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LASER ABLATION - CORROSION REMOVAL AND ADHESION IMPROVEMENTS

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ABSTRACT

Almost all surfaces need recoating regularly due to aging and environmental conditions that affect the surfaces' performance. For some items, such as houses, painting over the previous coat of paint is an acceptable practice. However, for other items, such as naval vessels, bridges, vehicles and aircraft over-painting is not acceptable because of poor adhesion, added weight, and performance impacts. For these reasons, it is necessary to first remove the existing coating before applying new coating. Making matters more challenging is that, in some cases, it is desirable to remove foreign materials from these assets while leaving the paint undisturbed or to address the corrosion build up that may have disturbed the surface profile.

Until recently, there were only three methods for removing coating and/or other foreign matter: manual scraping/chipping/sanding, media blasting and chemical stripping. Though each of these methods has significant shortcomings, each are deemed acceptable, despite the time, cost and effort needed to prepare the surfaces for stripping. These methods are used for corrosion control. Sanding, grit/sand blast and grinding have the ability to re-establish the profile per specifications and guidelines established through organizations such as The Society for Protective Coatings (SSPC), NACE International, Naval Surface Treatment Center (NST Center). However, the use of new alloys and composite materials have rendered the traditional methods unacceptable. Additionally, current environmental, human safety, time and cost concerns are challenging the use of traditional methods. An alternative to conventional methods is a process based on laser ablation. This paper will introduce the laser ablation process and testing completed validating the use of laser ablation to remove paint, debris, corrosion and either leave profile or re-establish profile to meet the specifications.

INTRODUCTION

Laser ablation methods for stripping paint and coatings have been studied and tested extensively in the past couple of decades. The advantages associated with this approach address the concerns raised using the traditional methods. Specifically, laser methods remove more paint per unit time, have no consumables (other than electricity), produce minimal waste (a volume smaller than that of the paint itself), produce no hazardous waste, use no water and do not expose operators to hazardous chemicals. The primary concern associated with laser methods is a lack of precision – removing more paint than desired, impacting profile and damaging to structure.

As the technology develops, companies are striving to meet customer's demands for a process control and address the perceived risk of using a laser, when, in fact, laser technology does not have near the risk factors as the traditional methods. Process control is approached using vision, cameras and sensors combined with advanced software. The difference between the approaches is the process time impacting productivity and transfer of thermal energy to the base materials.

Large assets that develop corrosion also have profile issues. Maintenance directives have established standards addressing profile and cleanliness by The Society for Protective Coatings (SSPC). SSPC is the only non-profit association that is focused on the protection and preservation of concrete, steel, and other industrial and marine structures and surfaces through use of high-performance protective, marine and industrial coatings. SSPC is the leading source of information on surface preparation, coating selection, coating application, environmental regulations and health and safety issues that affect the protective coatings industry. (1) The Department of Defense references these standards in their maintenance directives.

In addition, The Naval Surface Treatment Center (NSTC) is the centralized repository of coatings and corrosion control and prevention resources for use by the US Navy, other DOD branches, product manufacturers, and government contractors performing work aboard US Navy ships and submarines. (2)

Laser Coating Removal has been an emerging technology under consideration since the 1990's using what is known as CO_2 laser light sources. Numerous studies have listed the advantages as:

- Generates a small volume of ash particulate
- Non-hazardous particulate in most cases
- No substrate damage under variety of conditions
- Does not change metallurgical properties
- Does not damage composites
- Ability to strip topcoat without removing primer

The disadvantages were noted as:

- Requires filtration for particulates
- Requires laser barrier to protect others from laser beam
- Requires air flow to prevent ash re-deposition on the substrate
- Requires automation
- High cost

As the technology progressed to higher laser output powers, other studies were conducted concerned with the tri-biological effects of the metal surface structure and the ability to weld. (10) The transition to Fiber lasers also generated new concerns. However, the U.S. Air Force has been the driver of developing this technology and has successfully implemented and provided detailed studies not only on the material but the cost savings as well.

This paper is written to advise the industry of the progress Laser Coating Removal has made not only to remove the coating but to address corrosion and profile. We will also discuss the need for process control and address the safety concerns of outdoor use of laser systems.

