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What Is Your Machine Trying to Tell You?

IF YOU ARE READING THIS, there is a good chance you work in Aerospace, Automotive or a similar advanced manufacturing sector. You might be engaged in shot peening, grit blasting, etching or another value-added surface preparation operation on your component. Furthermore, if your machine is less than ten years old, and automated, it likely has a PLC, HMI and diagnostics to help you identify, or at least narrow down, issues when they arise.

With all that taken into consideration, most users of shot peening and blast cleaning equipment will also agree that there are more than the obvious reasons and causes when it comes to machine issues. Just as it is difficult to quantify what "exactly" happens to each pellet of abrasive after it leaves the blast nozzle or wheel, the same is true for the machine and process feedback we receive during regular use.

Our discussion will focus on some of the machine feedback and categorize it as having *obvious* or *not-so-obvious* causes. When we do so, let's bear in mind that peening and cleaning machine technologies continue to evolve. The process variables are constantly impacted in positive ways by technological advancements, and the resulting machine performance will be a continuing debate.

Problem: Media Leakage Around the Machine

Most of us share the same opinion on the propensity of cleaning and peening machines to leak abrasive. An astute, albeit facetious, solution that many offer to this ancient problem—stop adding media and this problem will go away! Unfortunately, this solution isn't very practical. Media leakage can occur in multiple locations in the machine. Typical areas are through openings such as work doors, access doors, the roof of the cabinet and near the reclaim system components. Each location has its own reason(s) for leaking media.

A well-designed machine will attempt to direct media from a nozzle or blast wheel away from an access door, work door or protected opening (Fig. 1). In addition, most cabinets are lined with wear-resistant material for protection from the incidental media stream or rebound media bouncing off the component. However, these features don't always prevent media leakage and then we must look into the causes.

Fig 1. Nozzles targeting specific areas on the component and away from the door.

Obvious causes

1. Faulty/worn nozzle holding arrangement or worn blast wheel part (typically the control cage or blades) that misdirects the abrasive towards the cabinet opening
2. Worn door seals or curtains (in the absence of doors) that allow abrasive to escape the cabinet
3. Worn seal on the cabinet roof slot provided for the purpose of nozzle carriage arm entry into the cabinet
4. Sharp radius of the blast hose resulting in rapid wear in tight areas, softening of the hose and an eventual tear
5. Loose hose fittings and gradual dislodgement at connection points

For the not-so-obvious causes of media leakage, let's start with a real-life occurrence:

> A customer who shot peens a high volume of automotive components reported that passersby in an aisle behind the machine were being hit by abrasive. Though this is not uncommon when standing in front of a badly leaking machine work door, in this case there was a solid machine cabinet wall in back of the machine where the leakage was reported. Within a few hours of machine usage, this leakage got more pronounced and a narrow opening was visible in the wall. The culprit was a cabinet liner that had come loose in the rebound area inside the blast cabinet, exposing the bare wall to abrasive impact. At 300 feet per second (91 meters per second), it did not take long for damage to exacerbate.

From every peening workshop we have attended, we have learned that the abrasive particle loses very little of its impact energy within the first few rebounds. Moreover, we also know that less than 100% of the media stream hits the target. The percentage that doesn't hit the part could be hitting a liner or deflector that is likely misdirecting abrasive towards a cabinet opening. The same holds true for parts with complex geometries and features that tend to deflect the abrasive as they spin on a satellite table.

Other not-so-obvious causes

1. Another classic source of leakage, typically on the cabinet roof, is from abrasive escaping through the air inlet. Steel shot, given its spherical shape, commonly exhibits this tendency, more so with smaller shot sizes such as S70 and S110. The round profile of steel shot allows it to effortlessly roll along the walls of the air inlet and make its way outside the cabinet. The solution could be a taller air inlet and multiple layers of internal baffles.
2. In an airblast machine with vacuum recovery, the media stream from the cabinet (reclaim duct) enters the reclaimer at almost 4500 feet per minute or greater. The tangential entry into the reclaimer is the first point of potential wear. Most reclaimers are built with wear plates at this first point of entry and lined with wear-resistant material where the media swirls. It is critical that the wear plate be inspected regularly for erosion or damage.

The most serious consequence of media leakage is that it's a safety hazard due to injuries from falls. Other problems include:

- Loss of media (if leaked media is recycled back into the machine, it should be thoroughly cleaned offline of large size contaminants before reuse)
- Insufficient coverage (particularly in peening applications)
- Longer cycle times

A lip below the access door will reduce media leakage onto the floor.

Problem: Finished Part (Peened or Cleaned) Has a Brown Residue

An aerospace customer complained that their shot peening process gave repeatable results but the parts exited the machine with a rust-colored coating on them. The diagnosis commenced with examining the obvious areas of concern. Being a wheelblast machine with high flow rates, it had a mechanical reclaim system with an airwash separator. The separator openings, the velocity of ventilation stream and all other obvious areas were checked and eliminated as possible culprits that could cause discoloration. Another potential problem area was the initial condition of the parts. Any oil or moisture on the part could lead to abrasive contamination and potential discoloration of the finished product. This reason was eliminated, too, since the parts were completely dry when introduced to the machine.

