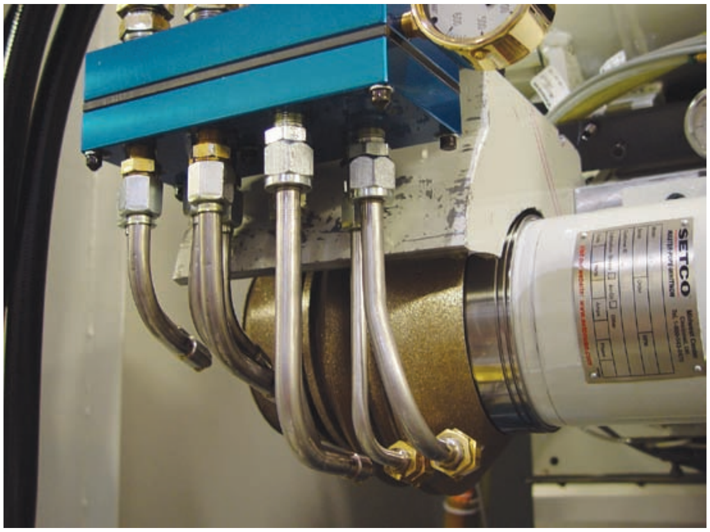
Compelling Grinding Productivity



Coolant Nozzles.

There are six areas of the grinding process that are capable of delivering exceptional productivity gains. When used together, they can deliver multiple gains.

In today's global economy domestic manufacturers can level the playing field of cheap labor, long distances and lead times by use of these improvements.

First, there are advances to process planning and simulation that allow for pre-production prove out. Second, there are advances to grinding wheels themselves, using smaller sizes capable of higher rpm, better material removal rates (MMR) and longer life. Third, there are improvements to fixturing desings and schemes. Fourth, there are advances to coolant delivery to better transfer heat off the work piece to increase material removal rates and avoid thermal damage to the workpiece. Fifth, there are advances to application software to deal with normal processing and to assist use of available labor. And lastly, thru long-term use of ISO principles, machines have become exceptionally reliable.

Multi-Tasking

Using a five axis machines it is possible to consolidate what previously required multiple set-ups in multiple stand-alone machines into a single setup in one machine.

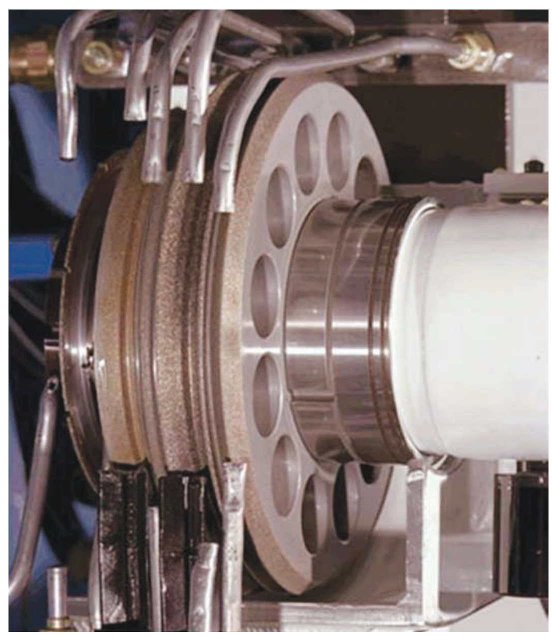
Several individual part feature wheel forms can be consolidated into a single wheel pack. This capability requires specially designed fixtures that can withstand side loads (discussed later). The final benefit of using a single datum for all part features is that it makes it easier to produce all part features to tolerance. This is more difficult when using multiple machines and multiple fixtures due to tolerance stack up issues.

This approach adds up to a truly "Ø" scrap process, an important quality goal. A single part flow process avoids the high scrap potential of running batch lots on multiple machines. Another major benefit is a reduced throughput time of the entire production cycle. Instead of days or weeks to run batches through multiple machines and multiple setups, the parts are complete as they exit the machine, dramatically lowering in process inventory.

Wheels

Your basic grinding wheel choices are Conventional Abrasive (CA) wheels that require either continuous dress or intermittent dress, Superabrasive (SA) in Electroplated CBN (EPCBN) or Vitrified Bond CBN wheels. EPCBN does not require dressing, and Vitrified CBN requires infrequent dressing.

In the past, the only choice was using CA wheels that wear out rapidly. Therefore, Conventional wheels tend be large in size, which limits the number of features which can be accessed at a time. Conventional grinding wheels tend to require a larger machine tool, driving up capital cost and floor space requirements.



EPCBN Wheel Pack

As Seen In

SOUTHWEST SOUTHEAST NORTHEAST MIDWEST

MANUFACTURING NEWS

Conventional wheels wear with each turn of the spindle, requiring compensation, which is a source of variation and requires a skilled operator and programmer.

Conventional wheels require frequent change due to a loss of wheel diameter and require either intermittent or periodic dress to hold form, all considered non-productive time. They produce a more abrasive swarth and require more storage space. Less swarth is created using SA wheels and they require less storage space.

