Quadruple Lap Shear Processing Evaluation

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ABSTRACT

The Thiokol, Science and Engineering Huntsville Operations (SEHO) Laboratory has previously experienced significant levels of variation in testing Quadruple Lap Shear (QLS) specimens. The QLS test is used at Thiokol / Utah for the qualification of Reusable Solid Rocket Motor (RSRM) nozzle flex bearing materials. A test was conducted to verify that process changes instituted by SEHO personnel effectively reduced variability, even with normal processing variables introduced. A test matrix was designed to progress in a series of steps; the first establishing a baseline, then introducing additional solvents or other variables. Variables included normal test plan delay times, pre-bond solvent hand-wipes and contaminants. Each condition tested utilized standard QLS hardware bonded with natural rubber, two separate technicians and three replicates. This paper will report the results and conclusions of this investigation.

INTRODUCTION

In 1993, the first QLS specimens were processed at SEHO during the down-selection of aqueous cleaners for the replacement of 1,1,1 trichloroethane (TCA) in vapor-degreasers. Over the course of a year, specimens were processed on five different occasions, each producing unacceptable and unexplainable levels of variation. A team comprised of NASA, SEHO and Utah S&E was established to investigate the problem, but was dissolved when all possible efforts to render a solution were exhausted. The QLS portion of the test was then transferred to Utah.

QLS testing at SEHO was revived again in the latter part of 1999, with changes to processing methodology that provided ample positive results to proceed with a formal Engineering Test Plan. These changes included the use of polyurethane foam brushes for primer, adhesive and tackifier applications instead of nylon bristle brushes, shimming the QLS molds instead of the cure press and changing the cure cycle to include a temperature ramp before initiating the cure cycle.

The primary objective of this test was to demonstrate QLS specimens could be successfully bonded at the SEHO lab after implementing the changes to our processing methodology. The secondary objective was to introduce typical variables and contaminants that may be encountered during hardware processing to demonstrate that the method was robust.

The test was designed to progress in a series of steps, each step introducing another variable. First, using standard QLS hardware and specified processing protocol, three replicates of four QLS specimens were processed at different times by two separate technicians. The second iteration incorporated normal test plan delay times for contamination purposes, with no contaminant. The third iteration incorporated normal test plan delay times that are encountered for contamination purposes, with no contaminant and a pre-bond hand wipe with TCA. The fourth and fifth iterations introduced the contaminants Conoco HD-2® grease and Permacel® tape adhesive respectively, delay times and a pre-bond hand-wipe cleaning with TCA. The test matrix is shown below in Table I.

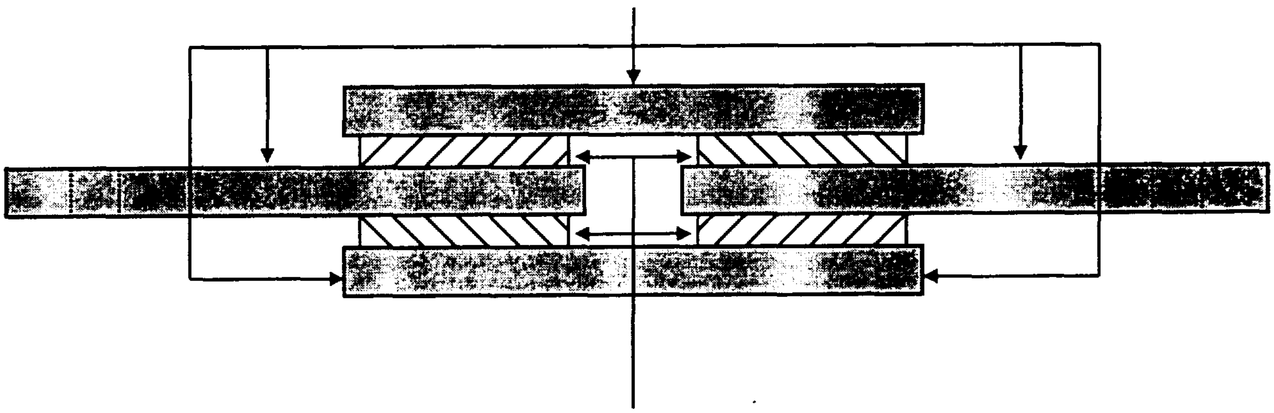
Table I: Test Matrix

Test	Specimens	Replicates	Technicians	Specimens per Test
Baseline	4	3	2	24
Normal Time-Delay	4	3	2	24
TCA Hand-Wipe	4	3	2	24
TCA Hand-Wipe HD-2	4	3	2	24
TCA Hand-Wipe Permacel Tape	4	3	2	24
Total				**120**

