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EFFECT OF SPENT ENGINE OIL WITH ADDITIVES ON WATER AND BIO RESISTANCE OF BIRCH AND PINE WOOD

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Abstract

A composition for impregnation of birch and pine wood was developed. The impregnation of samples 20x20 mm in size and 10 mm in length along the wood fibers was realized by the "hot-cold bath" method at 120^{o}C for 40 min. The efficiency of impregnating composition was evaluated according to physical parameters: water absorption, swelling in tangential and radial directions. It was found that impregnation of birch and pine wood with spent engine oil (SEO) allows improving the antiseptic properties and water resistance of wood and, hence, to decrease the water absorption and swelling of the wood of these species. To enhance the effect of hydrophobization of wood, inorganic (aerosol, clinoptilolite) and organic (oak bark flour) fillers (0.5; 1; 2%) were added to SEO. A non-linear dependence of the wood characteristics on the filler content in impregnating composition was observed. The addition of organic filler was more effective in improving the water resistance of wood as compared to inorganic ones. The impregnating composition with 1% of oak bark flour revealed the highest wood water absorption indicators, as a result, the present organic filler is the most promising in abatement of water absorption and swelling. The analysis of biostability of the samples allows us to ascertain that there is no biological damage in the impregnated wood. The present research illustrated that the use of SEO as a matrix for impregnation of birch and pine wood may partially solve the problem of its utilization, thereby creating the possibility of resource saving. The use of oak bark flour as a filler solves another problem – the obtaining of an effective and environmentally friendly impregnating composition.

Keywords: wood, impregnation composition, water absorption, swelling, inorganic filler, oak bark flour.

ВЛИЯНИЕ ОТРАБОТАННОГО МОТОРНОГО МАСЛА И НАПОЛНИТЕЛЕЙ НА ВОДО-И БИОСТОЙКОСТЬ ДРЕВЕСИНЫ БЕРЕЗЫ И СОСНЫ

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В данной работе разработан композиционный пропиточный состав для древесины берёзы и сосны. Пропитку образцов размером 20х20 мм и длинной вдоль волокон 10 мм осуществляли методом «прогрев- холодная ванна» при температуре 120 °С в течение 40 минут. Оценку эффективности пропиточного материала проводили по физическим показателям: водопоглощение, разбухание в тангенциальном и радиальном направлениях. Установлено, что пропитка древесины березы и сосны отработанным моторным маслом (ОММ) позволяет улучшить антисептические свойства и водостойкость древесины и, как следствие, снизить водопоглощение и разбухание древесины этих пород. Для усиления эффекта гидрофобизации древесины в пропиточный раствор ОММ вводили неорганические (аэросил, клиноптилолит) и органический (мука коры дуба) наполнители при различном процентном содержании (0,5;1,0;2,0). Обнаружена нелинейная зависимость исследуемых характеристик древесины от содержания наполнителя в пропиточном составе. Введение органического наполнителя более эффективно в сравнении с неорганическими для улучшения водостойкости древесины. Пропиточный состав с 1% муки коры дуба проявил наиболее высокие показатели водостойкости древесины, следовательно, данный органический наполнитель является наиболее перспективным для снижения водопоглощения и разбухания. Анализ биостойкости исследуемых образцов позволяет констатировать отсутствие биологических повреждений в пропитанной древесине. В данной работе показано, что использование ОММ в качестве матрицы для пропитки древесины берёзы и сосны позволяет частично решить проблему его утилизации, тем самым создавая возможность ресурсосбережения. Использование муки коры дуба в виде наполнителя решает другую проблему – получение эффективного, экологичного композиционного пропиточного состава.

Ключевые слова: древесина, пропиточный состав, водопоглощение, разбухание, неорганические наполнители, мука коры дуба.

Introduction

The wood remains one of the most affordable and environmentally friendly materials widely used in various industries and in everyday life [1]. However, the hydrophilicity of wood restricts the areas of its application. The presence of a variety of hydrophilic cavities and vessels in wood structure determines its hygroscopicity, and as a result, its swelling, cracking and changing the shape of product parts [2]. In addition, low biostability of wood, easily attacked by various types of wood-destroying fungi [3], also leads to a decrease in the strength indicators.

