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A Parametric Study of Grit Blasting Nozzle Variables for Aerospace Metals Surface Preparation

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***Abstract*- Grit blasting is a common and reliable method for surface preparation of aerospace metal components for subsequent operations. Unfortunately, the complex nature of aerospace components creates difficulty in providing sufficient cleaning of surfaces within tight cavities and intricate geometries. Manufacturers of grit blasting equipment have created different media types and sizes, along with different nozzles and blasting parameters, in order to provide a large variety of capabilities within this technology. This investigation of different nozzle designs and parameters, involved the use of quantitative methods, developed to evaluate the effectiveness of grit blast surface cleaning. The most critical aspect of grit blasting is the erosion effect on surface of the material, and therefore the amount of material removed is used as the response parameter for this study. This analysis will show amount of material removal and recommendations as to which method provides the safest parameters before significant amount of material is removed.**

***Index Terms*— contaminant removal, erosion, grit blasting, nozzle**

I. INTRODUCTION

A major sector of the jet engine manufacturing and service industry is overhaul maintenance operations, which provide a cost effective way of repairing engine components. During this process, all work on jet engine components begins with thorough cleaning to remove scale, soot, coke, varnish, and any other baked-on contaminants. Grit blasting is often used for initial cleaning of parts prior to inspecting for cracks. As this inspection is critical for a safe overhaul, a certain aspects of process control and end results need to be met. The key considerations are the amount of material removed during cleaning and the potential for loss of crack visibility.

A variety of grit blast cleaning methods are used to clean these titanium, steel, and nickel parts, using a variety of media types and sizes as well as different nozzles and blasting parameters. As the engine designs provide different configuration and size of parts, cleaning operators face challenges to sufficiently clean them. It is crucial to determine the proper grit blasting parameters necessary to sufficiently clean all surfaces, including those that are difficult to access. At the same time, it is critical that these cleaning operations remove all contaminants, without causing surface erosion in the actual part material. Operators are challenged to conduct cleaning of complex parts by removing all contamination while only removing an insignificant (measurable) amount of base material.

II. LITERATURE REVIEW

A review of literature indicated similar studies involving the effect of various grit blasting parameters on the process capability and quality of the resulting surfaces. One research paper describes a study in which two nozzles were compared to determine dispersion of particles leaving the nozzle and how this affects the shape of surface deformation if the nozzle is stationary [1]. The shape of the nozzle plays important role in the best and most effective method of cleaning the surface contaminations.

A report by Brasche, et al. [2] describes a study by the Federal Aviation Authority (FAA) and Original Equipment Manufacturers, which summarized the current processes used in cleaning of jet engine components during their overhaul and the effect on the ability to find cracks after cleaning. Results of this study provided recommendations for industry and path further evaluation of grit blasting as cleaning process.

Another paper discusses a study finding that different grit blasting parameters such as blasting pressure, blasting angle, grit size, and standoff distance play significant role

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in choosing effective parameters without causing significant increase in compressive residual stresses on a surface [3].

Deng, Zheng, Ding, and Wang [4] published a study that compares different materials used for nozzle material and evaluates its erosion rates. It is important to choose proper material to minimize the maintenance costs and at the same time choose material that can provide the most nozzle life.

Hitoshi [5] conducted a test that demonstrates the effects of different nozzle geometries, nozzle diameters and blasting parameters. Evaluation of erosion rates has been performed on a number of different materials and results show different aggressive intensity of the jet depending on the standoff distance.

III. RESEARCH OBJECTIVES

Every turbine (or jet) engine manufacturer allows certain cleaning methods and techniques that they have tested and certified. Once such operation, grit blasting, is used to clean parts using a variety of blasting media, and process parameters that are approved by engine manufacturers. Most of these nozzles are standard in the industry, although many different configurations are available. Some allow accessing tight cavities and channels in complex parts. To allow the use of different nozzles, testing needs to be completed to determine and constrain the proper parameters before they are used on parts.

This study will examine the effect of grit blasting if used on part surfaces. Samples used in this study did not represent the configuration of actual production parts, although fabricated from representative materials. Certain recommendations as to which media and parameters should be evaluated and additional study performed. Results of this study do not provide data on the actual amount of material removal during grit blast cleaning of production parts. However, all tests were performed with standardized standoff distance, angle, and dwell time in order to control these critical parameters.

The purpose of this study is to obtain measureable data from use of nozzles with different diameters and the resulting material removal rate during the grit blasting operation. If material removal is insignificant, the smaller nozzle diameter can be used by engine manufacturers to provide safe methods of cleaning surface contaminations and minimizing difficult hand scrubbing.

IV. RESEARCH METHOD

As determined in earlier study by chander (2009), the most significant parameters in grit blast cleaning that removes minimum material from the surface are the working pressure, distance to work surface, angle to work surface and dwell time. Therefore, his study will evaluate nozzles with different bore diameter with the same approach angle under the same pressures but different dwell times.

