A SYSTEM FOR SUCCESSFUL LAPPING OF PCD AND CVD DIAMOND

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The use of PCD (polycrystalline diamond) and CVD (chemical vapor deposition) diamond has been expanding into a wide variety of industrial, electronics and optics components and applications. While the technologies to produce these materials differ, they present similar challenges in flat lapping and polishing because of the extreme hardness of the materials.

To lap PCD or CVD diamond materials it is necessary to aggressively apply relatively large diamond abrasive particles in engineered slurry formulations against hard plates using robust equipment in order to achieve success.

When lapping with softer conventional abrasive, higher down force is not required. When using diamond, however, more pressure is needed so the abrasive particles abrade, rather than burnish, the workpiece. This downward force is even more critical when lapping PCD and CVD diamond with diamond particles of similar hardness, as there is even less cutting action from the particles and a greater tendency to only have a burnishing action. Providing sufficient load to deliver the abrasive to the work zone can be a daunting challenge requiring:

- *Stiff machine base, spindle and pressure mechanisms*
- *Aggressive abrasive media*
- *Hard plate material*
- *Exacting lap plate preparation*

It has been shown that, in order to optimize the plate preparation process, the use of lap plate facing technology to planarize, texture and cut spiral microgrooves in cast iron plates, results in increased lap rates and, therefore, reduced processing times.

This facing technology, when coupled with engineered diamond slurry, achieves consistent lap rates between 1μm/min and 8μm/min, depending on the surface condition of the parts. (Rough as-grown parts will lap faster than ones which have already been planarized.) These results represent a great advancement from more conventional lapping approaches which required more processing time. The bottom line is reduced costs for equipment, consumables, labor and most importantly, higher throughput.

Advanced Plate Preparation

Free abrasive lapping is a four-body process that involves an abrasive, a carrier (paste or liquid) that is