Birch wood refers to soft, diffuse vascular deciduous species. By contact with water birch wood easily starts decaying and this is inevitable during its exploitation. It refers to easily impregnated wood species [1]. Pine is a coniferous tree species. The main difference between pine and birch is the presence of resin ducts in its structure. The wood of pine is also subjected to rotting, which is its essential disadvantage.

New, effective and environmentally friendly modifying materials are being searched for in Russia and abroad to protect wood from external impact and to impart a set of necessary properties to wood products [4, 5]. One of the directions is impregnation of wood for stabilization of its dimensions (form stability), decrease of moisture and water absorption, cracking and increase of antiseptic parameters.

All impregnating compositions can be divided into antiseptics and hydrophobisers of mineral and organic origin. Traditional impregnating compositions of mineral origin are neutral salts of hydrochloric, sulfuric, hydrofluoric acids, sublimate ($HgCl_2$), sodium fluoride (NaF), copper sulfate (CuSO4*H2O), zinc chloride (ZnCl2). Compositions of organic origin include various oils produced from resins of dry distillation of coal, wood, e.g. creosote (creosote oil of coal, brown coal or wood tar), technological concervational liquid (ZhTK) of various modifications, tar, etc. [6, 7].

It is well known [8] that oil and oil products serve as an antiseptic for the protection of wood. An alternative material for the protective impregnation of wood can be oils, in particular used engine oils, produced from the base distillate oils. Basic oils mainly include aromatic hydrocarbons, polyolefins, paraffin hydrocarbons. A long work of oil in the engine changes chemical composition and liquid products of oxidation, residual fuel fractions, asphaltenes, carbenes, carboides, mechanical impurities (scale, carbonaceous particles, phosphates and calcium carbonates) appear in the engine oil. Spent engine oils proved to have antiseptic properties, cheap and are of low hazard (the fourth hazard class).

According to the data of AUTOSTAT, the consumption of motor oils by cars in Russia in 2016 exceeded 230 million liters per year and this figure continues constantly growing as the fleet of cars in the country keeps increasing. Despite this, nowadays, the utilization of spent engine oils does not have an industrial scale and is an urgent problem requiring an early solution.

In this paper, spent engine oil was used as the basis for the wood impregnating composition. The use of spent engine oils as an impregnating composition to a large extent solves the problem of utilization of wastes from automobile transport, and also allows reduces the cost of impregnated products.

The aim of this work was to study the effect of wood impregnation by spent engine oil with fillers of inorganic and organic nature on the water resistance and biostability of birch (hardwood) and pine (coniferous) woods.

Materials and methods

The objects of the study were samples of pine and birch wood in the size 20x20 mm in the radial and tangential directions, 10 mm in height along the fibers in air-dry state, as well as samples of impregnating compositions based on spent engine oil (SEO) and fillers of inorganic and organic nature. As fillers were used: 1) artificial silicon oxide (A300) - a nanoscale, non-porous material; 2) clinoptilolite (95%) - natural aluminosilicate of the zeolite structure (Zt); 3) oak bark wood flour (WF). The content of the filler was 0.5, 1.0, 2.0 (w. %).

The impregnation of the wood samples with compositions based on the SEO was carried out by the diffusion way applying the method of "hot-cold baths" (HCW), which is widely used for wood treatment with antiseptics, flame retardants, and hydrophobic agents [9]. The samples were placed into the impregnating composition heated to 120 ^{o}C and hold for 20 min, then transferred to an impregnating composition at ambient temperature for the same duration (20 min).

The effectiveness of the impregnating compositions used to increase the water and biostability of wood was evaluated by the following parameters: water absorption (W,%) according to GOST 16483.20-72 [10], swelling in tangential a_t,% and radial a_r,% directions (according to GOST 16483.35- 88 [11]) and biostability by the contact of wood samples with water for 1, 10 and 30 days.