Product changeover in a CA production lines are often measured in hours or even shifts; - which add to the overall cost of production. The amount of the wheel consumed as a percent of the material removed ("G" ratio) is relatively low. Conventional wheels are normally only partially used before disposal, especially when a small and a large wheel are used at the same time, which drives up abrasive cost.

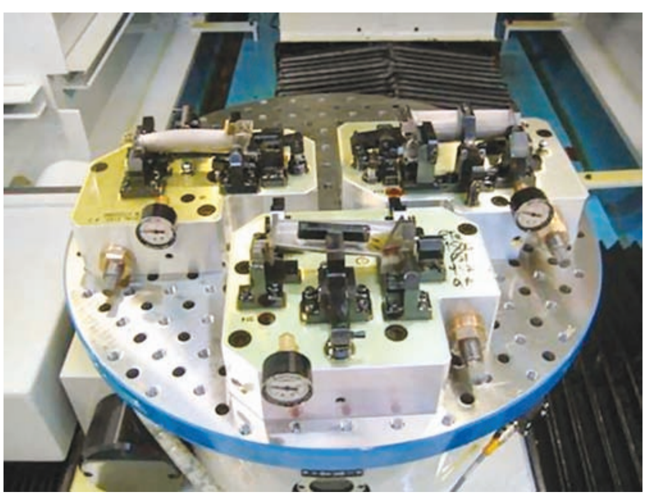
CA wheels are glued together materials and therefore have a speed limit before they explode. So bigger is better when using Conventional wheels. The larger size improve wheel surface speeds at lower rpm, but requires a larger machine, longer changeover times and more difficult handling. Actual SA per part abrasive costs are less than CA.

Super Abrasive (SA) wheels are metal core wheels with a layer of abrasive plated to the Outside Diameter (OD) and do not require dressing. Vitrified bonded wheels requires infrequent dressing.

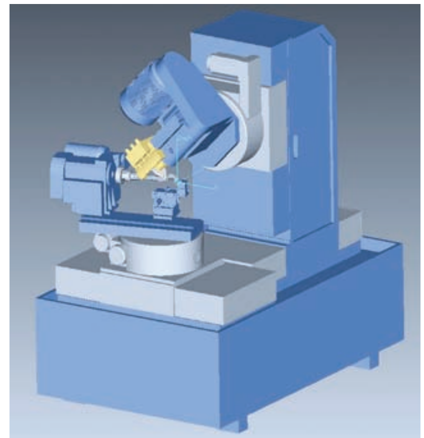
SA wheels have dramatically higher "G" ratios compared to CA wheels giving them some highly beneficial character-istics.

Because SA wheels do not wear, the wheels can be smaller diameter than CA, and can run at much higher surface speeds. Because they are smaller, more wheels can be mounted side by side in a wheel pack. SA wheels can run hundreds or thousands of parts before being re-plated (reused). The need for wheel dressing (and a skilled operator) is eliminated. And instead of many machines in sequence, one machine and wheel pack can do a complete part in a "multi stage fixture" and address all the features to be ground in a single part per cycle.

While the actual MMR rates of SA wheels may be simi-lar to CA, major economic advantages come from the single datum (reduced scrap and throughput time) and the ability to operate at faster surface speeds.



Progressive fixtures.



Virtual Design

SA wheels, use more tangential force than normal force and lowers the risk of thermal damage to the workpiece. The chip removes heat from surfaces rather than forcing heat into the part like a CA wheel.

Unlike conventional wheels that may require other operations (i.e. - milling) to produce part features an electroplated wheels can efficiently grind-in small grooves due to low wheel wear. So it is possible to streamline operations by consolidating features into the grinding process.

Still, today there are many new "hybrid" wheels available. New technology CA wheels have higher "G" ratios, in between traditional CA and SA. Often they use ceramic bonding agents. Most importantly, because of the lower wear rates, these wheels can be made smaller than conventional wheels and can be intermittently instead of continuously dressed. That means they can be either used in wheel packs, or can be changed in a few minutes, or used with an automatic tool changer (ATC).

Smaller hybrid wheels allow an ATC to avoid down time to change over of large diameter CA wheels by hand. Instead of a massive continuous dresser, these Hybrid wheels can use a "static" dresser, smaller and less expensive than a roll dresser. The longer grain in the new hybrid CA wheels al-lows for better coolant effect and higher Materials Removal Rates (MMRs).

Fixturing & Construction

CAD/CAM and virtual design capability mentioned above allows for better fixture utilization, especially using progressive fixtures within a machine. Still, sometimes a part can be chucked once and finished completely.

Compared to multiple sequential batch processing for parts, this is an advantage for quality and throughput time. Sometimes more complex prismatic parts can be accommo-dated by multiple fixtures on a table in one machine and then progressively moved through a series of grinding operations on fixtures to complete all features of one part to the same datum. One part per cycle. Often weeks or days of part pro-cessing can be reduced to minutes.

