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Industrial Adhesives and Tapes Division

Project IBIS: Shear Impact Testing
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<u>Application Description:</u>

Structural adhesives are increasingly being used to displace welds or mechanical fasteners in industrial applications. Many of these applications experience high impact loads, and as such it is important to understand the qualifiable and quantifiable impact performance of structural adhesives. Especially as applications migrate from welded steel-to-steel assemblies to bonded dissimilar material assemblies, high-strain-rate impact performance of a system will become more important for predicting the performance of the structural adhesive bond. The Corporate Research Labs at 3M have developed a test method for evaluating impact, providing a fully quantified impact curve for adhesives in shear.

One application family of interest is a tube-in-tube or collar-to-shaft assembly shown schematically in Figure 1. Applications such as these are prone to shear from an impact event. Some common industrial applications may include flanges or collars on pipes, shafts and hosels in golf clubs, drive shafts in automotive, or beam extensions in signage. Applications such as these that were historically welded are migrating to plastics, composites, or aluminum requiring the use of structural adhesives. This allows for weight savings, performance improvements, or cost reductions.

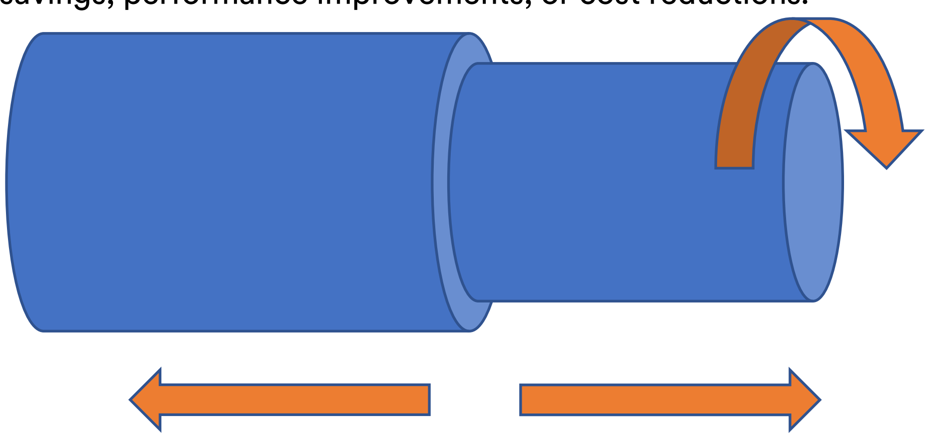

Figure 1: Representation of a bonded tube-in-tube assembly that maintains shear loading of the adhesive bond line.

Additional considerations in joints such as these include cure shrinkage, bond line spacing, void-free adhesive fill, among others. However, the testing outlined below attempts to provide quantified shear impact performance of two structural adhesives known for their impact performance and durability.

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Purpose of Test:

Shear impact can be reliably tested using an Instron CEAST 9340 drop tower. These drop towers have typically been used for puncture testing or as a platform for tensile impact; however, through modifications of the fixture and sample geometry, it can be retrofitted to test in shear modes. The sample geometry and impact location can be seen in Figure 2. The shear impact specimen consists of three substrate blocks bonded in two bond lines. The symmetry prevents torqueing of the sample or mixed-mode stresses common in other impact methods such as the shear pendulum.

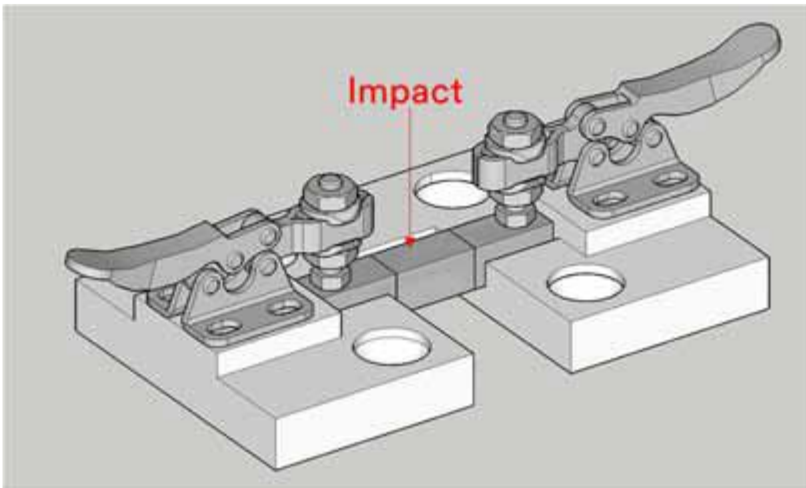

Figure 2: Fixture holder and adhesive geometry used during a shear impact event.

