

## Adhesion to wood-plastic composites

This application note illustrates how the Attension Theta Optical Tensiometer combined with the 3D topography module can be utilized to study adhesion to wood-plastic composites.

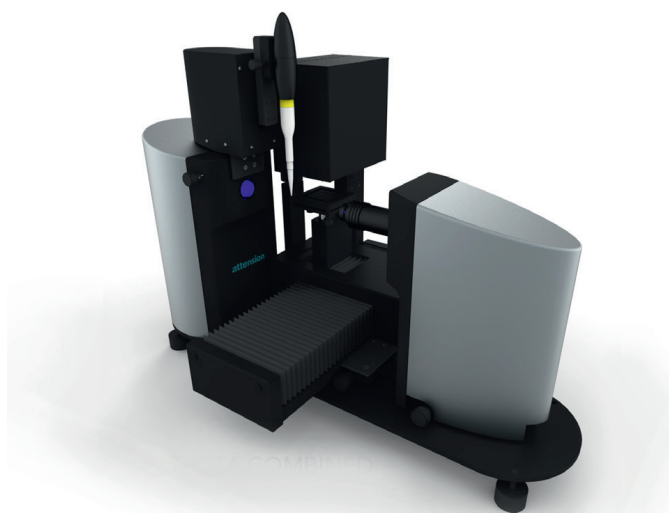
### Introduction

Wood-plastic composites (WPCs) [1] are composed of three main ingredients: recycled thermoplastics, such as polyethylene, polypropylene and polyvinyl chloride, wood filler and additives. The plastic part constitutes 30 – 70 % of the mass of WPC and the wood filler the additional 30 – 70 %. About 5 % of WPC are additives to improve their processing, stability and physical appearance. Wood-plastic composites are relatively new materials as they started to emerge at the beginning of 90's. The most widespread use of WPCs is in outdoor decking but it is also used in railings and siding as well as park benches and indoor furniture. Wood-plastic composites are thought to be more environmentally friendly and require less maintenance than the alternatives of solid wood treated with preservatives.



[Figure 1]: Wood-plastic composites

In some applications, the ability to coat or bond the WPC is needed. For example, overlaying the WPC panels with veneer sheets improves their appearance and properties for furniture manufacturing. Bonding of WPCs is required to fabricate laminated beams for structural applications. Adhesion is extremely important in both of these processes. The adhesion mechanism can be divided into three categories: I) mechanical interlocking, II) physical bonding and III) chemical bonding [2]. Together these mechanisms are responsible for adhesion and usually one of them plays a dominant role. Mechanical interlocking strength depends on the size and the geometry of the locking sites; thus surface topography. Topography will increase the surface area and thus increase the binding sites for other adhesion mechanisms.



Attension Theta combined with 3D topography module

Physical bonds include hydrogen and van der Waals bonds which are generally relatively weak. Chemical bonding is stronger and bonds include metallic, atomic and ionic bonds. Available physical and chemical bonds depend on the surface chemistry of the substrate and are sometimes collectively described as thermodynamic adhesion [3].

Wettability of the surface is closely related to the adhesion since better wettability usually indicates better adhesion. As most of the surface modification methods will influence both the roughness of the surface and the chemical composition, the separation of these two is important for comprehensive understanding of the adhesion process. The Theta optical tensiometer combined with 3D topography module enable quick and easy measurement of both surface roughness and contact angle.

As with any composite materials, the properties of a WPC depend on the properties of its components. Wood is a hydrophilic porous composite of cellulose, lignin and hemicellulose that are rich in functional groups like hydroxyls. On the other hand, thermoplastic

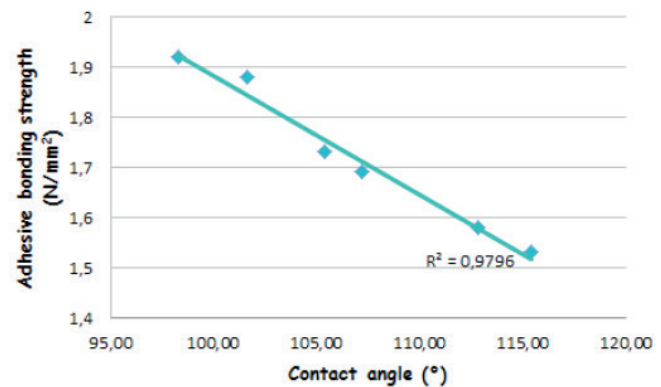
polymers are hydrophobic having very few functional groups on their relatively smooth surface. In the following case study both water contact angle and surface roughness have been evaluated to study the adhesive bonding of a veneer sheet to a WPC surface.

