

Bicarbonate of Soda Paint Stripping Process Validation and Material Characterization

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Abstract

The Aircraft Production Division at San Antonio Air Logistics Center has conducted extensive investigation into the replacement of hazardous chemicals in aircraft component cleaning, degreasing, and depainting. One of the most viable solutions is process substitution utilizing abrasive techniques. SA-ALC has incorporated the use of Bicarbonate of Soda Blasting as one such substitution.

Previous utilization of methylene chloride based chemical strippers and carbon removal agents has been replaced by a walk-in blast booth in which we remove carbon from engine nozzles and various gas turbine engine parts, depaint cowlings, and perform various other functions on a variety of parts.

Prior to implementation of this new process, validation of the process was performed, and materials and waste stream characterization studies were conducted. These characterization studies examined the effects of the blasting process on the integrity of the thin-skinned aluminum substrates, the effects of the process on both air emissions and effluent disposal, and the effects on the personnel exposed to the process.

Paper Content

San Antonio Air Logistics Center is responsible for the maintenance of the C-5 fleet. This maintenance involves among other things, corrosion control which includes depainting. In the past, we have always relied on the use of methylene chloride based chemical strippers for both aircraft and components. This method generated great quantities of waste which had to be drummed and disposed of as hazardous waste. The effluent itself was sent down the industrial waste lines to dedicated phenolic basins in our industrial waste treatment plant.

We began exploring various alternatives to chemical strippers in 1986. Many substitute processes emerged and two seemed viable for our requirements. Plastic Media Blasting (PMB) developed as an alternate method for depainting aircraft. We have since incorporated PMB in our aircraft depainting facility. The second alternative to chemicals which we considered viable was a similar abrasive process, bicarbonate of soda paint stripping. Having met various requirements for a paint removal process, we subjected the process to a series of vigorous tests. Proving successful through all the initial testing, we initiated a formal testing program to optimize the bicarbonate of soda blasting process parameters and characterize the effects of the blast stream on the substrate materials commonly used as aircraft skins. A separate test program was initiated to determine the environmental effects of the process on the worker, our existing industrial waste treatment system, and the ambient air quality.

The optimization and material characterization effort was contracted to Battelle out of Columbus, Ohio. The objective of the program was to determine if this particular process could meet or exceed Air Force criteria for productivity versus possible blast-imparted substrate damage. The process was tested in a fourteen foot wide by fourteen foot high by thirty-four foot long walk in blast booth installed in an existing chemical stripping room. The booth itself is basically a modified water wash paint booth. The

booth has a cross draft ventilation pulling the exhaust air through a water curtain and into the exhaust chamber, where it passes through a series of sheet baffles prior to exiting the stack. Used media and material removed from aircraft parts fall through a grated floor into a sloped trough filled with water. A series of pipes traverse the trough, each with 10 nozzles directed to maximize the agitation and mixing effect of the used media and water. The water is pumped through the agitation pipes and the exhaust chamber and recirculated throughout the system. A gravity drain weir accommodates the effluent discharge. The effluent travels through a wire mesh trash screen, over the weir, and finally out through a five micron sock filter. From there, the effluent mixes with the chemical waste from our component cleaning room and enters a sump outside the facility. A motorized trash screen and a rotary drum remove solids from the liquid. The liquid is then pumped through a force main to the industrial waste treatment plant. The blasting system utilizes a twenty cubic foot, two nozzle blast pot and is loaded via a two thousand pound super sack loading system.

In order to conduct the materials characterization testing, an optimum set of operating parameters had to be established. To accomplish the optimization we utilized an x-y positioning system to control the traverse rate, angle of impingement, and stand off distance. Additional parameters which were varied in a matrix format were: nozzle pressure, water pressure, and media flow rate. Almen arc height data was established for each combination of blasting parameters. The material used for optimization testing was 0.032 inch 2024 T3 Bare Aluminum. The optimum set of operating parameters evaluated and subsequently used in conditioning of all specimens in the materials characterization portion are:

Blast Medium: Armex Maintenance Grade XL
Stand off Distance: 18 inches
Impingement Angle: 30 degrees
Nozzle Pressure: 60 psi
Water Pressure: 150 psi
Traverse Rate: 0.8 inch/second
Media Flow Rate: 3.0 lb/min

The combination of these optimized parameters yielded a paint removal rate of 0.29 sf/min and 5.11 +/- 0.61 mils of almen arc height deflection. Conditioning of the specimens was conducted in preparation for tests to assess the effects of the blasting process on clad erosion, surface roughness, residual stress, fatigue crack growth rate, and fatigue life (notched). The materials characterization tests were performed on 0.032 inch specimens of 2024 T3 and 7075 T6 bare and clad aluminum.

