Generic Almen Fixtures for Intensity Measurement in Shot Peening

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Applying the shot peening process on aerospace parts can be a tough challenge as geometries can get complicated and requirements quite strict. Documented cases of aerospace component failures also remind us of the value of all processes involved in the production of a part, as every operation is important in order to achieve expected mechanical properties. In order to be as precise and flexible as possible, the use of CNC or robotic machines is often the logical way to deal with a wide variety of parts, complicated geometries and short turn-around times. As specifications are also evolving with more precise requirements in terms of intensity and coverage control, the new generations of CNC and robotic shot peening machines are often the only option that will allow meeting those requirements. However, when working with CNC machines, it doesn't take long to recognize that many current specifications were first issued when the only available methods for shot peening were manual, centrifugal wheels and simple automated nozzle machines. Requirements like the eight hours interval between intensity verifications and media analysis remind us that the new generations of precise and highly controlled machines were not available a few years ago. As specifications are evolving, it can be interesting to make them more applicable to CNC or robotic gun manipulator machines while enhancing control and quality.

The following document was produced to explain the concept of generic Almen fixtures in a CNC/robotic shot peening application, which is a technique that could be added in the near future to shot peening specifications. It will demonstrate how it can improve the accuracy of the intensity measurement during process setting and in production and the overall advantages of using this technique. It is important to note that this concept hasn't been fully validated yet. A test protocol is currently being developed in order to verify the basis of the generic Almen fixture concept and evaluate its validity for shot peening. The denominations given to various types of Almen fixtures are used for this document only and are currently not related to any documented shot peening specification.

The Concept

An Almen fixture is an assembly of Almen holders used to measure the intensity of the shot stream for given machine parameters. Although most specifications don't mention several types of Almen fixtures, it is possible to separate the widely used Almen fixtures in two types, the simulative and semi-simulative. The simulative Almen fixture is based on the geometry of the part being shot peened, simulating the position and angle of each surface relative to the other, which is the requirement of most shot peening specifications for the Almen fixture configuration. The simulative fixture should also be installed in the same work holding fixture as the actual production part, and be peened under the same conditions. This type of fixture is habitually constructed from a rejected part modified to fasten Almen holders, or from a welded assembly that orients the holders to replicate the surfaces to be verified.

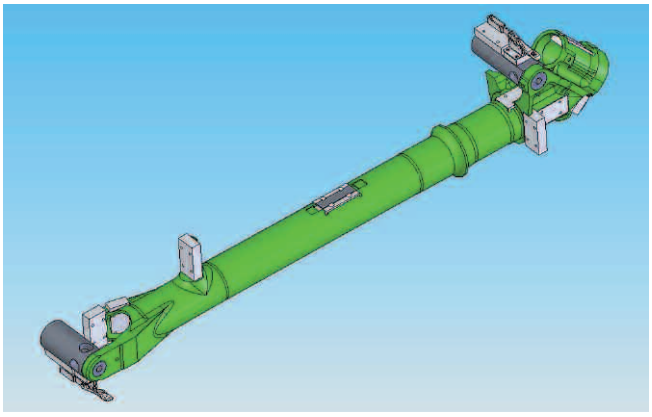

Figure 1: Simulative Almen fixture

Semi-simulative Almen fixtures are mainly aimed at measuring the intensity in bores or in holes when using rotary lances or deflectors. Those fixtures are already commonly used in shot peening applications on many types of shot peening machines, from the fixed position lances (non mounted on a manipulator arm) to the CNC/robotic manipulated lances. In both cases, it is an accepted procedure to control only the shot peening parameters of the lance, and not the position of the fixture in the envelope of the machine. In other words, the fixture can be placed anywhere in the machine, as long as the lance is positioned and translated along the axis of the bore. The semi-simulative Almen fixture thus replicates the geometric parameters (angle of incidence, distance) of the shot stream in the bore, but not its position in the workspace of the machine. It also replicates the conditions of rebound and turbulence that can interfere with the shot stream.

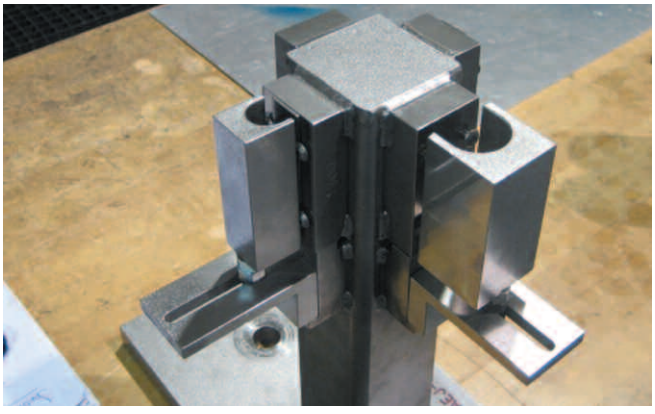

Figure 2 - Semi-simulative Almen fixture for small bores (1.500" and 0.750" diameters in that setup)

