EVOLUTION OF ENGINEERED BIOBASED MEDIA

ADM DRY STRIPPING TECHNOLOGY

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Introduction

Biobased products are defined by the US Secretary of Agriculture to be a commercial or industrial product that is composed in whole or in significant part of renewable domestic agricultural materials.

The objective of this paper is to:

- review the evolution of engineered biobased dry stripping products
- discuss the basic mechanical differences of various dry stripping products including petroleum based and mineral based media types
- compare the potential hazards and risks associated with other types of coating removal methods
- provide an update on new developments and applications of ADM biobased abrasive media

In 1985 the United States Department of Defense (DoD) took the lead in reducing methylene chloride dependence in the aerospace industry by adopting dry media stripping for military aircraft. Plastic media (originally with a urea formaldehyde base and more recently with acrylic plastic) are now used around the world to depaint aircraft and components. Plastic media, used extensively on metal surfaces, was found to be too aggressive for many delicate aerospace applications, such as thin aluminium skins or composite materials. In 1990 the first generation of engineered biobased dry stripping media was introduced to the aerospace industry. This paper will review the past, the present and the future of biobased dry stripping media types.

Starch History and Background Information

Most starches are composed of two molecules: branched and linear polysaccharides. Typically wheat and corn starches are approximately 75% branched amylopectin molecules and 25% linear amylose molecules. To produce a starch media, starch and water is specially processed under variable pressure, cooled to obtain the required hardness, and then ground to the specified mesh sizes (eg. 12-30, 20-50 etc).

EnviroStrip® Wheat Starch media was the first engineered, biobased media to be introduced to the aircraft depaint industry. This Wheat Starch media has been successful in supporting key commercial and military projects, including the B2 program. Wheat Starch media has received more aircraft OEM approvals than any other dry media on the market today. Its ability to remove tough aerospace coatings from sensitive composite and metal substrates has been well documented. However, because of Wheat Starch media's specific molecular structure, it is sensitive to moisture and flow issues and has not been considered a "drop-in" replacement in unmodified PMB systems.

There are over 100 different types of natural and modified starches available on the market today. These starches are obtained from a variety of plant sources.

In 1996 ADM committed to improving its starch-based media product performance to provide customers with a media that could be utilized in standard PMB systems and produce production (strip rate) similar to the plastic media currently used; while still maintaining the well established benefits of Wheat Starch media. A large scale evaluation of 15 different types of natural raw materials was conducted at ADM's research laboratory. Several experimental materials were included in this study. The evaluation consisted of a multitude of tests including media life, productivity, mechanical effects and material handling characteristics. During the evaluation one candidate media showed a series of special features. This particular starch media was made from a hybrid corn that was developed in the 1940's. Over the next 2 years many tests - such as hydration capacity, fatigue, crack detection, alclad removal and others - showed that this natural hybrid corn starch was equal to or better than the widely accepted Envirostrip® Wheat Starch product in several areas. The advantages of this next generation biobased product were confirmed in operational field tests that showed that the media would function well in standard PMB systems.

In 1998 **EnviroStrip® XL-Corn** hybrid polymer stripping media was introduced to the aerospace industry. The product was made from a hybrid corn starch using special techniques forming a novel bio polymer.

Because of its compact molecular structure, Envirostrip XL-Corn media was found to be far less sensitive to moisture and more resistant to impact. On the other hand the mechanical effects produced by XL-Corn are very similar to the original Envirostrip® Wheat Starch media. XL-Corn has now been widely accepted in the commercial aircraft industry as an excellent alternative to Wheat Starch and has been approved for use by several aircraft OEM's.

While XL-Corn continues to provide excellent results and has a strong following throughout the aircraft depaint industry, ADM has continued to seek ways to improve the overall product performance of our biobased media.

Using XL-Corn as a base formulation ADM was successful in designing a graft starch acrylic media. The co-polymer product, **e-Strip® GPX** was introduced in 2002 and is the newest ADM media to be used in the aircraft coating removal industry. It is not a loose blend of various media, but a graft particle that provides consistent performance. It offers the performance and media flow characteristics of standard plastic media, while still maintaining the superior surface results established with ADM's original starch products. GPX® can be used in standard design PMB systems, is moisture resistant, and will not produce the acrylic smear/residue typical of Type 5 plastic on the blasted surface.