The advantages of using a CEAST 9340 are threefold. The impact conditions can be carefully controlled and varied; the test provides a complete force vs. time displacement reading and the substrates, adhesives, and preparation conditions can be varied to match the requirements of the application.

Per internal 3M test methods, striker geometry and drop conditions were chosen to maintain a uniform strain rate throughout the impact. Based on the geometries chosen, the engineering strain rate of the impact can be calculated or modified as needed.

Process considerations such as bond line spacing, void-free filling, and cure shrinkage may impact assembly-level impact performance. Table 1 provides typical values and considerations to be used for production.

Table 1: Typical values and process considerations for 3M™ Scotch-Weld™ Epoxy Adhesive DP420NS Black and 3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS Gray.

Adhesive	Beads	Mixed Viscosity	Open Time (72°F (22°C))	Time to handling strength (50 PSI) at 72°F (22°C).	Cure Shrinkage
DP420NS Black	None	180,000 cps	20 min	120 min	2-4%
DP8407NS Gray	0.010”	20,000 cps	7 min	24 min	10-20%

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Results:

Impact specimen were prepared using three 10x10x20 mm 6061 aluminum blocks. Two adhesives were chosen for comparison with specimen seen in Figure 3: 3M™ Scotch-Weld™ Epoxy Adhesive DP420NS Black and 3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS Gray. Two different sample preparations were compared:

1. Solvent degrease, 180-grit grit blast, solvent degrease, plasma treatment
2. Isopropyl alcohol wipe only

The 3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS contains glass spacer beads at 0.010” thickness. For comparable results, 0.010” spacer beads were added to the bonds prepared with 3M™ Scotch-Weld™ Epoxy Adhesive DP420NS Black. Adhesives were cured for six hours at room temperature, followed by one hour accelerated cure at 100˚C. All samples were equilibrated to room temperature prior to testing.

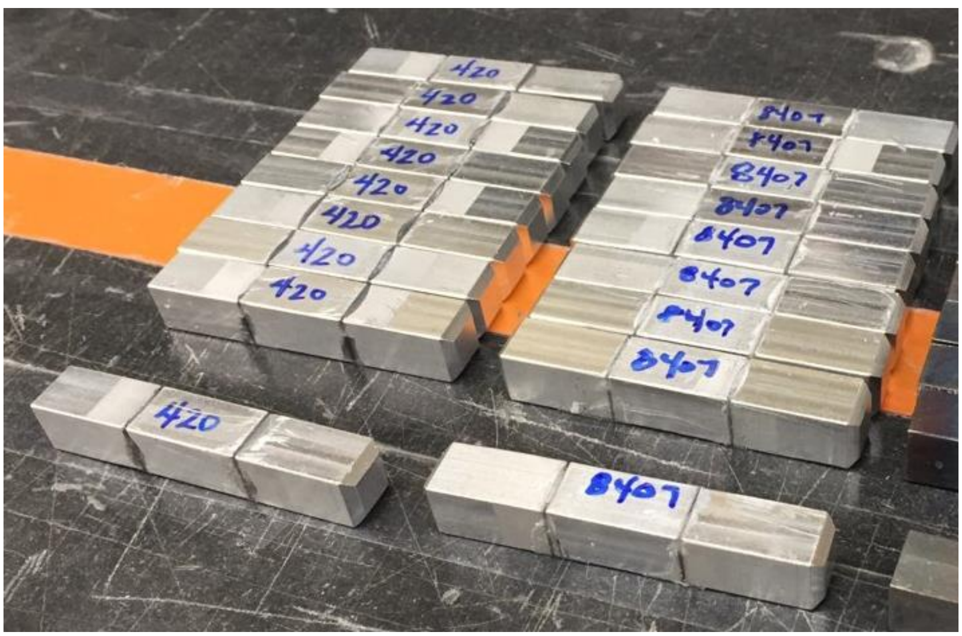

Figure 3: Bonded impact specimen using DP420NS Black and DP8407NS Gray.

