell, and almost all chemical reactions require a catalyst. However, it would be desirable to avoid multi component systems in the treatment as they require complex separation procedures at a later stage. An increase in temperature may improve the penetration, but the temperature of about 120 °C is the safe upper limit in there action. Generally, the reaction conditions must be mild enough in order to avoid undesirable properties of wood. Of the structural components of wood, lignin is more sensitive to substitution than the carbohydrate components (3).

The properties of the impregnation solution have an effect on the impregnation result. It's a foregone conclusion that the molecular components of the impregnator should be small, so that it can gain access to the cell wall interior. Some studies have shown that a molecular diameter of approximately 0.68 nm is the limit for the penetrating liquid, but its hydrogen-bonding ability has also a significant effect. Molecules with a greater tendency to form or break hydrogen bonds show greater penetrating ability. A chemical bond between the impregnator and cell wall may occur, but it is not a requirement for impregnation. However, the impregnator must be nonleachable in service conditions (2).

The status of the bordered pits has a great effect on the treatment of wood. The pit membrane is composed of a network of micro fibrils, called the margo, with a central thickened area, called the torus. When wood dries, the pit membranes move toward the pit apertures, isolating the conducting pits. This process is known as aspiration, and is illustrated in Fig. 1. Microscope pictures of unsprayed and aspirated bordered pits are presented in Fig. 2.

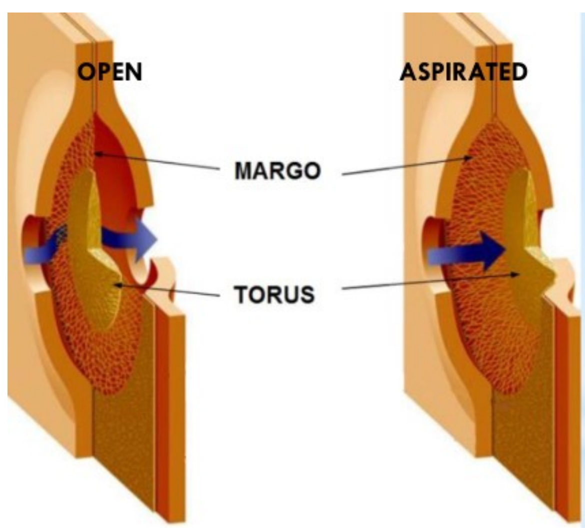

Fig. 1. Simple illustration of pit aspiration. In the open system, conduction via the pit(the blue arrow) occurs through the margo, while in the aspirated system, the torus has moved and conduction is inhibited (2)

The once aspirated pits remain at the aspirated status. A majority of the pits areunaspirated in green sapwood, while after drying, a majority of the early wood pits and about half of the latewood pits are aspirated. The weaker aspiration of latewood is due toe thicker Margo and the different shape of the pit, and therefore the pits of latewood don't close as easily as those of early wood (1). Also, the thickerS2 layer in the cell wall of latewood results in less pit aspiration. The penetration of liquids into latewood takes place partly by capillary action in the small lumens and passage through inspirited pits (2). In addition to aspiration, the more suitable treat ability of pine sapwood compared to other softwoods is explained by the opportunity of collapse of the thin-walled cells on drying (2). The most sensitive part of wood is from one to three growth rings -wide transition zone, which islets permeable than sapwood and less durable than heartwood (2)

AB

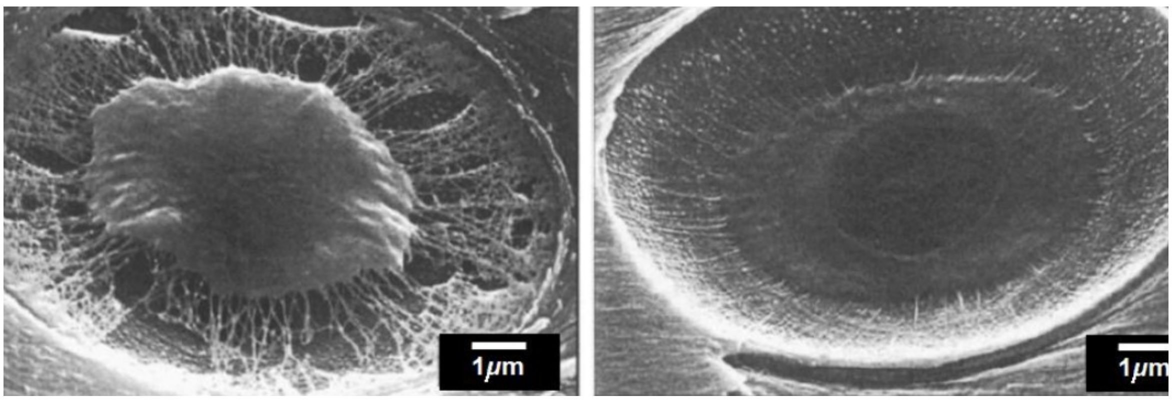

Fig. 2. Microscope picture of unaspirated (A) and aspirated (B) states of bordered pitsof pine sapwood. (2)

