Post-Extrusion Processing of Extruded Wood Plastic Composites and Selection of Belt Conveyor Cover Material

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Wood plastic composites (WPCs) have recently gained increased market share as a result of their beneficial properties and use of sustainable material sources. Currently, however, WPC products are limited to extruded profiles. More complex product shapes and geometries will increase market potential, but they demand additional post-processing after extrusion. Post-processing machinery coupled online with an extruder necessitates material handling, which is commonly achieved using belt conveyors. This paper considers transport of WPC material through a post-extrusion process using a belt conveyor system. Special emphasis is placed on studying the friction and surface energy properties of the belt conveyor. Friction at the interface of the raw material and belt cover was tested using a standard incline-plane method, and adhesion and stickiness were evaluated by determining the surface free energies of the belt cover and WPC material at 23 and 100 °C. On the basis of these measurements, this paper investigates key aspects of belt cover material selection and proposes a conveyor belt configuration for a prototype post-extrusion process line that can be utilized in commercial mass production of WPC products.

Keywords: WPC post-processing; Forming; Conveying; Belt conveyor system

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INTRODUCTION

Wood plastic composites (WPCs) have recently gained increased market share in a number of customer products, such as flooring elements and fencing, because of their desirable material properties of consistent quality, splinter-free structure, and good durability, and their use of sustainable material sources and economic viability. Currently, WPC products available on the market are mostly limited to extruded profiles (Klyosov 2007). However, there is increasing demand for more complex product shapes and geometries, which demand post-extrusion processing after the material fabrication stage. Tightening environmental legislation in the European Union, with its demands for greater utilization of different waste segments and reduction in landfill waste, mean that WPCs, which can utilize and recycle municipal and building waste (Carroll *et al.* 2001; Cruz-Estrada *et al.* 2010), are an increasingly interesting research area. For example, an interesting research topic recently has been combining WPCs with other composite materials such as fibre reinforced plastic (Lale Arefi *et al.* 2014) or pure polymer (Moritzer and Martin 2016) to increase the usability of the WPCs. Additionally recent research has shown that there are great possibilities to reuse and recycle mineral wool waste from building construction as a filler ingredient in WPCs (Väntsi and Kärki 2014).

In post-extrusion processing of WPC material, the stage after material fabrication, the composite material has to be conveyed through the process machinery in an optimal way, which demands that the composite material is efficiently transported and fully supported during the forming, cooling, and packaging phases. In this operation, the composite material should not stick on or slide across the conveying surface in an uncontrolled way, *i.e.* material behavior must demonstrate good run-ability during the post-extrusion processing. For successful utilization of a belt conveyor, the composite material should be discharged from the conveyor without deformations in the product or residual marks on the surface, and the conveying system should be able to operate at a speed commensurate with the feed rate of the preceding equipment, which for most common material fabrication extruders is in the range of 10 to 500 mm/s (Klyosov 2007). In addition to selecting appropriate conveying machinery, the composite material mix should be runnable in terms of material cohesion and temperature behavior. Even the best conveying system is unable to cope with materials having poor run-ability properties, and the post-fabrication stage therefore places considerable demands on WPC composition.

Selection of the conveyor belt should take into account the abrasiveness, stickiness, dustiness, corrosiveness, flow-ability, and temperature of the material (Wolpers and Hager 1990). Plastic is a key constituent of WPC composite material, acting as a matrix that bonds the wood fibers together; consequently, post-extrusion processing is a heavily temperature-dependent operation. Of special importance when utilizing WPCs is control of stickiness and ensuring that the belt covers can withstand the required temperature (150 to 160 °C) for successful forming and cutting operations (Kim and Pal 2011; Toghyani *et al.* 2016).