The amount of impregnating composition (Q,%) in the wood was determined by gravimetric method according to GOST 20022.6-93 [9].

Biostability of wood was determined visually by the presence of biological damage on birch and pine wood samples after being in water for 30 days.

Results and discussion

Fig. 1 shows the values of water absorption, swelling in the tangential and radial directions, the amount of impregnating composition absorbed for the samples of birch wood after impregnation with compositions based on SEO with additives of fillers.

According to Fig. 1, the use of the "hot-cold" bath method for the impregnation of birch wood by SEO made it possible to effectively perform this process and introduce the impregnating composition into the volume of wood by the amount of above 40%. A feature of the applied impregnation method is the formation of a vacuum as a result of the temperature difference in the volume of the wood. As the temperature rises, the volume of air in the wood increases with partial evaporation of moisture, and as the temperature of the impregnating composition falls, the air volume decreases and the vacuum is formed, facilitating it penetration into the wood at atmospheric pressure. Subsequent immersion of the sample into cold oil prevents the release of the absorbed impregnated composition from the wood. The addition of Zt and WF fillers into the impregnation composition in an amount of 0.5-1 w.% increased the impregnating capacity of the formulation, but a further increase in their content tended to lower amounts of absorbed impregnating composition (Fig. 1).

The analysis of the obtained values allowed one to estimate the linearity of the change in the content of the impregnating composition in wood from the nature of the filler in the amount of 1% (Fig. 1). The dependence of water absorption of wood on the nature of the filler observed an extremum at 1% of aerosil in SEO. The impregnation of birch samples by SEO without introducing the fillers significantly reduced their water absorption (by 2.9 times). By introducing the inorganic artificial silica (aerosil) into SEO in the amount of 0.5-2 % (w.) the water absorption of wood slightly increased from 1 to 6% (Fig. 1) due to the substantial hydroxylation of the aerosil surface. This facilitates the formation of hydrogen bonds between hydroxyl groups of aerosil and hydroxyls of water and is the cause of increased swelling in the tangential and radial directions (Fig. 1).

In case of clinoptilolite (Zt) filler all determined characteristics of water absorption by natural and impregnated wood samples varied via an extremum depending on the content of the filler. Namely, the highest amount of impregnant absorbed was found at 1% Zt in SEO formulation that resulted in the lowest swelling in two directions for the samples treated by this formulation. The value of water absorption of the sample in case of SEO+1%Zt formulation is comparable with that for formulation SEO and SEO+0.5%A (Fig. 1).

The addition of organic natural filler in the form of wood flour of oak bark (WF) led to a nonlinear dependence of water absorption on the filler content. A higher water resistance of wood was observed by introducing 1% of WF filler in SEO formulation (according to water absorption data), which naturally results in a decline of the tangential and radial swelling the sample. As compared with other fillers used, wood flour of oak bark is more effective, apparently as a result of higher chemical affinity for the structural components of the wood.

Thus, the analysis of the obtained results allowed choosing 1.0% content of the filler for the impregnation of birch wood as the optimal one.

On the next stage, a possibility of application of the developed compositions for the impregnation of another wood species, i.e. pine, was investigated.

Table 1 illustrates the data on water resistance of pine wood before and after impregnation by the developed compositions. The nature of the fillers and their content were the same as presented in Fig. 1.

