Shotmeter
A New Tool for Evaluating Shot Peening Intensity

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In the world of shotpeening, 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. 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.

When the Almen strips are shot peened on one side, the strips will bow after they are removed from their holding fixtures, and the amount of bow or curvature can be measured using a special gage called an Almen Gage (see Figure 1).

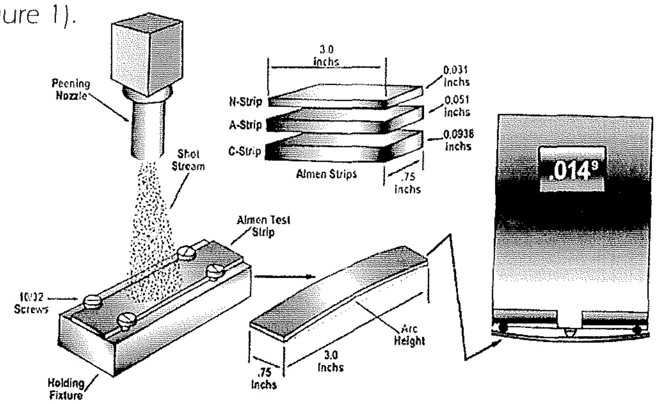

Figure 1 - Almen Strips bow after peening, and are measured with an Almen Gage.

The amount that the Almen strip bows is known as its arc height, and is normally measured in 1/1000 of an inch, or in millimeters. To determine the intensity of a peening process, a series of arc height readings for different time periods are recorded and plotted on a curve called a saturation curve (see Figure 2).

The saturation point of the curve, commonly referred to as "T1", is the first point on a curve (not necessarily a data point), beyond which the curve or arc height of the Almen strip increases by no more than 10% when the peening time is doubled ("2T").

As many 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 4 arc heights so you can plot a saturation curve.

Depending on the part you plan to peen, it could take a few hours 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 again to gather at least 4 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 3).

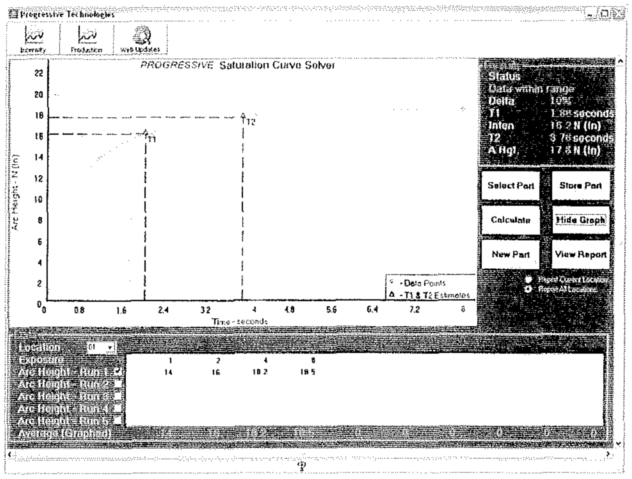

Figure 2 - Saturation Curve - Plot of arc height versus time. Note that the saturation point, T1, does not necessarily correspond to a data point.

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.

Fortunately, there is a new product available to the market that will make this process much faster and easier.

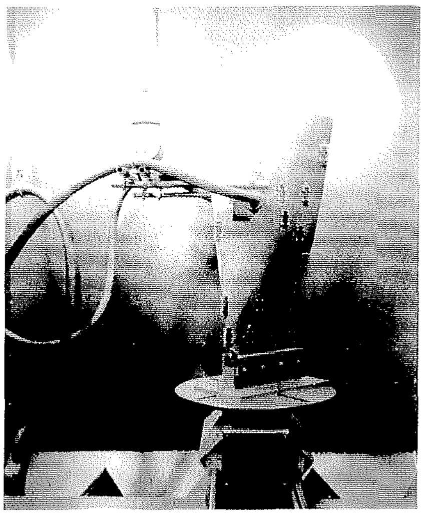

Figure 3 - This turbine engine fan blade has 40 Almen strip locations.

