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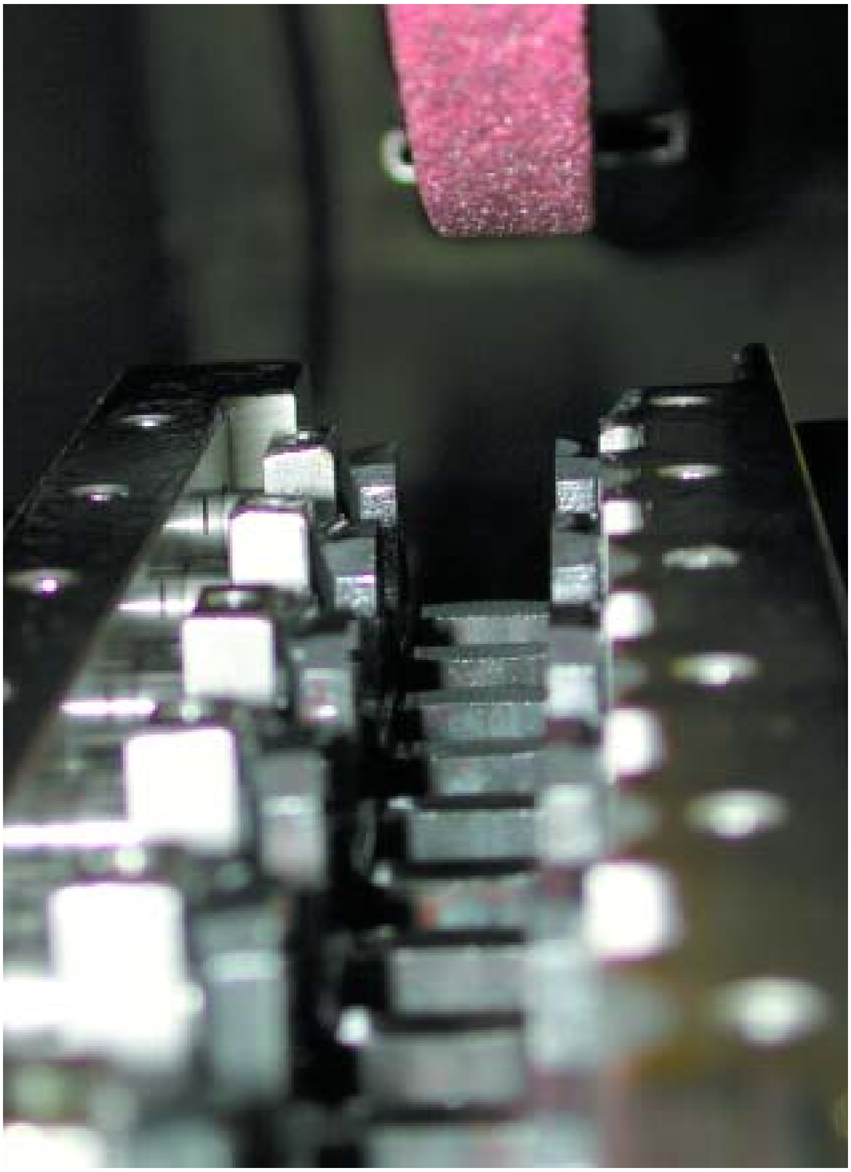
Grinding shop demonstrates benefits of continuous-dress creep-feed grinding.

Continuous Improvement



Abrasive-Form

U-joints were produced three times faster when the CDCF grinding process was used.

Revisiting long-established approaches to machining standard parts can lead to reductions in production costs, especially for high-volume jobs. Whenever creep-feed (CF) grinding processes are involved, the decision to intermittent-dress or continuous-dress merits careful consideration. The reason is because of the dramatic impact dressing can have on the piece-part cost.

This fact was demonstrated recently at Abrasive-Form Inc., a Bloomingdale, Ill., contract manufacturer that specializes in CF grinding. It conducted tests on a standard part—a 4140 steel U-joint—found in hand tools and used in a wide variety of industries. Abrasive-Form ground parts at different feed rates while dressing the grinding wheels intermittently and continuously.

In the tests, continuous dressing allowed the company to triple the U-joint production rate and lower costs.

