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THE BASICS OF FASTENER SORTING

Over twenty-five years ago when I first started working in the fastener industry PPAP, ISO9000, and zero defects were not yet commonplace ideas. In fact, when I first started, sorting was all manual and reserved pretty much only for salvaging parts that a customer returned with a major problem. Today, it is a very different story. A large percentage of fasteners made or sold in the U.S. are sorted, with some companies serving certain industries or customers adopting the philosophy of sorting 100% of their parts.

There are a variety of reasons to sort parts; however, the most predominant today stems from the customer's expectation for "zero defects." Unfortunately all too often a fastener supplier has been blindsided by an overzealous customer that has put thousands of parts in limbo because one questionable part was found in that lot. Don't get me wrong, suppliers need to be responsible for the product they make or sell and anytime a significant problem occurs where several questionable parts are discovered, the supplier needs to trouble shoot and find a root cause.

At one level the quest for "zero defects" is admirable and truly beneficial to the development and reputation of any supplier. However, the staunch demand and zealous adherence which some customers take the philosophy of "zero defects" can strain even the best relationships and be simply unrealistic. Take for example, a world class organization that is operating at a 6 sigma quality level. This means that they have a 99.99966% yield rate or 3.4 defects per million opportunities. Clearly, even at this world class level of performance, zero defects are not expected. In fact, the authors of ISO 16426:2002, a Fastener Quality Assurance System standard, realized this challenge and clearly state in Annex A1.1, "The quality objective, zero defects, cannot be realized with today's state-of-the-art methods. To achieve this aim, intermediate objectives are set by specifying criteria for evaluating the delivered quality of fasteners. In this International Standard, such criteria are based on non-conforming parts per million (ppm) and/or process capability (Cpk) for specified characteristics."

Therefore, if as the International Standard suggests, zero defects "cannot be realized" with today's technologies, suppliers must augment their process technology with other strategies to satisfy their customers. Today, that means that they must be prepared to engage in 100% sorting.

This article is intended to take a look at the current state of fastener sorting and provide a basic overview of different techniques, equipment, and several fastener specific scenarios which commonly employ 100% sorting technology. This article is not intended to make an argument for or against "zero defects" or any other philosophies that establish criteria for what is deemed acceptable or unacceptable, but rather to educate on the methods that can be performed to provide a reasonable assurance of the best product quality and enhance customer satisfaction.

Why Do We Sort?

Notwithstanding the fact that the customer demands it, at the core, is the reality that even with world class quality management systems in-place, today's technology simply cannot realize perfection. The speed with which fasteners can be produced is so great, that the number of opportunities for defects can overwhelm even the best system. Additionally, fasteners are usually transferred to different processes multiple times during the course of their manufacture exposing them to many opportunities for damage or contaminating them with foreign material. Currently, the only way to address these possibilities is to sort the parts immediately prior to packaging and shipping to the customer. Therefore, suppliers sort not only because their customers want them to, but also because they know that there are points in the production process that are outside of their control.

What Do We Look For In A Sort?

The type of sort will most likely be determined by a number of factors. These include what the parts need to be sorted for, the number of parts involved, the urgency with which they need to be sorted, the technology available to the party doing the sorting, and the costs associated with the process. Perhaps the most important of these questions and certainly the one that drives the others is what the part must be sorted for. In fact, a very different level of sorting technology is required, for example, to locate and remove parts with head cracks than simply to locate and remove mixed or foreign material. Most often the nature of what a part is being sorted for will guide the process by which it is sorted. Take for example, again, the need to sort out parts with head cracks. This is feasible to do visually with the human eye or a camera, but would not be effective with a sorting method that looks at a projected shadow or compares the head diameter.

Types Of Sorting

In general there are two classes of sorting, manual and automated. Normally every organization has some degree of manual sorting and many today possess varying degrees of automated technology as well. Manual technologies are relatively one dimensional and do not provide a great deal of variety of methods. On the other hand, automated sorting technologies are quite varied. The most common employ mechanical methods, cameras, eddy current, shadow projection, laser, or any variety of combinations of these technologies.

