Machining Platinum Rings - Do's and Dont's

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Abstract:

The processes involved in machining platinum have long been based on whatever experiences were available to the machinist or manufacturing professional. This condition is due in part to limited published information available to manufacturing professionals regarding specifically platinum and platinum group alloys.

In my 12 years of machining platinum and the precious metal group alloys, I have been through many manufacturing experiences both good and bad. It is my aim to share these experiences in the following topics with regards to platinum manufacturing.

- Advances in machine tool technology.
- Advances in PCD and consumable tooling technology.
- Common misconceptions about required tooling geometry.
- Strategies for effective recovery of precious metal.
- Process automation for ring blank production.

Hopefully this will aid the first time or even the long time jewelery manufacturer to avoid the common pitfalls related to the production of fine platinum jewelery.

• Advances in Machine Tool Technology-

There have been a huge number of advances in the technology of chip cutting machine tools over the last five years. The advantages for metal products manufacturers of any size are many.

Machine Tools For The Masses - Any manufacturer can readily see the benefits of a machine tool that can generate complex geometries and repeat those tasks numerous times. Gone are the days of a lathe operator cutting and measuring all of their parts by hand. In today's fast paced and ever changing manufacturing environment, the need for speed and accuracy in manufacturing dictate that CNC (Computer Numerical Controlled) manufacturing methods be employed. Almost any manufacturing process you can think of has been adapted to this technology. Manufacturing processes from standard lathes and mills, to more complex processes such as laser marking, cutting and welding have been adapted to this technology. Such widespread uses of this technology have driven the price of this technology down to the point that, no longer are CNC controlled machine tools and processes limited to capital rich or well established companies. Almost every worldwide machine tool manufacturer has recognized the need to offer true CNC controlled equipment to the small volume and start-up manufacturers. Some of these machine tool producers have also recognized that not every manufacturing shop has the talent to support the latest high-end machine tools. So, to cover the entire spectrum of metal working manufacturers, most every machine tool company offers entry level machines that can not only be operated by strictly manual operation, but also offer true CNC capability in the same machine. The benefits of this technology are designed to aid beginners in the principles of computer numeric control without compromising the flexibility of a manually operated machine tool. As a shop's expertise grows, the hope is that they will then expand on their CNC capability and capacity. The price ranges of these "hybrid" entry-level machine tools are typically under $30K US, with some of the highest end true CNC multi axis offerings bringing a price in the $500K neighborhood.

Programming Made Easy - The exponential advances in computing power have led to the most powerful and feature rich CNC machine controls in history. Most CNC controls of the modern era offer some type of conversational programming capability. Conversational programming allows the machinist to define the tool and cutting parameters desired, dimensional features of the part and any special features such as threads, grooves, chamfers and corner radii desired. The control will then assemble, based on the collective parameters selected, the required code to operate the machine tool. No longer does the machinist need to program the tool paths longhand or invest in a costly offline CAM (computer aided machining) system to get their parts made. CNC machine tools have even made the move to Internet capability. Manufacturers can use the LAN/and internet capability of their CNC controls for everything from offline service diagnosis of the machine to applications engineering and troubleshooting programs and machine parameters.

Faster Processing & Greater Accuracy - Some of the most significant advances in machine tool technology have been in the mechanical components involved in their construction. Traditional "box-way" machine slides, with their inherent friction factor, have given way to the engineered linear slides coming between the sliding parts of machine tools. Linear guides incorporate ball bearings and engineered races to control not only the friction but the rigidity of the machine tool assembly. A major benefit of this technology is that machine tools now have the capability of extremely high speeds in rapid traverse mode. A traditional box-way machine has rapid traverse speeds of 100 to 250 inches per minute. By comparison a linear slide way equipped machine has the capability, dependent on drive motor technology, of up to 2000 inches per minute traverse rate. This manifests itself in greatly reduced cycle times and "chip to chip" tool change times being as little as 1.5 seconds. Another technology advance is the incorporation of linear drive motors just now coming into vogue with higher end machine tool builders. Some of the major benefits of linear motors and encoders versus their standard rotary counterparts are not only huge speed advances but also vastly improved accuracy. Most of the latest linear motor/encoder units can register 0.00001" positional accuracy.

All of these and other technological advances in machine tool construction combine together to offer the fastest, most accurate, and most reliable machine tools ever available.

With all of these machine tool technology advances and given the current manufacturing environment, any manufacturer of metal jewelery should at least weigh the options of today's CNC machine tools. Johnson Matthey has invested considerable time and money developing our current precious metals machining processes. Over the last eight years process efficiencies developed with the latest generation CNC machine tools has risen in some cases over 600%. CNC technology has allowed Johnson Matthey to improve quality results by 100 to 200% over manual methods. To remain competitive in today's market place we continue to explore the capabilities of the current CNC technology to improve our quality, design capabilities, and process efficiencies.

• Advances in PCD and Consumable Tooling Technology.

Necessitated by the advances in machine tool technology, cutting tool manufacturers have been forced to improve not only the quality but indeed the very engineering principles involved in making a tool to cut metal. The need to advance these cutting tool attributes and properties are amplified when it comes to cutting platinum.

