Performance Evaluations of Blast Cleaning Abrasives

KTA Project No. 360679-1

Presented to:

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TABLE OF CONTENTS

INTRODUCTION

In accordance with KTA-Tator, Inc. (KTA) Proposal No. PN167125-R1 and subsequent signed Authorization to Proceed dated September 20, 2016, KTA has completed performance testing of six abrasive blast cleaning materials (copper slag and coal slag). This report describes the testing procedures employed and contains the test results.

EXECUTIVE SUMMARY

The performance characteristics of six abrasives were independently assessed by KTA. These characteristics included cleaning and consumption rates, surface profile generation, and chloride, sulfate, and nitrate testing of the steel surfaces (pre & post blast). The abrasive media was also tested for chlorides, sulfates, and nitrates. The table below contains the average determinations of the performance tests. The chloride, sulfate, and nitrate testing results and averages are appended.

Table 1 – Results Summary

Abrasive Media	Average Cleaning Rate (ft^2/min.)	Average Consumption Rate (lb./ft^2)	Average Surface Profile Depth (mils)
Coarse (20x50)	1.11	8.1	4.2
Medium (30x60)	2.24	5.7	3.5
Fine (40x80)	1.93	2.1	2.6
Medium (20x40)	2.57	5.5	3.2
X-Coarse (12x30)	1.35	6.7	4.1
Black Beauty (12x40)	0.91	8.3	4.3

SAMPLES

The abrasive materials listed in Table 2, "Samples" were received from Minerals Research, Inc. (Minerals Research) on the dates listed below. It should be noted that at no time did KTA personnel witness the manufacturing or packaging of the abrasive media.

Table 2 – Samples

KTA ID	Sample ID	Description	Date Received
360679-1	Coarse (20x50)	Six – 50 lb. buckets of Sharpshot® copper slag abrasive from Cottonwood, Arizona (air-cooled)	September 7, 2016
360679-2	Medium (30x60)	Six – 50 lb. buckets of Sharpshot® copper slag abrasive from Cottonwood, Arizona (air-cooled)	September 7, 2016
360679-3	Fine (40x80)	Six – 50 lb. buckets of Sharpshot® copper slag abrasive from Cottonwood, Arizona (air-cooled)	September 7, 2016
360679-4	Medium (20x40)	Six – 50 lb. buckets of Sharpshot®XL copper slag abrasive from Louisville, Kentucky (water-cooled)	September 26, 2016

Table 2 – Samples, continued

KTA ID	Sample ID	Description	Date Received
360679-5	X-Coarse (12x30)	Six – 50 lb. buckets of Sharpshot® copper slag abrasive from Cottonwood, Arizona (air-cooled)	September 7, 2016
360679-6	Black Beauty (12x40)	Six – 50 lb. buckets of coal slag abrasive (Medium)	September 23, 2016

BLAST CLEANING FACILITY

KTA used their internal blast cleaning room to conduct the testing described herein. KTA's blast room and the test conditions are described below.

The blast cleaning room at the KTA corporate headquarters in Pittsburgh, Pennsylvania, was used for the testing. The blast facility consists of an enclosed, illuminated 12′ x 8′ x 8′ walk-in blast room equipped with a Torit-Donaldson 5800 CFM dust collection system. The blast cleaning equipment includes a production Clemco six-cubic-foot gravity feed abrasive hopper equipped with a specially-designed abrasive metering valve and a fifteen-foot length of reinforced air/abrasive (blast) hose. A Boride No. 4 (¼″ orifice) Venturi nozzle was used for all the evaluations. Nozzle orifice size was measured prior to the testing using a Clemco Pressure Blast Analyzer Gauge (nozzle orifice gauge). The abrasive metering valve opening was adjusted for the abrasive size to attain optimum abrasive flow prior to production abrasive blast cleaning. Blast cleaning air pressure was maintained at 95 (± 5) psi at the blast nozzle for all evaluations, as measured using a hypodermic needle pressure gage. The nozzle-to-work piece distance was maintained at a constant distance (18 inches) throughout the testing. A single operator performed all blast cleaning operations and was equipped with a Bullard Series 88 Type CE supplied air respirator (blast helmet). The breathing air is certified Grade D quality.

TEST PROCEDURES AND RESULTS

The following test procedures were used to evaluate the cleaning and consumption rates, surface profile generation, and chloride, sulfate, and nitrate testing of the steel surfaces (pre & post blast). The cleaning and consumption rates, and surface profile generation test results are also included in this section. Chloride, sulfate, and nitrate results are appended.