TESTING

The test specimens consisted of steel QLS plates bonded together with natural rubber using a primer (Chemlok® 205); a rubber-to-metal adhesive (Chemlok® 220); and a tackifier (Tycement). A typical QLS specimen is illustrated below in Figure I.

Figure I: QLS Specimen



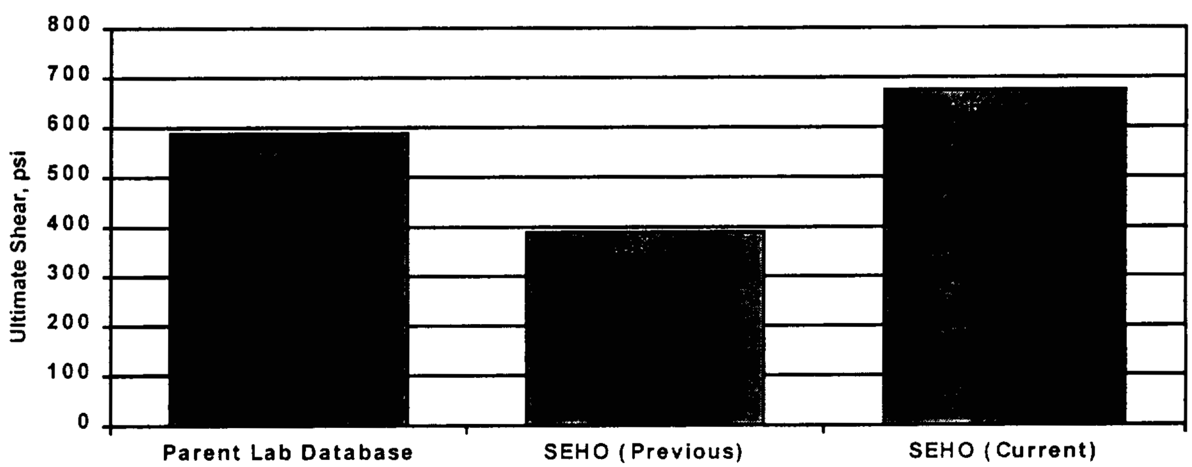
All QLS hardware utilized for this test was measured to the nearest .001" and placed in sets not varying more than .002". All bonding surfaces were grit blasted and spray-in-air cleaned after which they received a final grit blast before processing. Baseline specimens were bonded the same day as the final grit blast. Normal time delay specimens were allowed to sit undisturbed for 36-48 hours after the final grit blast prior to bonding. TCA hand-wipe specimens were allowed to sit undisturbed for 36-48 hours after which they were wiped using the double hand-wipe method prior to bonding. Specimens contaminated with HD-2 grease and yellow tape adhesive were placed in an oven for 24 hours at 100°F, allowed to sit at ambient for an additional 12-24 hours then cleaned with TCA using the double hand-wipe method prior to bonding.

Test specimens were cured for 2 hours at 300°F then allowed to condition for a minimum of 24 hours at ambient. Mechanical testing was conducted at ambient laboratory temperature and humidity using a test rate of 0.5 inches per minute.

RESULTS

Average results for the Baseline specimens exceeded the 500 psi minimum shear strength requirement for this bondline by 35%. Results also yielded a 73% increase over specimens tested previously at SEHO and surpassed our parent lab's historic average by 15%. Shear results are shown in Figure II.

Figure II: Baseline Shear Comparison



Results also denote a significant decrease in the Coefficient of Variance (CV) compared to previous SEHO testing and our parent lab's historic database as shown in Figure III.

