Environmentally Safe and Effective Processes for Paint Removal

( Les Procédés Efficaces et Ecologiques pour l'Enlèvement des Peintures )
Paint Removal Using Wheat Starch Blast Media

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SUMMARY

A review of the Wheat Starch Blasting technology is presented. Laboratory evaluations covering Almen Arc testing on bare 2024-T3 aluminum and magnesium, as well as crack detection on 7075-T6 bare aluminum, are discussed. Comparisons with Type V plastic media show lower residual stresses are achieved on aluminum and magnesium with wheat starch media. Dry blasting effects on the detection of cracks confirms better crack visibility with wheat starch media versus Type V or Type II plastic media. Testing of wheat starch media in several composite test programs, including fiberglass, Kevlar, and graphite-epoxy composites, showed no fiber damage. Process developments and production experience at the first U.S. aircraft stripping facility are also reviewed. Corporate and regional aircraft are being stripped in this three nozzle dry blast hanger.

Although dry stripping has proven its merits in a production environment, many commercial operations have backed away from the plastic media blasting process because of its aggressive nature on aluminum. Wheat starch media overcomes this negative by delivering a more acceptable surface finish, most noticeably on clad aluminum alloys.

Wheat starch media is best known for its gentle nature on delicate substrates; the finish left on aircraft materials surpasses other dry stripping processes. Starch blasting leaves a smooth finish on aluminum, bare or clad, and can strip 2024-T3 aluminum skins as thin as 0.016" (0.41 mm) without deformation. For example, flight controls with unsupported bare aluminum, 0.016" (0.41 mm) and 0.020" (0.51 mm) thick, are stripped at 25 psi nozzle pressure without any deformation of the metal surface. Investigations have also proven that the finish on 2024-T3 clad aluminum is smooth enough to allow the aluminum to be polished to a mirror finish after dry stripping.

Wheat starch media also has the proven ability to strip composite materials, including graphite, fiberglass, and aramid (Kevlar) systems. Many composite stripping applications, both commercial and military, are underway. Coatings are stripped from composite structures with less risk of substrate damage than any other alternative being developed today. Several companies, including large defense contractors and commercial airlines, are finding that wheat starch media can remove coatings efficiently, and save enormous time over current techniques such as hand sanding.

Commercial and military testing has shown that wheat starch media removes a wide variety of coatings, from common polyurethane/epoxy paint systems to more sophisticated systems such as rain erosion resistant coatings found on radomes, and radar absorbing materials used on stealth aircraft. Coating removal applications also include removal of bonding adhesive flash from metal-to-metal bonded parts (while leaving the metal bond primer intact), removal of vinyl coatings (Tedlar) from aircraft interior panels,
and removal of sealants from components or fuel cells. Some recent applications involve paint removal from cadmium plated parts where the cadmium must be left in place. The list of different applications will continue to grow.

2 PROCESS LABORATORY DATA

Almen Arc Data for Bare Aluminum

The first investigation of residual stresses imparted by wheat starch media was performed by Battelle in 1991. This study tested the response of 2024-T3 bare aluminum alloy using 0.032-inch-thick (0.81 mm) Almen strip specimens 0.75 x 3.00 inches (19.0 x 76.2 mm) in dimension. An Empire blast cabinet was used with a 3/8-inch-diameter (9.5 mm) nozzle.

Saturation curves with virgin 12/30 size media were developed at 35, 45, and 60 psi nozzle pressure. Figures 1 and 2 present the saturation curves plotted with arc height as a function of blast dwell time. These pressures were at the

Figure 1. Saturation Response of Wheat Starch Media for 2024-T3 0.032" Aluminum.

Figure 2. Saturation Response of Wheat Starch Media for 2024-T3 0.032" Aluminum.
This testing was conducted with a Battelle automated screw-feed valve. The arc height data presented in the Battelle PRAM study and painted Almen specimens) were generated at preselected time intervals. Several sets of blast parameters (varying angle and distance) were investigated. Figure 2 shows that even at very extreme conditions, arc height values did not exceed 0.002 inch.