The grit blasting nozzles used for this study are made of ppe with tungsten carbide insert material. Of material, in total of twelve test panels. Panels are from scrap material representing actual part material, as shown in fig. 1.

Table i provides the list of nozzles considered for testing. Two types of nickel alloy will be tested and represented by six test panels for each type.

Table i. List of nozzles considered for testing.

Bore diameter	Nozzle angle
3/8 in	0 degree (straight)
1/2 in	0 degree (straight)

Each test panel will be grit blasted using a suction grit blast cabinet at 45 psi, 60° nozzle to surface angle, 5 in standoff, 500 wet aluminum oxide media, and three different dwell times (2, 10, and 30 s). Refer to Tables III and III for control and experimental variables. Each blast condition will be tested 4 times to obtain a sense of repeatability. The cabinet used has a cyclone separator and recycles the grit blast media. The nozzles used during testing have 0.500 in (12.7mm) and 0.375 in (9.5 mm) diameters with a straight orifice.

All test panels were serialized for traceability and fixtured in fixed position with a 5.0 in standoff distance and angle of 60º. Nozzles are set up in vise mounted on holding fixture and held in place by set screw. Masking of measurement reference surface is completed prior to each blasting (Fig. 2 & 3). Upon completion, masking needs to be removed and surface cleaned with water.

Each test panel will provide two data points from each side of the panel and a total of four data points per test panel. Initial measurement of each test panel is done to provide base measurement using a dial
indicator with 0.0005 in graduations and dial depth gage 0.000025 in graduations. Final measurements will be performed using the same equipment. After the grit blasting is complete, measured amount of the material removal will be determined by subtracting initial and final measurements and defining the

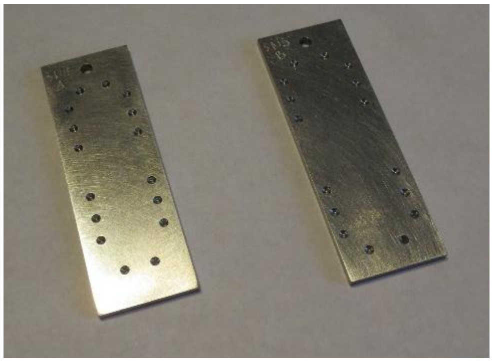

Fig. 1. *Test panels.*

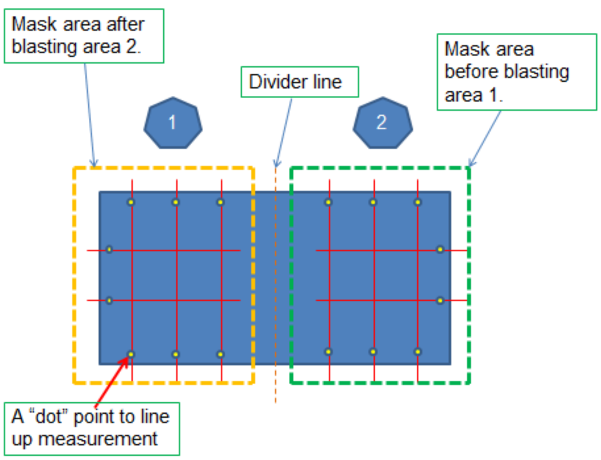

fig. 2. *schematic of masking process.*

maximum material removal by depth of the grit blasted area (Fig. 4).

V. Results and Discussions of Project

Calculated amount of material removal was determined by subtracting the initial surface measurement of each test panel and subtracting the value of depression after blasting. Each test panel had its "reference surface" masked to maintain the measurement neutrality. A dial depth gage with 0.000025 in graduations had been used to provide measurement for each data point. Results of measurement for material A are recorded in Table IV.

To compare the amount of stock removal for material A, all data points have been shown in Fig. 5. It can be noted that the 0.375 in nozzle removed

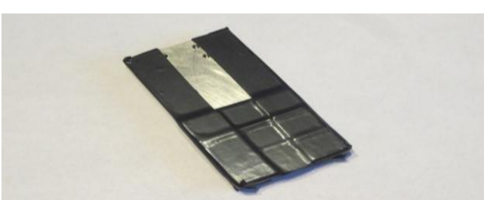

Fig. 3. *Test panel after masking.*

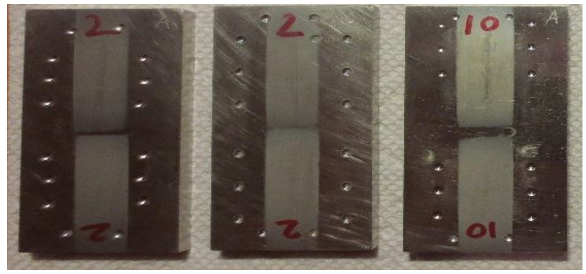

Fig. 4. *Test panels after grit blasting.*

significantly more material than the 0.500 in nozzle when the same parameters have been used, while both nozzles removed a similar amount of material with a dwell time of 2 s. The results of grit blasting with dwell time of 10 s indicate twice the material removed with the use of the 0.375 in nozzle. Finally, with dwell time of 30 s, the 0.375 in nozzle has 5 times higher rate of material removal.