Testing CDCF

With continuous-dress creep-feed (CDCF) grinding, the dressing tool is in constant contact with the grinding wheel. This keeps the wheel in a constant, maximum state of sharpness at all times. This, in turn, allows a significant increase in table speed, compared with the intermittently dressed CF (IDCF) grinding process, in which the dressing tool is applied to the wheel between grinding cycles.

	Volume of Metal Removed Per Min.	Volume of Abrasive Consumed Per Min.	Metal Volume Removed Per Abrasive Volume Consumed (G Ratio)
Using Intermittent Dressing Technique			
Feed Rate of 7 ipm	0.5746 in^3/min.	0.0522 in^3/min.	11.008 in^3
Using Continuous Dressing Technique			
Feed Rate of 10 ipm	0.9523 in^3/min.	0.2596 in^3/min.	3.668 in^3
Feed Rate of 12 ipm	1.0508 in^3/min.	0.4774 in^3/min.	2.201 in^3
Feed Rate of 14 ipm	1.1361 in^3/min.	0.7226 in^3/min.	1.572 in^3
Feed Rate of 16 ipm	1.2084 in^3/min.	0.8790 in^3/min.	1.375 in^3
Feed Rate of 18 ipm	1.2739 in^3/min.	1.0425 in^3/min.	1.222 in^3
Feed Rate of 20 ipm	1.3362 in^3/min.	1.2148 in^3/min.	1.100 in^3

Table 1: Analysis of metal volume removed vs. abrasive volume consumed at increased feed rates.

Compared with intermittent dressing, one can expect continuous dressing to reduce machining time 90 to 95 percent. Yes, that's right. If the machine time for a part is 5 minutes with IDCF grinding, it could be machined in 30 seconds with CDCF grinding.

If one were to look strictly at the G ratio (the volume of material removed divided by the amount of abrasive consumed), it would appear that intermittent dressing is a better process. The U-joint tests support this. Intermittent dressing at a feed rate of 7 ipm was compared with continuous dressing at varying feed rates, from 10 to 20 ipm (Table 1). With the slower intermittent-dress process, more than 10 times the material, by volume, was removed per abrasive volume consumed.

To those unfamiliar with the cost pricing of CDCF techniques, the rate at which abrasive is consumed might suggest that there is little benefit to increasing the feed rate. Indeed, Graph A shows that with a feed rate of 16 ipm or higher the amount of abrasive consumed is nearly identical to the amount of metal removed. However, the consumption of the abrasive is only part of what determines the overall piece-part cost when CF grinding.

Abrasive-Form conducted the U-joint tests to identify the breakeven point from a total cost-pricing perspective. Because CDCF grinding is a faster process than IDCF grinding, labor costs are less and output is far greater. For the U-joint tests, Abrasive-Form used a shop rate of $50 per hour, which includes labor and overhead. This is shown in the second column of Table 2. While the wheel costs per part are more than 10 times greater at the fastest feed rate (20 ipm), the labor cost is approximately two-thirds less.

As both Table 2 and Graph B show, the optimal output, i.e., the lowest piece-part cost, was achieved at a 12-ipm feed rate while continuously dressing. The total direct cost per part totaled $0.178.

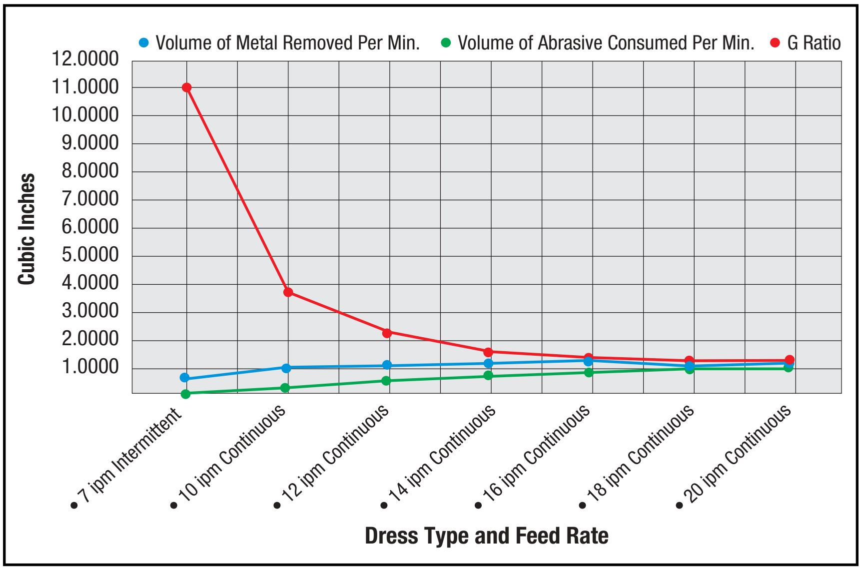
This represents nearly a 40 percent improvement in the total direct costs per part over the prior intermittent-dress technique. Hourly output more than doubled at this feed rate.