In 2010, a final report on Naval Application of Laser Ablation Paint Removal Technology was prepared by Concurrent Technologies Corporation. (3) The report concluded the laser ablation did not have any adverse effects on surface profile, paint adhesion and corrosion resistance of laser stripped test panels. Moreover, laser ablation had no effect on the tensile strength and yield strength of the steels, while the tensile elongation was well above the minimum required value. A metallographic inspection showed that laser ablation produced a non-continuous few-micrometer thick film of fused metal on the surface of a steel plate. However, the film was not characterized, and it was reported that the surface morphology and microstructure of the laser ablated surface had no adverse effect on paint adhesion or corrosion resistance. The same information was introduced in an Automotive Conference (ALAW) and is widely accepted in that industry known as "Body in White". Laser cleaning prior to welding on specific areas of an automobile (such as the roof) reduce cost by eliminating the need to put rubber molding in the seams. (10)

A possible reduction of surface roughness and an unknown chemical composition of the film described above was one of the major concerns of using laser ablation to treat metal surfaces, as it could lower adhesion properties preventing recoating or efficient welding. However, mechanical and microstructural properties of laser ablated surfaces of shipbuilding steel were recently studied by Shamsujjoha *et al.* (4) In the study, impact of the laser ablation on the substrate material and suitability of the surface for a subsequent coating application were evaluated in great detail. An analysis of the steel surface showed a 1-5 μm layer of a melted metal, like the one observed in the 2010 study. (3) It was shown that the chemical composition or mechanical properties of the surface had not changed. A surface roughness measurement also showed no significant change in the surface roughness as compared to the steel plates treated by more conventional methods. Moreover, a Pneumatic Adhesion Tensile Testing Instrument analysis of the surface demonstrated that the micron melted layer on the surface of the metal not only does not decreases but, in fact, improves an adhesive performance of the steel surface compared to the abrasive blasted and painted samples. Many studies have shown that the thickness and profile of the thin melted layer, resulting from the laser ablation, can be controlled by fine-tuning the laser parameters or adjusting a scan rate. (5) Thus, laser ablation can be used to enhance adhesive properties of steel. Other studies have shown high-power laser ablation is an efficient alternative to conventional abrasive blasting equipment for shipbuilding cleaning and repair maintenance offering high cleanliness, precise surface profiles, corrosion resistance and low maintenance cost. (6-8)

Until recently, an effect of high-power laser cleaning of metal surfaces on a porosity of fusion zones during laser welding was not well understood. High porosity is known to lead to poor mechanical and corrosion performance, so mechanical and chemical cleaning are usually used to preclean the surface for laser welding. However, in a recent study, Al Shaer *et al.* showed that laser cleaning of aluminum alloys, based on thermal ablation, reduced porosity significantly. For example, for the fillet edge welds, porosity was reduced to less than 0.5% compared with 10–80% without laser cleaning. (9) Researchers demonstrated benefit in introducing laser cleaning in improving the quality (reducing porosity) in laser welding of Al alloys.

Composite materials and light-weighting of assets – automobiles, airplanes, ships, vessels, bridges etc. is another reason for the development of laser ablation equipment. This material cannot be maintained with traditional methods due to the chemical interactions with the material stack ups and blast materials destroys the top layers of material. Research has found that CO_2 laser ablation systems are very well suited for this material but delivering the light is complicated to keep the system in alignment for accurate beam quality. It is next to impossible if automating the process is required.

But, with the introduction of fiber and diode pumped laser systems, handheld and automation equipment became easier to develop and easier to deliver to the work piece and addressed ergonomics issues with CO_2 equipment. High power laser sources increase the productivity levels, and the entire process becomes more economical to purchase driving the ROI to under 2 years. However, there is a downside. Thermal heat is absorbed in some paint colors, metals and composite materials due to the difference in wavelengths associated with the IR light spectrum. A process control system will eliminate that problem. There are numerous types of control systems: vision or camera based, thickness measurement devices, or spectral measuring systems. Selection is dependent upon the application and a desired output result.

One company has addressed this concern with the development of a real-time, closed-loop laser process controller and it is patent-protected in the USA with global patents pending. This system analyzes the material being ablated in real time and based on the analysis decides what laser power level is best suited for aggressive coating removal. The controller modulates the laser power such that high energy emits during paint removal and low (or no) energy emits as the laser passes over the primer and/or substrate.

The controller has additional attributes that allow use for a broad range of coating removal applications. First, the sensing methods used are quite generic, thus the system can be tuned to remove a wide variety of ‘coatings’ such as anodizing, rust and even biological growths (such as barnacles). Second, there are several, equally effective, means for detecting the differences between the coating removed and the material protected.