Abrasive Flow Optimization

In a traditional abrasive blast cleaning operation, abrasive media flows from the hopper into the blast hose through a metering valve. The design of the metering valve on commercially available blast pots uses either a gate valve or a pinch valve to dispense abrasive into the compressed air stream. This metering valve is adjusted by the operator to optimize the flow of the media into the blast hose. However, the actual size of the valve opening that is ultimately selected is unknown. For comparative evaluation of abrasive media, the flow rate of the abrasive must be controlled. To this end, a specially designed metering valve was used containing five known-sized openings ranging from ¼″ to ½″ diameter ($\frac{1}{16}$″ diameter incremental orifice size openings). Prior to conducting testing, the flow of the abrasive was optimized (at 95 ± 5 psi blast nozzle air pressure), starting with the smallest metering valve opening (¼″ diameter) and

increasing the opening size until proper flow was established (as judged by the operator). The metering valve orifice opening #4 and choke valve setting 60º was selected for five of the six abrasives tested. Sample 360679-3 (40 x 80, Fine) employed a metering valve orifice opening #4 and choke valve setting 90º. These settings were employed throughout all testing for that particular abrasive.

Cleaning and Consumption Rates

The cleaning and consumption rates of the abrasives were assessed in triplicate. One surface of two 24" x 24" x ⅛" hot-rolled carbon steel panels were blasted for each replicate run. Cleaning rate is an indication of abrasive productivity and is measured in square feet (square meters) of surface area cleaned to a "White Metal" condition (SSPC-SP5/NACE No. 1) per unit of time (square feet [square meters] per minute). A stop watch was used to monitor the total elapsed time of blast cleaning. Subsequently, the amount of surface area cleaned to a "white metal" condition was measured and recorded. The "white metal" condition was assessed by comparing the prepared surfaces to photograph "A SP5" in SSPC VIS 1, "Guide and Reference Photographs for Steel Surfaces Prepared by Abrasive Blast Cleaning." The amount of surface area cleaned (square feet [square meters]) was divided by the total cleaning time (minutes) to yield the cleaning rate. The higher the cleaning rate, the more productive the abrasive is.

Consumption rate is a measure of the amount of abrasive required to prepare a specific surface area (pounds per square foot [kilograms per square meter]). Pre-weighed quantities of abrasive (75 pounds) were loaded into the abrasive hopper. As much surface area as possible was cleaned to "white metal" with the pre-loaded quantity of abrasive. Blast cleaning was stopped either when the entire amount of surface area available was cleaned, or when the abrasive supply was exhausted, whichever occurred first. If the entire supply of pre-loaded abrasive was not used, the residual amount was drained from the base of the abrasive hopper, weighed, and the net weight of abrasive used was calculated. The actual quantity of abrasive used was divided by the area cleaned to "white metal" (in square feet [square meters]) to yield the consumption rate. The lower the consumption rate, the more efficient the abrasive is. The results of the cleaning and consumption rate studies are provided in Table 3, "Cleaning and Consumption Rate Test Data."

Table 3 – Cleaning and Consumption Rate Test Data

Abrasive Media	Run No.	Cleaning Rate			Consumption Rate		
		ft^2/ min.	m^2/ min.	Average	lb./ft^2	kg/m^2	Average
Coarse (20x50)	1	1.09	0.102	1.11 ft^2/min. (0.103 m^2/min.)	7.4	36	8.1 lb./ft^2 (40 kg/m^2)
	2	1.02	0.094		9.4	46	
	3	1.21	0.113		7.6	37	
Medium (30x60)	1	2.25	0.209	2.24 ft^2/min. (0.208 m^2/min.)	5.2	25	5.7 lb./ft^2 (28 kg/m^2)
	2	2.45	0.227		4.0	20	
	3	2.01	0.187		7.8	38	
Fine (40x80)	1	2.29	0.212	1.93 ft^2/min. (0.179 m^2/min.)	1.9	9.5	2.1 lb./ft^2 (10 kg/m^2)
	2	1.92	0.178		2.1	10	
	3	1.59	0.148		2.3	11	

