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Control Systems in Shot Peening – A Discussion

ELECTRICAL AND ELECTRONIC CONTROL SYSTEMS in shot peening equipment have greatly evolved in the last decade. Any peening machine manufactured now has, at the bare minimum, a Programmable Logic Controller (PLC) to monitor and control the programmable features of the process with an Human Machine Interface (HMI) so the machine operator can command the machine to perform desired tasks.

Shot peening machines of the past relied on relay logic controls, pushbuttons and other forms of controls/interfaces. A large part of this evolution was driven by users in aerospace who, with their familiarity of CNC controls from other equipment such as machining centers, raised the benchmark for shot peening equipment. Also, their desire to promote repeatability, accuracy and reliability along with process reporting requirements made it a compulsion for electrical controls in shot peening equipment to be upgraded to current levels. Conformance to specifications and audit criteria also assisted in this evolution.

These are steps in the right direction, but peening equipment may now be more complicated than it needs to be. Veteran experts in our industry often say, "Blast cleaning and shot peening as processes are not as complicated as the science of rocket propulsion!" There is a lot of truth to this statement, especially when compared to other machine tools such as multiple-axis machining centers and routers where precision is critical.

With this in mind, we should ask, "Are we over-complicating our peening machines?" Control sophistication comes at a cost, and it could easily be the single most expensive cost component in machines.

Process Controls in Shot Peening

In order to discuss electrical/electronic controls, we must understand the role played by process controls in shot peening. The prime variables that control the outcome of a peening cycle can be categorized into the following:

1. Impact Energy - represented by velocity of the blast media and its type/size/hardness
2. Exposure Time - this determines the percentage of coverage on the component being peened

Let us analyze the factors that determine impact energy:

- In a centrifugal wheel machine, the velocity is determined by wheel diameter and its speed of rotation. Gradual wear of wheel parts also has a marginal effect on the impact energy. Media velocity and impact energy are directly proportional to wheel speed. Variable frequency drives for blast wheels, some with closed loop feedback, ensure maintenance of constant wheel rotational speed.
- In an airblast machine, the velocity is determined by the air pressure/nozzle orifice size in direct proportion. Also, like with a centrifugal wheel, nozzle wear has an effect on the generated impact energy. Closed-loop feedback or air pressure monitoring will correct fluctuations in air pressure delivered to the blast nozzle.
- In both cases, type and quality of media affects the end result. Cast steel shot, the most commonly used peening media, is susceptible to the inherent imperfections of a cast product. MIL-specified cast steel shot is typically used for shot peening applications and the cast media is pre-screened and imperfections are separated out to provide ideal media conditions for peening.
- Size consistency of blast media is also very critical in peening applications. A mixture of blast media sizes will lead to difficulty in achieving saturation—the measure of process stability. Some of us have experienced the occurrence of the 'double knee' when plotting the saturation curve, signifying deterioration in the quality of abrasive in the machine, typically due to contamination of two or more sizes of media. Size consistency is kept in check by using a vibratory classifier. Some aerospace applications also require the use of a spiral separator to remove broken media from the mix (shape classification).

In comparison, the factors that determine exposure time are relatively simple. Peening coverage is always checked directly on the component being peened. Exposure time can be changed by changing the speed of the conveyor in an inline machine, or the speed of the rotary table in a table-type machine. Part exposure time is independent of the time taken to achieve time "T" on our saturation curve.

Simple Control Architecture

How is this discussion relevant to the use of a PLC in our shot peening machine? The PLC has digital and analog inputs and outputs that monitor the health of all the elements that have an effect on the impact energy. For example, an inbuilt digital timer in the PLC will trigger an alarm to shutdown the process if the air pressure doesn't reach the pre-set/desired

Continued on page 26

value within a specified time, or if it exceeds the pre-set value. Similarly, a feedback loop will attempt to correct the wheel speed in a centrifugal wheel-type machine through digital outputs from the motor and variable frequency drive. The diagram below is of a simple control system.

The system PLC also stores recipe/technique information and provides the data for downstream processing through an Ethernet (or similar) connection. The motors and associated variable frequency drives in the architecture could drive a centrifugal blast wheel or different axes of a multi-axis nozzle manipulator. The output is graphically represented in an HMI (touchscreen or otherwise) which also provides the ability to create recipes, store and retrieve when required.