The development of the newer technology products received the attention of the Navy Research Lab (NRL), an independent shipyard, and The Department of Transportation in Michigan (MDOT) which conducted a series of tests to evaluate the performance of laser coating removal process.

TESTING

Test 1. NRL

The NRL has provided samples of the various areas of the ships with a wide variety of coatings. These samples were given to a commercial lab to explore the laser ablation equipment capabilities to remove the coatings.

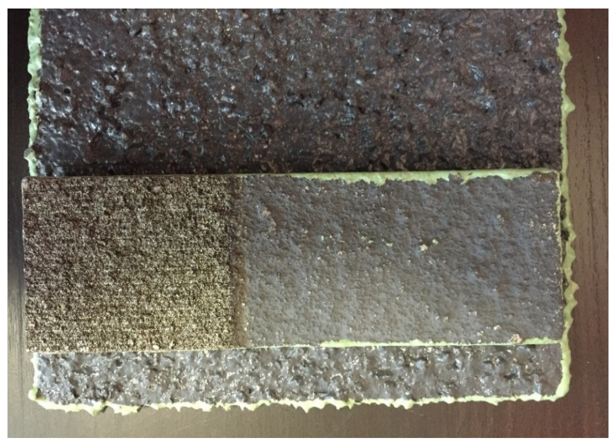

Figure 1
Nonskid sample after & before cleaning

The optical system used for the test is based on the Risley Prism theory. Testing of these optics at the Connecticut Center Advanced Technology (CCAT) proved the optical system to be 50% faster when compared to traditional galvo optics used in most ablation process heads. The off-the-shelf laser source provided 6 kW of output power and was delivered via fiber to the process head. The head was mounted on an off-the-shelf robot with standard PLC controls. The laser process control system was integrated to the laser source, PLC robot controls and used during the test.

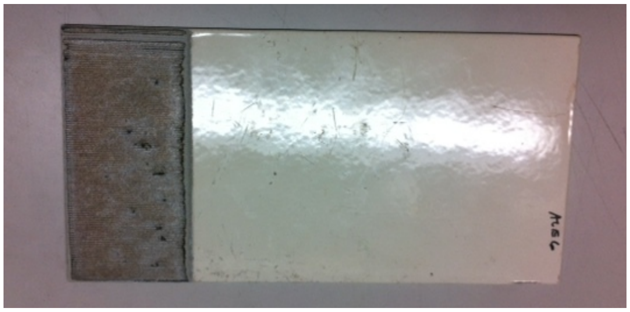

Figure 2
Standard Navy CARC Paint stack on steel

Figure 3
Navy primer on steel, back side of non-skid

Figure 4
Control/ no control

Additional passes were taken without the process control engaged. Visible damage took place to the surface, as seen on the right side of Figure 3. The pass with the process control provided a clean textured surface.

A nonskid stack sample was also provided. The team believed they failed when the coating could not be fully removed, Figure 4. However, the NRL staff observed, an opportunity and possible alternative to water blasting when required to clean the deck at sea.

They explained the EPA constraints to collect and contain all water and debris generated during a blasting procedure at sea. This discovery is being explored and led to a task order to build a handheld unit capable of utilizing the Risley Prism theory and explore the profile capabilities of laser ablation.

Test 2. Michigan Department of Transportation

The Michigan Department of Transportation were excited to learn how laser ablation is contained at the source of removal and has the ability to prevent corrosion. The MDOT Research and Development Team sent in samples of steel I Beams, flat panels used for repair and other samples they found in the yard that had been coated with all types of lead based paints and zinc primers. First pass of the corroded samples resulted in a very clean sample (Figure 5) and it took less than one minute utilizing the exact same set up as used for the Navy samples.

Figure 5
MDOT Sample Pass 1

Observations were taken after each pass.

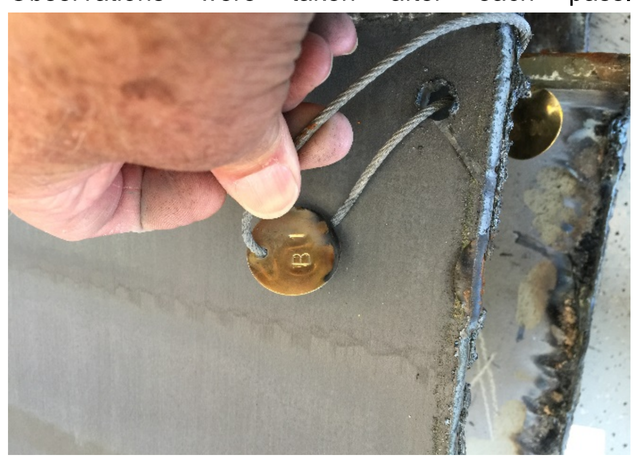

Figure 6
MDOT sample mid process

An independent contractor was hired for the next series of tests. Three foot steel beam samples were delivered to site, two having a zinc/epoxy/urethane coatings stack, and one having a lead based coating stack. A containment had been set up around the robot and work table area. Two air handling units had been placed for dust and smoke removal.

