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Influence of the Fiber Mat Compaction on the Permeability of Hybrid Composites

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Abstract – This work focuses on the determination of the in-plane permeability of different fiber mats (E-glass, sisal and hybrid - glass/sisal) through resin transfer molding (RTM) infiltration experiments. For similar fiber volume fraction (V_f), permeability of the sisal mat and the hybrid were much higher than that of the glass mat. The results of fiber mat compaction tests were used to help justifying the permeability findings, since, in the hybrid system, the sisal is able to maintain a much thicker layer in comparison with the glass one, and this favors the flow through the former and consequently, in the overall reinforcement.

In this work, rectilinear RTM infiltration experiments were carried out to determine the in-plane permeability of glass fiber (GLASS), sisal fiber (SISAL) and hybrid reinforcement mats (glass/sisal). The permeability experiments were performed injecting soybean oil, under constant pressure (0.1 bar), into the mould in which the dry reinforcement had been placed. The glass mats were used as received, and the sisal mats were manually produced after cutting (fiber length: 40 mm), washing, drying and hot pressing the fibers. Table 1 shows that the sisal yielded the highest permeability, followed by the hybrid mat, in comparison with the glass. A hybrid laminate composite [glass/sisal/glass] was molded using orthophtalic polyester resin and P-MEK (2% v/v) and an aluminum foil was inserted between the layers to help highlighting the interface. This composite was sectioned and its cross-sectional area was photographed and analyzed with an image analysis (Image J) software. Figure 1 shows that the sisal mat is much thicker than the glass one, even though the amount of sisal is half that of the glass (in volume). The single mats were then submitted to compression using a Schimadzu Autograph AG-X machine and the height of the mat for a certain load was followed (Figure 2) in order to correlate this with the final thickness of each layer in the hybrid composite. Using the load gradient between 10 N (stress = 0.127 kPa) and 7854 N (stress ≈ 100 kPa), for instance, the strain variation for glass was 4.62%, whereas for sisal was just 2.85%. In an analogous way, one may say that, for the same applied pressure, the expected thickness of the glass mat is much lower than the sisal mat (as in Figure 1). Therefore, the higher permeability of the sisal and its contribution to the hybrid stack can be partially explained by the higher thickness and therefore lower relative fiber volume fraction of that layer, allowing the development of wider channels or pathways for the fluid flow. In addition, a greater flow tortuosity in the glass mat explains why even when the fiber volume fraction is similar (See Table 1) sisal shows a much higher permeability.

Table 1: Permeability of the different materials.

Reinforcement	V_f (%)	Permeability ($\times 10^{-9}$ m^2)
Glass	18.9	1.28 ± 0.146
Sisal	19.7	3.82 ± 0.204
Hybrid (Glass/Sisal)	13.3 (glass) 6.7 (sisal)	2.74 ± 0.538

Figure 1: Cross-sectional view of the hybrid composite showing the three layers (glass/sisal/glass).

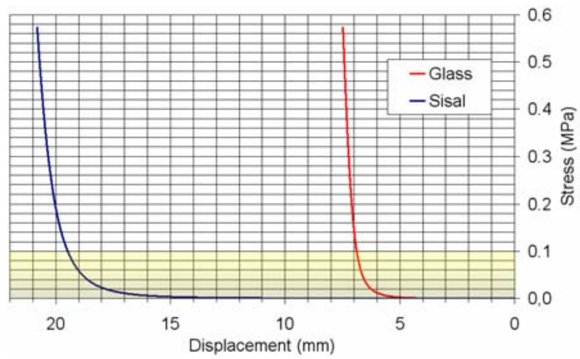

Figure 2: Thickness variation with pressure for different reinforcement mats (same fiber volume).

References
[1] T.M. Schmidt, T.M. Goss, C. Lekakou and S.C. Amico, Journal of Reinforced Plastics and Composites (2009), in press.