Cladding erosion evaluations were made by a determination of cladding loss by weight per blast cycle. Six cycles of blasting on unpainted clad surfaces yielded a high rate of clad erosion for both alloys. The erosion percentage data were calculated on the basis of a nominal cladding thickness of five (5) percent per side of the total sheet thickness. Since the densities of the alloy and the cladding were nearly the same, weight loss was correlated to volumetric loss by assuming the nominal thickness was 5 percent of the 0.032 inch sheet thickness. Three sample sets of each material were subjected to the blasting process and measured for weight loss after each blast cycle. The mean percent cladding loss for 2024 T3 clad material ranged from 1.54 % for one cycle to 4.03 % for 6 cycles and the loss on the 7075 T6 clad material loss ranged from 1.44 % for one cycle to 3.48 % for 6 cycles.

Surface roughness measurements were made on unpainted Almen specimens of both alloys, bare and clad. These specimens were grouped by alloy type and each of 6 specimens per set were blasted from one to six cycles to determine cumulative changes to surface roughness. As expected, the bare surfaces after one blast cycle were much smoother than the clad surfaces. Subsequent blast cycles increased the roughness on the bare alloys, while the clad alloys tended to become smoother.

Residual stress was measured by two different means. The saturation response of the substrate to the bicarbonate of soda blasting process by the system used in the study was determined as the delta almen arc height as a function of elapsed blast time for unpainted 2024 T3 and 7075 T6 bare specimens. The delta almen arc height is not a direct measure of blast induced cold work strains, but a change in the bending moment of the unrestrained specimen produced by the residual stresses associated with the cold work process. The overall response for 2024 T3 bare was higher than the 7075 T6 bare response by a factor of 2 or more. However the point at which saturation occurs is about the same for both materials.

Residual stress was also measured by XRay diffraction testing on 5 specimens each of 2024 T3 and 7075 T6 bare almen strips sheared from painted panels, measured for baseline, and constrained by epoxy to a 1/4 inch steel backing plate. They were then conditioned by one blast cycle of paint stripping, plus three additional blast cycles at the same rate to simulate a total of four blast cycles. Each of two sets of specimens included two Almen specimens which were unrestrained at the time of baseline strain measurements. All strain measurements were made after the conditioning was conducted with the Almen specimens in the constrained state. Both alloys exhibited an increase in surface compressive stress decreasing to a depth of 0.003 inch. Beyond the 0.003 inch depth, the distributions remained fairly constant. The 311 peak width distributions for both alloys indicated a surface maximum which may be a result of a more cold worked surface and near surface material.

Fatigue specimens were initially sheared from as received panels and from painted panels after bicarbonate of soda stripping. The individual specimens were then machined to final dimensions. A 60 degree angular notch was pressed 7 thousandths of an inch deep in the center of the specimen over 1/4 inch length. The notch was used to simulate surface flaws on the substrate (both front and back). The fatigue specimens were then tested following guidelines of ASTM E466 (with the exception of the notch). All specimens were cycled under load control with a sinusoidal waveform at 10 hertz. Tests were constant amplitude with a +0.1 stress ratio. The nominal maximum stress for the 0.032 inch material was 33 ksi. Results indicated no appreciable change in fatigue characteristics and in fact the front notched specimens showed an improvement in fatigue life.

Fatigue crack growth rate specimens were 2024 T3 bare aluminum material sheared from as received panels and from painted panels after bicarbonate of soda blasting. These specimens were machine finished to final dimensions. An 1/8 inch hole was drilled through the center of the specimen and an initial 0.040 inch starter notch was machined by electrical discharge machining using a 6 mil traveling wire cut. The test followed guidelines of ASTM E647 and cycled under load control with a sinusoidal waveform at 10 hertz. Test loads were constant amplitude with a +0.1 stress ratio and a maximum load of 1120 pounds. The nominal maximum stress for the 0.032 inch material was 8,750 psi. Crack growth measurements were made with cast epoxy Krak gages and showed no appreciable change in crack growth characteristics.

