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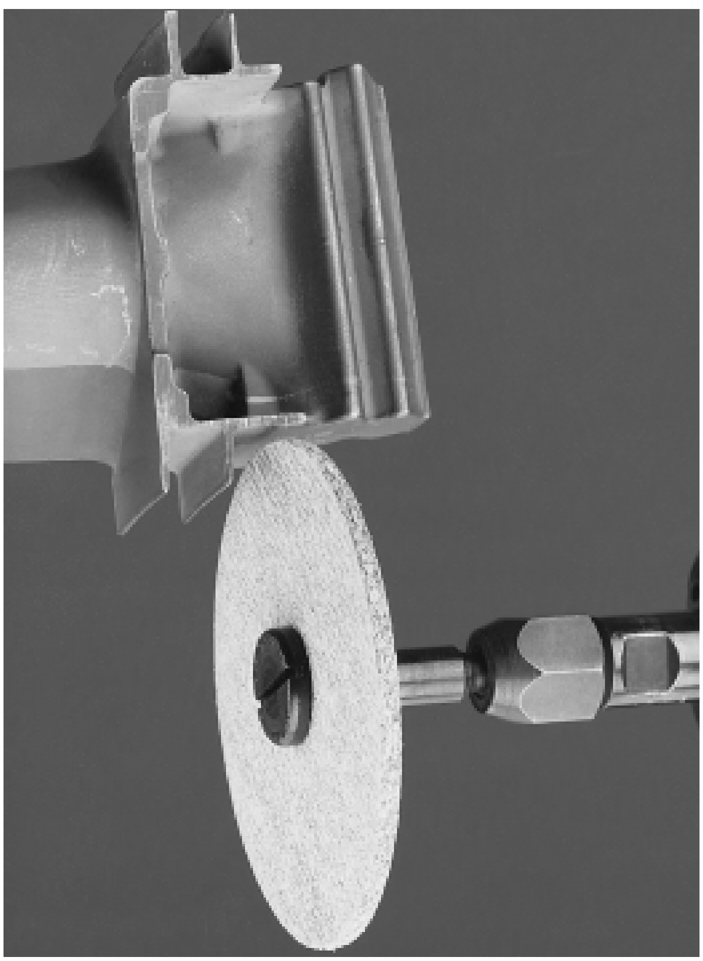
▸ BY MARK RICHARDSON

Quality's Hidden Costs

Deburring and the cost of poor quality.

More and more manufacturers are adding the "cost of poor quality" to the list of business metrics that they track. And when they examine the individual elements that comprise COPQ, many are surprised to discover that the highest costs lie outside the realm of traditional cutting, forming and joining operations. Deburring is one of these frequently overlooked costs.

Poor deburring practices can be a major obstacle to improving a manufacturer's COPQ performance. Therefore, it's critical to understand the impact deburring processes have on COPQ and rework and scrap costs.



Rex-Cut Products Inc.

Manufacturers often overlook deburring when they try to improve their COPQ performance.

Hidden Costs

COPQ has been used as a business metric for a while. Historically, companies that crafted a basic COPQ model tended to combine scrap, rework and warranty costs. Some also added inspection costs.

Applying COPQ in its most modern form requires looking beyond the obvious costs to the hidden costs. Among the latter are extra setups, "expediting" activities, lost sales and weakened customer loyalty, late deliveries, excess inventory, long cycle times and engineering change-orders.

Let's examine some of these concealed costs in more detail.

Repairing or replacing parts increases direct labor costs. These activities also cause a business to fall chronically behind on deliveries. This leads to an activity referred to as expediting. Besides the indirect labor costs of the expediter, expediting forces a company to reschedule work and, except for very lean operations, leads to additional setups. All of these steps generally drive overtime.

An organization can avoid late deliveries by carrying inventory. However, inventory is a huge drag on profits. It ties up cash and prevents those inventoried assets from seeking a return on investment. Furthermore, these assets become worthless if an engineering change occurs.

In addition, significant space must be allocated for inventory. This space is taxed, insured and, perhaps, even climate-controlled. Labor is needed to move inventory, organize it, receive it and count it on an annual basis.

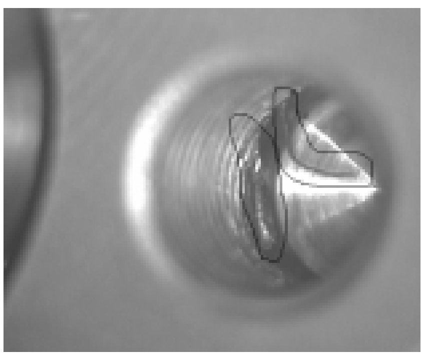
At a company that produces parts for the aerospace or biomedical industries, defects are segregated, or quarantined, in a special location. And at larger organizations serving these industries, the manufacturing, engineering, purchasing and quality-control departments often debate the future of the defective parts and what corrective actions are required.