High-speed footage of the impact events was taken for both 3M™ Scotch-Weld™ Epoxy Adhesive DP420NS Black and 3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS Gray.. Screen captures of the impact can be seen in Figures 4-5.

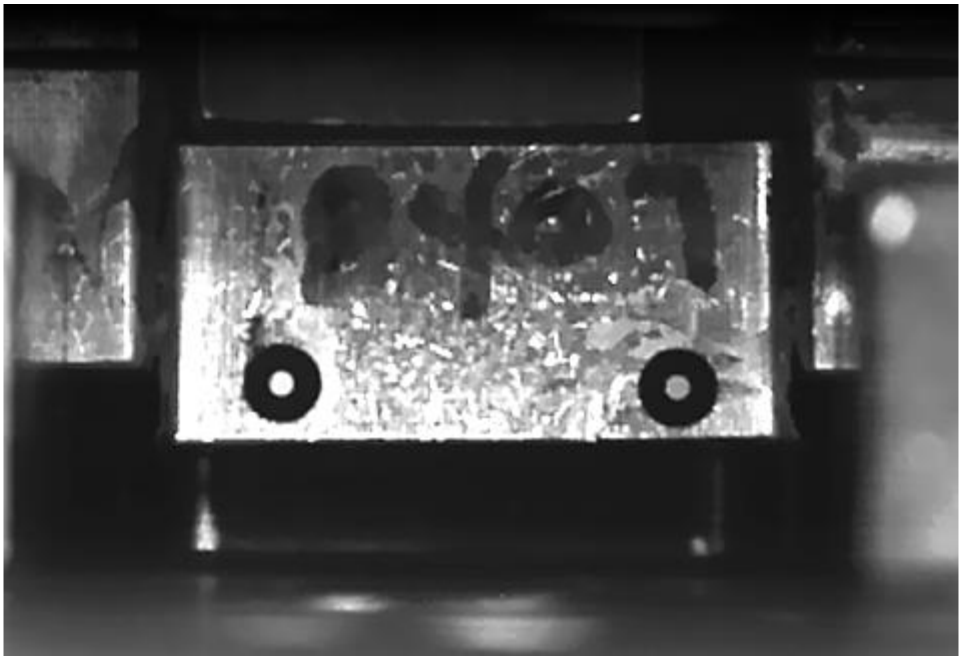

Figure 4: Screen capture of the DP8407NS Green failing under shear impact.

Figure 5: Screen capture of the DP420NS Black failing under shear impact.

Force vs. time and energy vs. displacement curves can be extracted from the load cells allowing for comparisons between adhesives or different surface preparations. The data are presented in Figures 6-11. Qualitative analysis of the failure modes can also be determined post-impact. The failure modes of specimen are documented in Table 2.