[1] Manual Sorting

Manual sorting falls into two primary categories: visual comparison and gaging.

Visual Comparison: In the first method, visual comparison, an individual is visually evaluating parts against a known or desired standard. The sort may be as simple as spreading parts out on a table or conveyor belt and removing any parts that don't belong, for example, when foreign material is mixed in with the subject parts. However, more often than not, the individual sorting parts with this method is actually picking each part up, rotating or turning it over and looking at the part from all angles. An example of this may be when appearance is important and small blemishes in the finish must be identified and removed.

Gaging: The other category of manual sorting is gaging. This is where a feature can be assessed by using a gage to obtain a "good" or "not good" determination with an attribute gage or by measurement with a variable gage. Attribute gaging is the more common scenario because the time invested is much shorter than using a variable gage, but if an actual dimension must be verified, it would not be unheard of to utilize variable gaging methods as well.

It is universally known that manual sorting is less than perfect. Although it is impossible to settle on an exact error percentage that is universally accepted, it is often suggested that manual sorting is only about 80%-85% accurate. In reality, it really depends on each specific situation, with minor or hard to identify defects being the least effectively detected and gaged features using proven gaging techniques potentially being very effectively checked.

In some cases, manual sorting may be the only way to proceed. This occurs when "high tech" methods are simply incapable or unfeasible to check the desired attribute. Remarkably this scenario is more common than one might think. For example, if parts are being sorted for slight shade differences or minor finish blemishes, even the best of today's cameras may not be as discriminating as the human eye or able to see every surface of the part. In another example, a common occurrence is the need to verify that a threaded part will freely accept a ring gage or a mating nut for its full threaded length. Because of the action required to thread a ring gage, this likely would not be feasible on available automated sorting equipment.

In addition to these feasibility arguments there are two other big advantages to manual sorting. First, it can usually be mobilized with little or no delay. In cases where urgency rules, this may be the determining factor why a manual sort would be employed. Secondly, it requires little capital outlay, although it is important not to be penny wise and pound foolish and opt for a decision to save the expense of automation in the short run at the expense of a wise long-term investment.

Besides the possibility that many of these sorts will not be perfectly effective, the other major drawback is throughput and cost. A manual sort, even in bulk (i.e. spreading many parts at one time across a flat surface) is slow and may require multiple human resources to satisfy necessary throughput requirements. If it is a subjective sort, having multiple individuals sorting the same thing only complicates matters and reduces overall effectiveness. Additionally, multiple individuals performing a slow task results in high labor costs which must be borne by either the supplier or their customer.

[2] Automated Sorting

Automated sorting falls into four categories: mechanical, vision, laser and eddy current sorting.

Mechanical Sorting: Mechanical sorting methods have been around for many years and are very good within a very limited range of capability. In particular, mechanical sorting methods are effective at removing debris, mixed and foreign material. They can also be effective in sorting out over or undersize heads. The most common mechanical sorting methods are roller sorting *(see Figure 1)* and bowl sorting *(see Figure 2).* In the roller sorter the rolls are counter-rotating cylinders and set-up in a way that the desired part will drop through the rolls at a predetermined location along their length corresponding to when the head or collar diameter are equal to the distance between the rolls. Parts or debris that have either smaller or larger diameters will not drop out in this location and can be segregated into reject containers. The bowl sorter is similar in theory, as parts progress out of the bowl they can be segregated by length or head diameter, producing an efficient means of sorting for debris, mixed or foreign material.

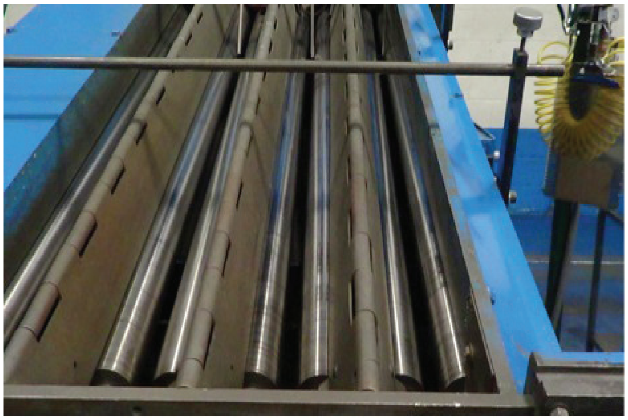

Figure 1: Roll Sorter (4x set of rolls)