All of these nonvalue-added actions boost costs. And because they are the outgrowth of activities that have become accepted as normal business practice, they create what is often called the "hidden factory."

Assessing COPQ

The first step in improving a company's COPQ performance is to identify what the defects are and rank them numerically. Be sure to include rework as well as scrap, and diligently seek out instances where rework has become so ingrained in the process that it has become accepted and, therefore, invisible.

Once the defects are known, the next step is to discover how many there are. This often can be determined with a simple check-sheet at an inspection station, machine tool or work cell.



A common deburring-related defect is a burr left in a hole.

With defects both identified and quantified, most COPQ seekers compile the data on a Pareto chart (Figure 1). This is a bar chart on which operations are arranged according to the costs of the defects they generate. The farther to the left a process falls on the chart, the higher the scrap rate. This type of chart makes it easy to focus time and effort on those defects that consume the most resources.

Generally speaking, defects that are evaluated subjectively—i.e., without the benefit of qualifying instrumentation—top the list of what appears on Pareto charts. This means, of course, that things like surface-finish errors and deburring-related defects (DRDs) are big contributors to scrap and rework costs. Common DRDs include burrs left in a hole, undersize or oversize edge-breaks, deburring operations that impact part dimensions and damage to workpiece surfaces caused by a deburring process.

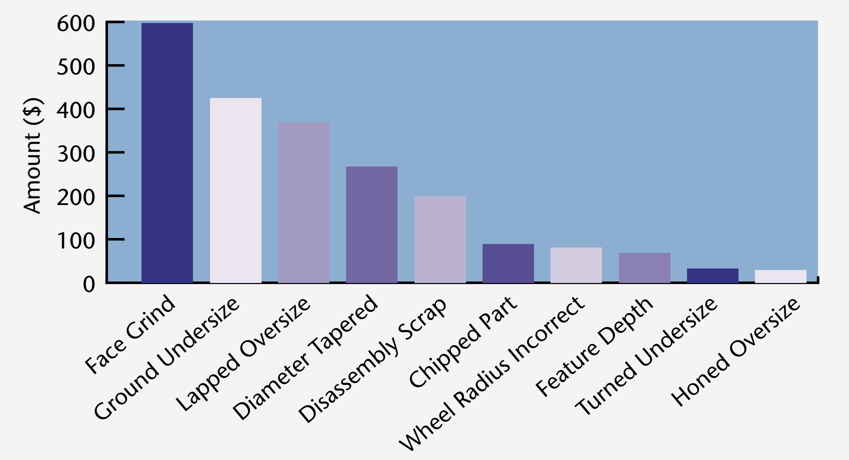


Figure 1: Many people charged with rooting out COPQ in the manufacturing environment compile the data on a Pareto chart. Operations are arranged according to the costs of the defects they generate.

Reducing DRDs has assumed an almost cult-like status among companies serving the aerospace and biomedical industries. The reason is because of the high cost of deburring and customers' negative reaction to burrs.

Traditionally, DRDs have been the source of bloated inventories and incredible rework loops. Moreover, DRDs consume indirect labor resources, such as quality and manufacturing engineering, to the point of diminishing a company's ROI.

Better Deburring

Compared to COPQ, burrs are only a little easier to define. Basically, burrs are undesirable remnants and sharp edges produced by traditional machining processes. Often, plastic deformation of the workpiece material at the edge of the machined feature is defined as a component of the burr.

Rex-Cut Products Inc.

Burrs are undesirable remnants and sharp edges produced by traditional machining processes.

Cratex Manufacturing Co. Inc.

Soft deburring can be performed with rubberized abrasive wheels like the ones shown. A benefit of this type of wheel is that it conforms to the workpiece shape better than harder wheels.

If the definition of burrs is expanded, edge-breaks become part of the overall picture. An edge-break occurs when workpiece material is removed, in addition to what's required to achieve a theoretically sharp corner at the intersection of adjacent features.

I say "theoretical" because most corners that appear burr-free to the naked eye are revealed to have burrs when examined under high enough magnification. Video-measurement systems and other optical tools enable the industry to measure edge-breaks up to 0.0001".

The first thing needed when attacking a COPQ problem that involves a deburring process is to have a complete understanding of customer expectations. I use the word "expectations" because drawings and other written specifications may not properly define what the customer actually wants.

The human element should be considered, too. The goals of the current quality movement in the U.S. center around the concept of Six Sigma standards. The term, originally coined by engineers at Motorola, refers to the goal of lowering the number of defects per 1 million manufacturing-process opportunities to 3.4. To achieve Six Sigma, key measurements of the process must remain centered on their nominal values; the spread of measurements around these values must be extremely narrow.

