Conventional ElectroChemical Grinding: Its Advances and Flaws

Purpose of this Article

The purpose of this article is to provide a quick overview of electrochemical processes important to the Molecular Decomposition Process (MDP) and its predecessor, Electrochemical Grinding (ECG). The problems with ECG noted by this article became the jumping-off point for much of Compositron Corporation's cutting-edge research into ECG and the subsequent development of MDP, the most advanced technology ever developed in this area.

This study is a modified and updated version of chapters appearing in a booklet entitled *ECM ECD ECG Simplified: All You Have to Know to Use These New Competitive Weapons* by Nicholas A. Golato of ChemForm, published circa 1980. Some diagrams were also taken from this study.

A Review of ECG (Electrochemical Grinding)

The Molecular Decomposition Process (MDP) and its predecessor, Electrochemical Grinding (ECG) are burr-free, stress-free metal removal processes specialized for difficult-to-machine alloys. Figure 1-1 shows a schematic diagram of a typical ECG system. Figure 1-2 shows a photograph of a typical ECG machine.

In ECG and MDP, the wheel lightly touches the workpiece. The tool and workpiece are connected to a direct current source. The electrolyte is applied onto the grinding wheel near the workpiece in a manner that will result in the wheel carrying it into the cut. This brings about electrochemical action (molecular decomposition or deplating) on the workpiece.

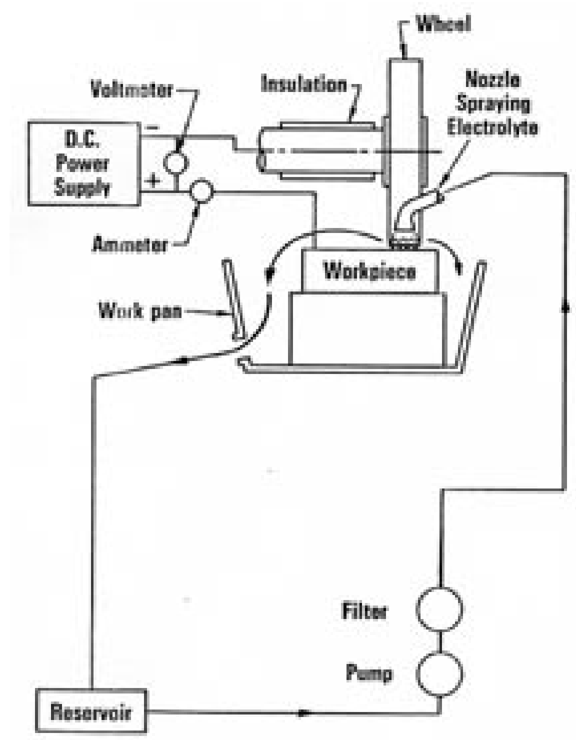


Figure 1-1

Because metal removal in MDP and ECG is largely brought about by non-mechanical action, only about 10% of conventional grinding wheel pressure is required, corresponding to the fact that only about 10% of the material is removed by the abrasive action of the conductive grinding wheel. Most of the metal removal is brought about by electrochemical action (molecular decomposition or deplating). Thus, the need for frequent wheel dressing (and the corresponding additional wheel wear) is eliminated.

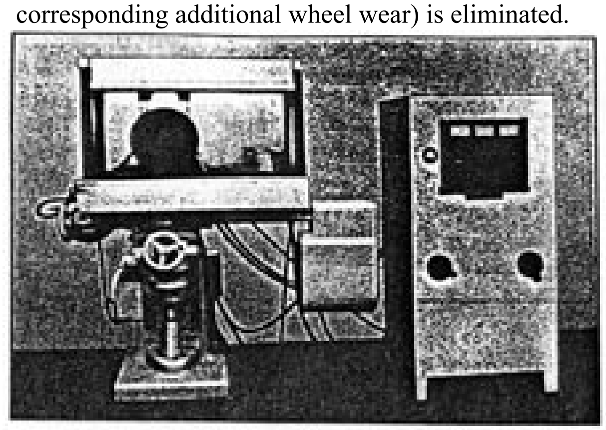


Figure 1-2

ECG is accurate and much faster than conventional grinding. The metal removal rate is largely governed by the amount of electric current and electrolyte applied, regardless of the material's hardness.

