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Kiss-roll Coating for the High-Speed Manufacture of Hybrid Bicomponent Fibers

Hybrid bicomponent fibers represent a promising class of intermediate materials that facilitate the high-volume production of thermoplastic composites. As a method to manufacture such hybrid bicomponent fibers, we propose a kiss-roll coating process in-line with glass melt spinning. A high-speed study is presented to prove the feasibility of the process to yield fiber volume fractions appropriate for use in advanced structural composites. The influence of the polymer concentration in the coating solution, the radius and the peripheral speed of the kiss-roll on the necessary fiber velocity to yield a given fiber volume fraction are assessed via a parametric study using a central composite design of experiment.

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Introduction

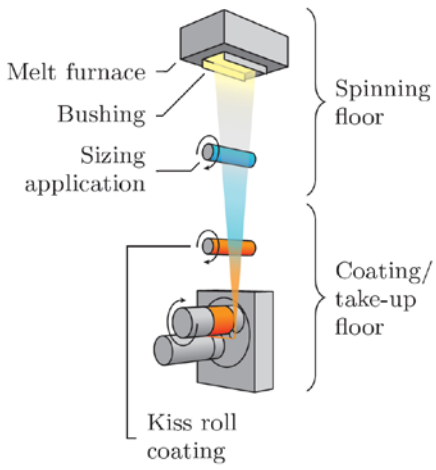
Compared to existing intermediate materials, bicomponent fibers[1-3] allow for very short cycle times in the manufacture of thermoplastic composites through the minimization of flow lengths during consolidation, while retaining the high formability of dry fibrous preforms.

The manufacture of hybrid bicomponent fibers is however not trivial and finding a fast and economical method is crucial for the concept to support the high-volume industry.

Fluid-based coating technologies seem to work best; they can be run at high speeds through the use of dilute polymer solutions and by introducing limitations to the volumetric flow of the coating liquid. Kiss-roll coating does this by running the fiber through a thin film on a rotating roll which is partially immersed in the fluid[1]. The short contact length coins the term "kiss-roll".

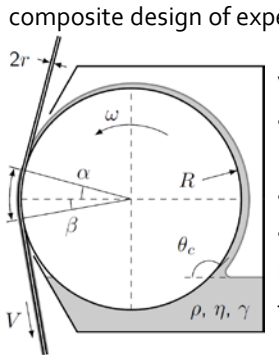
Economical in-line coating process

To allow individual filaments to be coated in a high-volume scheme, the coating method needs to be used in-line with the fiber spinning process, the only stage where the filaments are separately accessible. This is already used to size reinforcement fibers for improved adhesion to the subsequently added matrix material.[4]



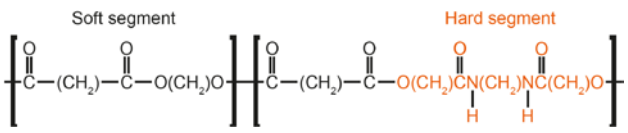
Parameter study

To idenfity the influence of coating parameters on the resulting coating and the achievable process speed, a parametric study was performed using a central composite design of experiment.



Variation of:
- Polymer concentration in solution w_p
- Peripheral roll speed $U = \omega R$
- Roll radius R

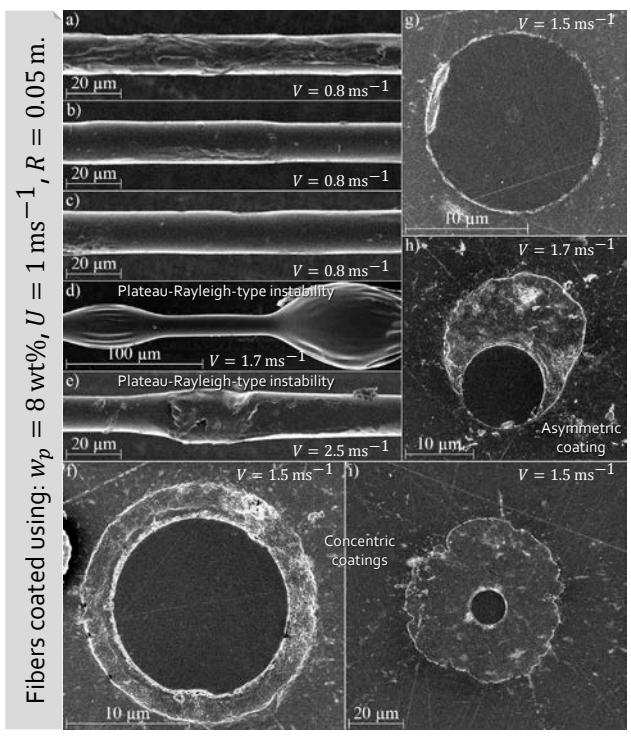
Measurement of fiber volume fraction $\overline{v_f}$ versus fiber speed V.



