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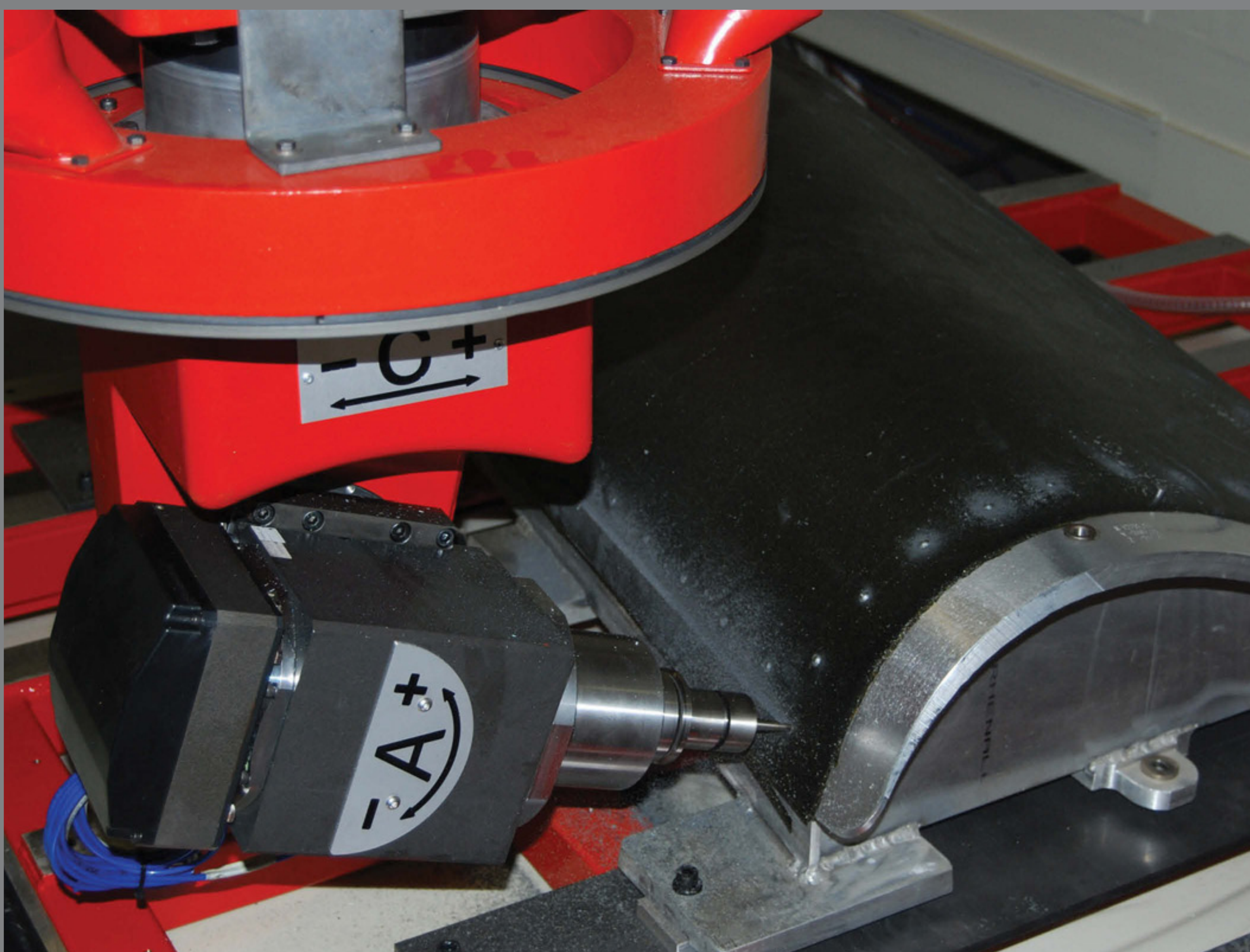

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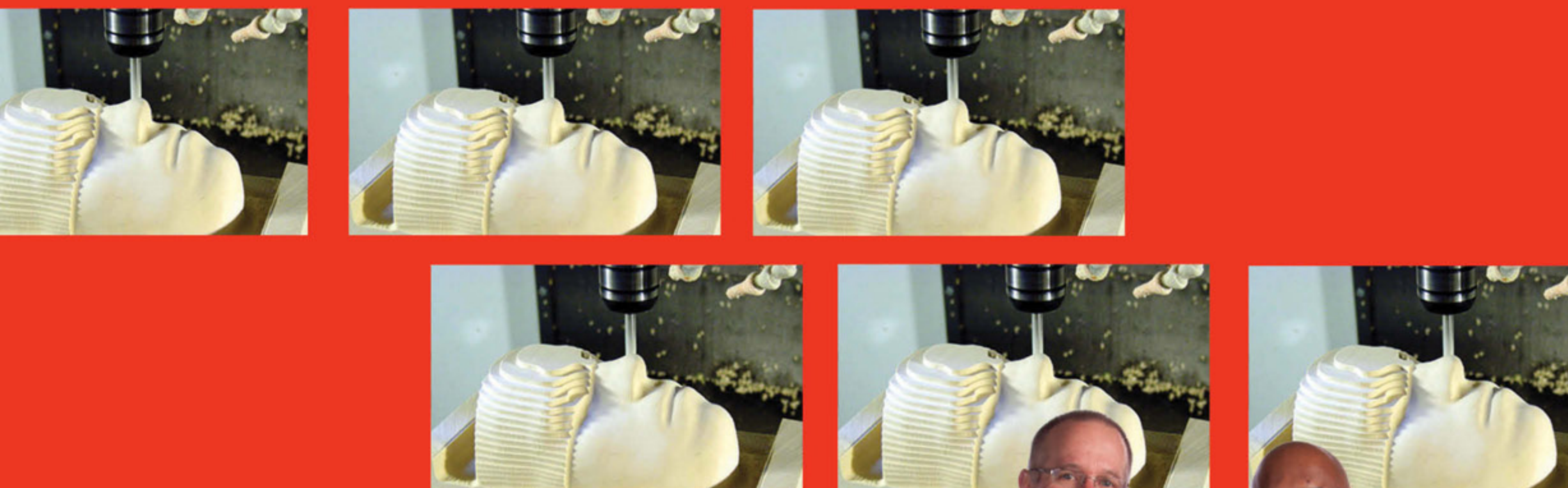

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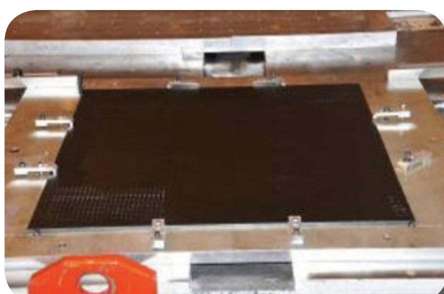
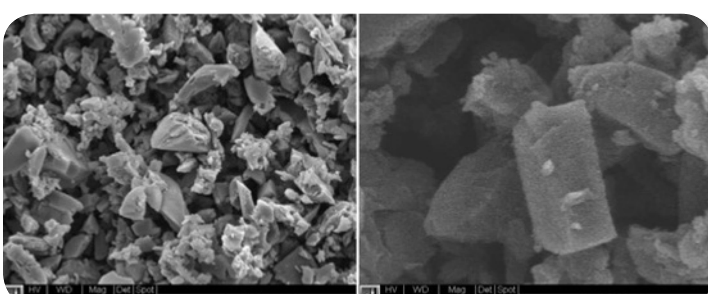
Feature Articles





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Belotti 5-axis machining center drilling, trimming and water-jet cutting of aerospace composite parts. Such part machining centers illustrate customer specific needs, right-sizing to required applications, and focused on specific configurations. *Photos courtesy Stiles Machinery, Inc. and Belotti.*

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President's Message

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There are times when opportunity presents itself. SAMPE is currently in the middle of two very exciting opportunities for our society.

The first is the efforts over the last few years by the SAMPE Board of Directors to create a new SAMPE global organization. As a reminder, the final vote on this plan will take place at our May Board of Directors meeting in Long Beach, CA during SAMPE 2013. The exciting thing about this discussion is we will have a structure that provides representation for our three major geographic areas where SAMPE members live and work. And for the North American members, the new SAMPE North America which will be created will allow us time at our board meetings to have meaningful, strategic conversations on topics most relevant to the SAMPE members in the United States, Canada and Mexico.

The second opportunity is about SAMPE's collaborative growth. At the October 2012 Board of Directors meeting, the directors authorized SAMPE to explore a new joint show with the American Composites Manufacturers Association (ACMA). This new event would take place in the fall and as early as 2014. Much work has already been done with joint exploratory committee meetings starting last July. One of the key drivers in this discussion is how to grow both the memberships and exhibitions for SAMPE and ACMA. New opportunities in the advanced materials industry for products that have the reliability of highly advanced materials (an area of expertise for SAMPE members) yet can be produced at high rates and large quantities (of which ACMA is considered subject matter experts) are best served by our two groups working together at this new event.

Many, if not all, of the features and activities you experience at our spring SAMPE show will happen at this new fall event. Plus there will be more. A larger exhibition hall, organized by areas of interest, will make this your one-stop exhibition experience. The conference sessions, a SAMPE brand strength, will be there along with conference programming provided by ACMA. In addition, there will be a new track of programming produced by the new event's joint programming committee. The SAMPE Fellows Banquet will be held at this fall event making this our premier event of the year.

The spring conference and exhibition will look like our current fall SAMPE Tech events – only perhaps a bit larger. The spring show will still feature the student bridge building competition as this activity is part of many schools' academic programs requiring the academic year to prepare for the competition.

More details will be available as soon as they are known. To take advantage of this opportunity, much due diligence is required. Contracts have to be negotiated; some re-renegotiated. Staffing assignments have to be made. The SAMPE and ACMA executive staff teams have been meeting for almost a year. The other members of the SAMPE and ACMA professional staff have been getting to know one another to develop positive, trusting relationships.

I am excited for what lies ahead for SAMPE in 2013 and 2014. I am hopeful that an affirmative vote on the globalization proposal will create new growth opportunities for SAMPE. The development of this new conference and exhibition for the fall of 2014 will position SAMPE to assist the industry as it looks for new materials and new processes to fulfill the needs of applications we can only imagine. This is definitely an exciting time for our industry and for SAMPE.

A Note from the Technical Director

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"Automated Fiber Placement Technology Has Made Significant Progress in Last 25 Years"

Automation and innovative composites manufacturing processes have continued to move our industries forward in several market arenas over the past few decades. Resin infusion technologies exploded rapidly in the mid-1980s with various versions of resin transfer molding (RTM), vacuum-assisted RTM (or VARTM), resin film infusion (RFI) and subsequently Bill Seemann's version, SCRIMP, Seemann's Composite Resin Infusion Molding Process. I have obviously left out numerous other versions of infusion processes that developed because they likely number well over 40-50 subsets or iterations, but in general it can be said that the "resin infusion" process technology explosion was extensive.

At roughly the same time that resin infusion technology began to expand, automated fiber placement technology (AFP) began to make serious improvements to established process technologies obtain from automated tape lay-up and filament winding manufacturing methods. Manufacturing engineers began in earnest to harvest the attributes of both technologies in order to establish a more automated, structurally optimized design technology into a process that could provide significantly more unique composite structures. Composites companies across the board (material suppliers, machine technologists, designers, structural analysts and numerous others) combined their talents to develop an automated technology that has truly been unique and adaptable across various markets.

One example of a very early complex geometry is the aircraft air engine duct made using an early fiber placement machine laying down carbon fiber prepreg materials. However, the early versions of automated fiber placement technologies were quite complex although they had numerous features such as tow-cut and tow-add aspects, tow-steering capability, thermoset and thermoplastic resin material machine offerings, etc. These early versions developed over several years from the mid-1980s through the mid-1990s at a time when machine manufacturers were only a very few and the material lay-down rates were often quite low. AFP technology at that time was pretty much limited to aerospace markets where such complex technological structures were required and only that process seemed to address the needs.

Today, there is considerable improvements in AFP machine capability, materials technology and availablity, and, applications in numerous other (non-aerospace) markets. As two examples, the complex iso-grid reinforced composite shell structures developed by the ALA Group and Electroimpact is typical of what can now be done at much higher lay-down rates and complexity.
At the same time, AFP technology has moved to more commercial markets as well. The manufacturing of large wind energy blades using AFP technology, as shown in the M-Torres machine fabrication of long blades is one of several where AFP and material lay-down technology has moved the composites industry forward significantly. One can likely expect even more in the near term.

Chemical Reactivation of Exterior Decorative Aerospace Topcoats

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Abstract

Exterior aerospace topcoats are typically highly cross-linked polyurethane based paints designed to be resistant to UV degradation with a high level of adhesion required during all aspects of flight. These topcoats are also designed to be resistant and inert to a variety of aggressive solvents and airplane fluids. Consequently, during processing, a topcoat surface can be inert to the reception of the next topcoat layer.

Proper surface preparation of each paint layer prior to the application of the next is critical for ensuring adequate adhesion. Historically, the only viable method to prevent de-bonding of cured paints has been to mechanically abrade (sand) prior to the application of subsequent coating layers. However, sanding is an ergonomically hazardous process, adds process flow time, and produces contamination. In addition, sanding intricate stencil lettering in most cases is not feasible without tearing the stencil material and/or leaving visible scratches in the areas immediately surrounding the stencil markings.

Chemical reactivation using a newly developed alkoxide-based chemical reactivator has proven to be a viable alternative to scuff sanding and has been successfully implemented on multiple aerospace platforms. This paper discusses the properties and application process of aerospace decorative livery, the mechanism and tests available for rain erosion durability and the performance of paint layers bonded by the chemical reactivation process.

Introduction

The conventional method for reactivation of coatings is through mechanical abrasion with a pneumatic vibrating sander (Figure 1). This method suffers from numerous drawbacks. The sanding process is ergonomically injurious and fatiguing to the painter, adds flow time, produces dust and is difficult to apply uniformly, especially with designs, signboards, or stencil letters involving small radii of curvature (Figure 2b). Additionally, the small radii of curvature in some designs may necessitate a paint application sequence for topcoats that is less than optimum for flow time, while abrasion may alter the color of a basecoat even after the subsequent clearcoat is applied.

The purpose of this work was to develop and qualify a chemical reactivator[1] that could replace mechanical abrasion of topcoats and meet environmental, production efficiency, and performance requirements. These requirements include using as environmentally friendly materials as possible and passing the ANESHAP (Aerospace National Emissions Standards for Hazardous Air Pollutants) limit, adding minimal weight to the airplane and not requiring significant capital investment. The latter requires using methods similar to those used for paint application, i.e. spraying (Figure 3a) or inexpensive techniques, such as aerosol application (Figure 3b).

Figure 1. Mechanical abrasion to reactivate aged topcoat.

Experimentation

Experimental Materials and Methods

Materials

During the initial development of the reactivator, Boeing and CSIRO worked together to evaluate various blends of metal alkoxide solution (such as zirconium and titanium propoxide) mixed with a glycol ether and an alcohol. The final proprietary blend, Paintbond SM-1, was obtained by comparing the effectiveness of these blends using a key performance test, rain erosion adhesion.

During development, the effectiveness of each chemical reactivator formulation was evaluated on aged high gloss polyurethane topcoats used for exterior decorative livery on Boeing aircraft. These consist of topcoats and clearcoats qualified to BMS10-72 [2a], and BMS10-125 [2b]. Initial success with the reactivation of these aged topcoats has led to additional evaluation on new paint systems that are currently in Boeing qualification.

Application Methods

The reactivator formulated using the reagents was mixed under inert nitrogen atmosphere and stored as either one or two component systems. It was stored in moisture impervious containers until ready to use and then mixed, if needed, by pouring one con-

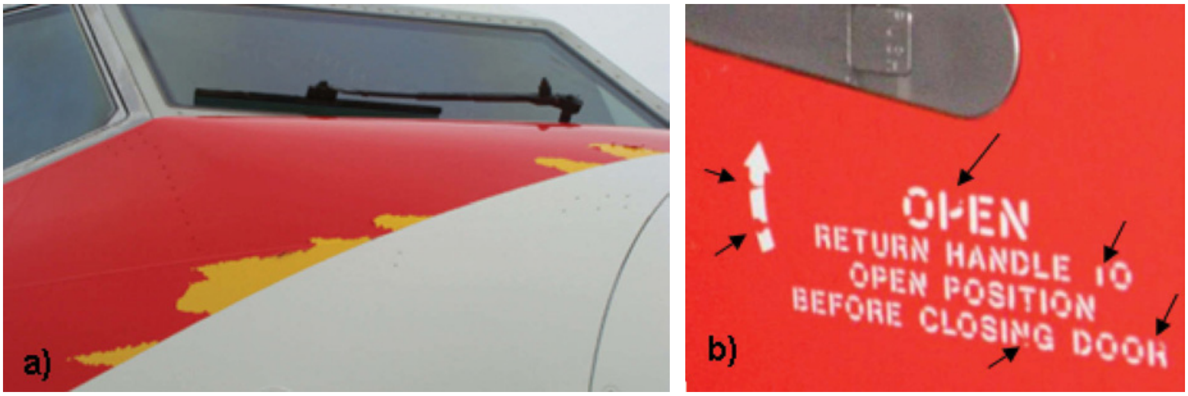

Figure 2. Results of non-uniform sanding on a) livery and b) stencils.

tainer into the other, resealing, and shaking for 5 minutes. The reactivator was transferred to a use container that was covered until time for application. Application was by spray either using spray guns such as HVLP (High Volume Low Pressure), air spray, or air assisted airless with electrostatics or by adding a propellant to the formulation and using an aerosol can.

The reactivator was applied to the coating systems until a single continuous wet film was visually confirmed. This continuous film dries to form a white grayish powder, 20 to 40 microns thick, and yields a coverage of 15 to 30 m^2/l when properly applied. The formation of the white grayish powder also is a visual indicator of areas covered as it reduces the visual gloss of a high gloss substrate from 90 to below 10 when measured at a 60° angle.

Material Development and Mechanism Testing

The mechanism of adhesion promotion for this reactivator[1] is derived from sol-gel chemistry and processing techniques. The sol-gel process commonly uses inorganic or organometallic precursors, such as a zirconium or titanium alkoxide, to form an inorganic polymer sol via a combination of hydrolysis and condensation reactions[3]. The relative rates of hydrolysis and condensation and the structure and characteristics of the resultant sol are controlled by a number of factors, including the concentration of reagents and the availability of water, alcohols, reaction modifiers, and catalysts such as acids or bases. Characteristics of the subsequent gel and whether it forms a continuous interconnected network also depends on the moisture present and the rate of evaporation of the solvents[4]. Figure 4 shows ESEMs (Environmental Scanning Electron Microscopy) of polyurethane topcoat specimens that were either untreated or treated with the chemical reactivator formulations, SM-0 and SM-1, which had different solvent blend ratios. Both reactivator formulations sprayed at atmospheric moisture vapor pressures above about 7.5 mbar, equivalent to 25% relative humidity (RH) at 22°C, produced a fine, textured, open structure (Figures 4b and 4d). However, SM-0 sprayed below about 25% RH at 22°C produced a less structured topology and a more continuous smooth, gel like structure (Figure 5c), while SM-1 sprayed at the same condition (Figure 5e) continued to display a somewhat cracked structure.

The reactivity of these reactivators towards an aged coating is shown through AFM (Atomic Force Microscopy) and ESCA (Electron Spectroscopy for Chemical Analysis) studies. The AFM study showed the changes in surface topography of untreated and reactivator-treated polyurethane topcoat under different conditions. It can be seen that thoroughly wiping the surface after 2 hours of treatment (Figure 5c) removed surface promoter when compared to the un-wiped, treated surface (Figure 5b). However, some reactivator remains strongly bonded to the topcoat surface and cannot be readily removed.

Reaction of the reactivator-treated, aged topcoat with fresh

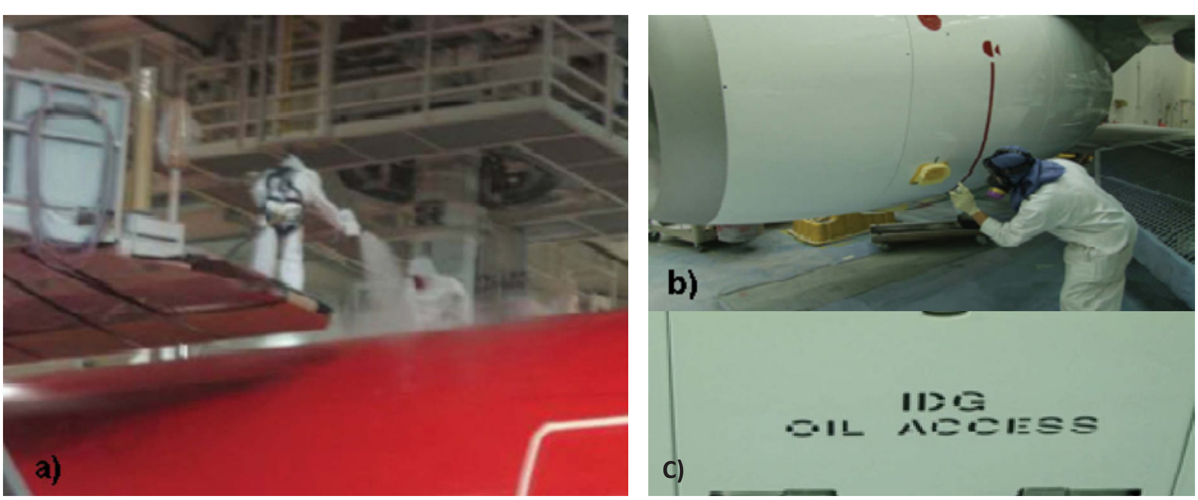

Figure 3. a) Spray application, b) aerosol application on a stencil, and c) stencil after painting.

