Spring 2021
Volume 35, Issue 2 | ISSN 1069-2010

The Shot Peener

Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries

TRIBAL KNOWLEDGE

Capturing the unwritten knowledge of seasoned employees

PLUS: FINE PARTICLE SHOT PEENING ▮ BACK TO BASICS: PEENING INTENSITY & COVERAGE ▮ SHOT PEENING & ADDITIVE MANUFACTURING

THE SHOT PEENER

Sharing Information and Expanding Global Markets for Shot Peening and Blast Cleaning Industries

OPENING SHOT

Jack Champaigne | Editor | The Shot Peener

In Memory of Pam Champaigne

MY SISTER, PAM, passed away on January 28 after fighting a courageous battle against cancer.

Pam was well known by many of our readers that attended our shot peening workshops because she worked for Electronics Inc. from 1999 to 2009 as the workshop coordinator. She enjoyed choosing venues for the US workshops and she traveled the country selecting the best locations. She was also responsible for coordinating the meals and after-hours activities. Many of you will remember the 2005 Texas cookout in the desert with a hatchet throwing contest, and events with magicians and ventriloquists. She even arranged for a Humvee test drive for a visitor from China.

Pam didn't follow my path into engineering but she was intelligent and inventive and she wasn't afraid to tackle home improvement tasks and creative projects. She helped me build my early products on a card table in my house before I acquired EI's first building. My brother Jim and I will greatly miss Pam's warm and vibrant spirit.

Use the QR code to link to the Pam Champaigne Tribute Website or visit www.tributes.com

Jeff Derda (EI) and Pam announce a contest winner at 2006 USA workshop.

Pam and Herb Tobben (Clemco) at the 2007 USA Workshop.

Pam helped everyone be at the right place at the right time.

Pam and I at the 2005 USA Workshop.

THE SHOT PEENER

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For a free subscription of the *The Shot Peener*, go to www.theshotpeenermagazine.com

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AN INSIDER'S PERSPECTIVE

Kumar Balan | Blast Cleaning and Shot Peening Specialist

Tribal Knowledge in the Blast Industry Part Three

THE ARROGANCE OF EXPERIENCE

When speaking to past colleagues for this series, I kept recalling an incident I was involved in a few years ago. In my anxiety to make it to a meeting on time, I kept directing the cab driver in my past hometown of Bombay, India to take routes presumably not known to him. After enduring me for a while, he abruptly stopped his car and displayed his driver's license to my face with an arrogant remark that even his credential was older than me and asked me to pipe down. He then proceeded to get me to my destination without delay! Similarly, I have often heard my seasoned colleagues complain that the new engineers were re-engineering proven designs and messing them up in the process! Would you call it arrogance, impudence or them simply knowing what has worked and will work again? So, why is it important to acknowledge the past in our industry?

Our industry suffers from extremes—there are only a few books on blast cleaning that are written to educate the everyday blaster, and then there are those that will require a graduate degree in surface engineering to assimilate. There is no middle ground. The middle ground is covered in this undocumented and almost latent repository of "tribal knowledge." My goal is to continue unearthing as much of it as I can through interviews with these experts that have hung up their well-worn hats, but still eager to transmit their experience to the eager listener. Fortunately, I was not met with any experience-accorded arrogance from those I spoke to!

In case you are just joining us in Part 3, in Part 1 we have discussed the significance of media velocity, fallacies of needing high velocity, wheel diameter and evolution of blast wheel speeds. In Part 2, we talked about the loss of velocity due to deflector tips in nozzles, fixturing, PVTs and MVTs, angle of impact resulting from different wheel locations, and tips on Tumblast style machines. I concluded with a discussion on a blast pattern verification technique for wheel machines. The focus in Part 3 is on airblast cleaning/peening/gritblasting. (Part 1 and 2 are available in the 2020 Fall and 2021 Winter issues of *The Shot Peener* magazine and are available for download at www.theshotpeenermagazine.com.)

ACHIEVING SURFACE PROFILE

My first contact for this article is Dennis Denyer, who started in this industry in 1973 and continues to serve in an active capacity with GMA Industries in Romulus, Michigan. Dennis is a wealth of information through his journey with Wheelabrator-Allevard and Metaltec in the past. "Though perceived as a low-tech operation with the newbies starting in the cleaning room, the final quality of finish matters to whether the product can be made to look attractive enough for a sale," explained Dennis. Those of us that assist end-users develop their surface finish process often get asked, "What size of media will give me a particular surface roughness (mil. Microinch etc.)." The application engineers at Ervin Industries, a global steel abrasive manufacturer, provided me with the following table data, with a caveat that I use this for reference since the result depends on a combination of several other process variables. Dennis explained to me, "There is no magic formula to obtain a particular surface profile. More so with non-metallic media such as AlOx that degrades relatively faster than metallic abrasives. To maintain consistency of finish, grit blast applications in the aerospace sector rely on process control components such as classifiers to maintain constant abrasive size, and not an operating mix as in general blast cleaning."

Surface Profile		
SAE Grit Size	SAE Shot Size	Estimated Mil Profile
G-14	S-460	4.0 to 6.0+
G-16	S-390	4.0 to 6.0+
G-18	S-330	3.0 to 6.0+
G-25	S-280	2.5 to 5.0+
G-40	S-230	2.5 to 5.0+
G-50	S-170	2.0 to 4.5
G-80	S-110	1.5 to 3.0
G-120	S-70	1.0 to 2.5

Table data is courtesy of Ervin Industries

When chatting with Dennis, he confirmed a myth that continues to haunt the blast industry—higher pressure leads to faster cycles. Most cleaning operations (as mentioned in Part 1 of this series) crank up their operating pressure to 120 PSI, or whatever their source would allow. "At 120 PSI, all you are doing is wearing out the operator and blast accessories. The media

gets pulverized (Dennis is referring to non-metallic abrasive), leading to a cloudy and unproductive environment to work in. This leads to re-work, larger amounts of dust generation and higher operating costs," explained Dennis.

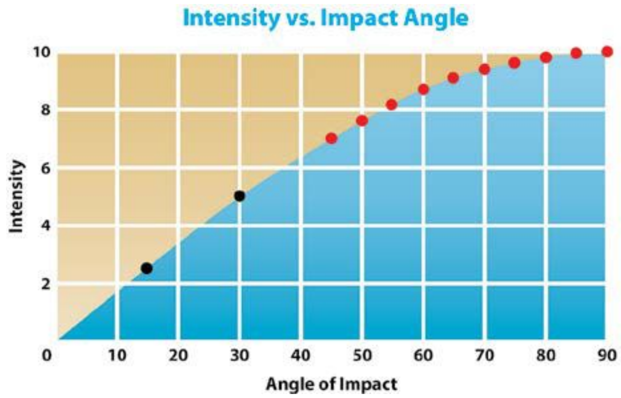
SO, WHAT IS THE IDEAL BLAST PRESSURE TO ACHIEVE A PARTICULAR ROUGHNESS?

A cursory search of abrasive supplier websites will provide you with several surface roughness estimates given different media sizes and types. Robert Heaton recently retired after 45 long years at Empire Abrasive Equipment in Langhorne, Pennsylvania. Empire Abrasive Equipment is a quality manufacturer of manual and automated airblast equipment. Robert remarked, "I wish it were that easy to publish a chart that shows roughness! The list of variables is endless with some having a greater impact than the others. For example, is it suction or pressure blast that you are using to generate your profile? Are you trying to clean and develop a surface at the same time, or are you starting off with a clean part? The efficiency of a suction gun starts diminishing after about 70 PSI." Robert adds a tip at this point if you are stuck with suction equipment and still battling a target surface finish. "Back down on the size of the airjet, keeping your nozzle insert the same size, and this will give you a potential boost in efficiency."

Process Characteristic	Impact
Flow rate	High
Air pressure	High
Media size	High
Nozzle and hose wear	Medium to high
Quality of media (durability and uniformity of size)	High
Stand-off distance	Medium to high
Nozzle type (venturi/straight bore/deflector tip)	High
Impact angle*	High

Effect of different process characteristics on profile

*Those of us that have gone through an EI Shot Peening Workshop will likely remember the following graph. The ideal impact angle to shot peening is 90 degrees (practical: 70 degrees). We profess that a part should not be peened at angles less than 45 degrees. Dropping from 90 to 45 degrees already reduces the impact by almost 30%. Similarly, when attempting a particular surface finish, the impact angle affects the magnitude of energy transferred by the abrasive on to the substrate. The converse is also true, wherein reducing the impact angle will allow easing of the surface roughness value, making it smoother.



Graph used with permission of EI Shot Peening Training

Though absolute answers are difficult to pin down, speaking to Robert and Dennis allowed me to formulate certain universal ground rules to achieve consistent surface finish:

1. A work ***mix*** is critical when attempting to achieve uniform **cleaning**. This holds true for metallic as well as non-metallic abrasive.
2. When **grit blasting** to a specific surface roughness, uniformity of size or a tight tolerance within a range of close sizes is essential. This can be maintained with a vibratory classifier.
3. Following along the lines of an ideal operating mix, 100% ***new*** media will not give consistent results. Allow the operating mix to develop over a few cycles, and when adding new media to replenish the system, add frequently but in low quantities.
4. Air pressure is a major determinant in maintaining consistent surface finish. High air pressures (greater than 60 PSI in suction and 90 PSI in pressure blast) need to be evaluated for their efficacy. Your process may not need such high pressures.
5. High air pressures will pulverize your non-metallic media at exponential rates, in addition to wearing out blast nozzles and hoses. Though hose wear does not directly impact surface finish, nozzle wear will change its blast pattern, decrease the intensity of blast, and could mis-direct the media to unintended areas inside the cabinet.
6. In shot peening applications, nozzle wear will reduce intensity (air pressure remaining unchanged).
7. If surface profile is your goal, it is important to maintain a tight tolerance with nozzle wear. It is time to replace your nozzle when a 1/16" change in nozzle bore is observed. Check with a calibrated dowel pin.
8. Air pressure loss will be experienced after a threshold hose length of 20'. A practical rule of thumb identifies a 5 PSI drop for every 50' of hose length. This rate of drop is exponential with hoses that are longer than 75'.
9. Threshold for nozzle sizes: a ¼" nozzle works with optimum efficiency for media sizes up to S110, 5/16" diameter for S230

and 3/8" for S280 and S330. Larger media sizes may require larger bores (and hose diameters), subject to media flow rate and air pressures.