Two hours fifteen minutes were required to effectively strip the approximate six square feet of existing zinc, epoxy, urethane coating system of H2 (Figure 10) side 1 down to bare metal. Some staining was evident where the laser paths have crossed. No visual contaminants noted. The average dry film thickness of this panel prior to starting was 18.04 mils. Many breaks were performed during the cleaning process to change air filters. A surface profile was present on substrate, a 2.9 mil profile was measured using X-Coarse Testex tape. Air monitoring was performed every half hour. Panel was stored in doors. Ambient conditions were monitored and were suitable for cleaning and coating operations.

Figure 7
MDOT sample completely cleaned

The testing was conducted in order to compare airborne levels of metals and waste characterization for disposal resulting from activities to remove paint using a laser technique (Phase 1) and a sandblasting technique (Phase 2).

Figure 8
H2

Three pieces of metal were collected by the contractor and labeled as “H” (Hess Road beam), “B” (Baker Road beam), and “L” (Lead beam from yard). Subsequently, the pieces were sectioned as “1” and “2” with each type of removal conducted on at least one of the sections.

Figure 9
H2 in process

The previously completed Phase 1 involved the laser removal that occurred on those pieces labeled H2 (Figures 8, 9, 10), B1 (Figures 11, 12), and L2 (Figures 13, 14, 15, 16). The previously completed Phase 2 involved the abrasive blasting removal that occurred on those pieces labeled H1, B2, and L1. H2 Sample had existing type 4 coating system intact (zinc primer, epoxy intermediate and urethane finish). The dry film thickness averaged 17.83 mils.

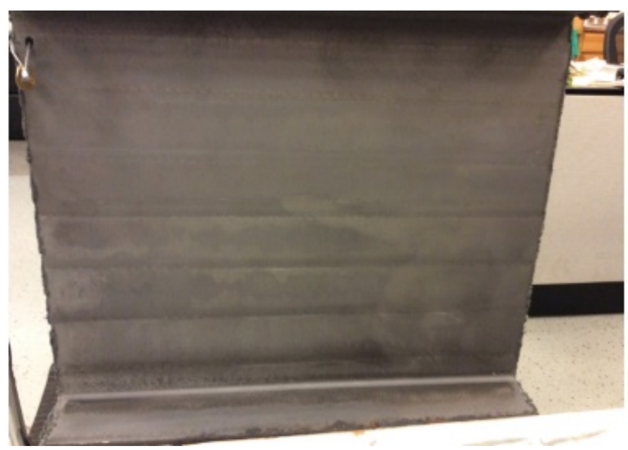

Figure 10
H2 Laser Process Complete

After the laser removal process was completed, surface profile was present on the approximate 6 square feet area of this substrate. X-Coarse Testex tape was used to validate the surface profile reading of 3.5 mils.

Figure 11
B1 Sample

Figure 12
Completed B1 Sample

Sample B1 had existing type 4 coating stack (zinc primer, epoxy intermediate, and urethane finish) with high degree of visible corrosion that included holes and pitting. Dry film thickness averaged 20.14 mils prior to start. Approximately 2.5 hours of cleaning using multiple passes from a Laserline 4-kW diode pumped laser was required to remove approximately 6 square feet of paint, oxides, and debris from this sample. A surface profile of 2.2 mils was measured from this substrate using X-Coarse Testext tape.

Figure 13
Sample L2

The process continued with Sample labeled L2. This steel I-beam had been primed with lead and had many layers of various types of paints with a mil thickness average of 23.11 mils. Heavy pitting, corrosion was visible across the approximate 6 feet square area.

Approximately 2.5 hours of cleaning was required to remove all visible paint from this sample. This panel had higher mils than the other test panels at start of cleaning process, and more smoke was generated by the thicker coatings.