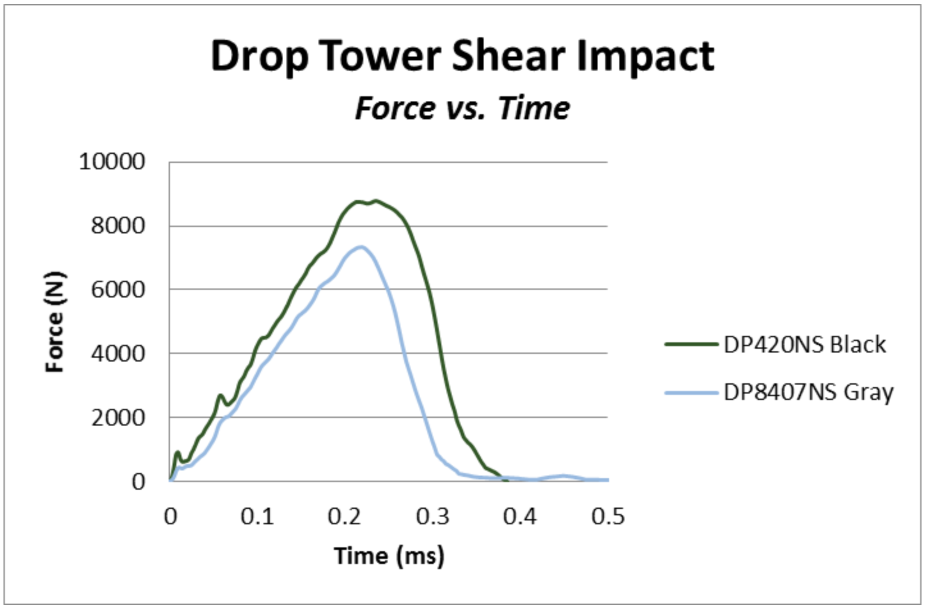

Figure 6: Force vs. Time curves for DP420NS Black and DP8407NS Green. Samples were solvent degreased, grit blasted, and plasma treated prior to bonding. Average curves reported.

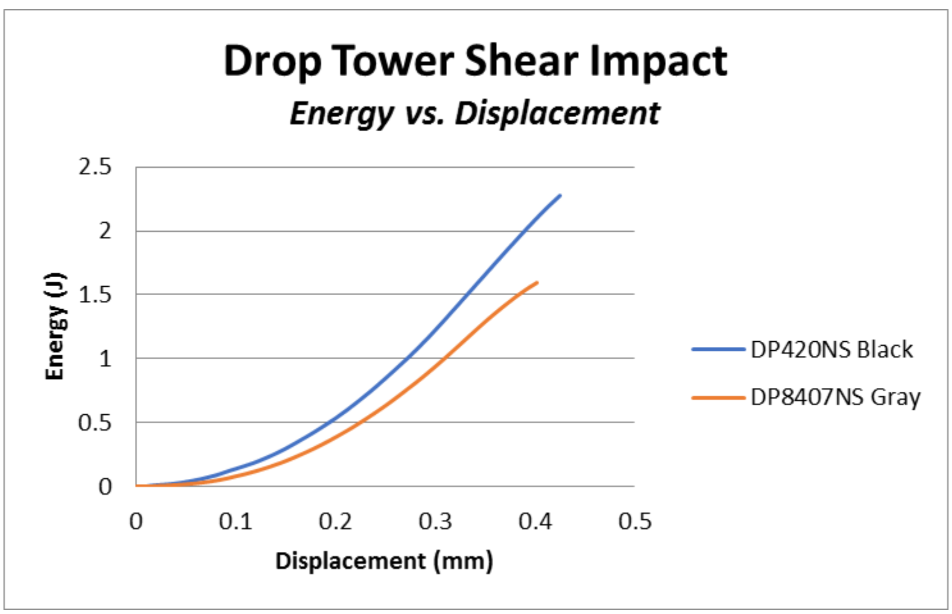

Figure 7: Energy vs. Displacement curves for DP420NS Black and DP8407NS Green. Samples were solvent degreased, grit blasted, and plasma treated prior to bonding. Average curves reported.

Table 2: Observed failure modes of test specimen after different surface preparations.

Adhesive	Surface Preparation	Failure Mode
DP420NS Black	Degrease, Grit Blast, Plasma Treat	Adhesive
DP420NS Black	Isopropyl Alcohol	Adhesive
DP8407NS Green	Degrease, Grit Blast, Plasma Treat	Cohesive
DP8407NS Green	Isopropyl Alcohol	Cohesive