10. Air pressure should always be verified as close as possible to the nozzle, using a needle gage.
11. In a pressure blast system, air and media consumption increase with nozzle wear. In a suction blast system, since the airjet determines the compressed air requirement, nozzle wear does not directly impact air consumption.
12. Depending on the nozzle design (straight bore and venturi) in a pressure blast system, the drop in impact is noticed at stand-off distances exceeding 8".

MEDIA HARDNESS AFFECTING SURFACE FINISH

Silicon carbide (SiC) and Aluminum oxide (AlOx) are two of the most aggressive and hard media used in our industry. They are rated 9 on Mohs scale where diamond gets a 10 and steel shot is at 7. Hard materials also tend to be brittle in structure. In aerospace, the durability of AlOx is accepted and accommodated for with process control. In other industries, users commonly experiment with alternate metallic abrasives such as stainless steel grit (in addition to conventional steel grit). Though brittle, particles of AlOx and SiC do create the intended roughness on the substrate before eventual disintegration.

Media hardness does have an impact on the roughness in equal proportion to the hardness of the substrate. A combination of all factors listed earlier will ultimately lead to the target profile/roughness. The article titled "Media Choices for Grit Blasting" in Spring 2019 of *The Shot Peener* has more details.

COMPRESSED AIR CONSUMPTION AND QUALITY

This is one of the first operating cost elements to be evaluated when considering a compressed air-type blasting or peening equipment. Compressed air is expensive to generate and, in a dynamic environment such as a blast machine, its requirement varies with component wear. Let us take the example of a 3/8" diameter nozzle blasting 80 PSI. This will require about 160 CFM of compressed air. Four CFM of compressed air requires about 1 HP to generate. In other words, this nozzle will require a 40 HP compressor. Consider the following with respect to this example:

- Though you will not always have the luxury of knowing the air pressure required for your application, you will need to plan for a compressor (or compressed air source) well in advance of process development. Therefore, fix the nozzle size and plan for compressed air requirement based on the next nozzle size (at 80 PSI). In other words, if your process requires a 3/8" (No. 6) nozzle, plan for compressed air requirement with use of a 7/16" (No. 7) nozzle. This will account for progressive wear of your 3/8" nozzle and resulting increase in compressed air consumption.
- If your plan involves diverting/sharing compressed air from an existing source, and if you are certain about the blast pressure requirement being no more than 50 PSI, for example, settle at that value, but still plan for the next size nozzle. A 3/8" nozzle will consume only 110 CFM at 50 PSI, a 50 CFM drop from that at 80 PSI. Most OEMs will be able to estimate the range of peening or blast pressure required for your specific application.
- In both cases, unless the compressor and dryer are located right next to the machine, always install a reservoir next to the machine to separate moisture (condensate) prior to feeding the blast tank, and ensure constant supply for an uninterrupted clean/peen cycle. Water in your compressed air line will wreak havoc on your media, both metallic and non-metallic. Surface rust on metallic media, due to this moisture, will transfer on to the part, leading to its discoloration. On this topic, the engineers at Ervin Industries provided me with suggested storage guidelines for AMASTEEL, Ervin's manufactured cast metallic shot and grit.
    * AMASTEEL should always be stored indoors in a covered shed without exposure to direct moisture or extreme humidity. Storage temperature should be stable with atmospheric temperature. Steel media stored in an air-conditioned environment, when introduced to a warm/humid environment for shipping or transportation, could cause moisture condensation. Therefore, temperature stability is important.
    * If a bag or drum of AMASTEEL is opened, it is advisable to store it in an atmosphere where the relative humidity is between 35 and 55. For unopened (sealed) bags and drums, standard humidity conditions indoors will be acceptable to prevent any material damage.
    * For opened drums, place a bag of desiccant on top and close the lid.
    * If the machine is scheduled to be taken out of service for any extended time (more than a week), empty the abrasive from the machine and store it in airtight drums. Before emptying the machine, it is advisable to run it for about two hours in the machine to remove any flash rust from the abrasive particles.

WHEN WE MEET AGAIN

What started as a single article has gained great momentum thanks to industry colleagues willing to share their knowledge. So, we will continue to Part 4 in Summer issue of *The Shot Peener* where I will share information specific to wheelblast equipment and process to benefit anybody working with a blast machine. I look forward to connecting with you again.

PREMIER

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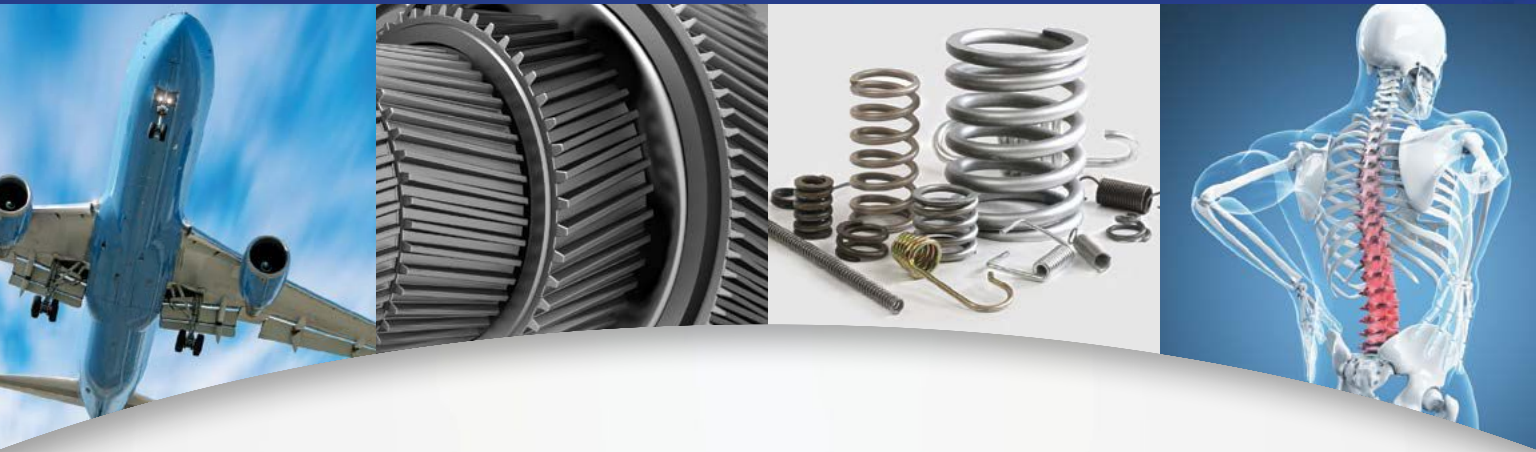
A Cut Above



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The Effect of Fine Particle Shot Peening on Carburized Material

1. INTRODUCTION

Shot peening is a process that improves the near-surface properties of metals by impacting the metal surface with small balls called shot that are made of metal or ceramic materials. The main effect is to improve the fatigue strength and it is used for various automotive parts.

The dent is created at the surface due to impact by shot during the shot peening process. The surface roughness characteristics will be modified by the peening process. Changes to the surface are dependent on shot peening conditions and the mechanical properties of metal parts.

In recent years, the demand to reduce fuel consumption of automobiles has led to weight reduction efforts. In a transmission unit for example, the goal of weight reduction is achieved by reducing the total length of the unit. This means that the tooth width will become thinner, and the load on a single tooth will increase. The two fatigue strengths required for transmission gears are the bending fatigue strength at the tooth root and the surface fatigue strength at the tooth surface. It is also important to reduce the surface roughness of the tooth surface in order to reduce noise and vibration. Therefore, the surface roughness after shot peening should be as low as possible. In order to reduce the surface roughness after shot peening, fine shot of 50 to 100 μm has been developed and applied to transmission gears.

In this article, we report on the fine particle shot peening for carburized materials which are widely used for automobile transmissions.

2. ABOUT FINE PARTICLE SHOT

The types of shot media can be roughly divided into cast steel shot, CCW (Conditioned Cut Wire), ceramic shot, and glass beads. The characteristics of each type is summarized in Table 1.

At the current time, the size of conventional shot varies from 30 μm to about 2 mm. For example, CCW is a process to obtain shot by cutting drawn wire at a length approximately equal to its diameter. Therefore, the smaller the wire diameter, the more difficult it is to cut. Currently, the smallest diameter is ϕ0.25 mm.

On the other hand, the diameter of the shot that is produced by casting is much smaller.

The "fine particles" discussed in this article are less than 100 μm.

Table 2 shows the specifications of the currently commercially available fine particle shot for reference.

Table 1 Specification of shot media

	Cast Steel Shot	CCW	Ceramic	Glass
Specification	Lower Cost	Higher Cost	Higher Cost	Higher Cost
	Fragile	High Durability	Durable	Fragile
	Work Hardening	Less Work Hardening	Fine Surface	Fine Surface
	Wide Distribution	Less Hardness Variation	Non-Work Harden	High Disposal Costs
		Narrow Distribution	Wide Distribution	Shallow Influence
Diameter	30 μm~2 mm	0.25 mm~1 mm	30 μm~1 mm	30 μm~0.8 mm

Table 2 Specification of available fine particle shot by SINTOKOGIO

	Ammo Beads	SBM-44T	SBM-100T
Diameter	50 μm~150 μm	45 μm~	100 μm
Hardness	900 HV	1200 HV	700~1200 HV
Specification	Amorphous Higher Young's modulus	Smallest shot of cast steel	Inexpensive cost among fine particle shot

3. CONFIRMATION OF THE EFFECT OF FINE PARTICLE SHOT ON CARBURIZED MATERIAL

3 • 1 Gas Carburizing and Vacuum Carburizing

Carburized materials are often used for automotive transmission gears and CVT sheaves. Gas carburizing and vacuum carburizing are two methods currently used in mass production.

In gas carburization, the surface is carburized by the denatured gas containing carbon monoxide. Simultaneously, the surface is oxidized along the grain boundary to form a structure called the inter-granular oxide layer (see Fig. 1 on next page).

The inter-granular oxide layer is softer and less strong than the martensitic layer directly below it. On the other hand, vacuum carburizing produces a very hard martensitic structure from the top surface without oxidation.

