AN INSIDER'S PERSPECTIVE

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Fine Particle Peening: Review and Challenges

Why Are We Discussing Fine Particles?

Automotive and Aerospace, the two common users of shot peening equipment, seldom refer to anything smaller than S110, or the equivalent in CW peening media. S110 is approximately 0.011" (0.28 mm) in nominal diameter. Smaller particle sizes are commonly used in thermal spray techniques. However, that is not always true. For instance, Japanese automakers have media that is smaller than the smallest SAE/AMS size of S70 for their peening operations. In "Fine Particle Shot Peening" (*The Shot Peener*, Winter 2010), Kathy Levy introduced us to this technique and also informed us of its history with our Japanese colleagues who continue to realize distinct advantages in terms of fatigue resistance among other attributes with its use. Kathy identifies the limited availability of this media in US and EU as one of its drawbacks but also contends that this is easily solvable.

I would like to stay on top of this potential trend and continue this discussion with (a) subtleties in manufacturing fine particles, and (b) equipment design challenges in reclaiming fine particles during process.

Classification of fine particles seems to be manufacturer-specific. The size range between 20 and 200 micron is being categorized as fine particle by some manufacturers of fine particles (175 micron is around nominal the size of S70). Given our familiarity with SAE J444 and AMS 2431, I suggest for our discussion that anything smaller than the smallest SAE size S70 (175 micron) be referred to as fine particles.

Fine Particles and Impact Energy

I often use the term "Impact Energy" and emphasize its importance in governing everything we aim to accomplish with blast cleaning and shot peening. Impact energy (or kinetic energy, transmitted energy, etc.) is the energy carried and transmitted by a particle of abrasive on to its target upon impact. This energy results in scale or rust being dislodged, or in the case of peening—creation of a dent that results in a desirable zone of compressive stress.

This impact energy is represented by ½ x m x v^2, where **m** is the mass of the individual shot or grit particle and **v** its velocity. Velocity is developed by multiple means, using a centrifugal wheel that accelerates the abrasive particles or air pressure that helps propel the media with the desired force.

Mass is directly proportional to the media type and size. Dense media like cast steel shot and cut wire carry greater mass than glass bead and ceramic. Therefore, in order to generate a desired value of compressive stress that requires peening your component to an intensity of 18A, your drawing and specifications will likely instruct the use of S280 or S330. Fine particles will not be capable of achieving this and will not be applicable here. You might be able to compensate for the small media size by ramping up the velocity (higher air pressure or wheel speed), but after a certain magnitude of pressure the abrasive particle will saturate in its ability to deliver energy. At this point, a larger size, or greater hardness of the same size of abrasive, will be required. If all the above are true, how and when do fine particles find suitability in our conventional applications?

Coverage Rate and Media Size

Phil Waser with Ervin Industries shares a chart in his class at the EI US Shot Peening Workshop. The chart shows the number of particles per pound of different media sizes. The lesson behind the chart is that smaller media will achieve faster coverage. To understand this, consider a pound of S170 with 745,000 pellets as compared to S230 with only 345,000! With comparable impact values, each of those S170 particles will pack the same punch, except that they are more than twice in number as S230 particles. The common nozzle size flows about 10 to 15 pounds per minute of this media! As a comparison, S70, though much smaller, dwarfs them all with its 8,200,000 particles per pound! Fine particles will only be exponentially higher in particle count, if someone attempts to count! This is where we derive the advantage of fine particles.

I recall a gear peening application from the past where the customer had specified dual peening with the second size of media in the "fine particle" range around 100 micron (close to S40, if there was such a size in SAE). The understanding with the use of fine particles was that it strengthened the compressive stress layer closer to the part surface and improved the surface finish of the gear. Another application in Aerospace used fine ceramic particles since it provided the desired compressive stress without causing the part distortion that took place with steel peening media.

Manufacturing Techniques and Challenges

Cast steel shot is manufactured by atomizing molten metal with high-pressure water as it is poured out of a furnace. Solidification of molten metal produces a range of different sizes of spherical (or almost spherical) particles, which are then screened and tempered to the required ranges of hardness.