Because of the dissolving action and the relative absence of both heat and wheel contact, the ECG process is ideal for grinding fragile parts through a stress-free, burr-free process, and for those parts that cannot stand thermal machining damage.

The electrolyte solution may be a saltwater solution or a less corrosive solution of sodium nitrate or nitrite. The latter solution is preferred for conventional grinding machines that have been adapted to the ECG process. Parts ground by ECG tend to be corrosion resistant. The rust contributing non-metallic constituents have been dissolved from the ground surface by the electrolyte.

ECG is applied to the four common grinding methods as follows:

1) Face Wheel Grinding - best for smaller pieces where the entire ground surface is attacked at once and maximal current can be applied.

2) Peripheral or Surface Grinding - best for large pieces when used in conjunction with a large diameter wheel. The large diameter generally produces faster metal removal, accuracy and electrolyte flow.

3) Cone Wheel Grinding - ideal for large, flat contact areas where high current can be applied for maximum metal removal.

4) Form Wheel Grinding (Square Grinding) - applied to the same workpieces as conventional form grinding but, because of negligible wheel wear, expensive dressing is reduced and wheel life is increased, usually seven to ten times.

The Equipment

Establishing an ECG installation is probably easier than any of the other non-conventional machining processes. Standard conventional grinders can be easily converted for ECG use. Grinders built specifically for ECG are normally constructed of non-corrosive material, particularly in the proximity of the grinding wheel. Often, brushes are fitted to the rear of an insulated spindle to carry the current to the conductive grinding wheel. Cable lugs are attached to the workpiece table. A housing is provided to contain the electrolytic solution. An installation also requires a power supply in a nearby cabinet, a very simple pumping and clarification system to provide electrolyte, and an electrolyte reservoir.

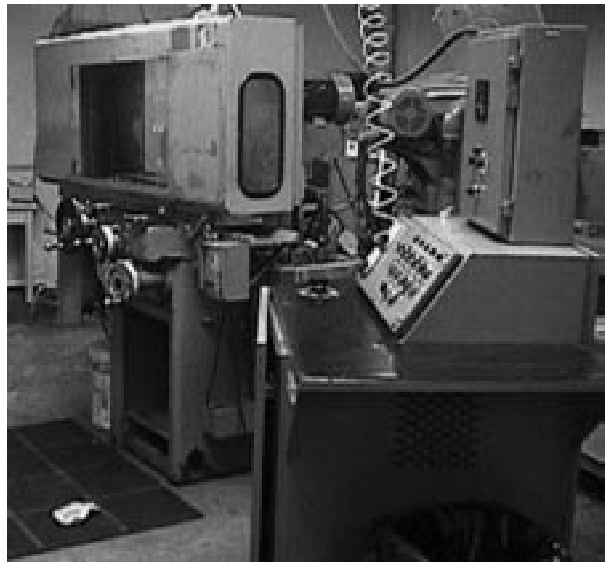


Figure 1-3

Conclusion

Though metal is dissolved by electrical and chemical energy, it is the grinding wheel that makes ECG the accurate and rapid metal removing process that it is. Diamond or aluminum oxide particles protruding slightly from the wheel remove the oxidized layer quickly, speeding up the dissolving process. Due to the slight wheel pressure and negligible frictional heat, ECG is suited for both the hogging and final finishing of delicate parts. Savings realized by the speed of the process, and by reduced wheel wear and dressing make ECG a more economical method of metal removal than conventional grinding. The abrasive wheel particles produce the dimensional accuracy and thereby reduce the need for critical control of electrolyte temperature,

A Closer Look

The Process and Applications

Electrochemical grinding is a relatively easy process to understand and apply. This is true for several reasons:

1) MDP and ECG machines closely resemble conventional face and surface grinders in both appearance and, to some degree, operation.

2) The tool, in all cases, looks just like the conventional grinding wheel and actually is, except that the wheels used in MDP and ECG contain an electrically conductive bonding material to hold the abrasive together. The bonds used may be metal, carbon or any other conductive materials.