3 • 2 Fatigue Strength

Fatigue fracture is a phenomenon in which repeated stresses below the yield stress initiate cracks that propagate and lead to

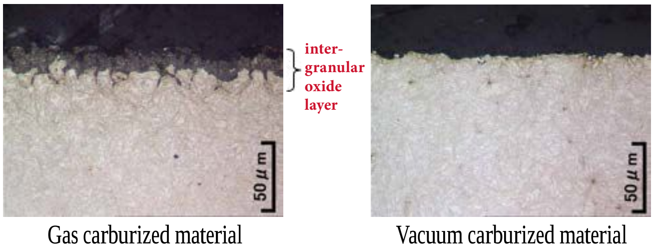

Fig 1. Microstructure of carburized material

failure. High-fatigue strength is required for important parts such as transmissions and valve springs. There are two ways to improve fatigue strength: To increase the life until fatigue crack initiation and to increase the life until the fatigue crack propagates to failure.

Shot peening enhances fatigue strength mainly by inducing compressive residual stress near the surface which prevents fatigue crack growth. As mentioned above, the surface of the gas carburized material has an inter-granular oxide layer, which reduces the hardness. As a result, the material strength is lower and the fatigue and crack initiation life is shorter than that of the martensitic layer below.

When shot peening using fine particle shot is applied to gas carburized material, there is a possibility that the soft inter-granular oxide layer on the surface will be eroded. Therefore, in the case of gas carburized material, it is necessary to change the shot peening conditions to prevent the erosion.

On the other hand, in the case of vacuum carburizing, the top surface is martensite which is hard. Generally speaking, there is little possibility that shot peening will cause erosion.

Poor surface roughness has a negative effect on fatigue strength. Therefore, it is necessary to use shot peening conditions to reduce the surface roughness as much as possible, whether gas carburizing or vacuum carburizing.

The fine particle shot is used in expectation of low surface roughness.

3 • 3 Four-point bending fatigue experiment

SCM420H is typical carburizing steel in Japanese Industrial Standard which is why it was chosen for this experiment. After machining, vacuum carburizing is applied to specimen. Thereafter, shot peening is carried out by four conditions which are described in Table 3. In this table, "HSP" means conventional shot peening condition for gear in Japanese automobile industries. Fig. 2 shows shape of specimen.

Table 3 Condition of shot peening for four-point bending fatigue test

Name	DASP①	DASP②	DASP③	HSP
Shot diameter (mm)	0.05	0.3	0.6	0.6
Shot hardness	900 HV	950 HV	950 HV	700 HV

Fig. 3 shows surface roughness and Fig. 4 shows residual stress after shot peening. In the case of DASP①, which has used fine particle shot, the surface roughness is lowest. On the other hand, residual stress was induced only in the shallowest layer.

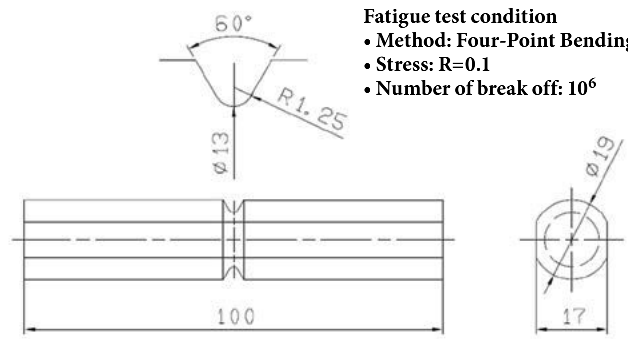

Fig. 2 Shape of specimen for four-point bending fatigue test

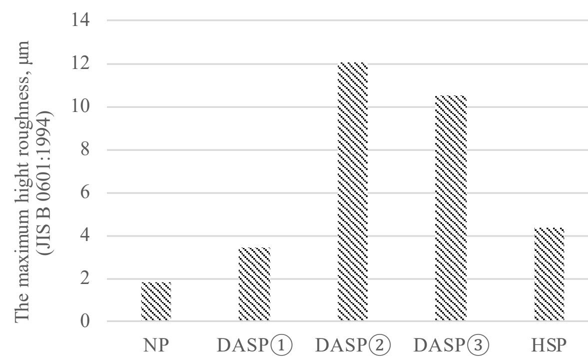

Fig. 3 The maximum height roughness

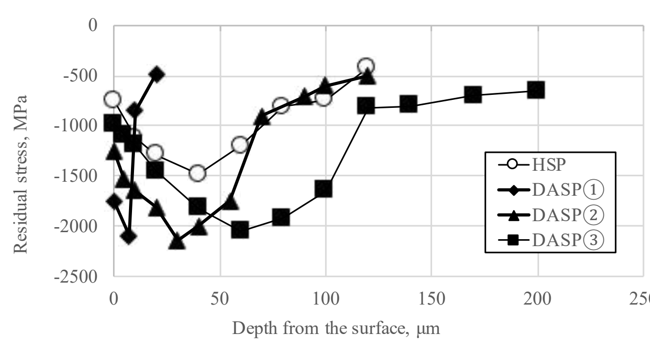

Fig. 4 Distribution of residual stress

Fig. 5 on the next page shows the result of the four-point bending fatigue test. DASP① obtained the best fatigue result. The results show that the best fatigue properties were obtained by fine particle shot peening conditions where the peening effects are only limited to a limited area of the surface which may have reduced the early fatigue cracks.

3 • 4 Rolling contact fatigue test

In order to evaluate the rolling contact fatigue characteristics of fine particle, shot peening was carried out on vacuum

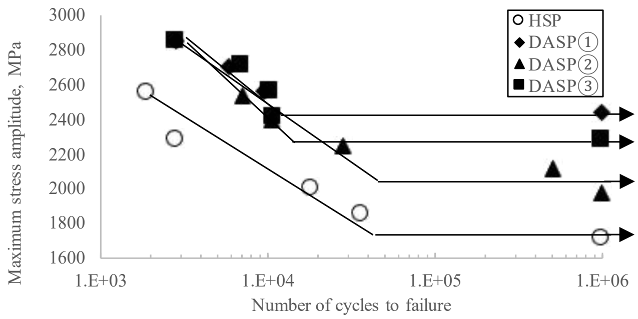

Fig. 5 Result of four-point bending fatigue test

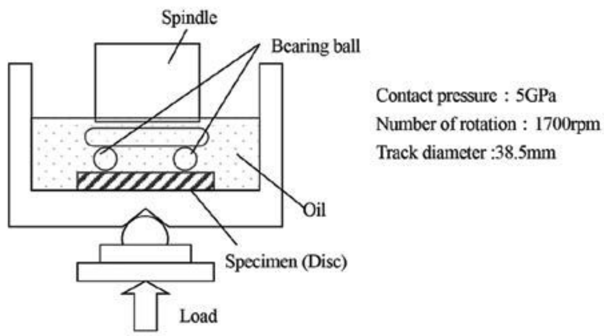

Fig. 6 Method of contact rotating fatigue test

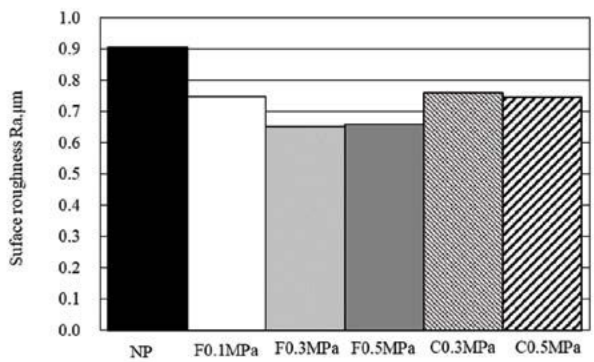

Fig. 7 Surface roughness after shot peening

carburized material. After machining, the specimen was polished before vacuum carburizing. The surface hardness is approximately 800HV. The conditions were selected so that surface roughness after shot peening is smaller than that of the untreated material. Two types of shot were used: Fine particle shot and conventional shot. In the case of fine particle shot peening condition, the air pressure are 0.1MPa, 0.3MPa, 0.5MPa. Also, in the case of conventional shot peening condition, the air pressure are 3MPa, 0.5MPa. Table 4 shows the shot peening conditions. In this table, F means Fine, C means Conventional.

Table 4 Shot peening condition for rolling contact fatigue test

Mark	F0.1MPa	F0.3MPa	F0.5MPa	C0.3MPa	C0.5MPa
Diameter of shot (mm)	0.05 (Amorphous)	0.05 (Amorphous)	0.05 (Amorphous)	0.03 (CCW)	0.03 (CCW)
Shot hardness (HV)	900	900	900	800	800

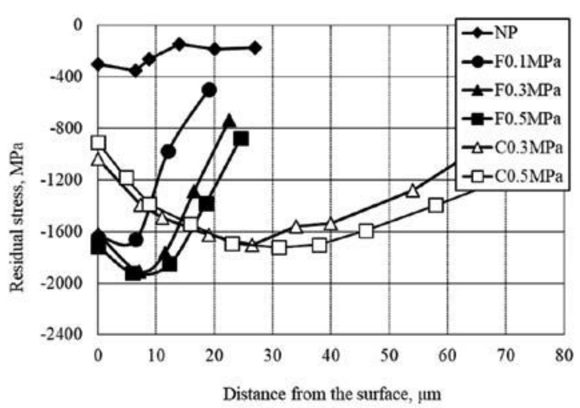

Fig. 8 Distribution of residual stress

Fig. 6 shows shape of specimen and method of experiment are described. Fig. 7 shows result of surface roughness. In the case of fine particle shot peening condition which uses 0.5mm diameter shot, the surface roughness is improved slightly due to increased air pressure. This was also the same in the conditions using conventional shot.

Fig. 8 shows the distribution of residual stress after shot peening. In the case of fine particle shot, the maximum residual stress is increasing when air pressure is increasing. On the other hand, in the case of conventional shot peening condition, the maximum residual stress is almost the same when air pressure changed. In addition, the compressive residual stress value near the surface is smaller than that of the condition using fine particle shot.

Fig. 9 shows result of rolling contact fatigue test. Best rolling fatigue properties were obtained when fine particle shot was processed at an air pressure of 0.5 MPa. On the other hand, the fatigue properties of conventional shot peening condition is almost same as the non-peened specimen.

