Achieving and Maintaining Required Roll Ra and PC via Steel Grit Blasting  

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Abstract

Steel grit blasting can produce virtually any required roll profile but only when the relationship of grit work mix size distribution to Ra and PC is fully understood, and rigid operating disciplines to control correct size distribution are practiced. Described are: work mix size and profile relationships, control measures needed.

Introduction

Upon examination of steel grit particles as small as 0.03" and 0.01" (the latter as small as the printed period on this page), one must marvel that the grit blast process can effectively etch the hard steel rolls typical for the industry.

Yet, grit blast roll etching can produce, and is producing the stringent etch profiles customers of the steel industry require. How? Calculations will show, for example, that an individual steel grit particle, 0.03" in size (0.75mm), thrown at a velocity of 245 FPS, can apply as much as 10 million pounds of force per square inch to its infinitesimal point of contact with the roll surface! With that kind of force, when the steel grit particle impacts on the roll, the roll surface will most definitely be etched!

How deep the penetration (referred to as roughness average, Ra), and how many penetrations per inch (referred to as peak count, PC), depends primarily on the size of the grit particle. The larger the size the greater the impact power, the deeper the penetration, and the higher the Ra.

Due to the difference in size, the 0.03" grit delivers 27 times the impact power of the 0.01" grit particle, and thus produces a much rougher profile. On the other hand, the 0.01" grit particle applies its lesser impact power to a much smaller contact area; it still has sufficient power to etch (particularly when enhanced via greater RPM), but produces a lower Ra, and a much higher PC.

Contributing to the higher PC is the difference in particle population: There are approximately 400,000 particles in a pound of grit with an average size of 0.03"; however, in a pound of grit with an average size of 0.01" there are as many as ten million particles.

Thus, the two factors that make the grit blast process such an effective, efficient, and high production system are: The awesome impact power of the steel grit particles when propelled at speeds of 200 FPS to more than 300 FPS (depending on wheel diameter and RPM), and the incredible grit particle population present in the blast stream.

Having seen the difference grit size makes with respect to both Ra and PC, it is readily appreciated that it is control of the grit size distribution in the work mix that governs roll profile. Just as you wouldn’t expect to put a heavyweight boxer and a bantam-weight boxer in the same ring, you cannot, must not, have a wide disparity of grit sizes in the same roll etch grit bin. When that occurs, control over roll profile is totally lost!

Invariably, in those instances where grit blast roll etch has failed to produce the required profile, it is lack of control over grit size distribution that is the cause. Just as invariably, when the required roll profile is not achieved, it is the grit blast process that is blamed.

Blaming the process calls to mind a magazine article published about two decades ago dealing with the use of steel abrasives in blast cleaning of cast metal products. The magazine has issued a call for its readers to do some “imagineering” (their term for “reinvent”) to suggest ways to overcome perceived negatives of the process. Despite some pie-in-the-sky wishful thinking about alternative methods, two decades later, no generally accepted, viable substitute for the process has emerged. The blast cleaning process is still by far the most effective, efficient, high production process available.

However, much was learned from the study: It wasn’t the process that was at fault; re-inventing the process was not the answer. Virtually all the problems that had been experienced were related to improper operating practices and the users lack of understanding of the principles of impact cleaning. Going back to basics was the answer! For those in grit blast roll etching who have not yet been able to achieve consistently the required roll profile results, going back to basics is the key, too.

Going Back to Basics

What are the basics that most apply to the roll etch process? Well over a century ago, in 1870, a patent was issued to General Benjamin Tilghman for a method of impelling sand by a pressure blast system, “to etch or shade glass, stone, metals and other hard materials by means of sand jet”. General Tilghman used these terms to describe how the system performed its function, “It is an impact cleaning operation that is neither cutting, grinding, nor abrading. It is essentially a pounding, battering, or bombarding of the work surface by successive impact of the flying abrasive.” The operative word is “impact”.

Going back to the basics necessarily, then, involves application of the formula for kinetic energy to the grit blast process. Today, cast steel grit, and centrifugal blast equipment, are popularly in use in place of sand and air blast equipment. In grit blast roll etching, the “mass” in the kinetic energy formula is steel grit (the variable being the grit particle size), and the “velocity” is the feet-per-second speed of the flying grit, developed by the blast wheel diameter and RPM (RPM being the variable).
In the final analysis, then, when going back to basics, what we really want to know is the effect of changes in grit size (mass) and/or wheel RPM (velocity) on the impact-power of the grit particles delivered to the roll surface, and, in turn, the effect of those changes on Ra and PC.