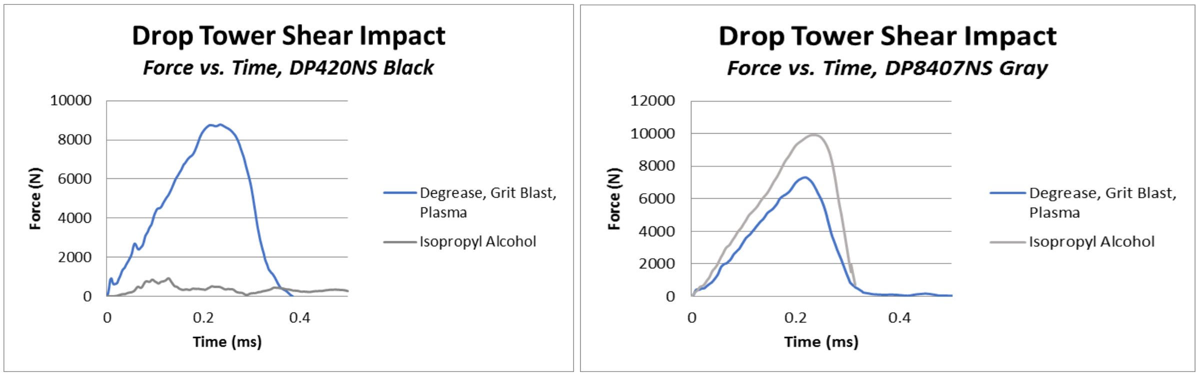

Figure 8-9: Force vs. Time curves for DP420NS Black and DP8407NS Gray comparing different surface preparations bonding 6061 aluminum. Average curves reported.

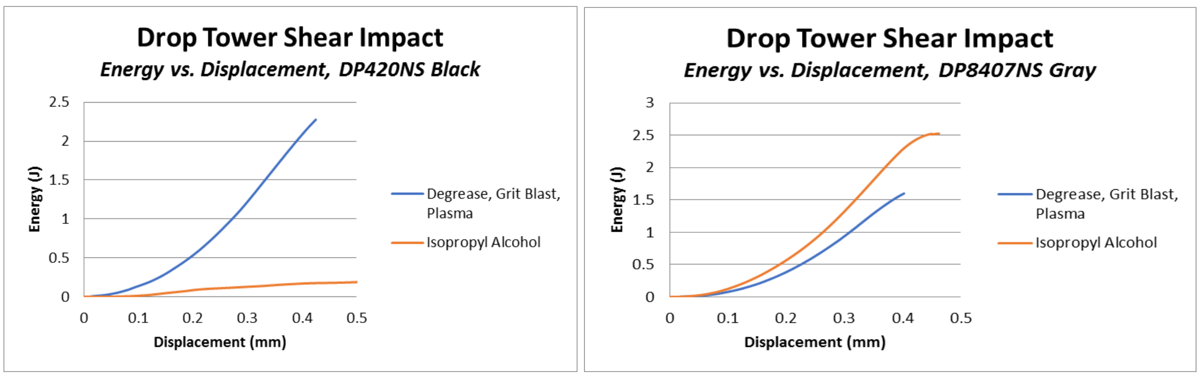

Figure 10-11: Energy vs. Displacement curves for DP420NS Black and DP8407NS Green comparing different surface preparations bonding 6061 aluminum. Average curves reported.

Conclusions:

Structural adhesives are more commonly being used in applications that experience impact. Impact is a complex stress event, and an adhesive's performance in impact must consider many variables including energy, force, time, stress mode, and the entire system geometry and materials. In addition, considerations such as substrate cleanliness, part alignment, void-free filling processes, or cure shrinkage must be considered to evaluate performance on the assembly level.

Using drop tower impact equipment, 3M Corporate Research Labs have developed a test method to provide quantified impact curves for adhesives in shear. The data generated is useful for predicting the performance of various structural adhesives used in a system, allowing engineers to compare different adhesives, substrates, or surface preparation techniques of an assembly. The test method described and a discussion of the results provide a useful tool for engineers to evaluate structural adhesives in their design.

Two adhesives, 3M™ Scotch-Weld™ Epoxy Adhesive DP420NS Black and 3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS Gray, were compared in their shear impact performance bonding 6061 aluminum under different surface preparations. Recorded data provides quantitative comparisons of shear impact performance adhesive-to-adhesive or under differing surface preparations.

Before choosing an adhesive for use in an application that experiences impact, all process and performance characteristics should be evaluated and compared. It is critically important to not only evaluate individual material properties but the performance of an entire assembly.

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