Improving Adhesive Bonding of Composites Through Surface Characterization
Using Inverse Gas Chromatography (IGC) Methods
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Objective & Need
Surface preparation is essential in the adhesive bonding process for composite materials. Methods are needed to inspect prepared surfaces for optimal surface conditions for bonding. This is of particular importance in the aerospace industry where joining composites by use of adhesive bonding rather than mechanical fasteners is desired. Adhesive bonding will reduce weight, thus increasing efficiency, and will eliminate stress concentrations introduced by mechanical fasteners. Peel ply preparation is often used as a surface preparation method for bonded composite structures. Polyester and Nylon fabrics are commonly used for peel ply surface preparation. Contact angle measurements provide a high level of understanding of the surface energies of these materials, however, measurements can be difficult to interpret because the peel ply leaves a surface with non-flat topography and wide range of surface energies. Inverse Gas Chromatography, while well-known for measuring the surface energies of powders, is a relatively new method for characterization of the surface energy of composite materials. With the development of a film shell attachment to accommodate cured composite samples, this dynamic technique is able to discern subtle differences between peel plies and depict the heterogeneity of surface energy across the panel.

Results

Figure 3: Surface energy comparison of four 60001 Polyester peel ply trials

Figure 4: T-test statistics show that IGC 60001 trials were all statistically identical

Figure 5: Total surface energy comparison of Polyester and Nylon peel ply trials

Figure 6: Distribution of total surface energy comparison of Polyester and Nylon peel ply trials

Conclusions

IGC Repeatability:
• IGC statically replicated data over several tests of a given peel ply (Figure 3 & 4)
• Small variability likely from panel fabrication and actual versus target fractional surface coverage areas

IGC Compared to Contact Angle Surface Energy Values:
• Contact angle measurements allow only a homogeneous representation
• IGC is able to measure the panel at higher fidelity and show the heterogeneous nature of the surface (Figure 5)
• Polyester IGC data bisects contact angle measurements at highest energy sites (Figure 5)
• Suggests contact angles do not necessarily represent the average surface energy
• Distribution of the surface energy measurements show the contact angles are within IGC measured ranges (Figure 6)
• Distributions indicate the degree to which the panels are heterogeneous
• IGC is able to measure at a higher fidelity on the surface energy sites across the panel

The Inverse Gas Chromatography (IGC) was able to provide high fidelity surface energy data through showing the variation of energetic sites across the composite surface. It is able to detect more subtle differences in energy sites between various surface preparation methods. At this time, the IGC method is a viable analytical lab method but requires more optimization for field use.

Future Work
Continued research is recommended to study the application of IGC to directly relate surface preparation to bond quality types. More information through the collection of additional statistical data and material coupon testing in the form of X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), double cantilever beam (DCB), and a topography study would help to provide a more complete representation of the bonding surface. Although IGC is able to provide more information on surface energies related to various surface preparation techniques, understanding the bonding surface will require investigation into other contributors.