The successful application of CDCF grinding allowed Abrasive-Form to take an application that was only marginally cost-effective and make it highly profitable. Although wheel costs increased dramatically with the increased feed rates, going from approximately 3 cents to 11 cents, that increase was more than offset by reductions in labor and overhead costs per part with CDCF.

Doubling the feed rate from 10 ipm to 20 ipm incurred only a 7 percent increase in direct costs per part. In other words, the cost structure varied very little while the output increased dramatically. At the maximum feed rate of 20 ipm both output and revenue tripled.

Know-How, Limitations

Tests such as those on the U-joint typically aren't conducted. Abrasive-Form has served various industries for more than 25 years. This cross-industry experience allows it to quickly bring the variables associated with CDCF processes into line. Unlike intermittent-dressing techniques, which are relatively easy to implement, factors such as coolant temperature and flow rate require adjustments learned through experience.



Graph A: Metal volume removed vs. abrasive volume consumed at increased rates using intermittent and continuous dress.

	Wheel Cost Per Part	Labor & Overhead Cost Per Part	Total Direct Cost Per Part
Using Intermittent Dressing Technique			
Feed Rate of 7ipm	$0.011	$0.286	$0.297
Using Continuous Dressing Technique			
Feed Rate of 10 ipm	$0.032	$0.154	$0.186
Feed Rate of 12 ipm	$0.053	$0.125	$0.178
Feed Rate of 14 ipm	$0.075	$0.116	$0.191
Feed Rate of 16 ipm	$0.085	$0.109	$0.194
Feed Rate of 18 ipm	$0.096	$0.103	$0.199
Feed Rate of 20 ipm	$0.107	$0.099	$0.206

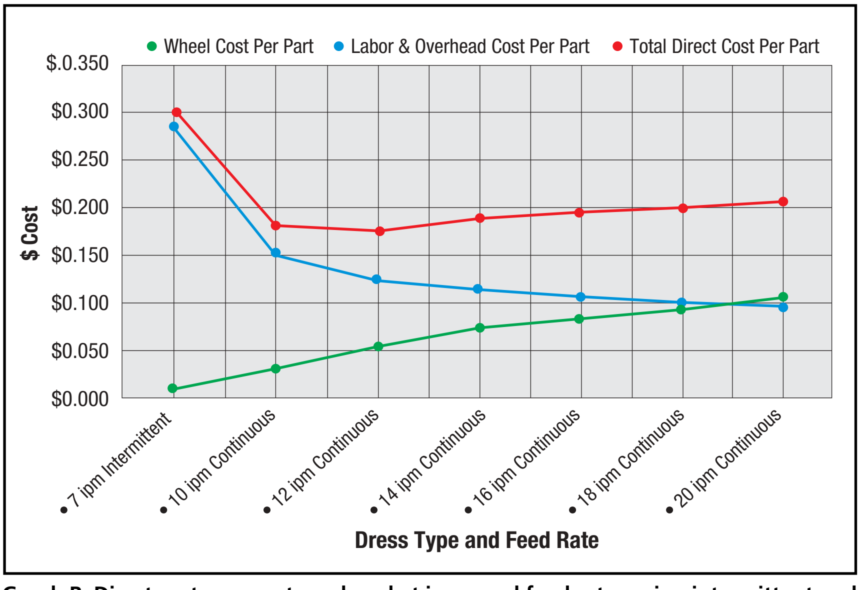
Table 2: Analysis of direct cost per part incurred at increased feed rates.