3) The electrolyte that is used is introduced to the wheel in much the same manner as conventional coolants used in grinding operations.

4) Very little special knowledge is required to use the process. An operator trained to run a wet grinder can run an MDP or ECG machine.

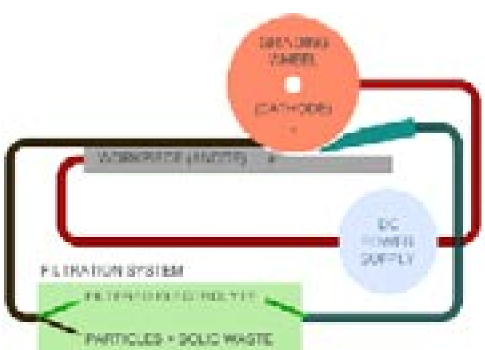


Figure 1-4

The Process

In MDP and ECG, the grinding wheel is negatively charged and the workpiece is positively charged. The electrolyte is wetted onto the wheel rather than the work area being entirely flooded by electrolyte.

The abrasive grains on the surface of the wheel and the porosity serve to act as paddles which pick up the electrolyte and cause a pressure to be built up at the work area. For example, a wheel turning at 5500 SFPM can easily produce an electrolyte pressure of 150 psi in the area where the wheel meets the workpiece.

Abrasive particles, themselves nonconductive, tend to maintain a gap between their bonding agent and the surface of the workpiece. This gap is filled with electrolyte, allowing DC current to flow. The metal on the surface of the workpiece is converted to oxides through the combined interaction of the DC current and the electrolyte. As the metal at the surface of the workpiece becomes an oxide, it is wiped away by the abrasive surface of the grinding wheel. Since the oxides are much softer than the parent metal, there is very little grinding wheel wear.

Figure 1-5

Higher Metal Removal Rates are Obtained with ECG than with Conventional Grinding in Hard Metals

Due to the assistance of electrochemical action combined with the scrubbing or wiping power action of the grinding wheel, metal removal rates are frequently up to 80% faster than rates obtained with conventional grinding of the same material. The two greatest factors affecting metal removal rate are current density and the contact area.

Current density is controlled to a great extent by the limitations of the available means of transferring current into the rotating spindle. A given size spindle is only capable of carrying so much current and the usual means of inducing current into the spindle is by typical motor brushes which, again, are limited (See Figure 1-1).

The amount of wheel area in contact with the workpiece governs to a great extent how much current can be conducted regardless of how much is available. The contact area will usually be governed by the shape being ground, the type of wheel and machine being used (surface, face, etc.), and the diameter of the wheel. We will explore these variables further, later in this section.

Cool Burr-Free Grinding with ECG

Due to the fact that there is very little mechanical contact between the wheel and the work-piece, there is very little heat (sometimes none) generated at the work surface. This fact, coupled with the near absence of mechanical metal removal, results in a very cool operation. Although it is difficult to prove how much metal is removed by mechanical grinding action, it is estimated to be approximately 10% for standard applications. This percentage can, however, be increased or reduced by varying the feed rate. Workpieces of all materials and descriptions can be produced free of thermal surface defects (heat checks) and burrs due to the relative absence of mechanical contact.

Wheel Wear Drastically Reduced

The reduction of mechanical contact of the abrasive particles in the wheel greatly increase the life of the wheel as compared to conventional grinding. Depending on the selection of feed rate, size of the wheel and other process variables, wheel life can be increased by a factor of ten on most ECG installations.

Tolerances Obtained with ECG

Conventional ECG, as opposed to MDP, cannot obtain the accuracy and tolerances needed in form grinding. However, as is the case with tolerances, it all depends on what you need. For instance, tolerances of ±.0005 inches are easily held on rather complex form grinding with ECG. Closer tolerances can be held depending on the nature of the setup and whether you want to use the mechanical grinding capabilities of the wheel.

Tolerances of ± .001 inches are easily held on all types of surfaces and shapes at maximum ECG metal removal rates.

