Wood plastic composites with conical Conex® Wood Extruder

Jaakko Raukola (Ph.D, MBA) Research Manager
Katri Mäkinen (M.Sc) Researcher

VTT Processes
P.O. Box 1607
33101 Tampere
Finland

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Introduction

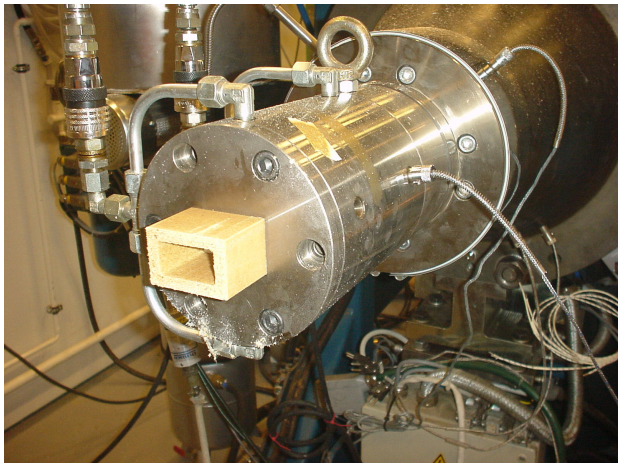
This report is related in wood-plastic composite research hold in VTT for several years. These studies has been carried out together with Conenor Ltd, which has developed the conical extruder, Conex® for wood-plastic composite products. The aim of this study is to extrude wood composite profiles with high wood content to be measured in moisture content, moisture absorbance and mechanical properties. Spruce and mixed spruce + pine has been used as pellets for wood matrix. Polypropylene (PP) , polyethylene (PE) and recycled PP grades has been used as plastic carrier.

Statute and experiments

One rotor 380 mm Conex® Wood Extruder has been used with two feeding screws. Hollow rotor design as of Conenor US Pat# 6,450,429 was used at approximately 20 kg output capacity. Processing temperature was about 160 – 190˚C for PP and 140-160 ˚C for PE with die land pressure around 200 bars. Die used was rectangular bar profile 60x40x8 mm.

Wood pellets: Compressed (manufacturer VAPO Oy) wood pellets were used. Pellets were made from spruce and mixed spruce + pine wood basis. Water content approx. 10%. Fiber length of spruce pellets is longer due to milder processing technique (compression method) compared with mixed softwood grade processed with percussion "hammer" impact treatment.

Wet and coarse sawing waste: untreated white pine sawing waste from Heinola Saw Mills, water content according to manufacturer over 50%, maximum particle size 40 mm, no sieving,/grinding nor drying was done prior to pouring the wet sawing waste and plastics into the extruder hoppers.



Picture 1. Conex® Wood Extruder 380-1 with rectangular bar profile die 60x40x8 mm

Picture 2. Spruce (left) and mixed spruce + pine (right) pellets

Picture 3. Wet and coarse pine sawing waste (untreated)

Plastics: Polypropylene used was heterophasic copolymer for injection moulding, MFR (230˚C) 18 in granule form
Polyethylene used was linear medium density grade, MFR(190˚C) 6 in powder form
Recycled PP as well as LDPE are collection of injection moulding grades scrap sieved out, separated and purified
Recycled plastics contain several colours affecting dark shade in the extruded profile

Plastic/wood weight ratios in material blends of tested profiles :

1. Wet sawing waste + PP (85/15)
2. Mixed wood pellets + PP (75/25)
3. Spruce pellets + PP (70/30)
4. Spruce pellets + PE (75/25)
5. Mixed wood pellets + PE (65/35)
6. Mixed wood pellets + recycled PP (75/25)
7. Mixed wood pellets + recycled LDPE (70/30)

In each blend 2% lubricant (acid amide) and 2% coupling agent (g-MAH) was added.

Dimensional stability of extruded profiles in hot water

The dimensional stability test were performed according to standard DIN 68705 /Teil 3 Bau-Furniersperrholz (=BFU), using elevated temperature 70°C (158°F) water bath.

Hollow profiles (60 x 40 x 8 mm) were cut to 1 m long pieces. Each 1 m long profile was cut into 3 similar pieces, approximately 200 mm long. Cut edges were laminated with epoxy resin, to prevent larger absorption of water through the machined edges. The samples were kept in controlled conditions, room temperature (23 ± 2°C) and relative humidity (50 ± 5 %) before testing. The samples were weighted and the dimensions, length, breadth, height and breadth of one wall, were measured before the samples were completely immersed in 70°C temperature water (three specimens of each). The samples were kept immersed in 70°C temperature water. After 48, 72 and 144 hours' immersion time had elapsed, the test specimens were taken out of the water, the excess water was removed and the samples were weighted and the dimensional changes were measured. The dimensional changes were also measured after 24 hours immersion. The weight and dimensional changes for each material are expressed in percentage of the original weight and dimensions.