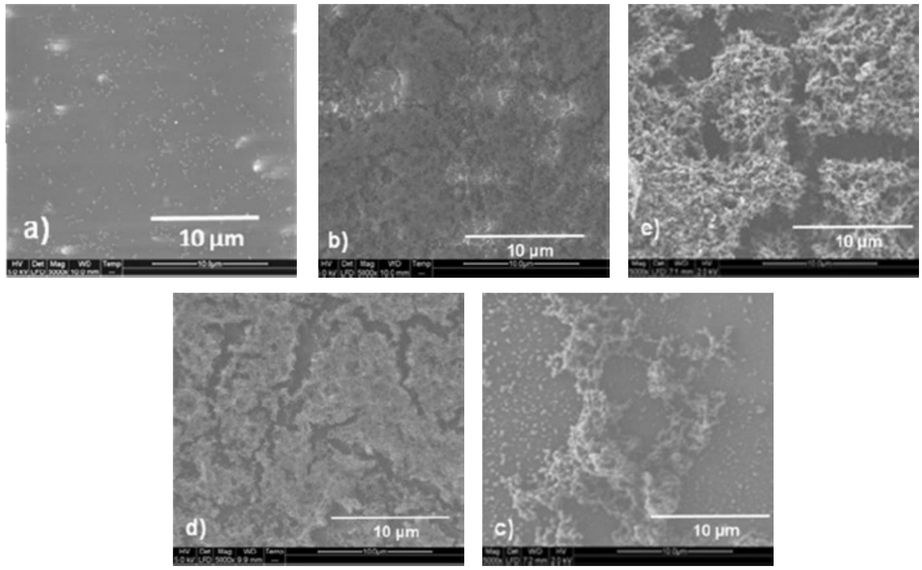

Figure 4. Environmental SEM of a) untreated topcoat, b) SM-0 applied at 22°C/38 % RH, c) SM-0 applied at 22°C/20 % RH, d) SM-1 applied at 22°C/38 % RH, and e) SM-1 spray applied at 22°C/20 % RH.

topcoat may occur via migration of the freshly applied topcoat isocyanate species through the loosely bound reactivator and chemical grafting with the tightly bound metal alkoxide species as shown via calorimetry data (Figure 6).

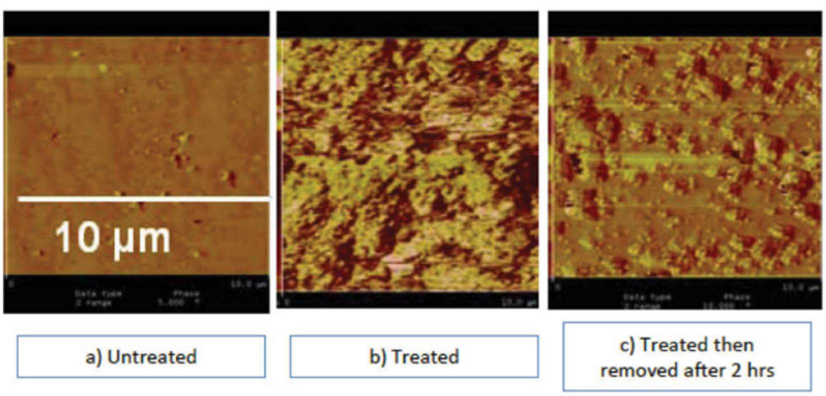

Figure 5. AFM of SM-0 formulation.

Additional reinforcement of the bond can come from molecular entanglement of the fresh topcoat resin with the aged surface as the promoter treatment likely reduces the crosslink density of the aged surface. SEM backscatter and EDAX (Energy Dispersive X-ray Analysis) pictures show that the metal alkoxide species penetrates less than a micron into either the aged or fresh topcoat (Figures 7a and 7b). However, the EDAX carbon (Figure 7c) map shows that resin from the fresh topcoat reaches the surface of the aged topcoat.

Results

Qualification Test Methods

For qualification and implementation of a material, numerous engineering and manufacturing tests need to be run and passed to ensure overall durability of the exterior coating system. The discussion here will be limited to a few key tests: 1) rain erosion resistance as it is the most stringent intercoat bonding test requirement; 2) hydraulic fluid resistance as it is a unique airplane fluid which must be flame retardant and is very aggressive towards paints; 3) impact resistance as representative of flexibility testing, and 4) initial and weathered appearance when applied in a basecoat-clearcoat system as representative of decorative considerations. All test results given below are from triplicates of each condition.

Rain Erosion Resistance

Several tests unique to Boeing are used to predict coating durability against rain erosion [5a, 5b]. The test described here is the whirling arm [5a] (Figure 8a). For intercoat evaluation, the first topcoat (blue in Figure 8a) is applied over the complete upper surface of the test foil, while the second topcoat (gray in Figure 8a) is painted over only part of the foil, leaving the bullnose with only the first color applied. The painted foils are then mounted on a zero lift rotating blade mounted inside a wooden barrel. The whole

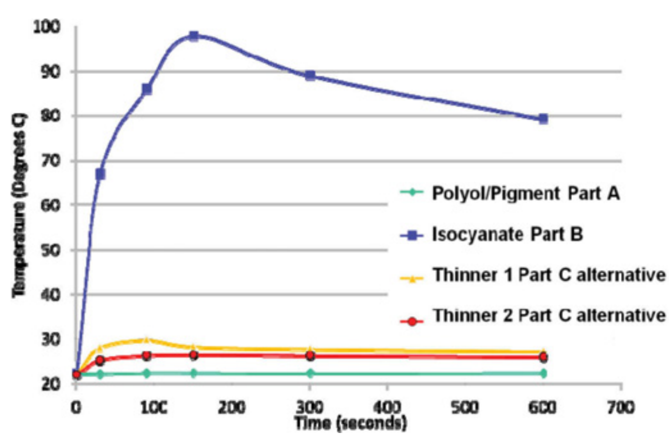

Figure 6. Temperature rise of coating components mixed with metal alkoxide.

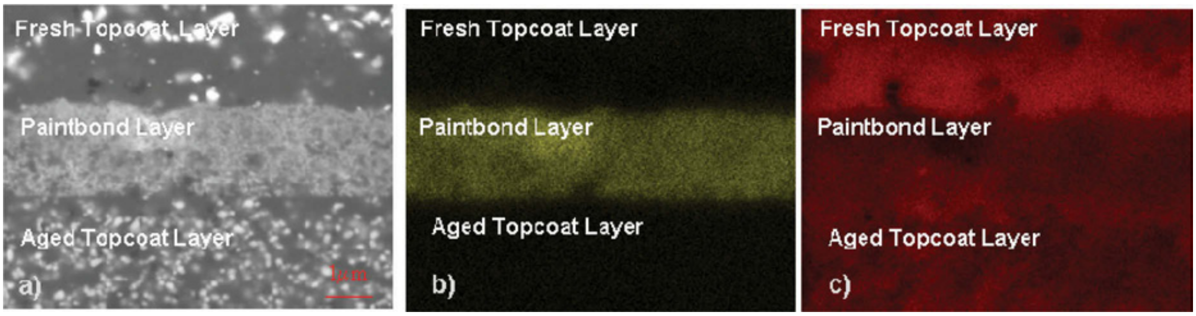

Figure 7. a) SEM Backscatter, b) EDAX metal component of alkoxide map, and c) EDAX carbon map of cured fresh topcoat/re-activator /aged topcoat cross-section.

apparatus is enclosed in a blockhouse. Water droplets are sprayed from the periphery of the barrel as the blade rotates. Because of the speed of the rotating blade, the foils impact the water drops at speeds on the order of half the speed of sound, which is slightly faster than the speed of an airplane through most rain. The impact of the droplets near the second topcoat paint edge produces a water hammer effect that creates Raleigh surface shock waves, which can cause intercoat bond failure. The localized stress produced in this test is an order of magnitude greater than that produced in the tape adhesion test ASTM D3359[6,7]. Rain erosion resistance is then evaluated by measuring the distance the second topcoat peels back from its original paint edge.

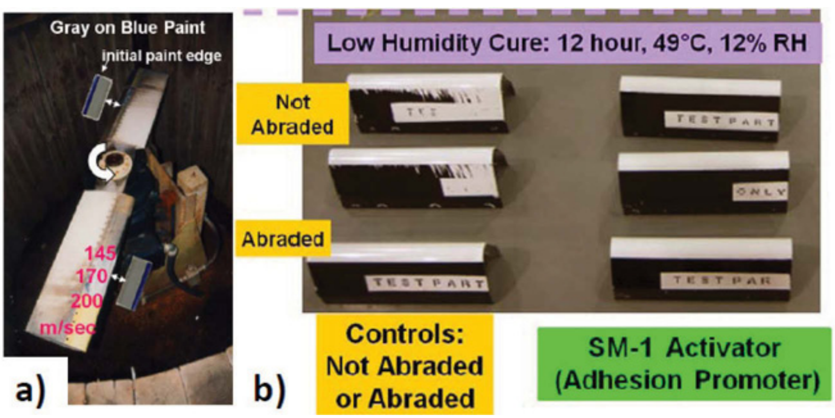

Figure 8. a) Rain erosion chamber, b) Rain erosion results with 25 micron thick stencil coating using SM-1 formulation.

The reactivator needs to provide adequate reactivation for Boeing qualified paints under cure conditions found in the Boeing paint hangars. Results demonstrate that the SM-1 formulation is equivalent to mechanical abrasion (sanding). Figure 9b shows results for a different suppliers' coating system where the intercoat bonding was modified to perform a stencil lettering paint test. These results again show that the SM-1 formulation is equivalent to mechanical abrasion.

The multiple exterior coatings in use at Boeing vary in the mole ratio of polyester polyol to isocyanate and type of polyol, as well as pigments and additives. These variables will have an effect on the maximum cure time and temperature allowed, as illustrated in Table 1.

Hydraulic Fluid Resistance

Aviation hydraulic fluid is phosphate ester based in order to meet requirements for fire resistance. It is very aggressive towards many plastics and finishes, which can be softened and eventually destroyed. Exterior decorative coatings must retain sufficient pencil hardness[8] after a 30-day ambient soak in BMS3-11[9] hydraulic fluid. Figure 9a show a hydraulic leak on an airplane, while Figure 9b shows sample test panels after completion of testing. Table 2 summarizes some data with and without the reactivator between layers of topcoats. The topcoats with SM-1 between layers perform equivalently to those that were abraded between layers and much better than the untreated controls.

Impact Resistance

Several flexibility/adhesion related tests are run during qualification including impact resistance[10], mandrel bend[11] and low temperature shock [2a]. Here a few representative impact test results are reported in Table 3 using a 15.875 mm (0.625 inch) hemispherical indenter. The apparatus and representative pass and fail results from impacts are shown in Figure 10 and Table 3, respectively.

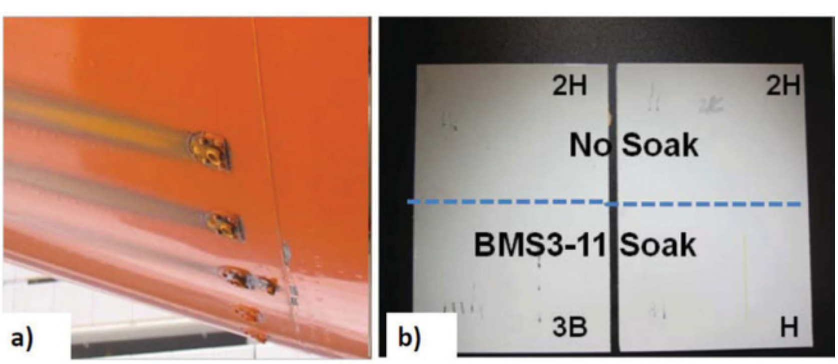

Figure 9. a) hydraulic fluid leak, b) hydraulic fluid test results - fail (3B) and pass (H).

Table 1. Aged topcoat cure scenarios known to produce acceptable rain erosion using SM-1.

Paint Type	Heat Cure	Post Cure
BMS10-72, Type VIII	49°C for unlimited hours	Up to 32°C for unlimited hours
BMS10-72, Type IX	49°C for 8 hours	Up to 32°C for 64 hours
BMS10-72, Ty IX	41°C for 12 hours	Up to 32°C for 60 hours

Table 2. Typical BMS3-11 hydraulic fluid soak results.

Paint Type	Treatment	Colors	Result	Comment
BMS10-72, Type VIII	Untreated	Gray on White	Pass	Control
BMS10-72, Type VIII	Abraded	Gray on White	Pass	2 hardness units higher than control
BMS10-72, Type VIII	SM-1	Gray on White	Pass	Same as abraded
BMS10-72, Ty IX	Untreated	Gray on White	Pass	Control
BMS10-72, Ty IX	Abraded	Gray on White	Pass	2 to 3 hardness units higher than control
BMS10-72, Ty IX	SM-1	Gray on White	Pass	Same as abraded

Initial and Weathered Appearance

When used with a basecoat-clearcoat (BCCC) system, the chemical reactivator between layers should not significantly change the initial appearance, such as gloss and color, as compared with the coating without the reactivator. The reactivator should also not accelerate gloss loss or color shift due to photo-oxidation and hydrolysis of the clearcoat from weathering. Table 4 shows that the shift in initial 60° gloss and the difference in gloss loss after 2 year outdoor exposure in Florida due to use of the reactivator SM-1 is negligible. The initial shift in color due to application of the reactivator was measured at less than 0.3 units in ΔE for all three colors. Figure 11 shows that the color difference between activated and non-activated, for a given color at any time in Florida exposure, was typically less than 0.1 units in ΔE with the color shift for activated BCCC less than non-activated BCCC.

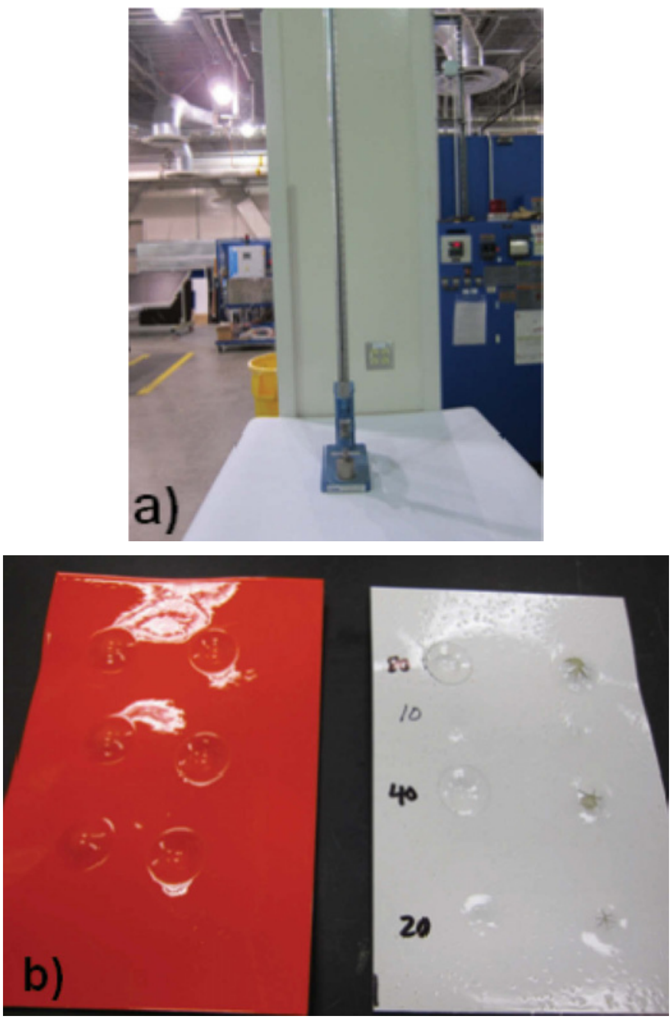

Figure 10. a) impact tester and b) pass (orange) and fail (white) panels.

Table 3. Typical ASTM D2794 impact results.

Paint Type	Treatment	Colors	Result	Comment
BMS10-72, Type VIII	Untreated	Gray on White	Pass	Control
BMS10-72, Type VIII	Abraded	Gray on White	Pass	Slightly better than control
BMS10-72, Type VIII	SM-1	Gray on White	Pass	Same as abraded
BMS10-72, Ty IX	Untreated	Gray on White	Pass	Control
BMS10-72, Ty IX	Abraded	Gray on White	Pass	Slightly better than control
BMS10-72, Ty IX	SM-1	Gray on White	Pass	Same as abraded

Table 4. Comparison in BC-CC of initial gloss and gloss change due to 2-year weathering in Florida.

Color	Treatment	Initial 60° gloss	Final 60° gloss	Difference
White	None	94.3	90.1	-4.2
White	SM-1	94.3	89.8	-4.5
Blue	None	90.6	88.3	-2.3
Blue	SM-1	90.7	88.8	-1.9
Red	None	92.3	88.6	-3.7
Red	SM-1	91.8	88.1	-3.7

Production Trials & Replication of Technology on Boeing Models

After meeting the engineering requirements, Boeing and CSIRO established a new BMS specification for this material and then contracted with a supplier to blend and package the SM-1 chemical reactivator. The reactivator was then trialed on a production scale.

The first trial was on a Southwest 737-800 production airplane in June of 2008, with SM-1 being used to reactivate the aged yellow topcoat under the blue and orange layers (Figure 12). Subsequent field evaluations have shown no rain erosion or appearance issues with this airplane.

The use of a chemical reactivator for intercoat bonding of a clearcoat over a basecoat was first trialed on a UPS 767 production airplane in June of 2010 (Figure 13).

The chemical reactivator has now been fully implemented on all Boeing commercial airplanes including the 787 and is allowed for use on monocoat as well as basecoat-clearcoat systems. The chemical reactivation process has been well received by the production facilities and has become the preferred method of reactivation.

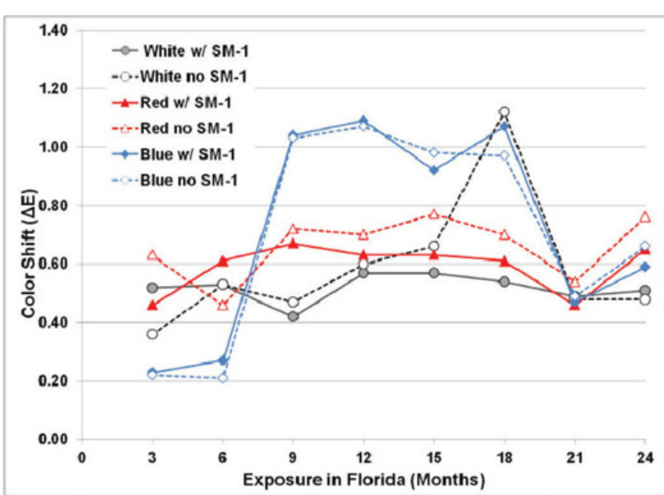

Figure 11. Comparison in BCCC of color shift (ΔE) due to 2-year weathering in Florida.

Conclusions

Chemical reactivation using a newly developed alkoxide-based chemical reactivator has proven to be a viable alternative to scuff sanding and has been successfully implemented on multiple aerospace platforms. This implementation has benefited the production paint hangar by reducing the number of ergonomic injuries due to sanding, reducing the process flow time, and reducing the amount of contamination (sanding dust) that is normally present during large scale mechanical abrasion of the substrate. In addition, it has been implemented with great success in the stencil application process, where mechanical abrasion is not a viable option due to intricate small lettering.

During development of the SM-1 chemical reactivator, the rain erosion adhesion test was the key engineering test used

Figure 12. 18 months after this SWA 737-800 received the first SM-1 application in June 2008. Application was under the blue and orange monocoat paint layers. *Photo (Dmitry Shapiro).*

Figure 13. One of several UPS 767-300's that have received basecoat-clearcoat. Application of SM-1 is on the entire basecoat of the fuselage and empennage prior to clearcoat application. *Photo (Boeing).*

to compare and evaluate the effectiveness of chemical reactivator formulations. After optimization of the proprietary formula, other key engineering tests, including hydraulic fluid exposure and impact resistance, were evaluated to ensure no decrease in performance when chemical reactivator was used. Successful engineering testing led to the subsequent productions trial on actual aircraft and the qualification of the chemical reactivator to a Boeing material standard, BMS10-127. The end result is a Boeing qualified chemical reactivator that provides for equivalent adhesion when compared to a mechanically abraded topcoat surface.

Acknowledgements

Scott Davis, Weston Anderson, and Dara Ung from Boeing and Ranya Simons and Emma Simmonds from CSIRO provided assistance in developing the test data. Dmitry Shapiro, a freelance photographer, provided Figure 12. Jason Smith of Zip-Chem assisted in manufacturing production quantities of Paintbond SM-1 under the name Sur-Prep AP-1.