Table 3 – Cleaning and Consumption Rate Test Data, continued

Abrasive Media	Run No.	Cleaning Rate			Consumption Rate		
		ft^2/ min.	m^2/ min.	Average	lb./ft^2	kg/m^2	Average
Medium (20x40)	1	2.50	0.232	2.57 ft^2/min. (0.239 m^2/min.)	5.6	27	5.5 lb./ft^2 (27 kg/m^2)
	2	2.58	0.240		5.5	27	
	3	2.62	0.244		5.5	27	
X-Coarse (12x30)	1	1.49	0.138	1.35 ft^2/min. (0.125 m^2/min.)	6.5	32	6.7 lb./ft^2 (33 kg/m^2)
	2	1.29	0.120		6.7	33	
	3	1.26	0.117		7.0	34	
Black Beauty (12x40)	1	0.49	0.045	0.91 ft^2/min. (0.084 m^2/min.)	9.5	46	8.3 lb./ft^2 (40 kg/m^2)
	2	0.87	0.081		9.0	44	
	3	1.36	0.126		6.4	31	

Surface Profile Generation

Surface profile or anchor pattern is generally considered a measurement of the maximum peak to valley depth of the roughness resulting from high velocity abrasive impingement to a surface. A profile effectively increases the surface area of the substrate, providing "tooth" which promotes coating system adhesion to the substrate. The anchor pattern is typically dictated by the size of the abrasive employed. In general, larger sized abrasives generate a deeper surface profile than comparatively smaller size abrasives. Profile depth is critical and has a direct relationship to the thickness of the coating system being applied. Too shallow a surface profile may result in poor adhesion of the coating system. Conversely, too deep of a surface profile may result in pinpoint rusting due to rogue peaks of the profile protruding above the coating film.

Surface profile was measured on the hot-rolled carbon steel panels cleaned during the "cleaning and consumption rate" trials in accordance with ASTM D 4417-14, "Standard Test Methods for Field Measurement of Surface Profile of Blast Cleaned Steel," Method C (Replica Tape). X-Coarse (1.5 – 4.5 mils) Testex® replica tape was used. Three spot measurements (two individual measurements per spot) were obtained for each blasting trial. The results of the surface profile measurements are contained in Table 4, "Surface Profile Generation Data."

Table 4 – Surface Profile Generation Data

Abrasive Media	Run No.	Individual Determinations (mils)			Run Average (mils)	Overall Average
Coarse (20x50)	1	4.1	3.8	4.1	4.0	4.2 mils
	2	4.2	4.1	4.4	4.2	
	3	4.2	4.4	4.2	4.3	
Medium (30x60)	1	3.3	3.6	3.3	3.4	3.5 mils
	2	3.4	3.4	3.6	3.5	
	3	3.5	3.4	3.5	3.5	
Fine (40x80)	1	2.6	2.7	2.6	2.6	2.6 mils
	2	2.6	2.6	2.7	2.6	
	3	2.7	2.7	2.7	2.7	

Table 4 – Surface Profile Generation Data, continued

Abrasive Media	Run No.	Individual Determinations (mils)			Run Average (mils)	Overall Average
Medium (20x40)	1	3.1	3.3	3.2	3.2	3.2 mils
	2	3.2	3.2	3.1	3.2	
	3	3.1	3.2	3.2	3.2	
X-Coarse (12x30)	1	3.7	3.9	4.0	3.9	4.1 mils
	2	4.3	4.2	4.2	4.2	
	3	4.2	4.1	4.4	4.2	
Black Beauty (12x40)	1	4.3	4.3	4.2	4.3	4.3 mils
	2	4.4	4.5	4.4	4.4	
	3	4.2	4.2	4.3	4.2	

Chloride, Sulfate, & Nitrate Testing

The hot-rolled carbon steel panels, were tested for chloride, sulfates, and nitrates on the steel surfaces in accordance with ISO 8502:1998, "Preparation of Steel Substrates before Application of Paints and Related Products-Tests for the Assessment of Surface Cleanliness," Part 5, "Measurement of Chloride on Steel Surfaces Prepared for Painting (Ion Detection Tube Method)" and Part 11, "Field Method for the Turbidimetric Determination of Water-Soluble Sulfate" using a Chlor*Test CSN SCAT Kit prior to and following abrasive blast cleaning. The sulfate transfer for all abrasives tested was less than 1 µg/cm². Testing of each abrasive for chlorides, sulfates, and nitrates was also performed using the Chlor*Test CSN SCAT Kit. A spreadsheet listing all results is appended.