Bending strength test

The flexural bending strength and the flexural modulus of elasticity of the composite material in each blend were determined as the 4-point bend. Span length was 720 mm.
The bending test are carried out in accordance with the standard EN 408 "Timber structures – Structural timber and glued laminated timber- Determination of some physical and mechanical properties

Results and discussions

Table 1. Material flexural bending strength and modulus of elasticity of tested profiles

Test sample	**Bending strength MPa**	**Modulus of elasticity GPa**
Wet sawing waste + PP 85/15	33,3	3,81
Mixed pellets + PP 75/25	36,6	3,86
Spruce pellet + PP 70/30	33,9	3,64
Spruce pellet + PP 75/25	40,0	5,24
Spruce pellet + PE 75/25	19,0	3,17
Mixed pellets + PE 65/35	17,0	2,81
Mixed pellets + recycled PP 75/25	35,5	4,89
Mixed pellets + recycled LDPE 70/30	10,5	2,28

Table 2. Moisture content, weight changes and densities of wood plastics test profiles.

Sample	**Moisture (%)**	**Weight change (%) 48 h – 72 h – 144 h**	**Density** (kg/m^3)
Wet sawing waste + PP (85/15)	1.70	not tested	1150
Mixed Wood pellets + PP (75/25)	0,49	5,9 - 7,8 - 15,2	1170
Spruce pellets + PP (70/30)	0,47	3,2 – 4,5 – 10,8	1150
Spruce pellets + PP (75/25)	0,69	3,8 – 5,0 – 10,6	1230
Spruce pellets + PE (75/25)	2,75	7,0 – 9,1 – 15,6	1230
Mixed wood pellets + PE (65/35)	1.85	5,4 – 5,9 – 13,4	1170
Mixed wood pellets + recycled PP (75/25)	0,45	3,7 – 5,0 – 10,3	1180
Mixed wood pellets + recycled LDPE (70/30)	2,47	6,5 – 9,5 – 14,1	1210

*) *Moisture and density measured before immersion in water bath*

As table 2 illustrates, the moisture content of composites is higher with PE-based carrier. Also the increased content of wood seems to behave correspondingly affecting higher moisture values. Compressed wood fibre increases the average density compared to virgin PE or PP (less than 1000 kg/m^3).

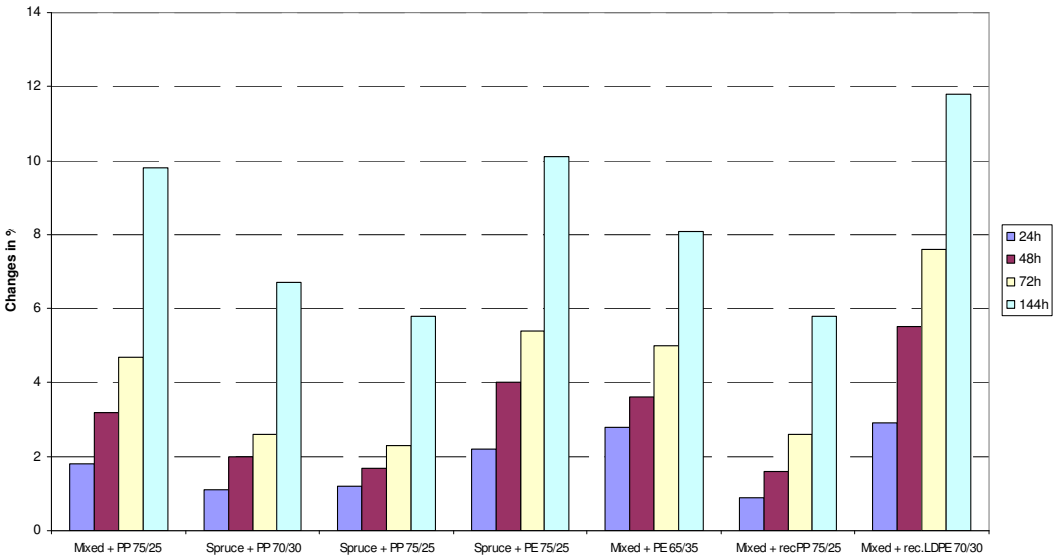


Figure 1. Dimensional changes of wood plastics composites. Water bath at 70 ˚C. (24, 48, 72 and 144 hours)

The weight changes correspond with the dimensional changes (compare table 2 and figure 1). The wood content affects the dimensional stability - the more wood fibres the bigger the dimensional changes are. Water penetration happens easier via wooden material. The dimensional changes increased for composites with mixed softwood pellets. Fibre length of mixed wood pellets is shorter. Surface contact area on profile bars is increased affecting water penetration.