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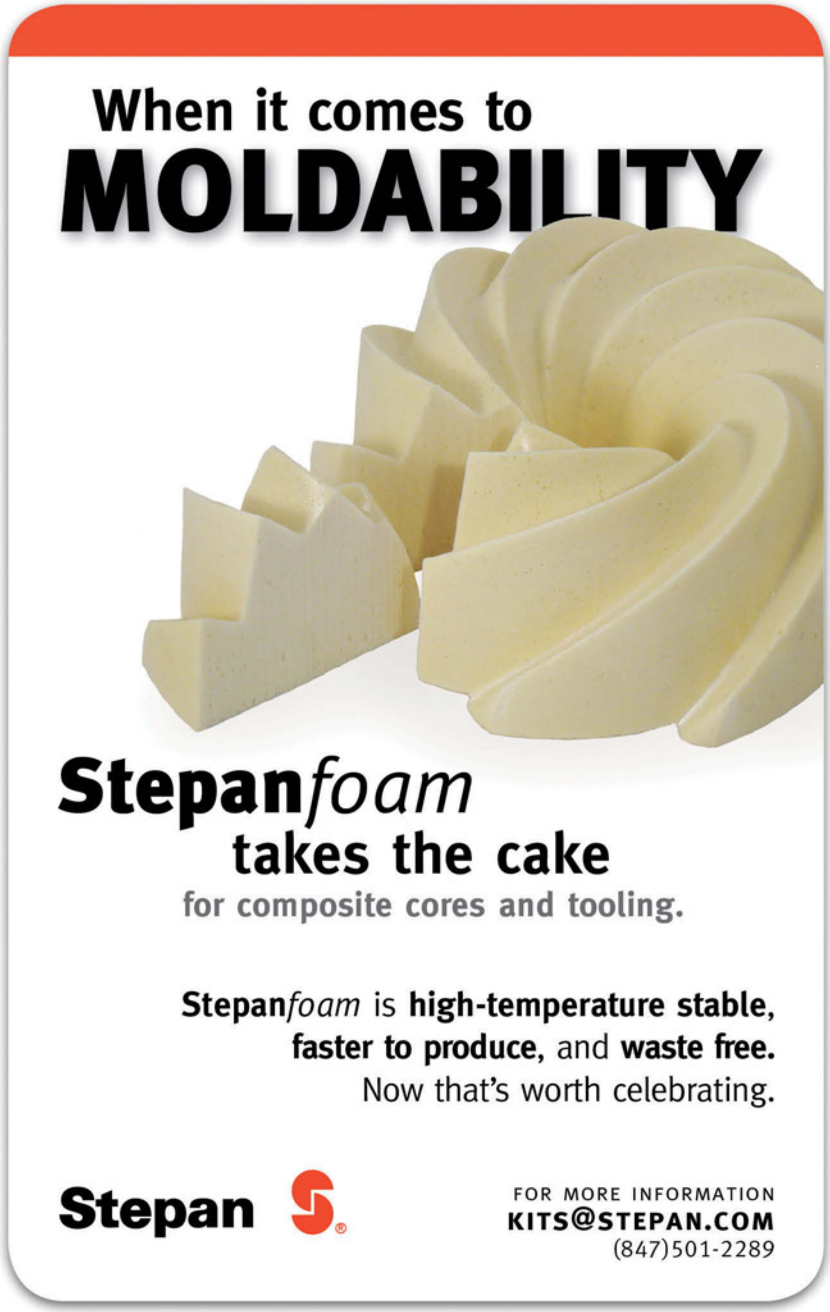

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For more information, visit: www.polymer-books.com.

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Experimental-Comparative Investigation of the Effects of Various Process Parameters on Drilling CFRP

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Abstract

Carbon Fiber Reinforced Plastic (CFRP) materials have superior properties such as high strength-to-weight ratio, elasticity and corrosion resistance which makes them highly preferred materials, especially in aerospace structures. Despite drastic increase in applications of CFRP, the machining processes of this material have been troublesome due to several reasons such as the variety of material configurations, their non-homogeneous mechanical properties and abrasive nature of their fibers. Typical and common CFRP machining problems are: defects formed on work piece such as delaminations, unconformities of dimensional tolerances and poor cutting tool life. In addition to the challenge of manufacturing a defect free part, potential quality issues may differ from one material to another even if the cutting conditions are same. Therefore; presenting effects of the fundamental process parameters such as work piece material, cutting tool configuration (i.e. geometry and material) and cutting parameters is extremely crucial so as to eliminate or minimize these problems and to define efficient CFRP machining strategies.

The aim of this study was to investigate effects of process parameters on cutting forces, hole tolerances and defect formation through experimental and comparative approach. In this paper; polycrystalline diamond (PCD), diamond coated carbide and uncoated carbide drills with several geometries are used in standard modulus 5-Harness satin woven CFRP epoxy system.

Introduction

In the aerospace industry, the importance of light weight, damage tolerant structures has been drastically increasing due to target of low-fuel-consuming designs. This goal can only be achieved by increasing composite materials usage in today's technology. Carbon fiber reinforced composite materials (CFRP) are preferred for their high stiffness and high strength properties and glass fiber reinforced composites are used for their damage tolerance characteristics. Among both materials; CFRP materials are said to be more problematic to machine, and especially to drill through. Generally, the abrasive nature of the fibers and stiffness of the whole composite material may give rise to defects such as delaminations, wear marks and unacceptable dimensional tolerances.

In the literature the number of studies on machining CFRP structures has significantly increased in recent years due to increased usage of these materials in the aerospace industry. Most of these studies are very beneficial for a researcher to understand the machining theory of these materials but one should remember that the outputs of these research studies are so sensitive to the type of application. Mohan et al.[1] showed that feed rate, cutting speed and material thickness have largest effect on delamination formation. And among these parameters feed rate is said to be the most critical one with respect to push down and peel up delaminations. They also showed how statistical methods such as Taguchi method can also be used in CFRP machining researches. Gaitonde et al.[2] have studied delamination tendency with respect to cutting speed, feed rate and point angle by developing a second order regression model. Qin et al.[3] indicated the relationship between wear of nano-diamond cutting tools and cutting forces. Faraz et al.[4] presented innovative tool wear characteristic called 'Cutting Edge Rounding' in drilling CFRP materials. Karnik et al.[5] developed a delamination prediction model with respect to cutting parameters and point angle of the drill. Shyha et al.[6] concluded that tool life and thrust force are affected mostly by drill type and feed rate. Hocheng and Dharan[7] introduced an analytical model to predict critical thrust force beyond which delamination occurs. Dharan and Won[8] proposed a smart control system based on an experimental model of the thrust force and torque as a function of cutting parameters. Piquet et al.[9] reported the effects of drilling tool geometry on the hole quality without using a backup plate.

In this study it is aimed to optimize cutting conditions on

Table 1. Some physical and mechanical properties of the CFRP laminates.

Material	Fiber Volume (%v/v)	Strength (MPa)	Modulus (GPa)	Density (g/cm^3)	Cured Ply Thickness (mm)
Epoxy Impregnated Graphite Fabric 5-Harness Satin[1]	50	520	52	1.485	0.33

[1] Given mechanical properties of the laminate are valid for both warp and fill directions at 23°C.

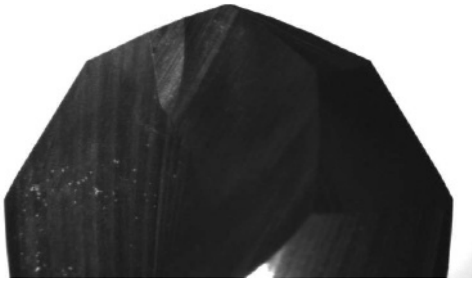

Figure 1. Tool geometry of diamond coated carbide (DCC) drill.

standard modulus 5-Harness satin woven CFRP epoxy parts in order to obtain the most rapid drilling process with an acceptable hole quality. In order to achieve this goal, diamond coated carbide (DCC) and Polycrystalline Diamond (PCD) drills are tested on standard modulus 5-Harness satin woven CFRP epoxy system through experimental approach.

Experimentation

Materials

In this study, CFRP work piece materials having a 10 mm thickness and dimensions of 1000 mm x 1000 mm were used. Physical and mechanical properties of these materials are given in Table 1. All parts were composed of 25% 0˚, 50% 45˚ and 25% 90˚ fiber-oriented laminates.

Cutting Tools

In this study, 6.38 mm and 6.35 mm diameter Diamond Coated Carbide (DCC) drills with the geometry given in Figure 1 were used. In order to compare performances of the PCD drills with those of DCC, 6.38 and 6.40 mm diameter PCD drills with tool profile given in Figure 2 also tested in this work. 6.38 mm PCD drills tested in tool life experiment and the 6.40 mm drills were used in run-out tests.

Experimental Procedure

All drilling operations were performed on a 5-axis precision milling machining (PMM) center with maximum 24,000 rpm rotational speed. Cutting force measurements were performed by rotary type 9123C Kistler dynamometer. Test setup was composed of the CFRP work-piece, and pre-drilled back-plate with 8 mm diameter holes as shown in Figure 3. The function of the back-plate was to support the work-piece and to minimize clamping related process defects.

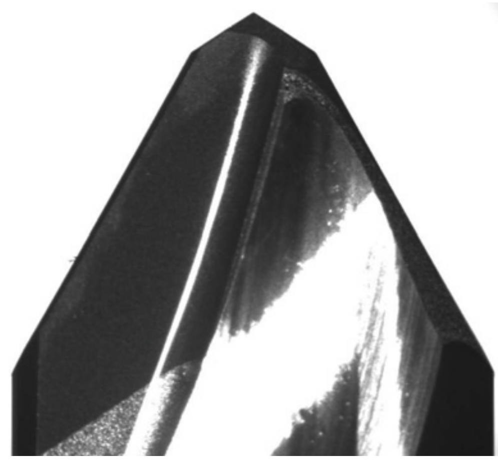

Figure 2. Tool geometry of PCD drill.

Since delamination and out of tolerance conditions occur because of tool wear, tool life can be related to the start of these defects and unconformities. Therefore tool life is directly related to the quality of the hole. In this study, the hole quality was determined according to unacceptable delamination and hole dimension. Delaminations were considered unacceptable when more than 1 ply is separated from the main structure or have an area bigger than 3 x the drill hole diameter circle. Delaminations were inspected by visual and by ultrasonic inspection methods. Hole dimension tolerance was accepted around ± 0.015 mm which is quite close to the common close-tolerance applications in aerospace designs. Hole dimension measurements were accomplished by a Coordinate Measurement Machine (CMM).

Results

Experimental Results of DCC Drills

When the feed rate increases, the thrust force also increases and is a well-known fact in literature about composite machining. In order to state limiting feed rate, thrust force measurements were performed for different feed values (Figure 4). 225 µ/rev was chosen to be maximum feed to be studied.

Figure 4. Thrust forces of various feed values measured by dynamometer

Drilling operations were performed with 7 different cutting parameters. As it can be seen from Table 2, in all conditions tool life results with respect to hole dimension were reasonably lower than that of based on delamination. This is quite

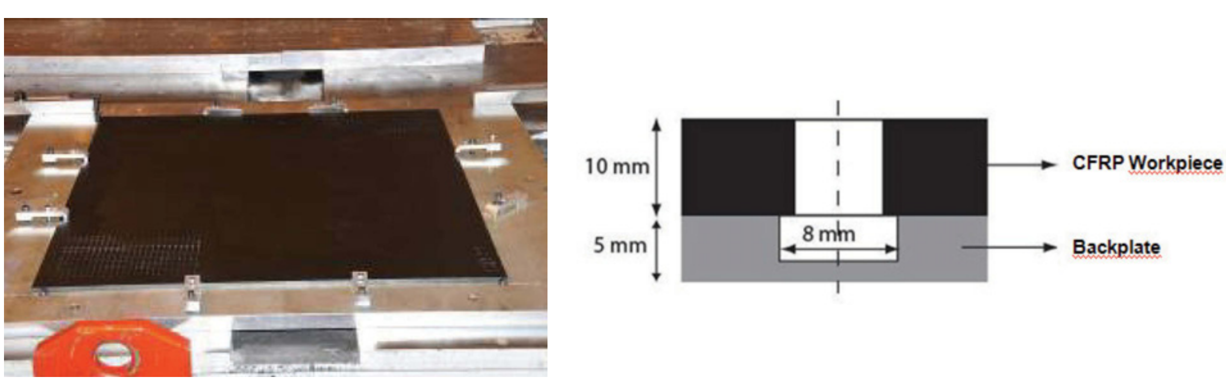

Figure 3. Test setup.

Table 2. Test configuration and results of the DCC cutting drill.

Experiment #	Spindle speed (rev/min)	Feed Rate (mm/min)	Feed (μ/rev)	Tool Life Based on Unacceptable Delamination (# of holes)	Tool Life Based on Hole Diameter Tolerance
1	10,000	1000	100	888	576
2	15,000	1500	100	2788	1056
3	10,000	1500	150	1861	1344
4	15,000	2250	150	1886	1056
5	5000	1125	225	2046	1152
6	10,000	2250	225	5369	864
7	15,000	3375	225	3933	3050

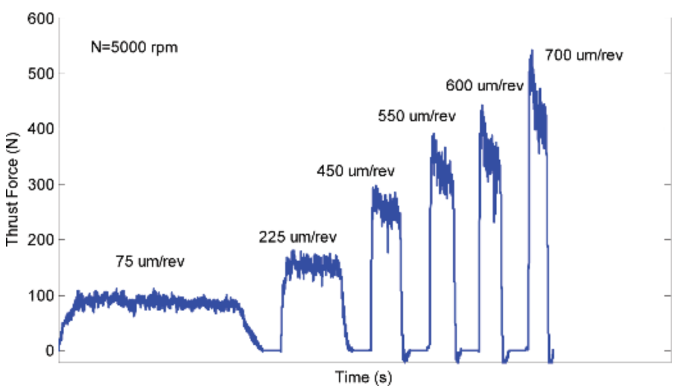

Figure 4. Test setup.

an important outcome since most of the tool wear studies in composite drilling have been based on delamination rather than the final hole dimensions.

Figure 5 and Figure 6 show the difference between drilled holes with no defect and drilled holes with delaminations and wear marks.

Figures from 7 to 13 show the exit hole diameter versus hole number scatter diagrams of each condition given in Table 2. As it can be observed in these figures, hole diameter band lowers far before an unacceptable delamination occurs.

Results indicate that experiment 6 gave longest tool life with respect to delaminations. On the other hand, experiment 7 presented the best tool life based on quality of the hole dimensions.

Experimental Results of PCD Drills

First of all, it was intended to compare tool life performances of PCD and DCC drills with the optimized cutting condition of DCC drills. Feed rate of 2250 mm/min and spindle speed of 10,000 rev/min was chosen since this cutting condition gave the best result according to delamination based tool life of DCC drills. Due to the out-performance of PCD drills in the studied work piece material, only one cutting condition with respect to tool life could be tested. More than 15,000 holes were drilled with no sign of delamination. However hole diameter values start to scatter around 10,000th hole before delamination occurs.

Figure 14 shows the exit hole diameter results with respect to hole diameter. As it is expected hole diameter values start to scatter significantly around 10000th hole before delamination occurs.

To be able to state the best cutting condition in drilling process with PCD drill, run-out tests with small scale of observations with highest spindle speed parameters were accomplished. During the dimensional measurements, no out-of-tolerance was observed except for the following condition:

Figure 5. Drilled hole with no sign of defect.

Figure 6. Drilled hole with delaminations and wear marks.

Table 3. Run-out measurements of PCD drills.

Spindle Speed (rev/min)	Feed Rate (mm/min)	Maximum Run-out in Top and Exit Hole Diameter (mm)
15,000	1125	0.11
15,000	3375	0
10,000	2250	0
5000	1125	0

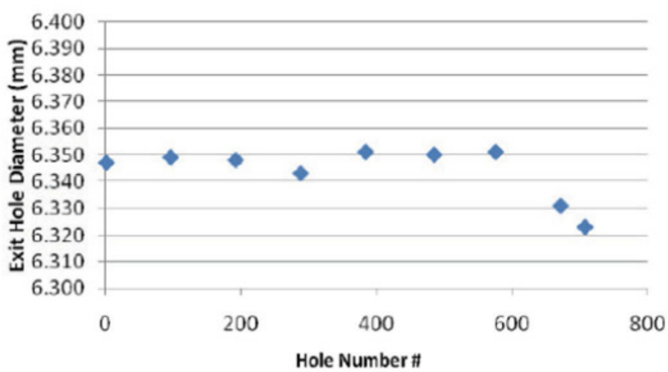

Figure 7. Exit hole diameter versus hole number for S:10,000 rpm /f:1000 mm/min.

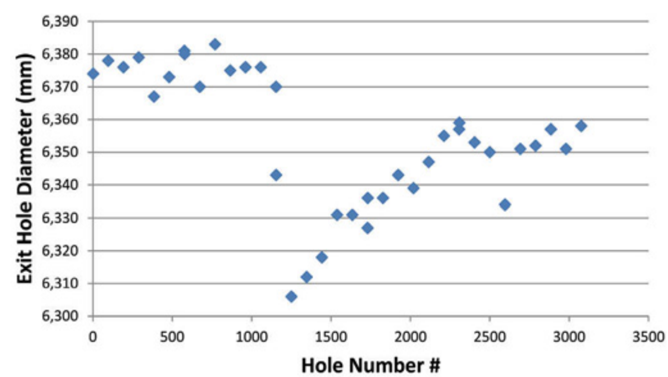

Figure 8. Exit hole diameter versus hole number for S:15,000 rpm /f:1500 mm/min.

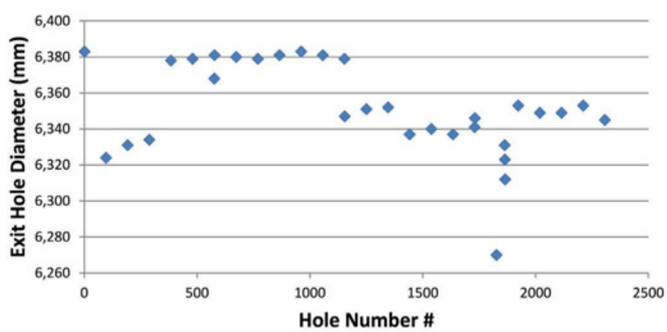

Figure 9. Exit hole diameter versus hole number for S:10,000 rpm /f:1500 mm/min.

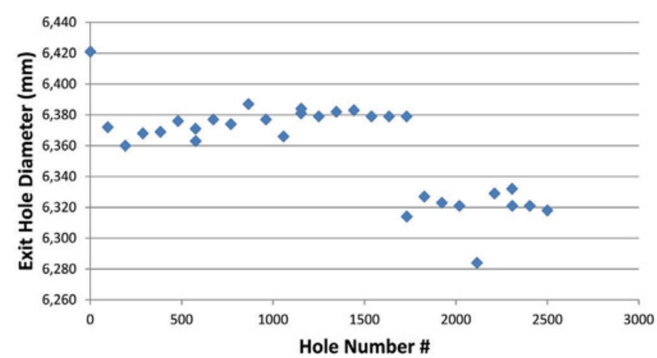

Figure 10. Exit hole diameter versus hole number for S:15,000 rpm /f:2250 mm/min.

[feed rate: 1125 mm/min -spindle speed: 15,000 rev/min]. Therefore; for the material selected, drilling condition of [feed rate: 3375 mm/min -spindle speed: 15,000 rev/min] can provide the most stable and at the same time the most rapid process.

Conclusions

The study stated the effects of process parameters on quality of holes in CFRP structures. The following conclusion can be drawn from this research:

•Below a critical cutting force, with increasing feed rate, tool life based on delamination also increases. And at constant feed rate, increasing spindle speed reduces the risk of delamination.

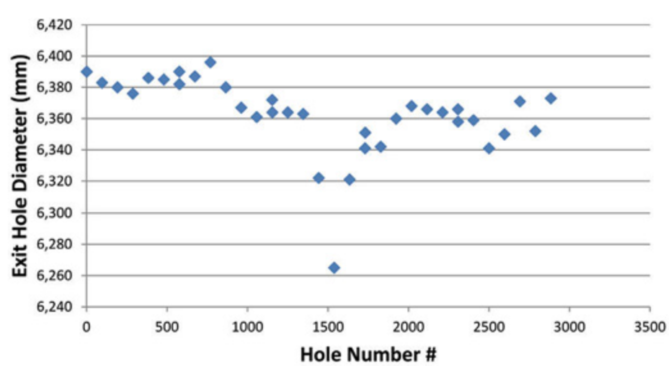

Figure 11. Exit hole diameter versus hole number for S:10,000 rpm /f:2250 mm/min.

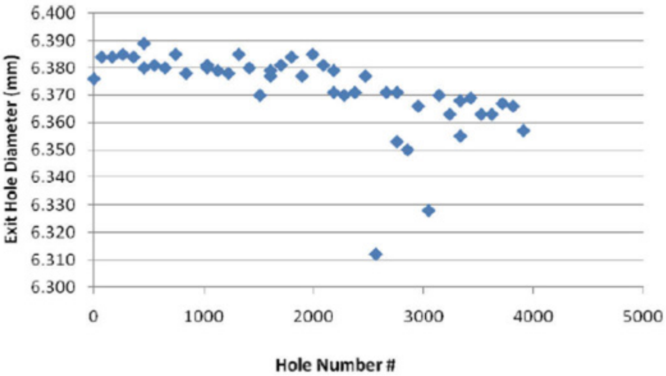

Figure 12. Exit hole diameter versus hole number for S:15,000 rpm /f:3375 mm/min for DCC drill.

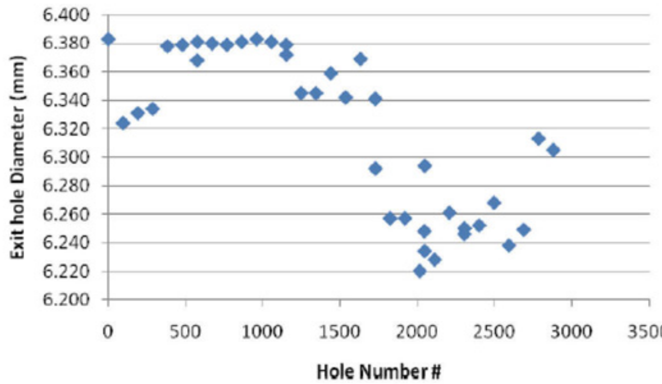

Figure 13. Exit hole diameter versus hole number for S:5000 rpm /f:1125 mm/min for DCC drill.

•In all performed conditions, hole diameters tolerances begin to scatter from ± 0.015 mm tolerances before a delamination occurs.

•PCD drills tested in the scope of this study are more suitable in CFRP drilling than DCC drills used in this research.

