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PARTICLE VELOCITY SENSOR FOR IMPROVING SHOT PEENING PROCESS CONTROL

Bill Barker, Kevin Young - Progressive Technologies, Inc. - Grand Rapids, MI USA
Luc Pouliot - Tecnar Automation, Ltée - St-Bruno, Québec CANADA

ABSTRACT

The shot peening industry has used Almen strips for many years as a means to measure the intensity of the peening process. As is widely understood, peening intensity is proportional to the particles kinetic energy, therefore if one were able to accurately measure the shot particle velocity you would also be able to determine intensity.

A new non-laser based shot velocity sensor that is capable of detecting particle velocities for a wide range of peening media including steel, stainless steel, glass bead, ceramic and others is described. Examples are presented showing particle velocities and their associated Almen intensities. In addition, results are presented which show that some process parameter combinations yield unstable results.

KEYWORDS

Shot velocity, Almen intensity, saturation curve, kinetic energy, media flow rate, shaded strip method, lance peening

INTRODUCTION

In the shotpeening industry, most people are aware of the fact that you must determine the intensity of your shot stream to help determine its effect on the target surface. The intensity of the shot stream is directly proportional to the particles kinetic energy (1). When a particle impacts the surface of a material, some of that kinetic energy is absorbed and used to cold work the surface and put the materials surface into compression.

Today's method of determining the intensity of the process uses strips of spring steel (Almen strips) with special fixtures to evaluate the energy absorbed into a surface.

As many pneumatic shot peen users know, developing a saturation curve for an actual component can be quite time consuming. First you must select a set of process parameters based on the specified media and size that you believe will provide the required intensity, including nozzle size and type, media flow rate, air pressure and impact angle. Once these items are determined, you then perform peening trials at various exposure times to gather at least four arc heights so you can plot a Saturation curve.

Depending on the part you plan to peen, it could take a few hours to gather enough data to develop just one Saturation curve. Many times the resultant intensity is not within the specification range, or may not provide you with optimized cycle times. Therefore, you must pick a new set of process parameters and re-run the peening trials to gather at least four more arc heights to plot another Saturation Curve, which may or may not yield the intensity you desire. To be honest, setting up a new peening process can take a number of days and can be quite frustrating at times, particularly if there are a number of Almen Strip locations that must all meet specification (see Figure 1).

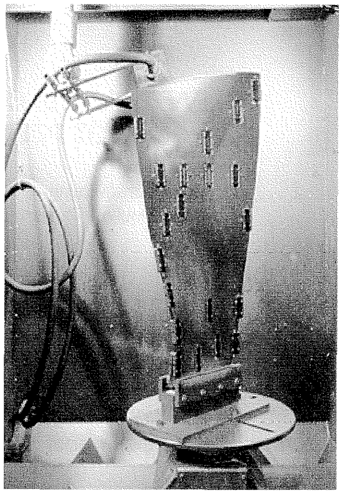


Figure 1 - This turbine engine fan blade has 40 Almen strip locations.

A more optimized method is needed that would allow users to quickly select process parameters that provide known kinetic energies for the shot particles, and thereby dial in the required intensity in a fraction of the time it currently takes.

SHOT VELOCITY SENSOR

PROGRESSIVE Technologies and Tecnar Automation jointly developed a shot velocity measurement device (ShotMeter) that can be used to determine media velocities exiting the nozzle for steel shot as well as ceramic beads, glass beads, aluminum oxides, plastics and other blasting media.

The shot velocity sensor uses a simple method of particle illumination and does not require special safety features. Two electro-optical sensors of a known spacing sense particles as they exit the shot peening nozzle. The signals from the two sensors are compared and the resulting phase shift is used to calculate velocity, with accuracy within 1%.

When we began using the shot velocity sensor to develop shot peening parameters, we believed that particle velocity was directly proportional to air pressure for a given blast nozzle style and inner diameter (ID) (2).

In Figure 2 we show the results of shooting 0.28mm (ASR110) shot through an 8mm (5/16") ID short venturi blast nozzle using three different media flow rates. Both air pressure and media flow were closed loop controlled. Figure 3 shows a similar test using a 9.5mm (3/8") ID medium straight blast nozzle, with similar conditions. In both cases, you see particle velocity increases with higher air pressures, but at some point there is a drop in particle velocities and then a further increase, but at a lower slope.