Basic Differences of Various Industrial Dry Stripping/Cleaning Media

In an effort to better understand why biobased media produce improved substrate results while still maintaining competitive performance rates, it is important to review how various media compare. The following industry standard tests confirm the benefits of engineered, biobased dry media over other media.

Aero Almen strips 3.0 x 0.75 inch have been used for years to determine the potential residual stress inducement of a given media type. Typical Almen strips used in the shot peening industry are made from 1070 steel; for aerospace applications a more sensitive material was needed. The USAF developed the Aero Almen strip, made from bare 2024 T-6 aluminum, 0.032 inch thick (AMS 4037 or QQ-A-250-4). After blast exposure over a given time period, the almen strips are removed from the almen strip holder and the strips measured for mid plane distortion. Resulting arc height deflection is an indicator of residual stress inducement potential

Test procedures

Using a blast cabinet, 5 almen strips were blasted for 5 seconds with each of the following media types. Nozzle pressure was 22-27 PSI on all tests. The stand off distance was 6-8 inches and the blast angle 45-60 degrees. The media was a production working mix in all cases. A 0.375-inch nozzle was used for all non-mineral media types. A 0.250-inch nozzle was used for mineral media types. The approximate MOH hardness is included here for perspective.

Table 1 Media Specifications

Media	Mesh	MOH Hardness (Approx)
Aluminum Oxide	90-120	8 - 9
Silicon Carbide	240-300	9
Zirconite	180-240	7.5
Urea (Type II)	30-80	3.5
Acrylic (Type V)	30-80	3.5
Corn Cob	30-80	2.5 - 4.0
Walnut Shells 30-80	30-80	3.0 - 3.5
GPX (Type VII)	**20-80**	**2.0**
EnviroStrip XL	**16-80**	**2.0**
EnviroStrip WS	**12-80**	**2.0**

Almen Arc Heights and Surface Roughness

The 5-second exposure test produced the following almen arc height and surface roughness results on bare 2024 T-3 aluminum*:

Table 2. 5-Second Exposure Test

Media	Almen Arc Height (inch)	Surface Roughness (micro inch)
Aluminum Oxide	0.0153	155
Silicon Carbide	0.0062	54
Zirconite	0.0100	88
Urea (Type II)	0.0092	57
Acrylic (Type V)	0.0061	17
Corn Cobs**	0.0053	10
Walnut Shells**	0.0081	10
GPX (Type VII)	**0.0021**	**9**
EnviroStrip XL	**0.0020**	**5**
EnviroStrip WS	**0.0018**	**5**

NOTE:
*Baseline surface roughness on bare 2024 T-3 is 3 micro inch
**The MOH hardness of media types such as corn cob and walnut shell can vary significantly from one batch to the other. This is because these abrasives are by-products and not engineered or manufactured to strict specifications. Corn cob hardness, for example, varies depending on which part of the cob the particles were ground from (the center of the cob is more dense than the outer edges) and in this particular study the walnut shell media had higher almen arc heights than acrylic media.

As shown in the previous chart, the engineered biobased products produce less stress on 2024 T3 aluminum when surface roughness and almen arc height tests are preformed. High residual stress can affect surface crack detection in non ferrous alloys (magnesium, aluminum). Pure aluminum and cadmium have an approximate MOH hardness of 2.0, which explains why alclad and cadmium protective erosion tests consistently show little or no erosion with starch based media.

The data shown on Type II (urea) and Type V (acrylic) justifies the aerospace industry's prudent move in the last ten years to go away from widespread use of the harder urea media to the softer acrylic product.

The tests results presented here confirm, and are supported by data generated by OEM's and independent testing agencies, that engineered biobased media have the lowest potential for damage on sensitive aerospace substrates.