As the machine progressed in passes, the smoke was nearly eliminated. This lead primed beam received the same amount of cleaning time that the other zinc primed beams had received, but the cleanliness of the surface was not equal. This L2 beam had many surface contaminants that could be described as fine metallic pellets/ beads / small balls, chrome and shiny in appearance, about the size of a tip of a dull pencil lead. These "balls" could be easily removed from the surface with hand tool scraping. There were however many areas of substrate that had a metallic residue or sheen that could not be removed by scraping or laser cleaning. This "residue" could be described as a tightly adhered, metallic, chrome and shiny in appearance, surface contaminant. A surface profile of 3 mils was measured from substrate using X-Coarse Testext tape.

Figure 14
L2 in process

Further laser studies on this type of lead primer have been done using laser power levels of 8 kW and the addition of an air knife to move the pellets, allowing them to be vacuumed into the exhaust HEPA filter for proper disposal. Because of this test, enhancements are being developed with the sensor system to detect harmful or hazardous materials to allow the operator and others to obtain proper protective clothing and follow EPA guidelines for hazardous waste disposal.

Figure 15
Surface L2

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Figure 16
L2 Complete

During the paint removal, the inspectors collected air samples what they determined would be a personal breathing zone (PBZ) Table 1, outside work area (OWA), Table 2 and field blank samples for the work. Please note this comparison utilizes those samples labeled as "inside work area" during the laser removal as personal breathing zone samples, since the sampling pump was mounted in the respective breathing zone just as if a person were in the area. Outside work area samples were collected in proximity to the actual work area but not inside it. All the samples were maintained under standard chain-of-custody provisions and submitted to an accredited laboratory. The laboratory analyzed the samples for airborne metals in accordance with NIOSH method 7300, specifically Arsenic, Barium, Cadmium, Chromium, Lead, Selenium, and Silver. A comparison of the personal breathing zone samples for each airborne contaminant per piece/per method of removal. As can be seen, during laser removal, the air sample results verified exposures below all the PELs except for Lead. In addition, the air sample results during abrasive blasting verified exposures were above the PELs for Arsenic, Barium, Cadmium, and Lead.

Table 1
Operator Breathing Zone Area

Metal	OSHA/MIOSHA PEL (TWA, mg/m^3)	Beam B		Beam H		Beam L	
		Laser	Abrasive Blasting	Laser	Abrasive Blasting	Laser	Abrasive Blasting
Arsenic	0.01	<0.0131	0.1500	<0.0149	0.2000	<0.0160	<0.1000
Barium	0.5	<0.0126	0.2900	<0.0073	0.6000	0.2789	0.2700
Cadmium	0.005	<0.0020	<0.0100	<0.0025	0.0260	<0.0024	<0.0150
Chromium	1.0	<0.0244	<0.1700	<0.0370	0.2800	<0.0398	<0.2500
Lead	0.05	<0.0228	1.100	<0.0176	2.400	1.3070	4.000
Selenium	0.2	<0.0131	<0.0670	<0.0149	<0.0770	<0.0160	<0.1000
Silver	0.01	<0.0032	<0.0170	<0.0037	<0.0190	<0.0040	<0.0250

In addition to the air samples, samples of the generated waste were collected for subsequent analysis by
EPA Method SW846 1311/6020/7470A [TCLP Leachate Analysis – Metals (RCRA 8)] for waste characterization. Table 3

Table 2
Outside the Breathing Zone

Metal	OSHA/MIOSHA PEL (TWA, mg/m^3)	Beam B		Beam H		Beam L	
		Laser	Abrasive Blasting	Laser	Abrasive Blasting	Laser	Abrasive Blasting
Arsenic	0.01	<0.0022	<0.0670	<0.0024	<0.0770	<0.0049	<0.1000
Barium	0.5	<0.0011	<0.0330	<0.0012	<0.0380	<0.1017	<0.0500
Cadmium	0.005	<0.0003	<0.0100	<0.0004	<0.0120	<0.0007	<0.0150
Chromium	1.0	<0.0054	<0.1700	<0.0061	<0.1900	<0.0125	<0.2500
Lead	0.05	<0.0011	<0.0330	<0.0015	<0.0380	6.3685	<0.0500
Selenium	0.2	<0.0022	<0.0670	<0.0024	<0.0770	<0.0049	<0.1000
Silver	0.01	<0.0005	<0.0170	<0.0006	<0.0190	<0.0012	<0.0250

The results and comments noted by the third party indicated the cleaned surface met the written definition of SP10 with no coatings, rust, or visible contaminants noted for H2 and B1. After 10 days, the samples remained in SP10 condition guidelines with no flash rust noted. These beams are currently stored at a MDOT contractor yard. Over the last 2 years, the samples have been monitored and compared to the sandblast samples. The laser samples have not had any rust or oxides accumulated on the surface, but the sandblast samples have rusted and no longer meet the SP10 guidelines.