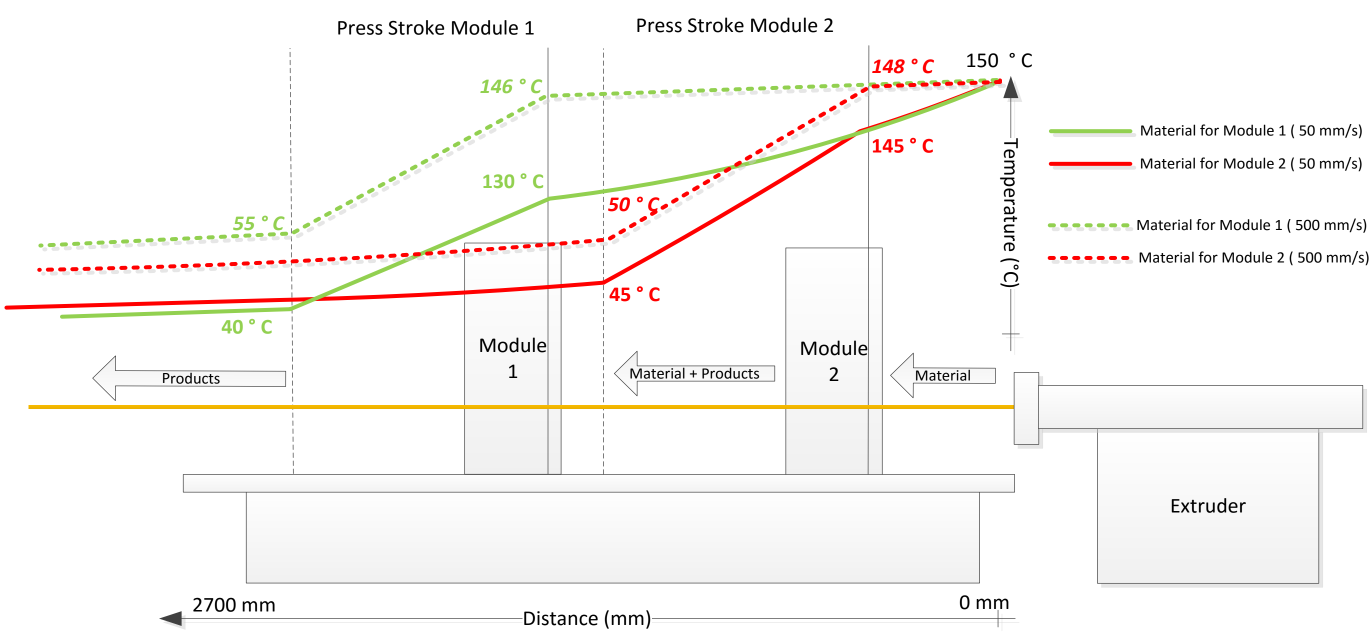

Fig. 1. Heat gradient across a post-extrusion process line used as a case example at two different extrusion speeds. The process line consists of two moving modules, described in experimental chapter under LUT KompoLine Platform- section. The yellow line illustrates the composite material web moving at the extrusion speed.

The composite material has to be moved from the extruder to the post-processing units at the forming temperature, and then the finished product has to be moved at room temperature. This places great demands on the material stability of the belt, which has to tolerate a wide range of different temperatures. Figure 1, which is based on the authors' previous work (Matthews *et al.* 2015), illustrates the temperature range across a post-extrusion process line with the same composite material. In view of the large temperature gradients, slow extrusion speeds of 5 to 50 mm/s set very different requirements for the belt cover material than higher speeds of 0.5 m/s and above. For instance, in Fig. 1, at a speed of 50 mm/s, the belt will be in contact with the composite material for a total of 54 s, which is sufficient for the material to possibly stick to the belt cover, while for a speed of 500 mm/s, the total contact time is 5.4 s.

Previous studies on conveyor belts have primarily focused on the conveying of bulk materials such as coal or sand (Wolpers and Hager 1990; Ilic *et al.* 2007), where material orientation is not a primary concern, and analysis of the durability and wear of the belt (Fedorko *et al.* 2014a,b). Conveyor belts have been widely used in transportation of thermoplastic composites (TPCs) such as glass fiber mat (GMT) thermoplastics (Long 2007). However, these closely analogous processes to WPC have not generated research papers in this area of interest. This study aims to clarify potential issues in conveying WPCs in a factory environment, in particular, the interface behavior between the composite material and the material of the belt cover. This interface was investigated by evaluating the friction and surface energy of the two most common belt conveyor cover materials suitable for this application, polytetrafluoroethylene (PTFE) and silicone rubber. These soft belt cover materials were selected because of their heat resistance and the non-abrasive nature of WPC composites (Saloni *et al.* 2011). The selected materials give insight into the effects of a wide range of friction, as PTFE has a very low coefficient of friction of 0.05, whereas silicone rubber has a coefficient of friction in the range of 0.2 to 0.6 (Bhushan 2013). The high temperature of the extruded material (170 to 190 °C) prevents the use of standard-type natural rubber covered belts, whose temperature limit is usually below 80 °C (CEMA 1997).

It is known that exposure to heat has a definitive effect on the structural properties of fibers and polymers (Fischer 1972; Hubbe *et al.* 2007; Norgren and Höglund 2009; Maryudi *et al.* 2013). Furthermore, friction and adhesion levels have been found to change with temperature, as measured by Ye and Zeng (2014). The friction of the belt cover was tested with a standard incline-plane method in a similar way to that used by Klyosov (2007), who tested slip resistance in different commercial WPC deck materials, and adhesion was investigated by determining the surface free energies. Klyosov (2007) claims that although, in theory, friction should be independent of surface area, speed, and temperature, in the real world, the contact area does matter. This is because real world objects are usually not homogenous and the surface roughness can deviate significantly from the average measured value. In polymer composites, in particular, the actual contact area is difficult to determine because of deformations of the plastic. In reality, applied force, test temperature, sliding rate, and duration of the test are all important (Klyosov 2007). In this light, the testing environment was selected such that it resembled the actual factory environment as closely as possible, to make the generated results applicable to material producers.

A fault tree, illustrated in Fig. 2, was developed based on preliminary tests with selected cover materials. Figure 2 shows typical sources of error and highlights the fault causing the error.