Generally, a high density of wood makes penetration more difficult (1),but penetrability varies also between wood species. In softwood, longitudinal permeability is dominant compared to transverse perm abilities which are approximately104 times less in number. The permeability of hardwood is limited due to the pits between contiguous vessels. In addition, the vessels are not very long (5).Early wood has thinner cell walls which contributes to and accelerates the penetration of early wood compared the latewood. In addition, a raised temperature and pressure in crease the penetration due to softening of the pit structure and displacement of the pit membrane(3). In the study of Leroy et al. it is proven that the uptake of pine is double in the radial and tangential directions, compared to the corresponding uptake of beech, birch, and spruce. Pine has good penetrability in the radial direction, where the liquid can pass through the racially orientated large size ray tracheas of the average diameter of 15-35 µm.

In the case of adhesive penetration, two levels of penetration are discussed: micrometer level (gross penetration) and nanometer level (cell wall penetration). In gross penetration, a liquid agent with low viscosity flows into the porous structure of wood, filling the microscopic cell cavities. In cell wall penetration, the agent is diffused into the cell wall or micro fissures if the agent is composed of small-molecular weight components (3).

Thermal modification. The thermal modification of wood is the most advanced wood modification method commercially. It causes a desired improvement in the wood material by heat. Thermal modification is usuallyperformedbetween the temperatures of

180 °C and 260 °C (4). At these temperatures, wood undergoes important chemical transformations. At lower temperatures, between 20-150 °C, the wood dries with loss of free and bound water. The substrate of wood degrades undesirably, starting a carbonization process with the formation of CO_2 and other paralysis products (4). Several very able shaven effect on the treatment and the properties, such as the wood species, the sample dimensions, the treatment time and temperature, together with the treatment atmosphere and systems (5).

Thermal modification modifies the structure of wood cell wall polymers, creating new properties to the material (5). The general changes of wood components aredepicted in Fig. 3. Microscopic examination has demonstrated that the cellwallsweredecomposed to lamella and the walls were broken to sharp-edged chips (5). In thermally modified wood, the percentage of carbonincreases, and the amount of oxygen and hydrogendecreases (6). The mainvolatilecompoundsare water, formic acid and aceticacidfurfural (5). The thermal stability of polymers differs according to their chemical structure, and the presence ofoxygenduring treatment has a significant effect on the degradation of wood. It is generally recognizedthathard woodsaremoresusceptible to thermal degradation than softwoods. Due to the amorphous structure of hemicelluloses, thermal treatment degrades most of the structural components of wood, which further increases the amount of crystalline and re-organize the amorphousregion of cellulose. Cellulose demands ahighertemperature for changes, but lignin is the most ther mall stable component (4). The stability of cellulose is probably due to its crystalline nature. Muster attractive disappear or degrade during thermal modification (6), but the extractives canals move to the surface of the sapwood due to moderate thermal modification (6).

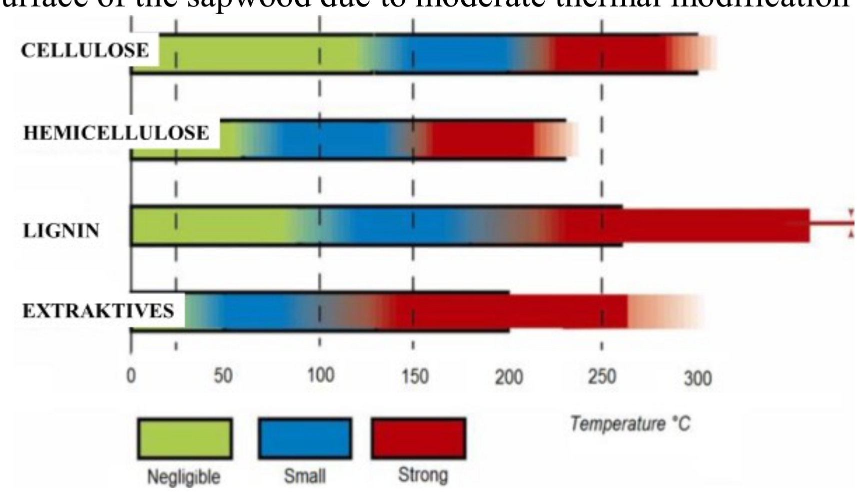

Fig. 3. General changes of wood components due to thermal modification. Adapted from Sundqvist (6)

The thermal modification of wood causes changes in the wood properties, for instance the color darkens and density decreases. The darkened colors of various thermally modified woods are presented in Fig. 4. Improved dimensional stability and decay resistance, together with reduced strength properties, are the characteristic alterations in thermally modified wood. The modulus of elasticity may increase slightly with the lightweight process parameters, but it too will decrease with the increased mass loss. A sufficient treatment time can increase the decay resistance of thermally modified wood to the same level with CCA-treated wood, which has 1 % retention (5). The permeability of wood is increased after thermal modification (6).