Table 3
Waste Characterization

Metal (µg/L)	MAC[1] (µg/L)	Beam B		Beam H		Beam L	
		Laser	Abrasive Blasting	Laser	Abrasive Blasting	Laser	Abrasive Blasting
Arsenic	5,000	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]
Barium	100,000	2,200	<RL[2]	1,800	<RL[2]	4,800	1,600
Cadmium	1,000	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]
Chromium	5,000	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]
Lead	5,000	<RL[2]	590	<RL[2]	630	<RL[2]	12,000
Selenium	1,000	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]
Silver	5,000	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]	<RL[2]

Test 3. Independent Shipyard

The technology comparison, cost and analysis information was provided by an independent shipyard who asked to remain unidentified due to the competitive nature of costs. The ownership of the shipyard recognized that real numbers were needed to authenticate the report. This information has been given the Navy for inclusion in the DoD database. The paint supplier for this test will be issuing a statement that will warrant their paint after specific laser ablation processing.

The shipyard sent various sizes and shapes of samples retrieved from a salvage yard (Figures 17, 18). The prospective customer is located in the Northwest and is under heavy regulations to not deposit any contaminants in the water or soil off the Pacific Coast. Additionally, workforce attrition is an issue, and, to attract young people to the shipyard, new technology is needed.

Corrosion and paint adhesion are two major costly problems for the owners of the vessels and the owners of the shipyards performing the tasks.

After conferring with the customer and understanding the conditions of their shipyard, the lab personnel set up three test plans utilizing the current beam delivery systems, laser process control, and off-the-shelf laser OEMs with output power ranges from 4kW to 8kW.

Figure 17
Heavy steel ½” thick curved surface plate

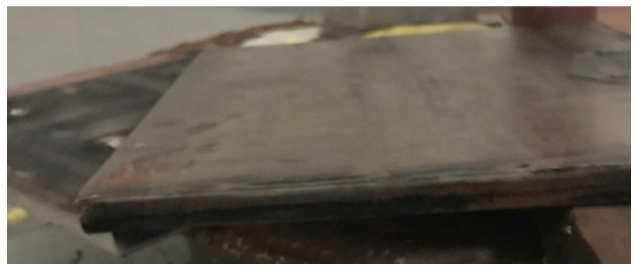

Figure 18
Flat 1” thick steel plate with paint and corrosion

The following table provides the set up for this test.

Table 4
Test Equipment Parameter & Assessments

Material Characteristics	Test 1 Sample Number		Test 2 Sample Number	
	1	2	1	2
Surface removal type	Paint & Rust	Paint & Rust	Paint & Rust	Paint & Rust
Primer	Green	Green	Green	Green
Layers	3 or 4	4	?	4
Base Material	Steel	Steel	Steel	Steel
Laser Power	4kW	4kW	4kW	4kW
Beam Profile	Line	Line	Line	Line
Removal Rate (mm/s)	20	20	20	20
Robot or Handheld	Both	Both	Robot	Robot
Thermocouple read (F)	180	180	175	175
Kerf Width (mm)	25	25	25	25

The first set of samples was tested October 2016 and returned to the shipyard. The shipyard Quality Control Department conducted profile measurements and cleanliness studies in addition to various metal tests. This information was communicated internally, and the decision was made to repeat the tests on a second set of samples. However, the second set of samples would be processed by their paint supplier.

This information was not communicated to our team in the lab. They were instructed the customer needed to verify our accuracy and to repeat the tests on the second set of samples.

Figure 19
Sample 1 Process

Test 2 was set up in December 2016, and the decision was made to utilize on the robotic equipment for speed control and uniform standoff from the part.

The samples were completed, packed back in the shipping crate and sent back to the customer without any special handling from the technicians.

Once received, the shipyard sent the samples to the paint supplier research lab. The paint supplier conducted particulate testing noting where contaminants were located on the samples.

The profile was measured and found to be within specifications at 2.75 mil. The samples were painted with the standard specified Navy 5 coat: 2 coats of primer, 2 coats of paint, and 1 coat of top coat. The samples were sent to a chamber that “ages” the paint to the equivalent of 7 to 10 years at sea - the average time for paint to start cracking and peeling.