•CFRP machining with high cutting speeds, a run-out concept should also be considered. According to the observations in this study, increasing feed rate with constant spindle speed significantly lowers the run-out.

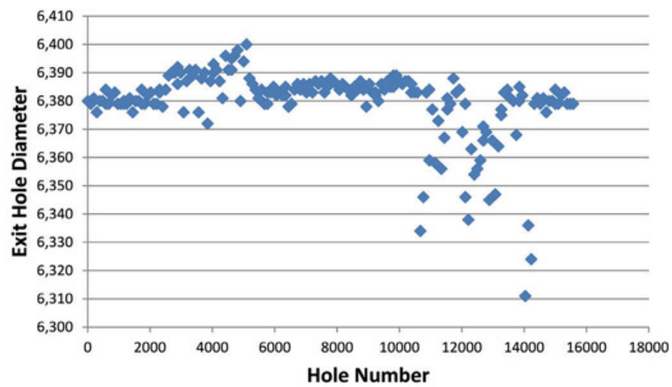

Figure 14. Exit hole diameter versus hole number for S:15,000 rpm /f:1125 mm/min for PCD drill.

Acknowledgements

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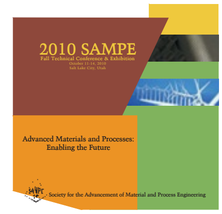
SAMPE Proceedings



SAMPE Tech 2012 Proceedings

The technical program and its associated Proceedings were developed with a number of conference tracks consisting of rapid processing, sustainable energy, transportation, nanocomposites, classical composites, renewables, and high temperature resin systems. A total of 168 technical papers are contained within the seven technical tracks and are related to the overall conference theme chosen. A wide variety of M&P subject areas are covered with topics such as analysis, damage, nanocomposites and multifunctional composites, nanomaterial property characterization, thermoplastics, and out-of-autoclave processing. Of special interest are the technical papers from the three focused sessions on high temperature resins, featuring papers from Japan and China. Over 20 papers are dedicated to advances in manufacturing. The special Infrastructure track features papers from the automotive, aircraft, aerospace, railroad, marine, and ocean energy industries. SAMPE Publishing, 2012, Edited by H.S. Kliger, B.Q. Lucht, L.A. Pilato, B. F. Schafran and S.W. Beckwith, ISBN 978-1-934551-13-4.

SAMPE 2012 Proceedings

The 5-track technical program produced complete technical papers in the following track areas: Applications, M&P Support Technology, Manufacturing Technology, Materials Technology and Nanotechnology. Over 250 technical papers are included in their full length within these Proceedings. A number of technical areas included papers from multiple sessions which were expanded within the actual conference program: composites processing, thermoplastics, nanotechnology development, out-of-autoclave/aerospace, composites analysis, inflatable structures, applications in automotive/ground transportation, out-of-autoclave composites/space exploration, testing/test methods, supportability, structural health monitoring, metal matrix composites and armor/ballistic materials. A large number of other traditional materials and process engineering technology areas are also covered in extensive detail with full technical papers. The technical content of these proceedings provides a summary of the current state-of-the-art of materials and their processing from an aerospace, commercial and theoretical prospective. SAMPE Publishing, 2012, Edited by Edited by M. Maher, G.M. Newaz, G. Reyes and S.W. Beckwith, ISBN 978-1-934551-12-7.

SAMPE Tech 2011 Proceedings

The Dallas-Ft. Worth (DFW) SAMPE Chapter sponsored a technical program designed for M&P professionals that showcased a compilation of about 140 presentations in six tracks that capture the theme of the conference within these Proceedings. These tracks were: nanotechnology, materials, applications, processing, testing and simulation. In the traditional M&P area, papers include topics such as: high temperature materials, adhesives, resins, bonding, joining, NDI, reinforcements, testing, sandwich construction, automated fabrication, out-of-autoclave processing and matrix science. Further, particular emphasis has been placed on material applications with papers on transportation, wind energy and aircraft applications. In the Nanotechnology area, papers include topics such as: flammability resistance, electrical and thermal properties, fabrication methods, graphene and high-performance resins. Finally, the Proceedings contain extensive information on the topics of adaptive & multifunctional structures, composite design, engineering simulation and damage tolerance. These papers present many very interesting emerging methods and technologies. The DFW area is centrally located, a fact that resulted in significant contributions to these Proceedings from many regions throughout the society. This is in addition to the contributions made by the strong base of local expertise. The combined result is a solid technical set of Proceedings worthy of addition to the knowledge base of the society. SAMPE Publishing, 2011, Edited by W. Chan, J. Koo, P. Oldroyd, P. Sears and S.W. Beckwith, ISBN 978-1-934551-10-3.

SAMPE 2011 Proceedings

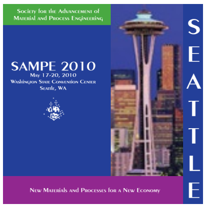
Specific areas of technology included in these proceedings, but are not limited to: materials properties and processing, nanomaterials, tooling, thermoplastics, sandwich and foam core, adhesives, coatings, sealants and surface treatments, vacuum infusion processing, resin and liquid infusion processing, design and analysis, green and renewable materials, elevated temperature, preforms, smart materials, multifunctional materials, out-of-autoclave, repair, fire and flammability, risk management, civil infrastructure, space, recycling and reuse, ceramics, and non-destructive testing. The technical content of these proceedings truly provides a summary of the current state-of-the-art of materials and their processing from the aerospace, commercial and theoretical prospective. Leading edge technology areas are covered completely within the proceedings across a number of well-developed industries and markets, as well as industries and markets currently envisioned to be in a growth mode supporting advanced materials and process engineering. SAMPE Publishing, 2011, Edited by V.P. Bailey, J.C. Leslie and S.W. Beckwith, ISBN 978-1-934551-11-0.

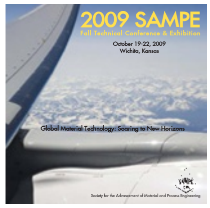
2010 Fall Technical Conference Proceedings

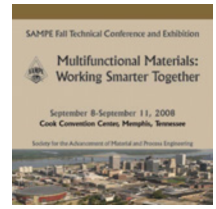
An extensive collection of technical papers appropriately reflecting a variety of advanced materials and processes ranging across all levels and market applications. The primary track technology areas that these Proceedings cover, capturing the focus of the theme, were: applications, manufacturing, materials, M&P support technologies and nanotechnology. However, there are a number of obviously associated technology areas that these Proceedings cover as well. Those technical papers fall into the following supported areas: adhesion and adhesives, sandwich/foam/core structures, carbon fiber materials, out-of-autoclave M&P, nanocomposites technology and applications, thermoplastic composites, modeling and FEA, ballistic and armor applications, aerospace/propulsion/space, green materials and processes, composite matrix chemistry, M&P advances, FST technology, joints/joining composite structures, multifunctional materials, fatigue and fracture, high temperature resins, NDT/monitoring/repair, alternative energy/wind energy, fiber placement and filament winding, resin infusion/liquid molding, testing materials and structures, and, aligned/discontinuous fiber materials. Within the full range of topics, these SAMPE Proceedings has something for everyone involved with the composites industry. SAMPE Publishing 2010, Edited by J. Berg, D. Buckmiller, D. Fullwood, M. Miles and S.W. Beckwith, ISBN 978-1-934551-08-0.

SAMPE 2010 Proceedings

An extensive collection of technical papers appropriately reflecting a variety of new materials ranging from nanotechnology level through the macro level in conjunction with today's expanding process technologies. The primary track technology areas that these Proceedings cover were: nanocomposites, adhesion and adhesive bonding, design and analysis, materials, and, manufacturing processes. However, there are a number of obviously associated technology areas that these Proceedings cover as well. Those technical papers fall into the following supported areas: repair, M&P, aircraft applications, NDE/NDI, process modeling, out-of-autoclave, thermoplastic composites, tooling, novel architecture and hybrid materials, rotorcraft, space applications, liquid molding processes, wind energy, testing, recycling, unmanned systems, textiles, ceramics and automated fiber placement. These Proceedings also reflect an excellent focus on M&P technology existing in Canada as a result of the organizing committee focus on Canadian research and advanced M&P technology. Within the full range of topics, these SAMPE Proceedings has something for everyone involved with the composites industry. These Proceedings contain over 350 technical papers. SAMPE Publishing, 2010, R. Albers, P. Hubert, and S.W. Beckwith, Editors, ISBN 978-1-934551-07-3.







2009 Fall Technical Conference Proceedings

In the classic advanced composites area, papers include topics such as design and analysis of composite structures, resins technology, tooling advancements, core and sandwich materials, infusion technology, advances in manufacturing and out-of-autoclave, testing and qualification of materials, high temperature resins and composites, filament winding, filament winding/pultrusion and automated tape placement/automated fiber placement. In the nanotechnology area, an area that has seen more interest in each succeeding year, the paper subjects include: nanofiber technology, nano-enhanced resins, nanocomposites/multifunctional materials, and 3-D nanostructured advanced composites. Because the conference was held in Wichita, the city that produces more aircraft than any other city in the world, the committee tried to solicit a very strong contribution of technical papers dealing with composite aircraft fabrication and maintenance/repair, and those are reflected heavily within these Proceedings. Within the full range of topics, these SAMPE Proceedings has something for everyone involved with the composites industry.
SAMPE Publishing, 2009 Edited by T.A. Chavez, H.S. Kliger, B. Lucht, L.A. Pilato, and S.W. Beckwith, ISBN 978-1-934551-06-6.

SAMPE '09 Proceedings

The theme is well aligned with current industry and academia needs, and reflects the challenges that we all face today to develop and provide higher performance materials, composites, and systems at reduced cost and at a faster pace. These technical Proceedings encompass a broad variety of technology topics, ranging from engineering design and analysis to advanced M&P, such as out-of-autoclave processing. While the subjects of "composite technology" and "nanocomposite technology" maintain their position and provide a strong foundation to the conference, they are supported by a wealth of M&P technologies for the development and utilization of advanced materials, which is the trademark of the SAMPE organization. The following topics, as well as numerous other pertinent topics, are featured: Nanoscience and polymers, nanocomposite properties, nanocomposite applications, composite repair, infrastructure and architecture materials technology, thermal management, fire safety and materials technology, testing, analysis, and NDE, marine applications, carbon-carbon composites and ceramics, sandwich structures, thermoplastic composites, liquid molding processes. Within the full range of topics, these proceedings have something for everyone involved with the composites industry. These proceedings contain over 250 technical papers.
SAMPE Publishing, 2009, J.C. Fielding, S. Prybyla, L. Tate, and S.W. Beckwith, Editors, ISBN 978-1-934551-05-9.

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I'll Second That E(V)Motion

"The real voyage of discovery consists not in seeking new lands but seeing with new eyes." – Marcel Proust, *"La Prisonnière"*

Sometimes leveraging technology to meet a need is not about looking for the big, splashy, newest thing. Sometimes it is about looking at the problem critically and finding a reasonable solution. Sometimes we seek a cutting edge solution and sometimes it is one that has been in use but has been unrecognized, underutilized or unappreciated.

A few weeks ago I was invited to attend the 2nd annual "Energy Development Summit" to be held in our state. It was a major event, drawing an audience of 1,300 people from 22 states and 5 countries. There were representatives from the major energy utilities seated with technology entrepreneurs of every size and shape. There were panel sessions, breakout sessions, panelists and keynote speakers. In the midst of all the activity I was drawn to a bus displayed in the back of the hall.

At first the bus seemed to be nondescript; a shuttle capable of hauling 16 seated people along its route. The more I looked at it the more attractive it became. The attraction was the way it performed its mission.

The bus was the work of Utah State University (USU). USU is located in northern Utah in the city of Logan. Logan is a city with a population of fewer than 50,000 people and is located in Cache Valley. When you understand Cache Valley the vehicle story becomes interesting. Cache Valley is in a rural county and is comprised largely of dairy farms. The altitude of the valley is 1,380 meters/4,500 feet and the mountains that surround it are more than twice that tall. In the winter Cache Valley is plagued by temperature inversions in which high altitude warm air settles on top of the cold air in the valley and holds it in like the lid on a kettle. During such an inversion Cache Valley can experience some of the worst accumulations of pollutants in the nation.

So when the need arose for a new transit system, USU began to look at electric vehicles. Of course, there are a lot of options to consider: Trains with third rails, busses with catenary lines overhead and battery-powered vehicles are all viable considerations. However, when looking at the impact on infrastructure, battery-powered buses are the easiest to implement.

USU's Inductively Charged Shuttle Bus

But there is a problem: A battery sufficient to power a shuttle bus for an entire day is big and heavy. It doesn't make a lot of sense to expend a significant percentage of the total battery power to simply haul the battery around. On top of that, the time to properly charge the battery might be sufficient to limit the number of hours the bus can spend in service. So USU turned to a concept that has been used in Genoa, Italy and Turin, Italy for more than a decade: Inductive charging on the fly. The battery is reduced in size to about 15% of the size and weight normally required. It is charged overnight in the bus garage in preparation for the next day's service. Every bus stop on the route has a non-contact inductive charger built into the roadbed and every bus has an inductive charging plate on the undercarriage that is positioned about 225 cm/9 inches above the road surface.

Every time the bus reaches a bus stop it stops over the inductive charger. All the time that the bus spends with passengers entering and exiting the bus recharges the battery. If the bus is positioned perfectly over the inductive charger the process is 98% efficient. If the inductive plate and the charging plate on the bus are offset by as much as 150 cm/6 inches the 25kW charger is still 90% efficient. At the end of the day the bus enters the bus garage with the battery barely depleted, which means that the amount of time to properly charge the battery is reduced allowing for extended hours of service. The shuttle bus itself was purchased "off the shelf" as a standard battery-powered bus minus the battery. The smaller battery and the induction charging system were installed by USU and together constitute a major reduction in weight for the vehicle. The installation of the inductive chargers at the bus stops is a minor modification to the infrastructure compared to installing rails and catenary wires required by other electric vehicles.

This is appropriate use of existing, if not well-known, technology. Yet this is not "the end of the road" for inductive charging systems. There is a move afoot to install inductive chargers in standard roadbeds in order to overcome the limitations of current electric vehicles. This "dynamic in-motion charging" would provide continuous inductive charging for electric vehicles in dedicated charging lanes. The charging pads are spaced at regular intervals allowing a vehicle on the move to top off the charge as it passes the pad. In theory, a vehicle could leave the charging lane with more power than it had when it entered. It is estimated that the inclusion of the charging pads would add about 10% to the cost of a road. Furthermore the pads are self-contained, sit below the asphalt, are not affected by snow or ice and are not prone to theft. There are people who predict that we could see this system in place by 2020.

So what role will advanced and engineered materials play in bringing this technology to maturity? Will it be in improved battery technology? Will researchers develop more efficient electric motors? Will economies of scale allow for adoption of lighter weight materials? Perhaps you will be the one to write the next portion of this article.

Gary Turner
European Section Editor
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ITALY

In 2012 SAMPE Italy supported the fifth edition of the COMPOTEC Exhibition in Marina di Carrara (Tuscany) together with the Seatec Exhibition, and endorsed some National conferences in order to support composites knowledge and expertise.

SAMPE Italy also supported the second annual congress of ASSOCOMPOSITI, the Italian Association of Composite Industry, May 29-31. The conference was held in Turin and attracted over 150 participants and 30 speakers. The first two days, held at the Environment Park, offered a very significant meeting point between companies, academics, designers, researchers and experts in composite materials.

The first day focused on composite materials in construction and design and hosted the first meeting of the Assocompositi Working Table for fiber-reinforced composites with inorganic matrix for the construction sector. The second day was dedicated to materials research and industrial applications, with a very special speech by Mr. Sagnella (Alenia) on the development and use of composites in aircraft. The gala dinner had brilliant guest speaker, Michael Robinson, designer of the Bertone Group, who focused on innovative composites for the automotive industry. The third day of the congress took place at the FIAT Research Centre in Orbassano and included a meeting with the Managing Director, Mr. Re Fiorentin. It included a broad overview of the activities of the Materials Centre offered by the Director, Mr. Serra. The visit was then concluded with a presentation of the activities of the Security Center where technicians explained the characteristics of crash tests.

The second edition of Assocompositi National Conference fully confirmed its aim of bringing together the Italian business, technical and scientific communities, also thanks to the role of SAMPE Italy.

SAMPE Italy and SAMPE Europe supported the 15th edition of ECCM (European Conference on Composite Materials) held in Venice on June 24-28. The conference was co-organised by the Department of Management and Engineering, University of Padova and Veneto Nanotech, the Italian Cluster on Nanotechnology under the patronage of ESCM, the European Society for Composite Materials. A significant contribution to the success of the event was indeed the endorsement of more than 30 worldwide Scientific Societies; among these, SAMPE supported the event within the framework of a bilateral support agreement recently signed with ESCM.

The topics of the contributions presented during ECCM15 ranged from materials characterization to final application, including manufacturing technologies, modeling and simulation, plus testing and design methods. The four plenary and eight keynote lectures offered the insights and perspectives of the world's leading experts from academia and industry. Report from Rocco Rametta, SAMPE Italy Chapter President.

UKRAINE

SAMPE Ukraine SUTEC-2 Technical Conference

SUTEC 2, the 2nd technical conference of SAMPE Ukraine was held on November 15, 2012 at the Ukrainian Research Institute of Aviation Technology (UkrRIAT), Kiev, Ukraine. The conferences theme was "Technical Modernization of Aircraft Manufacturing Production - The Key to Success in the Aviation Market". It was attended by representatives from various cities of the Ukraine. Participants, the total number of which amounts to more than 30, represented National Technical University of Zaporozhe, Institute for Problems of Materials, National Academy of Sciences of Ukraine, Yuzhnoye Design Office, National Aviation University, Polytechnic Institute of Kiev, ANTONOV, Aviation Institute of Kharkov, State University of Sumy and UkrRIAT.

The conference comprised three sections: Management Economics, Research Manufacturing Technologies and Simulation, and Composite Materials. 13 presentations were made. Some of the papers will be considered for nomination to be presented at the 34th international conference on composite materials SEICO 2013 to be held in Paris, March 2013. In addition, all the papers of SUTEC 2 will be published in the next issues of *Technological Systems* journal being published by UkrRIAT.

SAMPE Ukraine also Co-organized the Student Conference

The 12th Pan-Ukrainian Science and Technical Conference of students, post graduates and young science fellows was held on October 23-25, 2012 in Polytechnic Institute of Kiev, Ukraine. The Conference was themed on “Ukrainian Machine-building by the Eyes of Young Man: Progressive Ideas – Science – Manufacturing”. SAMPE Ukraine was a co-organizing society for this Conference. Mr. Victor Shulepov, Vice Chairman – Secretary of Board, SAMPE Ukraine presented one of the key-notes of the Conference – “SAMPE Ukraine as a tool for the advancement of material and process engineering”. Report by Victor Shulepov.

UK & Ireland Chapter...

...will hold their annual seminar and SME tabletop exhibition entitled: Advanced Composites: The Engine for Growth on Wednesday 27th February 2013, at Cranfield University. SME tabletop exhibits are sponsored by the NCC (National Composites Center).

The one day seminar addresses progress in design, materials and manufacturing technologies that are essential to secure continued success for cost effective high performance composites. Key innovators in the aerospace, defense, automobile, marine and sports sectors have been invited to make presentations. The full programme will be featured on the Chapter website: www.sampe.org.uk and registration documents will also be available on the website.

Presentations have already been secured from international contributors Messier Bugatti Dowty and Zoltek. Topics to be covered include component manufacture and qualification, material supply chain, Graphene development and market, and ceramic composites.

Sponsored by the National Composites Centre, the SAMPE UK & Ireland Chapter will host another tabletop exhibition for SMEs who offer innovative technologies and solutions. Application forms for the SME tabletops will be on the website. This is the fourth SME tabletop exhibition. The previous exhibitions have been very successful and proved to be great opportunity for delegates to gain information and network. For further information contact: Andrew Mills, a.r.mills@cranfield.ac.uk (Cranfield), David Carlton, sndcarlton@sedace.co.uk (SAMPE) or Trevor Cook, Trevor-cook@live.co.uk (SME tabletop).