**Almen Arc Data for Painted Aluminum**

Painted Almen strips were also tested in the 1991 Battelle study. All Almen test specimens (2024-T3 bare aluminum) painted for starch media were prepared and painted to U.S. Air Force standards. Almen strip data were developed after four blast cycles; one actual strip cycle followed by three simulated strip cycles were performed. Simulated strip cycles reiterate the first strip cycle at similar process parameters and dwell times. Almen strips were not repainted between the initial and subsequent strip cycles.

In this test, recycled wheat starch media (four times) was evaluated alongside new media. Almen strip data are presented in Table 1 as the mean of five Almen specimens per set of process parameters. The greatest Almen arc height values were observed at parameters that are very aggressive (e.g., 60 psi), well beyond typical process conditions (e.g., 25-30 psi). This data showed that blasting with new starch media generally produced larger arc height values than recycled starch media.

The arc height data presented in the Battelle study (bare and painted Almen specimens) were very comparable to data observed with Type I plastic abrasives (polyester resin). Accurate control of media flow rates. Blast parameters were held constant by using a fixed nozzle and moving the Almen specimens under the blast stream.

Wheat starch media (12/30 mesh), recycled several times, was tested and compared to Type V Acrylic plastic media (30/40 mesh).

Standard 2024-T3 bare aluminum Almen strips 0.032-inch thick, 0.75 x 3.00 inches in dimension were used. Figures 3 and 4 present logarithmic plots of the saturation response of aluminum to both wheat starch media and Type V plastic media. Process conditions of 30 psi pressure, 12-inch standoff, 480 lb/hour media flow, and varying angles were tested.

Both media types approached saturation level, where arc height increases are minimal, after 2 minutes of blasting. The arc heights recorded with wheat starch were lower than Type V media under identical conditions. Most noticeable is the difference in the rate of change in arc height. With wheat starch media, the increase in arc height as a function of dwell time is more gradual. Type V arc height values increase quickly within the first 30 seconds of blasting. Note that a dwell time of 1 second corresponds to an approximate strip rate of 1 ft/minute. Correspondingly, the residual stresses measured here within the first 10-15 seconds would generally exceed dry strip process effects encountered over the life of an aircraft.

To minimize the residual stress when stripping aluminum alloy, preferred parameters with wheat starch for a 3/8-inch nozzle are pressures of 25-30 psi, a stand-off distance of 8-12 inches, a media flow of 480 lb/hr, and an impingement angle of 45°-70°. These parameters provide the optimum wheat starch media strip rates for coating removal from aluminum alloys. The DREP study also generated Almen arc data for magnesium alloy, comparing the effects of wheat starch and Type V medias. Bare magnesium Almen specimens measuring 0.75 x 3.00 inches with a thickness of 0.042-inch (1.07 mm) were used. Even with thicker specimens, substantially higher arc height values were recorded for magnesium versus the aluminum alloy. Figures

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**Table 1. Painted Almen Strip Arc Heights on 2024-T3 Aluminum for Wheat Starch Media.**

<table>
<thead>
<tr>
<th>Blast Process Parameters (pressure, media flow, stand-off)</th>
<th>Angle (degrees)</th>
<th>Mean Arc Height (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 psi, 660 lb/min MFR, 12&quot; distance</td>
<td>70</td>
<td>0.64/0.38 (recycled media)</td>
</tr>
<tr>
<td>60 psi, 480 lb/min MFR, 6&quot; distance</td>
<td>40</td>
<td>1.25/1.94 (recycled media)</td>
</tr>
<tr>
<td>60 psi, 480 lb/min MFR, 6&quot; distance</td>
<td>90</td>
<td>2.36/1.66 (recycled media)</td>
</tr>
<tr>
<td>60 psi, 480 lb/min MFR, 6&quot; distance</td>
<td>90</td>
<td>3.30/3.91 (new media)</td>
</tr>
</tbody>
</table>

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Note that a dwell time of 1 second corresponds to an approximate strip rate of 1 ft/minute. Correspondingly, the residual stresses measured here within the first 10-15 seconds would generally exceed dry strip process effects encountered over the life of an aircraft.
5 and 6 compare the effects of wheat starch and Type V media. With Type V media, arc height values greater than 0.015-inch were recorded within the first ten seconds of blasting. Although arc heights for Type V media improved at a 45° angle, the warpage in the magnesium specimens was excessive. This data suggests that Type V plastic media is too aggressive for the softer magnesium alloy.