Figure 2: Bowl Sorter (Note chutes for suspect material on left)

Mechanical methods may also be employed for special features. Years ago I recall providing a part to a customer that had a hole drilled all the way through it. We had constructed a special machine that fired a pin through the part to verify the hole was present and went all the way through. Likewise in more recent times, I have been working with a piece of automation that has a check station to verify the presence and condition of a flat washer using a series of precise linear probes. The problem with these, however, is that they are specifically developed for only several parts and are not pieces of equipment that can be universally employed for many different parts.

In a similar vein as the special hole sorter described above, some automated sorting units have mechanical, spring loaded pins on carousels that are used to enter a recess and verify that the recess has no fill. These units tend to perform pretty well but are not perfectly effective. With better resolution by cameras, many of these systems are now being replaced by camera technology.

Vision Sorting: Today vision sorting is probably the most utilized of automated sorting techniques for fasteners. There are two methods that are commonly used, cameras and shadow projection (also known as optical sorting). Camera technology has so improved and has become so cost effective that it has all but replaced shadow projection technology. However, there are still many pieces of equipment in this realm that are operating quite successfully every day.

In the shadow projection technology parts cycle past a high intensity light source generating a crisp part shadow. Limit switches are set-up to determine desired edges on the shadow and are thus able to discriminate desired features. This technology is particularly effective in verifying that parts have threads, are the correct length, have the correct head diameter, and for separating foreign material. Additionally, this technique has long been used to verify SEMS washer presence, either single or multiple versions.

Traditionally this method of shadow projection used limit switches to detect desired criteria or set points. Today's equipment that utilizes this technology increasingly has gone to cameras and computers with precise edge detection technology. By evolving this technology, additional functionality in discriminating threads, thread conditions, diameters, and groove features has been gained.

Vision technology continues to evolve and accounts for many of the more recent advancements in sorting technology. Cameras can be placed both above and below the dial or rail that carries the part being checked as well as horizontally or vertically mounted *(See Figure 3 and Figure 4)*. This allows viewing of features both from the side and above. A wide assortment of features can be checked, but the more typical ones include thread presence, thread condition, length, head diameter, head cracks, recess fill, ball caps, out-of-round heads, shank diameter, point geometries, and grooves.

Figure 3: Vertically mounted camera for head cracks

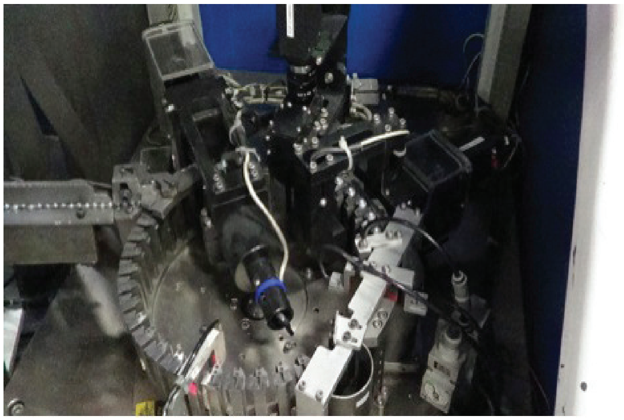

Figure 4: Multiple Camera Sorter- Mounted horizontally and vertically

One of the other advantages of modern vision systems is that they can be integrated with computer technology to collect and analyze a wide variety of data. *Figures 5 and 6* show screen shots of such a system. In addition to keeping track of the number of pieces sorted and/or the number of passed and failed parts, it may complete statistical calculations, report on ppm, or generate Pareto reports. This analysis can be very helpful to improvement processes downstream of the sorting.

