AUTEX 2022 Conference Proceedings 978-83-66741-75-1 

**DOI: 10.34658/9788366741751.116**

# EXPERIMENTAL STUDY OF THE TACK OF FLAX FIBERS BASED THERMOPLASTIC COMPOSITE REINFORCEMENTS

**Mathieu Joannes[1(*)], Karine Gautier[1], Gilles Arnold[1], Peng Wang[1]**

[1] University of Haute-Alsace, Ensisa, Lpmt, F-68000 Mulhouse, France

(*) *Email:* mathieu.joannes@uha.fr

## ABSTRACT

In this article we tested a flax fibres and polypropylene based composite reinforcement in order to determine its adherence to other surfaces around the melting temperature of polypropylene at 165°C. A rheometer with a thermal chamber is used to do a probe-tack test at a constant temperature. This test consists in three steps, the compaction of the sample between two tabs, the relaxation and the separation of the upper tab from the sample. Tackiness corresponds in the traction force measured during the separation. No tackiness was measured during our first tests although we could observe residue on tab surfaces. Further tests where the temperature is lowered beneath the solidification temperature of polypropylene during the relaxation step will be done. Preliminary results for these tests are promising.

## KEYWORDS

Composites, Thermoplastic, Tackiness.

## INTRODUCTION

Composite materials are common nowadays and are used in several industries such as automotives and aeronautics. Yet synthetic fibers (carbon, aramid, fiberglass) and thermosetting composite are the most common and they present an ecologic impact due to their process of fabrication and their low recyclability [1,2]. The idea of a composite made of flax fibers and thermoplastic comes from the fact that both can be bio-sourced and both are recyclable. Although, not as strong as some synthetic fibers, natural fibers such as flax can withstand significant amount of force and therefore make convincing reinforcements [3,4,5].

Thermal stamping [6] and draping [7] are key processes in the fabrication of composite materials for the automotive and aeronautics. Thermal stamping and draping need the thermoplastic to a more liquid phase in order to be shape properly or to adhere to other surfaces or to itself [8,9]. To control this adherence, we need to know its tackiness. Tackiness of a composite is measured experimentally as a force or an energy needed to be able to separate said composite from another surface. Although, tackiness is a majeure component of composite reinforcements, to this day there is only a few tests that are precise and repeatable [8,9]. And fewer models back up these tests [10]. Due to the fact that every variable such as compaction force and speed, relaxation time, temperature, and separation speed, as well as material properties, can impact the result of any experiment.

In our study, a probe-tack test [8] will be used on a flax fiber based polypropylene composite reinforcements. Our measurements will focus on this influence of the temperature over the composite tackiness.

## MATERIALS AND METHODS

The reinforcements threads are made of co-mingled flax fibres and polypropylene filament and are gimped with a thread of polypropylene. These threads are woven into a 2×2 twill.

Probe-Tack tests [8] will be conducted on a rheometer (Fig. 1) allowing us to control displacement, a force threshold and temperature. Tests are done at a constant temperature averaging the melting point of polypropylene at 165°C (Fig. 4). Due to the precision of the thermal chamber test will be done from 150°C to 190°C. Preliminary tests suggested that under 150°C the behaviour is not impacted by temperature and that over 190°C flax fibers are damaged.

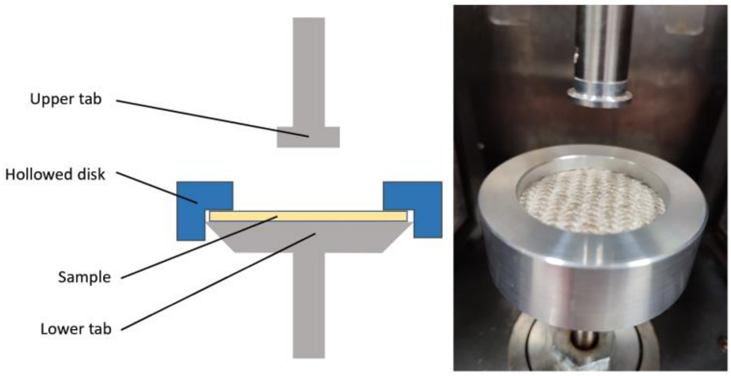


**Figure 1. Diagram and picture of the rheometer and its components.**

The probe-tack test [8] consists in three distinct steps, compaction, relaxation and separation (in black, green and red in Fig. 2). During the first step the upper tab of 15 mm in diameter is lowered at a speed 'Va' of 20µm/s until it applies a threshold force 'Fc' of 15N onto the sample at a time 'tc'. Then the second step consist of 30 second of relaxation. Finally, the last step is the separation at a speed 'Vs' of 50µm/s. From the graph can be read force 'Ft' of tackiness and its energy 'Ws' under the curve.