Test results of material B are shown in Table V. The same method of measuring has been used to measure of the stock removal on the second material. The stock removal comparison between two nozzles sizes for second material is shown in Fig. 6. It can be noted that material removal rate is similar to the test results for first material A.

Conclusion and Recommendations

This paper summarizes the mechanism of material removal during grit blasting of nickel

Table II. Experimental Setup Parameters.

Parameter	Level
Angle (degrees)	60
Pressure (psi)	45
Media	500 mesh size wet Al_2O_3
Standoff (in)	5
Sample Material	Material A and B
Dwell Time (s)	2, 10, and 30
Nozzle Bore Dia. (in)	0.500 and 0.375

***Table III.* Control and Experimental Variables.**

Parameter	Level 1	Level 2	Level 3
Angle (degrees)	60	-	-
Pressure (psi)	45	-	-
Standoff (in)	5	-	-
Dwell Time (s)	2	10	30
Material	A	B	
Nozzle Dia. (in)	0.500	0.375	

alloy surfaces using wet aluminum oxide with different nozzle sizes. Parameters such as speed of grit blast has been identified and reviewed. The key variables during grit blast operation are blasting angle, blasting pressure, nozzle size, and standoff distance play important role in defining the safe range before significant damage is done to the surface. As it was determined here, the smaller nozzle size allows an increased grit blast media velocity and energy, resulting in more material removal. It is important to note that both nozzles 0.500 in and 0.375 in have similar amounts of material removal with dwell time of 2 s. This data suggests that both nozzles could be used to clean contaminations as they remove very minimal amount of material, if dwell time of 2 s is not exceeded.

One recommendation is to determine the blasting pressure when using 0.375 in nozzle that will align with the amount of stock removal when using 0.500 in nozzle at 45 psi and blasting angle of 60º.

***Table IV.* Measurement results for Material A**

Dwell time (s)	Data point 1	Data point 2	Data point 3	Data point 4
0.375 in nozzle				
2	0	0	0	0
10	0	0.00005	0.0001	0
30	0.0001	0.0001	0.0002	.0002
0.500 in nozzle				
2	0	0	0	0
10	0.00025	0.0002	0.00025	0.0002
30	0.0008	0.00075	0.0007	0.00075

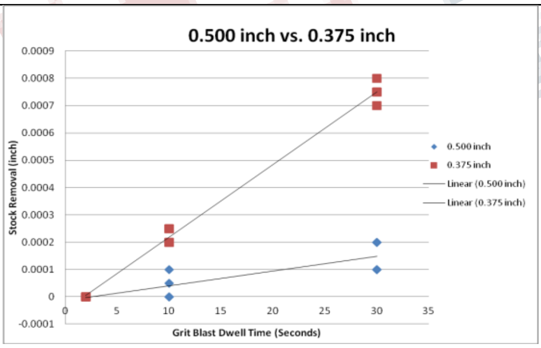

Fig. 5. Stock removal vs. dwell time for material A.

Another recommendation is to compare two different nozzles to measure the wear amount of the nozzle when using the same blasting parameters such as blasting angle, blasting pressure, and standoff distance. This will help determine the nozzle wear factor and help establish the time limit when nozzle reaches the life limit and should be changed.

A third recommendation is to perform a time study of cleaning service run parts with the two nozzle sizes at the same blasting pressure to determine the time savings. The smaller nozzle allows operator to have better focus and aim to clean targeted area and minimizing re-cleaning time.

Table VI. Measurement results for material B.

Dwell time (s)	Data point 1	Data point 2	Data point 3	Data point 4
0.375 in nozzle				
2	0.0005	0.0005	0.00015	0.00005
10	0.00035	0.0004	0.00025	0.0004
30	0.00065	0.00075	0.0007	0.00011
0.500 in nozzle				
2	0	-0.0005	0	0
10	0.0001	0.0002	0.00005	0
30	0.0001	0.00015	0.0002	0.00015

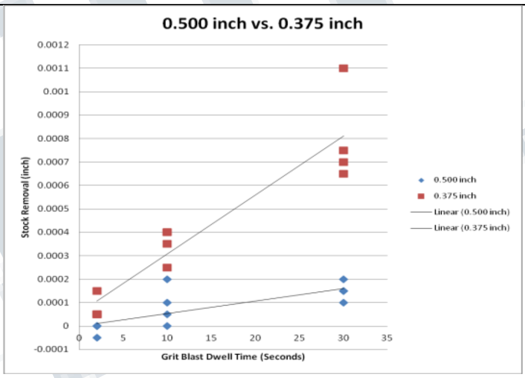

Fig. 6. Stock removal vs. dwell time for material B.

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