Residual stresses, as measured by Almen arc testing, show that wheat starch media imparts lower stress levels to aluminum and magnesium.

Beech Aircraft Corp. in Wichita, Kansas has experience with stripping thin magnesium skins using wheat starch. Improperly prepared 0.025" magnesium skins must sometimes be stripped of MIL-P-23377 primer. Wheat starch media removes this primer without warping the magnesium, leaving the Dow coating treatment intact. The porous magnesium can retain some starch in the pores, which interferes with Dow #7 reprocessing. Abrading with Scotchbrite...
removes the starch residue. Beech concluded that using Scotchbrite was economical for field maintenance of a magnesium control surface, even when Dow #19 treatment is required. However, it is not economical for unformed raw magnesium material.

 Crack Detection after Dry Blasting

DREP studied the effects of different dry blast medias on the detection of fatigue cracks on 7075-T6 aluminum, both bare and clad alloys. The effects of wheat starch media were compared to Type V and Type II on 7075-T6 bare aluminum only.

The cracks were prepared on a 12 x 24-inch panel 0.25 inches thick. The cracks were placed in the plate by fatigue using an MTS machine. Stress points were applied at 30,000 to 250,000...
cycles at 21 equally spaced locations on each plate. A variety of crack lengths were produced over the entire surface, ranging from 0.07 to 1.1 inch. The plates were blasted at a 30 psi pressure using angles of 45° and 90°, media flow of 660 lb/hour, and a standoff distance of 10-12 inches. Comparative data for all three media types was only developed at the 90° angle. The plates were blasted over the entire surface for two minutes, giving the equivalent of a 1 ft²/minute cleaning rate.

The following method was used in crack detection. Cleaner 9PR551 was applied prior to treatment with fluorescent penetrant 985-P2E and Zyglo developer ZP-9 Formula B. After each blast cycle and LPI treatment, the plates were immediately cleaned with water and alcohol to remove penetrant and developer, then vapour degreased with trichloroethane. Cracks were measured with a calliper under UV light to a precision of ±0.01 inch.

Figure 7. Comparison of Percentage of Cracks Detected on 7075-T6 Bare Aluminum.

Figure 8. Comparison of Percentage of Unchanged Cracks on 7075-T6 Bare Aluminum.
Figure 7 compares the percentage of cracks detected on 7075-T6 bare aluminum after different blast times with each of the three media types. The results with wheat starch media showed that virtually all cracks remained detectable after each blast cycle. Of the 60 cracks blasted on bare aluminum, only two were not detected after the first blast cycle. These were small cracks measuring 0.10" and 0.198" which branched from a very long crack (1.11") All remaining cracks were detected through 5 blast cycles. DREP concluded that with wheat starch media, the majority of cracks did not shorten in length and would be detectable in a production environment.

Results with Type V and Type II medias were less favourable in this comparison. Type V media appeared to be more aggressive on the bare aluminum than the Type II media, despite a similar crack distribution on the plates tested in each case. Type V media, when tested at a 45° angle, produced better results on the bare aluminum. Comparative results at the lower angle were not available for wheat starch.

Figure 8 presents the crack detection results on bare aluminum from a different perspective. The percentage of cracks unchanged in appearance (i.e. measured by length) are compared. In the case of wheat starch media, not only were most cracks detectable, but the majority (80%) did not change in appearance during the first three blast cycles.

Crack detection on 7075-T6 bare aluminum proved to be better on surfaces blasted with wheat starch media versus the plastic medias type V and II.

Surface Roughness on Clad Aluminum

Beech Aircraft Laboratory tested the surface roughness produced with wheat starch media on 2024-T3 clad aluminum. Clad panels 0.020" (0.51 mm) to 0.080" (2.03 mm) thick were stripped of a MIL-P-23377 primer without removing the Alodine 1200S chemical film. None of these clad panels were deformed. Table 2 shows the surface roughness measurements recorded at different clad aluminum thicknesses.