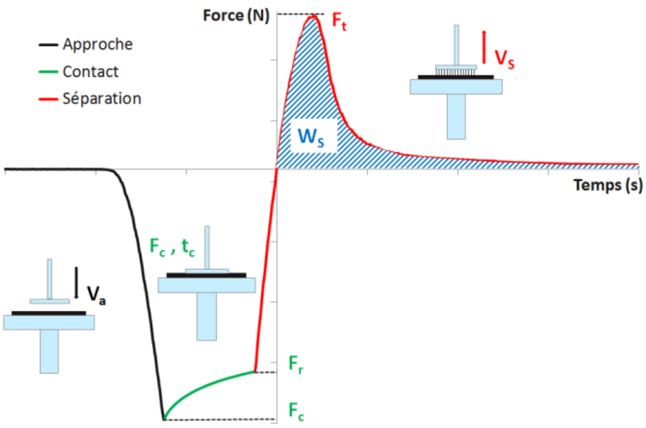


**Figure 2. Theoretical curve of a probe-tack test.**

The samples are of octagonal shape in order to better fit on the circular lower tab and to be easily cut from woven fabric. An aluminium hollowed disk is place on top of the sample to prevent its edges from warping during the eating process.

## RESULTS AND DISCUSSION

As we can see in Figure 3, results here are negative, during the third step, the stress doesn't become positive which implies a lack of traction, hence a lack of tackiness no matter the temperature. An explanation could be that the polypropylene is either solid or fully liquid due to our selection of temperature. In the first case, it does not adhere to the upper tab. In the second case it is too liquid to apply stress upon the upper tab although residue can be found on the tab. A measure at 165°C could provide positive results for tack but we lack the precision for now. Another explanation could be that our sample surfaces simply does not have enough polypropylene. A simple solution would to increase the compaction force and to push the inner polypropylene outside on the surfaces. But due to our rheometer we decided to used prepregs of our reinforcements. We define a prepreg as a sheet of our material that has already gone through a thermal stamping cycle with or without added polypropylene. Its surfaces contain noticeably more polypropylene and first results show that, indeed, tackiness can appear but it is still relatively low.

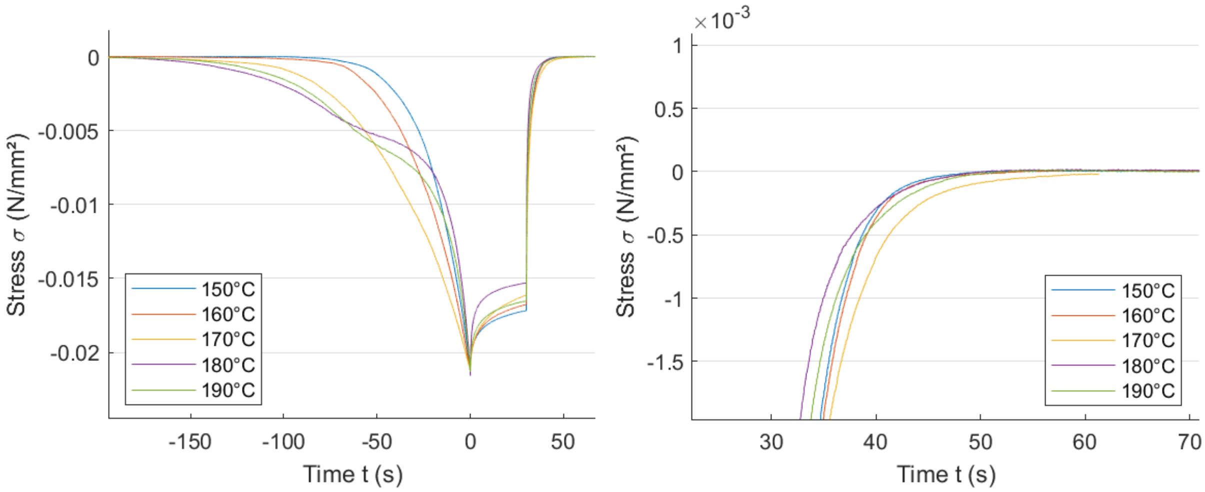


**Figure 3. Stress-time curve of probe-tack tests between 150°C and 190°C.**

However, our work focuses on the thermal stamping process [2,7] which does require another identification of tackiness at a different temperature. Indeed, the separation during this process is done at colder temperature when the polypropylene starts to solidify at around 115°C (Fig. 4). Now that our first test campaign is done, we are aiming to do a another one where the sample is heated up to 180°C then cooled down before separation. First preliminary results show significant amount of tackiness during separation as well as during the relaxation when the temperature is lowered. Those results will be discussed as our work progresses.

