METALCUTTING
CORPORATION

Quality Control in the Manufacture of Metal Parts

Achieving Design Specifications and End Functionality

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INTRODUCTION:
What is quality?

Most people would agree, the concept of *quality* is subject to a lot of interpretation. It can mean different things to different people and in different contexts.

However, as a product manufacturer, your goal is to achieve quality that is *exact* — a state that can be defined, verified, and reproduced again and again.

According to ISO 9000:2015 section 3.6.2, quality is "the degree to which a set of inherent characteristics of an object fulfills requirements."

In the manufacture of metal parts, which in turn are used to make countless other products, the purpose of quality control (QC) is to not only prevent defects, but also ensure that the parts are made to design specifications and will function properly.

A good QC program helps to keep manufacturing on time and on budget. It also helps to avoid product safety and reliability issues that can add to costs, result in product recalls, or cause problems that pose risks to users or consumers.

Since the quality of your end product and the success of your application depend on having quality components, your parts provider needs to have a thorough understanding of your requirements.

IN THIS GUIDE, WE'LL PROVIDE QUALITY CONTROL TIPS THAT WILL HELP YOU AND YOUR PROVIDER PRODUCE THE QUALITY COMPONENTS YOU NEED FOR YOUR MANUFACTURING PROJECT, INCLUDING:

- Part characteristics and requirements
- The method for achieving the desired results
- Accurate measurement tools
- Thorough quality inspections

What part requirements does your provider need to know?

The first step is to provide detailed design specifications that spell out the important characteristics and requirements of the components you need.

DESCRIBE THE PART CHARACTERISTICS

Provide your manufacturing partner with an engineering drawing that shows the requirements of the completed part.

The drawing should include all the characteristics of the part, such as straightness, flatness, circularity, concentricity, cylindricity, perpendicularity, parallelism, profile, and runout. Here at Metal Cutting, our customers are most concerned with the characteristic of length, outside diameter (OD), and, for tubing, inside diameter (ID).

This is where you have the opportunity to describe the part in precise detail, including the dimensions and tolerances for each characteristic. The specified ± tolerances will tell your provider how much variation is acceptable while still producing parts that will function as intended and meet your requirements.

For example, a part drawing might call out a perpendicularity tolerance for a feature such as a hole or pin, where that feature needs to be perpendicular to a theoretical axis. More typically for Metal Cutting customers, **measuring of perpendicularity** is specified in reference to the squareness of the end cut on small parts such as metal rods or tubes.

You also need to anticipate and account for downstream requirements. For instance, perhaps a product consists of a tube within a tube, both of which then must fit into another part when the final product is assembled. This would require precise **OD and ID concentricity** on the tubing components.

It is also important to be clear what system of measurement — standard or metric — you use and to how many decimal points any measurements should be rounded. This is especially true **when converting between inches and millimeters for part tolerances**, where you may need to also adjust for the upper and lower limits of the acceptable tolerance range.

Additionally, the accuracy of the tools that are used can be affected by conversion and rounding. So, for instance, if a part has a tolerance to three decimal places, at Metal Cutting we would make sure our measuring device goes out an additional decimal place, to maintain the upper and lower tolerance limits the customer has specified.

PRIORITIZE THE REQUIREMENTS

Your parts provider also needs to know which part characteristics are most critical to meeting your manufacturing quality needs.

While the goal, ideally, is to make all the characteristics of a part meet requirements, sometimes that is simply not possible. Therefore, you need to establish priorities and tell your provider which requirements are most important to:

- The functionality of the part — what it needs to do
- Its fit with other components
- How it interacts with other parts

Multiple Tolerances

Keep in mind that since tighter tolerances are more difficult — and therefore, costly — to achieve, it is important to not over-engineer the part and ask for the tightest possible tolerance on all features.

Again, the key is to ask for allowable tolerances that are tight enough to make the part function as it needs to, but not so tight that producing the part becomes too expensive.

When you have one part with multiple attributes that require tolerances — such as a part with both a diameter and a radius — you need to decide which dimension is more critical.