Alternative Coating Removal Methods

Sanding

Although time consuming, manual hand sanding and sanding with power tools is still used extensively in the aerospace industry. When scuff sanding (producing a minimal surface roughness and not removing all coatings) advantages include low implementation cost and reduced maintenance cost. However, while not immediate, the disadvantages of scuff sanding and repainting are (1) excessive coating thicknesses after 3-4 cycles; (2) multiple coatings adding unnecessary weight to the aircraft; (3) excessive paint thickness can cause other negative effects such has interfering with substrate defect detection; and (4) excess paint thickness results in premature paint failure.

Other disadvantages of mechanical sanding include potential chronic physical injuries to workers, such as H.A.V.S (Hand Arm Vibration Syndrome). The first symptoms of this syndrome usually occur many years after the physical damage has been done.

Sanded composite material surfaces may appear very smooth under visual inspection. However, aggressive sanding can cause removal of protective surface resin layers and damage/cut carbon fiber material that will require additional repair work and eventually reduce the life of the component.

Chemicals

Toxic methylene chloride (MC) based strippers are very effective in removing tough aerospace coating systems. The principal advantages being speed of paint removal and thus short dwell time required for molecular disassociation of the paint to take place. Methylene chloride has been listed by the EPA to be a very toxic chemical with considerable bio-persistent characteristics in the environment. Its future use has been severely limited. Today newer chemicals used for paint stripping may require dwell times that are up to 50 times longer than the MC based strippers. The longer dwell time required - and the tendency of some of the less toxic chemicals to be significantly less volatile - increases the potential for unforeseen damage. For example, while methylene chloride evaporates fairly rapidly, which minimizes potential seepage/ingress, potential ingress problems may be underestimated with low evaporation rate chemicals, especially for on-aircraft use. With that in mind, ASTM F-519 (hydrogen embrittlement evaluation) cautions:

"Service environments Notice: Because of the extensive variety of newly developed cleaners and maintenance chemicals, loading sequences and times of exposure are often user specific. As a result, the testing protocol should only be used as a guideline".

Finally, recent data suggests that, while the newer chemicals passed all required toxicity tests at the time of introduction, some may have other effects - such as reproductive toxicity - that was never an issue with MC.

Thermal and Water

Both of these methods are relatively environmentally friendly. However, highly precise and costly automation is typically required to avoid damage on delicate substrates and complex contours. Seven non-chemical paint stripping methods were tested by NASA (1994-1999). Three had acceptable results in fatigue testing and eddy current crack detection: ultra high water pressure was one. The other two acceptable methods were acrylic media and wheat starch media.

Updates

Engineered biobased dry media continues to make significant strides in the aerospace and industrial coating removal community:

Commercial applications

- Broad aircraft OEM approvals and applications
- Metal bond deflash
- Composite coating removal
- Thin aluminum aircraft substrates
- Mold cleaning
- Helicopter depaint programs
- MRO centers

USCG : Winter 2005 US Navy '*Currents*' magazine

Cornstarch and the Coast Guard

"Starch Media (GPX) is the cleanest, most environmentally responsible depainting media available"…….

USAF : Active projects

- Composite component depaint projects
- Selective stripping program
- Airframes
- Radome depaint
- Advanced tactical/stealth aircraft