Factors Accounting for Change in Ra and PC

With respect to the roll profile factors of Ra and PC, this fact of life must be recognized: Any change in operating conditions that affects one factor automatically affects the other inversely. When you increase Ra, PC is decreased. When Ra is decreased, PC is increased.

Under any given set of conditions with respect to grit size and RPM:
• An increase in particle size results in a higher Ra and lower PC
• A decrease in particle size results in a lower Ra and higher PC
• An increase in RPM results in a higher Ra and lower PC
• A decrease in RPM results in a lower Ra and higher PC

In addition to the above major factors, also to be considered (but with lesser influence on profile change) are: roll hardness and diameter. With all other conditions being equal:
• The higher the roll hardness, the lower the Ra and the higher the PC
• The lower the roll hardness, the higher the Ra and the lower the PC
• The greater the roll diameter (meaning shorter distance between wheel and roll) the higher the Ra and the lower the PC
• The smaller the roll diameter (meaning greater distance between wheel and roll) the lower the Ra and the higher the PC

Application of the kinetic energy formula \((MV^2/2)\) tells us that of the change factors listed above, increasing or decreasing grit size has, by far, the greatest potential for producing change in roll profile. Therefore, control of work mix grit size is paramount. It is also the roll etch operator’s greatest challenge.

Changes in RPM to alter profile are subject to operator decision. Changes in roll hardness and/or roll diameter are known factors from roll history, and can be compensated for by operator decision on RPM, also. However, most changes in work mix grit size are inadvertent, due mostly to improper classifying operation. Poor classifying results should not be compensated for by changing wheel RPM—the proper solution is to correct the classifying operation.

The Challenge: Controlling Grit Work Mix Distribution

When a roll etch work mix contains a spread in particle size where the largest particles are as much as two or three times larger than the smallest particles, there is no way the operation can meet today’s stringent profile requirements. That is due to the wide variance in impact values (A two to one difference in size means eight to two difference in size) and wide variance in particle count within the work mix.

Inevitable, segregation occurs in the grit feed hopper, resulting in constant variation in the size mix going to the wheel and being delivered to the roll surface.

If we were to assume, for example, that an 0.030” grit particle produces the Ra and PC required, then obviously, a grit particle only 0.010” in size (having only a small fraction of the impact power delivered by the 0.030” particle), will not, cannot, produce the required Ra. Those smaller, ineffective particles not only take up valuable space in the blast stream, but, also serve to impede, or cushion, the impact power of the proper sized grit particles.

Trying to compensate for improper work mix size distribution by increasing RPM has these negatives: Faster breakdown of the grit due to the higher velocity, significantly reduced abrasive flow, requiring increased blast cycle time per roll (the higher the RPM, the lower the flow rate). This results in higher operating costs due to these negatives. Plus, the blast stream still has a high percentage of ineffective fines.

How change in grit size affects the impact value is illustrated in Table I. Relative differences in impact value for selected sizes are shown. In each instance, an impact value of one (1) is assigned to the smallest size particle, to show how the relative impact value increases as size is increased.

Grit Size Range: The Optimum Impact Power Ratio

Experience has shown that a grit size range that results in an impact value holding fairly close to a 3:1 ratio, will enable the roll shop to produce profiles that can be totally satisfactory to the most demanding customer.

The key to attaining the target 3:1 impact value is proper selection of the classifier screens. For any given grit bin size, the top screen opening, in inches, should be no more than 1.45 to 1.5 times larger than its corresponding bottom, or retaining, screen opening. (Example: top screen opening of 0.041” maximum screen opening of 0.0282” = 1.45. Treating 1.45 as the “mass” variable in the kinetic energy formula (mass varies as the cube of the difference in size), we find that the impact value ratio for these two screen openings is 3:1 (i.e., a particle 0.041” in size, has three (3) times the impact power of a particle that is 0.0282” in size).

