Development of Wood Plastic Composite with Optimized Inertia

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Abstract – Regarding wood processing industry in Hungary the most of the companies are SMEs. Typical wastes are for such solid wood based production sanding dust, saw dust and shavings. These materials should be considered as by-products or secondary raw materials, which could be useful in other production processes. Wastes of plastic processing industry could be also considered as secondary raw materials for a new product. Combining these two types of by-product new wood-plastic products were developed for furniture and packaging industry. The main goal of this research (supported by European Union, European Social Funds, TÁMOP 4.2.1.B-09/1/KONV-2010-0006 and WPC_TECH BAROSS-ND07-ND_INRG5_07-2008-0087) was to find an easy production technology to process both wastes (by-products) into a lightweight product with high bending properties. First finite element simulations were done to determine optimal inertia for the product structure. Also optimal mixing ratio and particle size were determined to produce a suitable wood plastic compound. Finally aluminium press plates were produced to be able to produce the inertia optimized experimental products.

Major findings are: polypropylene - wood compounds were made with 60% of wood. Wood was applied in two different forms: saw dust (micro particles) and sanding dust (wood flour). Advantages of inertia optimized products are: production is based on by-products (formerly considered as wastes), simple production technology (dry blending also available besides compounding), low specific density compared to "clean" plastics, high strength, various utilization.

Keywords: WPC/ inertia/ compounds

1. OBJECTIVES AND HISTORY

The wood and plastics waste is a significant part of production processes. We consider that these wastes should not be handled as wastes, but rather as a by-product or secondary raw material. These materials with suitable technologies provide high value products. The worst of solutions are pointless burning or landfill. By our opinion it is environmentally and economically necessary that these materials should be processed in further products. By cascading these materials and products can store CO_2 (carbon pool).

A combination of the two materials which are definitely increasing at international level, gives lot of types of end products. The development of wood-plastic composites was started at

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the beginning of the 1980s, when began using the wood flour and polypropylene in extrusions technology.

In the international literature of cellulose based fiber reinforced plastic composites the following terminology is used: wood powders, wood flour, sawdust, wood fiber. If we look at these publications, it appears that nearly 100% of cases, use only wood flours (amorphous wood particles with largest size under 0.2 mm) or micro shavings (from cutting technologies with lengthwise shape, dimensions between 0.2-1.0mm). The wood flour practically works only as filler in these products, while the micro shavings are already a certain degree of fiber reinforcement. These wood particles are common in many plastic technologies such as injection molding, extrusion, form pressing. There are some other cellulose-plastic products, which are made from annual plants, e.g. kenaf with extremely long fibers needed advanced technologies.

The matrix material can be eg. polyethylene, polypropylene. Wood and plastic components also require additives which provide a better connection between wood and polymer ensuring the appropriate product strength. For this there are commercially available materials, as Clariant Licomont products.

The wood-plastic composite products are wide spreaded in the United States. Already in 1983, the American Woodstock (Sheboygan, Wisconsin) began the production of vehicles interior parts using Italian extrusion technology, where raw material was polypropylene and 50% wood flour.

At the beginning of the 1990s two companies Environmental Recycling Technologies (AERT, Junction, Texas) and Mobile Chemical Company (Winchester, Virginia) made wood-plastic composite products from recycled raw materials with 50% of wood fiber in polyethylene matrix. (Youngquist 1995):

Also in the early 1990s, the Strandex Corporation (Madison, Wisconsin) planted extrusions technology installed high (about 70%) of the weight of the wood fiber in polyethylene . (Clemons 2000)

Wood-plastic composite made from recycled raw materials is used for products such as roof shingles, pallets, New Hampshire "pots", tool grips, outdoor floor coverings and wall coverings, doors, windows, auto parts, et

2. PHYSICAL AND CHEMICAL BINDING, RELATIONSHIPS IN THE WPC SYSTEMS

Composites are built up at least of two basic materials. During the design of their composition beneficial properties of the components and combined the material structure should be considered to reach the pre- determined parameters such as strength, heat resistance, price etc.

This happens in WPC products. The cellulose fibers have good tensile strength and are relatively cheap. Combining these properties with the properties thermoplastics like moisture resistance, weatherproofness, stiffness and recycling possibilities, an advancer product can be developed (SANADI 1998).

The favourable properties of WPC materials are ensured by the properties of components and depend on the quality of the connection between the components.

After cooling in the WPC material structure the bindings can be simple physical adhesions, hydrogen-bridge or covalent bonds.

Physical adhesion is between the fiber surface and the polymer material. At higher temperature the polymer’s viscosity will be lower so the distribution of of that will be better around the wood elements. So the lower viscosity of the polymer provides a better bond to the wood fiber and after cooling the physical connection between plastic and wood will be stronger. Of course, melting point of the polymer should be below the temperature at which wood starts degrading (about 190-200 °C).