Reducing the variables that contribute to human fatigue will help en-

The economics of deburring

BY LAROUX GILLESPIE

Deburring costs are rarely examined closely to determine where savings can be made or what new process may be more economical. Equipment manufacturers can provide good estimates for a potential buyer, provided the user knows enough to ask all the right questions.

The equations listed here (there are more) provide an easy way to estimate costs. Users can also see which cost elements have the most impact. The equations assume the user knows how long it will take to deburr and radius edges. Not all burrs will be removed at the same rate because of part geometry or burr size.

Equations allow many variations to be made quickly, but spreadsheets or tabled data may be more useful for those who are mathematically challenged. These sheets are available for mass finishing, but, generally, not for other processes.

To illustrate the utility of these estimating tools, let's take an in-depth look at the constitutive elements of these equations. To calculate deburring costs per part, there are two main parts: The first comprises supplies, depreciation and maintenance; the second is labor. For the simplest applications, consider costs on an annual basis. Depreciation is readily calculated, and reasonable estimates can be made for maintenance. Power costs may be more challenging, but they can be a significant factor.

For this case, we explicitly separate deburring from cleaning costs, because automated equipment performs both functions. This may not be the case for manual operations. It may be useful for companies to evaluate cleaning as well as deburring costs. The cost of the cleaning compound and water used per hour can be estimated.

In electropolish deburring, it is useful to remember that chemicals and waste removal will generate higher costs. Waste removal is not included in these equations, yet every deburring process does create some waste. Equipment manufacturers typically do not provide estimates of waste treatment, except in the chemical industry.

Overhead for labor is often expressed as a multiple of direct costs. So if, for instance, deburring workers are paid $12 per hour, make certain that figure includes employee benefits and taxes.

For manual operations, the worker often does more than deburr parts. He may mark part numbers, inspect parts, do paperwork, break off tabs or perform tasks that, while needed for the product, really should not be included in deburring costs.

These equations do not explicitly include the costs of floor space, area heating, lighting, insurance and supervision, but these costs can be included in the overhead factor.

Vibratory Finishing:

$$C=[C_D+C_M+WC_P+C_B+C_E+C_C+C_W]/N+[C_L(1+D_O)(K_1+K_2)]/N$$

Electropolish Deburring:

$$C=[C_D+C_M+WC_P+C_A+C_L(1+D_O)]/N+C_t/N_p+C_s/N_{p1}$$

Variables:

C = Deburring cost per part.
C_D = Depreciation cost per hour.
C_M = Maintenance cost per hour.
C_L = Labor cost per hour to run machine.
C_P = Cost of power used ($ per kilowatt-hour).
C_A = Cost of cleaning per hour after deburring (labor and material).
C_E = Cost of media per hour.
C_C = Cost of compound per hour.
C_W = Cost of water per hour.
D_O = Overhead as percentage of labor rate.
N = Number of parts run per hour.
C_B = Cost of cleaning materials per hour.
N_p = Total number of parts run.
N_{p1} = Number of parts run for a given quantity of solution or tool life.
C_t = Total tool cost.
C_s = Total cost of solution.
W = Power used, in kilowatts.
K_1 = Percentage of cycle time that operator actually spends controlling deburring operation.
K_2 = Percentage of cycle time that operator spends cleaning parts.

About the Author

LaRoux Gillespie, CMfgE, has written and published extensively in the area of burrs and deburring. He lives in Kansas City. For a more complete treatment of the economics of deburring, please refer to Gillespie's textbook, Deburring and Edge Finishing Handbook, *published by the Society of Manufacturing Engineers and the American Society of Mechanical Engineers.*

sure accuracy throughout the deburring process. Owners of machine shops and other manufacturing facilities that are experiencing too many DRDs might examine how much overtime their workers have put in during the last 4 weeks, the last 12 weeks and the last year.

Often, those in manufacturing can quote what their overtime costs were for a given time period, yet they don't know what impact large amounts of overtime have on human operators. Humans are incapable of performing work that's highly dependent on hand-to-eye coordination for overly long periods of times.

Deburring is an inspection process, in a certain sense, because the operator cannot verify the success of an operation other than by viewing the part with the naked eye or an optical aid, such as a microscope or video camera. Therefore, the quality of the lighting can make all of the difference in the world to the success of a deburring process.

Over the years, there have been many attempts to improve, or render more consistent, the lighting conditions in manufacturing facilities. Fluorescent lighting, for example, has been with us for over 50 years. It was a big improvement over the light sources that existed at the time. But when inspecting small, intricate parts under high magnification, fluorescent light fails to deliver the necessary illumination.