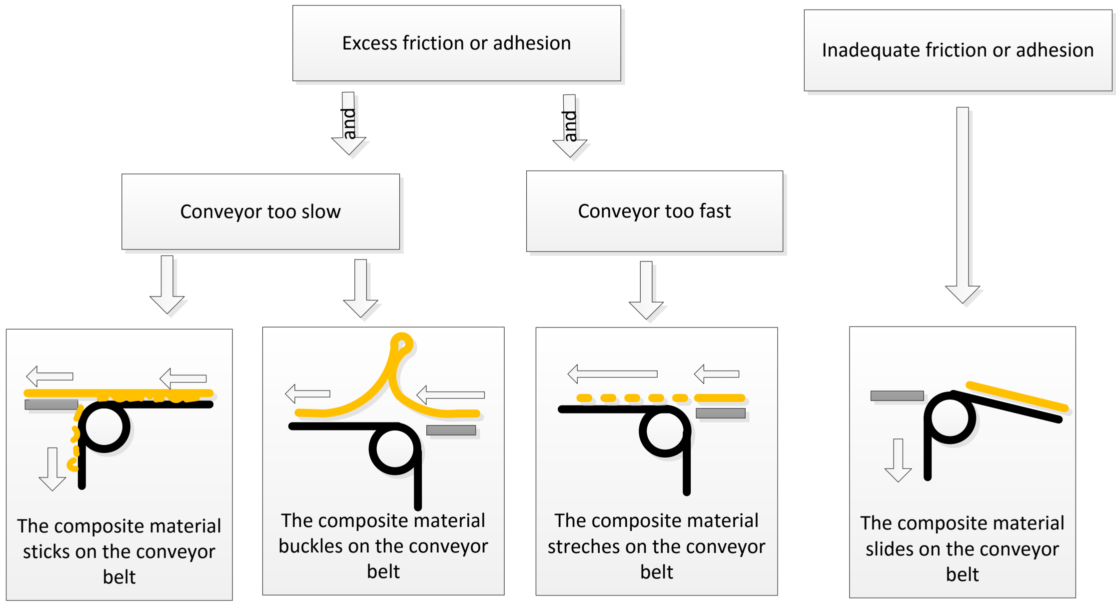

Fig. 2. Possible faults in conveying WPCs with a belt conveyor

The fault tree implies that selection and control of the conveyor speed and adhesion level have a significant role in successful conveying of WPCs. Unsuitable conveyor properties or material run-ability properties can cause material web breakage or belt malfunction, leading to total production failure. The highlighted buckling effect typically happens when line pressure caused by friction on the conveyor pushes the cooled material forcefully forward against the material moving at slower speed (McGuire 2010).

Based on friction and surface energy measurements of conveyor belt covers, and using the belt selection process investigated in this work, this paper proposes a conveyor belt material and a system configuration for it for post-extrusion processing of a continuously moving WPC web that can be utilized in commercial mass production of WPC products.

EXPERIMENTAL

As WPCs can have significantly different material properties, depending on the composition of the material, processing machinery should be able to run a wide range of different materials. In this paper, a wood plastic composite material with 50% high-density polyethylene (HDPE) derived from recycled plastic bags and 44% sawdust was used as a case example. The composition of the composite material is listed in Table 1. This material was selected because of promising preliminary formability tests for a very wide range of customer applications and because the material has a typical fiber to matrix ratio for thermoplastic WPCs, allowing evaluation of general run-ability in thermoplastic WPCs.

Table 1. Measured Material Properties of the Tested Composite Material and Its Major Ingredients

	Composition	**Hardness**	**Tensile strength**	**Modulus of elasticity**
Composite material	50% HDPE, 3% MAPE, 3% lubricant, 44% Sawdust MESH 20	5.06 HB	21.5 MPa	4.5 GPa
HDPE			15.0 MPa	0.8 GPa
Sawdust		2.6 to 7.0 HB	40.0 MPa	11.0 GPa

Tensile strength and modulus of elasticity were measured using a Z020 material testing device (Zwick-Roell, Germany).

A belt conveyor was selected as the conveying method instead of the more typically used roller conveyor because the melt composite material needs to be fully supported and moved at a constant speed through the process.

Table 2 lists belt cover properties, provided by the manufacturers, for the selected belt cover materials. Based on this preliminary information, it was decided that two different cover materials should be tested, in view of their good thermal properties and durability.

Table 2. Belt Cover Material Properties*

Brand name	Derco 2BRA 2-1 Sir/N blue	Hardick 510X
Carcass (matrix) material	PVC + 2x polyester layer	Glass fiber weave
Temperature range	-30 to 120 °C	-75 to 250 °C
Weight	2130 g/m^2	455 g/m^2
Thickness	2.00 mm	0.23 mm
Tensile strength 1%	10 N/mm	10 N/mm

*Provided by the manufacturers

In preliminary tests, A5-sized heated composite sheet at 160 °C was placed on the tested cover material at room temperature and temperature was measured from the underside of the cover material with a J-type thermocouple. On average, the silicone material reached 74 °C in 173 s, and the PTFE cover reached 106 °C in 115 s. Thus, the heat conductance of the silicone rubber belt was noticeably smaller than that of the PTFE belt.

Material stickiness and tendency to leave residuals were tested by heating WPC sheets to 160 °C and placing them on the belt cover material, where the sheets were allowed to cool to 40 °C, simulating the cycle of the post-extrusion process line. The preliminary stickiness experiments were conducted 20 times on the same spot on each belt cover material. No visual residuals were observed on either of the belt cover materials.

Angle Measurement Setup as Friction Analysis

Friction was tested using an incline-plane method similar to standard TAPPI T815 (2006) with a specimen on an inclined platform on the attached conveyor cover material, as shown in Fig. 3. Measurements were done with a bevel protractor with visual angular accuracy of ±0.5 degrees. Each specimen was measured 10 times, and the tests were conducted with example plates and cold and hot raw material sheets.