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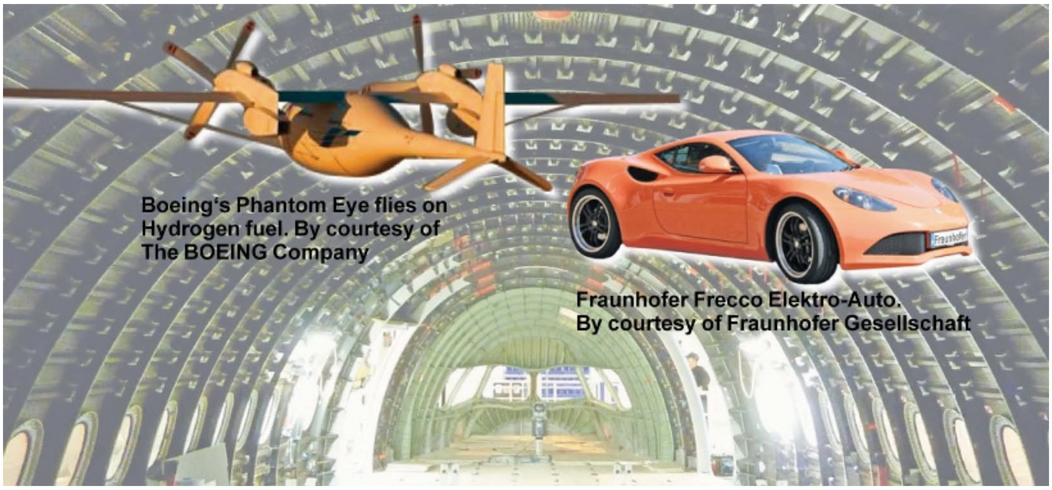
Advanced Composites On Its Way To Industrialization



SAMPE Europe welcomes you to attend our 34th International Conference SEICO 13 to be organized as in previous years at the Hotel Mercure, Paris Porte de Versailles Expo, Vanves, which is located in walking distance (10 minutes) to the Paris Expo Porte de Versailles where the JEC Composites Show & Conferences will be held from March 12th – March 14th to attract more than 10,000 visitors from the entire world. SEICO 13 will be organized as a two days International Conference presenting two attractive keynote addresses, one aerospace and one automotive oriented. For those two industry segments two special sessions each (session 1 and session 4A) have been organized to provide to all attendees of SEICO 13 the latest attractive results from related R&D, testing and industrialized application. The overall concept of SEICO 13 will provide in addition to the two keynotes – one plenary session on aerospace – and 12 parallel sessions presenting in total 55 state-of-the-art papers which have been selected with high dedication to guarantee a high attractiveness and good quality. All papers to be presented at SEICO 13 will be documented in the SEICO 13 Proceedings which will be remitted to each registered attendee. In regard of the JEC Composites Show which will open its doors as from March 12th at the Expo Complex Paris Porte de Versailles, SAMPE Europe provides on that date a free shuttle bus service operating from Hotel Mercure to Porte de Versailles Expo Complex from 08.00h – 18.00h proposing 4 departures per hour for each direction. The SAMPE Europe community welcomes you to attend SEICO 13 and will be pleased to be your host for the Welcome Reception on Sunday evening March 10th 2013, as from 18.30h at Hotel Mercure – and at the SEICO 13 conference dinner on Monday evening, March 11th 2013, again at Hotel Mercure as from 19.30h.

We look forward to welcoming you to Paris! Paolo Ermanni, President SAMPE Europe

Sponsorship of SEICO 13

SAMPE Europe greatly appreciates the very generous sponsorship from the following organisations and companies.

HITCO CARBON COMPOSITES, INC. | JEC GROUP Official Partner | JEC Composites magazine Official Media Partner | xperion THE COMPOSITE PEOPLE | Henkel

SEICO 13 Welcome Reception on Sunday, March 10th 2013 – 18.30-20.00h at Hotel Mercure

All early arrived conference attendees are kindly invited to the Welcome Reception to be organized in the Atrium next to the conference rooms of Hotel Mercure. There will be "finger-food" and drinks served as from 18.30-20.00h.

SEICO 13 Conference Dinner

Your conference registration badge serves as access pass to the SEICO 13 Dinner. Complementary access badges are available from the conference registration desk at € 80.00, VAT included.

SEICO 13 Registration Badge grants free access for 3 days to the JEC Composite Show

SEICO 13 Full Catering Service for all SEICO 13 Attendees

All SEICO 13 attendees will enjoy a full catering service proposed on each of the two conference days. A welcome coffee waits for you prior to the opening of the first session. In the morning and afternoon a coffee break will be served as defined in the conference programme. For lunch a buffet will be served at the restaurant of Hotel Mercure. The lunch is to be paid by remittance of the lunch voucher which will be given to you in your conference bag.

SEICO 13 AT-A-GLANCE

Sunday March 10th

17.00-18.30h Registration

18.30-20.00h Welcome Reception

Monday March 11th

08.00-16.30h Registration

09.00-18.00h Sessions

09.00-10.00h Opening and Keynote

P. Ermanni, President SAMPE Europe-Opening

N. Melillo & A. Mallow-Keynote Aerospace
Rapid Prototyping as a Tool for Technology Insertion-Recent Examples at the Boeing Company;

10.00-10.30h Coffee Break

10.15-12.15h	**Session 1**	
Plenary Session 1 - Aerospace		
B. Bernal		

12.15-13.15h Lunch

13.30-15.30h	**Session 2**	
Session 2A	Session 2B	Poster Exhibition
Nanocomposites	Repair 1	Students' Conference
L. Torre	*F. Collombet*	

15.30-16.00h Coffee Break

16.00-18.00h	**Session 3**	
Session 3A	Session 3B	Exhibition
Thermoplastic	Repair	Students' Conference
A. Offringa	*F. Collombet*	

19.30-22.30h Hotel Mercure
SEICO 13 Dinner and Award Remittance

Tuesday March 12th

08.00-16.30h Registration

08.30-18.00h Sessions

08.30-9.15h *A. Plath*-Keynote Automotive
From Small Scales to Volume Production-How to Make Carbon Fibre Mainstream

09.15-10.45h	**Session 4**	
Session 4A	Session 4B	Poster Exhibition
Automotive	SHM	Students' Conference
F. Henning	*P. Kat*	

10.45-11.15h Coffee Break

11.15-13.00h	**Session 5**	
Session 5A	Session 5B	Poster Exhibition
Manufacturing	Automation	Students' Conference
A. Mills	*K. Drechsler*	

13.00-14.00h Lunch

14.00-15.45h	**Session 6**	
Session 6A	Session 6B	Poster Exhibition
Design & Modeling 1	New Materials	Students' Conference
A. Akkerman	*J. Vuorinen*	

15.45-16.15h Coffee Break

16.15-18.00h	**Session 7**	
Session 7A	Session 7B	Poster Exhibition
Design & Modeling 2	Tooling	Students' Conference
R. Akkerman	*O'Bradaig*	

18.00-18.10h Conference Room Session 7B
Closure SEICO 13
P. Ermanni, President SAMPE Europe

SEICO 13 VISA Request for Temporary Immigration to France/EU

If you require a VISA to enter France / Schengen States, please contact at the very earliest moment SAMPE Europe by e-mail (sebo@sampe-eiurope.org) to provide you an invitation letter required for your VISA request application to the French Embassy or Consulate of your country of residence.

SEICO 13 Proceedings

The conference bag, to be collected with the conference badge by each attendee at the conference desk, will contain one CD Rom copy of the SEICO 13 Proceedings. Additional copy of the Proceedings are available from the registration desk at a special price per copy of € 70.00, VAT included..

Air France/KLM

Visitors to JEC Europe Composite 13 Show & SAMPE Europe SEICO 13 Conference can apply for getting discounts on AIRFRANCE / KLM fl ights to and from Paris during the travel period of March 7th to March 19th 2013. The reduction will be -10% of published non-restrictive public fares. A reduction of – 5% is granted on restrictive-discounted fares. Use the website for making the booking of your ticket under the following address: http://www.airfranceklm-globalmeetings.com/?eid=17433AF to access – the preferential fares granted for JEC Europe Composite 13 Show
- make your online reservation; - issue your electronic ticket*; - select your seat**; - print your boarding card **; - (*) not available in certain countries - - (**) subject to conditions
If you buy your ticket via Air France & KLM Global Meetings website, your electronic ticket will carry a special mention which justifies the application of the preferential fares. Should you prefer to process your reservations and ticket-purchase directly with an Air France and KLM sales outlet, you must keep this current document which serves to justify the application of the preferential airfares:
Event: JEC EUROPE 2013; Event Id: 17433 AF
Validity : Flights from March 07th – March 19th 2013
Event location: Pavillion 1 – Parc des Exposition de la Porte de Versailles; 1, Place de la Porte de Versailles, F- 75015 PARIS
To locate the nearest Air France and KLM sales point, visit www.airfrance.com
You will need to quote the reference given above which is registered in Air France and KLM date under: GGAIRAFGLoBALMeeTINGS
Frequent flyer / loyalty programs of Air France and KLM partner airlines are credited with "miles" when Air France and KLM flights are used.

For more detailed information, registration & hotel forms see the complete Preliminary Programme at www.sampe-europe.org

8th International Technical Conference & Forum

10th – 12th September 2013

Novel Aspects in Composite Technologies: From Fibre to Lightweight Structures

SAMPE Europe is pleased to inform you by this First Announcement & Call for Papers for the upcoming SETEC 13 Wuppertal Conference and Tabletop Exhibition on the 10th–12th September 2013.

SAMPE Europe SETEC 13 is a rewarding Conference dealing with aspects of advanced composites and applied material science. Today's fibre reinforced thermoset and thermoplastic matrix composite materials are being studied to improve the sustainability and performance of the in service and future advanced composite materials. New types of fibres and novel elements to enhance performance of matrix-systems are gaining importance. Demonstration of their proof of concept and industrialization is the key to these technologies being realized in structural applications. Under this framework, the theme of SETEC 13 has been defined as: "Novel Aspects in Composite Technologies: from Fibre to Lightweight Structures".

Venue of SETEC 13

SETEC 13 will be held at the Stadthalle of Wuppertal, in Wuppertal, Germany. Wuppertal is located in the Bergische Land between Köln and Düsseldorf to the east of the river Rhine. From Düsseldorf Airport, Wuppertal can easily be reached by rail in about 45 minutes. The 19th century Wuppertal and its partner city Barmen home the first monorail Schwebebahn train in the world, suspended 6 metres above ground. This Schwebebahn has remained till today as the only such type of public transport anywhere in the world. A ride on the Schwebebahn is included as part of the SETEC 13 registration.

SETEC 13 Tabletop Exhibition

The Tabletop Exhibition of SETEC 13 will consist of 30 tabletop units. The tabletop area will be located next to the conference auditorium and is integrated in the catering area where the Welcome Reception, the coffee breaks and the lunch will be served. Each unit will be equipped with a table (size 1700 x 700 mm), two chairs, and power to allow exhibitors a wonderful position to present their products and services.

Hotel Accommodation and Wuppertal

The Stadthalle Wuppertal is located in the centre of Wuppertal, set on the Johannisberg Hill, a short walk (12 minutes) from the Wuppertal Hauptbahnhof (main station) Next to the Stadthalle, Hotel ARCADIA Wuppertal has been pre-booked for the conference by SAMPE Europe, and will serve as the conference hotel: € 91.00 (single room) or €127.00 (double room). Additional hotels in the centre of Wuppertal will be added on walking distance to the conference at the Stadthalle.

All hotel details will be published in the Preliminary Programme, which will be published by the end of April 2013. The SETEC 13 Conference Dinner will be held at the Brauhalle of Wuppertal, on the evening of the 11th of September. The journey from the Stadthalle to the Brauhalle will be made with a ride on the Schwebebahn – a very unique chance to glide through a centre of a city at a very low altitude. This experience should not be missed!

Call for Papers

Attendees to SETEC 13 will receive an insight into the current technologies and state-of-the-art realisations of composite materials in engineering applications for different industry segments. The Scientific Committee of SAMPE Europe is composed of experts from leading Research Institutes, Universities and Industry to that will assess the received abstracts and invite the best to present at SETEC 13 in Wuppertal. The received abstracts will be judged, and speakers informed by the end of March. Speakers will be asked to prepare a conference paper by May 1st, 2013, which will be included in the SETEC 13 Proceedings.

Presentations are invited in the areas of:

Design	Processing	Materials	NDT & Repair	Tooling	Structures
Bonding and Joining	Sandwich	Thermoplastics	Nano Technology		

Accepted abstracts are due to become prepared as a paper, not later than January 31st 2013,to be transmitted as an electronic file.

For any related inquiry or question you will be welcomed to contact either:

Prof. Paolo Ermanni (permanni@ethz.ch)	Mark A. Erath (erath@bluewin.ch)
ETH Zürich	ACMC Consulting GmbH
CH-8092 Zürich	CH-4125 Riehen/Basel

SETEC 13 Plant Tours

All SETEC 13 attendees will get the opportunity to register for a Plant Visit, to one of the companies located in the Bergische Land, being active in the development and processing of industrial sized, advanced composite structures. Related details will be published in the Preliminary Programme.

SETEC 13 Conference language for presentation of the papers and documentation in the Proceedings will be English.

SETEC 13 Sponsoring

SAMPE Europe is pleased to welcome your organisation to sign a sponsor agreement for SETEC 13 based upon a comprehensive scheme providing in exchange the visualisation of your company name and logo on all printed and electronic publications in relation to SETEC 13 and by providing additional collaboration that may be defined together. Please contact the conference manager Mark Erath (sebo@sampe-europe.org) for any such inquiry.

For more information visit www.sampe-europe.org

Machining and Drilling of Carbon Fiber Reinforced Plastic (CFRP) Composites

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Abstract

The use of carbon fiber reinforced polymers (CFRP) has been steadily increasing because of superior specific strength, corrosion resistance, and fatigue performance. Machining of CFRP structures is often necessary for achieving final dimensions following cure and for assembly operations. Edge trimming or milling is the most common secondary processing method for achieving net engineering geometry and hole drilling is the most common method for producing features necessary for assembly. There are significant differences between the machining of metals and composites due to the inhomogeneity and anisotropy of the material system. The choice of constituent materials and fiber orientation has the most significant influence on the cutting process. A common concern when drilling and trimming CFRP materials is machining quality, which is essential for dimensional accuracy, and minimizing defects. Chip formation modes, abrasiveness of the fibers, cutting tool selection, and cutting conditions impact hole and edge quality of machined components. This paper will provide some recent experimental results along with a review of the issues and challenges for edge trimming and drilling of CFRP materials.

Introduction

While fiber reinforced plastic (FRP) composites structures may be produced that achieve near-net geometry, it is often necessary to perform additional machining processes to meet specific engineering requirements, such as edge trimming for critical dimensions, and/or hole generation for mechanical joining and assembly with other components[1-3]. Among the machining processes utilized for assembly of composite structural parts, drilling is the most frequently executed operation whereas for achieving dimensional requirements, edge trimming through milling or routing is most common. Unlike drilling of conventional metallic alloys and other material systems, the drilling process of composites is complex in nature with many new damage modes and chip formation mechanisms. The inhomogeneity and anisotropy of FRP composites coupled with the abrasive nature of the reinforcing fibers and complexity of cutting tool geometry make quality hole production challenging, largely due to process-induced damages and defects while drilling. Moreover, the abrasive nature of the reinforced fibers expedites the rate of tool (drill) wear dramatically, which in turn presents a risk to drilled hole quality. More than 60% of composite part rejections at the assembly stage are due to poor quality of drilled holes.

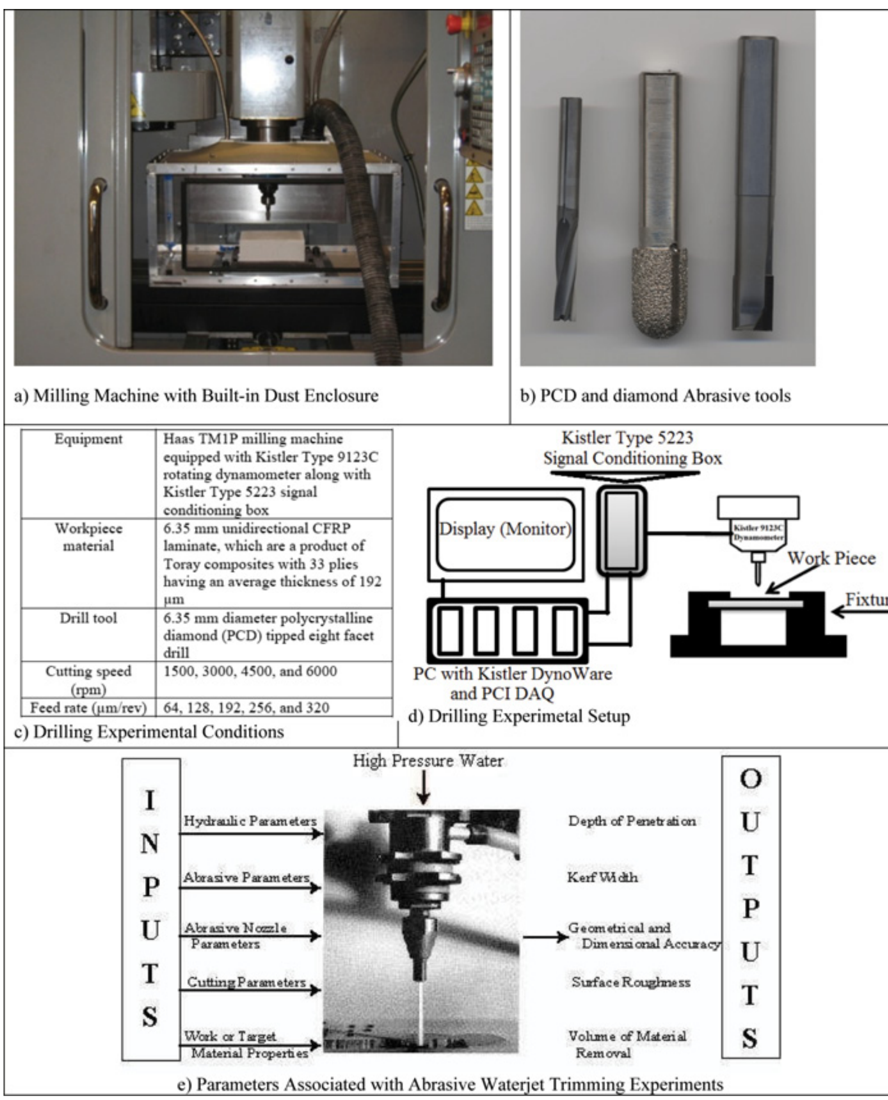


Figure 1. Experimental setup for trimming and drilling.

Edge trimming by the milling process is one of the most common machining processes employed to provide the required surface finish and dimensional accuracy of a composite part. Edge trimming is performed after the laminates are fully cured using hand held routers or large numerically controlled (NC) multi-axis routers or milling machines. Milling of composites is challenging because of the anisotropic and abrasive nature of the material. Some of the challenges include delamination, fuzzing, fiber pullout, and short tool life[4]. The chips or dust generated through machining of carbon fibers are electrically conductive and can cause shorting in electrical equipment. In addition, exposure to airborne carbon fibers, currently classified as a nuisance particulate, may sensitize and irritate nasal and respiratory systems and may cause skin irritation in some individuals[5]. These challenges are considerably different issues than those encountered during milling of homogenous materials such as metals and thus merit study to understand the mechanics and process conditions to maximize productivity and achieve desired quality results.

Several other traditional manufacturing techniques typically utilized in shaping homogeneous materials such as sawing, grinding, water jet (WJ), abrasive water jet (AWJ) and trimming with single point cutting tools are also applied to achieve net shape geometry in composites[2,3]. Non-traditional techniques such as electrical discharge machining (EDM), ultrasonic machining, and laser cutting have also been utilized to a limited degree because of process limitations. Waterjet (WJ) and abrasive waterjet (AWJ) cutting are effective techniques for machining composites based on their success with difficult-to-cut materials and omnidirectional cutting capability. In "pure" waterjet machining of FRPs, material removal occurs by material failure through erosion, macro-bending induced fracture, and out of plane shear. Material removal in AWJ machining of FRP's is comprised of localized shear through abrasive impact and micro machining. An AWJ cut FRP retains its micro structural integrity with limited visible constituent damage compared to a WJ cut surface[6]. WJ and AWJ cutting processes are differentiated by the addition of abrasive particles into the jet stream. Abrasives serve primarily as an erosive medium, providing a diverse group of micro-machining mechanisms that assist in material removal. In a comparison of WJ and AWJ cutting of unidirectional Graphite/Epoxy composites, it was found that AWJ is much more suitable based on mechanisms of material removal and superior surface quality.

Experimental Work

Current fabrication methods for graphite fiber reinforced composite materials require that each laminate be trimmed to the final dimensions after curing. This requirement exists regardless of the method used for laminating a component, since current techniques for fabricating composites leave rounded edges. Square edges and accurate final dimensions are often required for assembly of laminates into finished structures. As a result, trimming operations can comprise a substantial portion of the total manufacturing flow time for these materials. A number of methods exist for trimming composite materials, each method having different requirements, costs and advantages. The method selected will depend on

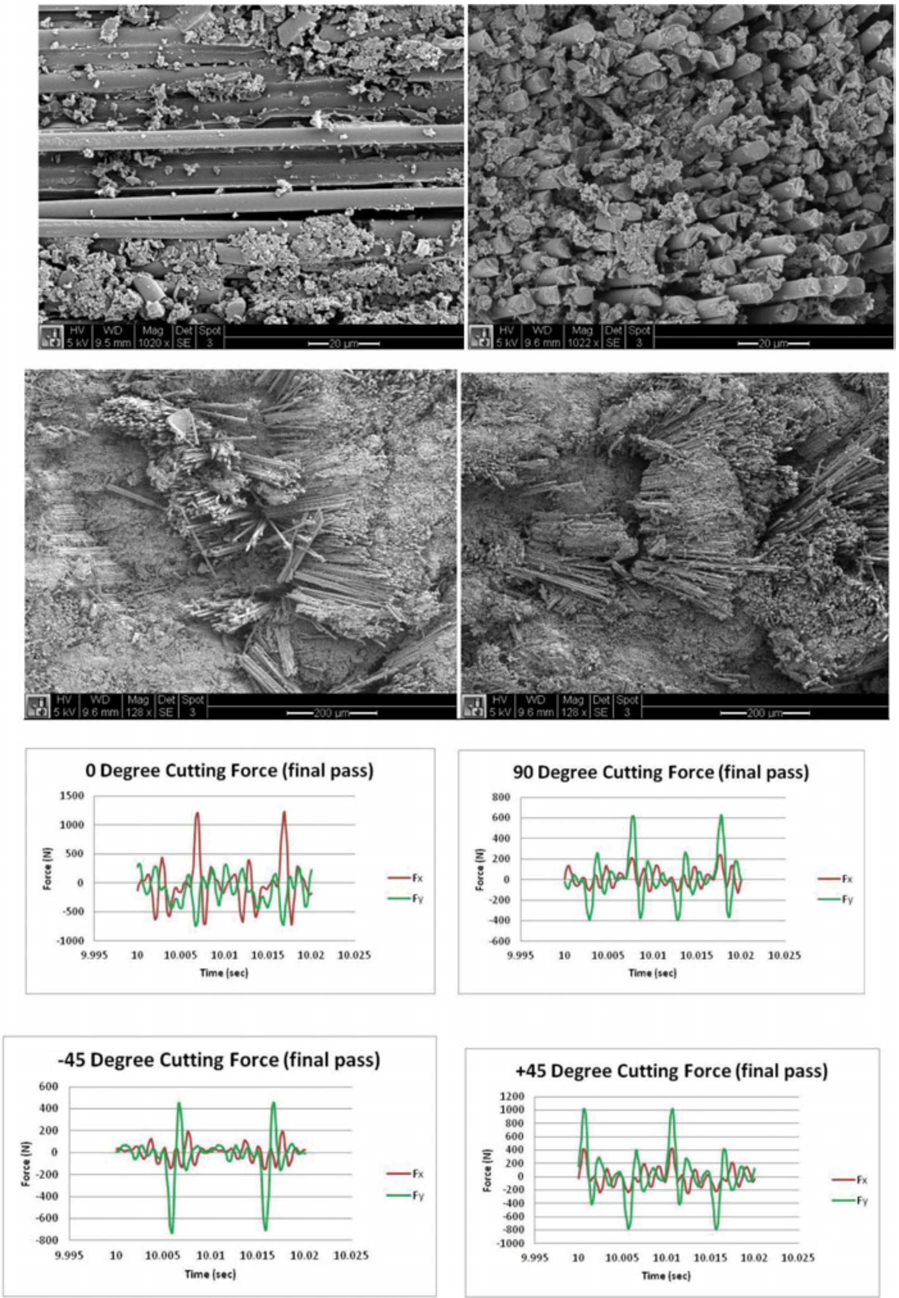


Figure 2. PCD edge trimmed UDL surface and typical cutting forces.

many factors, such as availability of equipment, material dimensions and thickness, and manufacturing lot size. The three predominant trimming methods used in the aerospace industry are hand routing, end milling with numerical control equipment, and trimming with abrasive waterjets. In the following sections, recent results on machining of advanced composites by edge trimming using PCD and diamond abrasive tools; drilling using carbide and PCD twist drills and AWJ trimming of both FRPs and fiber-metal laminates are discussed.