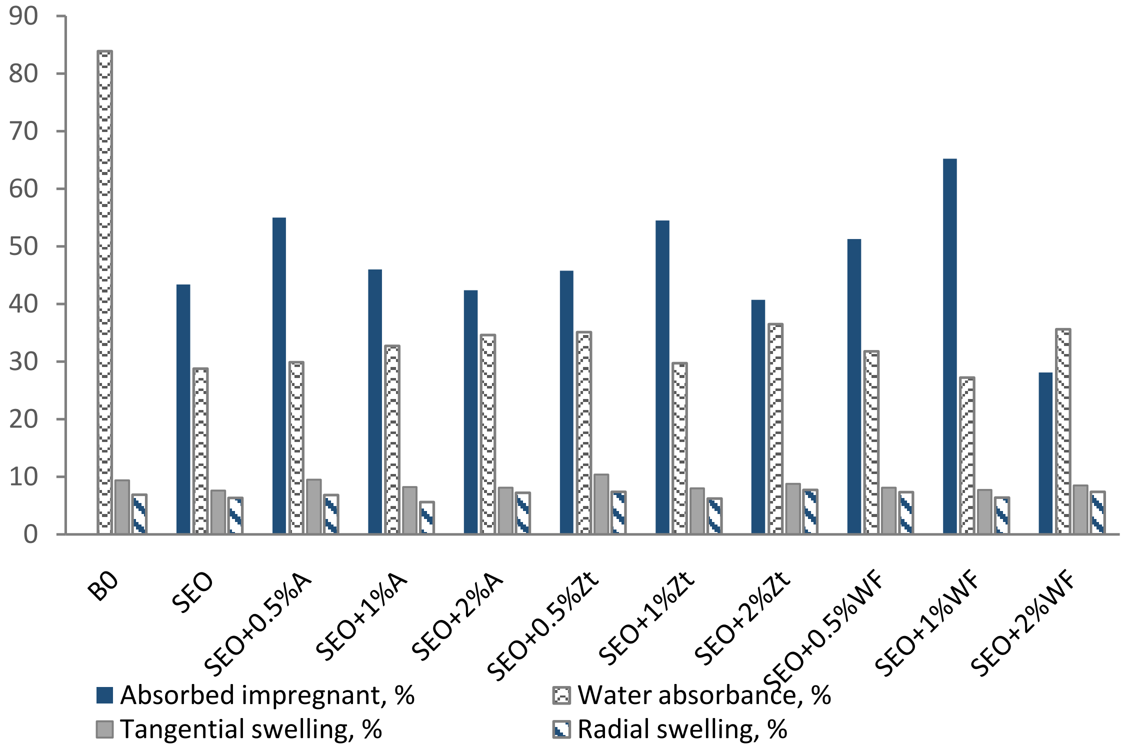

Fig. 1. Indicators of water resistance of birch wood samples impregnated with SEO without and by addition of fillers of A-300, Zt, WF

Table 1

Indicators of water resistance of pine wood before and after impregnation by compositions based on SEO and inorganic/organic fillers

Wood sample	Amount of impregnating composition absorbed by wood, %	Water absorption, W , %		Wood swelling			
				a_t, %		a_r, %	
		1 day	*30 days*	*1 day*	*30 days*	*1 day*	*30 days*
P0	-	43.1	91.0	5.3	12.3	3.3	8.7
P-SEO	46.1	7.9	35.0	2.8	10.4	1.5	8.1
P-SEO+1%A	55.2	6.8	31.6	1.8	9.7	0.8	7.3
P-SEO+1%Zt	47.3	6.9	36.1	2.8	9.6	1.0	8.3
P-SEO+1%WF	54.5	7.6	29.7	2.6	8.0	1.0	6.2

The impregnation of coniferous wood species (pine) differs from the impregnation of hardwood. The structural composition of coniferous wood species contains tar pitches (resin ducts), the content of which from the total volume in pine wood is 0.7% [1]. They prevent filling of the intercellular spaces and voids of wood with the impregnating composition.

The amount of impregnating composition in pine practically does not change in comparison with the data obtained for birch wood (Fig. 1, Table 1). With the introduction of 1% of aerosil in SEO, the amount of impregnating composition absorbed by pine sample increased by 9%; with the addition of 1% of Zt it did not practically changed, and when filling the formulation with WF the amount of impregnant significantly increased (by 11.3%) as compared to that for birch wood samples.

The water absorption of pine samples under no impregnation after 1 and 30 days of contact with water was 43.1% and 91.0%, respectively. The addition of 1% A into SEO formulation cause a decrease in water absorption of pine samples, i.e. by 6 times after 1 day and by 3 times after 30 days of contact with water. The highest water resistance during 30 days of water absorption conditions was shown by pine wood sample impregnated by SEO+1%WF.