The point where the velocities drop is dependent on nozzle size, nozzle type, hose diameter, media size and media flow rate and most likely is caused by turbulence in the nozzle at those given conditions. What the shot velocity data demonstrates is that for some nozzles there are portions of the operating range which are unstable.

Figure 2. 8 mm (5/16") Short Venturi Nozzle
ASR110 Shot

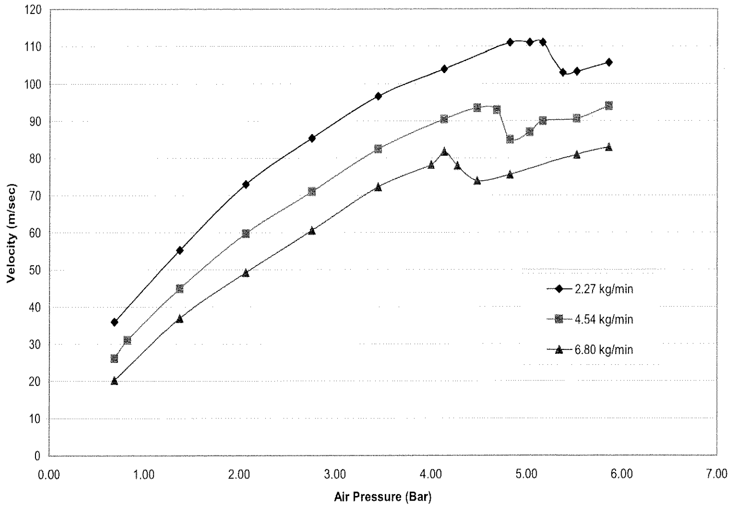
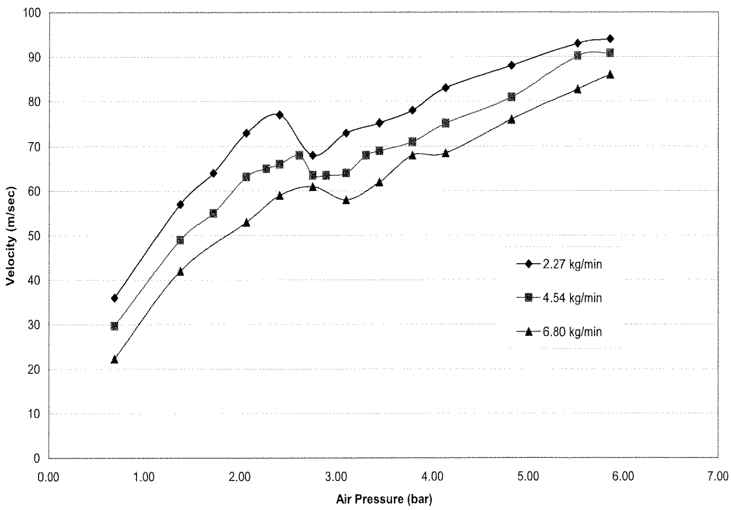


Figure 3. 9.5 mm (3/8") Medium Straight
ASR110 Shot



In the case of the 8mm (5/16") short venturi nozzle (Figure 2) operating with 6.8 kg/min (15 lb/min) media flow, if the peening operation required a particle velocity of 80 m/sec to achieve the correct intensity the operator may have been running at 5.5 bar (80 PSI) when 4 bar (60 PSI) would yield the same results with a 22% reduction in total air consumption. In addition, you would not want to operate in one of the velocity "valleys" since reducing air pressure would actually increase your intensity, making process troubleshooting very difficult.

If you compare Figure 2 and Figure 3, you will also note that in Figure 2 as media flow is increased from 2.27 to 6.80 kg/min (5 to 15 lbs/min), the velocity discontinuity (dip) occurs at lower air pressures. However, in Figure 3 the velocity discontinuity occurs at higher air pressures as media flow is increased.

We believe this data suggests that no hard and fast rules will apply to every shot peening case. Every nozzle and media combination will behave differently. Therefore, the best way to evaluate your process is to get a baseline set of velocity data using your machine and your operating parameters.