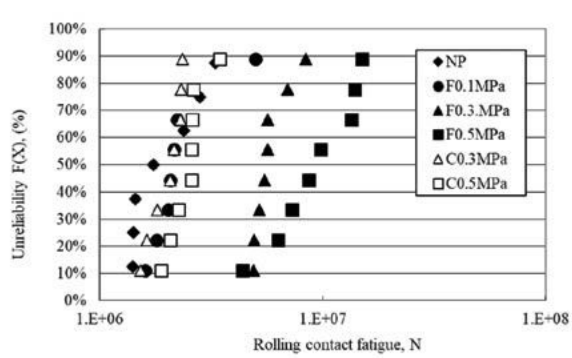

Fig. 9 Result of rolling contact fatigue test

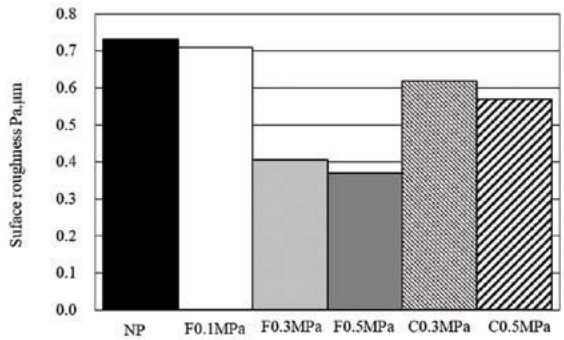

Fig. 10 Surface roughness after rolling contact fatigue test Pa (μm)

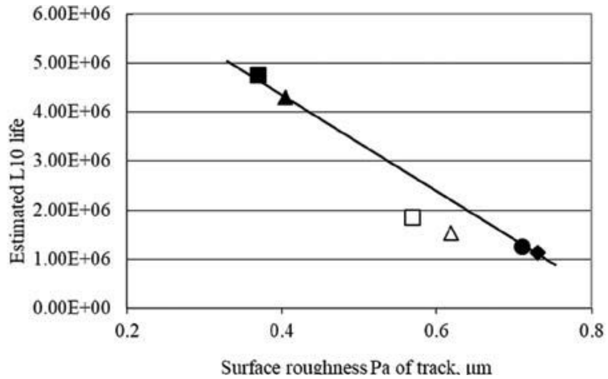

Fig. 11 The relationship between surface roughness of track after fatigue test and L10 life

Fig. 10 shows surface roughness Pa after rolling contact fatigue test. In the case of fine particle conditions, the surface roughness is reduced when the air pressure is high. On the other hand, under conditions of conventional shots, the roughness of the track increases as the air pressure increases.

The primary regression equation was obtained from the Weibull plots obtained from each shot peening condition. The obtained regression equation was used to estimate the rolling contact fatigue life L10 life N at unreliability F(X)=10%. Fig. 11 shows the relationship between surface roughness Ra and 0 N. Fig. 11 shows the relationship between surface roughness Ra and L10 life N.

From Fig. 11, it can be observed that under the condition of direct pressure, the L10 lifetime N increases with decreasing surface roughness. However, in the gravity type, the L10 life N was lower even though the surface roughness was lower.

4. CONCLUSION

In order to evaluate the fatigue strength characteristics of fine particle shot peening condition, a four-point bending fatigue test and a rolling fatigue test were conducted on vacuum carburized material.

This is due to the peening effect of the residual stress introduced near the surface by fine particle shot.

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Effects of Shot Peening on the Fatigue Strength of Parts Produced by Additive Manufacturing

WITH MORE THAN 55 YEARS of experience, FerroECOBlast® Europe, based in Dolenjske Toplice, Slovenia, is one of the global leaders in the field of surface treatment technologies. What makes them stand out from the crowd is their dedication to research and development. This study, performed by their R&D department in collaboration with the Jožef Stefan Institute—the leading scientific laboratory from Slovenia and Joanneum Research Centre from Graz—explores the effects of shot peening on additively manufactured parts.

Due to the outstanding growth of the additive industry (also known as 3D printing), new guidelines and requirements appeared in the surface treatment of unconventional structures and materials. Cold micro-forging, better known as shot peening, is a well-known surface treatment process, commonly used on machine parts in the most demanding industries such as aerospace and automotive. Shot peening improves the technological properties of machine parts and increases their lifetime.

The question arises as to what extent the porosity and resulting micro-cracks affect the mechanical characteristics of the 3D printed part and what can be done to improve it. Research is being conducted into various directions: annealing and the consequential change of the metal microstructure, compression/rolling and probably the most appropriate of all, a modern shot peening process. Since AM technologies are relatively new and the effect of shot peening on such machine parts has not yet been extensively researched, our company decided to conduct a study about the effects of shot peening on metal parts, manufactured by Additive Manufacturing.

TEST OVERVIEW

The different 3D printing processes facilitate the manufacturing of complex parts and prototype pieces, making it difficult to select a typical machine part manufactured using these processes as a test subject. We chose a common test piece that is often used to perform fatigue strength tests in laboratories. The test pieces were manufactured using the SLM (selective laser melting) process, also known as LPBF (Laser Powder Bead Fusion). As for materials, we selected three different frequently used metal alloys:

1. Aluminum Alloy AlSi10Mg
2. Maraging steel MS1 (DIN 1.2709)
3. Titanium Alloy Ti6Al4V

Figure 1: Test subject – 3D printed test piece
Left: Raw, untreated part • Right: Ground, before shot peening

HEAT TREATMENT

The 3D printed test pieces were cleaned of residual dust and oxides, followed by annealing and aging. The test pieces were then ground to their final dimension to ensure dimensional accuracy and better technical properties of the test parts. Each of the selected materials required a different heat treatment as seen in Table 1.

Table 1: Test pieces heat treatment parameters for each selected material

	Process	Temperature (°C)	Time (min)
AlSi10MG	Annealing	270	90
MS 1	Aging	490	360
Ti6-Al4	Annealing	650	180

MECHANICAL TREATMENT

Since the test pieces produced by AM didn't have a sufficiently precise shape after heat treatment, mechanical post-processing, namely grinding, was required to ensure the precise geometry needed for testing. This way, we obtained accurate results during permanent dynamic strength testing. All tested parts were manufactured according to the standard shape and dimensions of common laboratory test pieces.

SHOT PEENING

The last process before testing was shot peening. The selected parameters were empirically determined according to the most common parameters in practice for each particular type of conventional base material. To determine the most appropriate method, three shot peening methods with different types of shot and different intensities were selected for each tested material: Steel shot ASH110, ceramic shot Z150 and a combination of both ASH110 and Z150 for double peening.

Table 2: Shot peening parameters for AlSi10Mg, MS1 and Ti6-Al4-V samples

No. Pieces	Abrasive	Coverage	Intensity	Intensity	Intensity
			Al Si10Mg	MS1	Ti6-Al4-V
5	**ASH110**	100%	4-7A	6-10A	6-10A
5	**Z150**	100%	4-7A	4-7A	4-7A
5	**ASH110 + Z150**	100 + 100%	4-7A	6-10A + 4-7A	6-10A + 4-7A

Figure 2: Shot peening of samples in the machine

FATIGUE STRENGTH TESTING

Tests for fatigue strength were performed in the laboratory with a dedicated machine on five samples that had not been treated with shot peening. The goal was to determine the load required to reach the breaking point of the test piece in 10^5 cycles and at a frequency of approximately 70 Hz. After determining the parameters, we tested five more reference pieces with the same parameters which again were not treated with shot peening, and five more pieces for each individual material and each type of shot peening separately for a total of 60 tests.

RESULTS OF FATIGUE STRENGTH TESTING

As shown in the diagrams below, shot peening had a very positive effect on the lasting dynamic strength of the tested pieces. A reference piece, not treated with shot peening, reached breaking point in an average of 10^5 cycles, while pieces treated with shot peening survived from an average of 5×10^5, and up to 2×10^6 cycles. The number of cycles required for failure depends on the shot peening parameters as well as on the base material of the tested piece.

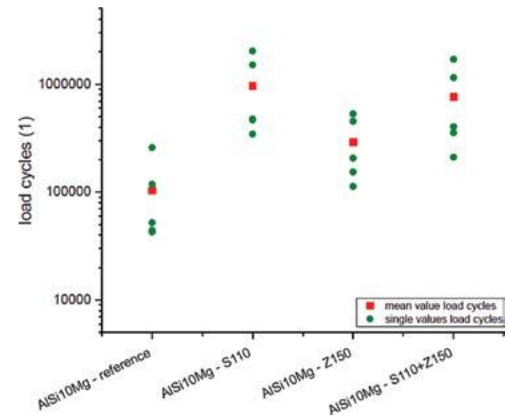


Figure 3. Diagram of tests on AlSi10Mg samples

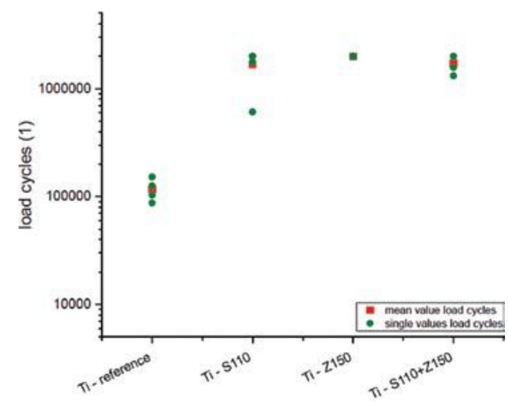


Figure 4: Diagram of tests on Ti6-Al4V samples

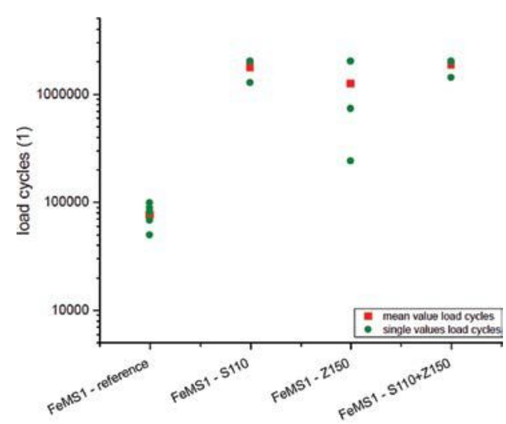
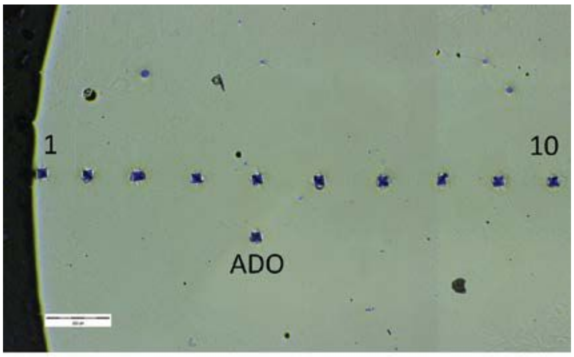