### Case study: Adhesive bonding of veneer sheet on WPC surface

Jarusombuti et al. [4] studied the bonding of veneer sheets on six different type of WPC. The amount of wood filler was varied from 40 % to 60 % and the amount of polypropylene (PP) from 37 % to 60 %. Maleic anhydride-graded polypropylene (MAPP) was used a coupling agent and its effect on the bonding quality was also studied. Table 1 shows the raw material formulations used for the WPC panels, as well as measured roughness, contact angle and adhesion strength values.

Contact angles were measured by using CAM 101 Optical tensiometer (Biolin Scientific, Attension, former KSV Instruments). Surface roughness was also evaluated. Surface roughness values of WPC samples decreased with increasing PP content. This is understandable since there is less wood exposed on the surface. Smaller surface roughness was observed with samples that contained MAPP, which is thought to be due to well-developed contact between wood filler and plastic on surface layers. Contact angle measurements showed increased wettability with increasing wood content due to the hydrophilic surface properties of wood.

The adhesive bonding strength as a function of contact angle was also studied. Lower contact angle values resulted in better adhesion between WPC and veneer. A significant relationship ( $R^2=0.98$ ) between contact angle and bonding strength was found to be significant (Figure 2). Contact angle could be an indicator for the degree of adhesive bonding strength of the WPC. In previous study [5], veneer bonding to medium density



[Figure 2]: Adhesion bonding strength as a function of contact angle.

fiberboard (MDF) showed a slightly higher bonding strength (2.3 N/mm<sup>2</sup>) than to WPC. Different types of surface treatments including chromic acid treatment, oxygen plasma treatment, Benzophenone/UV treatment, and flame treatment have been studied to improve the adhesive bonding of WPC [6].

### Conclusion

Wood-plastic composites gain interest in many different application fields due to their environmental friendliness and easy maintenance. New application fields such indoor furniture and use of WPC as a structural material will require deeper understanding of the bonding mechanisms of the WPC. Both contact angle and surface roughness can provide good information on the bonding ability of the WPC. The Theta optical tensiometer together with the topography module is a powerful tool for the characterization of WPC surfaces.

### References:

- [1] B. S. Gupta, I. Reiniati and M-P. G. Laborie, "Surface properties and adhesion of wood fiber reinforced thermoplastic composites", *Colloids and Surfaces, A*, 302 (2007) 388.
- [2] A. J. Kinloch, "Adhesion and Adhesives: Science and Technology, Chapman & Hall, London, New York, 1987.
- [3] D.S. Rimai, L. P. DeMejo and K. L. Mittal, "Fundamentals of adhesion and interfaces", VSP, Netherlands, 1995.
- [4] S. Jarusombuti and N. Ayrilmis, "Surface characteristics and overlaying properties of flat-pressed wood plastic composites", *European journal of wood and wood products* 69 (2011) 375.
- [5] N. Ayrilmis and J.E. Winandy, "Effects of post heat-treatment on surface characteristics and adhesive bonding performance of medium density fiberboard", *Materials and manufacturing process* 24 (2009) 594.
- [6] W. M. Gramlich, D. J. Gardner and D. J. Neivandt, "Surface treatments of wood-plastic composites (WPCs) to improve adhesion", *Journal of adhesion science & technology* 20 (2006) 1873.

WPC panel composition (by weight %)						
WPC panel type	Wood-fiber	Polypropylene	Maleic anhydride-grafted PP	Ra (µm)	CA (°)	Bonding strength (N/mm <sup>2</sup> )
A	40	60	-	5,1	112,8	1,58
B	50	50	-	7,88	105,4	1,73
C	60	40	-	9,67	98,3	1,92
D	40	57	3	5,52	115,4	1,53
E	50	47	3	7,34	107,2	1,69
F	60	37	3	9,14	101,6	1,88

[Table 1]: WPC composition by weight %, average surface roughness, contact angle and bonding strength.



E-mail: info@biolinscientific.com  
biolinscientific.com