Surface finishes are easily held in the range of 8-10 microinches. It should also be remembered that the surfaces produced by ECG are essentially non-directional, and because of little abrasive contact, there are little or no tool marks.

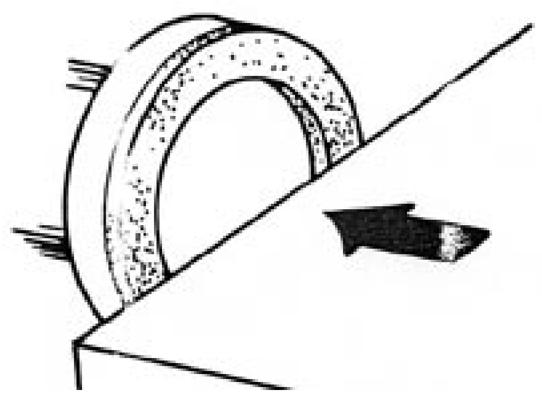


Figure 1-6

Types of Wheels and Effects of Size

Shown in Figure 1-6 is the face type of grinding wheel. The workpiece is usually plunged into the face of this type of wheel, thus allowing for maximum metal removal rate, since the entire surface to be ground is in constant contact with the wheel.

This type of wheel is most commonly used to grind carbide cutting tools. However, this wheel is limited as to the size of workpieces it can accommodate and, in some cases, will show traces of the effects of difference in surface speed from its outer diameter to its inner diameter on the finish of the work-piece

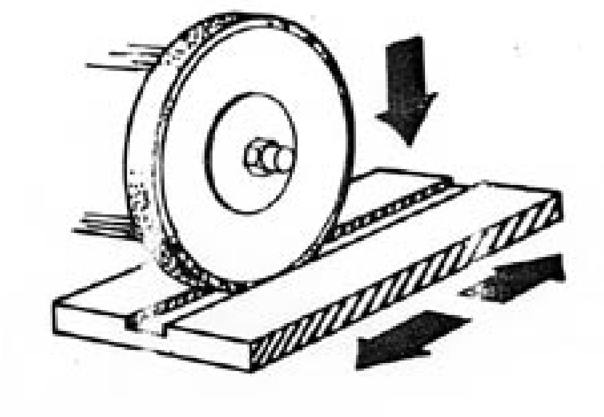


Figure 1-7

Shown in Figure 1-7 is the peripheral type or surface grinding wheel. This type of wheel is most commonly used for larger workpieces.

This type of wheel may be fed into the work-piece in several different ways. In cases where older surface grinders are converted to ECG, the wheel may be fed down into the work-piece on multiple passes as in conventional surface grinding practice. One of the advantages of MDP and ECG is that a full depth cut can be made in one pass. If tolerances are tight, a second pass may be required.

On machines specifically designed to take advantage of ECG, very often the entire operation may be performed in a single pass of the table. This is particularly advantageous, as it allows a larger area of the grinding wheel to be in contact with the workpiece, thus allowing greater current density and much faster metal removal rates. This effect is illustrated in Figure 1-8. It can also be seen in this illustration that the larger the diameter of the wheel, the greater the contact area and its subsequent beneficial effect on metal removal rate. In the case of the face type wheel, increased wheel diameter serves to allows for the accommodation of large workpieces as well as increased metal removal rate.

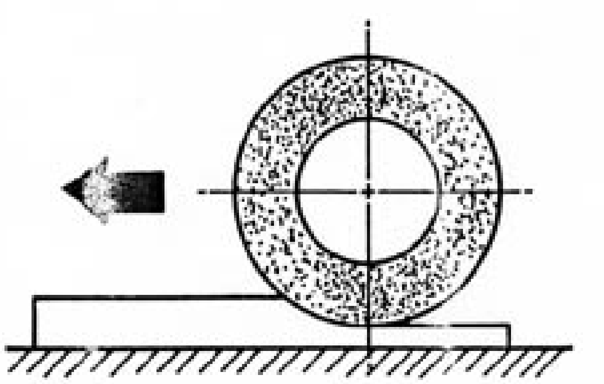


Figure 1-8

In the case of both types of wheels, the larger diameter wheel will hold its shape longer between dressings. Although there are other types of wheels used in ECG, such as the conical dressed face wheel and cup type wheels, the aforementioned basic rules apply in the same way.