US Navy : Winter 2005 US Navy "Currents" magazine

Cornstarch as an Alternative Blast Media

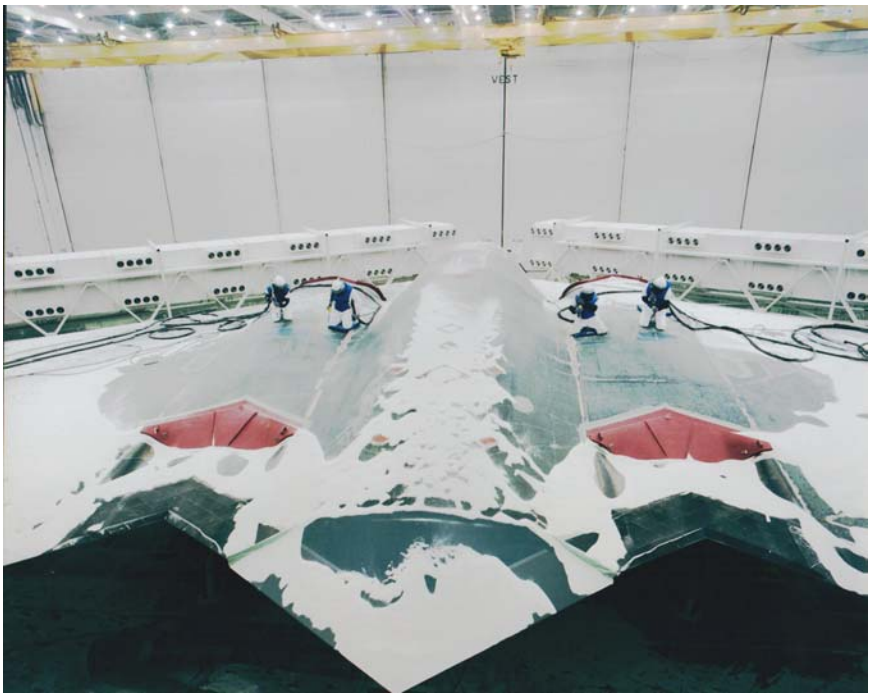
- Implementing GPX for composite and metal aircraft components
- Ongoing tests supporting NAVSEA & NAVAIR composite programs
- Selected for NAVSEA weapon system program

Structural adhesive removal

- Starch based media continues to be adopted by metal bond industry for removal of excessive adhesive (flash).
- Popularity is due to the media's ability to remove various adhesives without compromising the bond primer or substrate.
- Typically mechanical methods (hand scrapping, grinding and sanding) are slow and often cause extensive damage.
- Current users of starch based media have reported increase in productivity by a factor of 10, with no damage to the parts being processed.

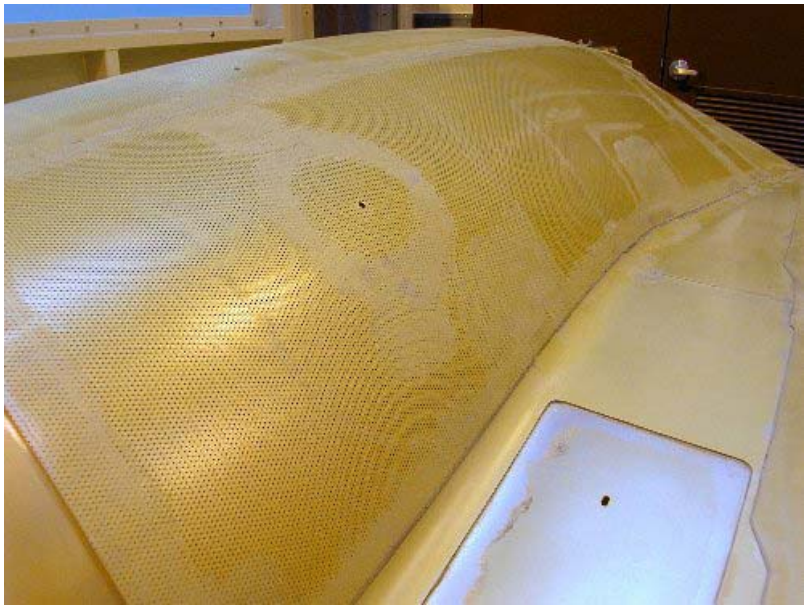
Conclusions and Future Work

- Starch-based media offers a mature alternative to chemical strippers and hand sanding processes
- Starch-based media provides proven coating removal capabilities for composite and aluminum aircraft substrates
- Starch-based media meets the intent set forth in the recently enacted US Federal Biobased Procurement Program
- The process has strong support from, and is used by, commercial aircraft OEM's and repair facilities
- New biobased products will continue to be developed for the aerospace industry
- A responsible, approved media/dust recycling program is now available for starch-based media



B-2

USAF AWAC



Goodrich Deflash

U.S. Coast Guard

Photos courtesy of Northrop Grumman; Goodrich; USCG; USAF