The Role of Specifications

Specifications and their interpretation also had a role to play in the evolution of controls. For our purposes, let's refer to two of the commonly used specifications:

AMS 2430 (Rev. S, revised 2012-7) - (R) Shot Peening, Automatic (*only relevant discussion points are cited from the specification*)

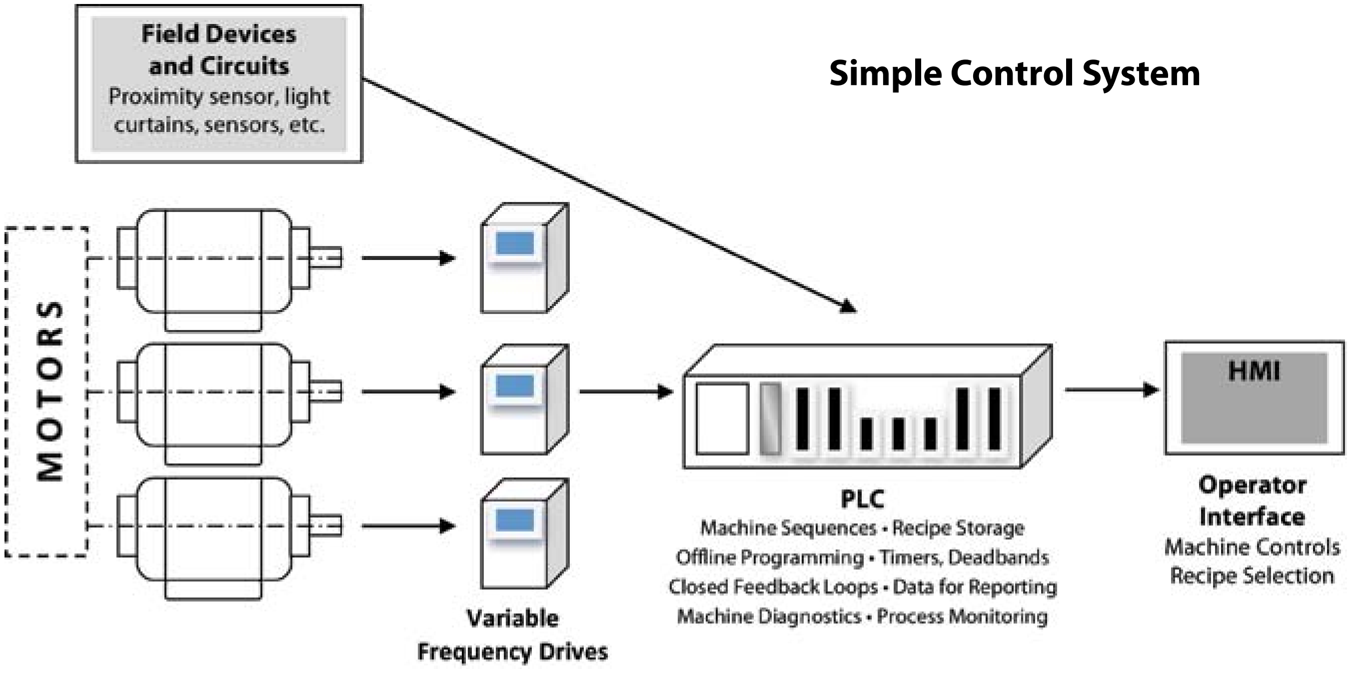
- The purpose (1.1) is identified as "specification covers the requirements for automatic shot peening of surfaces of parts by impingement of media, including metallic, glass or ceramic shot."
- 3.2.1.1 states, "the peening machine shall run automatically and may be computer controlled."
- Under 8. Notes, the specification defines Automatic (8.2.1) as "A class of peening machine that precludes use of manual movement or either the shot stream or the work part but relies upon mechanical means to provide these features".
- 8.4.5.3: Peening Equipment states as follows, "Robotic machines provide line of sight media impingement for a wide variety of geometries reducing multiple setups. Computer controlled and monitored machines offer the industry's best practice for process control. Computer controlled shot peening equipment should be considered for use in man flight [*sic*] vehicle components, components where shot peening is used as part of the design strength of the component, and components that are considered critical to system success."

AMS 2430 also elaborates on maintenance of media quality in the machine, measurement of results and other aspects for a thorough peening process set-up.