The second portion of the testing performed at SA-ALC was to verify that the bicarbonate of soda blasting process conformed with the Pollution Prevention Act of 1990. The Act emphasizes that the preferred method of preventing pollution is to reduce, at the source, the volume of generated wastes and that reuse should be performed whenever possible. Air Force Directive 19-4 went a little farther by making a commitment to "... prevent at the source, to the greatest extent possible, environmentally harmful discharges to the air, land, surface water, and ground water."

This portion of the testing was contracted to Pacific Environmental Services in Mason, Ohio. They were tasked to evaluate effluent samples, air emissions for total particulates and metals, analyze stack gases and determine worker exposure effects.

During the testing phase, a variety of aircraft parts were used and tasks were performed. Tasking involved depainting, parts cleaning, and a combination of paint stripping and parts cleaning. One operator was used in the booth for the purposes of the report.

Average stack gas velocity for the sampling runs was 52 feet per second with an average temperature of 60 degrees F. The average flow rate was 30,831 dry standard cubic feet per minute. The stack gas averaged a particulate mass emission rate of 1.855 lb/hr. Particle size analysis of the air emissions showed that more than 98% of the particulate mass emitted was comprised of particles smaller than 10 microns. The absence of large particles suggests that the larger particles settled out or were captured in the water curtain. Analysis of the metals present in the emissions were also conducted during the runs. Sodium accounted for 99+% of the total mass of all metals detected. Other metals detected included: iron (0.0033 lb/hr), zinc (0.0020 lb/hr), total chromium (0.00093 lb/hr), and cadmium (0.00080 lb/hr).

Workspace air samples were collected and analyzed for alkaline dusts, nuisance dusts, and multiple metals. Dust samples were collected between the blast stream and the exhaust chamber, to simulate worst case of one operator working directly downstream of the other. Workspace air sampling resulted in measurable quantities of total nuisance dusts, alkaline dusts, and elemental sodium, and detectable quantities of calcium, zinc, aluminum, and chromium.

Measured concentrations of total dust were in excess of OSHA's Permissible Exposure Limit of 15 mg/cubic meter. The American Conference of Governmental Hygienists have a Threshold Limit Value of 10 mg/ cubic meter for exposure to total particulate matter. The concentrations of detectable metals did not exceed any TLV or PEL standards. With these concentrations in mind, worker exposure limits are negligible. As a comparison, air-supplied hoods can be used in nuisance dust concentrations up to 375 mg/cubic meter. The half faced respirator with a protection factor of 10 can be used in an environment up to 150 mg/cubic meter.

Analysis of the effluent included samples of the rinse water, sump suspension, filtered solids, and filtered effluent. The Total Suspended Solids (TSS) in the sump suspension was 4,850 mg/l. This is 0.00485 kg of solids per liter. The liquid effluent from the process has a pH of about 8.9 and is high in both alkalinity and total dissolved solids, indicating that the effluent contains primarily dissolved NaHCO_3 . Results indicated that the NaHCO_3 concentration in the effluent was no higher than 15 g/l, well below its solubility limit of 96 g/l. The effluent contained, on the average, 50 mg/l suspended solids and had a low content of metals and other contaminants.

The solid material collected in the filter sock had a high oil and grease content as well as a high metals content. The concentrations of antimony, cadmium, chromium, lead, and zinc were sufficiently high that the waster would be classified as hazardous. Less than 1% of the solids in the sock was spent blast material.

To summarize the results of the effects of the bicarbonate of soda stripping process as an alternative paint removal process, utilizing the process parameters developed by this program; it exhibits minimal blast imparted substrate damage. The major exception being that this process tended to erode cladding on the aluminum at higher than preferred rates. The production stripping rate associated with the test panels was only 0.3 sf/min however, in normal production coating removal, rates in excess of 1 sf/min are common. Bicarbonate of soda is a viable alternative for paint stripping as well as a great carbon remover, degreaser, and overall cleaning agent.

We currently utilize the process to remove carbon from F100 engine nozzles and gas turbine engine deswirlers, depainting of fiberglass and fiberglass/aluminum panels as off the T-38 aircraft or TF39 engine, and depainting of fighter aircraft accessories, all resulting in considerable savings in time

and materials. The bicarbonate of soda blasting process has successfully demonstrated that it cleans surfaces in preparation for welding operation significantly better than previous nitric acid processes and has proven to be very effective on cleaning and depainting aircraft wheels, struts, reverse thrusters, and brakes. The process has performed very well for us and, depending upon the application, could work very well as an alternative to chemicals in any industrial operation.