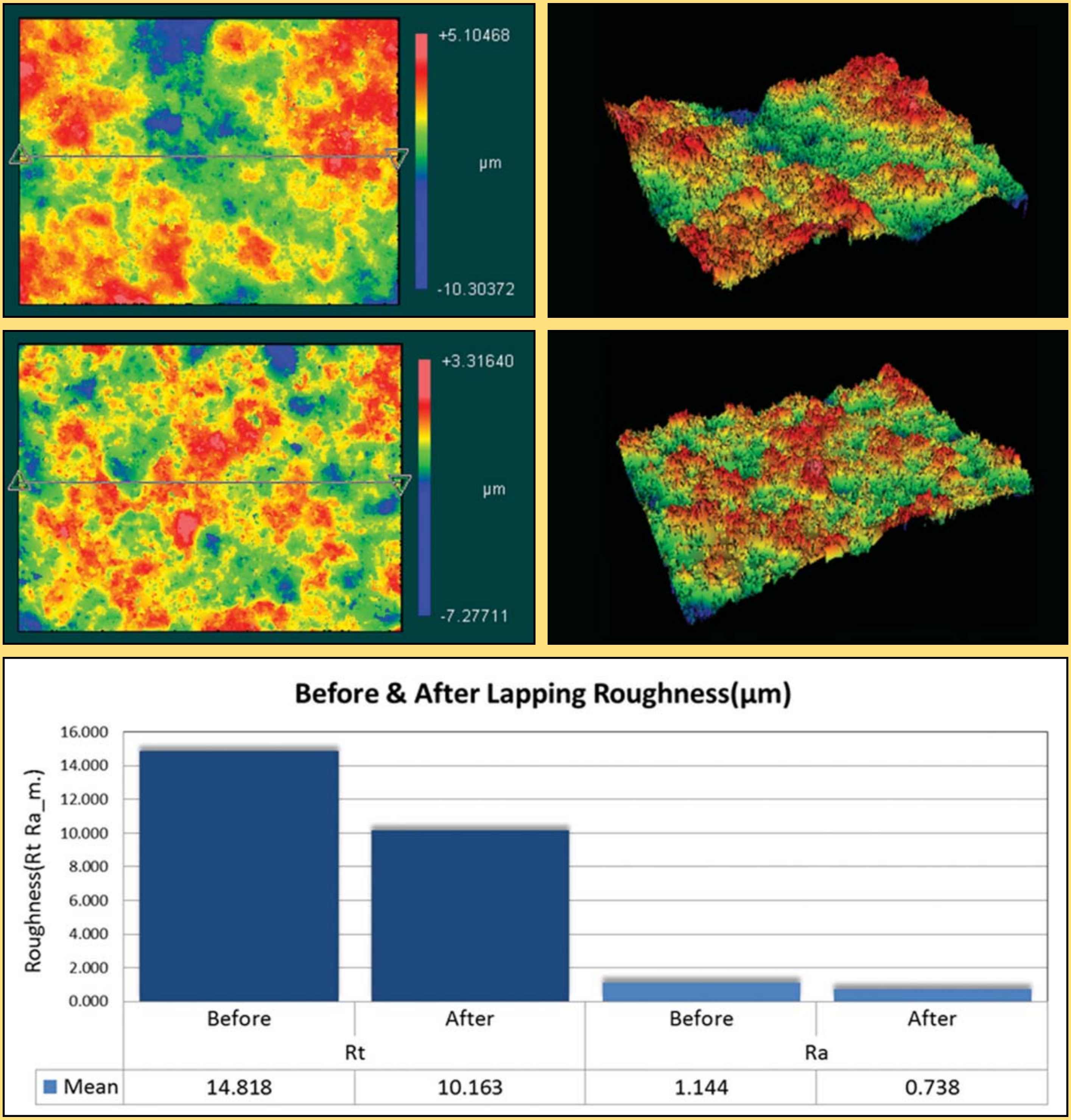


FIGURE 1: Surface mapping of a PCD diamond surface prior to (top image) and after rough lapping (middle image) – images generated using a Zygo white light interferometer – random surface finish results.

applied between the workpiece surface and a lapping plate. While some of the diamond particles contained in the carrier become embedded in the lapping plate to perform a fine grinding action, abrasive particles may also be continuously loose and rolling ("free particles"- see Fig. 2). The lapping process works by pushing the points of the diamond grains into the work surface to abrade microchips of workpiece material, a process well suited to brittle-fracture materials such as hard ceramics. As a result, lapped surfaces do not have directional marks.

Material removal rate in the lapping process is a function of relative work speed, time and pressure. Pressure is defined as load per unit area and is determined by the contact

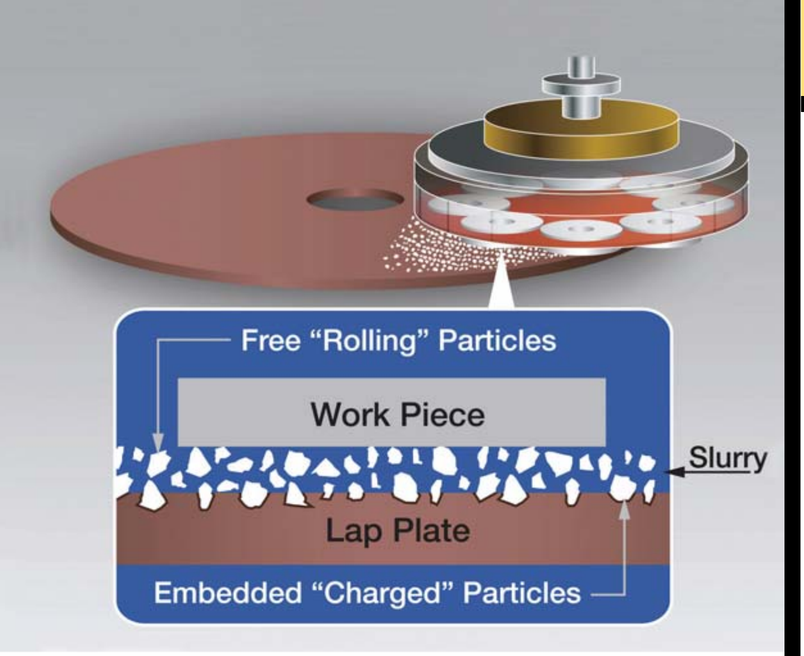


FIGURE 2: Lapping uses a combination of embedded and free diamond abrasive particles.

area (bearing ratio) of lap plate on the work surface. Material removal rate is explained in Preston's equation as follows:

MRR = Kp(P)vr where
MRR = Material Removal Rate
Kp = Preston Coefficient (process dependent)
P = Pressure (load/area)
Vr = Relative lapping velocity