Fine particles are not as easy to manufacture. I spoke with Mark Hash, the Research & Development Director at Ervin Technologies (E-Tech) in Tecumseh, Michigan. His company manufactures speciality powders for unique applications and also private labels fine particles for a customer that markets it for shot peening applications. Mark explained, "High-yield fine particle manufacturing requires high energy atomization such as centrifugal. (Gas atomization is an alternate technique that yields similar results.) Finer particles are more prone to oxidization simply due to larger surface area-volume ratios. Additionally, these fine particles require slower screening methods for size uniformity."

Mark disclosed that this technology and the first centrifugal atomization rig were acquired from a defence contractor. The technology, called Rapid Solidification Rate (RSR), consists of pouring molten metal on to a rotating disc that disperses it centrifugally and allows it to atomize in a controlled, gaseous atmosphere.

"The most common cover gas is nitrogen, though our process sometimes requires the use of helium (**He**) and argon (**Ar**). **He** provides high thermal conductivity and helps in quenching whereas **Ar** is inert and allows the system to stay hot," added Mark, thereby concluding a short refresher for me in metallurgy and particle chemistry! He also cautioned that fine powders have to be manufactured in a highly controlled atmosphere to prevent formation of dust clouds that can initiate hazardous process explosions.

To summarize some of the manufacturing challenges: (a) likelihood of non-roundness is very high unless the process is minutely controlled (alloy composition, temperature gradient, rotating disc speed and disc design are some controlling factors); (b) any process that relies on stringent controls will also carry a hefty price tag, and finally (c) yield that is not highly predictable due to the above. E-Tech takes special precautions in proper storage since fine particles could cause inhalation issues—which brings us to the next important segment in our discussion—the equipment.

Equipment Design for Fine Particle Peening

Unlike thermal spray applications, where recycling is not a key part of the process, the media in shot peening applications impacts the part and has to be returned to the blast system for re-use. As we established earlier, fine particle peening is most effective as a second stage process (dual peening). Assuming both stages are designed to be carried out in the same machine, the cabinet and reclaim system should be able to handle both sizes.

I remember a past conversation with an end-user of such a system. The primary peening media (that delivered the desired compressive stress) was S330 (or the equivalent CW shot), and the secondary media was in the range of 125 micron. The application was to peen automotive gears at a very high production rate. The system utilized eight pressure blast nozzles, each flowing at least 15 lb/min (my estimate) of S330. This system utilized a mechanical recovery system, as is required for the quantity of media being processed.

Conveying fine particles through a mechanical recovery system, with a screw conveyor and bucket elevator, causes a lot of concerns. The transit loss in such a system could lead to several dead pockets of fine media, in suspension, and in general results in a very inefficient recovery system. If the fine particles somehow did manage to be elevated by the buckets to the upper recovery, expecting the airwash separator to handle this fine particle and differentiate it from the dust that it normally extracts is another challenge.

Finally, we rely on the classifier to maintain consistent shot size through all peening cycles. Maintaining that with fine particles poses the same screening challenge that was referred to earlier when we discussed the manufacturing process of such particles. There is likely a solution to all of the above, either already established and kept proprietary, or yet to be made commercial by a creative manufacturer. Perhaps two different machines, one for each media type—in a cost-effective fashion—just a thought.

Is There a Future for Fine Particle Peening?

I have often commented in these columns that our industry doesn't change rapidly. However, I will only exhibit unintended pessimism by doubting that a process has potential for improvement by a new technique, material or automation. Our discussion here attempted to continue the work started by Kathy Levy in 2010, and to get all our minds thinking collectively to (a) understand and expand on those niche markets that have benefited from fine particle peening, (b) consider changes to machine and the reclaim system design that will allow use of fine particles efficiently, and (c) make the process commercially cost effective.

Let us also not forget the importance of non-conventional peening techniques such as laser peening, needle peening, ultrasonic peening, vibratory peening, flapper peening and cavitation peening. Fine particle peening may end up a mainstream process or be restricted to specific applications, and prove to be the optimum solution, whether it be by increasing the compressive stress layer near the surface or forming minute cavities to store lubricant and decrease contact friction. As someone once said, "If it doesn't challenge you, it won't change you!"