Tips on Form Grinding with ECG

When establishing the relationship between the workpiece and the wheel, in ECG as well as in conventional grinding, it is always advantageous to divide the angles involved in the form as equally as possible across the face of the wheel as illustrated in Figure 1-9. This may involve tipping the workpiece at an angle, but it is well worth the extra effort since it tends to equalize wheel wear at all points in the form and allows the holding of closer tolerances.

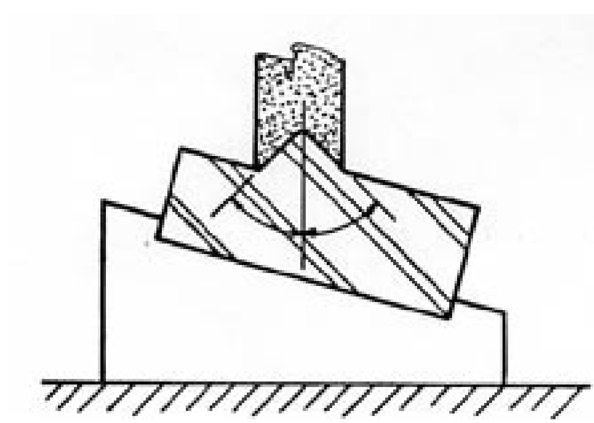


Figure 1-9

In complex forms having a variety of depths as shown in Figure 1-10, it is advantageous to minimize the difference in these depths, which in turn minimizes

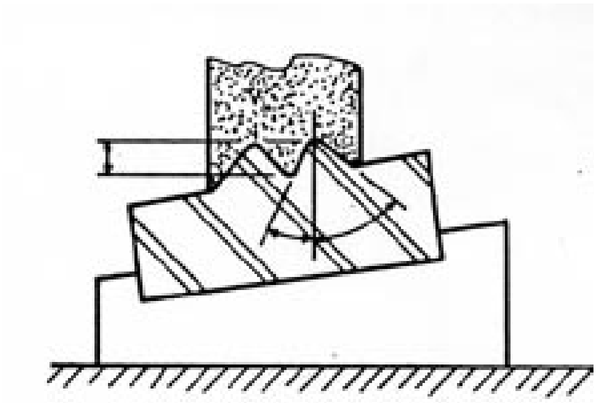


Figure 1-10

the effects of the differences in surface speed and wheel wear at different diameters in the grinding wheel.

ln most cases, some compromise is necessary in accommodating both angle variations and depth variations so that each particular form will have an optimum angle at which the work should be tipped and presented to the wheel.

MDP: The Future

Now that you have been acquainted with ECG machines, including their many advantages but also numerous disadvantages, be prepared to be blown away by Compositron Corporation's giant leap forward: MDP. The next document is this manual will explain how our engineers have dealt with the shortcomings of current ECG technology to produce the next generation of high-precision grinders.

The Molecular Decomposition Process

A Comparison with Electrochemical Grinding, ECG

Introduction

Insight behind ECG – Development of MDP – Superior Performance of MDP

Your new G1 grinder represents the first existing implementation of the Molecular Decomposition Process, developed by Compositron Corporation after a decade of research that began in 1992. Compositron's MDP research built off the initial insights, which took form in the 1950's. It was then noted that, if an electrical current flow is established between a negatively charged abrasive wheel and a positively charged workpiece through an electrolyte, the resulting electrochemical oxidation produces a soft hydroxide film on the workpiece surface that may be easily wiped away by the abrasive wheel.

But this insight, which represents the state of the art, in terms of fundamental science, of Electrochemical Grinding, was but the first step in the development of the science and technology of the Molecular Decomposition Process. MDP has reinvented and revolutionized every aspect of the preexisting ECG process, all the while introducing new aspects and innovations that were not possible under the now-obsolete ECG paradigm. At the foundation of MDP lies not only a superabundance of technological innovation, but a brand new science, only bare hints of which were available to the designers of the ECG systems of today. The most robust grinding technology available, an MDP system is powerful enough to cut any material known to man, precise enough to cut any shape within .0002", and gentle enough to work with the most delicate materials without leading to warping, burring, damage, or distortion.