Figure 20
Sample 1 Finished

At this point, the samples were returned to the shipyard quality control office. The paint supplier and shipyard QC staff conducted a paint adhesion pull test. Adhesion of a multi-coat system of paint is assessed by measuring the minimum tensile stress necessary to detach or rupture the coating in a direction perpendicular to the substrate. This method maximizes tensile stress as compared to the shear stress applied by other methods, such as scratch adhesion, and results may not be comparable. The test is performed by securing a loading fixture (dollie) perpendicular to the surface of the coating with an adhesive. After the adhesive is cured, a testing apparatus is attached to the loading fixture and aligned to apply tension perpendicular to the test surface. The force applied is gradually increased and monitored until either

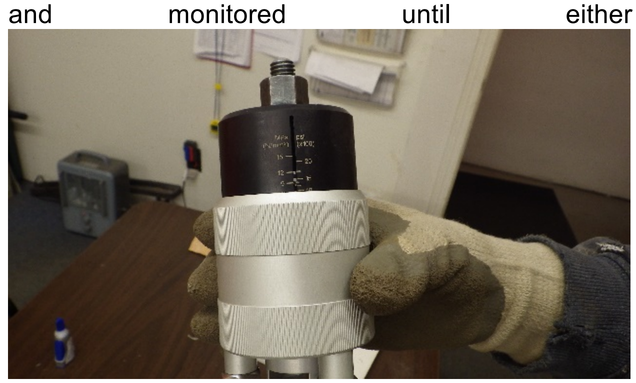

Figure 21
Paint Supplier Adhesion Tester Used

a plug of coating material is detached, or a specified value is reached. The normal range acceptable is 385 psi to 400 psi after a ship has been sandblasted, water jet washed, profile checked, and repainted. In some cases, and in some locations on the vessel, 325 psi will pass. These are considered great ratings.

In this case, the Elcometer 106 Adhesion Tester is easy to operate and fully portable and provides a numerical value for adhesion

Figure 22
Paint Supplier-Dollie separated from glue bond

After the initial testing was completed, the lab was informed of the results reaching 1400 PSI. At this point the test dollie separated from the glue bond and not the coating separating from the glue bond with the dollie which is normal in most testing cases.

Figure 23
Sample after Paint Supplier Pull Test

After receiving unexpectedly high results, the owner of the shipyard asked his Senior Manager to prepare an analysis of laser ablation processing compared to traditional sand blasting used at their facility.

The adhesion test was performed again on the same samples utilizing the shipyard equipment and receiving almost identical results 1380 psi.

The PosiTest Adhesion Tester measures the force required to pull a specified test diameter of coating away from its substrate using hydraulic pressure. The pressure is displayed on a precision digital indicator and can be related to the strength of adhesion to the substrate.

Figure 24
Shipyard Hydraulic Pressure Digital Readout

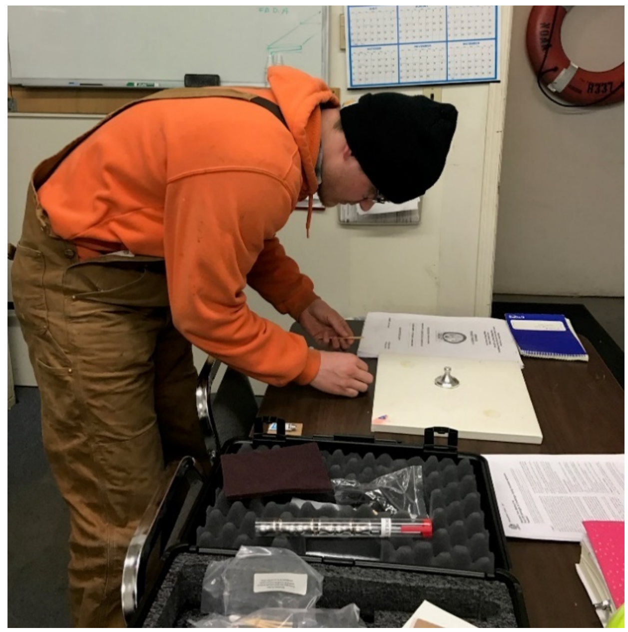

Figure 25
Shipyard QC Office preparing sample for test 2

The Senior Manager researched the data and conferred with laser professionals that 8 kW of power applied for 1 minute will remove 2.4 square feet of coating at 20 mils thickness. He noted the following advantages:

- Selectively removes layers
- Safe on all forms of metals and carbon fiber
- Low power consumption
- Eliminates waste and associated costs
- Saves labor for clean-up, set up and logistics
- Low maintenance
- 80 dB noise laser vs 120 dB noise sand blast
- Laser power increasing costs are decreasing

The cost analysis followed resulted in an ROI calculation of 155%, as detailed in Tables 5-7.

