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THERMAL AND MECHANICAL ANALYSIS OF AN EPOXY FOAM SYNTHESIZED BY MEANS OF A CHEMICAL FOAMING AGENT

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ABSTRACT

This paper presents a study on the mechanical and thermal properties of an epoxy foam. It is synthesized from a commercial epoxy resin with the addition of a Chemical Foaming Agent. Epoxy foams are of interest in structural applications in junction with more popular Polymer Matrix Composites. The foam can add buoyancy and thermal insulation to composite structures, thanks to its reduced density. The material showed a range of properties that have the potential to be tailored in function of the end application.

Keywords: epoxy foam, chemical foaming, DMA, mechanical, thermal insulation.

INTRODUCTION

Polymer Matrix Composites (PMCs) are becoming more widely diffused in the Oil & Gas industry. One of the issues affecting offshore oil recovery is the need to keep the extracted crude in a fluid state to avoid clogging or solid-phases precipitation in the pipeline, despite the low temperatures of ocean water. Thermal insulation is not only a technical requirement: it can deeply affect the energy consumption of the system, hence the operational costs. Among the different techniques in use for maintaining the fluid in optimal condition, passive thermal insulation (applied to the pipelines) is one of the most convenient. PMCs are already a step ahead compared to metal alloys, thanks to their overall lower thermal conductivity. Their insulation performance can be further improved through the addition of foam liners to the pipe layered structure. Epoxy foams are interesting for composite structural applications, as they can adhere effectively to different substrates, show good mechanical properties and are thermally and chemically stable.

Another positive feature of foam usage in the pipe structure is that leads to a reduction in the overall density of the structure. This can play a relevant role in offshore riser systems which often have to withstand high structural tensile loads (Jha *et al*., 2013), and require the addition of external buoyancy to achieve a stable structure. The ability to tailor the foam layers to achieve a neutrally buoyant pipeline would greatly ease the design work, relieving important stresses to the components and materials involved, and increasing the versatility of these pipeline systems.

The industry is developing systems where the blowing agent is introduced as an additive in the resin formulation. This releases the foaming gas simultaneously during the curing reaction, exploiting the polymerisation heat generated. Foams of different morphologies can be obtained by adjusting the resin formulation and the curing parameters. This represents an easy and economical method for the epoxy foam production. In this work, we started from a commercial epoxy resin to which we added a siloxane as Chemical Foaming Agent (CFA) (Stefani *et al.*, 2003). Different amounts of CFA were attempted in multiple formulations, between 1 to 5% of the weight fraction, to find the optimum for the foam morphology sought. Once the preferred curing route was defined, representative samples were cut using a numerically controlled tool machine, in order to maintain a strict dimensional tolerance. The specimens underwent mechanical testing as quasi-static compression (following ASTM D1621 standard) and 3-point bending (as ISO 1209).

RESULTS AND CONCLUSIONS

The results highlight how the morphology of the porosities and the apparent density are pivotal to the achievement of improved mechanical strength. Thermal testing was performed as well: Dynamic Mechanical Analysis (DMA) allowed the assessment of the *glass-transition temperature* in comparison to the not foamed epoxy, while Thermal Gravimetric Analysis (TGA) offered insight about the thermal stability of the foam.

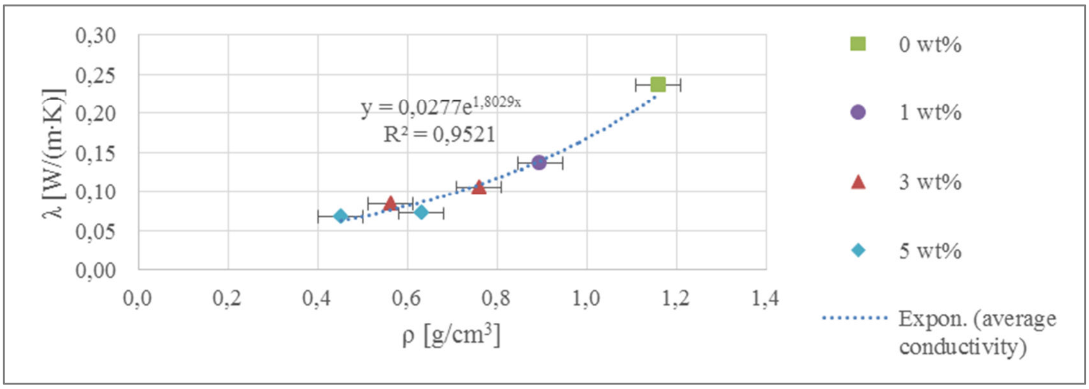

Fig. 1 - Correlation between the apparent density of the foam and the linear thermal conductivity measured at 25 °C. The percentages refer to the weight fraction of the CFA added.

Table 1 - Mechanical properties of different batches of resin in relation to their apparent density

ρ	Compressive modulus E	Compressive strength σ	E/ρ	σ/ρ	Flex modulus	Flex strength
g/cm^3	MPa	MPa	MNm/kg	kNm/kg	MPa	MPa
0.268	123.4	4.1	0.460	15.4	-	-
0.224	109.7	3.2	0.490	14.5	-	-
0.401	154.9	10.4	0.386	25.9	377.7	12.6

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