Ever since the first Roman soldiers tossed their armor into a barrel full of water and river stones to shine it for battle, mass finishing has played a major role in efficient post-production surface improvement. That sort of approach is great—so long as the parts in question are, well, armor-like. But, what about today's world of advanced materials, miniaturized components, electrical connectors and micro devices? Finishing challenges have followed suit, giving metal finishing professionals increasing numbers of small, delicate parts that present special challenges in surface preparation, processing and handling. Processing delicate parts is one of the greatest ongoing challenges in mass finishing. And, here's the great irony: the smallest parts are often the ones produced in the greatest quantities. So, they are begging for a mass-finishing solution. But, due to their gage, shape and construction, they are often the ones least likely to succeed in a mass-finishing process.

Defining "Delicate"

While the term "delicate" is strictly in the eye of the beholder (producers of two-gram steel stampings or two-pound jet engine turbine blades may both legitimately see their parts as being delicate), we'll limit our discussion in this article to particular types of parts that can present the most "tricks" to metal finishers:

- **Thin parts.** Small, flat parts, such as stampings thinner than 0.025-inch present several challenges. First, they can easily bend or twist in-process. Second, their profile introduces the issue of capillary attraction; the tendency for thin, flat parts to stick together and "stack," effectively negating consistent surface finishing. This is especially true in wet finishing processes that, despite advances in dry processing methods, represent more than 90% of all mass-finishing applications.
- **Small parts.** Die casting is an inexpensive way to produce high quantities of detailed, decorative "near net shape" parts. Unfortunately, the typically thin walls and soft material often cannot withstand the weight, contact or force of the parts/media/water finishing mass without distorting. Other smaller parts such as powdered metal components may court damage due to their softer metallurgical structures.
- **Protrusions, tabs or slots.** Often, a delicate parts-finishing challenge comes not from size or weight but from shape. Parts with long "arms," protruding tabs, large slots or openings present challenges of part-part entanglement, media lodging or damage/distortion.
- **Fine finish requirements.** The final category of delicate parts is that in which the quality of the finish itself is the issue. For the customer who insists on a "mirror finish" or finished parts that "look like jewelry," this may require zero-impingement processes or other gentle handling requirements that produce the kind of low Ra results needed.

What can you do if you have parts that fall into one of these categories? As with most issues in mass finishing, start by learning your options. The easiest way to break them down is by examining each of the four main mass-finishing variables: machinery, media, chemistry and parts/media ratios.

The Machinery Connection

Tumblers and vibratory systems. This is where delicate parts finishing hits its first troubling paradox. While it may seem logical that delicate parts require delicate processes, "kinder, gentler" machines such as tumblers and vibratory tubs are not necessarily the best options. Small, flat parts tend to stick together (and to the sides of the processing chamber) and these machines can have a harder time breaking the capillary attraction that binds them. Changing to a processing chemistry with more "slip" can help, but doing so takes more energy away from the deburring, descaling, edge-radiusing or other jobs that the process is meant to accomplish. Parts handling can also be an issue, as flat parts are more likely to hang up on vibratory parts discharge ramps and chutes, making 100% parts accountability difficult at best.

That said, vibratory tubs and bowls are often the only mass-finishing systems that can do the job on parts with odd-shaped protrusions or tabs that can easily bend in higher-energy processes. Likewise, some super-smooth/mirror-finish processes (such as those used to burnish hand tools) are designed and optimized only for vibratory or tumbling processes. Also, vibratory tubs and bowls lend themselves to the use of dividers that section the processing chamber into discrete sub-chambers. This allows process development in low- or zero-impingement environments (e.g. just a few parts or even one part per "section"). One tip: if vibratory proves the way to go, choose a machine with fully-adjustable amplitude and frequency so that processes can be fine-tuned. A small change in either parameter can have immediate and visible results.

Parts with thin profiles, tabs, slots or unusual shapes present special challenges to metal finishers. Parts shown range in thickness from 0.187-0.012 inches, penny shown for scale.

High-energy systems. Counter-intuitive as it may seem, high-energy finishing machinery like centrifugal disc and centrifugal barrel systems can provide excellent solutions for delicate parts finishing. They have the raw power to overcome capillary attraction problems, and many offer parts loading/unloading/handling systems that can be very gentle on parts. Properly designed centrifugal barrel finishing (CBF) systems can actually offer the greatest process flexibility for delicate parts. In systems where barrel-to-turret rotation ratio is adjustable, processes can be designed from very aggressive to incredibly gentle—all while imparting up to 10 G of energy to the finishing mass. Even without adjustable barrel or turret speeds, CBF processes can be "cushioned" by simply increasing the amount of media or water/compound solution in the barrel. The small "mini" CBF machines are often the only high-energy choice for tiny parts.

Probably the biggest downside of CBF is the heat generated in a closed, high-energy barrel. While gentler cycles are possible, these cycle times are generally longer and can generate significant heat in the processing mass. This can reach the point of requiring intermittent pauses to pressure-relieve the barrels—thereby losing some of the advantage of shorter cycles.

Centrifugal disc (CD) systems present no such concerns, since the top of the processing chamber is open. And, at two to three G of energy, they provide plenty of processing power. So, many of CBF's advantages translate to CD. However, there is one unique feature of CD designs that can limit its usefulness in small parts processing—the gap between the stationary processing chamber and rotating disc or "spinner." Typically, this gap begins its life (in a new machine or spinner/chamber pair) around 0.01-0.015 inches. Over time and with use, this gap eventually wears and widens, with obvious results—thin parts or protruding tabs getting caught and jamming the machine or damaging the part. Also, due to its aggressive "slide" action, parts bending, tangling or part-on-part impingement can become issues. Still, in the hands of a skilled process developer, centrifugal disc can be a powerful processing tool that also offers perhaps the best opportunities for pre- and post-process parts handling and accountability. If centrifugal disc is an option, choose one with both an adjustable gap (preferably one that can be set and held at or below 0.01 inch) and infinitely variable spinner speed.