Figure 5: Diagram of tests on MS1 samples

METALLURGICAL ANALYSIS

The purpose of the metallurgical analysis was to check the effect of shot peening on the base material of the tested samples, the result of which is best reflected in the microhardness. Measurements were performed on the same kind of samples tested for sustained dynamic strength.



$$\Delta^{XY} > 30 \cdot h_{max} = 30 \cdot 4.7 = 141\ \mu m$$

Figure 6: Image of microhardness measurement of samples

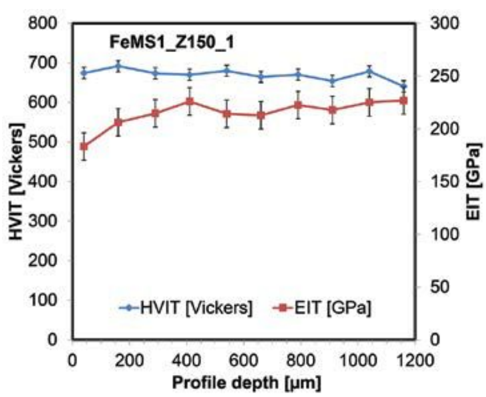


Figure 7: Example of a graph of HV microhardness measurement and modulus of elasticity of a sample of MS1

SUMMARY

The results of the research confirmed a significant positive effect of shot peening on the fatigue strength of parts produced by AM, regardless of the base material.

The greatest effect was detected on the titanium alloy Ti6-Al4V where the lifetime was extended up to 20 times. It could have been even better, but we stopped testing at 2 × 10^6 cycles. Samples made of MS1 steel showed a lifetime extension of approximately 15 times, and finally samples made of AlSi10Mg, where the improvement was up to 8-10 times.

The results show the best outcome is obtained with shot peening using steel shot S110, followed by double peening with steel and ceramic shot S110 + Z150 and concluding with ceramic shot Z150. Results for pieces made of AlSi10Mg presented the largest deviation, followed by the steel samples, while with Ti6-Al4V all tested methods of shot peening produced very good results.

The effects of shot peening on the microhardness of the material, as the metallurgical analysis has shown, were not significant. Only a slight increase of microhardness has been detected on the surface and up to 200-300 µm in depth. The best effect was detected with double peening with S110 + Z150, which displayed an increase of the modulus of elasticity.

Shot peening significantly improves the mechanical properties, fatigue strength and corrosion resistance of products produced with AM processes thus extending their lifetime.

Therefore, the manufacturer is able to optimize the designs of such products, reducing their weight, which in the end means a faster and more cost-effective production process and significant energy savings during operation.

As shown in this study, keeping shot peening in mind from the design phase makes a lot of sense for all metal parts produced by additive manufacturing methods.

Figure 8: One of FerroECOBlast®'s many automatic shot peening machines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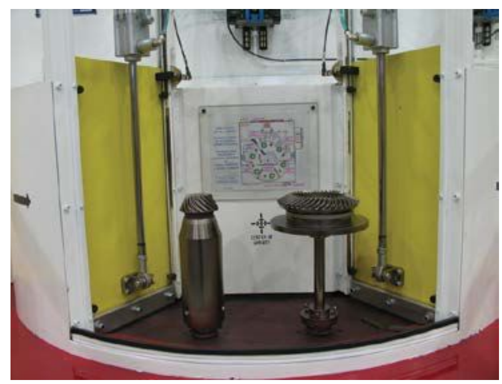

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ACADEMIC STUDY

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Back to Basics: Peening Intensity

INTRODUCTION

Peening Intensity and Coverage are our two main shot-peening parameters. As such, they cover separate aspects of shot peening. Coverage will be the subject of the next article in this mini-series.

Peening intensity, aka Almen intensity and saturation intensity, is currently unambiguously defined—thanks to the adoption and availability of dedicated computer programs and a precise definition. This definition states that "Peening intensity is the arc height of a point on an Almen curve such that doubling the peening time increases the arc height by 10%." Fig.1 illustrates the definition applied using a computer program.

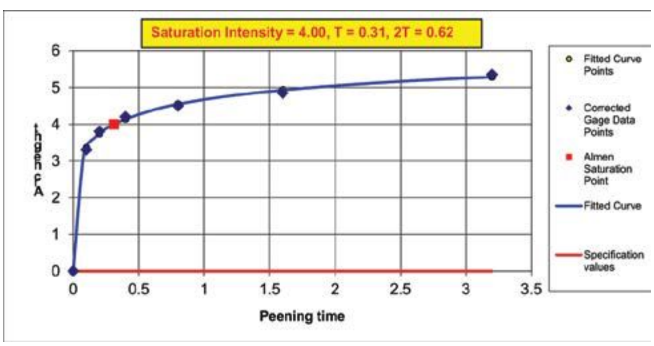

Fig.1. Peening intensity (saturation intensity) as arc height satisfying definition.

The most important feature of peening intensity is that it is directly related to the thickness of the work-hardened, compressively stressed "magic skin." This is illustrated schematically by fig.2.

As the peening intensity increases so does the thickness of the "magic skin." For a given peening intensity the skin thickness also increases with the softness of the component. The optimum skin thickness generally increases with the thickness of the component. An analogy from the animal world is that elephants have thick skins whereas mice have relatively thin skins. It follows that peening intensity is a very important, basic parameter. The level of peening intensity must be measured with reasonable accuracy and then related to process parameters such as shot size and velocity.

The mechanics of peening intensity measurement are familiar to all shot peeners and are amply explained in J442. This article therefore concentrates on the basic principles involved.

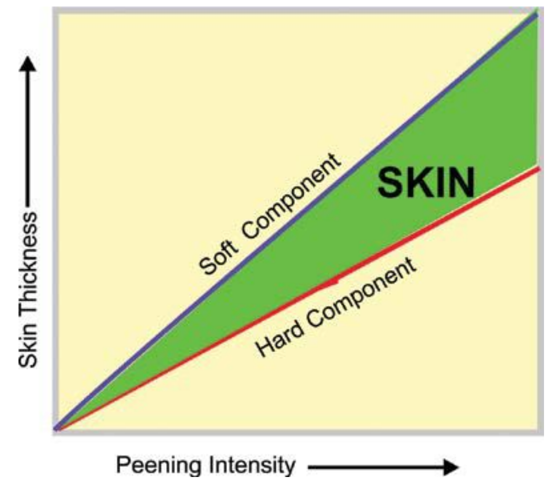

Fig.2. Relationship between peening intensity and skin thickness.

PEENING INTENSITY VERSUS SHOT SIZE

The thickness of the "magic skin" is also directly proportional to the size of shot being used. Small shot is used to produce a thin skin whereas large shot is used to produce a thick skin. Fig.3 shows the effects induced by a single indentation. Each individual indentation makes a contribution to the curvature of a peened Almen strip. The greater the radius, **r**, of the impacting spherical particle the greater will be the depth, **h**, of the indentation and hence the greater the contribution to the depth, **t**, of the "magic skin." The indent material, shaded yellow, has to go sideways thereby producing an outflow of the surface and hence curvature.

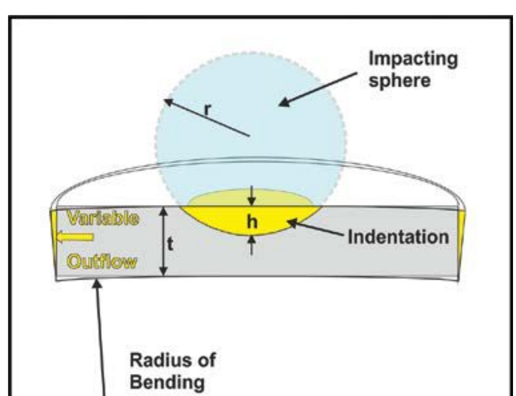

Fig.3. Single indentation causing outflow and thereby contributing to Almen strip curvature.

A single indentation makes only a tiny contribution to Almen strip curvature. This tiny contribution depends on the size of the indentation. Numerous indentations are needed to induce the arc height that we measure. Interestingly there is a linear relationship between declared peening intensity and shot size provided that we keep all other peening parameters constant. This is illustrated in fig.4 which is based on actual data produced for wheel-blasting when all other peening parameters were kept constant.

Fig.4. Peening intensity versus shot size.

DATA

Data is an essential feature of shot peening. Without it shot peening would not exist. Peening intensity estimation requires data points. Each data point consists of the deflection measured on an Almen strip peened for a known time (or its equivalent). A set of these points is then used to derive a peening intensity curve (aka saturation curve). This curve is then analysed to assign a peening intensity value.

It cannot be emphasised too strongly that shot peening data has real value. Think of each data point as being worth at least a dollar. For a complete set of data points, saturation curve and derived intensity value, we have at least a double figure's worth in dollars. Data should be stored in a database (aka data bank). The term "bank" properly emphasises the value of data. Microsoft's Excel allows creation of a database. Stored data can then be accessed using the sorting feature. A parallel is a Google search, which involves entering words as a sorting mechanism for its vast database. The main value of peening data also lies in being able to access it at any future date. This accessibility has many advantages, e.g., saving time when having to achieve the same peening intensity with the same peening parameters (shot type and size, air pressure, nozzle size, required peening intensity, etc.).

A shot peener's basic database should include the peening parameters, peening date and a copy of the data set and curve-fitting used to estimate the peening intensity. Armed with such a database, sorting can be used to answer such questions as "When and how did we last achieve a 5 - 7 peening intensity using S170 shot?" This avoids guesswork as to what parameters to employ for a current job.

