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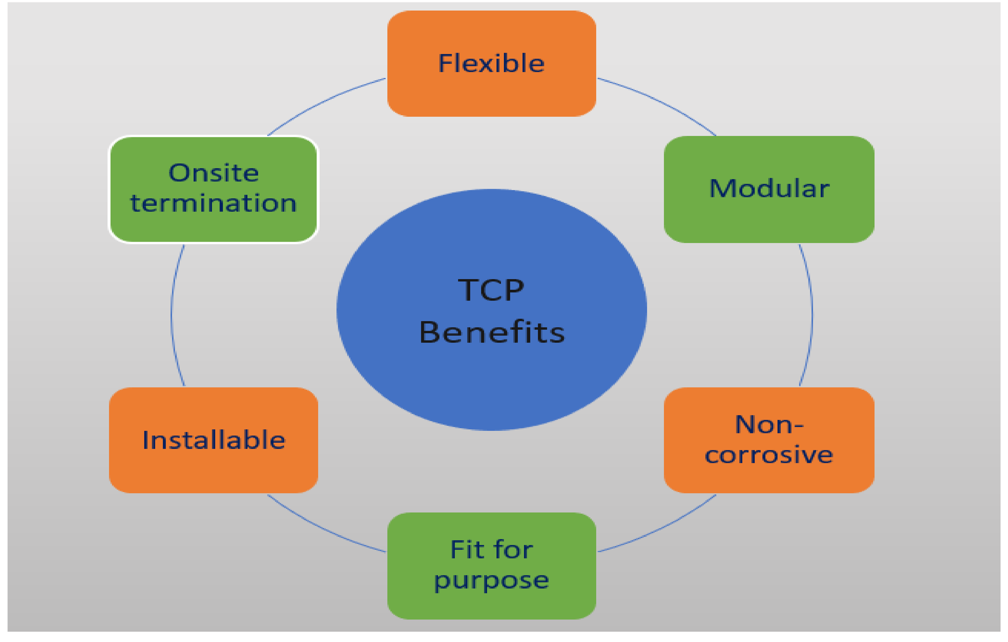
An evaluation of the morphological, microstructural and mechanical behaviour of the glass fibre/HDPE thermoplastic composite pipe

Obinna Okolie/ Strohm, Subsea 7, SP Advanced Engineering Materials PVT LTD/ Prof James Njuguna, Prof Nadimul Faisal (start date: 01/04/2020)

Introduction

- **Composite pipes** are increasingly being used as an alternative solution to conventional metal-based pipes.
- This development is in response to significant **corrosion failures** with the metallic pipes and enables better decision making especially for the plausibility of alternative offshore energy sources.
- Flexible pipes which **thermoplastic composite pipes (TCP)** belong to have proven to have beneficial features.



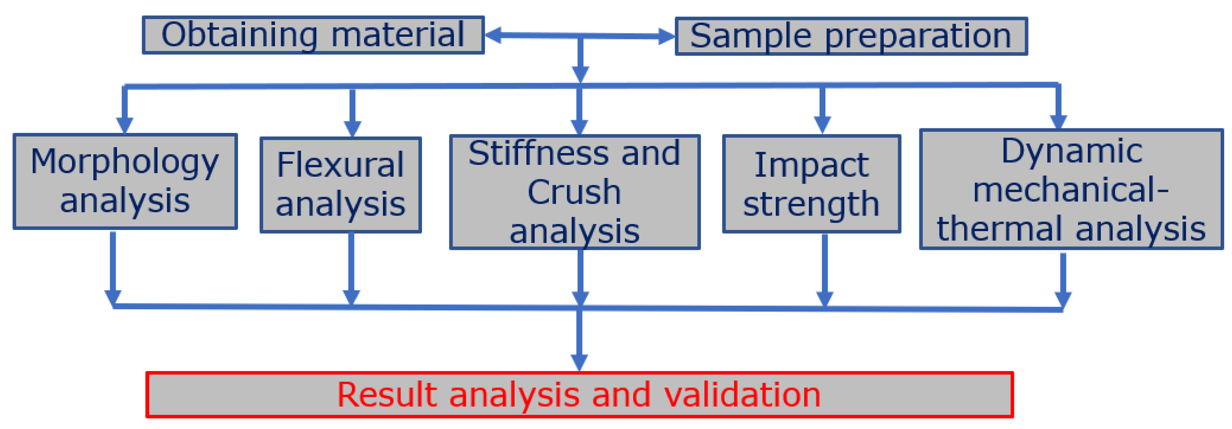
Research gap

- The challenge is that TCP can be affected by several **environmental conditions** (e.g. temperature, creep, pressure and loading conditions) during their service life.
- There is a lack of research directed towards the determination of **material behaviour** during testing.
- This work will enable the understanding of the TCP layers' **fatigue behaviour** as well as the **interlayer** and **interfacial** (matrix to fibre) compatibility.

The aim of report

- To experimentally investigate TCP and the layers based on the morphological and mechanical properties.
- To identify and utilize the methods to obtain relatively precise material properties of the TCP which are currently barely known.
- The **end properties** are to be validated based on tests and analysis from an available TCP section to establish **consistency** and serve as a **reference**.