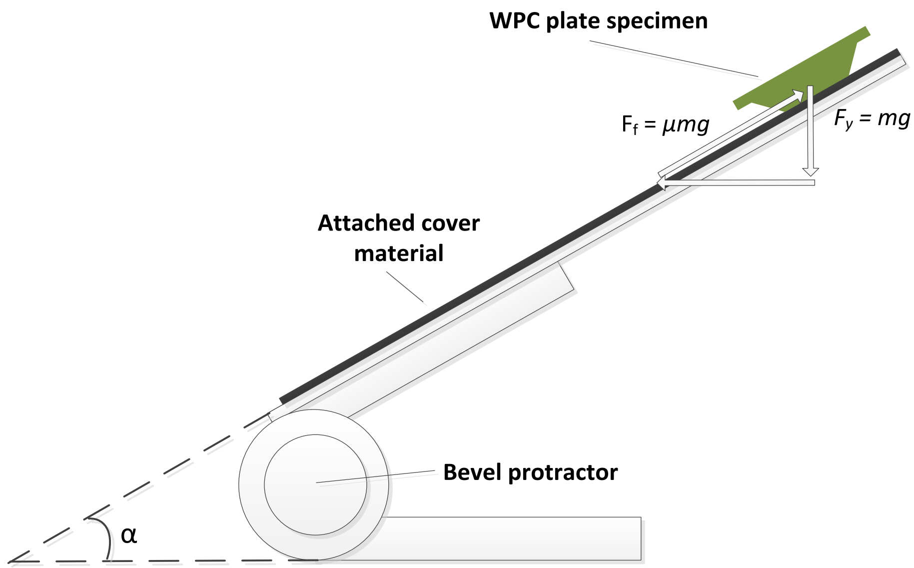

Fig. 3. Friction test setup based on an inclined plane and a bevel protractor based on TAPPI T815 (2006). The gravity force *Fy* causes the tested WPC material to slide at the angle where the friction force F_f is exceeded.

Surface Energy Measurement Setup

Liquid-substrate interactions were assessed from contact angle measurements (Theta optical tensiometer, Biolin Scientific AB, Sweden, equipped with an electrically heated measuring chamber) at WPC surface temperatures of 23 and 100 °C. The probe liquids were deionized water, ethylene glycol (VWR S.A.S. International, France), and diiodomethane (Alfa-Aesar, Germany). The contact angles are presented as average values of 10 independent measurements. The surface free energies (SFE) were calculated using the acid-base approach, which allows closer inspection of solid surfaces. All three probe liquids were usable at 23 °C, but the rapid evaporation of diiodomethane prevented its usage at 100 °C. Thus, only the surface energies calculated from the contact angles of water and ethylene glycol are reported. The surface energy values were used as an indicator for heat-induced stickiness alterations.

Fig. 4. Specimen plate made of thermoplastic WPC used in evaluation of friction and surface energy

Case Product Used as an Example

A test specimen plate, shown in Fig. 4, with overall diameter of 160 ± 0.5 mm and measured surface roughness R_z of 30.5 ± 5 µm, was used as a case product to simulate the surface behavior of typical customer product on the conveyor belt materials. In addition, a 100 mm x 100 mm sheet of raw composite material, with R_z of over 75.0 ± 10 µm, was used to test the surface behavior of raw material sheets on the conveyor belt materials.

LUT KompoLine Platform

A post-extrusion processing system called LUT KompoLine, shown in Fig. 5, was used as a post-process platform in evaluation of conveying performance with the composite material and in design of the belt conveyor system. The KompoLine system consists of two moving press units, each consisting of an Exlar (USA) model GSX60-1005 actuator with 55 kN of press force and a Tecnotion linear motor TL12 with 1 kN of linear force. Both units move on the same linear magnetic track with total length of 2 m. The extruder is positioned to the right side of the direction of the highlighted material flow.