Figure III: Baseline CV Comparison

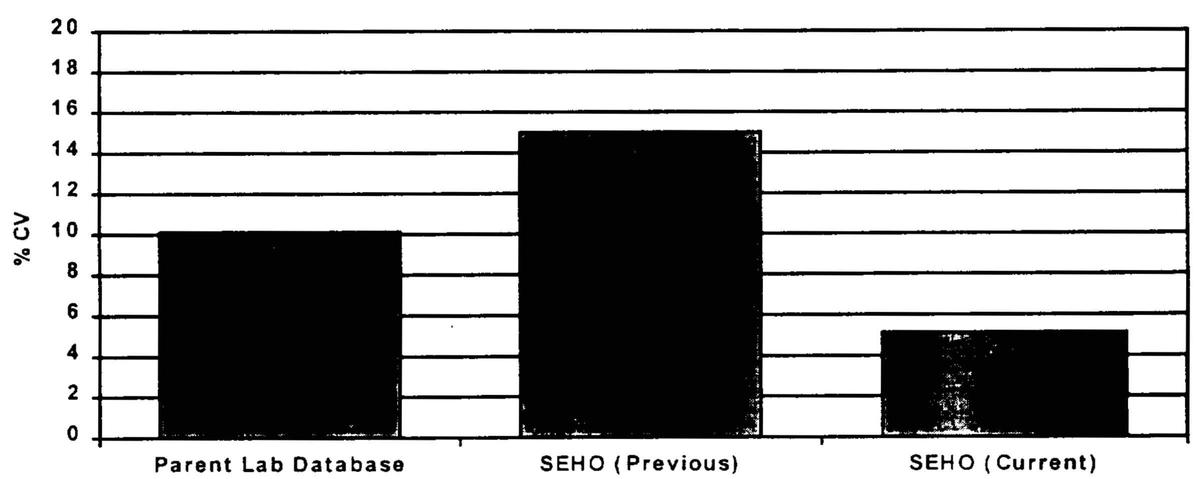


Figure IV summarizes average shear strength results obtained from the test conditions that were shown in Table I. As with the Baseline specimens, all conditions tested significantly exceeded the minimum shear strength requirements for this bondline.