The more critical dimension is generally the one that determines how well a part will function in the end application and, therefore, merits the tightest tolerance. In turn, the tightest tolerance usually determines what type of machine and tools will be used, which determine the cost of the part.

Conflicting Requirements

Sometimes, a part is designed with specifications that are at odds with each other. What do you do when there are conflicting requirements?

For example, at Metal Cutting Corporation, our customer might specify a part that has both deburring and radius requirements. However, the process of tumbling the part to deburr it would increase the radius size; therefore, if a smaller radius is critical to functionality, the customer might have to skip deburring.

Or, a customer's part specifications might ask for a very large radius, but a large radius might eat into the diameter of the part. Again, the customer would need to establish which requirement is more important — the radius or the diameter?

In other cases, compromise might involve adjusting one tolerance up or down to allow the most critical dimension to be achieved. For example, a customer might need to loosen a radius tolerance to hold a tight diameter that is necessary to the part's function.

IDENTIFY RAW MATERIALS AND SOURCES

What raw materials will have the characteristics necessary to meet the requirements of your parts? In other words, what do you have to start with to get the end result you need?

For instance, perhaps a certain straightness might be needed so that the material will feed through a machine correctly. Or, a specific chemistry might be required so that the part will be nonreactive when it is assembled with other components.

It is important to research qualified suppliers for your raw materials and create an approved supplier list, either for your own reference or to provide to your parts manufacturer. In addition to listing the raw material sources, your purchase order should spell out exactly what you need, including the size, grade, and quantity of material.

Once a raw material is delivered, you or your provider should do an inspection to make sure the order is correct and the material has the right characteristics to meet your requirements.

How will your requirements be achieved?

Once you have established the requirements of your project — including the design specifications, your priorities, and the materials to be used — the next step is for your parts provider to document how they plan to achieve the best results at the best cost.

DOCUMENT THE QUALITY CONTROL SYSTEM

Your provider should document the components of their quality control system in writing, including the processes to be used, general procedures, and any other factors that can have an impact on quality. For instance, the documentation might provide details such as:

- Equipment capacity, tolerance capabilities, tools, and features
- Staff skills, training, and experience
- Work instructions for operating the equipment
- Process controls and recordkeeping
- Quality measures and certifications
- Tracking of materials throughout manufacturing
- Inspection points, processes, and tools

In short, the written documentation should provide information that supports your manufacturing partner's ability to meet your specifications and achieve your quality requirements. For example, a partner might detail **how to minimize metal expansion from heat**, humidity, air pressure, or other conditions in the production environment.

The documentation should specify the methods that will be utilized to make the specific part, including the inspection process and tools that you and your partner have agreed to use.

For instance, the **presence or absence of material surface defects** depends a great deal on how closely a material is inspected. Therefore, the tool and magnification level that will be used to determine whether a part surface is defect-free should be specified.

In addition to spelling out when and how inspections will be performed, the documentation should include how to:

- Track and report the inspection results
- Handle any issues that may arise
- Segregate any nonconforming materials
- Remedy/Repair any defects
- Verify that issues have been resolved

CONFORM TO QUALITY STANDARDS

In metal parts manufacturing, as well as many other industries, **ISO 9000 guidelines** are used in establishing, documenting, and supporting quality control methods. In addition, there are ISO standards for areas such as auditing, risk management, environmental management, social responsibility, and food safety.

Many industries must also conform to strict regulations, such as FDA and Current Good Manufacturing Practice (CGMP) requirements for companies in medical device manufacturing, biotechnology, pharmaceuticals, and many other businesses. Additionally, many companies employ process improvement tactics such as Six Sigma, Kaizen, and lean manufacturing.

Here at Metal Cutting Corporation, we maintain **our up-to-date ISO certification**, and our quality management system (QMS) adheres to the latest ISO 9000 standard. That means the written method we create for our customers aligns with ISO recommendations as well as each customer's specifications and unique quality requirements.

How will accuracy be maintained?