PEENING INTENSITY ESTIMATION CURVES

Peening intensity is estimated using curves computer-fitted to the arc heights of a number of Almen strips that have been peened for different lengths of time using the same shot stream. Basic questions are "How many strips and which curve should I use?"

Number of Almen Strips in a Data Set

Specifications require that at least four Almen strips should be used. One or two of these should give arc heights less than the subsequently derived peening intensity and one must exceed the time, 2T, where T is the time associated with the peening intensity point.

The most economical answer to the question "How many strips should I use?" is obviously four. This does not mean that four is the best choice. There are two reasons why more than four could be a better choice. The first reason is that each individual data point is subject to variability—repeating the exposure for the same peening time yields slightly different arc heights. Using extra data points helps to iron out this variability. The second reason is that the larger the number of data points in a set, the closer will be the computer-fit to the true shape of a saturation curve. Table 1 is an actual data set that is used in this article.

Table 1. Six-point data set

Strip No.	Peening Time	Arc Height
1	0.25	10.8
2	0.50	12.9
3	0.75	13.7
4	1	14.4
5	2	15.7
6	4	16.4

Selecting the Equation of Computer-Fitted Curve

Computers use a program that finds the parameters of a pre-selected equation. The program best-fits the data that it is supplied with. Users may or may not be in a position to pre-select the equation employed. The author's Solver Suite does offer several choices. Any program used must, however, satisfy specification requirements.

A basic question is "Does it matter which equation I use, if I have a choice?" Different equations will produce slightly different values for the peening intensity that it derives from a given set of data points. This difference is illustrated by figs. 5 and 6 which were created using the same data set (Table 1).

Fig.5 poses a basic question: "Why is the two-parameter fitted curve such a poor fit?" The answer lies in what the computer program has been told to do. It has been told, in effect, that the data points are supposed to have the shape of a simple exponential equation that has only two parameters, a and b. This is incorrect! The proper shape of a saturation


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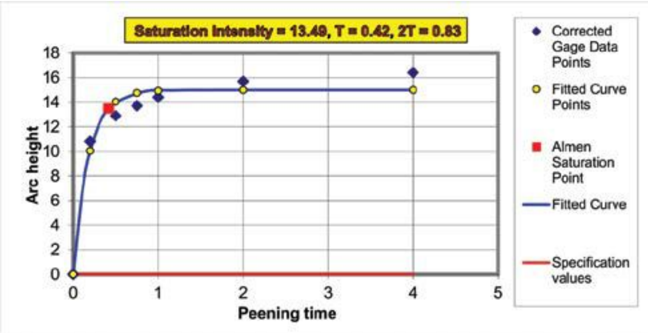

Fig.5. Intensity derivation using a Solver Suite two-parameter equation.

Fig.6. Intensity derivation using a Solver Suite three-parameter equation.

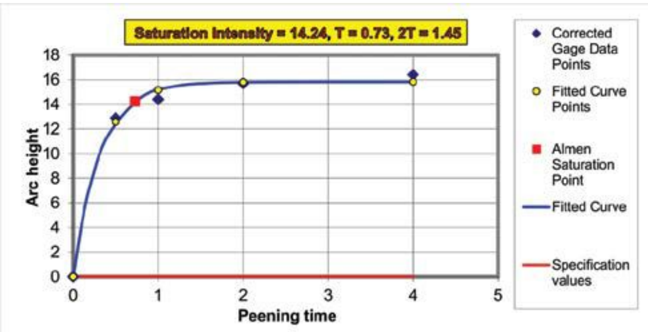

Fig.7. Intensity derivation using a Solver Suite two-parameter equation on reduced data.

curve is much nearer to that of a more complex exponential equation—one that has three parameters, a, b and c. That is why fig.6 presents a good fit.

Comparing the derived intensity values in figs.5 and 6 is interesting. Although the derived intensity-point times differ by a factor of 2, the intensity values are very similar—13.49 and 13.94. Fig.7 is included as an educational exercise. It uses just 4 of the 6 data points from Table 1. The derived peening intensity,14.24, is similar to the 13.49 and 13.94 of figs.5 and 6.

Computer Specification

A very sensible specification, J2597, requires that a computer program must derive peening intensity from all of their table of data sets to within stated limits. In a previous article (TSP Summer 2016) three different computer programs fitted to the same data set gave values of 5.38, 5.47 and 5.49—all well within SAE's stated limits of 4.4 to 6.4.

ACCURACY AND PRECISION OF INTENSITY MEASUREMENTS

Accuracy and precision of measurements are of basic importance in all fields of science and engineering. Although the procedure for intensity measurements is carefully laid out in publications, such as SAE's J442, it cannot prevent variations in both accuracy and precision. The following are definitions of the terms involved:

Accuracy: The difference between measured values and the true value of a particular strip's arc height.

Precision: The random spread of measured arc height values made on the same strip.

To illustrate accuracy and precision, consider the following hypothetical case study.

Case Study: Student Training in Use of Almen Gauge

Three students, Tom, Dick and Harry, were being instructed on the proper use of an Almen Gauge by Big Joe. Each student measured the same peened Almen strip three times using the same Almen gauge but recorded different values as follows:

Tom: 6.12, 6.12 and 6.11 • Dick: 6.10, 6.14 and 6.11
Harry: 5.92, 5.90 and 5.88

Tom piped up, "Dick and I got very similar values but they are very different from Harry's. He must have made a mistake." Big Joe sighed deeply before replying, "All three of you made at least one mistake. You and Dick forgot to zero the gauge before making measurements. Additionally, Dick was careless when replacing the strip on the gauge as was Harry. I can record that you, Tom, had the highest precision but had inaccurate values. Dick had a lower precision and was also inaccurate. Harry had the best accuracy but not the best precision. When I measured the same strip earlier today, I got values of 5.90, 5.90 and 5.89."

After lunch Harry came up to Big Joe with a problem. "Sir, my boss gave me a peened strip to measure that he had found to have a deflection of 7.52 as the average of 10 measurements. I did 10 measurements on the strip during the lunch break that gave an average of 7.19. Why is there such a difference?" "You are keen," said Big Joe. "When you get back, ask when was your firm's gauge last overhauled? It could be that the support balls have now got flats worn into them."

Accuracy and precision are commonly presented graphically as shown in figs.8 to 11. The random spread of measurements—precision—is shown as what statisticians call a "Normal Distribution." This a continuous curve, with individual measurements lying somewhere within the curve,

usually between a range such as a-b. The range increases as precision decreases.

The four situations presented correspond to the type of findings of Tom, Dick, Harry and Big Joe given in the case study. As a quick exercise, associate Tom, Dick, Harry and Big Joe with the most appropriate figure from 8 to 11, (Big Joe as fig.11 would be wrong), answers at the end of the article.

Lack of precision is usually due to a combination of independent factors, e.g., strip thickness and strip placement. This combination is not simply quantitatively additive but has to conform to a definite rule. The range, a-b, is directly proportional to what statisticians call the curve's "standard deviation" and is assigned a value, s. Think about the effect of combining two independent variables that have standard deviations of 1 and 5 respectively. The rule tells us that the standard deviation for the combination is given by:

$$\mathbf{s^2 = 1^2 + 5^2}$$

Expressed verbally, it is saying that the square of the standard deviation is the sum of the squares of the independent variables. For $\mathbf{s^2 = 1^2 + 5^2}$ we have that $\mathbf{s^2 = 1 + 25}$ giving $\mathbf{s = 5.1.}$ We might have thought that the relative contributions would have been in the ratio 5 to 1 but we would have been wrong. With the aid of the statisticians' rule we see that the second variable, value 5, dwarfs the first variable, 1. That does not mean that we can ignore the first variable. As an example, what if the 1 represented strip thickness variability and the 5 represented strip placement errors. Strip manufacturers would be ill-advised to relax their control of strip thickness. That could lead to having a much larger standard deviation, even larger than placement errors.

The Rule of Additive Deviations is very important in all aspects of shot peening.

PEENING INTENSITY CONTROL

The basic principle of peening intensity control is to control the size of the dents being produced. Several factors are involved, principally shot size, velocity and density, together with strip hardness. Each shot particle produces a dent that contributes to the induced strip curvature. A strip peened for a given time (or number of passes) acquires numerous dents. Measured strip curvature is therefore an example of integral calculus as it sums the individual contributions with the maths done for us!

Effective peening intensity control requires a combination of practical experience in the application of the basic principle of dent size control. Fig.12 is a pictorial representation of the principal control factors. These factors can only be considered individually provided that all other peening factors are kept constant.

Shot Size

It was shown in a previous article (TSP Spring 2004, "Prediction

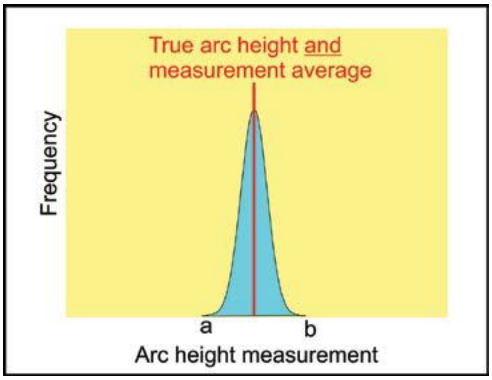

Fig.8. Good accuracy and precision.

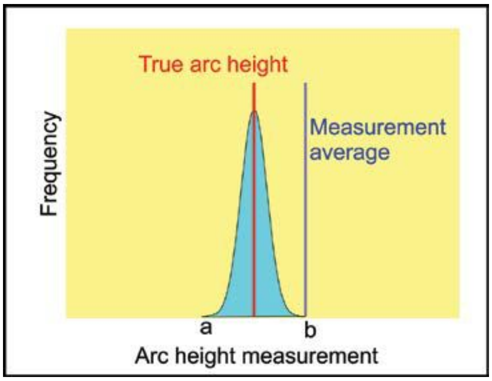

Fig.9. Poor accuracy but good precision.

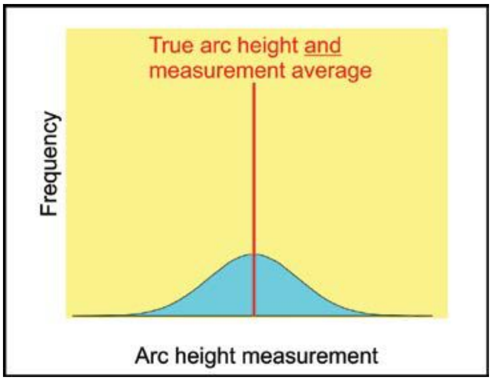

Fig.10. Good accuracy but poor precision.

