ISSN 1069-2010

THE SHOT PEENER

Fall 1994 International Newsletter for Shot Peening-Surface Finishing Industry Volume 8, Issue 3

1994049

IN THIS ISSUE:

And much, much more!

Shot Peening Process Tolerances

by Jack Champaigne, Electronics Inc.

The purpose of establishing process tolerances is to provide a defined environment where certain results are expected. The goal of the shot peening process is to provide a residual compressive surface stress.

Unfortunately, we do not have a non-destructive method of verification. It is, therefore, necessary to establish which process parameters are responsible for affecting successful peening (proper stress distributions).

In its simplest description as a process, "we make dimples". These dimples should be uniform in size and shape and distributed evenly and completely over the area of intended coverage.

Process variables that affect the peening process include the following:

1. shot type
2. shot size
3. shot hardness
4. shot velocity (velocity = speed + direction)
5. shot flux (coverage of surface)

Each of these variables can influence the peening. The extent to which any one or combination of variables influences the process is therefore addressed by process variation tolerance limits. The methods used to determine the process tolerances can be based upon influence of:

1. residual stress distribution
2. fatigue tests

Ideally, a design engineer would request a residual stress distribution that the peener must provide. The peener, using a recipe of the five process variables, would produce the desired stress distribution. Furthermore, the peener would know how each process variable influences the distribution and therefore operate with tolerance limits that insure that the correct stress profile is obtained.

Unfortunately, few design engineers specify stress profiles, and (probably) fewer peeners would know how to develop a recipe to provide it. This is probably why we see design engineers calling for peening intensity and shot size. These two process variables are the dominant factors in the stress profile. The peener can complete the process recipe and the design engineer can then have the effort verified.

The peener's recipe can be verified in fatigue tests. In either case, a successful recipe has been identified. Now all the peener must do is repeat the recipe. Unfortunately, he may not know (specifically) what tolerances he is allowed without corrupting the process. Fortunately, peening is a forgiving process (almost any peening is beneficial) and industry practice tends to accept a modest degree of peening inconsistency.

I realize it is unlikely that the peener is going to receive the benefit of process analysis where he would be given specific process variation tolerances for the five variables. However, there is a contribution that the peener can make that will enhance process consistency. If the design engineer requests an intensity and size then the peener can operate within limits if the peener knows what the influence is of each variable upon intensity.

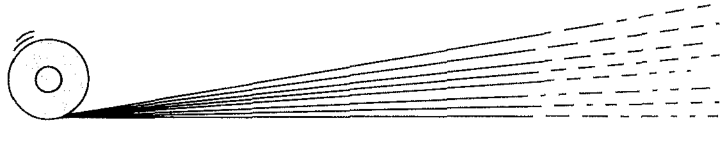
The next step requires a little imagination. Usually the manufacturing process will request a target value (i.e. diameter) with upper and lower limits and demonstration of process capability (Cp and Cpk). The peening industry declares the upper and lower intensity limits but doesn't address the issue of process capability.

I can tell you how to determine the influence of air pressure on velocity and, hence, the effect on intensity. But if you don't tell me the "accuracy" of the intensity that you want, I cannot tell you the precision of the air pressure that you will need.

You may choose to default to "accuracy = tolerance". In other words, 10-12A intensity implies an accuracy of ±1 will be deemed acceptable tolerance.

It shouldn't take long before someone asks the question, "What if two or more process variables

Continued on page 3



drift within their tolerance, but the combined effect violates the total allowable tolerance?". This could get deep.

I would propose that the above be ignored for the present time. Due to the complexity of the interactions and lack of expertise in process measurement, a refined process control may not be within our grasp. However, to define allowable process variations for each of the five factors is really quite straight forward, and I would propose that the following approach be considered.

Of the five process variables, the operator has the closest control of only the last two, velocity and flux. The shot type will be fixed by the designer. Tolerances for shot size and hardness, for the present discussion, will be deemed appropriate. (I would like to investigate this later.)