The ability to measure parts and provide assurance that they have been produced according to their specifications is another crucial aspect of manufacturing quality control. That's why it is vital to make sure you and your manufacturing partner use the same type of devices and that the devices are cross-calibrated correctly.

CALIBRATION, STANDARDIZATION, AND TOLERANCING

The devices that will be used to measure the dimensions of finished parts must be **calibrated according to accepted standards**, such as NIST, and validated that they will provide the accuracy you need.

Additionally, you need to consider **what the calibration tolerance is** for the measuring device — looking at not only the tolerance the device is capable of, but also the tolerance to which you need to measure.

For instance, a laser micrometer may have a total measurement range of 0.005" to 1.000", but the parts that will be measured are 0.025" to 0.050". When calibrating, it is best to use a library that is calibrated to the range being utilized, such as using pin gages that are 0.020" to 0.055" in diameter to calibrate.

Calibration is also involved when pass-fail inspection methods are used, as when parts are so small that taking actual measurements of their dimensions would be impractical, if not impossible. Here at Metal Cutting, we often employ **NIST-traceable pin gages (or plug gages) for pass-fail inspection** of very small diameter tubing and other parts we produce.

The different classes of small pin gages (XXX, XX, X, Z, and so on) have their own tolerances based on the amount of variation allowed in the manufacturing of each pin. For example, a Class XXX pin gage has a tolerance of 0.000010" (0.00025 mm), providing a straightness and uniform length that make it a good choice for inspecting parts with a small ID and very tight tolerance.

As part of our QC program at Metal Cutting, pin gages are regularly sent out to a certified lab for calibration. In addition, tools we use ourselves to calibrate other devices in-house are also periodically sent out for recalibration to NIST standards, to maintain consistency, accuracy, and reliability.

GAGE R&R STUDIES

A gage repeatability and reproducibility (R&R) study can be done to analyze how much variation there is due to (1) the device itself and (2) the people (such as machine operators or part inspectors) doing the measuring. If there is too much variation, knowing where it is coming from allows the manufacturer to take steps to reduce the variation.

A typical gage R&R study might involve having 10 parts measured three times in random order by three different operators/inspectors using the same gage. An analysis of the measurement data is then performed to identify the source of any variations, such as differences from one part to the next or from one operator/inspector to another.

Note that R&R studies are not limited to gages and can be done to evaluate other types of measuring devices, test methods, and inspection systems. The study might be employed before a new tool is used, as part of training a new technician, or for periodic tool inspection.

How will results be verified?

Naturally, no QC program would be complete without inspections throughout the manufacturing process.

For example, in the world of small metal parts manufacturing, **metal inspection** is often done in receiving, at various stages in the production process, and prior to packaging and delivery. It might include visual inspections by eye or using optical tools; pass-fail (go/no-go) testing; or mechanical processes such as eddy current testing (ECT), which is used to detect surface defects.

Again, the schedule for inspections, along with the inspection method and tools to be used, should be agreed upon ahead of time and put in writing.

For instance, perhaps your finished metal parts have very stringent requirements for surface roughness. If so, you and your partner might agree to follow the guidelines in a specified **surface finish chart** to determine whether the parts meet your requirements.

Or perhaps you require a tiny wire that must be perfectly straight for use in a medical device, but the part's diameter is so small that measuring it with a pin gage, micrometer, or other device would be very difficult, time consuming, and costly. In this instance, Metal Cutting might recommend **measuring straightness** using a test based on the ASTM F2819 specification for medical devices.

Below are some additional recommendations for an effective inspection process in a typical parts manufacturing operation.

INITIAL AND IN-PROCESS INSPECTIONS

In addition to inspecting all incoming materials before production begins, your parts provider should establish inspection points along the manufacturing process, to maintain acceptable part quality and spot any variations before they have an impact on quality.

This includes inspections at initial setup and whenever tools or wheels are changed, as well as at designated checkpoints during production.

A certain amount of tool and wheel wear is normal and expected in metal parts manufacturing. In-process inspection of parts helps to minimize the impact by allowing the manufacturer to monitor for wear and change out the equipment *before* parts go out of spec.