Segmented block poly(ester-amide). *Source: Dow Europe GmbH.*

Coating solution: poly(ester-amide) (Dow Europe) in trichloromethane.

Results parameter study

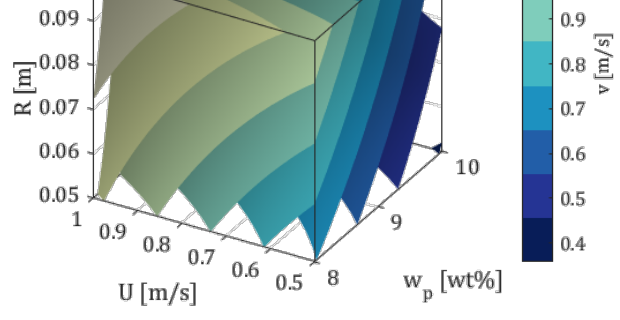


Experiments performed using single glass mono-filaments (lengths < 4 m, mean diameter 12 µm)

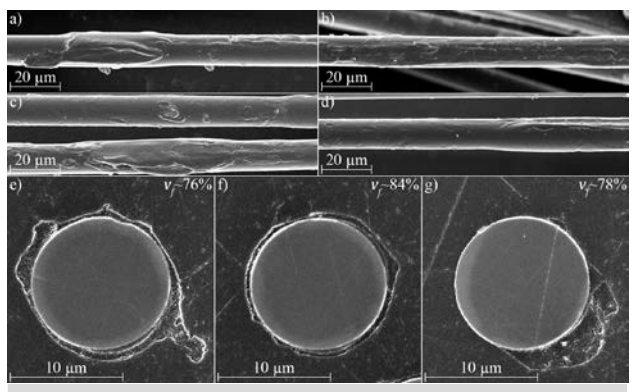
Properties of the coatings created in all experiments:
- Mostly concentric cross-sections
- Uncorrelated variations in surface roughness
- Varying thickness (Plateau-Rayleigh-type instability)

Sensitivity of possible process speed

Linear multivariate regression of V yielding $\overline{v_f} = 0.7$.



Results high-speed coating trials



$V = 14\,\mathrm{ms}^{-1}$, $w_p = 5$ wt%, $U = 1.88\,\mathrm{ms}^{-1}$, $R = 0.1$ m.

Conclusion

High-speed trials ($V = 14\,\mathrm{ms}^{-1}$) prove that **kiss-roll coating in-line with glass melt spinning** ($V \in [8, 60]\,\mathrm{ms}^{-1}$)[3,4] **is feasible**.

Highest fiber speeds are achieved by:
- **Minimization of polymer concentration**
- **Maximization of roll speed and radius**

$w_p \downarrow$
$U \uparrow$
$R \uparrow$

References

[1] C. Schneeberger, N. Aegerter, J. C. H. Wong, and P. Ermanni. Manufacture of Hybrid Bicomponent Fibers by Kiss-roll Coating. *ICCM-21*, Xi'an, China, 20-25th August 2017.
[2] C. Schneeberger, J. C. H. Wong, and P. Ermanni. Bicomponent Polymer/Glass Fibres for Stamp Forming. *SAMPE Europe Conference 16*, Liège, Belgium, 13-15th September 2016.
[3] C. Schneeberger, J. C. H. Wong, and P. Ermanni. Manufacturing of Bicomponent Fibers for Thermoplastic Composites: A Feasibility Study. *ECCM17*, Munich, Germany, 26-30th June 2016.
[4] K. L. Loewenstein. *The manufacturing technology of continuous glass fibers*. Elsevier, 2nd ed., 1983.

Partners

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