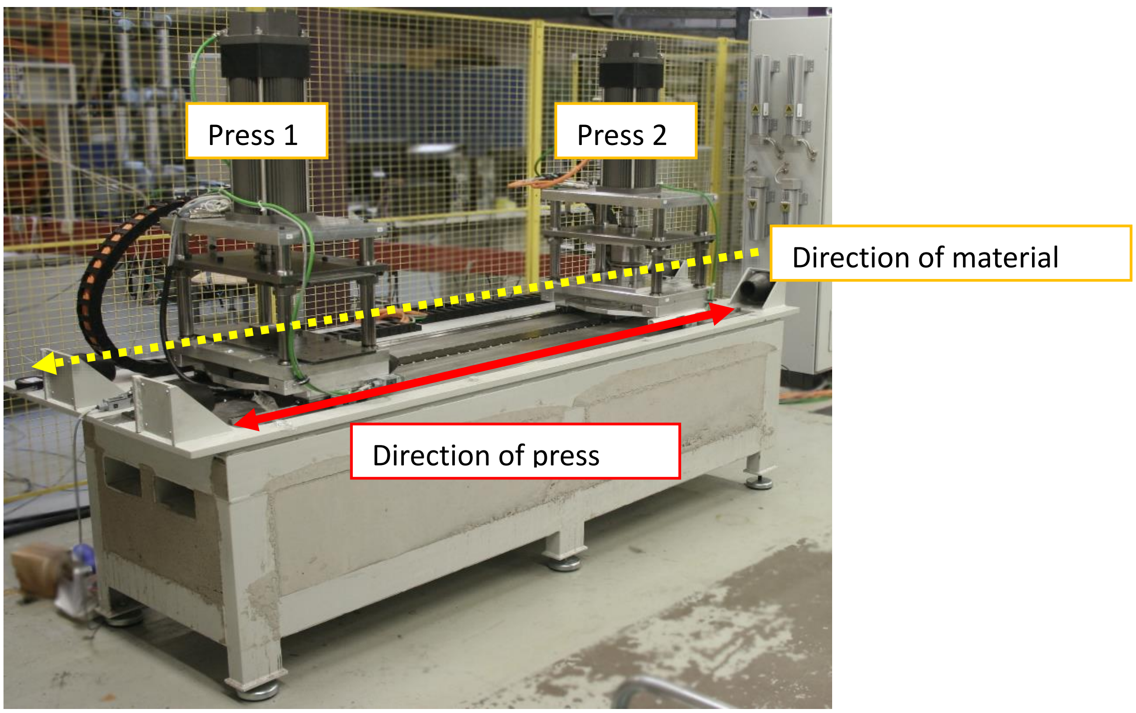

Fig. 5. LUT KompoLine press line with different elements illustrated

RESULTS AND DISCUSSION

The results of the cooling experiments are combined in the following graphs with indicated average and bandwidth of the measurements.

In the measurements listed in Table 3, the total coefficient of friction of the PTFE was in the range 0.1 to 0.16, and the coefficient of friction of the silicone rubber was in the range 0.42 to 0.72. The static to kinetic friction ratio was roughly 1.1 for the silicone and 1.2 for the PTFE.

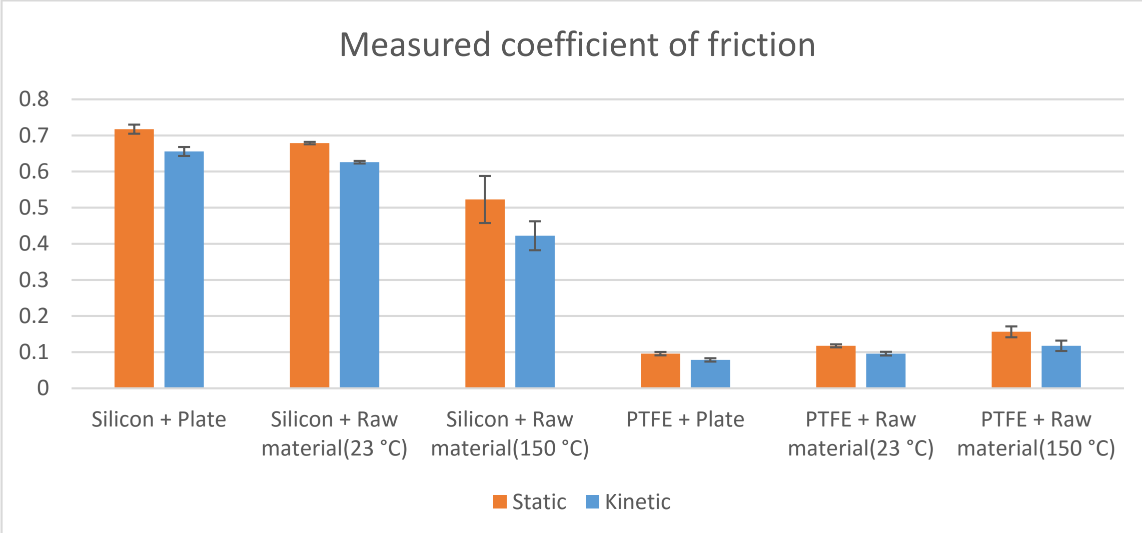

Fig. 5. Measured static and kinetic friction coefficients for the silicone and PTFE coated conveyor belts with standard deviation indicated.

Table 3. Measured Average Coefficient of Friction Values and Standard Deviations*

	Static coefficient		**Kinetic coefficient**	
	Average	Deviation	Average	Deviation
Silicone + Plate	0.72	0.025	0.66	0.025
Silicone + Raw material(23 °C)	0.68	0.006	0.63	0.007
Silicone + Raw material(150 °C)	**0.52**	**0.130**	**0.42**	**0.080**
PTFE + Plate	0.10	0.009	0.08	0.009
PTFE + Raw material(23 °C)	0.12	0.009	0.10	0.010
PTFE + Raw material(150 °C)	**0.16**	**0.030**	**0.10**	**0.028**

*Hot tests in bold

The results show the noticeable effect of elevated temperature on the friction coefficients with a decrease of 23.5 % and 33.4 % with silicone material and increment of 25 % with PTFE material. Behavior of PTFE has also been presented by Sujuan and Xingrong (2014), who found that pure PTFE had a 27% increase in the coefficient of friction as temperature increased from room temperature to 150 °C. The standard deviation in the hot material measurement was over tenfold higher on average than in the room temperature measurement, especially with the silicone coating (22 times higher deviation). This variation can be attributed to the fact that the material temperature and cooling were not precisely controlled because of the uninsulated environment. Even with the increased margin of error, it can be seen that the hot material led to decreased friction with the silicone.

