# EXPLORING THE POSSIBILITY OF PRODUCING NEW LIGHTWEIGHT COMPOSITE USING RECYCLED ALUMINUM AND MINERALIZED WOOD WASTE

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## 1. Introduction

Aluminum alloys are the second most used metallic alloys in buildings (skirting, roof, cladding, window and door frame, solar panel, staircase, air conditioning system, heat exchange system, furniture, curtain wall) and constructions (consumer electronic, power line, thermal and electrical engine, spacecraft component, component of land and sea vehicle), thanks to their low density, high ductility and specific strength, higher corrosion resistance than plain carbon steels in environmental atmospheric conditions, and could be 100% recycled, thus reducing the environmental footprint and ecological impact. Furthermore, aluminum is considered non-combustible (A1-Euroclass reaction to fire) because it does not sustain combustion. Some recent research works (Ubertalli., Ferraris., 2020; Ferraris et al., 2022) proposed the use of aluminum foams to produce core cavity in stiffer cast products for automotive and aerospace with increased stiffness, damping properties, vibration absorption, and acoustic and thermal insulation characteristics, even if the wide pore size distribution and the non-homogeneous localization of pores in the component cause anisotropy in material properties (Ferraris et al. 2021).

In this research it is crucial to focus on improving the efficiency of component materials (Turakhujaeva et al., 2023). Additionally, we investigated the macro and microstructure of the composite samples. Aluminum alloy components are manufactured using sand casting process. Sand casting is one of the oldest and most popular methods that allowing for the production of small batches. The process involves pouring liquid aluminum alloy into sand molds that contain Mineralized Wood (MW) chips inside cylindrical permeable cages, which serve as the core volume inside the component. The liquid aluminum infiltrates the spaces between the wood chips resulting, after solidification, in a continuous, interconnected metal structure, connected to the aluminum skin of the component.

## 2. Materials and methods

Four samples have been prepared. Mineralized Wood (MW) chips were selected based on two different size distribution, fine and coarse (Figure 1), oven dried at 103°C until a constant mass was reached, weighed and proportioned for each sample as reported in the Table 1.

**Table 1**

**MW weight and weight percent of coarse and fine chips used in the AMW composite samples (#)**

| Sample ID # | $MW_{wt}$ g | Coarse $MW_{wt}$ % | Fine $MW_{wt}$ % |
|---|---|---|---|
| 1 | 3.18 | 79% | 21% |
| 2 | 3.16 | 62% | 38% |
| 3 | 3.27 | 55% | 45% |
| 4 | 3.55 | 40% | 60% |

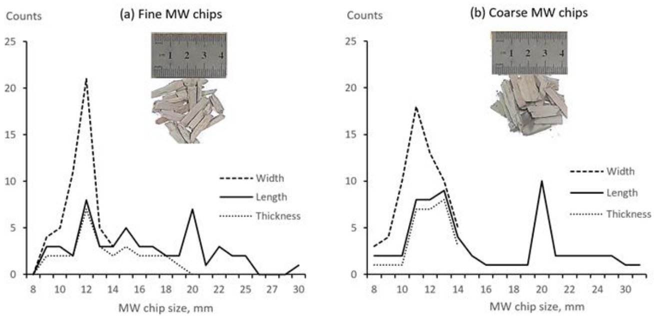
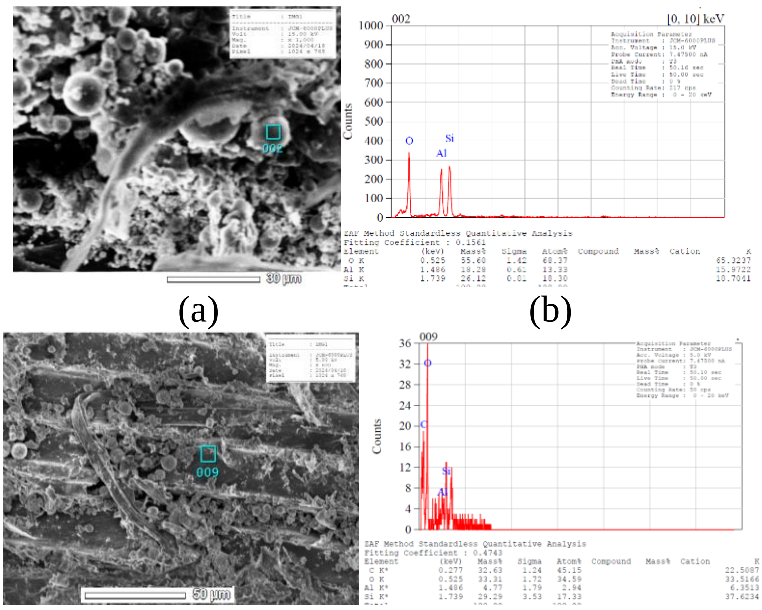



**Figure 1. Mineralized wood chips: particle size distribution (length, width and thickness) of fine (a), and coarse chips (b).**

In Figure 2 are reported the SEM micrographs of the spherical, silicon-rich, aluminosilicate particles formed in mineralization process (a) and the associated EDS spectra (b). These particles have a slight variation in Al, Si and O proportions and significantly differ in size. The morphology and elemental analysis indicated that the particles were composed of aluminosilicate spheres and probably traces of iron.



