EXPERIMENTAL STUDY ON THE REDUCTION OF INTERFACIAL ADHESION BETWEEN EPOXY AND MOLD USING COMPOSITE PARTS AND LASER ABLATED TOOL SURFACES

Martin Roy

Department of Chemical Engineering & Mechanical Engineering, McGill University, Montreal, Quebec

What are Composites?
For the purpose of this study, composite materials consist of a continuous matrix that surrounds a reinforcement. Specifically, for this project, high performance composites are used, which usually come as pre-impregnated layers (Prepreg) from the manufacturer.

What is Interfacial Adhesion?
Interfacial adhesion occurs when the matrix from the part bonds to the surface of the tooling. In order to reduce interfacial adhesion, release agents are used on the mold surfaces.

Why is Reduction of Interfacial Adhesion Important?
1. The release agents used to reduce adhesion are hazardous and add production costs.
2. Interfacial adhesion causes residual stresses in the part which in turn can "warp" the part.

How Does Laser Micromachining Reduce Interfacial Adhesion?
By use of a femtosecond laser, distinct micro- and nanostructures can be ablated on the tool surface (for example, micro-channels). By creating these structures, the effective contact area between the tool and part can be reduced, thereby reducing interfacial adhesion.

Objective
Our objective is to develop a testing procedure that can characterize the interfacial adhesive strength between tool and part by producing repeatable and comparable results.

Method
Lap shear testing (similar to ASTM standards) was used to see if differences in apparent shear forces could be measured between differently treated tooling surfaces. Utilizing this method, a correlation between release agent content and reduced lap shear strength is to be expected. Femtosecond laser micro machined tool surfaces can then be compared with these standard treated tool surfaces.

Introduction

Lap shear test

MTS Results for CYCOM 5320 2 plies [*0⁰ /0⁰+]

Results from Hot Pressed Samples

As an initial attempt, lap shear samples where made using a hot press. Although a hot press is not commonly utilized to manufacture high performance composites such as prepreg, it was presumed that similar conditions can be mimicked while simplifying the processing of the samples. Contrary to the initial presumption, it was found that the hot press presents various complications:

1. Mismatched CTEs causes residual stresses in the part which in turn cause interfacial debonding during the cooling phase
2. Order of debonding consistently follows proportionally to the order of release agent content (sample with no release agent will debond first)
3. Samples with closely matched CTEs to the aluminum showed unusually high apparent shear forces.
4. This is caused by excess pressure and epoxy volume during curing.

Lap Shear Samples
4"x4"x1/16" aluminum 6061T6 (tooling aluminum)
• Three samples are prepared per curing cycle
• All samples are polished with 5IC abrasive paper, cleaned and coated with sealer (2 coats)
• Two coats of release agent is applied to the first sample, one coat is applied to the second and the third is uncoted.
• The square inch prepreg tabs are sandwiched between the aluminum coupons and cured.

PrepTab Tabs
Two high performance composites are used in these tests:
CYCOM 5320 (carbon/epoxy) [unidirectional] 2plies [*0⁰ /0⁰+]
• Curing cycle: 3 hour 127°C heat hold at 68kPa
• Recommended ramp rate: 0.6-2.8°C/minute
• CTE: 3.6-9µm/°C

CYCOM 3203 (glass/epoxy) [woven] 2plies [*0⁰ /0⁰+]
• Curing cycle: 1.5 hour 121°C heat hold at 81kPa
• Recommended ramp rate: 1-3°C/minute
• CTE: 14.4-19.8 µm/°C

Results from Vacuum Bagged Samples

As a secondary approach, vacuum bagging was utilized to make samples. It was believed that this processing technique could reduce the variability of the test results by maintaining consistent pressure and consistent cure cycle temperature profiles.

Observations
• The vacuum bag system reduced excess resin during curing.
• Due to reduction in excess resin, some samples with CYCOM 3203 prepreg tabs were successfully debonded in shear on the MTS machine.
• Although the 5m load cell was still a limiting factor for this material, a correlation began to emerge from the data.
• The correlation is the reverse of the correlation originally expected.

A hypothesis to this unexpected correlation is that the release agent reduces residual stress within the part caused by mismatched CTEs which, in turn, reduces instantaneous debonding in the adhesive interface.

Summary

• A correlation was observed between release agent content and increase in shear force required to debond the samples.
• This suggests that the release agent reduces residual stresses within the part caused by mismatched CTEs.
• Further experimentation needs to be conducted to validate this observed correlation.

• If such correlation is validated, the lap shear test could be used to compare results between femtosecond laser micro machined tool surfaces and tool surfaces treated with standard release agent coatings.

• It should be noted that this test method is limited to comparative data and that in-situ testing would be required to produce fundamental data.

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