Tow Mechanics: Improving The Accuracy Of Deformation Modelling

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The mechanical properties of a continuous fibre reinforced polymer are determined to a large extent during the forming phase. The continuous fibrous tows deform geometrically. Knowledge of the tow orientation and tow deformation behaviour is essential to obtain the desired product quality in terms of e.g. strength and impact performance. Modelling efforts have so far been focused primarily on the macro (fabric) and meso (tow) scale [1,2]. A physically based model of tow deformation which includes information on the filament (micro) level can improve the accuracy of existing draping and forming simulation software.

A set of five mechanisms is determined to describe the deformation of fibrous tows:

1. **Tension:** A load is applied in axial direction with respect to the local tow or fibre axes.
2. **Compaction:** A load is applied perpendicular to the longitudinal axes of the tows or fibres.
3. **Bending:** A moment is induced in a tow or fibre section (the case of tow bending behaviour is described in previous work [3]).
4. **Twist:** Torsion due to a relative rotation between two locations is applied along the longitudinal axis on the tows or fibres.
5. **Shear:** A load is induced by a relative displacement of two parallel planes, which remain parallel during and after the displacement.

Friction plays a role in all the mechanisms, with effects on macro, meso, and micro scale. The determination of the involved friction coefficients of the tows and fibres with respect to each other and mould materials such as tooling steel is necessary to accurately predict the tow deformation in the dry and impregnated fabric. Current research in this project is focused on determination of the frictional properties on meso and micro scale.

The friction coefficient on meso scale is determined experimentally by means of a fibrous tow specimen (glass or carbon fibre) on a rotating drum. This capstan type experiment relates the friction coefficient μ to the tensile forces T_0 and T_1 in both ends of the tow specimen, which is wrapped around the drum under pre-tension over an angle of π radians, see figure 1.

Preliminary results (see figure 1) are obtained by using Amontons' law (1). The test was performed for a combination of a 12k carbon fibre tow and a PVC cylinder rotating at 12.8 min^{-1} (reference measurement);

$$\mu = ln\left(\frac{T_1}{T_0}\right)\frac{1}{\pi} \tag{1}$$

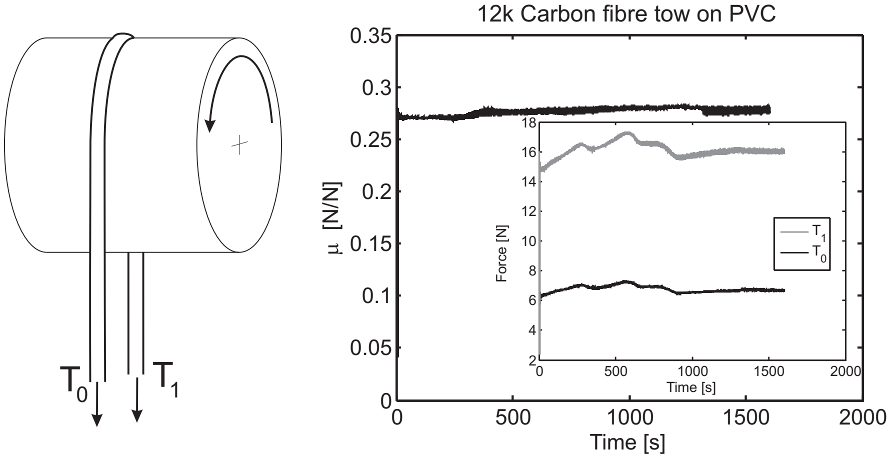

Figure 1: Outline of the capstan friction experiment and preliminary results

The dependence of the coefficient of friction on the rotational speed of the drum and the applied pre-tension on the tow specimen are subject of investigation. Robins et al. [4] performed Capstan friction tests with single carbon fibres (among other materials) and did not find a dependence of the friction coefficient on the rotational velocity of the drum. Nevertheless, this independence has to be verified for tow specimens as well, since the behaviour of those materials is not necessarily the same as that of the individual fibres. The sizing with which the tows are treated for better handling and adhesion to the matrix can play a significant role in the determination of the measured friction coefficient. The use of eq.(1), based on Amontons' law, implies a contact area independent friction behaviour. This assumption will be verified for the fibrous tow friction coefficient.

References

1 P. Boisse, B. Zouari, A. Gasser, Compos. Sci. Technol, 65, 429-436 (2005)

2 S.V. Lomov, I. Verpoest, Compos. Sci. Technol. 66, 919–933 (2006)

3 B. Cornelissen, R. Akkerman, Analysis of yarn bending behaviour, *Proceedings of the* 17^{th} *International Conference on Composite Materials (ICCM 17)*, Edinburgh, Scotland, 2009

4 M.M. Robins, R.W. Rennell, R.D. Arnell, J. of Phys. D: Appl. Phys. 17, 1349–1360 (1984)