For example, if you are machining a part to achieve a certain feature, that feature will change as the tool wears. Regular inspections allow a manufacturer to:

- Identify when the upper or lower limit of the tolerance range is approached
- Change the tool to bring the measurement back to nominal and keep the parts within the acceptable tolerance range

The movement away from nominal is steady and somewhat predictable, allowing in-process checkpoints to be set. In addition, the parts manufacturer can establish a tool change tolerance so that the tool will be monitored and changed before it goes out of the upper or lower tolerance limit.

If a part inspected at the checkpoint is within specifications, the assumption is that all parts made since the last check must also be good. If the part fails for a particular characteristic, all parts produced since the last check would require a 100% inspection for that feature.

If the 100% inspection finds that other parts have also gone out of spec, the machine is adjusted as needed to correct the problem and the cycle continues.

In addition, any nonconforming material or parts need to be segregated from the rest of manufacturing process. Per ISO 9001:2015, here at Metal Cutting we have a system in place to:

- Quickly remove nonconforming material or parts from the production line
- Maintain traceability throughout the manufacturing process

It is important to remember that random things can occur during manufacturing that might cause a nonconforming part to slip past a sample inspection checkpoint.

For instance, a tiny bit of metal shavings or dirt might momentarily get between the tool and the material, resulting in one part within the lot that is not good. Unless that single nonconforming part happens to be inspected at the checkpoint, the lot would still pass the in-process sample inspection.

FINAL INSPECTION AND SAMPLING PLANS

A sampling plan is an important part of quality control, allowing a manufacturer to inspect a portion of a product lot to determine if the entire lot meets the customer's quality requirements.

Especially for small metal parts and other high-volume production, a sampling plan is far faster and less expensive than inspecting every part. Yet, a sampling plan still provides a statistically valid and reliable indicator of whether a lot is defect-free.

When the time comes to determine whether the finished product meets your specifications, at Metal Cutting we generally recommend a final inspection using an Acceptable Quality Level (AQL) sampling plan.

We establish a customer's sampling plan at the beginning of a project, along with the written method and other requirements. The plan typically includes:

- How to inspect the finished parts, including which dimensions of the parts will be examined
- When inspections will take place, including in-process checkpoints and final inspection
- The AQL and index values that determine how many randomly selected parts in each lot will be inspected

We generally use AQL 1.0 c=0, a zero acceptance sampling plan, in which 100% inspection must be performed for a feature if one randomly selected part in a lot fails inspection.

That means at final inspection, a random sampling of all the produced parts is taken, based on the lot size and the quantity of parts that would statistically indicate that all parts are acceptable quality. For instance, we might inspect a random sampling of 50 parts in each lot size of 5,000 small metal parts.

Using the zero acceptance sampling plan, if one part in the randomly selected sample fails inspection, then the entire lot is subject to 100% inspection for the affected characteristic. If all the parts in the random sampling pass inspection, the entire lot is deemed acceptable.

According to well-established probability theory and its implementation in the sampling plans used by our industry, there is a high probability that all the parts in an acceptable lot are good. While there remains a slight probability that a very small percentage of parts may not be good, our experience has shown us, time and again, that a zero acceptance sampling plan is a statistically reliable, efficient, and cost-effective way of assuring quality results.

Conclusion

Quality control doesn't end when the parts come off the production line and pass inspection. The final step of the quality program is packing the finished components so that they are properly protected when shipped and arrive safely at their destination.

By aligning the unique requirements, variables, and challenges of your project with a QC program, you and your manufacturing partner can ensure you get quality parts for your application.

From there, the parts can play their role in creating a high-quality product — one that delivers the form and functionality your end customers want and expect from your brand. Thus, manufacturing quality control plays its part in the success of your application.

That means working with a partner that is committed to manufacturing quality control is vital to the ultimate success of your business.

To learn more about ensuring quality for your small metal parts, **check out our guide on how to fine-tune your quote request.**