Co-moulding of C/PEEK and C/PFA composites for tubular applications

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INTRODUCTION
Among the thermoplastic composites, C/PEEK is a top-ranked material, combining high mechanical, chemical and thermal properties. On the other hand, perfluoro alkoxy (PFA) exhibits an extremely high chemical resistance and a elevated service temperature, but has a low strength. A C/PFA protective coating in a C/PEEK tube would get very valuable parts, adapted for severe environments like high pressure, aggressive chemicals and elevated temperature up to 250°C. In this work, the development and manufacturing of tubular parts were carried out, satisfying the requirements: good adhesion between the two materials, full protection by the coating and minimal thickness.

METHODS
Processing
Two kinds of parts were produced:
• Plates by compression moulding (Greene, Tweed’s process)
• Tubes by Techna3™ moulding (Greene, Tweed’s process)

Two moulding steps:
1. C/PEEK part
2. C/PFA coating over C/PEEK

Machining after each moulding step to get a uniform thickness

The target thickness of the C/PFA protective layer was varied between 0.5 and 3mm.

A moulding temperature of 375°C was used for most of the parts produced in this work, excepted at the end to evaluate the influence of the moulding temperature.

Melting temperatures: PEEK: 334°C, PFA: 300°C

RESULTS
Screening phase
Among two available PFA-based materials (multiaxe mat vs. WR600™), the best candidate to fulfil the function had to be found.

Paper was clearly the best in adhesion but the worst in protection. However, knowing that:
• Manufacturing is much easier with the multiaxe
• Adhesion can be highly increased by adequate techniques

C/PFA multiaxe was selected as raw material

Thickness variation
Some tubes were analysed using X-ray tomography. It allowed to differentiate the two components and thus observe the interface position.

It appeared that the C/PEEK material moved a lot during the second moulding, leading to a nonuniform C/PFA thickness. The coloured picture is a 3D reconstruction of the protective layer, where thickness variations are represented by different colours.

The minimal target thickness of the protective layer for a reliable production is 0.5 mm

Adhesion improvement
Adhesion between C/PEEK and C/PFA multiaxe was really bad and had to be significantly increased.

The best solutions, using coupling agents between the two materials, were:
• PFA film
• PFA film combined with an additional C/PFA layer

The PFA film works at small scale and is related to the plasticity around the crack tip. The C/PFA layer creates large scale mechanical interlocking, making a rough interface. The combination of the two phenomena was the best solution regarding adhesion.

However, the waviness of the interface significantly reduces the thickness control of both materials. This solution was thus not selected.

Mechanical interlocking

Process parameters evaluation
Adhesion decreased when moulding temperature decreased. This temperature should absolutely be higher than 350°C to guarantee enough fracture toughness.

However, the protection level increased when moulding temperature decreased. The full protection was obtained when moulded at 340°C while leakage were observed for 375°C. The best compromise between adhesion and protection still has to be found out. It is supposed to correspond to a moulding temperature close to 360°C.

CONCLUSION
Greene, Tweed is now able to co-mould a C/PFA protective layer of 0.5 mm wall thickness in C/PEEK tubes. Adhesion between the coating and the main tube was increased to a point where cohesive failure inside the C/PFA coating was observed. Separately, the full protection of the C/PEEK part against pressurised concentrated sulphuric acid was obtained. The process parameters guaranteeing both requirements simultaneously have to be find out. The optimal moulding temperature is assumed to be close to 360°C.