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Pultrusion of large cross-section thermoplastic profiles for high voltage insulator cores

With energy demand increasing worldwide, high voltage insulators with increased length and cross-section are required to ensure efficient power transport. The manufacturing of glass fibre reinforced rods, which are the central component of a composite insulator as shown in figure 1, is becoming increasingly difficult using Epoxy matrices due to the formation of cracks and other defects. This research project is therefore aimed at investigating the substitution of epoxy matrices with thermoplastic materials in two steps. First, challenges related to the manufacturing of large cross-section profiles need to be solved, before investigating the suitability of thermoplastic materials for insulation purposes.

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Motivation

Drawbacks of state of the art insulator cores:

- Exothermic reaction of Epoxy matrix causing cracks and other defects
- Use of solvents & limited shelf life of matrix
- No recyclability, limited fracture toughness

Approach: Substitute Epoxy with thermoplastic matrix

Challenges:

- Different manufacturing concept required due to up to 1000x higher viscosity of thermoplastics
- Efficient cooling solution to solidify the profile
- insulation property investigation of thermoplastic composites under different conditions

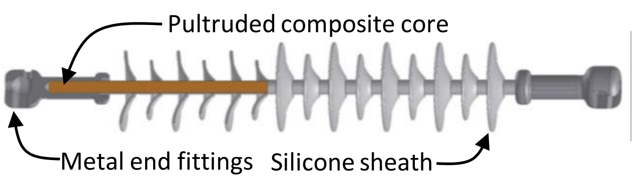

Fig. 1: *composition of composite insulator*

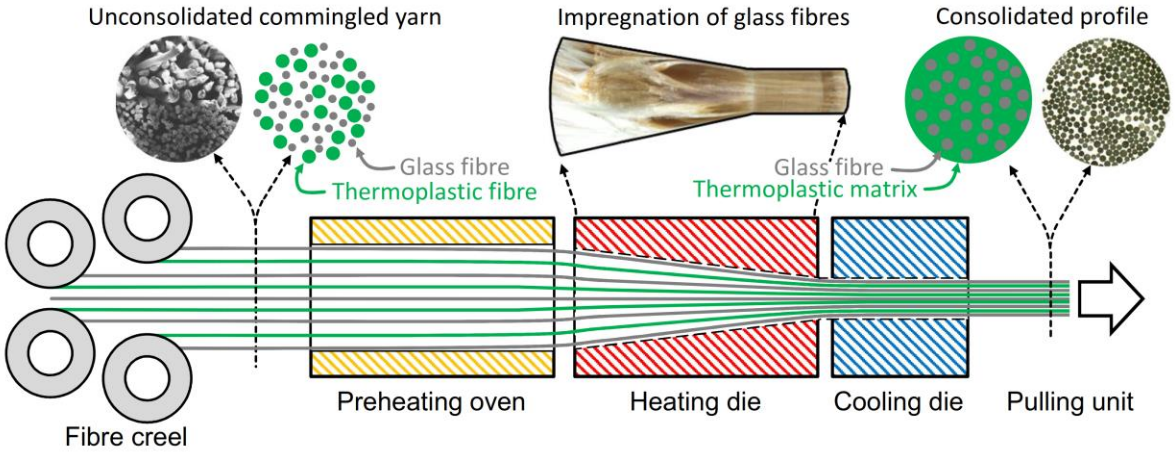

Fig. 2: *Thermoplastic pultrusion process using commingled yarns*

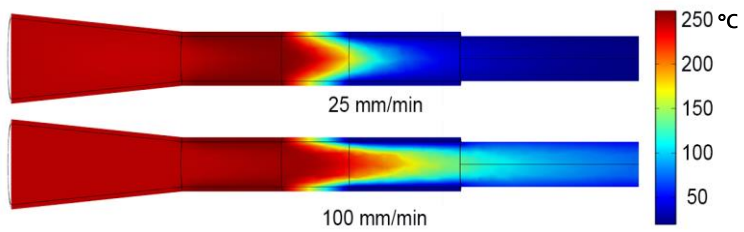

Fig. 3: *temperature distribution inside pultrusion die*

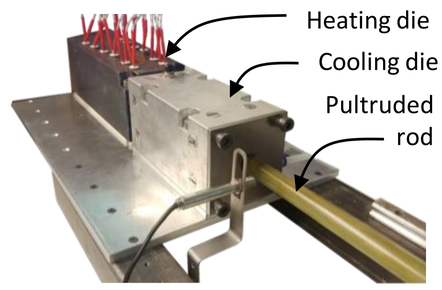

Fig. 4: *pultrusion set-up*

Manufacturing & material analysis

Development of in-house pultrusion machine:

- 100 kN pulling force, 400°C, 6 m length
- Pultrusion of profiles from Ø5-Ø40 mm
- PP, PA12, PET, PBT, PEI, PC polymers tested

Material quality:

- Increasing material throughput reduced void content as shown in Figure 6 (left to right)

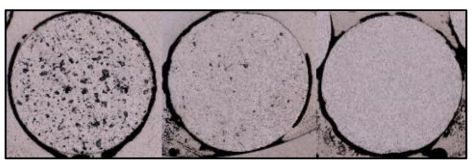

Fig. 6: *Ø 10 mm PET samples with increasing throughput*

- High quality, low void content can be assured over large range of processing parameters and diameters:

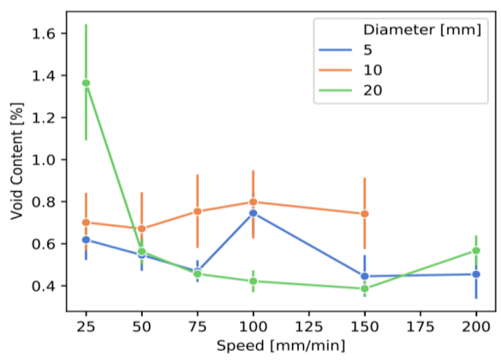

Fig. 7: *void content of pultruded samples*

Suitability for insulator cores

Insulator certification tests:

- E.g. voltage test: After 100h of boiling in salt water, the breakdown voltage of 30 mm long pultruded samples is measured. Figure 8 shows the formation of voids after the voltage test, due to thermo-mechanical relaxation effects.

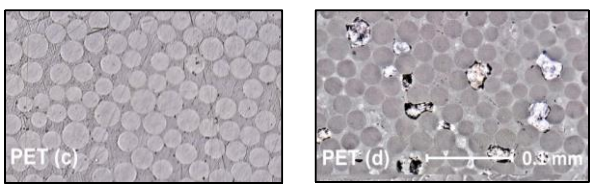

Fig. 8: *PET samples before (c) and after voltage tests (d)*

- Of all investigated polymers, PET shows the best breakdown voltage results and successfully passes all tests

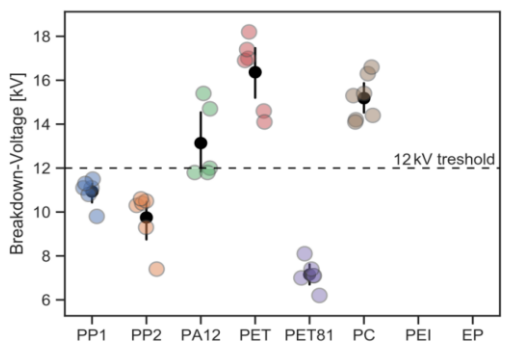

Fig. 9: *Breakdown voltages for different polymers*

Conclusion and Expected impact

Pultrusion of large cross-section thermoplastic profiles has been successfully demonstrated for profiles up to Ø 40 mm through a combination of numerical modelling and experimental investigation.
The impregnation and cooling challenges can be overcome through the right processing conditions and die design, but this processing windows becomes increasingly small with higher pultrusion speeds and larger diameters.

The suitability assessment of pultruded thermoplastic composites for insulator core applications shows that PET is the best suited polymer with a performance similar to the reference Epoxi, closely followed by PC.

Although this project focused on the application of thermoplastic profiles for insulator cores, thermoplastic pultrusion has a great potential for other sectors such as wind, automotive and construction through its solvent free, recyclable, weldable and reshapable nature at a competitive manufacturing price.

References

M. Volk; S. Arreguin; P. Ermanni; J.Wong; C. Bär; F. Schmuck, Pultruded thermoplastic composites for high voltage insulator applications, IEEE Transactions on Dielectrics and Electrical Insulation (Volume: 27, Issue, 2020)