Typically, friction tests differ significantly in wet and dry conditions. In this case, the experiments were conducted in a dry environment, and the materials and the belt remained dry throughout the process. The range of static dry coefficient of friction to metal in commercial WPC decks is 0.28 to 0.5, according to Klyosov (2007). The considerable variation can be attributed to the different polymers and fibers used in the composites. HDPE, used as the polymer matrix in the tested composite material, is characterized by low coefficients of friction, and as the density increases, the static and dynamic coefficients of friction decrease. For the polymer part of the polyethylene used in the tested composite material, the density is 0.965 g/cm^3, and the coefficient of friction is equal to 0.10 according to Carrol *et al.* (2001). Aurrekoetxea *et al.* (2008) found in their analogical WPC material that the WPC material friction is influenced more by the fiber part when the commonly found thin layer of polymer on the surface of the WPC material is worn off. In the case studied here, the outer layer remains intact, as the conveying action should not cause wear on the product, keeping the friction level closer to that of the polymer used, as can be seen from the results in Table 3.

Roth *et al.* (1942) found with natural rubber, and later Zhang (2004) with analogous silicone rubber, that rubber elastomers exhibit run-in-friction, where the coefficient of friction usually increases in relation to sliding time. In this study, this change in friction can be disregarded because there should only be a very minimal amount of sliding in successful operation of the conveyor.

The example specimen plate had a 0.04 and 0.2 greater coefficient of friction on the silicone belt in the cold and hot tests, respectively, than the sheet of raw material, although the raw material surface roughness was greater (75.0 ± 10 µm) than the roughness of the specimen plate (30.5 ± 5 µm). Klyosov (2007) states that friction is not necessarily higher when the surface is rough, as the area of the interface between surfaces is smaller and roughness is a minor factor affecting friction. Roth *et al.* (1942) found in friction tests with natural rubber that, except at very low speeds lower than 0.01 mm/s, smoother surfaces generated more friction.

Interestingly, with the PTFE studied here, the change was in the other direction, with an increase in the coefficient of friction of 0.02 and 0.06 in the cold and hot experiments, respectively. This phenomenon can be attributed to the smoother surface of the PTFE belt, permitting the hot material to melt more easily into the shallow cavities on the surface of the belt or to the increase in adhesion between the WPC and PTFE at elevated temperatures, as shown below.

Results of Surface Energy Measurements

Table 4 presents the contact angles of the probe liquids and the surface free energy of the belts and composite material at 23 and 100 °C. Because of the limitations of the testing apparatus, the upper temperature was set only to 100 °C. Although the working temperature of 150 °C in post-extrusion processing is considerable higher than 100 °C, indicative conclusions can be drawn. At room temperature, the wetting phenomena of the belts differed, but the difference narrowed with increased surface temperature. The contact angles of water and ethylene glycol on the PTFE belt increased substantially with the increase in surface temperature. The interaction between the silicone belt and the probe liquids was different. The silicone belt was not only hydrophobic at 23 °C, but it also repelled both ethylene glycol and diiodomethane more than the other substrates. The results indicate that PTFE is a more heat-sensitive material than the siliconized surface, suggesting that the siliconized belt could be more suitable for use in industrial converting processes in which the temperature varies significantly. The more stable nature of the silicone-based coating also kept the surface energy almost unchanged at hotter conditions.

The surface energy of the composite material increased slightly with increasing temperature. This was ascribed to polymer pre-melting behavior (Fischer 1972) and, possibly, to the movement of polyethylene towards the surface. More detailed study of the chemical composition of the surface should be conducted to confirm that thermal treatment causes migration of polyethylene.

The contact angles of vegetable oils, which are slightly polar compounds, have been reported to decrease on PTFE surfaces when the ambient temperature rises (Aydar *et al.* 2016) This finding suggests that interactions between the PTFE and the probe liquid are highly dependent on temperature, and it is plausible that the same applies to interactions between PTFE and other solid surfaces.

Based on the surface energy measurements, it is clear that the silicone is more stable at elevated temperatures and has relatively similar internal energy to the WPC product across the temperature range. This result indicates that the siliconized belt might be more suitable for industrial use, as it is less sensitive to heat in terms of adhesion properties.

Table 4. Contact Angles (θ) of Water, Ethylene Glycol, and Diiodomethane on the Studied Belts and WPC and their Surface Free Energies at 23 and 100 °C

	θ (H_2O)	θ (EG)	Θ (DIM)	SFE, [mN/m]
PTFE belt				
23 °C	69.5±7.6	65.9±4.5	79.9±5.6	66.2
100 °C	106.1±1.8	81.1±6.7	**-**	51.6
Silicone belt				
23 °C	103.7±1.3	95.2±2.6	84.3±5.4	59.6
100 °C	102.1±3.2	89.2±3.1	-	57.6
WPC				
23 °C	88.3±7.3	69.7±5.2	71.8±5.0	56.8
100 °C	64.6±11.0	54.1±6.0	-	59.8

Belt Cover Material and Applicability

Table 5 lists advantages and disadvantages of the silicone rubber and PTFE covered belts based on information from the belt manufacturers, common practical knowledge of the belt materials, and measurements listed in this paper.