Observations

General observations were recorded by the blast-cleaning technician over the course of the testing at optimized flow. The observations document the operator's assessment of the materials with regard to dust generation and cutting speed. The observations are provided in Table 5, "Observations."

Table 5 – Observations

Lab ID	Abrasive Media	Technician's Observations
360679-1	Coarse (20x50)	Light dust, heavy rebound, good cut
360679-2	Medium (30x60)	Light/medium dust, medium rebound, good cut
360679-3	Fine (40x80)	Medium dust, light rebound, good cut
360679-4	Medium (20x40)	Light dust, medium/heavy rebound, good cut
360679-5	X-Coarse (12x30)	Light/medium dust, heavy rebound, good cut
360679-6	Black Beauty (12x40)	Light dust, medium rebound, good cut

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		Chlorides		Sulfates		Nitrates	
Abrasive	Panel #	Pre-blast	Post-blast	Pre-blast	Post-blast	Pre-blast	Post-blast
Coarse (20x50) Sharpshot®	1	None Detected	None Detected	2 µg/cm²	0 µg/cm²	0	0
	3	None Detected	None Detected	0 µg/cm²	0 µg/cm²	0*	0
	5	None Detected	None Detected	2 µg/cm²	0 µg/cm²	0	0*
Medium (30x60) Sharpshot®	7	1 µg/cm²	None Detected	1 µg/cm²	1 µg/cm²	0*	0*
	9	None Detected	None Detected	1 µg/cm²	1 µg/cm²	0*	0
	11	None Detected	1 µg/cm²	1 µg/cm²	0 µg/cm²	0*	0*
Fine (40x80) Sharpshot®	13	None Detected	None Detected	1 µg/cm²	0 µg/cm²	0*	0
	15	None Detected	None Detected	2 µg/cm²	1 µg/cm²	0*	0*
	17	None Detected	None Detected	1 µg/cm²	2 µg/cm²	0*	0
Medium (20x40) Sharpshot®XL	19	1 µg/cm²	1 µg/cm²	1 µg/cm²	1 µg/cm²	0*	0*
	21	None Detected	None Detected	1 µg/cm²	0 µg/cm²	0	0
	23	None Detected	None Detected	1 µg/cm²	1 µg/cm²	0	0
X-Coarse (12x30) Sharpshot®	25	None Detected	None Detected	1 µg/cm²	1 µg/cm²	0*	0*
	27	None Detected	None Detected	1 µg/cm²	0 µg/cm²	0	0
	29	1 µg/cm²	None Detected	1 µg/cm²	0 µg/cm²	0*	0*
**sample pink but not readable (< 5 µg/cm ²)*							

*Testing was performed using a Chlor*Test™ CSN SCAT Kit with a LaMotte 1200 Chlor-Rid Colorimeter*

Minerals Research						360679	
Abrasive	Trial #	Chlorides	Average	Sulfates	Average	Nitrates	Average
Coarse (20x50) Sharpshot®	1	0 µg/cm²	0 µg/cm²	162 µg/cm²	170 µg/cm²	0 µg/cm²	0 µg/cm²
	2	0 µg/cm²		178 µg/cm²		0 µg/cm²	
Medium (30x60) Sharpshot®	1	0 µg/cm²	0 µg/cm²	166 µg/cm²	170 µg/cm²	0 µg/cm²	0 µg/cm²
	2	0 µg/cm²		174 µg/cm²		0 µg/cm²	
Fine (40x80) Sharpshot®	1	0 µg/cm²	0 µg/cm²	324 µg/cm²	320 µg/cm²	0 µg/cm²	0 µg/cm²
	2	0 µg/cm²		316 µg/cm²		0 µg/cm²	
Medium (20x40) Sharpshot®XL	1	0 µg/cm²	0 µg/cm²	7 µg/cm²	6 µg/cm²	0 µg/cm²	0 µg/cm²
	2	0 µg/cm²		5 µg/cm²		0 µg/cm²	
X-Coarse (12x30) Sharpshot®	1	0 µg/cm²	0 µg/cm²	150 µg/cm²	142 µg/cm²	0 µg/cm²	0 µg/cm²
	2	0 µg/cm²		134 µg/cm²		0 µg/cm²	

*Testing was performed using a Chlor*Test™ CSN SCAT Kit with a LaMotte 1200 Chlor-Rid Colorimeter*