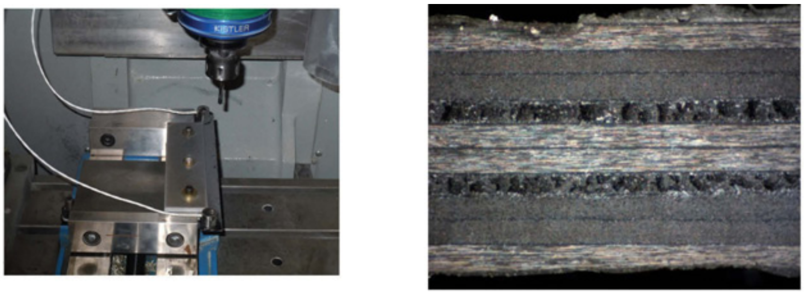
Edge Trimming and Drilling Experiments
Materials

CFRP composite materials consisting of a 10 ply thick balanced and symmetric $[0/-45/90/45/0]_s$ laminate, a 20 ply thick balanced and symmetric $[0/45/90/45/0]_{2s}$ laminate, and a unidirectional composite laminate (UDL) was used in a trimming and drilling study. The resin used in the laminates was 177°C curing epoxy. Carbon fiber volume fraction was about 60% and the ply thickness varied between 120-140 mm. By weight, the resin content of the laminates was 35.5 % of the total weight. In addition, 25 mm thick laminates composed of plain weave woven graphite fiber fabric laminated by alternating between 0°/90° and +45°/-45° orientations were used with abrasive diamond cutters and AWJ. The fabric used was composed of IM-6 fibers preimpregnated with 3501-6 thermosetting resin which was hand layed up and cured at 177°C. Finally, a hybrid titanium composite laminate was trimmed with AWJ process.

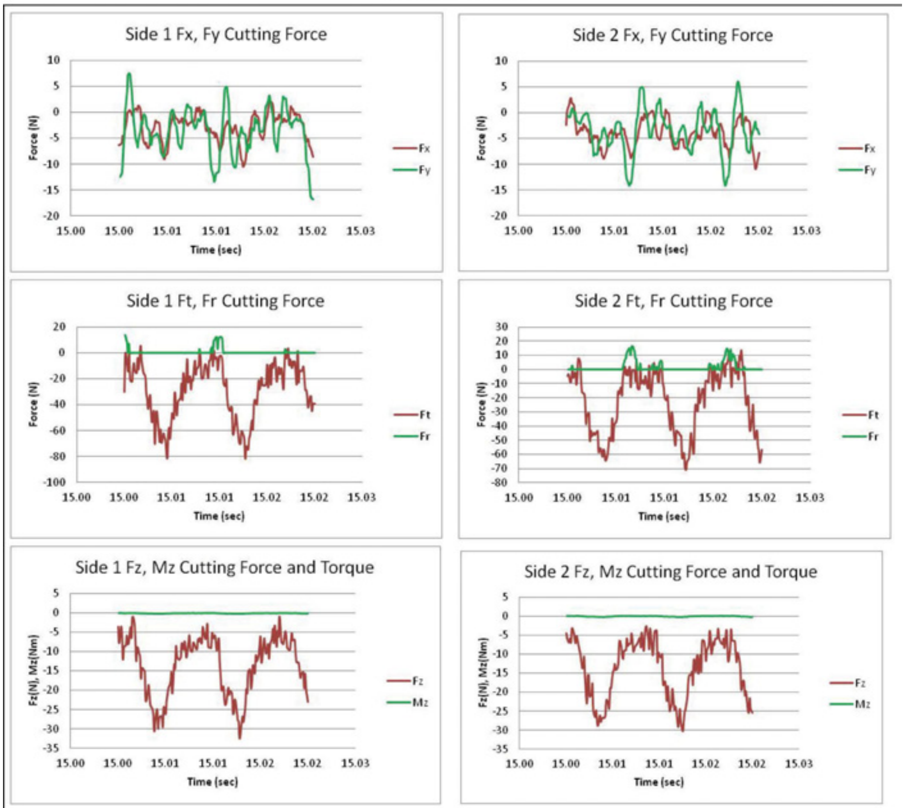
Experimental Procedures

Machining and drilling tests were conducted using a HAAS TM1P vertical milling machine equipped with a Kistler type 9123c rotating four component dynamometer, shown in Figure 1a. The milling machine was also equipped with an internal dust enclosure to capture the abrasive dust particles in order to preserve the longevity of the machine. Two types of cutting tools (Figure 1b) were used in an attempt to vary the surface roughness and the amount of induced damage. First, trimming experiments were conducted using a PCD cutting tool and diamond abrasive (DA) type tool with varying grit sizes (mesh #30, 50,80 and 125). All drilling experiments were conducted in dry condition without the use of coolant. The experimental plan was designed using State-Ease Design-Expert® software by taking cutting speed and feed rate as experimental factors at different levels as shown Figure 1c. AWJ trimming conditions and its effects were schematically shown in Figure 1d. Details of the experimental setup can be found in[7,8].

Surface quality was measured in terms of surface roughness and surface defects. Surface roughness profiles were recorded from the machined surface using a MahrSurf XR20 surface profilometer with a probe stylus radius of 2µm and a cut-off length of 0.8 mm as per ANSI standard, in an attempt to quantify the surface quality. Three surface roughness measurements in both longitudinal and transverse directions were taken from each surface machined using PCD and DA tooling. From the surface roughness profiles were characterized by evaluating the average surface roughness, R_a; maximum peak-to-valley height, R_t; root mean square roughness, R_q; and ten point average surface roughness, R_z. Defects were examined using both optical and scanning electron microscopy.



a) Multi-directional laminate cutting setup and 10-ply multi-directional laminate ($[(0/45/90/-45/0)]_s$) machined surface



b) Cutting force and torque (two revolutions)

Figure 3. Multi directional laminate trimming forces.

Results and Discussions

Edge Trimming

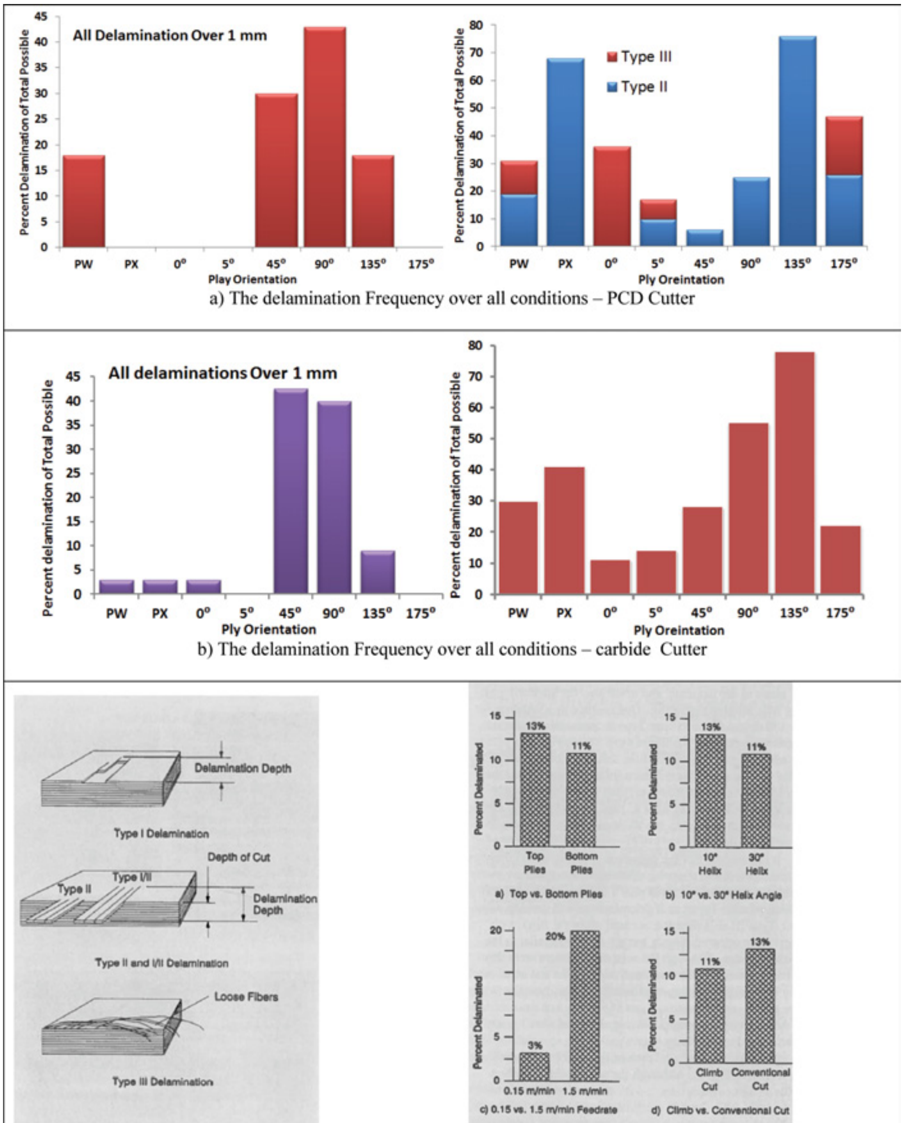
This section of the paper focuses on an edge trimming process, comparing Single edge PCD, carbide and multi-edge abrasive diamond tools available for CFRP machining. It further presents the results of an orthogonal machining test performed on unidirectional and multi-directional laminated CFRP panels.

PCD and Carbide Cutters

Typical edge trimming resultant force results for a unidirectional CFRP laminate using a straight 12mm diameter PCD 2-flute end mill at 6000 rpm, climb cutting, with 0.72 mm radial depth of cut and 6.35 mm axial depth of cut, at a .635 m/min linear feed rate are provided in Figure 2. Surface morphology of machined surface clearly is dependent on the fiber orientation. Note that severe damage was associated with -45 degree fiber orientation. Two rotations of the cutter are shown to illustrate periodicity of the resultant cutting force. Figure 3 shows a multi-directional laminate trimming surface and the resulting cutting forces. Multi-directional laminate cutting setup for 10-ply multi-directional laminate ($[(0/45/90/-45/0)]_s$) and the machined surface is shown in Figure 3a. Note that the fiber pull out and damage consistently occurred at -45 degrees and can be seen on the edge trimmed multi-directional laminate. Similar to the UDL cutting forces, multi-directional laminate cutting forces are periodic.

Chip formation mechanisms in edge trimming of CFRP materials were found to significantly influence the cutting forces. Positive fiber orientation laminates induced much higher forces than those with negative orientation. Cutting force trends were justified by chip formation observations which indicated that positive oriented fibers fail in tension rather than shear. In negative orientations, tool induced bending forces displace the fibers causing shear failure along the fiber matrix interface. Surface roughness increased with fiber orientation for $0<\phi<90$. However, composite surface roughness was significantly higher when edge trimmed at fiber orientation angle of -45 degrees tool wear measurements also corresponded to the fiber fracture and cutting forces, with positive fiber orientations inducing the highest degree of tool wear and is consistent with our reported results[3]. It becomes apparent that chip formation is influenced primarily by the fiber orientation, rather than operating parameters.

A specially designed composite laminate was used for edge trimming experiments consisting of top and bottom surface plies of different orientation plain weave (PW), plane angular (PX), 0,5,45,90,135,175 unidirectional plies and core of ($[(0/45/90/-45/0)]_s$) plies[2]. Figure 4 show the summary results of surface ply delamination in edge trimming by using PCD and Carbide cutters. Delamination along the fiber/matrix interface is the most common and severe damage characteristic that occurs in composite production edge trimming. Surface ply delaminations observed on trimmed composite panels by percentage is presented for PCD and carbide cutters in Figure 4a and 4b respectively. Type I delaminations are characterized as areas where the surface ply fibers have broke some distance inward from the trimmed edge and are missing. Type II delaminations consist of uncut fibers that protrude from the trimmed edge and may be delaminated from the next ply a distance from the edge of the part. Type III delaminations are characterized as loose fibers that are partially attached



a) The delamination Frequency over all conditions – PCD Cutter

b) The delamination Frequency over all conditions – carbide Cutter

c) Types of Surface Ply delamination

d) Effect of Maching Condition on Delamination

Figure 4. Surface ply delamination in edge trimming by using carbide and PCD tools.

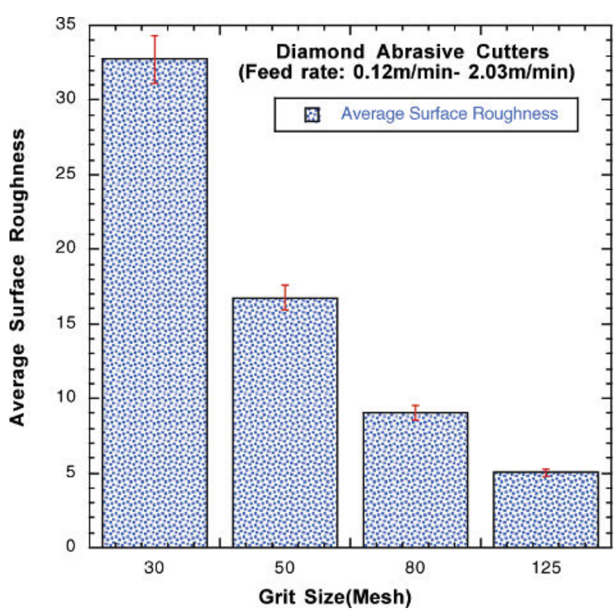


Figure 5. Typical surface roughness on edge trimmed CFRP composite with abrasive diamond tools.

to the machined edge causing a fuzzy appearance. The types of surface ply delaminations are schematically shown in Figure 4c. Type II and III delaminations are similar as they appear to be created by fibers moving out of the way of the advancing cutting edge without completely breaking which leaves uncut fibers protruding from the edge of the laminate. Delamination was found to be most severe when the exit plies are oriented with fibers perpendicular to the plane of the trimmed edge. Effects of cutter helix angle, feed rate, and cutting direction with respect to percent of delaminations is shown in Figure 4d. A recommendation from this study is to use fibers that are parallel to the trimmed edges on all straight edges and fabric surface plies on all curved edges to minimize delamination of surface plies and increase the ease of fabrication when trimming.

Abrasive Diamond Cutters

Four diamond abrasive grit sizes were used in the tests performed. The grit sizes used were 30 grit, 50 grit, 80 grit and 125 grit. The 30 grit cutter is the most common cutter used for roughing operations since it has large diamond grains and is relatively aggressive. The 125 grit cutter is often used for finishing operations since it produces a uniform, smooth surface. The 50 and 80 grit cutters represent intermediate grit sizes and were included to reveal any trends that are a function of grit size. The cutter diameters used were 12.7 mm, 19 mm, and 25.4 mm. The selection of cutter diameters for each grit size was dependent on cutter availability[9].

Inspection of the machined surfaces produced by diamond abrasive cutters revealed that the machined edges can generally be described as having a pattern of grooves that run along the plane of the cut. From the surface finish measurements taken, the severity of the grooving pattern correlated with the grit size of the cutter used. Inspection of the sectioned specimens with a 40X magnification did not reveal any subsurface matrix cracking, nor did it reveal any delamination of the plies. This result is significant since delamination is generally associated with a reduction in the ultimate strength of a laminate. However, the failure to detect delamina-

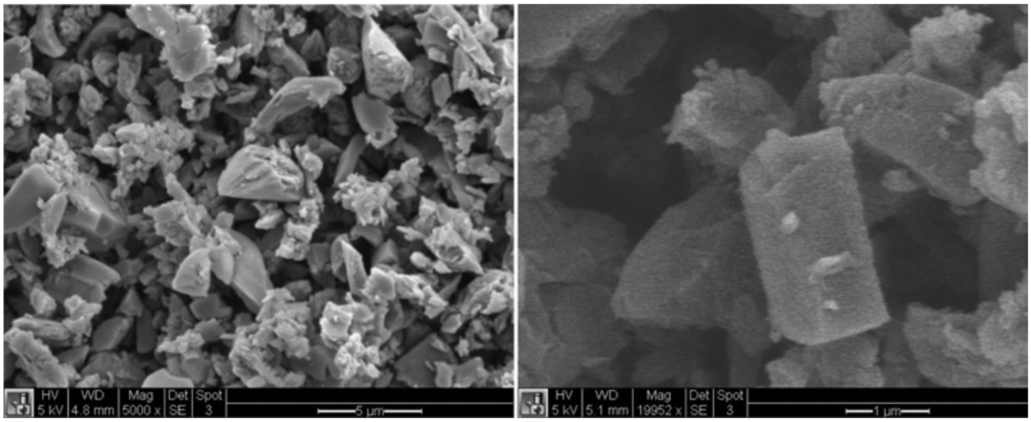
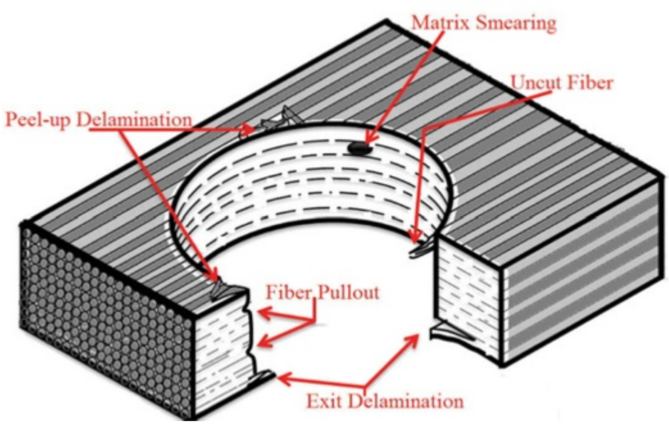
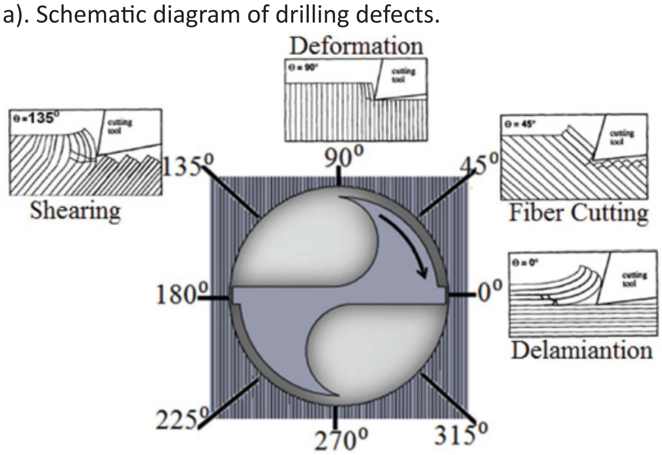


Figure 6. Typical dust particles from composite edge trimming.

tion in the tests performed does not indicate that diamond abrasive cutters are incapable of producing delamination in a laminate. It is possible that if long cutter lengths are used, in excess of four cutter diameters in length, chatter of the cutter may result in delamination at some point in a laminate. Diamond abrasive cutters produce a machined surface that has a surface finish which is directly related to the grit size of the cutter being used and is not significantly related to other process parameters such as feed rate, cutting mode, and cutter diameter. Figure 5 show the effect of grit size on surface roughness. The quality of laminates trimmed by the diamond abrasive cutter trimming process was found to be relatively insensitive to variations in cutter feed rate, cutter diameter, cutting mode, and width of cut. Also, since the surfaces produced by 30, 50, 80, and 120 grit cutters do not appear to affect the compression strength of laminates, it is apparent that surface finish requirements on graphite/epoxy materials that are cut with diamond abrasive cutters may be relaxed to allow increases in production rate by using coarser, more aggressive diamond abrasive cutters, provided that delaminations are not present in the machined surfaces. Although it is not impossible for a diamond abrasive cutter to produce delaminations, this trimming process was not found to cause delaminations in the tests performed.



a). Schematic diagram of drilling defects.



b). Chip formation and cutting modes.