Upon further investigation, it was discovered that the machine had not been used for an extended period of time. If a machine is mothballed for time periods greater than two to three weeks, abrasive left in the machine could develop flash rust and transfer the rust to the component being blasted. In addition, rust from the insides of reclaim system components could also enter the media stream and cause further contamination.

Two possible solutions are recommended, with the first preferred over the second. A machine should never be idle for extended periods of time. It should be operated with blast media for at least an hour or two every five to seven days, more frequently in humid environments. This keeps the abrasive in circulation and reduces the possibility of rusting. The second method is to clean out all the abrasive from the machine and store it in a dry location. However, this doesn't eliminate the possibility of reclaim system transfer rust.

Problem: Process Parameters Haven't Changed but Arc Heights Have Dropped

This is a common complaint from regular users of this process. Most of these users are aware of potential causes, but lose track of them when focusing on routine production tasks. However, we know that all peening processes are critical and the implications of a non-repeatable process can be disastrous to the end product.

Obvious causes

1. Air pressure in a nozzle machine and wheel speed in a wheel machine are directly proportional to arc height (and intensity). A drop in air pressure or wheel speed will result in reduced arc height. Air leakage, faulty PID loop for air pressure, or faulty speed controller (inverter) in a wheel machine are some of the common causes.
2. Blades that are too short were installed in a wheelblast machine during machine maintenance and blade replacement. Media velocity is directly proportional to the wheel diameter.

3. The wear of nozzles and hoses will impact arc height. Similar results can be expected with wear of wheel components such as blades, control cage and impellers.

Not-so-obvious causes
A customer in aerospace had a very efficient peening operation with over 20 Almen blocks in a part verification tool (test fixture). The customer maintained arc heights within 0.002" over the set of Almen strips. After several years of peening with this stellar record, they started experiencing a drop in arc heights even though all parameters remained unchanged. Several days of fault diagnosis bore no productive result until it was disclosed that they were trying out a new media supplier. The new media supplier was supplying media that conformed to SAE specification so this is not to say that the new media was of poor quality. Though seemingly innocuous, it simply means that any change in media could lead to different impact energy, possibly because of a difference in the metallurgy of the metal. Process parameters will require tweaking and new saturation curves will need to be plotted.

Other not-so-obvious causes

1. Wrong type of Almen strips used for testing (A instead of N, or C instead of A). There is also the possibility of a faulty Almen strip due to a manufacturing error.
2. Change in the hardness of the part. This reason doesn't necessarily belong in this category since we only peen strips for verification and not the actual parts, but yet worthy of mention in context. However, it is important to note that given the same set of process parameters, a hard part will bear different results than a softer part when peened. This is amply demonstrated in coverage times and residual stress results.
3. The Almen gage needs to be calibrated.

Problem: Process Parameters Haven't Changed but Cycle Time Has Increased or Coverage Is Insufficient
Arc height (i.e., intensity) is a function of air pressure, wheel speed or wheel diameter; it has nothing to do with the actual part. Coverage and cycle time (the latter in cleaning applications) is observed on the part and is a function of the amount of abrasive propelled onto it (lb/minute or kg/minute). Other than specific applications where high flow rates could result in flooding the part, an increased flow rate will generally result in a shorter cycle time in most applications. Increased flow rates have different reactions in a wheelblast and airblast machine, where it has to be matched with proportional changes to air pressure (in the air-blast machine).

Here are some of the obvious and not-so-obvious causes:

1. Is the part now made from a harder material?
2. Has there been a change in your media supplier or abrasive quality?
3. Have you changed the size of the abrasive? Smaller abrasive provides better coverage. (2:1 Size = 8:1 Impact Value and 1:8 pellets/lb. Source: *Effective use of steel shot and grit for blast cleaning*, E.A. Borch, Ervin Industries, Inc. April, 1999)
4. Issues with the work-handling arrangement such as a slipping belt that improperly presents the part to the blast nozzles/wheels, a faulty bearing, a broken chain, etc.

It's advisable to conduct a Media Catch test for each nozzle and blast wheel in your machine to validate the results and ensure consistency.

Summary
Our discussion here merely scratches the surface of the issues you face in your blast cleaning or shot peening operation. Such is the nature of cleaning and peening. Importantly, the point of this article is to recognize that there is more than the obvious when it comes to recognizing the causes of common machine issues. If the problem is sorted out by addressing the obvious, that might be it. However, recurrence indicates that you have to drill deeper, and the past may not necessarily be a good predictor of the future when it comes to fault diagnosis.

Blast cleaning and shot peening machines follow very basic principles. With a clear understanding of the relationship between mass, velocity and resulting impact energy, you will be on the right track to correcting issues that surface with your machine during routine operation.

The Role Played by Specifications

When taking a honest look at the process and equipment, it's not uncommon to conclude that there is still sufficient mystery in its operation. This mystery, particularly in shot peening, is not desirable. This is where we can take refuge in established specifications because they have been created with the intention of providing uniformity and repeatability to your process.

For example, AMS 2430 clearly identifies every aspect of a peening process including media quality, media maintenance in your machine, the plotting of saturation curves, and more. Following this document will help pinpoint machine issues before they become catastrophic to the end product.

Specification conformance is onerous, but the cost of non-conformance is much higher. Faulty machine design, however, cannot be fixed by specification conformance. Therefore, a thorough knowledge of relevant specifications will help you identify the features you need in a machine before making a purchase.