Research methodology



- This research combines the investigation of TCP performance with the properties of the material.
- The end properties are validated based on obtaining the results from the displayed standardized tests and characterization obtained from a pristine TCP for establishing consistency.

Result and discussion

Morphology analysis

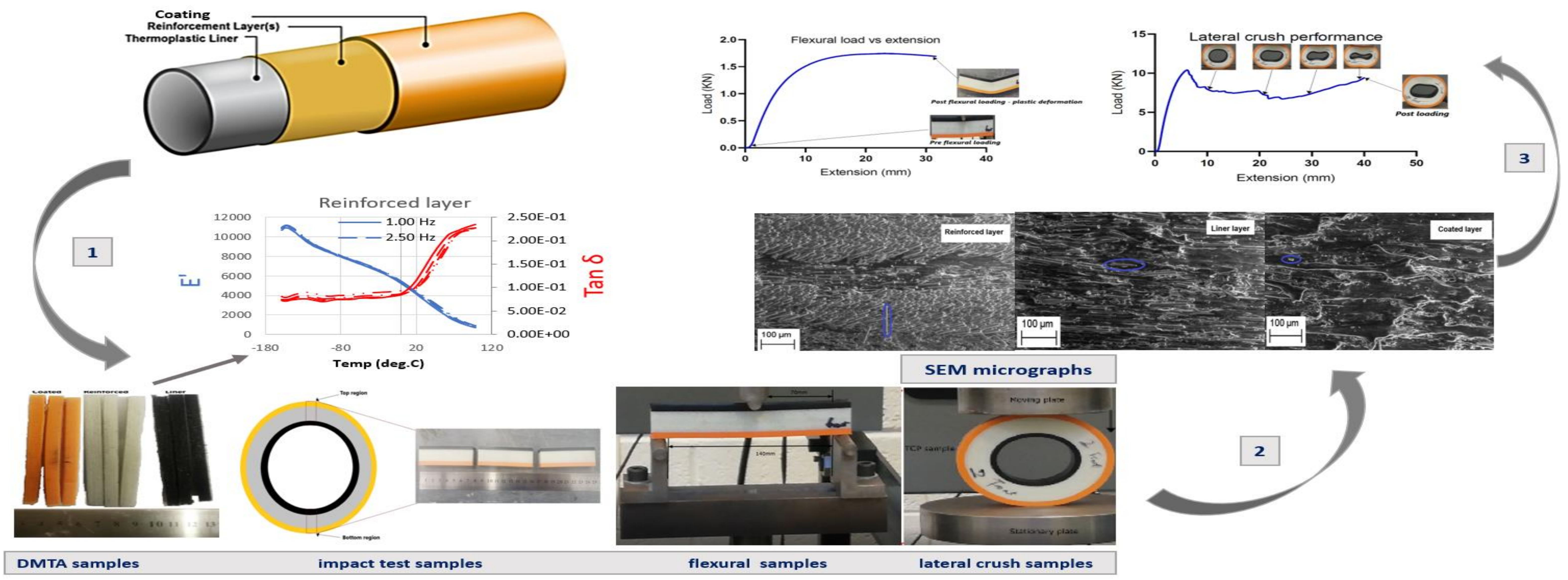
- SEM of the TCP layers at 200x magnification
- Confirmation that the reinforced layer has the most fibre followed by the liner layer and coated layer.
- From the matrix of the coated and liner layer, they are **steam sterilized**.

Flexural analysis

- From the flexural plot, a plastic deformation occurred across the midline.
- No other failure was noticed across all the layers and establishes that TCP is a **solid-walled fabrication**.

Crush analysis

- Failure mode is initiated by **matrix cracking** in the plies of the reinforced layer which encourages delamination of this layer.
- Indication that the polymer matrix in the reinforced layer has lower density due to the ease of the matrix cracking.



Impact strength

- High impact strength performance as the **layer order** has an effect on the impact strength where the typical (top) order and reverse (bottom) order are 576 and 480 KJ/m^2 respectively.
- Ductile fracture – fibre splitting.

DMTA

- Tan δ curve displays two relaxation peaks at temperatures of roughly in the γ and α stages for all layers indicating the polyethene group presence across all layers.
- γ relaxation correlates to Tg which determines the processability window. This is common with HDPE as it relates to small portions that move in the amorphous state while α relaxation is related to the molecular chain mobility in the crystalline phase.

Key findings and Conclusion

- The key failure mode is **matrix cracking** in the reinforced layer plies that encourages **delamination** which is indicative of the low density of the polymer matrix in this layer due to the ease of the matrix cracking from loading.
- An **interface modifier** is present for the glass fibre and HDPE matrix interface which has a collaborative influence that results in the improvement in the reinforced matrix and interfacial strength which enhances the **storage modulus** at the glass state in comparison to the other layer.
- Further investigation for the interlayer **bond strength** and adhesion.

Further work

- Tensile and interlayer strength tests
- Damage characterization analysis
- Thermal behaviour investigation
- Improvement of TCP manufacturing from derived properties

References

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Okolie, O., Latto, J., Faisal, N., Jamieson, H., Mukherji, A. and Njuguna, J., 2022. Manufacturing defects in thermoplastic composite pipes and their effect on the in-situ performance of thermoplastic composite pipes in oil and gas applications. *Applied composite materials*.

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