Shotmeter, a joint solution between PROGRESSIVE TECHNOLOGIES and Tecnar Automation, is a shot velocity measurement device that can be used to determine media velocities exiting the nozzle for all steel shot sizes as well as ceramic

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beads, glass beads, aluminum oxides, plastics and other blasting media.

The Shotmeter uses a simple method of particle illumination and does not require special safety features (Figure 4). 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 an accuracy within 1%.

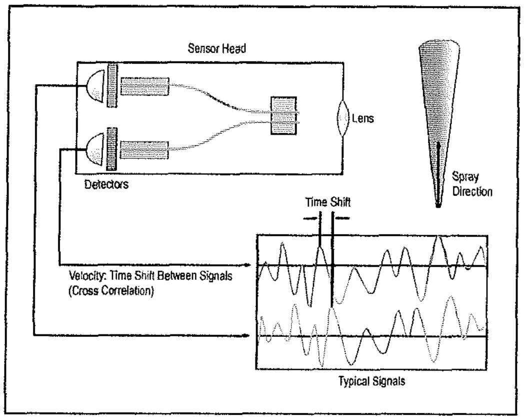

Figure 4 - Shotmeter sensor uses time shift of signal to determine velocity.

The particle velocity data is collected and displayed on a Windows-based computer system and is extremely easy to use. In addition to particle velocity, the system also calculates a relative flow value that can be correlated to media flow rate in pounds or kilograms per minute. All of this data is archived for statistical evaluation.

The Shotmeter system is offered in both a portable configuration (Figure 5), as well as integrated with PROGRESSIVE's process control and integrated monitoring system (PRIMS). Both configurations provide the user with adjustable setpoints and alarms for shot velocity and relative flow readings (Figure 6).

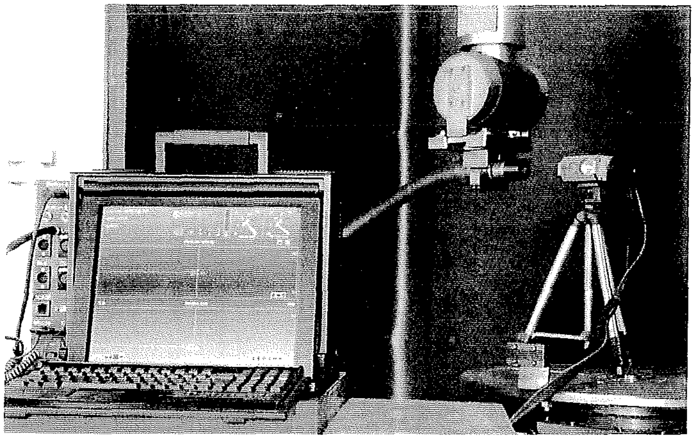

Figure 5 - Shotmeter system on a PROGRESSIVE CNC shot peen machine.

The portable unit's sensing head is very lightweight and easy to position using the camera style tripod mount provided. Users simply position the sensor head perpendicular to the shot stream and focus the unit to the center of the nozzle trajectory. Within minutes you can be gathering velocity data.

What does the Shotmeter tell you?

When we began using the Shotmeter to develop shot peening parameters, we thought it would demonstrate that particle velocities were directly proportional to air pressure for a given blast nozzle style and ID, since this has always been assumed. In reality, particle velocities certainly

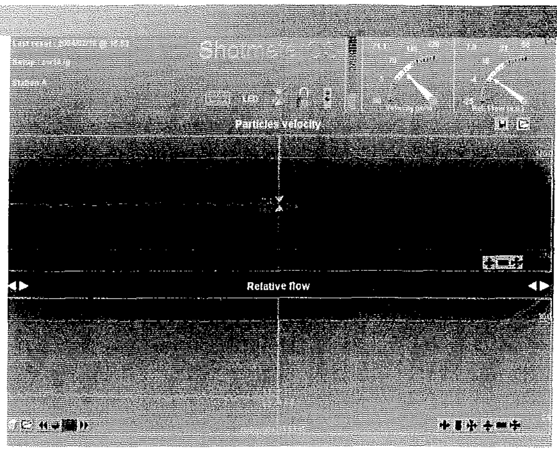

Figure 6 - Shotmeter particle velocity display screen.

increase with increasing air pressure, but they don't always increase in a linear fashion and sometimes we see non-linear zones as well.