The operator can influence the peening intensity by controlling the shot velocity. This is accomplished either by controlling wheel speed or air pressure. Consistent shot velocity by wheel speed control is quite straight forward. However, air peening velocity control is a little more complex.

Peening process sheets often (but not always) will cite a value for air pressure and nozzle size. Unfortunately, several things can affect velocity that are undetected by measuring air pressure at the source (near regulator or pressure pot).

1. nozzle wear
2. shot flow rate
3. hose condition (deterioration)
4. hose attitude (for movable nozzles)
5. air dew point

Except for dew point, these other conditions can be monitored by sensing air pressure at, or directly behind the nozzle.

Measurement of the source pressure in direct pressure peening systems is insufficient information, especially if a good quality pressure regulator is used. The "measured" pressure will be the "regulated" pressure. If the nozzle were to become completely plugged, the measured pressure will read the regulated pressure. If the nozzle wears or falls off, the measured pressure may not change, depending upon regulator efficiency and compressor capacity. Therefore, measurement at the nozzle would be desirable.

Electronics Incorporated is presently developing three distinct techniques for measuring shot velocity (in situ). Although I cannot disclose much about the means and methods, I can share with you Fig. 1. This illustrates that the Almen intensity is affected .0005" intensity per one pound variation in shot flow rate, in the range of 3-9 pounds/minute (for this particular experimental setup). In the 9-18 pound/minute flow rate range, the influence is somewhat less. Therefore, if you revert to your ±1 arc height tolerance, it would be necessary to maintain a ±2 pound/minute flow rate tolerance (in the 3-9 pound range).

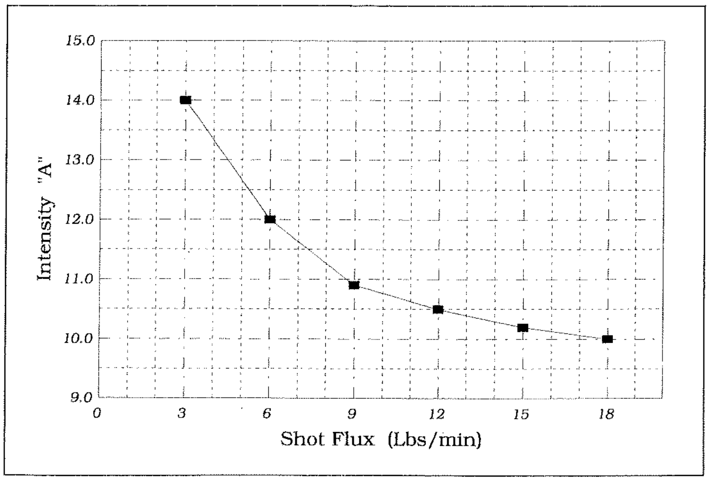


Fig. 1

Air pressure variation tolerance can be determined by experiment or by graphical interpretation. If experimentation is used, then a typical pressure should be selected that provides the necessary Almen intensity. Then, by increasing and decreasing the air pressure, the influence can be calibrated. Caution should be exercised in this experiment. The air pressure should be measured at (or behind) the nozzle and the shot flux must be kept constant. If you are not using an active shot flow rate regulator (such as a MagnaValve), then the effects of shot flow rate change at different air pressures will have to be addressed. Orifice plates or mechanical feed valves will generally allow higher shot flow rates at higher air pressures. (See Fig. 2 below.)