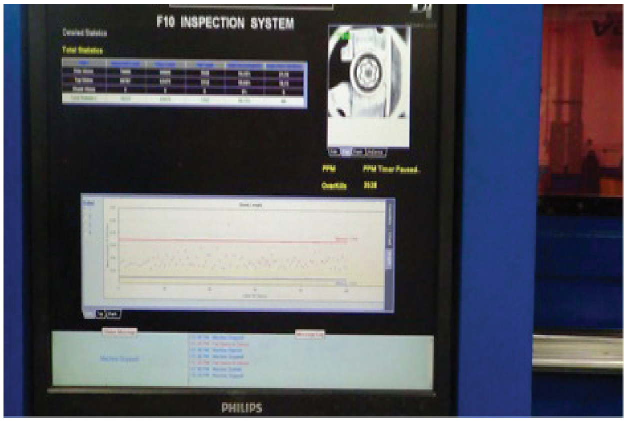

Figure 5: Sample Output of Sorting Run

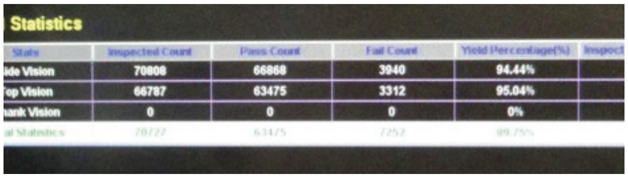

Figure 6: Sample (above) of counters and statistics kept during Sorting Run

Unfortunately cameras are limited in a number of ways. Unless the part is rotated or the camera has very special lenses, a camera is only able to view the surface at which it is pointing. This means that if there were damage on the reverse side of the part, it would escape detection. Cameras are also very dependent on lighting. If areas are dark so that edges and features are indistinguishable the camera will not work. This could limit trying to look down into internally bored features. Additionally limited or stray lighting conditions can impact the ability to discriminate part features; however, many systems today employ ingenious means of eliminating these issues.

Laser Sorting: About ten years ago laser system technology was introduced to sorting fasteners. Unlike many of the other techniques that were simply pass or fail in nature, laser technology brought the ability to actually establish variable measurements. Depending on the number of lasers and their placement, usually multiple features could be measured from several different directions. This made laser sorting a versatile and powerful method of sorting.

Like the vision systems described above, the laser systems can be integrated with computer technology to supply a great deal of useful data on the parts being sorted. In the right hands this information can be very valuable at making continuous improvements in downstream processes.

Like any of these methods, lasers have limitations. The number of lasers will greatly influence the precision which the equipment can discriminate features, so that machines employing only a few lasers are likely to be less capable than those employing many . Like many of the other sorting methods, seeing into a part is difficult or impossible and to get an accurate measure the laser must be looking straight onto the part. Many laser systems utilize a v-shaped rail to feed the parts past the lasers. Although there is nothing inherently wrong with this method of feeding, it does require that parts are spaced out from one another which usually means they are slower than systems that incorporate a dial feeder or straight line conveyor systems. Additionally, lasers must operate in a shrouded environment to not only protect individuals that might be nearby from potential eye injury from the laser beams, but also the laser beams from ambient light interference.

Eddy Current Sorting: None of the methods reviewed so far are capable of making any kind of determination of what cannot be seen. The only prevalent method available today to do this on a limited basis is eddy current technology. In this technology, the parts are passed through a rapidly changing magnetic field which generates electrical currents in the parts known as eddy currents. These are either compared against a known good sample or “learned” by the computer after running a number of known good samples. When a part is introduced that has a different eddy current pattern from the reference, it is sorted out.

Eddy current sorting is commonly used to determine whether parts are heat treated or not, have a significant volume difference, or have significant cracks. Eddy current sorting is very effective when comparing against extremes such as parts that are fully hardened or dead soft. However, it may not be very effective when discriminating between small differences, for example, like a couple of points of hardness.

Eddy current technology is commonly combined with other sorting methods to give a comprehensive evaluation of parts. In combination with the other methods such as cameras or lasers, eddy current makes a potent addition to the overall effectiveness and capability of the sorting method.