Table II shows the plus/minus tolerance (in thousandths of an inch above and below selected median sizes) that gives a top screen to bottom screen range approximating the 3:1 impact value ratio.

| Table I |
|---|---|
| **Size** | **Relative Impact Values** |
| 0.048” | 8.0X |
| 0.042” | 5.3X |
| 0.036” | 3.3X |
| 0.030” | 2.0X |
| 0.024” | 1.0X |
| 0.018” | 1.0 |
| 0.012” | 1.0 |

Note: The smaller the initial size, the greater the effect of size change.

| Table II |
|---|---|
| **Media Size Particle** | **Plus/Minus Factor** |
| 0.036” | 0.007” |
| 0.030” | 0.005” |
| 0.024” | 0.0045” |
| 0.021” | 0.004” |
| 0.018” | 0.0035” |
| 0.015” | 0.003” |
| 0.012” | 0.0025” |
Example: $0.036'' + 0.007'' = 0.043''$ top and $0.029''$ bottom.
Dividing $0.043$ by $0.029 = 1.48$ size difference, which is within the 1.45 to 1.5 range above. (Note: Tensil bolting cloth screens should be used rather than market grade screens. Optimum percent open area of TBC screens is essential for good screening efficiency.)

**Implementing Correction Procedures**

The obvious first step toward achieving optimum results from the grit blast roll etch process is to evaluate the present operating conditions with respect to classifier top/bottom screen openings in use for the various bin sizes. How do they relate to the 1.45x to 1.5x size difference required to attain the approximate 3:1 impact value ratio? How does the specification for the grit you purchase correlate with the classifier screens? Obviously, there should be compatibility.

Should the analysis show that changes in classifier screen openings are indicated, be sure to go to the next step before making any change in screen openings.

The next step is to determine how effectively the classifier system is performing its function. Even though the correct screen openings are in the classifier, that is no guarantee screening results are proper. Today's 48' round classifiers are capable, when operated properly, of good, efficient size separation and can screen so that no more than 5% to 7% fines (that should have passed through) are retained on the bottom screen of a given bin size. It can be done.

It is being done by those who implement rigid operating disciplines.

The challenge: Is the bottom screen for a given bin size retaining fines that should have passed through to the next bin? Your laboratory test sieve equipment can tell you what the actual size range is (test 100 grams only, at 10 minutes, in a W.S. Tyler Ro-Tap Unit).

While the classifier screen openings tell you what the range should be, you need to know the actual size range, coarsest to finest, in order to calculate the impact value ratio now being used to etch your rolls.

When roll profiles stray from the required Ra and PC measurements, almost invariably the cause lies in improper classifying. Thus, before changing classifier screen openings, be sure first to correct the present operating practices, and then evaluate the profile measurements attained with proper screening of the present set-up. Then you will have a better reading as to changes required with respect to Ra and PC. (Caution: It must be remembered that any changes in a given bin size affects an adjacent bin (i.e., the bottom screen for one bin serves as the top screen for the next smaller size bin. The 3:1 impact value should be maintained for all bin sizes.)

With respect to classifier operating practices, it is of most importance to understand that a properly maintained and properly operated classified system is capable of achieving 93% - 95% screening efficiency. Three problems almost invariably involved when screening efficiency fails to meet that target are:

- Excessive grit feed rate to the classifier screens (the smaller the size, the lower the feed rate must be)
- Failure to have the grit feed drop vertically dead center on the screen
- Blinded or broken classifier screen mesh

**Conclusions**

Typical of the benefits that can be realized by correcting classifier screening to attain the 93% - 95% efficiency are the following:

- First, and most important, roll profiles with improved Ra and PC values and remarkable consistency will be achieved.
- Elimination of unwanted, ineffective fines enables operators to reduce RPM and still achieve the desired RA because the cushioning factor of the fines has been eliminated.
- Due to the lower RPM, the peak count will increase significantly.
- The rate of grit breakdown will decrease substantially due to the lower velocity.
- The lower RPM will generate an increase in grit flow rate, which, in turn, will permit shorter blast cycle times.
- Fine-tuning the operation for further improvements in Ra and PC is now possible, and more controllable, via changes in work mix size (always holding to the 3:1 impact value ratio), and/or changes in wheel RPM.

All of these benefits will have been achieved simply by gaining an understanding of the relationship of grit work mix size distribution to the roll profile measures of Ra and PC and then “going back to basics” by applying rigid operating disciplines to control work mix size distribution.

Going back to basics doesn’t cost — it pays. In every way! ●

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