Figure 7. Major area (sectors) of interaction angles and four major cutting mechanisms.

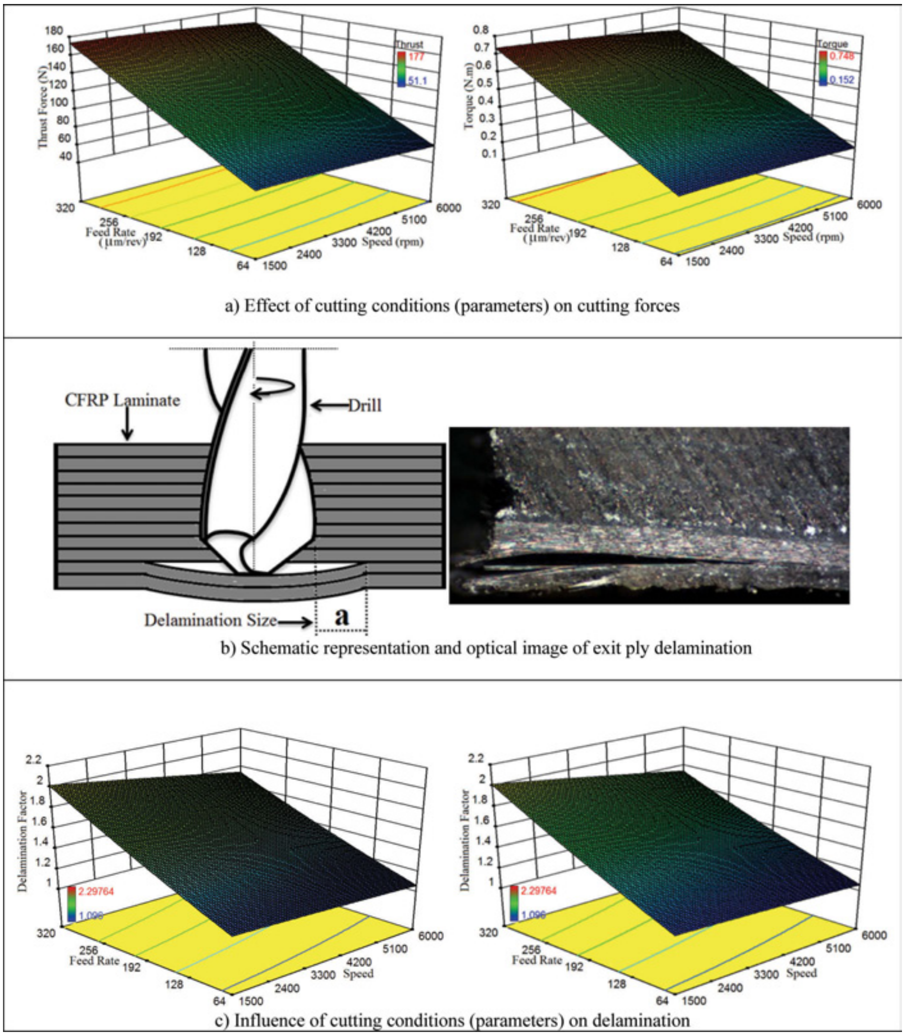


Figure 8. Effect of drilling conditions on cutting forces and delamination factor.

Three different chip types are typically found in edge trimming. Powder-like chips are produced primarily by fracture. Figure 6 is an example of powder chips produced from the composite edge trimming process. Ribbon-like chips consisting of unbroken segments are produced by fracture with fiber breakage. Large delaminated brush-like chips are produced by interlaminar facture in shear. Burr formation is determined by fiber orientation and cannot be avoided except when cutting parallel to the fibers, which is the recommended cutting direction. The morpholological characteristics of the dust particles and powder depend on upon the chip formation process and cutting conditions. A concern is that the health hazards of composite dust may not be fully understood. Therefore there is a desire to prevent inhalation of the particles. An area for future research may include a study on the effect of process conditions where it may be possible to reduce the likelihood of inhalation by optimizing cutting conditions so the chips generated are non-respirable.

Drilling

The drilling process of FRP composite materials is more complex than drilling of metallic alloys, as FRP drilling introduces induced damage and defects which do not occur in metallic drilling. FRP drilling induced damage which may compromise structural integrity includes spalling, delamination, fiber pullout, matrix crack, matrix melting (smearing), and fiber breakout. Exit delamination and fiber pullout are the most severe process induced defects. The chip formation mechanism is a controlling factor that makes drilling and trimming of FRP composites complex and different from drilling or edge trimming of traditional metallic alloys. In metallic machining shearing is the major chip formation mechanism, whereas in the case of FRPs local bending at the fiber-matrix interface controls chip formation[10]. In addition, during drilling of FRP composite materials, the cutting edge encounters reinforcing fibers at different angles at every instant of the cutting action. The interaction angle between the cutting direction and fiber orientation varies based on the position of the cutting edge along the circumference and stacking orientation of each individual ply. Based on the angle of interaction, the primary cutting mechanisms are accomplished by delamination, fiber buckling, fiber cutting, deformation, and shearing (by plow up). Figure 7 shows the defects and cutting mechanisms in drilling of a composite material. Most of the damage and defects shown in Figure 7a, which occur during the drilling process are dependent on the interaction angle between the cutting direction and fiber orientation. While suppressing some drilling induced damage could be achieved by optimizing drilling parameters such as cutting speed, feed rate, and tool geometry, eliminating all rejectable defects remain a big challenge. Figure 7b, shows the major areas (sectors) of the interaction angles and four major cutting mechanisms. Each cutting mechanism repeats itself every 90°.

Most process-induced damage is controlled by cutting conditions and drill tool geometry. Figure 8 shows the drilling forces, associated delamination, and the effect of cutting condition on delamination factor. The resulting cutting forces in the drilling process vary depending on the combination of cutting speed and feed rate used. In FRP drilling, the thrust force and torque increases with increasing feed rate and decreases with increasing cutting speed as shown in Figure 8a. The resulting cutting forces are more influenced by feed rate than cutting speed. Since the resulting drilling forces account for the quality of the hole produced and type and severity of process-induced defects, a variety of cutting parameter combinations were studied. From these studies, a combination of lower feed rate and higher cutting speed was found to reduce the resulting cutting forces and improve drilled hole quality.

Delamination is a severe problem in drilling FRP composite materials. It is generally regarded as matrix domi-

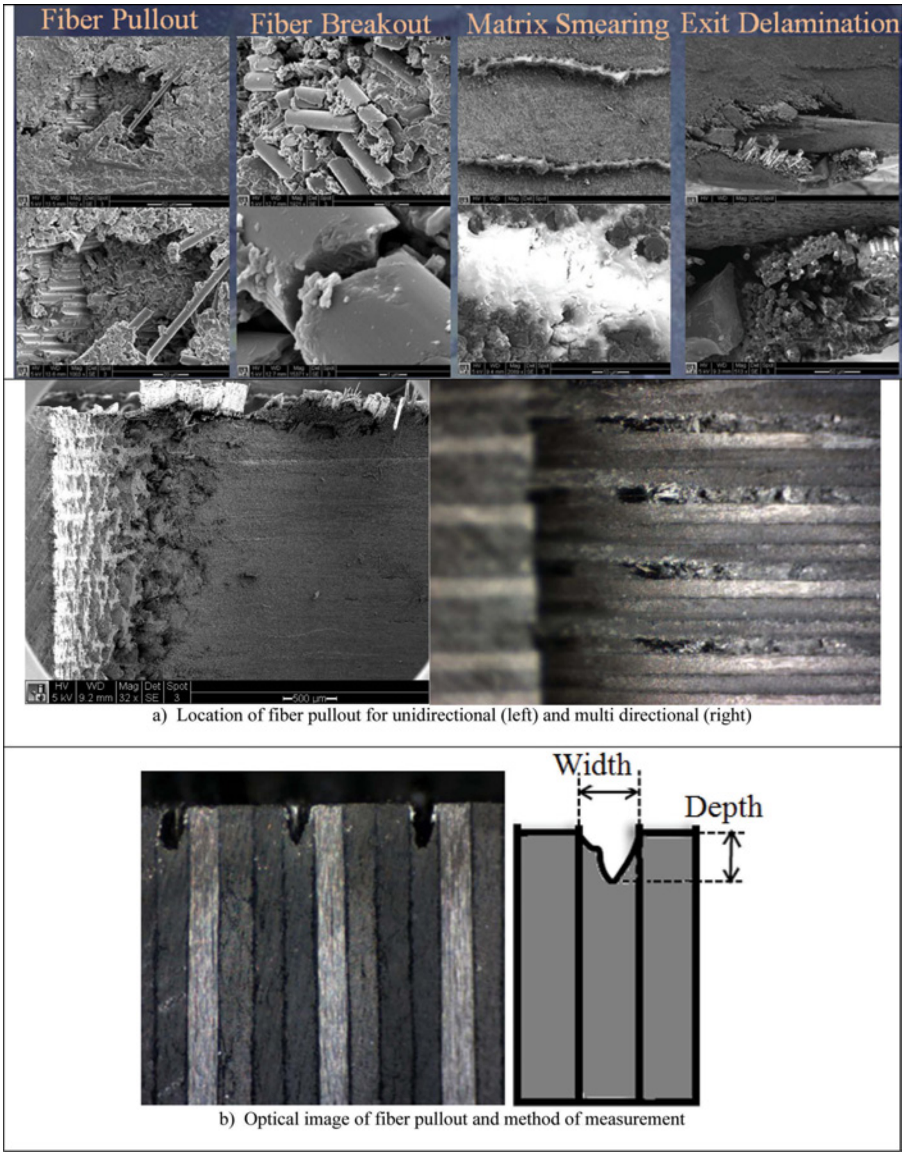


Figure 9. Typical defects induced in drilling CFRP.

nated failure behavior, and usually occurs in the inter-ply region. Delamination can be introduced by three mechanisms; peeling up of the top layer, punching out of the uncut layer near the drill exit, and through thermal stress. From these, exit ply delamination shown schematically along with SEM micrograph (Figure 8b) is the most common mode when drilling FRP composites. Exit delamination occurs when the drill progresses towards the bottom of the laminate where the uncut thickness of the laminates decreases. At this stage, the number of plies under the ply being cut also decreases as the drill approaches the bottom of the laminate, so there is less backing support for the plies being cut. At the same time, the stress caused by the drilling thrust force becomes larger than the inter-laminar strength of the laminate resulting in an exit-ply delamination. The resulting thrust force as the drill progresses towards the bottom of the laminate mainly controls exit ply delamination. The cutting forces are influenced by the cutting conditions (parameters) including feed rate and cutting speed as well as tool geometry. Exit delamination is influenced more by feed rate than cutting speed. The amount of material removed per revolution of the drill or the vertical (transverse) distance traveled by the drill for each revolution governs the amount and occurrence of exit delamination. The amount or length of delamination increases with increasing feed rate and shows a small reduction with increasing cutting speed. Smaller exit delamination is found by a combination of lower feed rate and higher cutting speed. Based on our experimental investigations conducted in previous years for minimizing exit delamination, feed rate should be kept below one third of the ply thickness. The influence of drilling conditions (parameters) on delamination at the exit and entrance is shown in Figure 8c. In this plot, delamination factor is plotted against feed rate and cutting speed. Delamination factor is a normalized quantity that is determined by dividing the size of the delamination by the nominal radius of the drill used to produce the hole.

Figure 9 shows a typical scanning electron microscopy (SEM) image of most common drilling defects, namely fiber pull out, fiber break out, matrix smearing, and exit delamination. Theses SEM images are from holes drilled in a unidirectional CFRP composite using an eight-facet carbide twist drill. Fiber-pullout is the tearing away of the fiber/matrix from the wall of the machined edge. The occurrence and location of fiber pullout mainly depends on the interaction angle between cutting direction and orientation of the fibers and/or stacking sequence of the individual plies[11]. When drilling unidirectional FRP composites, the location of fiber pullout encompasses two sectors around the circumference of the drilled hole when the interaction angle between the direction of cut and fiber orientation is between 135° and 315°. These sectors have an included angle from 30° – 40°. When drilling multidirectional FRP composites, the location of fiber pullout is rather periodic in nature around the hole based on the orientation of individual plies with respect to the cutting direction. The average width of fiber pullout is approximately equal to one ply thickness, whereas, the depth of fiber pullout varies from 52µm to 300µm, depending on the material and drilling conditions used. The location of fiber pullout when drilling unidirectional and multidirectional FRP composite laminates is shown in Figure 9b. Even though direct measurement of fiber pullout using various measurement tools is possible after sectioning and polishing the drilled hole for multidirectional laminates, it is not always possible especially in the case of unidirectional FRP laminates. The method used for fiber pullout measurement is shown schematically in Figure 9c, along with an optical image of fiber pullout of a sectioned and polished hole from a multidirectional laminate.

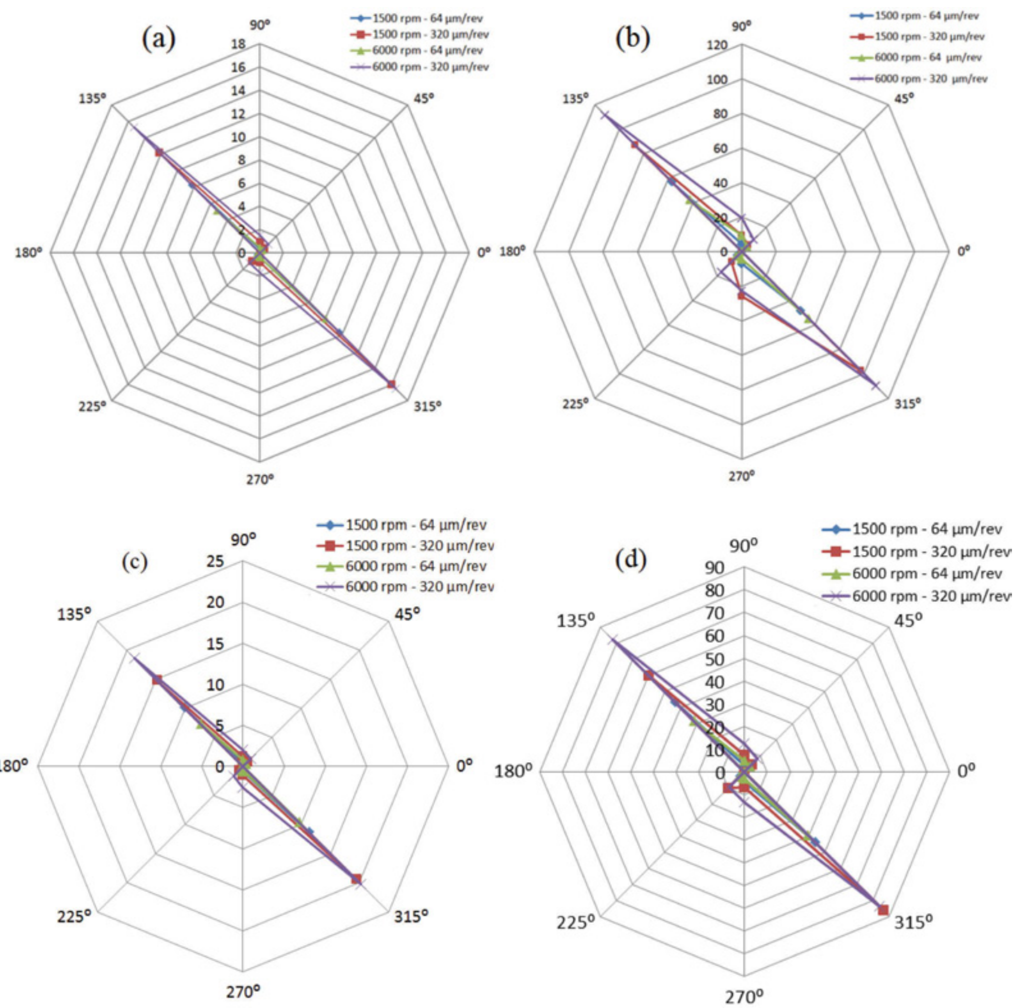


Figure 10. Surface roughness measurements for different combinations of drilling parameters at different interaction angles, where: (a) R_a, (b) R_t, (c) R_q, and (d) R_z.

Since fiber pullout occurs in continuous sectors in the case of unidirectional laminates, surface roughness measurement and its describing parameters is the common tool to quantify the amount of fiber pullout. Figure 10 shows a radar plot of selected surface roughness parameters for holes drilled in a unidirectional laminate with multiple combinations of cutting speed and feed rate. The radar plot confirms SEM results that fiber pullout mainly occurs when the angle of interaction between the cutting direction and fiber orientation is between 135° and 315°. Lower values of roughness parameters were measured with the combination of a higher level of cutting speed and lower level of feed rate. The lower roughness values indicate better surface quality and a minimum amount of fiber pullout. The lowest values of the surface roughness parameters were measured when the feed rate was one third of the ply thickness.

Finally, one of the most important topics in conventional trimming and drilling of FRPs is tool wear. To account for the abrasive nature of fiber reinforced composites, HSS (high speed steel), carbides, polycrystalline diamond (PCD), abrasive diamond, and ceramics have been examined for their applicability to trimming. Carbide tools have demonstrated superior cut quality compared with conventional HSS. Although tool life of carbide cutters has been substantially increased over that of toughened steels, it is still quite limited and not sufficient for a production environment. From our study it was concluded that trimming of FRP materials with PCD cutting tools was feasible from both economic and quality aspects. It was discovered that PCD could provide a cutter life many times that of carbide. It was also found through extensive experimental investigations that the microstructure of the PCD material could influence tool wear and that large grain structure PCD was the most desirable for wear resistance. It was further determined that an optimum PCD geometry could be established for minimum tool wear and maximum cut quality in cutting of Graphite/Epoxy composites[11], where in comparison to coated tools, which have a larger radius, sharp tools improved quality.

Abrasive Waterjet Cutting and Trimming

Abrasive waterjet trimming of graphite/epoxy laminates is prone to producing exit ply delamination, and the delamination may ingest abrasive particles which tend to hold the delaminated surfaces apart. Figure 11 shows the effects of abrasive waterjet trimmed conditions on surface roughness, delamination and compressive strength. The characterization of machined edges produced by abrasive waterjet indicates that the surface finish of the machined edges is closely related to the feed rate, abrasive flow rate (AFR) and laminate thickness. The surface finish produced tends to be rougher toward the exit point of the jet, rougher with increasing feed rate, and rougher with decreasing abrasive flow rate. The practical implication of these results is that an abrasive waterjet trimming process must be based upon extensive testing to establish appropriate process parameters for each laminate thickness to be cut, and there must be automatic process monitoring devices in place to insure that variations in the process parameters do not result in the creation of exit ply delaminations. Compressive strength clearly decreases with higher surface roughness and with increasing delamination size. Since these delaminations may have ingested abrasive particles, making the flaws very difficult to repair, it is critical that the creation of delaminations be avoided by proper process design and monitoring.