<table>
<thead>
<tr>
<th>Aluminum Skin Thickness</th>
<th>Clad Layer Thickness</th>
<th>Surface Roughness After Blasting (μ-inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.020&quot; (0.51 mm)</td>
<td>0.0010&quot; (5.0%)</td>
<td>40 (1.02 μm)</td>
</tr>
<tr>
<td>0.025&quot; (0.63 mm)</td>
<td>0.0013&quot; (5.0%)</td>
<td>70 (1.78 μm)</td>
</tr>
<tr>
<td>0.032&quot; (0.81 mm)</td>
<td>0.0016&quot; (5.0%)</td>
<td>90 (2.29 μm)</td>
</tr>
<tr>
<td>0.040&quot; (1.01 mm)</td>
<td>0.0020&quot; (5.0%)</td>
<td>142 (3.61 μm)</td>
</tr>
<tr>
<td>0.080&quot; (2.03 mm)</td>
<td>0.0020&quot; (2.5%)</td>
<td>132 (3.35 μm)</td>
</tr>
</tbody>
</table>

Wheat starch media achieves a very smooth surface finish on clad aluminum as shown by these low surface roughness results.

Metal Fatigue Data

Although fatigue data generated by a qualified process lab is not available at this time, Boeing Commercial Airplane Co. will have completed its study on wheat starch media by late 1992. Initial indications look favourable.

Composite Evaluations

Several commercial and military composite stripping programs are underway. On the commercial side, a United Airlines/Boeing Commercial Airplane study will be completed in the fall of 1992.

In this study, the full range of Boeing coatings and composite substrates are being evaluated. The study's objective is to establish both selective stripping and complete coating removal on aged and unaged composite test panels, for both a single and multiple strip sequence.

The coating system used for this test program on the graphite panels is BMS 10-103 Desoto nonchromated epoxy primer and BMS 10-60 type II polyurethane top coat. The fiberglass and Kevlar panels have an initial layer of Desoto conductive coating BMS 10-21 type III, followed by the BMS 10-103 and BMS 10-60 type II system. Composite substrates included in the study are the graphite, fiberglass and Kevlar honeycomb core materials, the fiberglass fluted core (radome), and the graphite laminate and...
graphite honeycomb with EMF (conductive wire mesh).

Preliminary results of the single selective strip cycle showed no indication of internal delamination or fiber damage.

An evaluation was also conducted by the U.S. Army at the Corpus Christi Army Depot (CCAD). Their process laboratory concluded that wheat starch media could effectively remove MIL-SPEC coatings from composite structures, primarily for military helicopters. Resin rich and resin starved S-Glass honeycomb panels, and S-Glass skins from a UH-60A Blackhawk were stripped of MIL-P-23377 epoxy primer and MIL-C-46168 top coat. The S-Glass composites were stripped both selectively (leaving the primer intact), and completely without erosion of the resin layer or fiber damage. This study noted that operator skill is a factor on resin-starved substrates. Excessive dwell times in one spot beyond 3-4 seconds would lead to damage of the resin layer first, and then fiber damage. Optimum parameters for stripping these composites, using a 3/8-inch nozzle, were a pressure of 25 psi, a standoff distance of 6-8 inches, angles between 30°-70°, and a media flow of 480 lb/hour.

A resin-starved Kevlar formed skin panel from an AH-64 Apache was also included in the CCAD study. For complete coating removal, operator skill was found to be critical on the Kevlar where minimal dwell time was needed to avoid damage. Kevlar materials are best stripped selectively, leaving the primer intact if possible.

DREP (Canadian Forces) investigated effects on graphite-epoxy substrates similar to those found on CF-18 fighter aircraft. Coatings removed were the MIL-P-23377 primer and the MIL-C-83286. Scanning Electron Microscopic examination showed no cracking of the epoxy resin layer or fiber damage. The graphite panels were blasted for extended dwell times beyond 60 seconds at 40 psi pressure and a standoff distance of 12 inches.