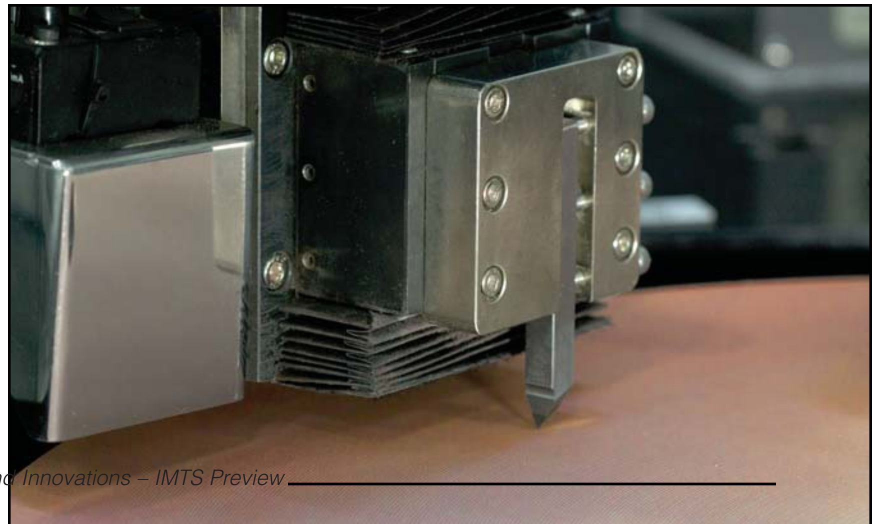
So a flat plate that presents itself well to the work surface will maintain this pressure at the interface between plate, abrasive particle and workpiece, resulting in a steady material removal rate.

What is more challenging in the case of PCD or CVD diamond lapping is the extreme workpiece resistance; high loads strain the interface between the lap plate and the particle and, as a result, any embedded particles strip away and the plate surface rapidly degrades. Rolling particles then do the bulk of the work but only to the extent that strong support from the plate and equipment allow. Efficient, repeatable plate surfacing is required because in a lapping process that utilizes high pressures, large particle abrasive and tough workpieces, the lap plate will lose flatness over the course of a process cycle.

The traditional method to define plate flatness and groove configuration involves using conditioning rings (rotating in a planetary motion with the lap plate rotation) and the experience of a highly skilled operator. While results are generally satisfactory, it is a demanding task, resulting in machine downtime and unpredictable material removal rates. Optical micrographs and image analysis software reveal that this process imparts a random texture and an uneven "bearing ratio" (the percentage of surface area with which the workpiece will ultimately come in contact).

The preferred method for lapping PCD and CVD diamond utilizes a plate facing (machining) device which uses a turning tool bit to remove the top worn layer of the lapping plate, machining it flat to within microns. To then produce a controlled surface geometry and texture, the device makes a second pass at a different feed-rate, machining a groove pattern that serves as a basis for structured embedding of abrasive particles. Controlling the overall plate flatness, groove pattern (macro texture) and lands (micro texture) of the plate surface results in a more consistent bearing ratio. A consistent bearing ratio means consistent unit load and removal rates and incidentally, consistent surface finishes. The groove also aids in clearing away lapping debris and spent slurry.

In most diamond lapping applications a soft metal or metal composite plate is the choice in lapping softer materials to high finishes. For these plates a PCD or single-crystal diamond turning bit will be used. But in lapping PCD or CVD diamond higher plate strength and wear resistance is in order, so cast iron is the choice. In this instance the facing bit used is tungsten carbide. As mentioned, due to the hardness of cast iron plate material when compared to



standard composite metal plates, the facing mechanism must be very rigid, with robust drives and ballscrew to produce flat, controllable surface and grooves.

Besides their role in carrying away debris and in controlling bearing area and unit load, the groove also plays a role in presenting the abrasive particle to the work, especially in the case of large particles. What's more the texture of the lands is a factor in effective particle retention and plate aggressiveness. So, in effect, we are designing our plate macro and micro texture to suit the slurry. In this task the programmability of the facing device is of great advantage in optimizing the plate surface

