STRUCTURAL STUDY OF THE SURFACE OF WOOD-BASED PANEL MATERIALS (LDSP, LMDF, MDF) USING SEM AND OPTICAL MICROSCOPY METHODS

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Abstract. The thesis presents a comparative analysis of the microstructure of widely distributed wood-based panel materials in the market of the Republic of Uzbekistan — particle boards (DSP), laminated particle boards (LDSP), medium-density fiberboards (MDF), and laminated MDF (LMDF) samples using scanning electron microscopy (SEM). Seven types of samples obtained from manufacturers in Russia, Iran, and the European Union were studied at magnifications from ×100 to ×6000, and a total of 95 microphotographs were analyzed. Microstructural parameters were evaluated on a 5-point scale, and an overall quality ranking of the samples was compiled. It was determined that the highest indicators belonged to European LMDF and LDSP samples (30/30 points), while the lowest indicators belonged to the Russian DSP sample (6/30 points).
Keywords: particle board, MDF, LMDF, LDSP, scanning electron microscopy, microstructure, resin distribution, porosity, quality of panel materials.

Wood-based composite panel materials — DSP, LDSP, MDF, and LMDF — are widely used in the modern furniture industry, construction, and interior decoration works. In recent years, panel materials imported from Russia, Iran, and European Union countries have become widespread in the local market of the Republic of Uzbekistan. However, the quality indicators of these materials — mechanical strength, formaldehyde emission level, moisture resistance, and durability of surface lamination — differ significantly among manufacturers. To explain these differences, an in-depth study of the internal microstructure of panel materials is of great importance.

Scanning electron microscopy (SEM) is considered one of the most effective methods in modern materials science for studying the internal structure of wood-based composites. Using SEM, it is possible to observe with high precision the arrangement of particles/fibers, resin distribution, the quality of the particle–resin interface, the formation of macro- and micropores, as well as the anatomical structure of wood cells (tubular cells — tracheids, bordered pits, perforation plates, and spiral elements).

The aim of the study is to comparatively investigate the internal microstructure of seven types of panel materials obtained from manufacturers in Russia, Iran, and European Union countries using SEM, to quantitatively and qualitatively evaluate microstructural parameters, and to compile a quality ranking based on the obtained results. The scientific novelty of the study lies in the fact that, for the first time, the microstructural indicators of the seven most common types of panel materials in the local market were comparatively analyzed within a unified methodology, and a quality ranking was developed.

In the study, seven types of panel material samples were selected: Russian DSP, Russian LDSP, Iranian DSP, European DSP, European LDSP, European MDF, and European LMDF. Cubic samples measuring 5×5×5 mm were cut from each panel material using a sharp ceramic knife. To preserve the microstructure, the fresh fracture method was applied. The samples were fixed onto an aluminum holder-disc using double-sided conductive carbon tape; no metal coating was applied.

SEM measurements were carried out in the laboratory of the Institute of Polymer Chemistry and Physics of the Academy of Sciences of the Republic of Uzbekistan under the following parameters: detector — secondary electron detector (SED); accelerating voltage — 5.0 kV; working distance — 11.8–13.1 mm; vacuum — high vacuum; magnification range — from ×100 to ×6000. Each sample was imaged from several different areas at various magnifications: ×100–×200 (general arrangement), ×600–×1500 (resin distribution and interface), ×1000–×2000 (anatomical structure), ×3000–×6000 (bordered pits and micropores). A total of 95 microphotographs were analyzed.

The microphotographs were evaluated on a 5-point scale according to the following criteria: (1) orderliness of particle/fiber arrangement; (2) uniformity of resin distribution; (3) strength of the particle–resin interface; (4) degree of porosity; (5) quality of the surface lamination layer (for LDSP and LMDF); (6) preservation of the anatomical structure of wood.

Results and discussion. The Russian DSP sample demonstrated low quality indicators: wood particles were arranged irregularly and loosely, and large macropores were observed between them. Resin accumulated in separate local areas; at ×3000 and ×6000 magnifications, the resin film on the cell wall surfaces was thin and discontinuous, indicating weak mechanical bonding at the particle–resin interface. The Iranian DSP sample was relatively denser but exhibited a non-uniform structure: local resin accumulation and signs of separation at the interface surface were identified.

The European DSP sample showed the highest quality among non-laminated DSP samples: particles were densely packed and oriented in the same (horizontal) direction, and uniform resin distribution was observed. At ×800–×4000 magnifications, a high degree of preservation of the wood anatomical structure was visible — tubular cells (tracheids), bordered pits, and conducting plates were clearly distinguishable.

The Russian LDSP sample demonstrated significantly better indicators than the non-laminated Russian DSP due to the lamination layer: a dense and smooth surface layer (approximately 50–100 µm thick) was observed, while the internal layer preserved the anatomical structure well. The European LDSP sample proved to have exemplary quality among laminated panel materials: the surface part had a very dense, smooth, and homogeneous lamination layer, the particles in the internal part were orderly arranged, resin distribution was uniform, and porosity was low.

The European MDF sample possessed a microstructure fundamentally different from DSP types — thin fibers (10–50 µm in diameter) formed a tightly interconnected network. The European LMDF sample exhibited the highest microstructural quality indicators among all investigated samples: fine fibers (10–30 μm) were tightly compacted, the resin covered the fibers in the form of a continuous layer, and no signs of separation were observed.

Table 1. Comparative ranking of samples based on SEM indicators (5-point scale)

Parameter	**Russian DSP**	**Iranian DSP**	**Russian LDSP**	**European DSP**	**European LDSP**	**European MDF**	**European LMDF**
Orderly arrangement	1	2	3	5	5	4	5
Resin distribution	1	2	3	5	5	4	5
Interface strength	1	2	3	5	5	4	5
Porosity (low = good)	1	2	3	5	5	3	5
Surface lamination	—	—	4	—	5	—	5
Anatomical structure	2	3	4	5	5	4	5
Overall rating	6	11	20	25	30	19	30
Quality level	Low	Low	Medium	High	Highest	Medium-high	Highest

The highest overall rating (30 points) belonged to the European LDSP and European LMDF samples, while the lowest rating (6 points) belonged to the Russian DSP sample. The identified differences can be explained by several factors: European factories employ modern continuous pressing equipment, precise temperature and pressure control, and particle orientation stages; high-quality MUF or PF resins are used; wood raw materials of the same grade grown under controlled conditions are utilized; and pressing conditions are strictly controlled within the framework of EN 312 and EN 622 standards.

The identified microstructural characteristics directly determine the macroscopic эксплуатацион properties of panel materials. An orderly, dense structure well coated with resin (European samples) ensures high bending, fracture, and compression strength, low water absorption, and a low swelling coefficient. A loose, disordered structure with uneven resin distribution (Russian DSP) leads to low mechanical strength, high water absorption, and a high swelling coefficient. A porous, open-pore structure results in higher formaldehyde emission, whereas a dense, closed-pore structure leads to lower emission.

Conclusion. According to the results of the conducted study: SEM was confirmed to be a highly effective method for evaluating the quality of wood-based panel materials. The highest quality indicators belonged to European LMDF and European LDSP (30/30 points), while the lowest indicators belonged to Russian DSP (6/30 points) and Iranian DSP (11/30 points) samples. The main causes of microstructural differences are the modernity of production technology, the composition and quality of resins, the homogeneity of wood raw materials, and pressing conditions. The obtained results may serve as a basis for establishing quality standards for local production in the Republic of Uzbekistan and for evaluating imported panel materials.

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