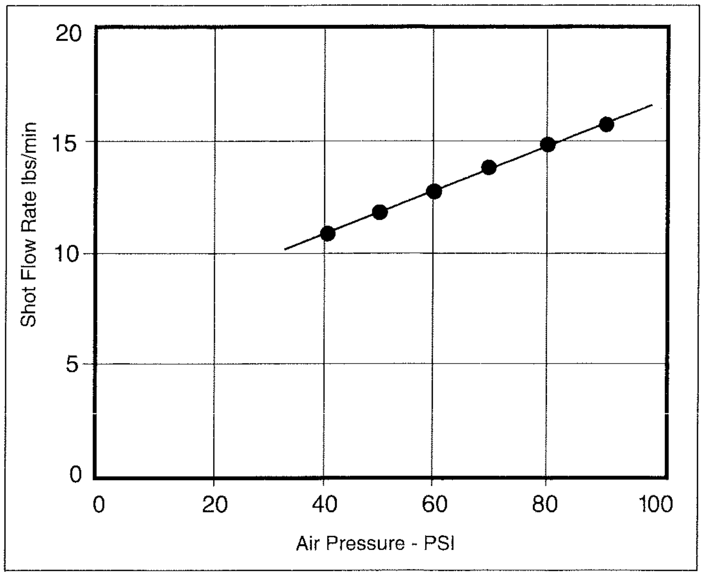


Fig. 2 Shot flow rate vs. air pressure in direct pressure system with fixed feed rate orifice.

An alternative to experimental procedures is to interpret earlier graphical presentation of intensity/pressure data. The graph from Metal Improvement Company can easily indicate influence of air pressure on Almen intensity (Fig. 3 on the next page).

For example, using S-330 shot at 40 PSI will provide an Almen intensity of 13A. If air pressure drops to 30 PSI, the intensity drops to 10.8A. Conversely, if the pressure is raised to 50 PSI, the intensity increases to 15.5A. The influence, then, is (10.8-15.5) / (50-30) = -.24, or for every one PSI change in pressure, the intensity will change by .24 (a quarter of a point). If you want to maintain ±1 intensity, you would have to have a precision of ±4.26 PSI for air pressure.

Again, caution must be exercised before accepting the above numbers as candidates for air pressure tolerance. If the "air pressure" were the regulator setting and not the nozzle pressure, then other factors, such as hose length, diameter and condi-