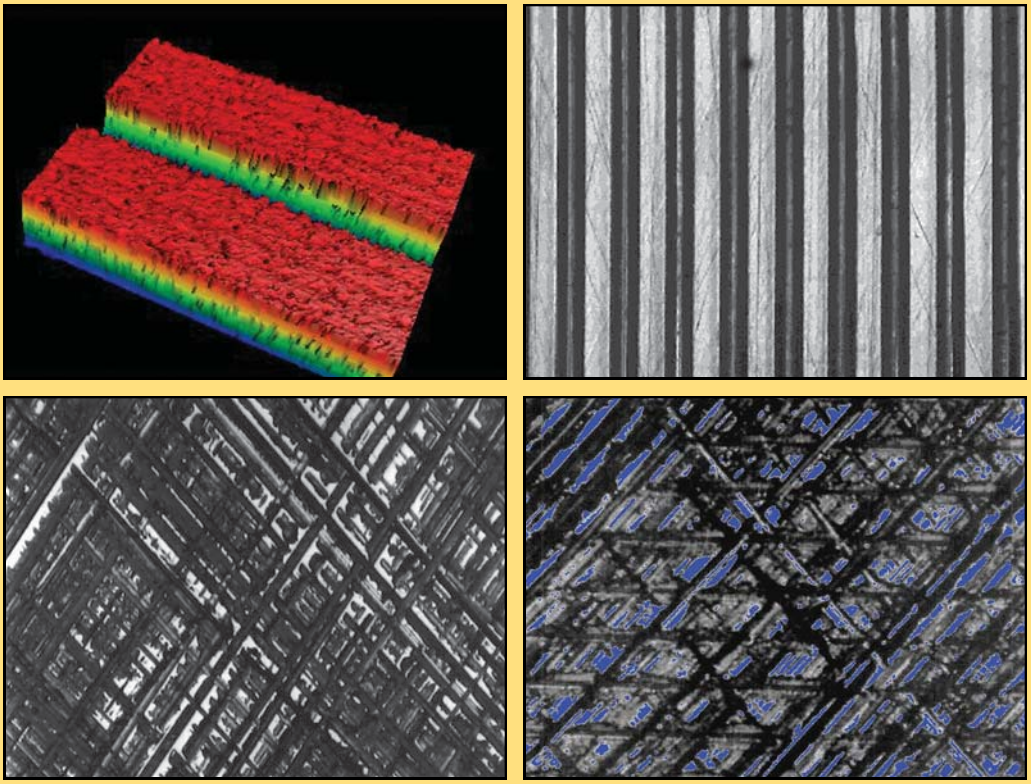


FIGURE 3: Magnified views of textured plates. AT TOP: Examples of controlled textured surfaces with defined surface areas. AT BOTTOM: An example of a random texture. The enhanced view shows the bearing, or working, area in blue.

New Water-Based Diamond Slurry

It was found that standard slurry formulations were inadequate for operating within the higher lapping forces required for PCD and CVD diamond processing. A new diamond slurry was developed specifically for this purpose with a carrier that is thixotropic and maintains an even diamond particle suspension without stirring for long periods of time. Given the rough texture of the lap plate, this formulation allows for easy distribution of the slurry and full plate wetting. The key is for the carrier to evenly coat the plate but thin down as shear forces come into play between the workpiece and cast iron lap plate. An additional advantage of this water based slurry formulation is that it was easy to clean and environmentally friendly. Because large (generally 30-150 micron) diamond particles are required for this application, a tough synthetic monocrystalline particle type was selected for its ability to withstand the elevated loads and resist breakdown.

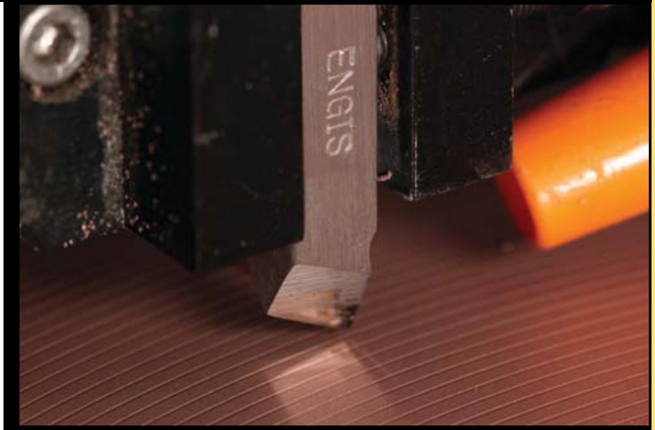


FIGURE 4: A facing device uses a diamond tool bit to remove the top (worn) layer of the lapping plate, machining it flat to within microns. It simplifies reconditioning of the lapping plate. A micro-groove is shown.

CONCLUSION

PCD and CVD diamond components can be lapped and polished but only with significant modifications to the traditional process. Lapping superhard materials requires significantly greater pressures so that the diamond particles can begin to abrade, rather than burnish, the parts. This down force can only be achieved by using robust machinery and properly prepared cast iron plates. In addition, the diamond particles used in the process should be relatively large and durable and applied to the work zone with a thixotropic carrier which fully wets the plate and breaks down efficiently in the process.