The dimensional changes are bigger for composites with polyethylene matrix than for composites with polypropylene matrix. This is obvious due to higher permeability values of PE compared to PP.

The difference (smaller weight gain and smaller dimensional changes for the composite with more wood fibres) in the results for the composites with recycled polypropylene can result from differences in the recycled PP. There can be big differences in material properties even inside the same recycled batch. The bending strength properties indicate the same.

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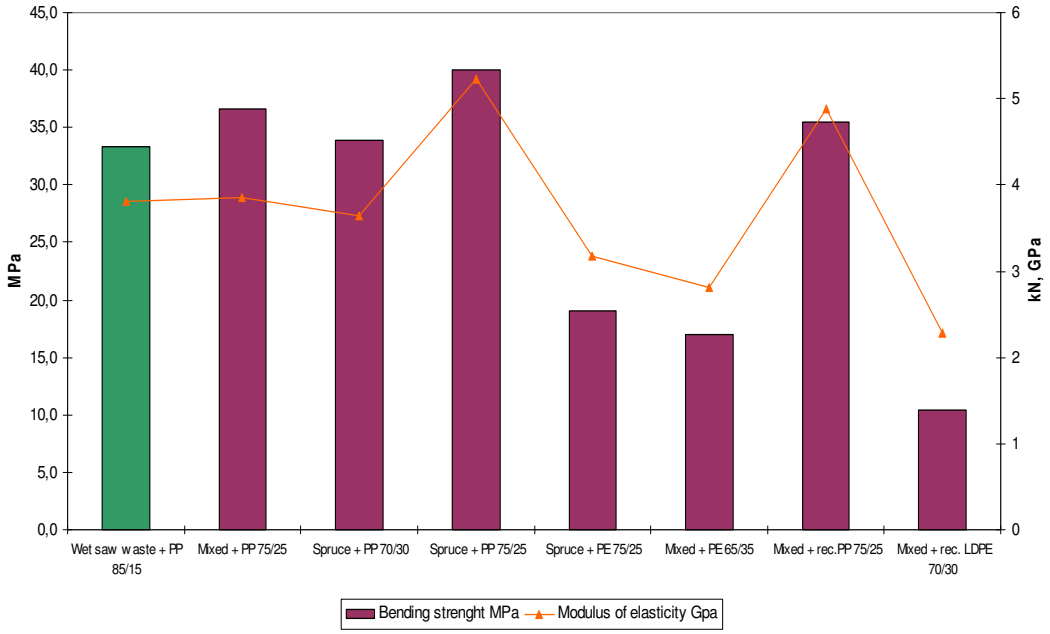

Figure 2. Mechanical properties of wood plastic composites.
Comparison to wet sawing waste + PP sample (green bar).

Mechanical properties of spruce based composites is higher in general as figure 2 submits. This is most probably due to longer fibre length. It could be estimated also that higher wood content corresponds with increased mechanical properties, especially with bending strength. PE basis decreases bending strength and modulus of elasticity, which is also presumed. Wet sawing waste (85 % sawing waste and 15 % PP) has been extruded to make a comparison. Due to finer wood matrix the level of bending strength does not reach the values of suspected ones in spruce or mixed wood pellets with same content.

Conclusions

This study shows that extrusion with conical Conex® extruder is possible with high wood contents (up to 85 %). Extruded profiles were nice in shape and smooth at their surface.
The level of dimensional changes due water absorption when immersed in water at ambient temperature were low 1-2 % in general compared to plywood 7-20 % according to general information.
Mechanical properties were acting in a predicted way taking into account wood pellets and their content as well as polyolefin (PP or PE) grade. With PP flexural bending strength values up to 40 MPa, and with PE 19 MPa respectively were achieved.

The study shows, that with a specific hollow rotor design it is possible to produce high quality wood plastic composites in a direct extrusion process from wet wood and without compounding.

Acknowledges Acknowledges to Conenor Ltd which has enabled this to study to be carried out.

References Woodfibre-Plastic Composites, report 31.12.2003, VTT et.al, Finland