VELOCITY VERSUS INTENSITY

The comparison of air pressure and media flow rate to particle velocity is interesting, but the real question is how closely does particle velocity correlate to Almen Intensity?

In Figure 2 we showed velocity data for a 8mm (5/16") short venturi nozzle flowing three different media flow rates. Figure 4 shows only the set of data for 4.54 kg/min (10 lb/min) media flow, but also graphs intensity for five sets of air pressures. As you can see, intensity rises with increasing air pressure, but the intensity dips in the region of turbulence and then increases again at higher air pressures correlating exactly with the velocity data.

We have tested the Shotmeter using a wide variety of media and sizes, and have found that you can predict the intensity for a given shot type and size by measuring particle velocity regardless of media flow rates, since the intensity charts are very linear (see Figures 5 and 6).

Figure 4.
8mm Short Venturi
Velocity and Intensity

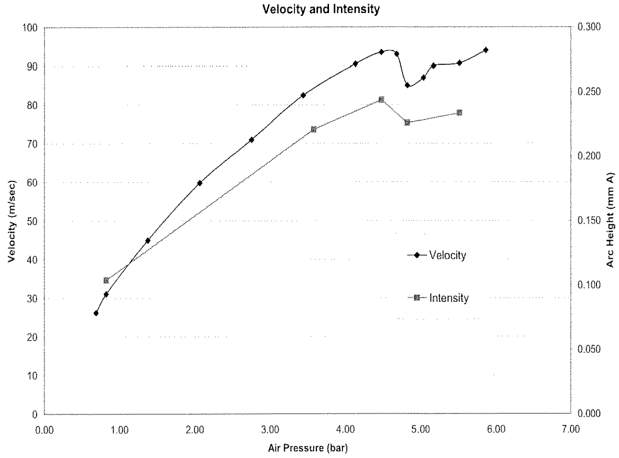


Figure 5.
ASR110 Shot Velocity vs. Intensity

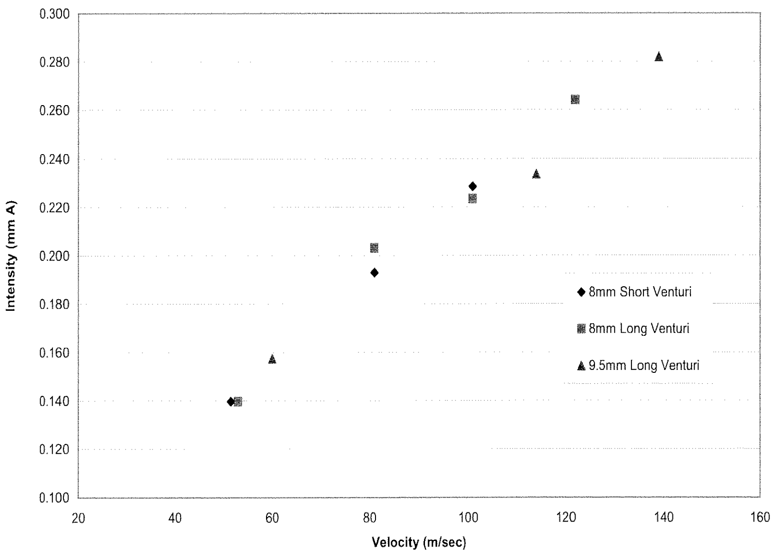
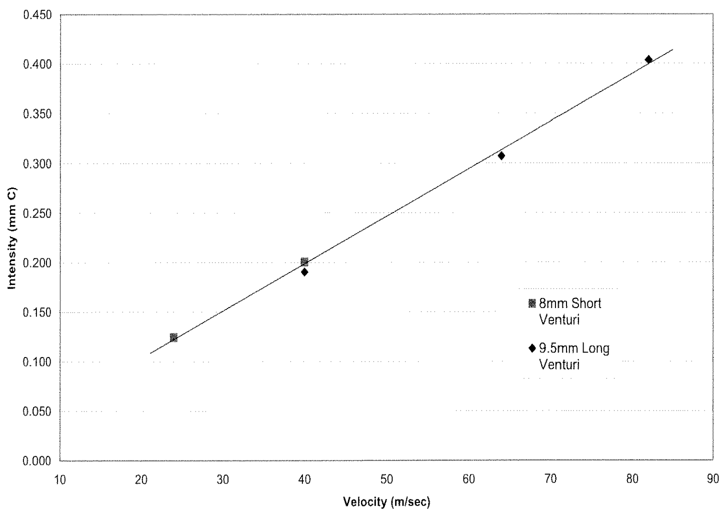