It should be mentioned the role of the additive glycerol, which is acting as surfactant and reduces the viscosity of the molten surface layer of polymer and provides a better physical connection. (SANADI et al. 2004)

Among many of available additives the chemical binding agents can be most effective for hydrogen-bridges and covalent bonds. The most common by references is the maleic acid anhydride modified by polypropylene, which engages with the polypropylene chains and develop covalent and hydrogen- bridge bonds with chemically active elements of the fibers. (KLYOSOV 2007)

3.DESIGN AND METHODS

3.1 Raw materials

During the research of wood-plastic composite products by-products of a carpentry shop were used. Our composites are designed for furniture parts, for packaging and for interior purposes. The wood raw material samples were delivered directly from the enterprise.

The waste examined materials were shavings, sawdust, sanding dust.

The plastic components, obtained from several places: the polypropylene (PP) from WolfPlastic Ltd. (recycling), the polyethylene (HDPE) is manufactured by TVK Co. (pellets).

Where required the polymers were ground by a Rapid 150-21 Solo granulator which is suitable for the production of raw materials in a variety of pellet sizes.

3.1.1.Test of raw materials

The particle size distribution of every sorts of wood-based by-products were analysed.

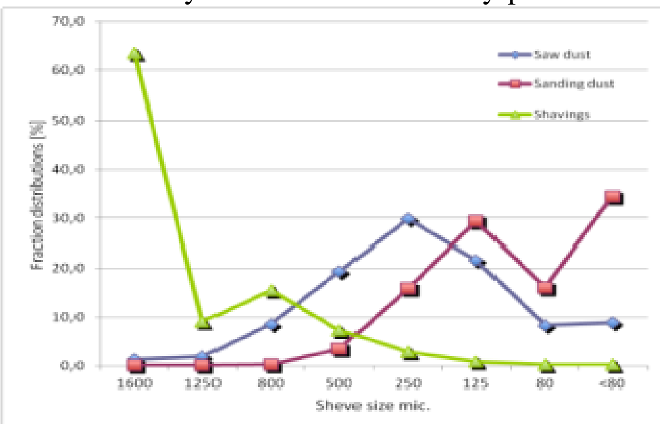

Figure 1: wood-based by-products sieve analysis

Figure 1. introduces the particle size distribution of all the three types of wooden elements. The shavings have low quantity of small particles (dust), which is suitable for insulating products. In such product the fine elements would be work as filler, which are consuming a lot of adhesive. In this report the experiments on insulation boards are not presented, we focus on thermoplastic polymers.

In the mid-sized fraction the saw dust has a minimal amount above 1 mm, a significant amount of micro particles are around 0.25 mm and contains only a little dust fraction. This material is ideal for traditional wood-plastic composites especially for the injection moulding, the extrusion technologies and form pressing. This material contains mainly micro particles however fiber bundles are represented too.

The third group is the sanding dust. This has the largest quantity and it is set up of fine powder below 0.5 mm, and practically does not contain particles. This material is actually the same as wood flour, which is commonly used in wood-plastic composites. In this sanding dust there are inorganic, silicate particles from the corundum of sanding paper.

3.2 Inertia optimized tools

Three types of inertia optimized press tools were designed: two plates with square textures (a smaller and a larger for the thinner and thicker boards) and a hexagonal texture. Due to the ease of handling these were produced of aluminium (Figure 2.).

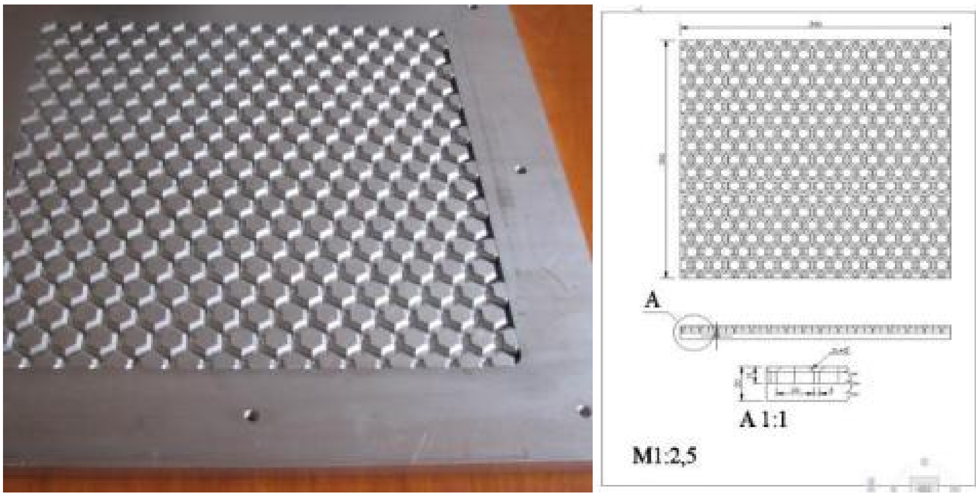

Figure 2. The hexagonal press tool and the aluminium frames

The static final element analysis of the inertia optimized board are shown on Figure 3. The tools were manufactured by Somatech Ltd. We have created three product types: square profiles with 4 mm and 20 mm rib distance and the hexagonal cells with a diameter of 20 mm.