The Media is Part of the Message

Metal finishing media is a subject for a full-day seminar. The sheer array of materials, cuts, weights, shapes, abrasive materials and binders is dizzying. But, when processing delicate parts, the options are a bit more limited. Steel media, for instance, is often rejected pretty much out of hand because of its weight (with the exception of some burnishing operations). Likewise, many ceramic pre-forms can be too heavy to produce material removal without misshaping delicate parts. However, smaller ceramics with lower cut rates can offer good solutions. So can plastic media, which can be one-third the weight of ceramic, offer long wear life and cut rates that range from smooth burnishing to medium material removal. Porcelain media can also offer interesting possibilities. While they typically are not the choice for material removal, porcelain can be effective for burnishing or achieving low Ra finishes (the downsides: long cycle times and extremely higher per-pound cost). There are also some new media being developed right now with porcelain-like weight but with cut rates approaching aggressive plastics. The key is to select a medium that will do the job without imparting too much stress on the part—especially in high-energy machinery, which applies a physical force that reduces the aggression needed from the media. Generally speaking, when dealing with delicate parts, you'll have to live with trading off cycle time for the ability to mass finish them at all. But, as media technologies improve, this gap will close.

In some machines, including centrifugal disc, delicate parts can be processed in a "closed-loop" process. While most processes allow water and process chemistry to flow through the processing chamber, some call for closing the drain valve and allowing the water to fill the chamber. By using porcelain or other low-abrasive media and adding a fine abrasive powder (such as silicone carbide, aluminum oxide, etc.) very small or delicate parts can be gently processed. In these cases, the media is used mostly to support the parts while the powder and water "slurry" does the work. The down-side is that without a continuous flow of water to cool the chamber, friction from the process causes heat to build up in the mixture, especially in high-energy machinery. When not properly controlled, this heat can reduce the effectiveness of the process, damage delicate or sensitive parts and even damage the process chambers of some machines—especially in centrifugal disc machines with urethane liners.

This could also be a time to look into so-called "dry processing." Using special media (and, usually specially designed machinery that goes with them), a small percentage of parts are candidates for being finished with no water at all. The upsides: no capillary attraction, no wastewater stream and media that are exceptionally light and therefore gentle on parts. The downsides: dry processes can be dusty or dirty, usually require specialized equipment (which can be very expensive compared with similarly sized conventional machinery) and often require that the part be cleaned and completely dried before and after deburring. Several "dustless" media are becoming available. They are produced primarily in the Orient where high-energy dry processing seems to be catching on. These media may offer a solution in some applications, but the media is not commonly available and is often expensive.

Developing the Right Chemistry

The overriding theme of chemistry in any process is simply to keep parts and media clean, while minimizing water use. There may be other special considerations such as the need to descale, degrease, rust-inhibit or lubricate parts. But, the chemistry you select depends primarily on the media you plan to run and the type of part being processed.

Generally speaking (and, especially when dealing with delicate parts) finishers should avoid high-foaming agents—or the common temptation to run unnecessarily high concentrations of soap. In fact, according to U. S. Chemical Company's Dave Govoni, "Excessive foam only dampens the machine's processing capabilities. It can also retain fluid in the machine, increasing the potential for re-deposit of soils onto the part. In most mass- finishing processes, we look for chemistry concentrations of around one percent. If you can't do the job at that rate, you've probably picked the wrong compound."

That said, many delicate parts will benefit from chemistries that add lubricity or "slip" to the process. This can help finishers overcome challenges of capillary attraction, part-on-part impingement and in-process parts cleaning. Ask your metal finishing chemical supplier about compounds that provide low-foaming lubrication. Combined with a "flow-through" process, such as those that can be run in vibratory bowls or centrifugal disc systems (one of the upsides of the CD's spinner-chamber "gap") a good cleaning compound can go a long way to creating a clean, gentle processing cycle for delicate parts.

Parts/Media Ratios

The standard rule-of-thumb for a typical parts/media ratio in mass finishing is 3:1 by volume—thus, in a four-cu-ft working capacity machine, you would load three cu ft of media along with one cu ft of parts. This is always a good place to start. But, with very delicate parts, you may have to stop thinking in terms of a load of parts lying in a box. Instead, picture them tumbling and turning in a mass-finishing machine. To create this new rule-of-thumb ratio, determine the "orbital volume" of the part—a spherical shape. Calculate it by first measuring one-half of the longest dimension of the part. This becomes the radius of the sphere. Plug that dimension into this standard mathematical formula for calculating the volume of a sphere: 4Pr3/3. This more accurately represents the shape and "volume" of the part in-process. Now, convert that into the 3:1 media:parts ratio and go from there. You may be able to get more aggressive as you develop your process, but it's a good, safe starting point for parts that are easily damaged or cannot tolerate part/part or part/machine contact.

A Gentle Conclusion

Delicate parts can represent a challenge for even experienced mass-finishing professionals. As always, the only real answer is to continually try new processes and be willing to experiment. Work with your local metal finishing rep or job shop. They'll help you approach process development with a logical, scientific and experienced approach. Take advantage of the free parts testing and process development services that most media and equipment manufacturers offer. Remember —they want your business and are usually willing to help you develop processes in order to get it. Above all, don't listen to those who say it "can't be done." Sometimes, the most impossible-looking combination of parts, media, machinery and chemistry turns out to be the breakthrough process you were looking for.