Table 5
Laser Operation Cost Analysis

4 Each 8KW Laser Cost of Ownership per Laser For Ten Years & 40,000 Hours of Operation Total (1000 hours per laser per year)		
Purchase Cost of 8 KW laser	$	2,500,000.00
Estimated Laser Use In Hours		40,000
Hardware cost per hour per unit	$	62.50
Cost of Money @ 7% for 10 years	$	786,600.00
Cost of money per hour of operation	$	3.94
Laser Power in KW		8
Estimated Laser Use in hours		40,000
Life time energy in KW Hours		960,000
Chillers & Air Compressors in KW Hours		1,000,000
Cost of energy per Kilowatt hour in ₵		0.14
Power Cost for 10 years Operation	$	274,400.00
Power cost per hour	$	6.86
3% spares per year @ 10 years budget	$	750,000.00
Spares and Support Cost per hour	$	3.00
Total Lifetime Cost per Hour of Usage	$	107.78
Total Operating Cost for 10 Years	**$**	**4,311,000.00**
Total Operating Cost per Year	**$**	**431,100.00**

Table 6
Laser Cost Analysis with Labor

Labor Cost for 4 each lasers operating for 40,000 Hours of combined Operation over 10 years (not including supervision)	
Labor @ 40,000 hours operation @ $44 per hour	$ 1,760,000.00
Additonal operator hours due to 25% ineffeciency	$ 440,000.00
Operational Support	$ 440,000.00
Protection & Containment @ 10% operation time	$ 176,000.00
Clean Up at 10% of operation time	$ 176,000.00
Laser Safety Officer 10 years 2000 hours per year	$ 880,000.00
Total Labor @ 10 years and 80,000 hours	**$ 3,872,000.00**
Operational Support	
Total Operating and Labor Cost For 10 Years	
Total Operating Cost for 10 Years	**$ 4,311,000.00**
Total Labor @ 10 years and 40,000 hours	**$ 3,872,000.00**
Total Operating and Labor Cost For 10 Years	**$ 8,183,000.00**

Table 7
Cost of Sand Blasting Operations

Projected Sand blasting cost to perform 5,788,000 square feet of surface preperation over a 10 year period		
34,560 tons of Blast M @ $290 per ton	$	10,022,400.00
26,000,000 KW hours of energy @ .14₵	$	3,640,000.00
192,645 man hours of labor@ $44 per hour	$	8,476,380.00
Subcontractor built containments	$	5,550,000.00
Blasting supplies and consumables	$	656,000.00
Rental Equipment to support blasting	$	690,380.00
Total Operating and Labor Cost For 10 Years	**$**	**29,035,160.00**

CONCLUSION

Naval Systems Command issued CWP-371 on July 15, 2015 approving the use of Laser Ablation Coating Removal on Non-Nuclear Surface Ship Applications. This approval was issued from Reference NNSY letter 4793 Ser 250-01-2014 of 21 January 14. The letter makes specific reference to selected locations. This is defined in MIL-STD-1689 as steel structures on U.S. Navy non-nuclear surface ships. Cleanliness and profile requirements must meet NAVSEA Standard Item 009-32. The exception is shell and uppermost strength deck plating within the 3/5 midship region and is not approved for aluminum structures. Safety requirements contained in the Uniform Industrial Process Instruction (UIPI) 1905-115A may be tailored for this process.

The letter went on to identify that “Laser ablation can reveal existing surface profile of the substrate, but does not create surface profile so that additional surface preparation may be required.”

While this approval is a major milestone, technology advancements since the letter was written have moved forward.

- Not all laser coating removal suppliers have equipment that will provide the same results.
- It is possible to create profile IF the beam delivery system can be controlled
- Laser ablation reduces corrosion through the metal passivation layer as first discovered in the automotive industry body in

white. But speed and thermal energy control the passivation to not become solidified metal on top of metal

- Cleanliness of the material is increased
- Adhesion is increased
- Cleanliness and adhesion of the coating eliminates early corrosion and unplanned maintenance.
- Laser ablation is safe, clean, green and efficient
- Laser ablation reduces costs

We must move forward and push this technology into maintenance and manufacturing of our large assets.

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