The terms "computer controlled and monitored" could be open to interpretation not only in terms of this specification, but also in general use of the terminology. However, our industry has taken the safe approach and automated its controls to use PLCs and PCs. Interestingly, the specification defines the process without forcing the user to employ a particular type of control system in the machine. In the simple architecture shown below, the enhancement to "computer controlled and monitored" will result in the use of an industrial PC to store a greater number of recipes/techniques and also provide the interface to transfer process information through an electronic data highway to the customer's central controls system for further processing. Some industrial PCs are also available with a soft PLC integrated into the PC as a software PLC. This results in less hardware with a possible cost savings.

AMS 2432 (Rev. C, revised Sept 2007) - Shot Peening, Computer Monitored (*only relevant discussion points are cited from the specification*)

- The purpose (1.1) is identified as "specification establishes the requirements for computer-monitored peening of parts surfaces".



- 3.2.4 states that "Peening machines shall be equipped with computers for continuously monitoring and recording the parameters shown in Table 1 within the tolerance indicated." Table 1, paragraphs 3.2.4.1 to 3.2.4.12 lists all critical parameters such as media flow, air pressure, wheel speed, nozzle speed, and table speed. with their respective allowable process tolerance (shutdown limits).

AMS 2432 elaborates on process monitoring and the user could draw similar inferences about the use of computers/ industrial PCs when referring to this and AMS 2430. However, AMS 2432 provides background information on a much debated topic in our industry—motion control.

Motion Control in Shot Peening Equipment

To quote from AMS 2430S 3.2.1.1: "…The machine shall provide a means of propelling, at a controlled rate, media with air pressure against a part…The nozzles and the part shall be held and moved mechanically. The part shall not be subject to any random movement during the process. The machine shall be capable of consistently reproducing the required shot peening intensities."

The goal of a peening process specification is repeatability and accuracy in a reliable machine. With regards to motion control related to shot peening, this means maintaining a constant stand-off distance from the component being peened, and repeating it when the same part is processed at a later date. This also means maintaining the same angle of impingement to all surfaces of the component, usually between 45 to 80 degrees, preferably towards the higher end of the range. AMS 2432C, 3.2.4.11 and 3.2.4.12 tabulate process tolerances for nozzle/wheel position and table/part indexing at 0.062" (1.57 mm)/5 degrees. My machine programmer colleagues in this industry will agree that these tolerances are a far cry from tolerances of 0.00004" to 0.004" that could be possible and even a requirement with other machine tools. In order to achieve such tolerances, the use of CNC machines is inevitable.

A survey of various peening applications over the years makes it abundantly clear that such tolerances in a shot peening machine have never been called for. The peening process is very forgiving in terms of tolerances. Accuracy of ± 0.005" and repeatability of ± 0.002" are well within compliance with all specifications drafted to date for peening processes. Such values can be easily achieved using servomotors and motion controllers without the need for CNCs and a knowledge of their programming codes.

This discussion is not to advocate the use of one system over the other, in this case the use of motion controllers over CNCs, but to evaluate the need and simplify our equipment for a relatively simple process (shot peening).

A shot peening machine with simpler controls will allow the operator and maintenance personnel to focus on the most important aspect—the peening process itself. The use of robots in shot peening machines has added a new dimension to our discussion where complete proven and packaged solutions have eliminated discussions of motion control and G codes. Although not applicable for all applications, robots are also commonly used with nozzle manipulators to increase the versatility of the shot peening machine to handle parts of varying geometry.

Summary

- The success of your peening operations depends on more than just controls. When your machine specification lists a "CNC Peening Machine," it is beneficial to evaluate your peening process and determine whether CNC is really a requirement. Motion controllers are usually less expensive than CNCs and don't require a special programming language. There is no argument about the aerospace customer's familiarity with CNC equipment, but it has to be made clear that shot peening cannot be placed in the same category as a CNC milling center when discussing the process.
- The next generation of shot peening machines need to emphasize user-familiarity with the process and make the controls intuitive with less needless sophistication. This can be achieved only if the user takes ownership of the equipment and develops the process with established and documented procedures.
- The peening process has been established with proper measures for process stability such as the plotting of saturation curves. It's important that shot peening be treated as a special process and not an extension of an existing blast cleaning process.
- Machines are secondary; your peening process design comes first.

A robotic peening cell with an ABB 6-axis robot to control nozzle movement and a DC or Servo drive to control part movement.