Continued on page 5

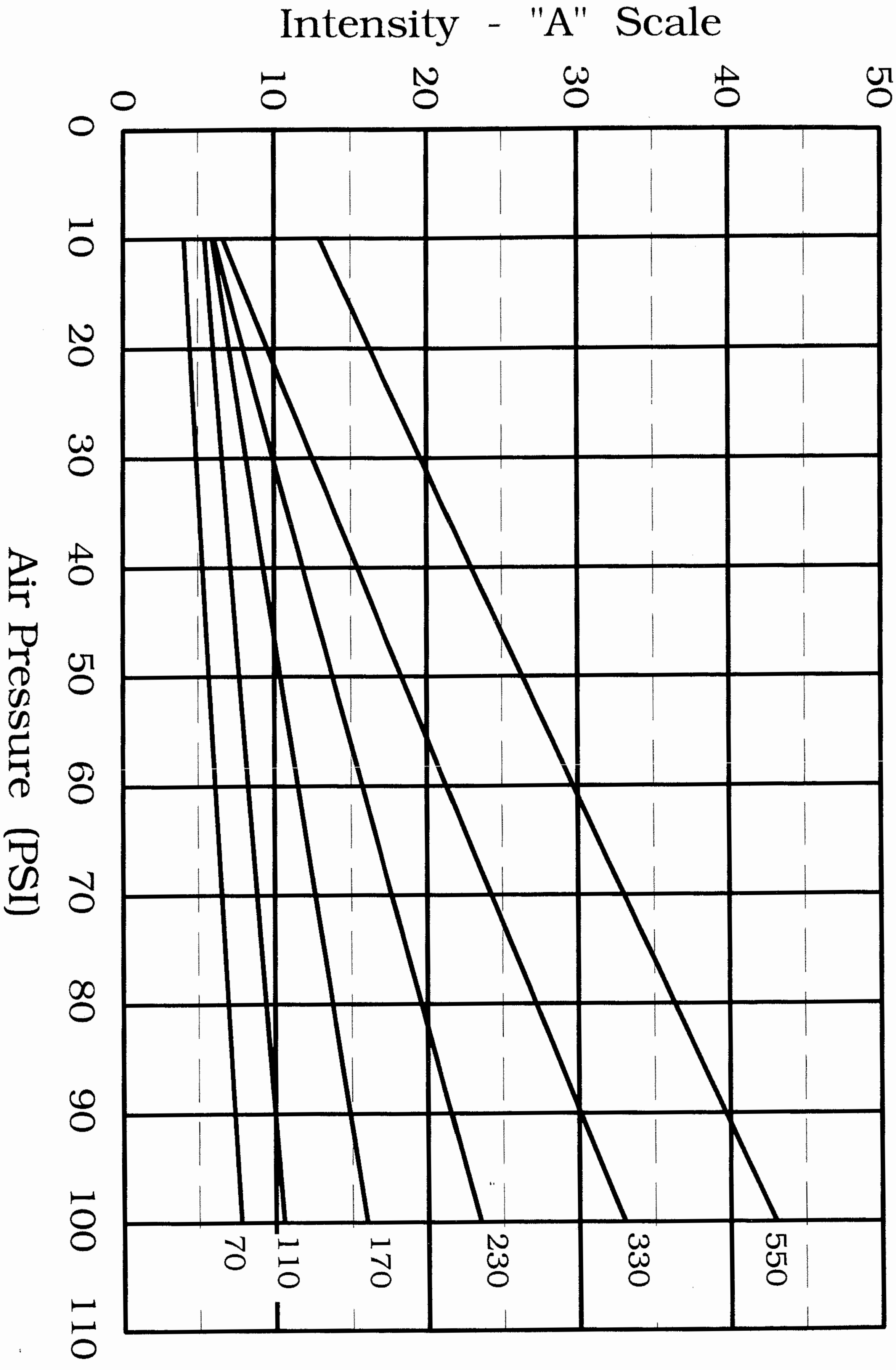

Intensity - "A" Scale
0
10
20
30
40
50
Air Pressure (PSI)
0
10
20
30
40
50
60
70
80
90
100
110
70
110
170
230
330
550

Fig. 3

tion, shot flow rate, nozzle size, etc. would have to be specified. Otherwise, you can not imply that the graph is appropriate for a different equipment set.

The attributes of turntable speed, part speed and conveyor speed suggest a paradox. None of these variables is important to intensity or coverage unless you have:

1. catastrophic failure
2. barber poling
3. incomplete coverage

If a part that is to receive 3 minute exposure time is placed onto a 1 RPM turntable, we can expect the entire surface to receive 3 exposures to the blast stream. Increasing the table speed to 6 RPM will not affect the total part coverage. However, reducing the table speed to 0.1 RPM presents a serious problem. Some of the surface will not be peened during the 3 minute cycle.

Barber poling occurs when a (cylindrical) part is rotated in front of a translating nozzle. If the nozzle "feed rate" is too fast, then a spiral groove (non-covered) area will exist. It is possible that the cycle time may be long enough to allow coverage in subsequent passes of the non-covered areas. However, the possibility also exists that the exact same path may be traversed and the non-covered area may never be covered. No degree of rotational and translational accuracy will remedy this problem.

It may be helpful to list "some" tolerance in Table 1 (even if it is just common practice or commercially available hardware). Where it is practical, tolerances should be chosen that reflect Almen intensity accuracy expectations.

From my experience, I would recommend the following tolerances:

		the greater of
3.2.5.1	shot flow (through each nozzle)	±5% or ±0.5 lb/min
3.2.5.2	air pressure (at each nozzle)	±5% or ±2 PSI
3.2.5.3	wheel speed rpm	±1% or ±20 RPM
3.2.5.4	air flow	?
3.2.5.5	nozzle/wheel speed (travel)	±10% (1)
3.2.5.6	shutdown time	?
3.2.5.7	turntable speed rpm	±10% (1)
3.2.5.8	part speed	±10% (1)
3.2.5.9	conveyor speed	±10% (1)
3.2.5.10	cycle time	±10% or ±1 second
3.2.5.11	nozzle/wheel position	?
3.2.5.12	table indexing position	?

(1) Dynamic peening (part or shot stream movement) should provide 3 or more exposure opportunities. Care should be taken that feed rates preclude barber pole effects and that all surfaces receive (essentially) required coverage. ❍