The purpose of this section is to introduce, in a non-technical way, the marked differences that you will find between a MDP-G1 grinder and an ECG system. We will also emphasize the advantages that this new technology represents for you, in terms of precision, environmental-friendliness, energy-efficiency, and the productivity bottom line.

Who are the main characters in this drama of high-speed grinding?

Power

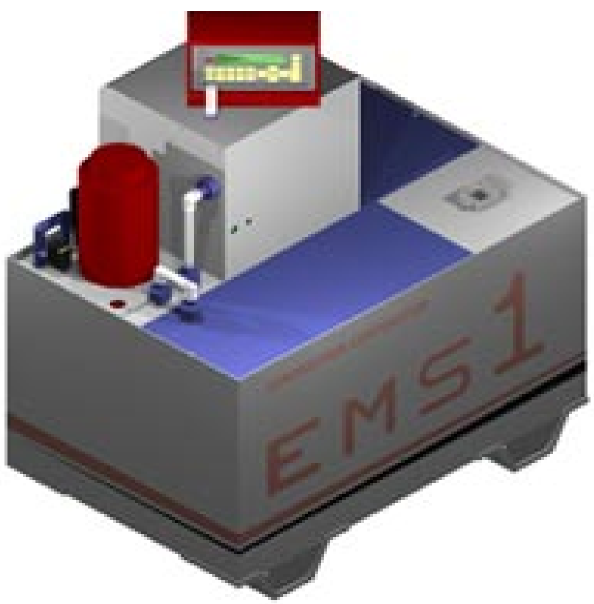
The Need for Precise Modulation – Rapid Response in MDP

The first character's introduction can be easily motivated by a very simple observation: if electricity is used to decay material, as in the ECG process, precise modulation of the electrical output of grinder and wheel must be made possible in order to ensure a precise cut. Too much current – and how much current is enough may vary widely during a single cut! – is not just unnecessary, but deeply counterproductive. To most effectively harness the material decomposition capacities of electrical current, it must be possible to, nanosecond-by-nanosecond within the course a single cut, modulate and maintain precisely the optimal levels of electrical current. The electrical designs and power supplies used in the ECG process lack both the required energy capacity, quick response, and the precise modulation necessary for precise operations. Standard ECG operating procedures are characterized by the often wildly varying currents that are actually applied to the workpiece – between inefficiencies in the power supply, and the crude state of the system in general – and it is impossible to precisely control, much less modulate, the electrical exchange between the system and the workpiece.

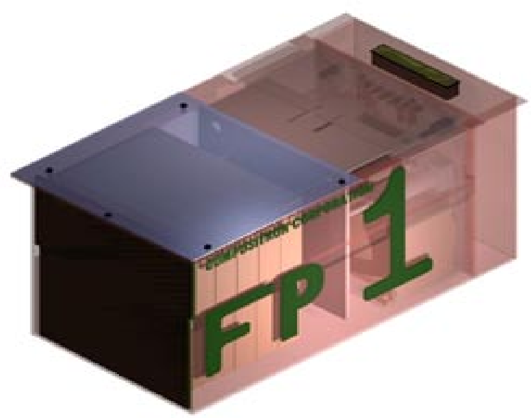
In contrast, the MDP-G1 power supply is a solid-state system capable of on-time voltage control, ranging from 0 to 18 volts, with current ranging from 300 to 1000 amperes. The response time of the unit is several orders of magnitude faster than what is used in traditional ECG power supplies. Working in tandem with the redesigned electronics that are some of the centerpieces of an MDP system, there is virtually no lag time between the detection of suboptimal performance and the resulting correction. Thus, in MDP, power output is constantly modulated to guarantee that optimal levels of current arrive at the workpiece at all times. And since no excess power is drawn, you will be delighted to find that overall power consumption is significantly reduced! In terms of spatial efficiency, the G1 power supply is built into the structure of the grinder itself, leading to significant reductions in the requisite floor space.