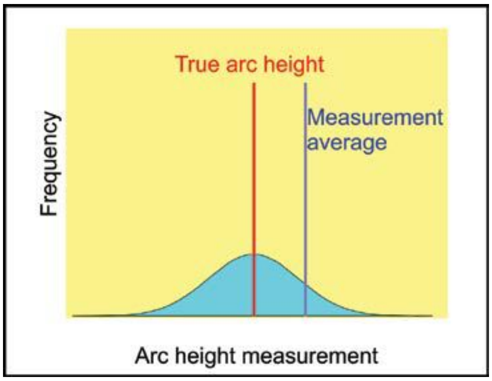

Fig.11. Poor accuracy and poor precision.

and Control of Indent Diameter") that dent diameter is directly proportional to the shot diameter provided all other factors are kept constant. Fig.4 of this article shows this linear relationship between peening intensity for a particular set of peening parameters. Basically, as shot size increases so does peening intensity. Hence, if we want a high peening intensity, we must specify a large shot size. Large dents can be smoothed by applying a second peen using smaller shot.

Cut wire and as-cast shot have different ranges of size within each grade. This is a consequence of the respective manufacturing methods.

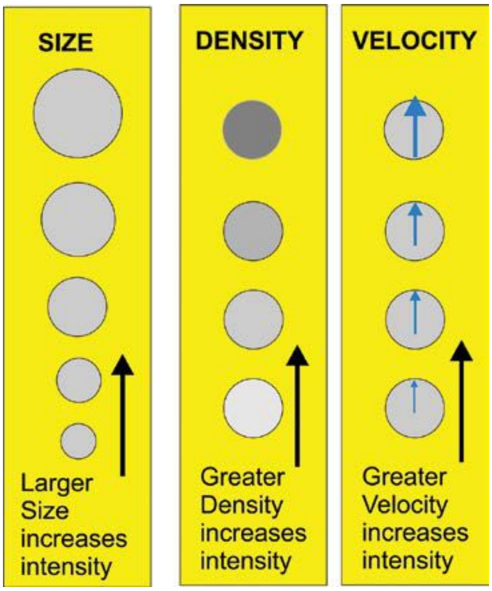

Fig.12. Principal control factors affecting peening intensity.

Density

The main effect of density is to increase the mass of a given size of shot particle thus increasing its kinetic energy and therefore the peening intensity. Steel shot, both ferritic and stainless, has a density of about 8g/cm^3 whereas ceramic shot can vary between 2 and 6g/cm^3. The lower the density, the higher the velocity that must be imparted in order induce a given peening intensity.

The enduring popularity of steel shot lies in its combination of properties (cost, hardness, density, etc.). Steel shot manufacture is a well-established industry, largely because of its massive use in engineering products.

Velocity

Shot velocity, v, is the simplest method of controlling peening intensity. This is because the kinetic energy of shot particles is ½mv^2. Air blast and wheel blast peening provide us with quite different control mechanisms. With air blast peening the emergent air velocity is always constant at about the speed of sound. As the applied air pressure increases so does the density of the air. The greater the density of the air in the nozzle, the greater will be shot acceleration. Nozzle length is also important. Equations have been presented (TSP Winter, 2007 and Spring 2007) that allow prediction of shot velocity:

Air blast

$$\mathbf{v_S = (C_D.A.\rho_A.s/m)^{0.5}\,(v_a - v_s)}$$

where $\mathbf{C_D}$ is the "drag coefficient" (a dimensionless number that depends upon the shape of the object and for a smooth sphere $\mathbf{C_D} \approx 0.5$), **A** is the cross-sectional area of the object, $\boldsymbol{\rho_A}$ is the density of the **compressed** air (1.2kgm^{-3} times the compression ratio), **s** is the nozzle length, $\mathbf{v_a}$ is the velocity of the air stream, **m** is shot mass and $\mathbf{v_s}$ is the velocity of the shot particle. ($\mathbf{v_a} - \mathbf{v_s}$) is termed the "relative velocity" of the particle compared with that of the air stream.

Wheel blast

$$\mathbf{V_S = 2.\pi.N(R^2 + 2.R.L - L^2)^{0.5}}$$

where **N** is wheel speed, **R** is blade tip radius and **L** is blade length.

CONCLUSIONS

The measurement of peening intensity poses an almost unique chain of problems for shot peeners. At times they must feel as if they are jugglers having to handle so many factors—from choice of strip, choice and maintenance of gauge facility, care in measurement technique and using stored data to facilitate successful intensity aims. A great deal depends on prior experience and careful attention to detail.

It cannot be stressed too highly the importance of maintaining a data bank of previous measurements.

Appendix

What is meant by the term "peening intensity"? Of itself, the term is misleading! The word "intensity" implies both magnitude and frequency. Think of a lightning storm. We associate lightning storm intensity with a combination of flash magnitude and flash frequency. Similarly for a hailstorm we associate intensity with a combination of both size and frequency of hailstones. Think of enduring a hailstorm whilst sitting in a stationary car. Hailstones hitting the car's roof will cause a pinging noise. This noise has two components: (1) loudness of individual pings and (2) frequency of pings. The loudness of the individual pings will increase with hailstone size and hailstone velocity. For peening, we can associate intensity with a combination of shot size and shot velocity but not frequency—which affects coverage. That said, we must endure the misleading name as it is so firmly fixed in our vocabulary. A better name would have been "Arcivity"—ability to induce arc height.

Problem Answers

Tom: Fig.9
Dick: Fig.11
Harry: Fig.10
Big Joe: Fig.8

INDUSTRY NEWS

Roxana Hegeman and David Koenig | IEN Industrial Equipment News | www.ien.com

Bombardier Pulls Plug on Learjet, Cuts 1,600 Jobs

Synonymous with lifestyles of the rich and famous, the Learjet is about to fade into aviation history.

WICHITA, Kansas (AP) — Canada's Bombardier announced in February that it will stop production of the Learjet later this year to focus on more profitable planes.

That means the elimination of 1,600 jobs in Canada and the United States, another blow to aircraft manufacturing, which has withered in the pandemic.

The iconic jet was among the first private luxury planes. William Lear based his design in part on military jets. The first Learjet flew in 1963, and more than 3,000 had been built since.

"It was sleek and it had almost a fighter-jet pedigree," said Richard Aboulafia, an aerospace analyst for Teal Group.

"For its time it symbolized personal executive transportation. Besides, Carly Simon put it into a fantastic song — that cemented its place in popular culture."

Along with being a line in Simon's 1971 hit, "You're So Vain," the jet showed up elsewhere in pop culture, including the hit TV show "Mad Men." Frank Sinatra let Elvis Presley borrow his Learjet to elope with Priscilla Beaulieu in 1967.

In recent years, production of the plane had slowed to about one a month. Thursday's decision was foreshadowed in 2015, when Bombardier pulled the plug on an all-new model, the Learjet 85, citing weak demand. Analysts could see the end of the line.

"The only thing the pandemic did was accelerate a sad ending," Aboulafia said.

Bombardier said it will continue to support the Learjet fleet, and existing jets will fly for many more years.

Most of the projected job losses for Montreal-based Bombardier will occur in Canada, with about 700 planned in Quebec and 100 in Ontario. The company said about 250 jobs will be eliminated in Wichita this year and next year, with another 100 job losses scattered across the rest of the U.S.

CEO Eric Martel said in a statement that job cuts are always difficult," but these reductions are absolutely necessary for us to rebuild our company while we continue to navigate through the pandemic."

Air travel has plummeted during the COVID-19 outbreak, causing a sharp drop in demand for new planes.

Bombardier said that ending production of the Learjet later this year will let the company focus on its more profitable Challenger and Global aircraft and accelerate the expansion of its services business.

The Learjet 75 Liberty on runway approach.
Source: Bombardier media library at bombardier.com

The Learjet: The Private Plane That Changed Travel

The following has been adapted from an article by Jonathan Glancey at www.bbc.com.

A high-school dropout named Bill Lear was the mastermind behind an aircraft that flew the world's wealthiest people, writes Jonathan Glancey.

Based partly on the design of a prototype Swiss fighter, its performance was sensational. It could fly as fast as a transatlantic Boeing 707. Up to 40,000 ft, it could outclimb a US Air Force F-86 Sabre.

Its twin General Electric turbojets were a civilian version of those thrusting the latest Northrop F-5 Freedom Fighter way past the sound barrier. The Learjet 23 was aerobatic, potent and glamorous. For many, it was and remains the definitive business jet.

The Learjet, which had gone from design to production to cult status within a very short time, was the brainchild of Bill Lear, a self-taught inventor and high-school dropout born in Hannibal, Missouri in 1902. In the late 1920s Lear invented the Motorola for the Galvin Manufacturing Company. It was the world's first successful car radio. He learned to fly, buying his first aircraft, a Canadian Fleet bi-plane trainer, in 1931 and developed early autopilot systems and radio direction finders for the aircraft industry. These, and other inventions, were to earn him more than $100 million during World War Two.

Lear also invented the 8-track cassette player, a pollution-free steam turbine engine for cars and buses (sadly, unsuccessful) and was forever dreaming up new ideas. He is best known, though, for the Learjet, a project he initiated when he was nearly 60.

In 1960, he founded the Swiss American Aviation Company at Altenrhein, Switzerland, working with the aircraft engineer Dr. Hans-Luzius Studer and a team of Swiss, German and British engineers on the design of a business jet based on Studer's FFA P-16, a prototype supersonic fighter jet.

However, after prototype P-16s crashed, the Swiss Air Force bought British Hawker Hunters instead. Undeterred, Lear brought that project—his first aircraft was built in Switzerland— and a number of key ideas from Studer, back to the US. He would establish Learjet in 1963 in Wichita, Kansas —the home of Cessna and Beechcraft, two rival aircraft manufacturers.

The man had a certain sense of humour, having named his daughter Shanda (as in Shanda Lear), and he quipped upon being handed an investment bond for $1.2m by the US government: "Can you think of any place I can steal more engineers?"