Table 5. Advantages and Disadvantages of Belt Cover Materials Based on General and WPC Specific Properties

	Silicone covered belt	PTFE covered belt
Advantages	Inclined belts possible, more durability and wear resistance, better material stability in elevated temperatures, thermal insulation	Dimensional stability and very limited elongation, wider usable temperature range, lightweight, less flexural stiffness
Disadvantages	More flexural stiffness, heavier	Centering of the belt difficult. Thermal conductance. Design limitations caused by crosslinking the surface

PTFE cannot be used in inclined belts because of the very low coefficient of surface friction (0.10). Based on the measurements, the maximum permissible elevation angle of the belt would be 5°, whereas when using silicone belts, the maximum angle would be 45°. PTFE thus sets strict requirements for correct horizontal positioning, whereas silicone belts can be used more freely. However, the lower friction in PTFE allows improved product accumulation with less line pressure and raw material deformation in cases where product discharging is temporarily interrupted.

PTFE is lighter in general and has a very wide operational temperature range, from -75 to 250 °C. Its insulation ability is lower than silicone rubber, as assessed in the preliminary tests in the methods section. This can be beneficial for external control of the process temperature by enabling the use of additional heating elements or infrared sources.

Although the silicone rubber belt manufacturer only guarantees support for operation at a maximum of 120 °C, because of the heat sensitivity of the matrix materials such as PVC used in the carcass layer, the belt was tested for short periods at 150 °C to simulate the effect of hot material touching the silicone cover. During the tests, no observable changes were observed in the cover or matrix. This may be due to the good insulation properties of the belt material, as noted in the preliminary tests (where the cover temperature peak reached only 74 °C). It is likely that in the long run, thermal wear of the belt matrix would be observable and disadvantageous, and it is recommended that a silicone rubber covered belt with a more heat-resistant carcass material should be selected. In this paper, because of time constraints and lack of availability, no such carcass was tested; thus, the findings can be considered as indicating only the short-term behavior of the silicone cover layer.

Silicone offers better crosslinking of the belt cover to the carcass material and has a better resistance to sharp shocks. Based on the measured internal energies, the silicone maintains similar adhesion levels in normal and elevated temperatures (100 °C); thus, the interface of the belt cover with the WPC is more stable than with PTFE. The better insulation properties mentioned in the preliminary measurement section lead to less cooling of the WPC products during the conveying process. However, the greater thickness of the silicone belt leads to increased flexural stiffness and consequently increased power requirement from the belt motor.

Roth *et al.* (1942) found in his friction tests with natural rubber belts that talc or bloom of rubber could cause a significant change in friction levels during long-term operation. This is a relevant issue with WPC; residual leftover or carry-back material could change the friction level considerably and cause misalignment of the belt.

Proposed Belt Conveyor Construction

Based on the measured results and the above discussion, a configuration was designed for practical implementation of a belt conveyor for post-extrusion processing of WPCs.

According to Harper *et al.* (2006), in staged production where the process has to be stopped for the cutting operation, the conveyor belt has to feature a bowed effect to allow the continuously flowing material to fold properly. This common problem was avoided, as the post-process system was planned to operate continuously with the flying shear principle. In this way, the conveyor belt geometry could be kept at a horizontal level. As the material input is set to constant, because the extrusion process cannot be quickly stopped or started without significant deterioration of material quality (Giles *et al.* (2005), the post-extrusion process must process composite material flowing at steady extrusion speed.

Because of the cyclic nature of the pressing event, illustrated in Fig. 6, the belt cover material has to have tractive effort in an inclined plane, which depends on the size and depth of the pressed product. This key factor limits the use of PTFE cover material in this conveyor belt configuration and favors the use of silicone material.

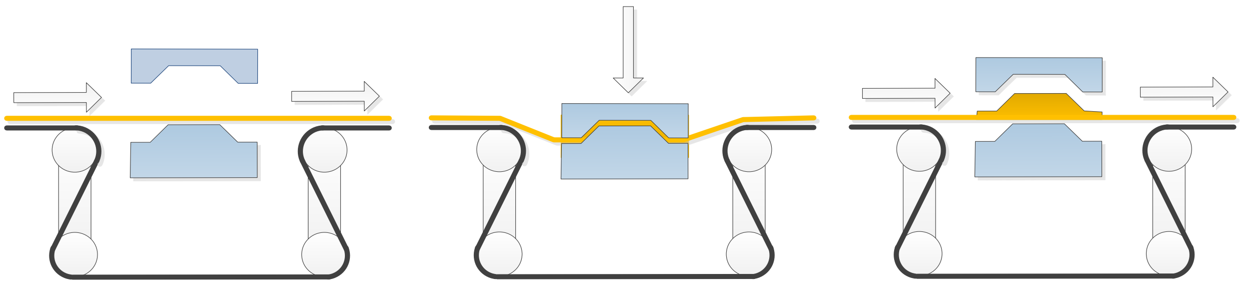

Fig. 6. A single pressing cycle for a WPC material web, illustrated in yellow, and press forming tools, in blue. The pressing event is illustrated in three stages relevant for the conveyor.