Fig. 4. The effect of Thermo wood- treatment on the colour of oak, ash and poplar. The treatment temperatures for Thermo-S - 185°C and Thermo-D - 215°C.

Conclusions.

The aim of this study was to investigate the impacts of selected modification substances and methods that improve or upgrade the material properties of solid wood without undue strain on the environment. The studied properties were weathering, moisture and mechanical properties, and fire performance. Also the effects of the modifier and the treatment parameters were assessed. The study revealed that wood modification can succeed and improve the properties of solid wood with certain parameters.

In conclusion, the functional properties of solid wood can be improved by a combination modification of impregnation and heat treatment. The effect of modification depends on the type of substance and the parameters used in the treatment phases.

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Методи просочування і термічної модифікації деревини

Конструкційні матеріали класифікуються за кількома основними групами, такими як метали, кераміка, полімери та композити. Натуральна деревинаодин з найстаріших матеріалів, що використовуються людьми. Сьогодні для задоволення потреб сучасної архітектури і дизайну доступні велика кількість матеріалів з різними естетичними і фізичними властивостями, і вибір потрібного матеріалу може бути проблемою в багатьох випадках. Однак, економічна точка зору може бути вирішальним фактором у виборі матеріалу. Матеріал може містити ідеальний набір властивостей, але бути непомірно дорогим.

Крім нейтрального впливу на навколишнє середовище, деревина має велику кількість позитивних властивостей, які сприяють його використанню в багатьох областях застосування. Сприятливими властивостями є, серед іншого, легкість в обробці, хороша теплоізоляція і висока міцність у порівнянні з вагою. Однак деревина має і негативні властивості, такі як; вразливість до вологи, біологічних пошкоджень. Завдяки своїй гігроскопічній природі деревина змінює свою форму, розміри і біологічну стійкість при зміні вологості. Всихання і розбухання деревини змінюються між напрямками вздовж і поперек волокон через свою анізотропну природу. Наведено аналіз методів просочення і термічної модифікації деревини з метою покращення її експлуатаційних характеристик.

Ключові слова: рівноважна вологість деревини; термічно модифікована деревина; вакуум; зольність термічно модифікованої деревини; термогравіметричний метод; ваговий метод.

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КОМПЛЕКСНІ ДОСЛІДЖЕННЯ ЗМІНИ ПРУЖНИХ ВЛАСТИВОСТЕЙ ВЖИВАНОЇ ДЕРЕВИНИ ЯЛИЦІ З ВІКОМ

Досліджено пружні властивості ВЖД ялиці різного віку (за терміном експлуатації), оскільки відсутні нормативні документи, що визначають фізико-механічні властивості вживаної деревини різного віку, які потрібні для прогнозування характеристик отриманих майбутніх виробів. Досліджено характеристики ВЖД поширеної породи ялиці в діапазоні користування від 0 до 20 років, з проміжним контролюванням властивостей через кожні 5 років. Визначено пружні (механічні) властивості ВЖД за такими показниками: міцність при статичному згині, модуль пружності при стиску, модуль пружності при статичному згині, модуль зсуву, коефіцієнти поперечної деформації, знайдено відносні деформації, визначено графічно залишкові деформації. Встановлено, що з часом експлуатації в різних умовах, зокрема на відкритому повітрі, механічні властивості змінились, в основному, у бік зменшення. Проаналізовано, що коефіцієнти поперечної деформації також змінюються і, виходячи із припущення про існування пружного потенціалу, мають виконуватись такі умови при яких ВЖД може характеризуватися як ортогональний трансверсально-ізотропний матеріал (особливо в клеєних конструкціях), як окремий випадок ортотропного. Доповнено базу даних показниками – механічними властивостями ВЖД різного віку деревини ялиці.

Ключові слова: вживана деревина, механічні властивості, пружні характеристики, міцність, модуль пружності, модуль зсуву, деформація, ялиця.

Аналіз літературних джерел. Деревина, як основний сировинний ресурс для виготовлення виробів з деревини, перебувала під постійним дослідження широкого кола науковців, що вивчали її з різних аспектів: структуру, фізичні та механічні властивості. Широко відомі праці таких науковців як Уголєв Б.Н., Боро-