That money went fast, but Lear was lucky. The crash of the first Learjet on a test flight in 1964, with a Federal Aviation Authority pilot at the controls, gave Lear the money he needed to push on with the project. The FAA pilot had forgotten to put the flaps down on take-off. The jet lifted to 10 or 20 feet and then fell to earth. No one was injured, but the aircraft was written off, and Lear received an insurance pay-out of $500,000.

Crashes came to haunt the Learjet. It was a chic, lithe and very fast aircraft and designed to be easy to fly. But, in the world of early business jets, pilot error was rife: within three years of the first sales, 23 out of 104 Learjets crashed, four with fatal results.

Improved pilot training and improved low-speed handling incorporated in the design of the Learjet 24 helped matters, but the 20-series Learjets were involved in too many accidents for anyone's comfort. In January 1977 Frank Sinatra's 82-year-old mother, Dolly, died when the Learjet 24 he had chartered to take her from Palm Springs to Las Vegas for an opening night at Caesar's Palace flew into a blizzard and crashed on Mt San Gorgonio.

Later series, including today's bigger, quieter and far more efficient composite-bodied Learjets made by Bombardier are inherently safe.

Equipment Doesn't Ship Until Rick Approves It

THIS MORNING Clemco Quality Assurance Inspector Rick Frick is giving an RPH-2 900 CFM Dust Collector the once over. He checks that the dust collector's motor is running correctly and confirms that the motor-housing welds are secure. Next, he verifies that the controls in the electrical panel are set properly and that its wiring is correct.

Rick has been with Clemco 30 years, but he has been manning Clemco's new Test and Inspection Cell for only one year—the Test and Inspection Cell was established a year ago as part of Clemco's new Factory Acceptance Program. The program ensures that all Clemco equipment passes rigorous testing and inspection before it ships to customers. The Test and Inspection Cell focuses on large equipment such as cabinets, dust collectors, reclaim systems, blast rooms, and custom-engineered projects.

Rick Frick, one of three Clemco Quality Assurance Inspectors, has been with the company for 30 years.

A GOOD FEELING

"It feels good to know I'm helping Clemco's customers get exactly what they expected when they ordered their equipment," Rick says as he tests the dust collector's tubing for air leaks and proper connections. He finishes checking a total of 62 items on the dust collector while cross-checking his results against diagrams and engineering specs.

Up next is the ZERO® BNP-220 Pressure Blast Cabinet that accompanies the dust collector. Rick confirms that the cabinet's CFM measurements and decibel readings are correct. He then takes the cabinet through a test and inspection checklist as thorough as the one for the dust collector before approving both machines for shipment.

Rick examines an RPH-2 Dust Collector's magnehelic gauge for air leaks and proper connections as part of the Factory Acceptance Program's 62-point inspection checklist.

TAKING EQUIPMENT QUALITY TO A NEW LEVEL

"We've always had quality control procedures throughout the factory," says Jake Tate, Clemco Quality Supervisor. "And Clemco wouldn't be where it is today if for decades we hadn't manufactured quality equipment. But now we are taking monitoring, measuring, and improving equipment quality to a new level."

"Of course, we'd like to have a flawless production floor," Jake adds. "But anybody who has worked in a factory knows that's unrealistic. However, our quality initiatives have led to about a two-thirds reduction in issues since implementing the program. Incorporating the Test and Inspection Cell as the final step in our process has been a huge help. Our approach is working."

Rick checks that the dust-collector motor is rotating correctly and that the motor-housing welds are secure.

PRESS RELEASE
Pierce Cleary | Director of Business Development
CWST | www.cwst.com

Curtiss-Wright Provides Laser Peening to US Department of Energy

CURTISS-WRIGHT'S Surface Technologies Division, a leading global provider of highly engineered surface treatments and analytical services, has announced that it has been selected as a partner with Michigan State University (MSU) for a U.S. Department of Energy Advanced Research Projects Agency-Energy (ARPA-E) program.

The initiative will develop an advanced heat exchanger for supercritical CO_2 generators—a more energy efficient, more compact, and lower cost electric turbine that offers the potential to significantly reduce greenhouse gas emissions. The project will employ MSU-developed HIPPED (Heat Exchanger Intensification Through Powder Processing and Enhanced Design), which features a plate-type heat exchanger that enables lower cost, powder-based advanced additive manufacturing.

"We are very excited to partner with MSU and ARPA-E on this critical new program," said David Rivellini, Senior Vice President and General Manager, Curtiss-Wright Surface Technologies. "Curtiss-Wright's recent breakthrough using laser peening technology coupled with newly developed thermal microstructure engineering (LP+TME) is enabling enhanced performance of nickel-based alloys when subjected to high temperatures and corrosive environments as required for supercritical CO_2 turbine systems."

Surface treatments, such as peening, have not generally been used in high temperature applications due to the fading out of the benefit in elevated temperature environments. However, Curtiss-Wright's LP+TME advanced technology creates improved fatigue and corrosion-fatigue performance in high temperature and corrosive environments, thereby offering the potential for higher temperature turbine operation which translates to improved efficiencies for jet engines and gas turbines. For the ARPA-E development, the Curtiss-Wright LP+TME process will be applied to the heat exchanger material exposed to the high temperature and corrosive environment of the supercritical CO_2 system.

About Curtiss-Wright Corporation
Curtiss-Wright Corporation is a global innovative company that delivers highly engineered, critical function products and services to the commercial, industrial, defense and energy markets. Building on the heritage of Glenn Curtiss and the Wright brothers, Curtiss-Wright has a long tradition of providing reliable solutions through trusted customer relationships. The company employs approximately 8,900 people worldwide.

PRESS RELEASE
Jeffrey Pruitt | Magnetic Inspection Laboratory, Inc.
www.milinc.com

MIL Announces Mark Sullivan as President

MARK SULLIVAN has been named President of Magnetic Inspection Laboratory, Inc. located in Elk Grove Village, Illinois. MIL is one of the largest leaders of non-destructive testing, metal finishing, coatings, and welding services for Aerospace, Defense, and Medical industries.

Mr. Sullivan brings over 25 years of experience to the role of President and he is highly regarded for his success in leading executive teams, growing business value, and his commitment to continuous operational improvement.

Mr. Sullivan is an alumnus of Albion College where he earned his Bachelor's Degree in Economics and Management. He went on to earn his Master of Science degree in Industrial Administration from Krannert Graduate School at Purdue University.

Mr. Sullivan began his career at the Dow Chemical Company working across multiple applications and markets in commercial, management, and leadership roles. He has held the president position at GrafTech International, Cast Nylons Limited, and Buckhorn Incorporated. He successfully improved operating margins and developed new growth at all three companies.

Mr. Sullivan will be working collectively with Tim Schiewe, CEO and Owner of the family-owned business established in 1942. Mr. Sullivan's deep experience and proven accomplishments will be an asset as he helps to achieve profitable growth and adds long-term value to MIL.

Magnetic Inspection Laboratory, Inc. is a globally recognized leader in special processing for critical components of aerospace, defense, medical and power generation industries. Established in 1942 as a one-man operation by Robert Schiewe Sr., MIL has grown to over 115,000 square feet across three facilities. With over 2,500 approvals for NDT, Chemical Processing, Coatings, and Surface Enhancement, MIL is one of the most diversified aerospace special process providers in North America. Awarded the MFC Small Business Award by Lockheed Martin in 2019, MIL is a trusted partner for Boeing, Honeywell, Airbus, Raytheon, GE, Rolls Royce, Space-X, United Technologies, Lockheed Martin and many others. For a full list of our services or more information, visit www.milinc.com.

PRESS RELEASE

Patrick Folick | Production Planning/Business Development | Saturn Machine Works | saturnmachineworks.com

The Saturn Media Blast Swivel

INTRODUCTION

Designed for those who service, supply, manufacture, and use shot peen, abrasive, or media blast equipment, the Saturn Media Blast Swivel from Saturn Machine Works provides 360 degrees of freedom of movement for your hose. The Saturn Media Blast Swivel was created to reduce operator fatigue in the wrists, elbows, and shoulders due to resistive pressure and working with the binding hose.

The swivel is a solution to the daily fatigue operators are experiencing. Our operators have been using the swivel for over three years without any lost time injuries or discomfort.

INNOVATIVE DESIGN

Saturn Media Blast Swivel is an innovative addition to your shot peen operations. When using the swivel, the operator has free and easy movement in the cabinet and is able to reach difficult areas in the part configuration. Operators no longer need to fight with the hose as it rotates freely and it allows for natural motions, reducing operator fatigue and repetitive strain injuries. Swivel bodies are time tested and durable with no serviceable parts. Our unique and patent pending seal design keeps contaminants from entering the bearings, contributing to long continuous service life.

Internal seals and liners stand up to the most abrasive environments from steel shot to hardened stainless shot, to cut steel and heavy grit.

BENEFITS

Reduced operator fatigue and pain

Lessens the impact of fatigue on operators.

- Slim profile and lightweight
- Full 360° rotation of the hose for maximum reach
- Increased product run time without fatigue or pain
- Reduction of OHS claims

Product efficiencies

Reduces work time, maintenance and repair costs, while increasing throughput.

- Part-to-part time decreases
- Performs in very abrasive environments and against harsh media
- Eliminates hose binding
- Reduces time dedicated to dealing with OHS issues
- Long product life available with carbide liner and sealing surfaces
- Field tested and proven
- Patent pending design

Ease of use

Makes blasting simple.

- Simple to install
- Available in various sizes for different hose diameters
- Makes working on inside features easy
- Can be handled by a single user
- Designed to fit onto existing hose for easier hose management and for maximum reach

INDUSTRIAL APPLICATIONS

- Oil and gas
- Automotive
- Ship building
- Bridge building
- Aerospace engineering

ABOUT SATURN MACHINE WORKS

Located in Edmonton, Alberta, Canada, Saturn Machine Works is the go-to, problem-solving machine shop. Established in 1999, Saturn is committed to providing state of the art, innovative solutions and strives to consistently provide top quality turnkey parts from our 24,000 sq. ft. facility for a wide range of industries such as oil and gas, mining, automotive, industrial, and electrical. Saturn is recognized with customers for providing top quality machined parts of all types, as well as prototypes and parts with complex geometries.


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