Similarly, Abrasive-Form's in-house tooling design and production allows it to both select the proper abrasive wheels for a given application and set up fixtures optimized for the application. While CDCF techniques used in the U-joint tests have been around for approximately 20 years, they require more expertise than the intermittent process.

Moreover, not all CF-grinding machines are capable of continuous dressing. A properly designed overhead dresser is required, as are the appropriate drive mechanisms. There also must be a system available to chill the cutting fluid. An adequate CNC also is a prerequisite.

Not every CF grinding process is well-suited for continuous dressing. A major factor is the number of parts being processed. The advantages of CDCF grinding are most fully realized in mass-production situations.

Another factor is material handling. At some point, operators won't be able to handle parts as fast as CF grinders produce them. Automated part loading and unloading generally makes CDCF grinding a more attractive proposition. If the time it takes to load and unload the grinding machine does not offset the in-



Graph B: Direct costs per part produced at increased feed rates using intermittent and continuous dress.

Understanding CF grinding

Don't know much about creep-feed grinding? That is more common than not.

CF grinding is an abrasive machining process that combines the high stock-removal rate associated with milling and broaching with the precision and surface finish associated with grinding. Both hard and soft materials can be CF-ground. Today's CNCs allow the CF grinding of almost any form or shape. And, CF-ground parts are virtually burr-free.

Although the process has been put to practical use for many decades now, the lack of information—or rather the abundance of misinformation—about CF grinding has kept many from enjoying the remarkably low piece-part costs that may be realized.

Misconceptions about creep-feed grinding begin with its very name. Creep feed sounds "slow." The word "grinding" inspires visions of conventional grinding process where a very small amount of material is removed over a long period of time. Further, some imagine that CF grinding involves a great deal of downtime to dress grinding wheels. But the fact is that dressing can be continuous (see main article), or, in the case of plated CBN wheels, nonexistent.

There is a significant learning curve required to optimize a CF grinding process. In many cases, overcoming assumptions born in more traditional manufacturing methods is required. For example, CF grinding allows one to make very deep cuts that less-experienced practitioners are typically hesitant to make.

Even when the capabilities of the CF grinding process are understood, there are numerous reasons why many opt to look for qualified contract manufacturers to assist with CF grinding tasks. Dedicated facilities have the advantage of drawing upon cross-industry expertise to both speed up prototype development and drive down costs when a part is in full-production mode.

—S. Salmon

Abrasive-Form

The U-joints Abrasive-Form tested were made of 4140 steel.

creased cost of the abrasive, then the process cannot be made economical.

Similarly, other factory operations can negate the benefits CDCF grinding provides. For example, if CDCF-ground parts stack up in crates as they await sandblasting, coating, drilling or some other operation, there is less likely to be an overall cost advantage.

Practical limitations sometimes preclude the use of CF grinding, too, regardless of whether intermittent or continuous dressing is used. An example is very large parts. They might not fit into the machine enclosure. Contract manufacturers like Abrasive-Form can modify guarding and rearrange the plant floor plan to accommodate these parts, which include marine diesel-engine connecting rods and aircraft-engine fan blades.

In some of the more difficult CF applications, there also can be problems with part deflection. Nonetheless, CF grinding routinely delivers tolerances in the range of 0.0005" to 0.001". That compares with typical milling or broaching tolerances, which range from 0.005" to 0.010".

However, in situations where small-diameter cutters are required because of part configuration, milling is the only process that will work. For example, a CF process that requires a 20"- or 24"-dia. wheel would not be able to clear a 1"-high flange face at the end of a 0.250" deep slot.

Continuous or Intermittent?

Difficult-to-machine materials—such as those used in the medical and aerospace industries that tend to gum up the grinding wheel or are heat- and crack-sensitive—are generally thought of as ideal matches for CDCF techniques. Another determining factor is the amount of stock to be removed. Removing a significant amount of stock, as was the case with the U-joint, often is better accomplished with CDCF grinding. Experience in designing fixtures that allow machining multiple surfaces in one clamping also can influence the decision to apply continuous or intermittent dressing techniques.

For production schedules that require a rapid ramp-up in production, irrespective of cost, CDCF grinding will prove better than IDCF grinding.

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