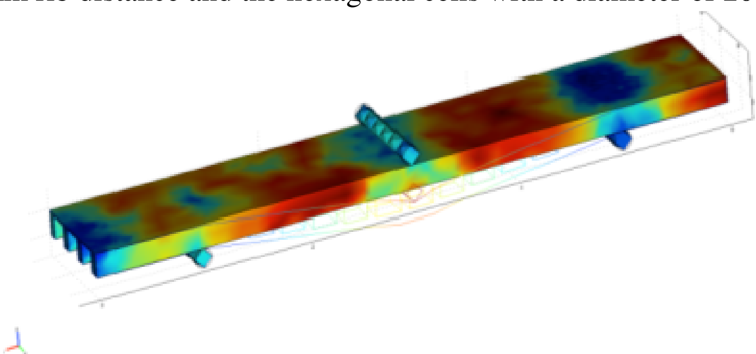

Figure 3. The final element modeling of the square profile board

3.3 Experimental work

3.3.1 Cold mixed wood-plastic composite materials (thermoplastic)

For producing the boards ground plastic was used with size of 1-2 mm. After the determination of quantities the materials were blended in a self designed mixer. It took about 3-5 minutes in solid and cold conditions. Mats were formed manually. The warm up time of the mats was 15-20 minutes long in general. The required heating up time was determined during the preliminary experiments. To control the warm up process a thermocouple was inserted into the mats.

The planned parameters of the cold blended series were as follows:
ρ = 1,0 g/cm3
v = 3 mm
V = 346,8 cm3
Ratio of micro particles to the PP= 50%:50%; 60%: 40%
PP particle size: 1-2 mm
m_{pp} = 138,7 g
m_{mf} = 208,1 g
spacer = 3 mm
On the Figure 4. is a photo of a cold blended inertia optimized WPC with 50 percent of PP.

Figure 4: Cold-mixed inertia-optimized product

3.1.2 Compounded wood-plastic composites

Although the cold blending would be the cheapest production solution, the quality problems don't allow to produce homogenous WPC material. Therefore the LabTech twin screw extruder of the Technical University of Budapest, Department of Polymer Technic was used (Figure 5). The process run between 180 °C and 200 °C. Several types of compounds were produced where a mixture of 60%, 50%, 40% and 30% of polymer and wood particles. Compound from saw dust, sanding dust and wood fibers were made as well. The extruded threads were granulated at the site. Besides PP and wood additive was also added during compounding. The additive was Licomont AR 504 GR which treats the surface of wood particles and increases the adhesion between the matrix and the filler.

Figure 5: The extruder used for PP and wood compounding

From different composition of wood-plastic compounds every type of panned product were produced in a Siempelkamp laboratory hot press. The inertia optimized WPC products from the hot melt based compounds are shown on Figure 6.

Figure 6: Experimental inertial-optimized components from compounds

4. CONCLUSIONS

During the research the mechanical properties of the experimental products were also tested, but regarding the available space for this report these can not be introduced here.

The advantages of the inertia optimized boards can be summarized as follows:

- use of secondary raw materials,
- simple production technology (with cold blending),
- high quality when compounding,
- low specific density,
- high specific bending strength,
- easy to handle (post processing),
- large variety of utilization.

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REFERENCES

YOUNGQUIST J.A. (1995): Unlikely Partners? The marriage of wood and nonwood materials. Forest Products Journal, 45(10), 25-30p.

SANADI, A – HUNT, J. - KOVÁCSVÖLGYI, G. – DESTRE, K. - SANJOT, B. - CAUFILD, D. (2004). Lignocellulóz-polypropylene composites mechanical properties

SANADI A., 1998. Molecular Tailoring of Highly Filled, Formaldehyde Free, Natural Fiber Thermoplastic Composites, Standard Research Proposal 0524-003, Dept. of Biological Systems Engineering, U. of Wisconsin.

KLYOSOV, A. A. 2007.Wood Fiber Plastic Composites

http://books.google.hu/books?id=KmuK4w_D7UUC&pg=PA191&lpg=PA191&dq=coupling+agents +WPC&source=bl&ots=Cy8N-