Friction of carbon fibre tow: contact geometry and boundary condition effects

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The friction of a carbon fibre tow is investigated on two homemade experimental setups. By varying the contact geometry, a cylinder on plane and a plane on plane configuration, the mean contact pressure in the assumption of smooth surface made of carbon fibre material, differs from 46 kPa to 13 MPa. Moreover, in two experiments, the distance between the contact and the clamping is 100 and 10 mm, respectively. The measured friction coefficients are two times higher for plane/plane configuration than in cylinder/plane one, and higher in parallel than in perpendicular orientation. The reason is sought in the surface state.

Keywords : friction, carbon fibre, polymer composite, roughness, boundary condition

1. Introduction

Woven polymer composite materials have been used increasingly in many industrial branches, such as automotive or aeronautics. Throughout the manufacturing processes, the tows of the composite reinforcement are subjected to local friction with the tool. If this friction is not understood and controlled, significant defects can appear and lead to poor mechanical performance of a part or even premature failure. The aim of this work is to contribute to this understanding by applying a high contact pressure at a thin band and a much smaller contact pressure at a larger area. Another effect on friction studied here is the ability of fibres to move, which is controlled by changing the distance from clamping.

2. Methods

The tribological experiments were carried out in two configurations: a cylinder/plane contact with the cylinder covered with carbon fibres firmly attached close to contact, and a plane/plane contact between a carbon tow clamped at more significant distance and a glass plate. In both cases, the friction force was measured during the test and the surface topography was studied before and after the sliding. The mean contact pressure is estimated as roughly 46 kPa in the flat surface experiment and 13 MPa in the cylindrical surface experiment in the assumption of the smooth surface made of carbon material in contact with glass. The friction mechanisms are studied in parallel and perpendicular to tow orientations.

3. Results

The average friction coefficients measured in both experiments are given in the Table 1. Moreover, a reduction in surface roughness was observed in both experiments regardless the boundary condition and possible mobility of fibres. Though the initial surface roughness varied significantly in each family of experiments.

Table 1: Average friction coefficients

Configuration	Perpendicular to tow	Parallel to tow
Cylinder/plane	0.17± 0.032	0.19± 0.019
Plane/plane	0.34 ± 0.051	0.42 ± 0.027

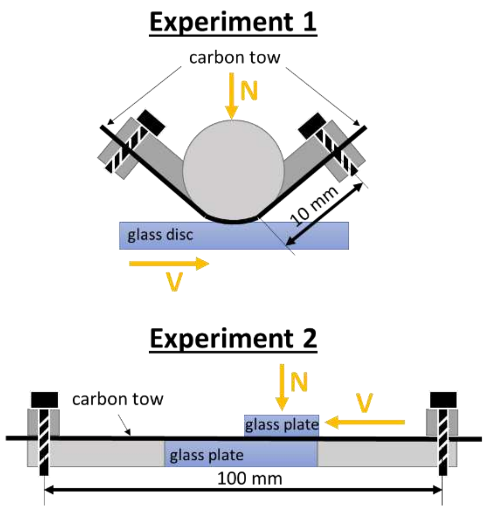

Figure 1: Two tribological setups for carbon tow friction study.

4. Discussion

Previous studies on the same tow showed that the friction of dry carbon tow is governed by the real area of contact [1, 2], which varied in power law with contact pressure. Moreover, the friction coefficient decreased with normal pressure in inverse power law. Although the plane/plane experiment performed in this study confirms the friction values measured in ref [2] in parallel orientation, the cylinder/plane configuration reveals a different frictional mechanism since the friction coefficient is two times smaller for both orientations. The reason for this change of mechanism might be in a significant difference in contact pressure or in the mobility of fibres in the contact. These aspects are investigated through the contact area observations.

5. References

[1] Smerdova, O., et al., "Multiscale tool–fabric contact observation and analysis for composite fabric forming", Composites Part A, 73, 2015, 116-124.

[2] Mulvihill, D., et al., "Friction of carbon fibre tows", Composites Part A, 93, 2017, 185-198.