Fluid Control

Highly Inconsistent Fluids of ECG – EMS guarantees Consistent Fluids – Resultant improvement in Precision – Elimination of Hazardous Wastes



Another crucial component can be similarly motivated. As you might know, in an ECG system, chips and debris from the cutting process are constantly flushed away by – and, consequently, are accruing in – the electrolyte. This represents a systematic contamination of the electrolyte by foreign substances, giving rise to two fundamental types of problems. The first: these materials are conductive, and usually contain many large particles. This dramatically alters the performance of the electrolyte itself, changing its overall conductivity throughout the process and, even more dangerously, leading to dramatic nonuniformities in the conductance properties of the electrolyte on a nanosecond-by-nanosecond scale. This is because the conductivity of the fluid as an interface between wheel and workpiece can be dramatically altered by the random grains of passing particulate matter. For this reason alone, even if precise power output were made possible in an ECG system, it would be impossible to precisely modulate power as applied to the workpiece. In an ECG system, the dramatic moment-to-moment electrolytic nonuniformities lead to wild fluctuations in the voltage actually applied to the workpiece; this drastically affects the performance of the machining process. A second huge drawback associated with this process is the resultant generation of huge volumes of waste fluids. As the electrolyte becomes increasingly contaminated, it eventually requires replacement, leading to the disposal of tens or hundreds of



gallons of volatile, liquid toxic wastes that is expensive to the user and exceedingly dangerous to the earth's environment.

In response, Compositron has developed the Electrolyte Management System (EMS), as well as the new line of DTS electrolytes. The package, a crucial component of any MDP system, is designed to completely control the physico-chemical properties of process fluids, optimizing fluid parameters at all times and removing excess contaminants, chips, and pollutants. This impacts the process in two ways. First, it guarantees that the fluid applied between the wheel and workpiece, the

medium through which electrical current must pass, is chemically consistent, both from moment-to-moment and across long spans of time in which the machine is operating. Undesired pollutant accrual simply cannot take place, because the pollutants can be removed by the EMS long before they ever return to the machine. With a highly constant medium separating wheel and workpiece, it is possible to modulate the voltage actually applied to the workpiece with a precision hitherto undreamed of in ECG. Instead of wild, erratic electrical performance, the combination of robust power supply and consistent process fluids leads to the possibility of ultraprecision grinding, while using on average 60% less electricity. A second crucial outcome: by removing wastes, chips, and debris, and compressing them into a safe, non-toxic, semi-dry cake, the generation of wastes is dramatically curtailed. A small packet of solids may be removed, leaving clean electrolyte, instead of the lengthy, highly expensive, and environmentally risky process of disposing and replacing 50 – 100 gallons of contaminated electrolyte. This dramatically extends the life of process fluids and completely eliminates a very dangerous environmental hazard. This bottom line for the user: reduced power and chemical costs, longer wheel life, and easier machine operation.

Mechanical Precision

Power Delivery through Spindle –

Feed Rate Modulation

Two mechanical flaws characterize all current ECG systems.

Firstly, the design of existing ECG spindles has been plagued by serious limitations on their ability to consistently deliver current given the mechanical constraints due to their high-speed rotation. To ensure the possibility of delivering current with the highest precision, MDP utilizes a completely redesigned spindle that eliminates these mechanical and electrical problems entirely.

Secondly, in conventional ECG, feed rates cannot be precisely controlled. As a result,

the precision of the process suffers significantly, and abrasive action cannot be properly modulated. Additionally, the risk of doing unnecessary damage to the workpiece is far greater. In an MDP system, a fully-redesigned spindle, as well as a number of crucial improvements to the entire mechanical ensemble, make it possible to control feed rates with less then 1% variation. This represents a dramatic improvement over the erratic performance of ECG systems. The new design also makes possible an on-time response system: feed rates can be modulated during the course of a cut to constantly maintain optimal levels.