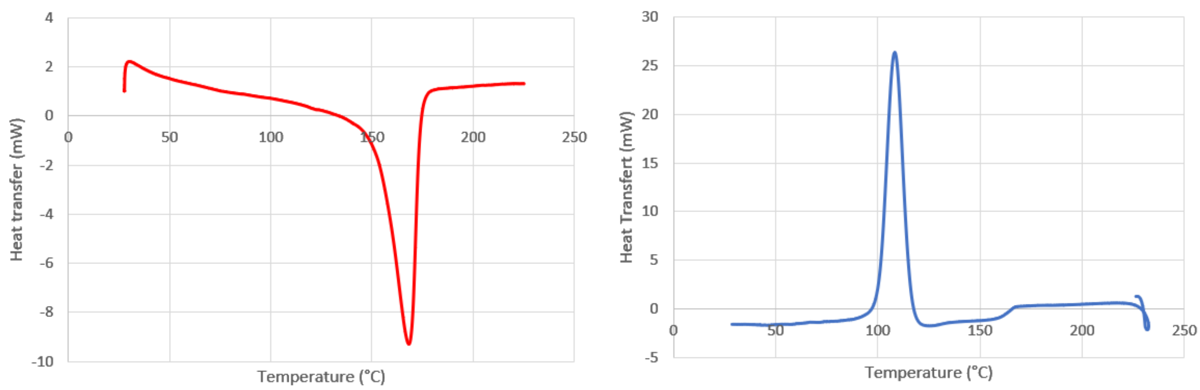


**Figure 4. DSC of the polypropylene, in red the heating phase, in blue the cooling phase.**

## CONCLUSION

Our first campaign of probe-tack tests shows us that the polypropylene melts between 160°C and 170°C and although residue can be found on our tools after 170°C, there is no amount of tackiness for the composite. A campaign will be done using prepregs as they showed results during the first tests. In order to replicate the thermal stamping process, we decided to implement a cooling phase during the separation step of the probe-tack test. For the draping process a more precise study of the behaviour of the composite at the exact melting temperature of polypropylene is needed. Furthermore, studies will be conducted on multi-layered reinforcements and reinforcements with different structures and proportions of polypropylene to see how tackiness evolves with those parameters.

## REFERENCES


[1] Zhang J., Chevali V.S., Wang H., Wang C.H., *Current status of carbon fibre and carbon fibre composites recycling*, Composites Part B: Engineering, 2020.

[2] Zhang Q., Qiang G.A.O., Jin C.A.I., *Experimental and simulation research on thermal stamping of carbon fiber composite sheet. Transactions of Nonferrous Metals Society of China*, 2014, vol. 24, no 1, pp. 217–223.

[3] Pickering K.L., Efendy M.A., Le T.M., *A review of recent developments in natural fibre composites and their mechanical performance*, Composites Part A: Applied Science and Manufacturing, 2016, vol. 83, pp. 98–112.

[4] Xiao S., Wang P., Soulat D., Gao H., *Thermo-Mechanical Characterisations of Flax Fibre and Thermoplastic Resin Composites during Manufacturing*, Polymers 2018, vol. 10(10), no 1139.

[5] Bourmaud A., Beaugrand J., Shah D.U., Placet V., Baley C., *Towards the design of high-performance plant fibre composites*, Progress in Materials Science 2018, vol. 97, pp. 347–408.

[6] Gong Y., Song Z., Ning H., Hu N., Peng X., Wu X., Liu Q., *A comprehensive review of characterization and simulation methods for thermo-stamping of 2D woven fabric reinforced thermoplastics*, Composites Part B: Engineering 2020, no 108462.

[7] Hou M., Friedrich K., *3-D stamp forming of thermoplastic matrix composites*, Applied Composite Materials 1994, vol. 1, no 2, pp.135–153.

[8] Budelmann D., Schmidt C., Meiners D., *Prepreg tack: A review of mechanisms, measurement, and manufacturing implication*, Polymer Composites 2020, vol. 41, no 9, pp. 3440–3458.

[9] Budelmann D., Detampel H., Schmidt C., Meiners D., *Interaction of process parameters and material properties with regard to prepreg tack in automated lay-up and draping processes*, Composites Part A: Applied Science and Manufacturing 2019, vol. 117, pp. 308–316.

[10] Ahn K.J., Seferis J.C., Pelton T., Wilhelm M., *Analysis and characterization of prepreg tack*, Polymer Composites 1992, vol.13, no 3, pp. 197–206.