In Figure 7 we show the results of shooting S110 shot through a 5/16" (8mm) ID short venturi blast nozzle using three different media flow rates. Both air pressure and media flow were closed loop controlled. Figure 8 shows a similar test using a 3/8" (9.5mm) ID medium straight blast nozzle, with similar conditions. In both cases, you see particle velocities increase with higher air pressures, but at some point there is a drop in particle velocities and then a further increase, but at a slower pace.

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 Shotmeter demonstrates is that there are portions of a nozzle's operating range where you don't want to operate since they are unstable zones.

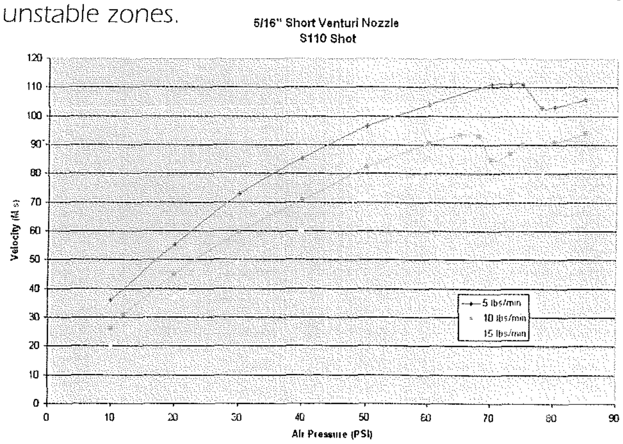

Figure 7 - Shotmeter measured velocity versus air pressure for 5/16" short venturi nozzle and S110 shot.

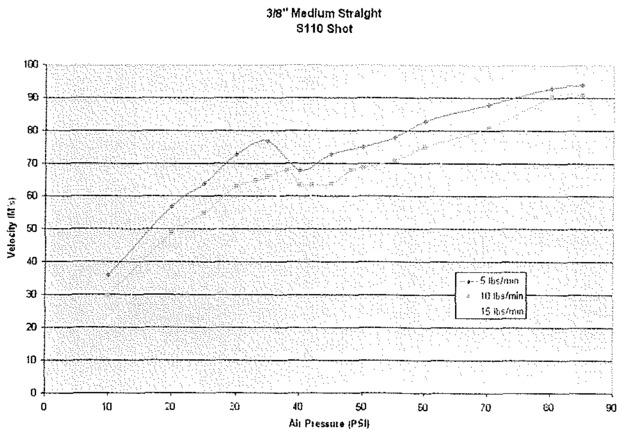

Figure 8 - Shotmeter measured velocity versus air pressure for 3/8" medium straight nozzle and S110 shot.

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In the case of the 5/16" (8mm) short venturi nozzle (Figure 7) operating with 15 lb/min (6.8 kg/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 80 PSI (5.5 bar) when 60 PSI (4 bar) 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, and make process troubleshooting very difficult.

If you compare Figure 7 and Figure 8, you will also note that in Figure 7 as media flow is increased from 5 to 15 lbs/min (2.27 to 6.8 kg/min), the velocity valley occurs at lower air pressures. However, in Figure 8 the velocity valley occurs at higher air pressures as media flow is increased.

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

How do velocities correlate to intensities?

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 7 we showed velocity data for a 5/16" short venturi nozzle flowing three different media flow rates. Figure 9 shows only the set of data for 10 lb/min media flow, but also graphs intensity versus 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.