The Molecular Process Control: MDP as a Grinding Symphony

Vast Array of Inputs – Possibility of Precise Controls in MDP – Artificial Intelligence of the MPC Limited Role of Operator – On-time Optimization of Process Parameters

All the above-mentioned characters combine to produce a grinding machine whose every property and parameter can be precisely controlled and modulated at every moment to achieve optimal parameters. But how can such optimal operating conditions be determined? And who must ensure that the modulation of such a complex mechanism is implemented? How can nanosecond-by-nanosecond control be possible over the hours and hours of an MDP system's operation, given the physical and mental constraints on even the most skilled of human operators?

This brings us, naturally, to the deepest and most profound innovation characterizing MDP. At the heart of any MDP system lies a hub, known as the Molecular Process Control (MPC), whose functions are thoroughly integrated into every component of the system, provide on-time monitoring, diagnosis, and control. The inputs of a vast sensor array (including data about a range of fluid parameters, workpiece properties, spindle parameters, power output, and material decomposition rate) are constantly channeled into the MPC. Next comes a crucial part of the science of MDP: with ECG, since process parameters are, of necessity, highly variable, it is impossible to determine or implement optimal functionality, and one must always settle for relatively crude, imprecise performance; MDP, in contrast, is characterized by a pluripotent grinding ensemble that can precisely implement an unimaginably wide range of parameters and performance specifications. As a result, a new question arises: what are the optimal parameters for a wide array of cutting processes? But this problem is one that an MDP operator need never consider, for the MPC is, among other things, an automated scientist: guided by a carefully crafted artificial intelligence mechanism combining neural networks and fuzzy logic, and based in part on a body of extensive field research, the MPC automatically translates the input data into an array of optimal operating parameters. (Nor is the MPC limited to any body of preset applications: it can quickly be "trained" to perform almost any machining task.) Without any need for operator control, the MPC then oversees the implementation of optimal grinding settings. Like the conductor of a vast symphony of thousands of components and parameters, the MPC ensures, nanosecond-by-nanosecond, that every component in the grinding system is doing exactly what it needs to be doing.

Performance
Advantages Precis

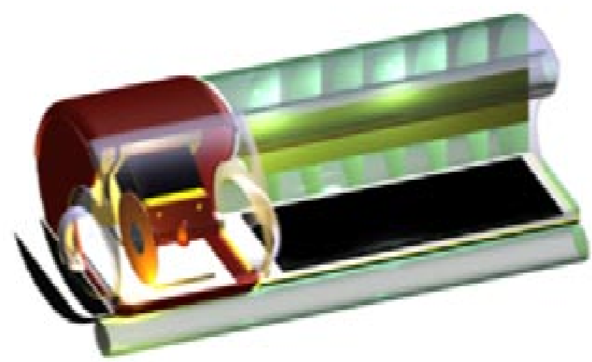
Cost-Reduction – Elimination of Wastes - Labor-Reduction –

Dramatic Improvement in Tolerance – High Speed Performance

What can a fully operational MDP system, such as the MDP-G1, do for you? For starters, the unparalleled precision of its controls and operations will eliminate 90% of scrappage, saving raw materials, machine time, and labor. And, as above, power usage is decreased by 60%, and waste volume by over 99% (while eliminating toxicity!). The virtual elimination of liquid wastes, in the form of disposed electrolyte, significantly reduces the labor involved in proper maintenance of an MDP system and dramatically reduces water usage. Costly setup time, too, rarely enters into the MDP reality: the MPC can automatically detect the "metallurgical fingerprint" of the workpiece, identifying its material, size, shape, and location. In essence, all the operator needs to do is turn the device on.

Finally, tolerances have been improved from .006 inch, the previous limit for automated electrochemical grinding systems, to .0002 inch with the MDP-G1, a thirty-fold improvement. MDP is also the clear choice in terms of speed, capable of cutting twice as quickly as the best ECG systems, and four times as fast as a conventional machine. Thus, MDP can be applied to a whole array of processes demanding the highest degree of precision, while still maintaining unparalleled speed and performance.

Outlook



Significance of MDP

To sum up, MDP is, quite simply, the most advanced grinding technology ever developed. No other method is capable of comparable performance in terms of speed, precision, and clean operation. The MDP-G1 that you have purchased is the beginning of a revolution in cutting technology, and we are pleased that you have chosen to join us on this exciting voyage.