Figure 6
ASR550 Shot Velocity Vs Intensity



LANCE PEENING

Determining intensity has historically been difficult when shot peening holes with diameters smaller than the width of an Almen strip (19mm). Therefore, we conducted a set of tests to determine if one could accurately calculate intensity when peening holes with small diameter lances by evaluating shot particle velocity.

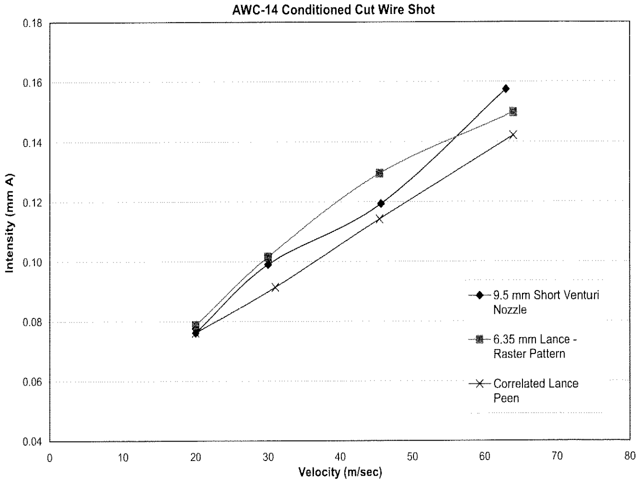
One method for determining intensity for small holes is to use only a portion of the Almen strip, known as shaded strip peening (3). This test involved peening a 12.7 mm (1/2") diameter hole using AWC-14 conditioned cut wire shot. Intensities were determined using Almen A strips peened with a 9.5 mm ID (3/8") short venturi nozzle. We then covered an Almen N strip with a plate, exposing only 12.7 mm (1/2") of width, and peened using the same full strip parameters from above. This data allowed us to develop a correlation curve between fully peened A strip readings, and their corresponding "shaded" N strip readings.

Next we used a 6.35 mm (¼") OD rotating lance device to peen a 12.7 mm diameter hole fixture which also included an Almen strip mount. The N strip was only peened for 12.7 mm width. The particle velocities exiting the lance were then plotted against correlated Almen A strip intensity.

In addition to these two sets of data, we also peened a full Almen A strip using the 6.35 mm OD rotary lance in a raster pattern to determine if it made any difference in intensity.

The results shown in Figure 7 indicate that by measuring the particle velocity for a given size of shot, we can accurately predict the resulting intensity, regardless if the media is

Figure 7.
Intensity Comparison for 12.7 mm Hole Peen
AWC-14 Conditioned Cut Wire Shot



delivered by a standard pressure blast nozzle or by a rotating ID lance nozzle using shaded strip method, or by rastering a rotating lance over the entire Almen strip.

CONCLUSION

Shot velocity measurements provide a useful tool for developing and evaluating shot peening operations. This data enables users to quickly dial in a set of process parameters which yield the desired particle kinetic energies without the need for running numerous saturation curves, drastically reducing process development times.

Measuring shot velocity can also be used as a performance monitor. Most pneumatic shot peening systems monitor air pressure and media flow rates, but they are unable to account for nozzle wear, hose wear or component failures. When used as part of a process verification strategy, shot velocity data enables users to monitor actual peening conditions and provides for data collection and process reporting.

Shot velocity measurements can become a key aspect of a total machine calibration plan, since specified Intensity parameters can be benchmarked and then validated on a regular basis very quickly using either a machine integrated sensor or portable version.

With enough history and statistical data, shot velocity sensors could lead the shot peening industry toward the ultimate goal of machine and process verification, thereby minimizing the number of Almen intensity verification runs.

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