Figure IV: SEHO Current Shear Results

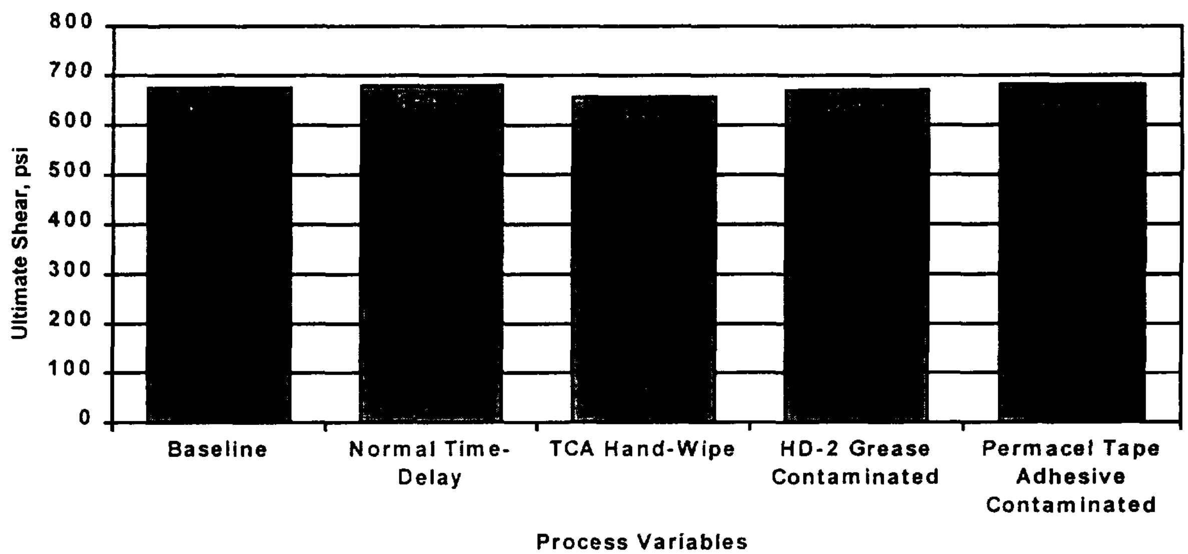
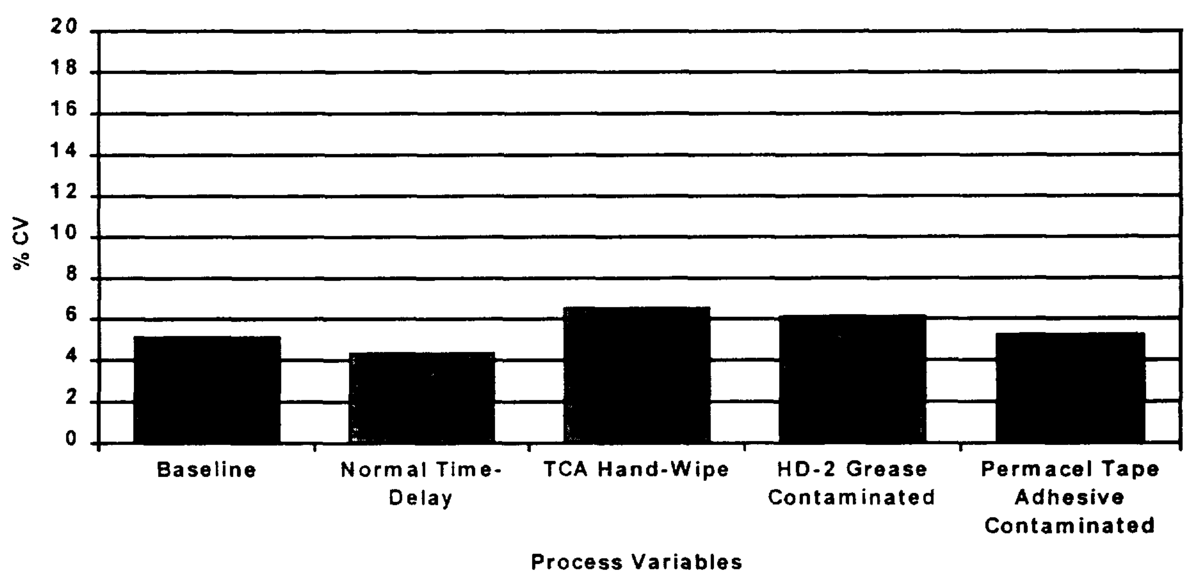


Figure V summarizes average CV results obtained from this testing. As with the Baseline specimens, all conditions tested displayed minimal percentages of variation.

Figure V: SEHO Current CV Results



CONCLUSIONS

The program objectives were accomplished demonstrating that SEHO can reliably process QLS specimens without unexplainable variation in test results. Successful QLS processing can be achieved with or without intentional test variables introduced. Current testing demonstrated shear strengths that significantly exceeded minimum requirements.

The success of this program can be attributed to changes made to processing methodology that included:

- Brushes
  - Nylon bristle brushes previously used for application of the primer, adhesive and tackifier were found to be conducive to introducing "streaks" on the surface that seemed to be causing adhesive bond failure
  - Polyurethane foam brushes currently used produce a thin, uniform coating that eliminates streaks and significantly reduces adhesive bond failure
- QLS mold pre-heat
  - The previous method of shimming the cure press did not allow top platen to contact the QLS molds during pre-heat
  - The current method of shimming the molds allows maximum heat transfer from the top platen directly to the molds
- Cure cycle:
  - The cure cycle previously used did not allow time for the press to reach cure temperature before initiating the 2 hour cure
  - Cure cycle currently used incorporates a ramp to cure temperature before the 2 hour cure cycle is initiated

ACKNOWLEDGEMENTS

This effort was accomplished as the result of a collaboration of many individuals. The following people played significant roles in this work: Richard Boothe, Troy Daugette, Charlie Davis, Jill Keen, Ken Peacock and the SEHO Test Lab.