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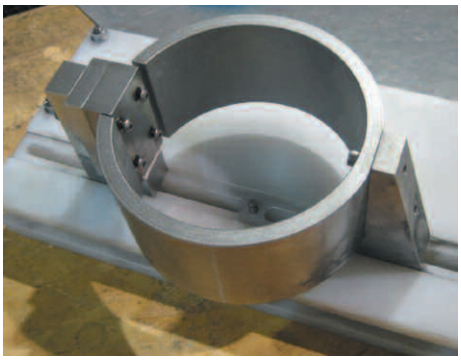

Figure 3 - Semi-simulative Almen fixture for large bores (5.000" diameter in this setup)

The use of semi-simulative Almen fixtures has given the concept of generic Almen fixtures for nozzle peening applications. This new concept was established based on the fact that a semi-simulative Almen fixture doesn't have to exactly replicate the part (the position of the bore on the part) because the machine can ensure the position of the lance in the bore. Considering that point, we can extrapolate that this procedure could be applied to external peening. On CNC/robotic shot peening machines, the accuracy of the manipulators ensures that the position of the nozzle relative to the shot peened surface is precisely controlled in terms of distance and impingement angle. Those two parameters being handled by robot programming, Almen fixtures can be used to control the other intensity influent parameters as air pressure, media flow and media properties. It is important to note that those parameters are independent from any of motion-related parameter. The next section defines the concept of generic Almen fixtures, the way they are used and their limitations.

The use of generic Almen fixture is based on the fact that the new generations of shot peening machines, through the use of CNC or robotic motion, have precise control of the position of the nozzle in the work envelope of the machine. As those machines are habitually programmed using teach mode, it important to note that if generic Almen fixtures are to be used, teach mode should be limited to simple nozzle motions, so that direct measurements of impingement angle and distance can be performed directly on the part used for programming. If the geometry calls for complex trajectories in which constant impingement angle and distance can't be assured by teaching, offline programming should be used. Offline programming consists of computer generation of nozzle trajectories using 3D model of the part, along with simulation and collision check software. Those tools allow a really precise control of the motion of the nozzle in the work envelope, along with the possibility of specifying precise impingement angle, distance and feed of the shot stream relative to the part.

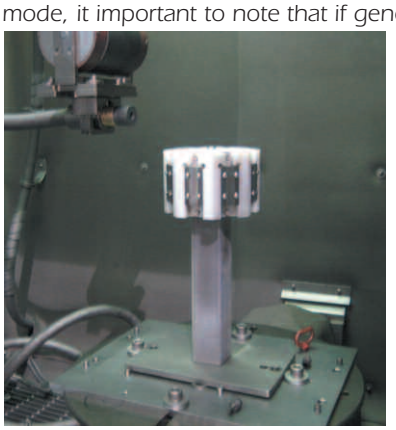

Figure 4 - Generic Almen fixture

When using a generic Almen fixture, the nozzle is first positioned as in figure 4 and shot peening parameters (air pressure and media flow rate) are stabilized after starting the blast nozzle. The blast gun is then moved down with a given distance, impingement angle and feed relative to the strip. Once the Almen curve has been built and the saturation point is within the requirements, the impingement angle and distance will be associated to a recipe in the machine, along with air pressure and media flow rate. This recipe will then be used in offline or teach programming for given surfaces on which impingement angle and distance are physically possible. If many combinations of impingement angle and distance are necessary to shot peen all surfaces of a part (because of shading or machine limits), every one of them will be assigned to a recipe, and every recipe will be tested on a separate strip of the fixture when performing intensity verification at the required time intervals.

To get a good understanding of the concept, it is important to separate intensity from coverage in the shot peening process. As definition, intensity is the measurement related to the kinetic energy of the shot stream when it hits the surface of the part and coverage is the percentage of the surface which is covered by shot peening dimples. Given those definitions, we can dissociate the test strip saturation time and the 100% coverage exposure time of the part. This can be simply explained by the fact that the high hardness spring steel used for Almen strips will take a different exposure time to reach 100% coverage than a part made of aluminum or any other material. Based on those facts, we can control intensity on the generic Almen fixture, and then use a rejected part to perform coverage mapping for each surface with the appropriate recipe, which ensure uniform and optimal coverage over the whole part. More information on the distinction between intensity and coverage determination can be found in SAE documents AMS 2430 (shot peening, automatic), SAE J2277 (shot peening coverage) and SAE J443 (procedure for using standard shot peening test strips). It is important to note that the concept of generic Almen fixtures is based on the distinction between intensity and coverage, and the understanding that the exposure time at saturation generated by the Almen curve does not influence the exposure time (or nozzle surface feed in CNC/robotic machines) needed to obtain 100% coverage.

The use of generic Almen fixtures requires CNC or robotic equipment equipped with precise monitoring and control devices. This monitoring ensures that all parameters that are important for intensity and coverage are controlled, stabilized and that production is stopped if a problem occurs. Generic Almen fixtures as presented are aimed at pneumatic shot peen machines that allow control of the shot stream compared to a wheel blast machine which has a wide blast pattern with variable impingement angles. However some examples of intensity verification on wheel machines have been known to work a lot like the present concept, measuring the properties of the shot stream in a position different than the position of the part. It is, however, out of the scope of this document to describe those techniques.