At the initial stage of water absorption (1 day of contact with water) the lowest tangential and radial swelling was observed in pine wood sample impregnated by SEO+1%A. At the later stages of water absorption (30 days) the least swelling in two mutually perpendicular directions was found for wood samples impregnated by SEO+1%WF.

Comparison of the impregnation characteristics for pine and birch wood shows that in case of impregnation of both wood species by SEO with no fillers their impregnation ability is comparable. On the other hand, application of wood samples by SEO+1% filler formulations testifies to their different impregnation ability. The higher amounts of impregnant absorbed by birch wood (Fig. 1) indicate that this wood species is easier impregnated than pine wood (Table 1). Moreover, the values of a_t, and a_r for birch wood samples confirm their higher dimensional stability against that of pine wood samples.

The effect of SEO+1%WF formulation on water absorption and shape stability of wood is similar for both birch and pine wood species.

The kinetic dependences of water absorption of birch and pine wood before and after impregnation are given in Fig. 2.

As follows from Fig. 2, the water absorption of unimpregnated wood (B0 and P0) occurred at a high rate in comparison with the samples of impregnated wood. During the first day of contact with water natural birch and pine wood absorbed about 40% of moisture. Subsequently, the water absorption process slowed down and developed almost at a constant rate of about 3% per day for both types of wood.

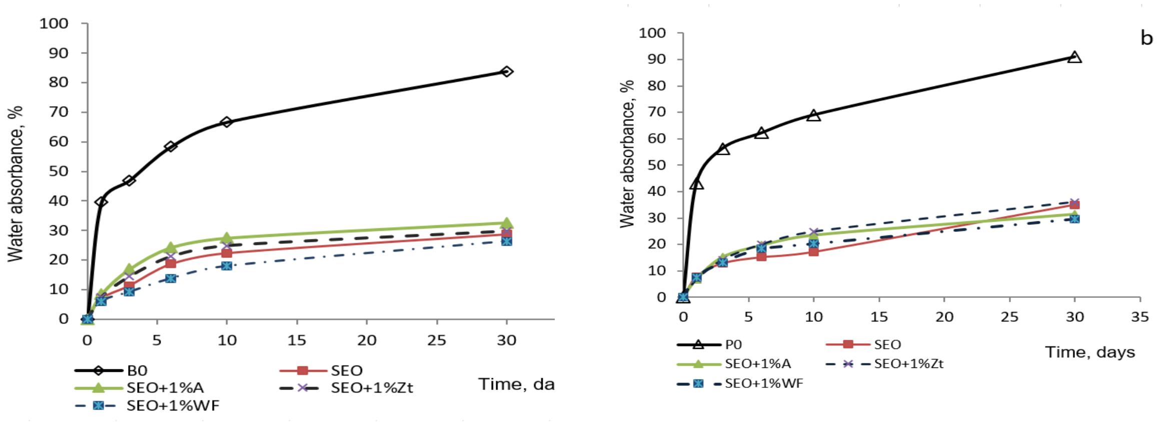

Fig. 2. Kinetic dependences of water absorption of birch (2a) and pine (2b) wood before and after impregnation by different SEO based compositions

The kinetic curves in Fig. 2a and 2b indicate that the treatment of the test samples with impregnating compositions reduced their water absorption by an average of 3-5 times and significantly slowed the water absorption process from 2% per day during first 2-10 days to 0.5% per day for water absorption within more than 10 days. As opposed to the untreated samples of natural wood, the samples treated by impregnating formulations were able to absorb only about 8-9% moisture in the first day of process. Subsequently, the rate of water absorption in the case of impregnated wood was ~0.25% per day for birch and ~0.5% per day for pine sample.

The value of water absorption (after 30 days) of unimpregnated pine wood (P0) samples was 7.4% higher than that of natural birch w ood (B0). Within 10-30 days of water absorption process there was a slight increase in moisture absorption by birch, especially in the case of impregnation by SEO+1%WF (Fig. 2a). The difference of the kinetic curve for pine is the absence of saturation region (Fig. 2b) whereas for birch sample almost the plato was reached.