Developing Technology

Sorting is an area that has seen a great deal of advancement in the last ten years and will continue to do so for some time. Advancements in speed, accuracy and capability are underway. In particular, a great deal of development is underway to utilize better camera technology. In particular higher resolution cameras are discerning things today that just a short time ago were impossible. Lenses and lighting are also a place where advancement is occurring. It is now possible to utilize prisms and mirrors that allow the lens to not only see the surface the lens is pointed at, but also to see vertical or oblique faces. This is especially promising technology for being able to see all the way around a part and for discerning cracks on the sides of heads.

Speed continues to be an area of improvement. Most automated equipment operates in the 300-500 parts per minute range, but there are pieces of equipment that can operate well in excess of these values, in the multiple thousand pieces per minute range.

Fastener Specific Issues

The most sorted for item by fastener manufacturers and resellers is mixed or foreign material. This is likely for two reasons;

[1] Even with state-of-the-art processing techniques, many opportunities exist for small quantities of parts to get intermixed, and,

[2] As customers automate more assembly operations, they simply cannot afford to have mixed material jam up their feeder systems. Fortunately, in most instances, this is likely the easiest attribute to sort for.

Every one of the methods described in this article is capable of discerning foreign material and removing it. If this is the only area of concern, it is likely to be sorted at the highest speed and in the most simplistic fashion possible, such as roller or bowl sorting.

Perhaps the second most prevalent sort is for cracked heads. This one is a little more challenging as small or tightly held cracks or cracks predominantly on the side wall can be very difficult to discern. Today, these sorts are predominantly done by vision or eddy current *(See Figure 7 and Figure 8).* Again, technology is ever improving the discernment capability, but small cracks or ones that are not open often miss discernment and remain a challenge today.

Figure 7: Typical Compression Cracked Head

Figure 8: Sample Screen Shot of Cracked Head Detection

Missing threads are another feature that is commonly sorted for. Like foreign material, missing threads are very problematic for the customer. In many cases a Tier supplier has little or no way of discerning a stud missing a thread. It is not until after an expensive assembly makes its way to the OEM that the missing thread is discovered. By this time, however, it is too late and significant rework, downtime, and scrap costs may have accumulated. Fortunately, like foreign material, missing threads are easy to discern and visual, laser, and manual methods are all reasonably effective at discerning these problems.

One of the more problematic characteristics to discern is recess fill or minor pin break-out in a recess. Recess fill is somewhat subjective, which complicates what is considered acceptable or not. Although it might be distinguished using a camera or mechanical pin, these methods are not 100 effective. Often this is sorted for manually.

The most challenging characteristics to sort for are probably one-time dimensional and tolerance issues, especially those falling in the geometric tolerance category. Certain features, like a diameter, may be easy to discern with mechanical, camera, or laser sorting or overall length with camera, shadow projection, or laser sorting. However, when parts are bent, not concentric, or have significant run-out, none of the automatic methods are particularly effective and the only option may be to manually gage the parts.

Sorting Equipment

There are a variety of equipment types to choose from and suppliers to furnish them. The table below lists many of the predominant suppliers of automated equipment to the fastener industry today and the primary technologies their equipment employs. Surely this list is not all inclusive, but captures many of the players active in the United States fastener industry and illustrates the diversity of options available.

Conclusion

Sorting is a process that will continue to gain acceptance and momentum in the years to come. In some industries, particularly automotive, almost all fasteners are currently sorted. It is likely that additional industries will continue to follow suit. As there is greater demand there will continue to be higher expectations of what sorting processes are capable of. As a result, we can expect continued development and advances in technology. Sorting will never perfectly address the “zero defects” request, but for now, it will be one of the best tools in a supplier’s toolbox to address his customer’s expectations.

Acknowledgement

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Company	Location	Prime Technologies
Dimac Srl	Italy	Camera, Eddy Current
Dunkley International	Michigan USA	High speed and throughput systems
General Inspection	Michigan USA	Laser, camera, eddy current
LinearGS	Michigan USA	Laser, camera, eddy current, ultrasonic
Mectron Inspection Systems	Michigan USA	Laser, eddy current, camera
Pace Automation	Britain	Camera, optical, eddy current, probe carousel
Resec Systems	New Jersey USA	Optical
Retina Systems Inc.	Connecticut USA	Laser, camera, eddy current
San Shing Fastech Corp	Taiwan	Camera