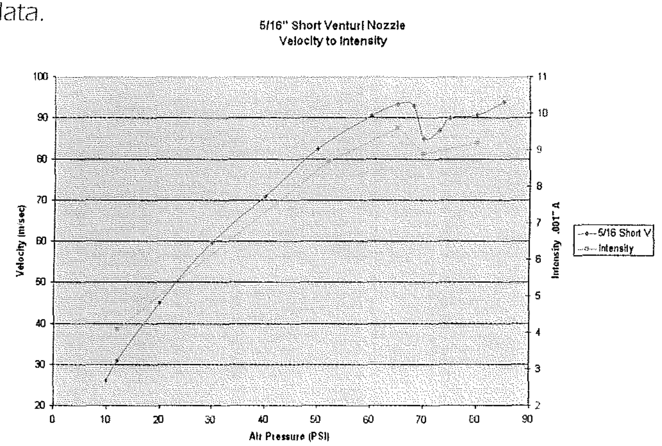

Figure 9 - 5/16" Short venturi nozzle flowing S110. Velocity vs. air pressure on left hand scale, intensity vs. air pressure on right hand scale.

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 10 and 11). This data has enabled us to optimize the shot peening process quickly since we can determine the best combination of air pressure and media flow rate to provide the required intensity with minimum cycle time and air consumption.

Conclusions

It is clear that the Shotmeter provides a new tool for

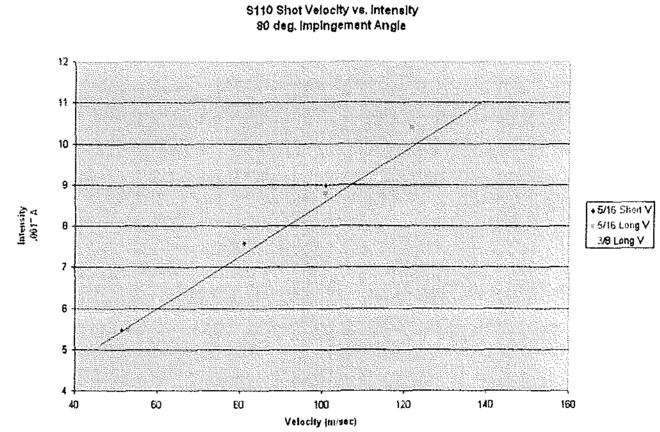

Figure 10 - Intensity vs. velocity profile for S110 steel shot.

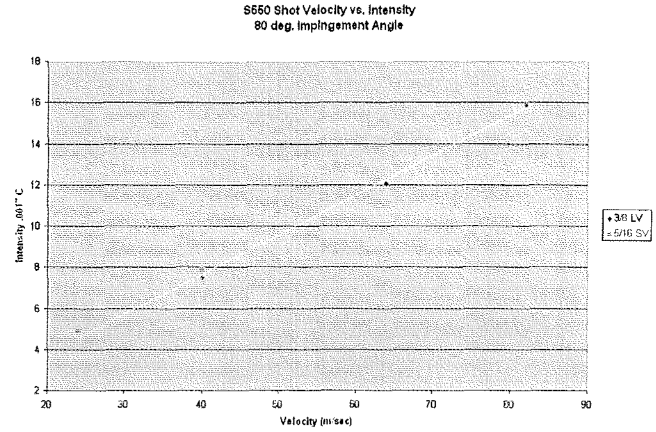

Figure 11 - Intensity vs. velocity profile for S550 steel shot.

developing and evaluating shot peening operations. It enables users to quickly dial in a set of process parameters which yield the desired particle kinetic energy without the need for running numerous Saturation curves, and thereby drastically reduces process development times.

The system can also be used as a performance monitor. Most 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, the Shotmeter enables users to monitor actual peening conditions and provides for data collection and process reporting.

The Shotmeter 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 the portable version.

With enough history and statistical data, the Shotmeter should lead the shot peening industry toward the ultimate goal of machine and process verification, thereby minimizing the number of Almen intensity verification runs. In the end, isn't that what we all want - to peen parts rather than Almen strips?

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