Using multiple wheels and multiple surfaces on a wheel in a pack of wheels as mentioned above allows you to complete all features in a single chucking, eliminating wheel changes, or changing machines.

For example, complete shrouds can be done one part per cycle, leading edge, trailing edge and slash faces. Fixtures are designed for side wheel loads and taking the force of the heavier material removal rates.

Coolant & Application

In CA grinding, conventional wisdom has been based on the volume of flood coolant per HP used rather than in coolant direction in relation to the grind area and the actual heat transfer capability of the coolant. In SA grinding, more attention has been placed on matching coolant velocity to wheel speed and on controlling the application of the coolant stream to the grind zone. Much work has been done along these lines to specifically design coolant nozzles for better "laminar flow" and pointing improvements. The result is a "coherent stream" of coolant.

Still, coolants contain a lot of entrapped air, functioning like Swiss cheese between the wheel and work. Now, there is more attention on eliminating aeration from the coolant sys-tems by better plumbing, use of line conditioners, new coolant nozzle designs and better filtration settling. These work to eliminate trapped air that undermines the heat transfer capability of the coolant. Dramatic improvements metal removal rates are being achieved without thermal damage to the material.

Application Software

One of the biggest economic benefits has been the evo-lution of application software to assist the operator to make good parts and reduce down time waiting for highly skilled programmers to make simple process changes to deal with reoccurring process anomalies. Also, with the complexity of many processes, more user-friendly interfaces have been de-vised to allow use of "available labor" personnel through computer prompting to follow defined procedures. Lastly, manufacturing plans can be stored and updated on a ma-chine for quality control purposes.

The trend is away from hogging parts from solids to use of investment cast or forged raw materials. Investment cast-ings are sort of like exoskeletons with a hard shell or casing left on the metal. When these parts are first machined, internal stresses can be released that cause the part to "warp". For example, shrouds or vanes with radial grooves tend to spring out of shape; too deep or shallow a radius, or an incline or decline following a rough pass that relieves internal stress. CAM programs fail to allow for operator compensation. New software allows operators to compen-sate for part distortion and the daily reality of residual stress release.

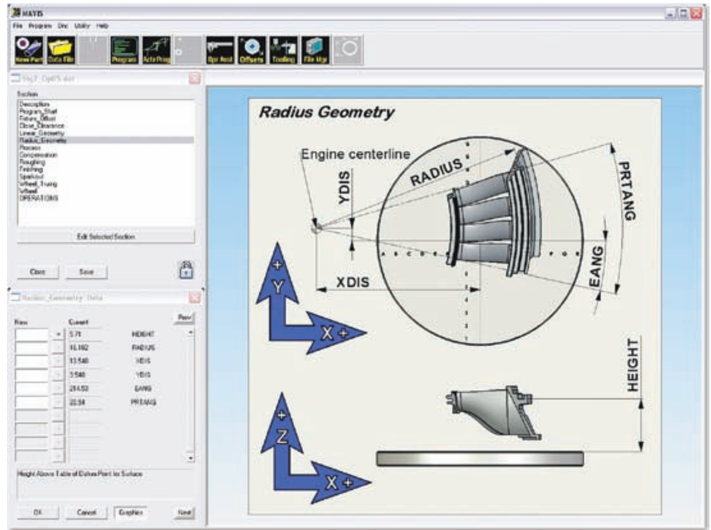
Further, some CA grinding machines use compound tables that require all five axis of motion to machine a feature.

When a part springs out of shape it is nearly impossible to compensate using offsets.

A solution is to use a "B" and "C" axis and position to grind using only 2 or 3 axis allowing for simplified offsets. We developed **MAVIS** (Machine Application Visual Interface Software) in order to simplify to offset input without stopping production to wait for a programmer.

Reliability

Lastly, all the technology is for naught if the machine is not relaible. When a machine is down for service, it is not producing.



Long term application of Quality standards such as ISO9001-2008 in manufacturing and modular machine designs are yielding warranty claims in the .1% and machine uptimes of >99%.

ISO standards require customer collaboration to address the end product and process requirements to be designed into the machine tool. Machine designs can minimize thermal distortion, linear and rotary axis are laser mapped for accuracy and coolant chillers can maintain grinding temperatures to ±1 degree.

Modular machine designs allow customized configurations from standardized components for reduced cost, increasing flexibility and lowering downtime. Machine causes for down time can be virtually eliminated.

These factors result in significant improvements in process, quality, productivity and lower cost.

A recent application for an aerospace component a 5-axis, CBN process with Wheelpacks demonstrated a five times productivity gain over a conventional grinding process. That amounts to an 80% reduction to cost.

These factors are ushering in extraordinary levels of competitive advantage favorably altering the economics of the entire industry.

Collectively there are many technical equalizers that can offset cheap labor, long supply lines (inventory), poor response or confusing communications from offshore manufacturing locations.

These factors together provide compelling economic reason to invest in a down market, to lower cost in the short term and to position for economic dominance in the upturn.

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