As a result of impregnation of wood by SEO the water absorption (by aging for 30 days in water) of birch and pine samples decreased 3-3.5 times. The higher water absorption values were reached for birch and pine samples treated by SEO+1%WF. The use of SEO for impregnation of wood significantly reduced water absorption ability of both deciduous and coniferous species (birch, pine), and the introduction of the filler to SEO composition improved this indicator by 3-6%.

A visual assessment of the biostability of the investigated samples during the water absorption test (30 days) revealed that for the samples of pine wood both before and after impregnation there were no visible signs of biological damage. Apparently, the presence of resin ducts in the structural components of the wood caused antiseptic properties of pine and prevented the formation of fungi and mold.

At the same time, on the samples of natural birch wood in the absence of impregnation there were minor biological damages appeared in the period after 10 days of contact with water. However, the use of developed impregnating compositions led to an increase in the biostability of birch wood samples for which traces of mold and fungus were not detected even after 30 days of water absorption.

Consequently, birch wood has weaker antiseptic properties, in comparison with pine, which negatively affects its exploitation performance [12].

Conclusion

1. It has been found that impregnation of birch and pine wood by spent engine oil made it possible to impart improved antiseptic properties and water resistance, thus decreasing water absorption and swelling of wood of these species.

2. Addition of inorganic (aerosil, clinoptilolite) and organic (oak bark flour) fillers to the solution of spent engine oil at different percentages (0.5, 1.0,

2.0 % (w.) enhanced water resistance of wood. The efficiency of organic filler exceeded that for inorganic fillers.

3. The evaluation of the prospects for the use of the investigated fillers in the impregnating composition was carried out by the change of the absorbed amount of impregnating composition by wood, water absorption, swelling in the tangential and radial directions. It was observed that wood flour from oak bark was the best filler from the presented ones to reduce water absorption and swelling in two directions.

4. The non-linear dependence of all investigated parameters on the content of fillers in the impregnating composition was determined, and the higher indices were obtained by addition of 1% of wood flour of oak bark.

5. The researches carried our illustrated that the use of spent engine oil as a matrix for impregnation of birch and pine wood is able to partially solve the problem of its utilization, thereby creating the possibility of resource saving. The use of oak bark flour in the form as a filler solves another problem - obtaining an environmentally friendly impregnation composition.

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МАТЕМАТИЧЕСКОЕ МОДЕЛИРОВАНИЕ ПРОЦЕССА СКЛЕИВАНИЯ ДРЕВЕСНОГО ШПОНА В УСЛОВИЯХ ПЛОСКОГО ПРЕССОВАНИЯ ФАНЕРЫ

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В целях повышения качества производимой фанеры, древесно-слоистого материала разработана математическая модель, описывающая склеивание древесного шпона в условиях плоского прессования. В основе предлагаемой модели лежат процессы, протекающие в вязкой (ньютоновской) несжимаемой жидкости, находящейся в слое между двумя движущимися навстречу друг другу плоскопараллельными плоскостями конечных размеров. В рамках принципов механики сплошной среды в условиях плоского деформированного состояния, отсутствия объемных сил и инерционных эффектов (малая скорость смыкания плит пресса) совместно решаются уравнения вязкости и неразрывности связующей жидкости. Полученное при этом уравнение Лапласа для давления решалось методом полиномов. Это позволило получить напряженно-деформированное состояние исследуемой жидкости в плоскости скольжения, результаты которого позволяют управлять параметрами давления и скорости прессования при склеивании шпона. Кроме того, получены аналитические выражения для кинематических характеристик клеевой массы: распределение скоростей по плоскости скольжения, позволяющее качественное построение линий тока, касательные к которым совпадают с направлением скорости течения. При измененных условиях нагружения получена формула для определения времени прессования и коэффициента вязкости клея. Предлагаемая математическая модель может быть использована для описания физических процессов, протекающих при прессовании не только фанеры, но и других многослойных клееных материалов: бумажно-слоистых пластиков, сэндвич-панелей и др.

Ключевые слова: математическая модель, шпон, вязкость, ньютоновская жидкость, склеивание, прессование.