Abrasive waterjet Machining of Hybrid Titanium Composite Laminates was recently investigated to evaluate machinability by AWJ. Titanium graphite (TiGr) hybrid composite or fiber-metal laminate is a promising material for future high speed, high temperature transportation vehicle structures. Different machinability of titanium and PIXA-M composite makes machining of TiGr challenging. Because TiGr composite is a relatively new material system, limited work has been reported on determining machinability. A 1.3 mm thick laminate with ([Ti/90/Ti/0]2) lay-up was used in AWJ edge trimming. Abrasive waterjet cutting experiments were conducted using garnet abrasive with a mesh size #80 with a constant stand off distance (SOD) at a pump pressure of 240MPa. Figure 12 shows the AWJ machined surface of a fiber-metal laminate macro surf. AWJ cutting time and material removal rate (MRR) are significantly dependent on traverse speed. Fastest cut and highest MRR were obtained at 720 mm/min traverse speed. However, high traverse speed when used with low AFR, in this case 720 mm/min and 3.53 g/s, produces a relatively irregular surface finish. The best surface finish was obtained using 60 mm/min traverse speed and 9.78 g/s AFR. Optical Micrographs show abrasive wear tracks and shear deformation on the titanium ply. Within the PIXA-M composite, matrix material and IM-7carbon fiber were also subjected to a different machining mechanism. AWJ machined surface, inspection by SEM showed a distinct material removal mechanism for titanium, fiber, and matrix material (Figure 12 (Bottom micrograph)). Titanium Ti-6Al-4V was cut by ductile shearing, abrasive plowing, and scratching action. The matrix material was cut by shearing and plastic deformation while fibers were cut by micro-chipping, brittle fracture, and bending failure. The presence of matrix deformation, fiber bending, and chipping

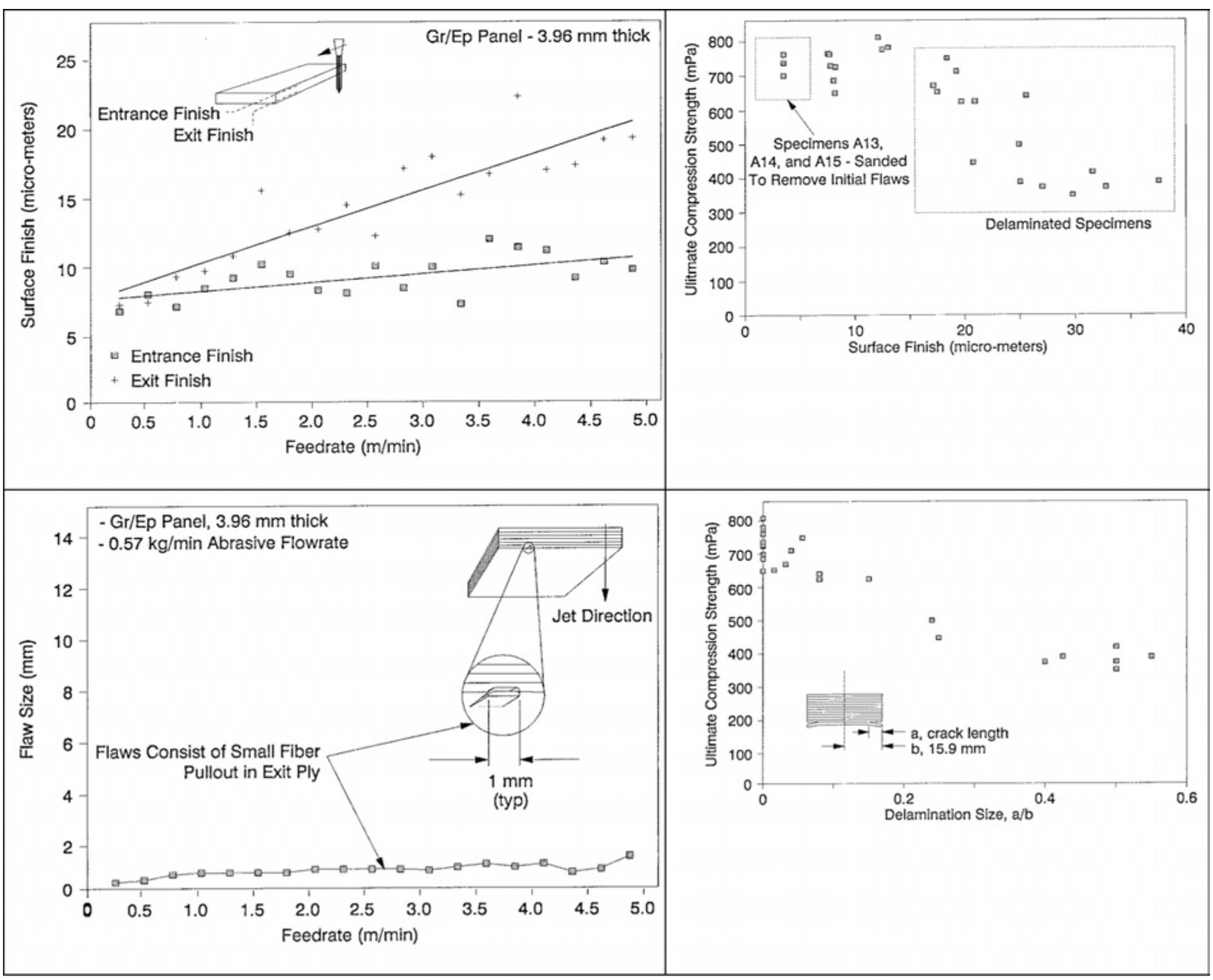


Figure 11. Effects of AWJ process conditions on surface roughness and degradation of strength due to AWJ induced delamination.

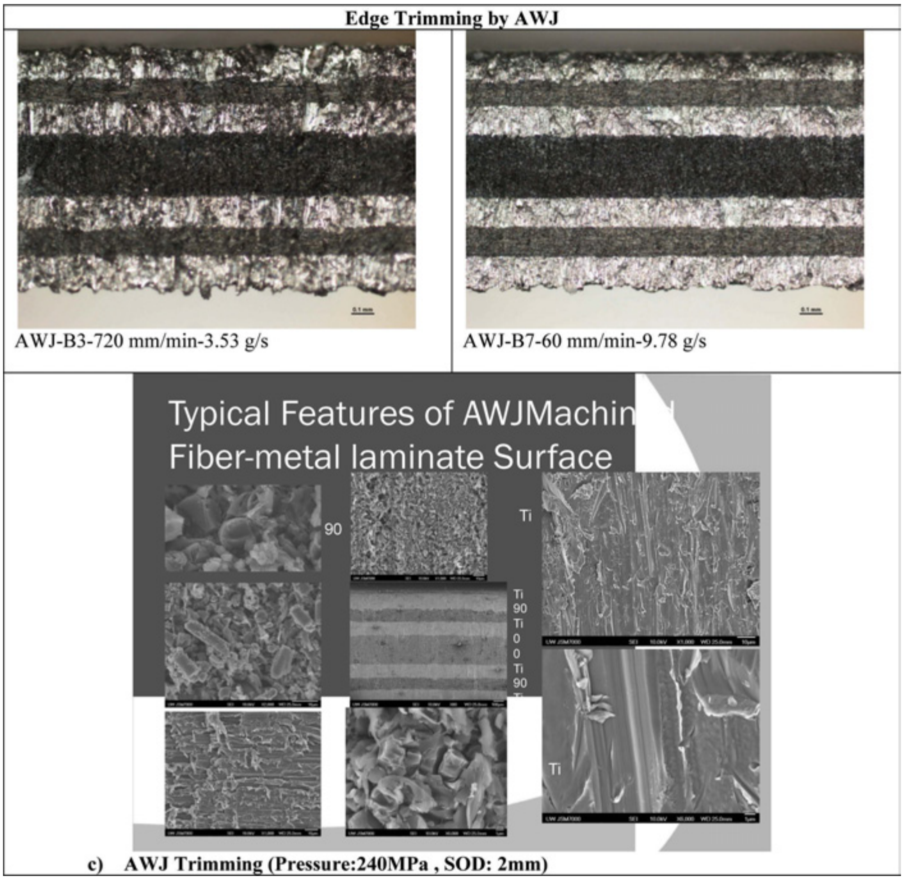


Figure 12. Abrasive waterjet cutting of fiber-metal laminate.

is evident in the machined surface at the top 90 degree composite ply. The overall machined surface remained in good condition. The thickness of the specimen was small enough that a smooth cutting region was extended throughout the depth. No delamination was observed. In some locations, an abrasive particle plowed through the material, fractured, and became embedded in the bottom of the track.

Summary

Machining of CFRP materials is significantly different to that of metal cutting with respect to cutting forces, chip formation, and surface integrity due to the anisotropic nature and effect of fibers and matrix. Fiber orientation critically influences all aspects of traditional edge trimming and drilling. Edge trimming related damage and chip formation mechanisms are attributed to the fiber/matrix interfacial strength of the composite. Studies on new tool geometries and process conditions are needed to further optimize material removal rates while minimizing damage such as delamination and fiber pull out. Small discontinuous dust-like chips produced during cutting operations pose an additional concern. There is limited research on the environmental effects of dry CFRP machining and relevant safety issues. Contrary to the problems associated with traditional cutting methods, AWJ machining of FRP materials is not fiber orientation dependent and is capable of producing a high quality machined surface when using proper cutting conditions. In addition to the qualitative benefits, potentially harmful medium associated with material removal, i.e. dust and chip debris, are entrained by the jet stream and collected within a containment system. Future studies should investigate the influence of machining on the mechanical properties of composites.

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WEB INDUSTRIES, INC., a leader in custom manufacturing and development services for flexible materials, is pleased to announce the acquisition of **CAD CUT, INC.,** the leading provider of fabric cutting and kitting services for the aerospace, medical, and industrial fabrics markets. Under the terms of this transaction, Web has purchased essentially all of the assets of CAD Cut, including the company name, and will continue to operate CAD Cut's facilities in Middlesex, Vermont, and Denton, Texas.

Based in Vermont, CAD Cut utilizes the latest in computer controlled laser and knife cutting systems, supply chain management services, and world class quality systems. The company specializes in providing composite ply kits to the aerospace, aviation, defense, and industrial markets and also manufactures multilayer insulation blankets for cryogenic applications in medical devices as well as process aides for wind tunnel testing devices.

Web Industries, a privately held 100% ESOP company, provides commercial-scale, best-in-class outsource converting, manufacturing, and development services to a wide array of customers in the aerospace composites, consumer products, medical, and wire & cable markets.

The synergy between the two companies is especially strong in the aerospace sector, where Web is the recognized leader in providing precision composite slit tape for automated manufacturing, and CAD Cut has a strong background in providing precut and kitted material for hand layup of advanced composite parts. The addition of CAD Cut's ply cutting and kitting capabilities to Web Industries' existing array of proprietary composite slitting, spooling, chopping, and winding technologies and services will allow the company to offer a full range of advanced composite formatting solutions to the aerospace, automotive, and industrial markets.

For more information, contact: principal@lauriepartridge.com.

Toronto-based **INTEGRAN TECHNOLOGIES, INC.** (Integran) received their AS9100C:2009 certification on December 13, 2012 after an intensive audit of their quality systems. The certification applies to Integran's Toronto facility for the design, development and application of advanced activation and electrodeposition processes based on patented technologies.

AS9100C:2009 was established by the International Aerospace Quality Group (IAQG) and is the most recent quality management system standard for the supply of products to the aviation, space and defense sectors. It incorporates the ISO9001:2008 standard but adds the additional expectations of the aerospace and related industries. Major aerospace OEM's, manufacturers, and suppliers require compliance and/or registration to AS9100C:2009 as a condition of being able to do business with them.

The main goals are to ensure product reliability, enhance risk management and improve customer satisfaction.

Integran passed the audit without any significant findings.

For more information, visit: www.integran.com.

MATRIX COMPOSITES, INC. has been awarded a significant contract from Materials Sciences Corporation (MSC) to produce carbon fiber reinforced composite Hardback assemblies for the U.S. Army's Reduced Weight Missile Launcher (RWML) Program.

The project was awarded to Matrix Composites to continue the US Army's Armed Scout Helicopter (ASH) and Joint Attack Munition Systems (JAMS) Project Offices goals for reduced weight, low cost and long life assemblies for the Kiowa Helicopter. Production of the Hardback assemblies will be performed in Matrix Composites' Rockledge, FL manufacturing plant and is expected to be complete by 2014.

MSC chose to partner with Matrix Composites for their cost competitiveness, full service capabilities and twenty-year heritage in the military and aerospace sectors.

For more information, visit: www.matrixcomp.com/.

ROGERS CORPORATION has announced that it has received the 2012 Innovation Excellence Award from the Connecticut Technology Council (CTC). The annual award recognizes significant technology leadership and innovation by Connecticut-based technology companies.

"Rogers is honored to receive this prestigious award that highlights our long history of innovation," said Robert Daigle, Senior Vice President and CTO. "For over 180 years, innovation has been at the heart of what Rogers does as a materials solutions company. Today, our team collaborates with the world's leading developers of next-generation technology, helping them power, protect and connect the world."

Rogers' unique power electronic solutions help power module and traction motor designers to safely and reliably increase efficiency and manage the power generated by electrified vehicles, high-speed trains, solar energy and wind farms. The company's high-performance cushioning and sealing materials protect everything from your tablet computer to the most sophisticated medical devices. And its high-frequency laminate materials for printed circuit boards enable the telecommunications industry to achieve the ever-increasing speeds and reliability consumers demand from the Internet.

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DUCOMMUN INC. announces that it has received a contract from **THE BOEING COMPANY** to produce titanium detail components and subassemblies for the Boeing 787 Dreamliner. Under the terms of the contract, production on the titanium assemblies will continue at the Ducommun AeroStructures facility in Coxsackie, N.Y.

The 787 Dreamliner is a mid-size, twin-engine jet airliner with various configurations that can carry up to 290 passengers on routes of 8,000 to 8,500 nautical miles, all while using 20 percent less fuel than today's similarly sized airplanes.

Ducommun Inc. provides engineering & manufacturing services to the aerospace, defense, & other industries through a wide spectrum of electronic and structural applications. The company is an established supplier of critical components & assemblies for commercial aircraft and military and space vehicles as well as for the energy market, medical field, & industrial automation.
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CREATIVE PULTRUSIONS, INC. (CPI) celebrated their 40th Anniversary in January. The company was founded in 1972 by Robert D. Sweet, Jr., in Bedford, Pennsylvania. In 2008, CPI was acquired by Hill & Smith Holdings PLC, a global leader in the design, manufacture and supply of infrastructure products, galvanizing services and building construction products. CPI is a world-class pultruder that utilizes the most advanced manufacturing processes to provide high-end profiles. A global leader in the design, manufacture and supply of infrastructure products, galvanizing services and building and construction products, HS has sales of over $700 million. Headquartered in the UK and quoted on the London Stock Exchange, HS employs some 3,300 staff across 54 sites, principally in the UK, France, USA, Thailand, and China.
For more information, visit: www.creativepultrusions.com.

The U.S. Navy awarded **RAYTHEON COMPANY** a $254.6 million contract to procure Tomahawk Block IV tactical cruise missiles for fiscal year 2013. The contract calls for Raytheon to build and deliver Tomahawk Block IV cruise missiles, conduct flight tests and provide life-cycle support. Production and delivery of the missiles is scheduled to begin in 2013.
"Tomahawk Block IV enables the warfighter to precisely engage heavily defended and high-value targets from extremely long distances, which is critical to maintaining national security," said Capt. Joe Mauser, U.S. Navy Tomahawk program manager. "With more than 2,000 combat missions and 500 successful tests completed, Tomahawk has proven its outstanding reliability and effectiveness."
A major enhancement to the Tomahawk Block IV missile includes a two-way satellite data-link that enables a strike controller to redirect the missile in-flight to preprogrammed alternate targets or more critical targets.
"Tomahawk has an excellent record of reliability, effectiveness and accuracy. No other tactical cruise missile in the world can come close to matching it," said Harry Schulte, vice president of Air Warfare Systems for Raytheon Missile Systems. "This missile provides unparalleled capability and has greatly contributed to the security of our country and our allies."
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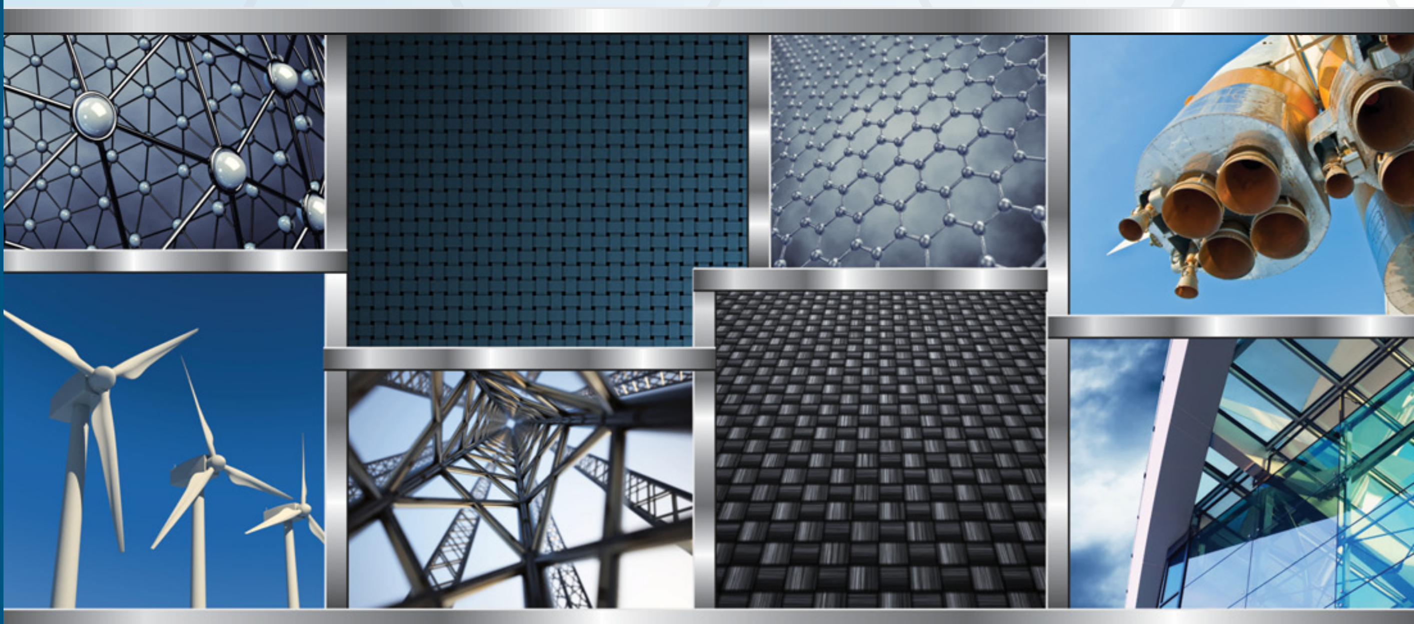

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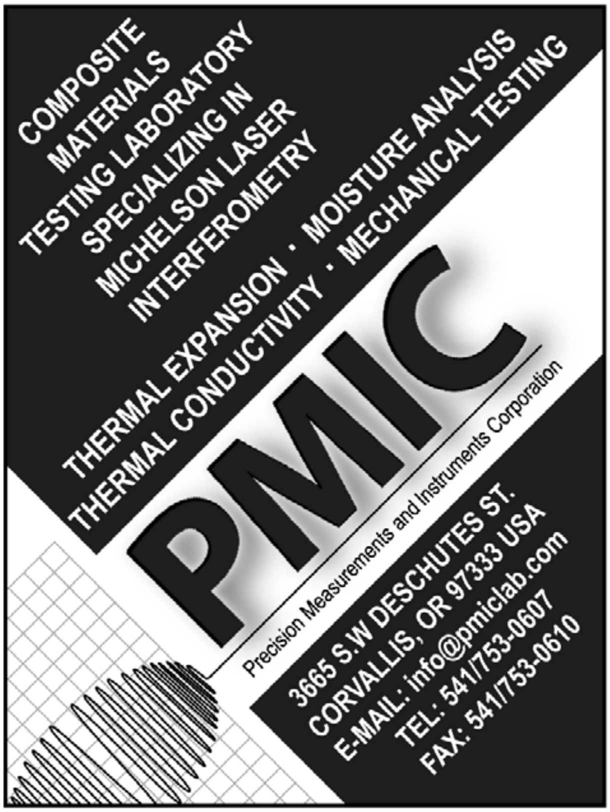
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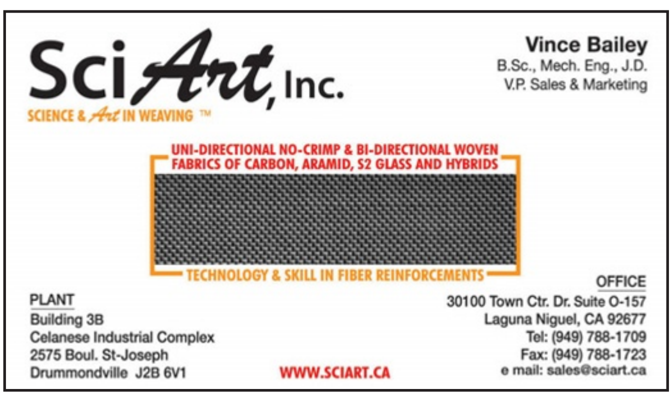
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INDUSTRY EVENTS Calender 2013

MARCH 2013

11-12, SAMPE Europe International Technical Conference (SEICO 13), Paris, France; Web Site: www.sampe-europe.org; E-mail: sebo@sampe-europe.org

12-14, JEC Europe Composites 2013, Paris Convention Centre, Paris, France; Web Site: www.jeccomposites.com

19-21, SME Composites Manufacturing 2013, Long Beach Convention Center, Long Beach, CA; Web Site: www.sme.org

MAY 2013

6-9, SAMPE 2013, Long Beach Convention Center, Long Beach, CA; Phone: +1 626.331.0616 (ext 610); E-mail: priscilla@sampe.org; Web Site: www.sampe.org

JULY-AUGUST 2013

28-August 2, ICCM 19 - 19th International Conference on Composite Materials, Palais des Congres Montreal, Montreal, Quebec, Canada; Web Site: www.iccm19.org

SEPTEMBER 2013

10-12, SAMPE Europe Fall Conference SETEC 13, Wuppertal, Germany; Web Site: www.sampe-europe.org; E-mail: sebo@sampe-europe.org

SEPTEMBER-OCTOBER 2013

September 29-October 1, TRFA (Thermoset Resin Formulators Association) 2013 Conference, Hyatt Regency Newport, Newport, RI. E-mail: info@trfa.org; Web Site: www.trfa.org

OCTOBER 2013

1-2, High Performance Composites for Aircraft Interiors, Washington State Convention Center, Seattle, WA. Web Site: www.composites-worl.com; Email: scott@compositesworld.com; Phone: +1 207.221.6602

21-24, SAMPE Tech 2013, Century II Convention Center, Wichita, KS. Phone: +1 626.331.0616 (ext 610); E-mail: priscilla@sampe.org; Web Site: www.sampe.org

29-31, SAMPE China 2013, Shanghai Everbright Convention & Exhibition Center, Shanghai, China; Web Site: www.sampe.org.cn

NOVEMBER 2013

4-8, ASNT Fall Conference and Quality Testing Show, Rio Hotel, Las Vegas, NV; Web Site: www.asnt.org

6-8, 13th Japan International SAMPE Symposium & Exhibition (JISSE-13), Exhibition, Tokyo Big Sight, Tokyo, Japan. Web Site: www.bigsight.jp/english/index.html.

11-13, 13th Japan International SAMPE Symposium & Exhibition (JISSE-13), Symposium, WINC Aichi Conference Hall, Nagoya, Japan. Web Site:http://www.winc-aichi.jp; Email: jisse13@sampe.nuae.nagoya-u.ac.jp

DECEMBER 2013

9-12, Carbon Fiber 2013, Crowne Plaza Knoxville, Knoxville, TN. Web Site: http://short.compositesworld.com/cf2031; Email: scott@compositesworld.com; Phone: +1 207.221.6602

CHAPTER MEETING CALENDAR Dates & Contacts

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Additional information on chapters can be found at http://www.sampe.org or by calling +1 626.331.0616, ext. 632.