In conclusion, there is considerable variety in the composite structures used on aircraft. The experience gained in these composite evaluations shows that some epoxy resin systems withstand starch blasting better than others. Several programs have proven that high temperature cured or toughened epoxy resins are not removed from composites when stripping with wheat starch media, nor is fiber damage observed. With softer resin systems or resin-starved composites, operator skill becomes much more of a factor in achieving satisfactory results.

3 PRODUCTION EXPERIENCE WITH DRY WHEAT STARCH STRIPPING

Airframe stripping of small corporate and regional aircraft began this summer at Hunting Aircraft Inc. (formerly Field Aircraft Inc.) in the U.S. A Pauli & Griffin three nozzle system, specifically designed for starch media, was installed in Hunting's new completion center. A dedicated hanger bay, measuring 100 feet by 100 feet, is used to dry strip entire airframes. A Beech King Air 200 was one of the first aircraft stripped in this facility. On this particular aircraft, skin thicknesses varied down to 0.016" on flight controls and 0.020" on the airframe. All surfaces, except composites, were stripped to a pristine finish. No metal warpage was observed even on the thinnest skins. Seventeen man-hours on each of three nozzles were needed to dry strip the airframe and flight controls. An estimated strip rate of 0.6 ft²/minute was achieved. Military and commercial polyurethane paints are generally easier to remove than paint systems found on smaller corporate aircraft.

The system at Hunting features several important items required for any wheat starch system. The compressed air supplied to the three nozzles (680 cfm) is dried with a refrigerant air dryer to a 35-40°F dew point. Dry compressed air is usually recommended for any dry blast system, a recommendation not always respected. With wheat starch media, a compressed air dryer is mandatory.

Since Atlanta can encounter very hot, humid summers, a moisture control system is used as a precautionary measure. Dry air is fed into product hoppers to control product storage conditions, particularly during extended shutdowns. Moisture effects on the media have not been encountered at this facility.

The Hunting system includes a dense particle separator designed to remove contaminants, such as sand and metal, from the wheat starch media. Because the finish on aluminum is very smooth with wheat starch media, low levels of heavy particle contamination are noticeable. The finish with plastic media blasting will generally mask the presence of a much higher level of contaminants. An effective dense particle separator is highly recommended for any wheat starch dry strip hanger.

Experience on the first few aircraft at Hunting has also shown which masking materials and methods work best. Three masking tapes have been identified as being effective with wheat starch media. A 3M YR-5005 (quite different from the YR-500 used with plastic media) and a...
Bron Tape BT-818 (Bron Tape Inc.) have performed the best. A black vinyl tape Permacel P-320 (Permacel Inc.) is also effective, but cannot withstand the starch blasting for the same length of time.

New Developments on Disposal

Considerable work has been done in past years on biodegradable products. In the effort to develop degradable products, composting technology has received much attention.

Degradation of starch dust and paint, via similar composting technology, is currently being investigated at Archer Daniels Midland. Since starch media has a 100% carbohydrate content, proper aerobic digestion in a compost system can reduce waste volume substantially, leaving primarily paint residues behind.

Composting experience with degradable products show that proper aeration is essential in order to keep the digestion process aerobic. Aerobic, as opposed to anaerobic, would favor bacteria which require oxygen. The effects of heavy metals on compost activity needs to be investigated further. Once the ideal compost system, bacterial organism, and its required supplements are identified, efficient composting could degrade starch dust within days.

4 CONCLUSION

The wheat starch dry stripping process has evolved into a viable alternative to chemical paint strippers. Both material process laboratory work and actual production experience is proving that wheat starch media provides the best possible finish from a dry stripping process. Combined with the potential dry toxic waste reduction possible with biodegradation of starch, wheat starch blasting offers an environmentally and ecologically sound option. Recent work in the area of composting stands to substantially minimize the dry toxic waste generated.

From a production perspective, wheat starch blasting is one of the few processes that can achieve excellent results in a manual system. Yet, this process also has the potential to benefit from robotic application.

REFERENCES

Reports


Conference Proceedings