Given those assumptions, there is no necessity to perform intensity measurement on a fixture that simulates the actual geometry of the part when using equipment that controls the "geometric" parameters (angle of impingement, nozzle distance) with good accuracy. However in some situations the simulative and semi-simulative Almen fixtures are still necessary, like in the following cases:

- Shot peening is performed with rotary lances.
- Geometries can cause important shot rebound that could alter intensity.
- Geometries can cause turbulences which could affect the shot stream.

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- Media build-up could cause interference with the shot stream.

Improvement of Accuracy

From the results of preliminary testing, the use of generic Almen fixture can improve accuracy when building Almen curves, as well as during intensity verification in production. It is important to note that the following observations are qualitative and based on experience in building saturation curves, as no qualification or any other quantitative data is available at the moment.

- An important point when using Almen strips, as stated in SAE J443, is that the test strip shall exhibit uniform coverage. In cases where simulative test fixtures are used, it is often impossible to ensure that the coverage is uniform. When inspecting a strip after an exposure time greater that the saturation time, the strip will probably show complete coverage, but in most cases it will be impossible to prove that the whole surface is at exactly the same coverage. This can be explained by the fact that all shot peening machines (wheel or air blast, CNC or not) rely on multiple passes on the part to attain complete coverage. When using generic Almen fixture, a single pass is performed on the strip with a given feed rate. This ensures uniform coverage on the strip and thus greater precision or arc height measurement.
- Nozzle motion programming often calls for complex curved trajectories, on which it is hard to specify a given and uniform feed on the part surface (except when using offline programming). As feed is really important when building a saturation curve, the concept of performing a single pass, with a simple motion at a given feed will allow a greater level of correlation between the feed (which is correlated to exposure time) and the arc height. This more precise correlation again allows more precision when building saturation curves.
- When building a simulative Almen fixture from a scrap part or a welded frame, Almen holders often have to be welded in place. This causes a risk of warping the grinded surface, as well as altering the hardness locally near welding points. Generic Almen fixtures don't have those problems making them more compliant to SAE J442. Welded Almen fixtures can also become distorted from being shot peened numerous times, which can cause errors in intensity evaluation.
- Building a simulative Almen fixture from a rejected part or a welded frame is a complicated task, which involves designing the fixture from a 3D model, producing detail drawings for machining, performing machining, welding or attaching the Almen holders and often heat treat the fixture. This takes a considerable amount of time in process preparation in a context where lead time is an extremely important variable. The use of generic Almen fixtures eliminates all the mentioned tasks, which can easily cut many days and even weeks of process preparation for complex parts.

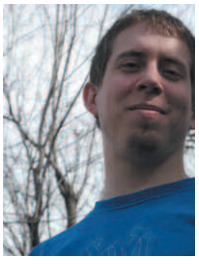
Conclusion

With the introduction of new materials, more complex shapes and stringent requirements in aerospace components, it is obvious that intensity measurements techniques have to be adapted to the new generations of CNC/Robotic shot peening equipment. Those new machines have greater control on the process oriented variables and are moving from non-precise and poorly controlled machines to precision oriented equipment when the proper programming techniques are used. The implementation of offline programming allows greater consistency on the application of the shot stream, which should allow us to step away from simulative Almen fixtures as long as the limitations mentioned before are considered. The next step is to verify if the machine can keep all intensity influent parameters constant in the work envelope. This step is being developed in a validation plan which will be aimed at verifying the influence of the motion and position of the blast gun (which changes the blast hose radiuses, position and vertical length) on media flow and air pressure. To follow the aerospace industry's highly developed technology, the generic Almen fixture is only one of the steps that have to be made toward the replacement of the Almen technique by shot velocity sensors or other measurement devices. This could lead to development and acceptance of closed loop intensity control systems implemented in shot peening equipment.

CNC/robotic machines have many advantages in application of shot peening, especially in aerospace applications. The only downside of the new generations of shot peening machines is that the actual specifications are not yet fully adapted to a high level or process control, by requiring testing and validation to be performed according to old technology and poorly controlled techniques. The use of generic Almen fixture is one of the ways that can lead to a more efficient use of CNC/robotic shot peening equipment while still complying to the main specifications requirements. As more testing is performed, the concept will be refined to enhance efficiency and quality of results during production and process settings. ●

References

AMS-S-1316 5Shot Peening of Metal Parts
SAE J442 Test strip, Holder and Gage for Shot Peening
SAE J2277 Shot Peening Coverage
SAE J443 Procedures for Using Standard Shot Peening Test Strip
AMS 2430M Shot Peening, Automatic
AMS-2432B Shot Peening, Computer Monitored Work Biography



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Tekalia Aeronautik Inc. is a Montreal-based company specializing in surface treatments and NDT inspection of aerospace components, mainly landing gears. Tekalia Aeronautik Inc. integrates all the main special processes under one roof including NDT, CNC shot peening, plating, anodizing, thermal spray application, grinding, and honing.Tekalia Aeronautik Inc, relies on a highly developed ERP system and a high level of equipment automation and standardization to provide accurate, precise, repeatable, and reproducible processes with live monitoring and data acquisition.

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