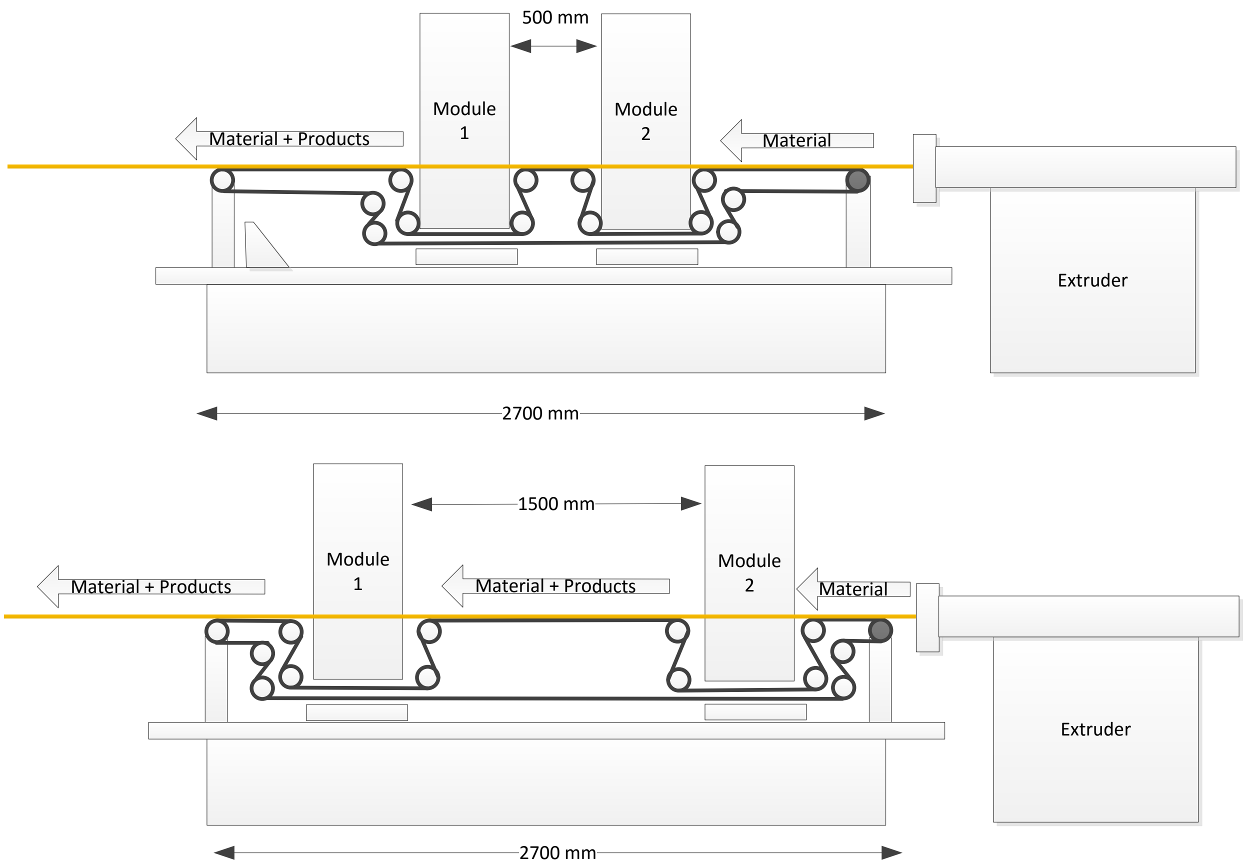

Fig. 7. Principle of 2-phase KompoLine process operation with an extruder and the proposed conveyor system. Press modules 1 and 2 move back and forth in relation to each other, while the composite web, marked in yellow, provides constant input from the extruder. The belt conveyor system consists of 13 idler pulleys and a drive pulley, illustrated in dark gray. The maximum distance between the press units in phase 1 and 2 is set to 1500 mm.

In the proposed system and in belt conveyors in general, end pulleys are located at both ends of the belt conveyor, where the belt turns around and returns. For successful operation at this stage, the composite material has to be easily discharged from the belt without sticking or leaving residual marks.

To control long-term friction of the silicone belt, an external cleaning device can be used or a lubricant such as talc. Marshall (2015) suggests a mechanical wedge system made of polyurethane as a possible way to peel off residuals, and this approach is used in the proposed design.

Bulk material properties are affected by an agitation effect when passing over multiple idlers (CEMA 1997). As there are 8 to 10 idlers under the moving composite material in the proposed design, even though the material is not bulky, this agitation effect should still be taken into account. Agitation effects are especially relevant for uncooled semi-molten products moving to the cooling department; thus, there should be a minimum number of idler pulleys at this stage of the conveyor line.

CONCLUSIONS

1. Based on short-term friction and surface energy measurements, it was found that commonly used heat-resistant conveyor belt cover materials (silicone rubber and PTFE) do not set limits for production extrusion speed from the perspective of composite material temperature or adhesion.
2. It was further found that both materials are suitable for use with wood plastic composites, if cover material-related design limits for machine construction are considered and the belt matrix or carcass material is properly selected.
3. For the special application of post-extrusion processing of WPC material, the silicone rubber coated belt, which has more stable adhesion and internal energy levels at elevated temperatures and a higher coefficient of friction, was found to be the more suitable of the two cover materials investigated.

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Article submitted: April 15, 2016; Peer review completed June 12, 2016; Revised version received and accepted: June 14, 2016; Published: July 7, 2016.
DOI: 10.15376/biores.11.3.7001-7015