As optical magnification became more commonplace, the quality of lighting grew in importance. The advent of bifurcated illumination, following World War II, was another notable advancement. Bifurcated illumination means that a pair of light sources illuminate from two discrete sources. This was an improvement over both overhead ambient lighting and unidirectional light sources. Today, bifurcated illumination relies on fiber-optic technology.

Microscopes work in unison with bottom lighting, ring lighting or true coaxial illumination. Bottom lighting refers to a light source emanating from beneath the viewed specimen. This method is of limited use in most industrial applications.

Ring lighting, which is usually fluorescent, illuminates from above the subject workpiece. It provides omnidirectional, reduced-shadow lighting from a direction close to that of the optical axis.

True coaxial illumination, most often generated by angled mirrors, will direct light into the deepest of cavities and holes up to 15 diameters deep. When deburring or inspecting the intersections of deep holes, this type of light usually is the best choice.

'Predeburring' Steps

There are a number of "predeburring" steps that can be taken to improve the deburring process. First are those steps that can be taken during the initial machining operation. Through skillful programming, informed cutting tool selection and optimization of speeds and feeds, burrs can be reduced in size and/or be generated in a location optimal for removal during a subsequent deburring operation.

Over the last 5 years, I have seen many machined parts that were chamfered, corner-rounding milled and countersunk on a CNC machining center so that a downstream mass-finishing operation (tumbling or vibratory finishing) delivered parts that were burr-free and edge-broken to aerospace standards. Minimal human labor was involved.

Before such a downstream process is adopted, it's advisable to first quantify the operational costs for the additional work on the CNC machine compared to the highly manual, highly variable costs associated with manual deburring. (Spindle-use time is a simple, effective method for determining machining costs.) If there's a cost savings, the next step is to determine if a downstream, mass-finishing process can effectively remove the burrs that develop during the metalcutting process.

Life is especially good for those chasing burr-related COPQ in the world of CNC lathes. Except for the tiniest internal features, a correctly configured cutting tool can create true radii on most corners. Modern programming

ECD: An 'in-between' deburring process

Electrochemical deburring is a process that falls somewhere between the soft processes and mass finishing. This is an electrolytic process that erodes workpiece material from burred areas in a fashion similar to an electrical discharge machine.

With well-designed fixturing, this process is suitable for deep-hole intersections and offers good opportunities for process control. This process' strengths are its ability to reach tight places and provide better process control than hard processes. Its weaknesses are that the requisite fixturing can run into the thousands of dollars and these fixtures are sometimes fragile.

Naturally, the process also requires an ECD machine, which is a sizable capital expense.

—M. Richardson

Extrude Hone Corp.

The ECD process is ideal for parts that have hard-to-reach surfaces. This ECD machine is deburring automobile airbag parts.

aids and languages have further simplified the job.

Deburring Options

There are many types of deburring systems. But they can be broken down into three basic categories: hard, soft and mass finishing.

Hard deburring includes most of the time-honored cutting-type processes, like filing, countersinking, scraping, knifing and grinding. The advantages of hard deburring are that these processes are familiar and the tools required are relatively inexpensive.

The disadvantages are that these deburring processes are highly dependent on the operator's manual dexterity, the tools must be maintained and, ironically, the tools generate burrs themselves. Called secondary burrs, they are visible with high-magnification inspection systems.

Soft deburring is performed with compliant materials used in conjunction with abrasives. These include woven abrasives, rubberized abrasives and different types of air-blasting systems. With air blasting, abrasives include frozen water and CO_2, which eliminates the contamination risks inherent with conventional abrasives.

The strengths of soft deburring are that all of these media conform—to a certain degree—to the form of the workpiece and exhibit somewhat of a buffered cutting action. With a soft process, the risk of secondary burrs is greatly diminished.

The downside to these deburring tools is that they contact areas of the workpiece adjacent to the edges being worked. This can cause dimensional changes in the part, which proves problematic when tolerances are tight.

Mass finishing includes the batch processes: electropolish, tumbling tanks, vibratory tanks and thermal-energy deburring. In cases where size can be controlled and the location of burrs can be optimized, mass finishing is often the low-cost choice. This is almost always the case when the primary deburring process is performed on the machine tool.

Mass-finishing processes can address secondary burrs when they are accessible to the deburring media and, for the most part, are highly controllable processes.

The downside of mass-finishing techniques is that they require large batches of parts to be efficient, and the fact that all surfaces accessible to the media may be subject to dimensional change. This is especially true in the case of electropolish, where the mass process must be part of an overall strategy, including tightened machining tolerances

About the Author

Mark Richardson is a manufacturing engineer at a Midwest producer of aircraft components.