(c) (d)

**Figure 2. Micrographs of MW chips: SEM image (x1000) (a) and EDS elemental spectra of the spherical, silicon rich, aluminosilicate particles (b); SEM image (x600) (c) and EDS elemental spectra of wood (d).**

The micrographs of wood (c) associated with the EDS spectra (d) highlights the morphology of the long tubular wood cells and the deposition on wood cell walls of spherical, silicon-rich, aluminosilicate particles. EDS analysis on wood walls showed the presence of carbon and oxygen, which are the main elements in wood, and, possibly, also the impregnation of the walls by silicon-rich compounds.

The recycled aluminum alloy used for casting is the AK5M2, according to the GOST designation (GOST 1583-93, 1993). It is a foundry alloy of the system Al-Si-Cu used to manufacture shaped castings by various casting techniques, including sand casting, and having the chemical composition reported in Table 2.

**Table 2**

**Chemical composition of AK5M2 aluminum alloy (weight %)**

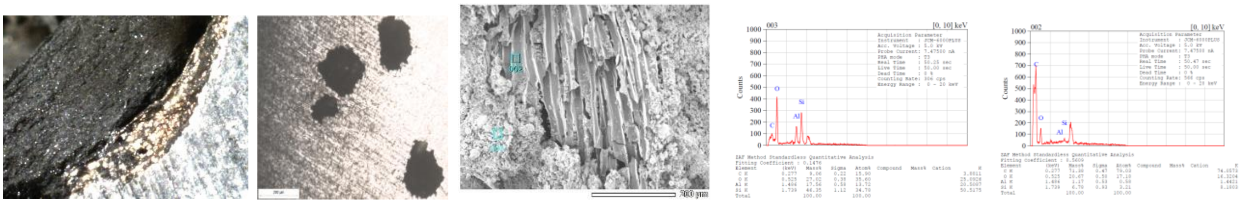
| Standard | Si | Cu | Fe | Ti | Al |
|---|---|---|---|---|---|
| GOST 1583-93 | 4-6 | 1.5-3.5 | ≤1 | 0.05-0.2 | Rest |

Four permeable cylindrical aluminum mesh cages containing the MW chips have been placed inside the molds. Sand molds are formed by packing sand around a pattern, which replicates the external shape of the desired cylindrical casting. These cages formed the core of AMW samples. Molten AK5M2 alloy is heated up to 750 °C, and it is than poured into the molds containing mineralized wood chips .

Characterization of samples was performed by macro observations (VEVOR Stereo Microscope), metallographic analysis (Leica Reichert Jung MeF3 microscope), SEM-EDS analysis (JEOL JED-2300 Analysis Station), CT-scan (performed in air by a custom-built Computed Tomography Fraunhofer IKTS, Dresden, Germany).

## 3. Results and discussion

After solidification, the axial section of the samples showed that the mineralized wood chip had become black in color (Figure 3a) undergoing a pyrolysis process with marked development of fume (observed during casting) and that the aluminum metal cage had melted, allowing to charred wood to float on liquid aluminum. The interface between wood and aluminum appears to copy the shape of the chips, but there is an almost continuous gap between the two materials, also due to the poor wettability of the wood. In the metallographic image of a cross-section (Figure 3b) some bubble-like cavities and nodule-like particles appear. We can assume that they have been generated by bubble gas developed during casting (Figure 4).



(a) (b) (c) (d) (e)

**Figure 3. Sample 1 after casting: macro image (a); metallographic image (b); SEM image of MW surface after casting (c); EDS analysis of spherical aluminosilicate particles(d); EDS analysis of MW after casting (e).**

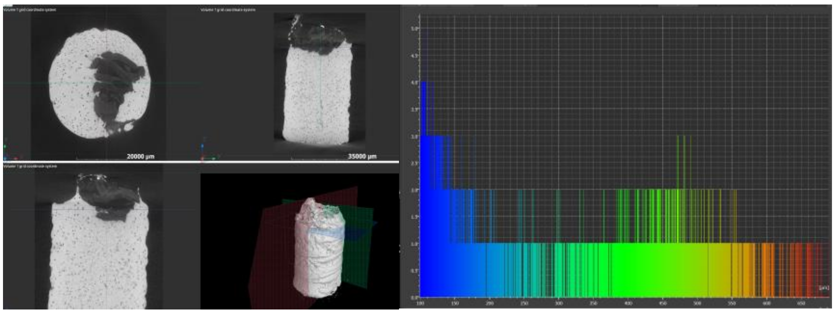


**Figure 4. Sample 1 after casting: CT-scan images.**

## 4. Conclusion

In this initial research, the feasibility of casting aluminum-mineralized wood composites was evaluated. The wood chip can guarantee the formation of a light component core, thanks to the low reactivity of the wood, when pyrolyzed, with liquid aluminum. The casting process highlighted some critical issues that can be addressed by improving the pouring step and optimizing the architecture of the AMW-based components. Our future efforts will focus on overcoming these problems and, also, optimizing materials and components.

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