Quick Change Tooling - As the focus on process efficiencies increases, the need for efficient tooling systems are crucial to their success. Machine tools have evolved to be extremely fast and accurate. So naturally the tooling manufacturers need to keep pace with these advances. Cutting tool changes in the past have involved quite a bit of labor in replacing and resetting of the cutting tool. As process efficiency is scrutinized, the time it takes to keep the machine in optimum cutting condition is paramount.

All of the major tooling suppliers have devised their own methods of improving tool replacement processes. The quality and repeatability of today's insert style tooling has made huge strides in improving the cutting cycle uptime. Most insert style cutting tools will repeat on indexing (rotating the same insert in the holder) within .001". Insert to insert replacements are typically within .003" or better. Some tooling systems even have indexable or replaceable tool holder ends that will repeat within .0005". With development of these systems came the decrease in the portion of the tool that needs to be replaced. Modern day lathe tooling inserts are typically sized smaller than a penny. This also translates into lower costs for the replacement tips. First generation insert tools were in the $30-$40 per cutting edge price range with a fairly short life expectancy. Current multi faceted tool inserts are in the $3-$10 per cutting edge range with vastly improved longevity.

Figure 1: Assortment of Insert Style tool Holders for Lathes
Courtesy Sandvik Coromant USA.

Speeds, Feeds & Shapes for Longer Tool Life & Better Surface Finish - Some machine tools have a spindle speed capacity of 10,000 rpm or more. The cutting tool suppliers have stepped up to the plate with tooling solutions for increased rigidity and specialty coatings for micro-grain carbide inserts to withstand the high cutting pressures generated by the higher speeds. Much development has been done with regards to different methods and geometries designed to break the resultant chip being machined off. This problem is increased with the introduction of platinum. Its molecular density dictates that any chip being generated will be long and stringy. These chip strings can then wrap around the cutting tool and work piece, precluding proper cooling and lubrication of the cutting tool. Most often this results in greatly increased and sometimes catastrophic tool wear or failure. Work piece surface finishes also suffer in this condition.

The strategies to combat these conditions begin with selecting the proper cutting tool geometry and chip breaking forms. While very few carbide insert manufacturers retain cutting data pertaining to platinum, it is possible to acquire "off the shelf" carbide insert technology that works. My experiences machining the metal have led to some comparisons to existing tooling data that work quite well. Most applications engineers for cutting tool companies do indeed maintain data regarding the machining of high-nickel and stainless steel alloys. These alloys most closely replicate the actual cutting forces generated when machining platinum or platinum group alloys. An example of the different insert geometries and chip breaker surface are shown on the following pages.

ANSI, T-MAX P

C	N	M	G	4	3	2			-	PF
1	2	3	4	5	6	7	8	9		12

ISO, T-MAX P

C	N	M	G	12	04	08			-	PF
1	2	3	4	5	6	7	8	9		12

ANSI, CoroTurn 107

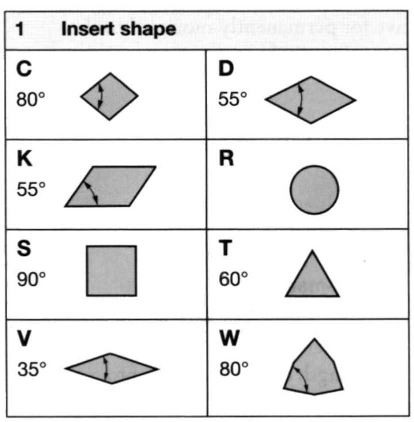
C	C	M	T	3	2.5	2			-	PF
1	2	3	4	5	6	7	8	9		12

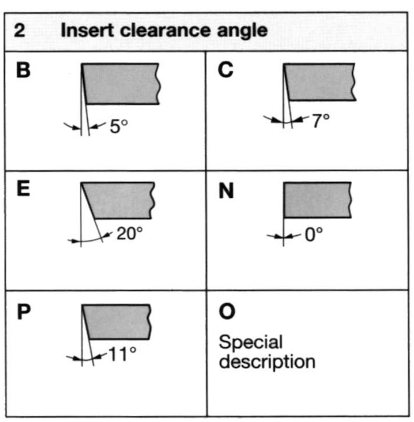
ANSI, Ceramic

C	N	G	A	4	3	2	T	03	20
1	2	3	4	5	6	7	8	10	11

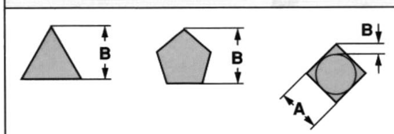
ISO, Ceramic

C	N	G	A	12	04	08	T	010	20
1	2	3	4	5	6	7	8	10	11





3 Tolerances, inch



A: Theoretical diameter of the insert inscribed circle.

T: Thickness of the insert.

B: See figures.

Tolerances in inch

Class:	B:	A:	T:
A	±.0002	±.001	±.001
B	.0002	.001	.005
C	.0005	.001	.001
D	.0005	.001	.005
E	.001	.001	.001
F	.0002	.0005	.001
G	.001	.001	.005
H	.0005	.0005	.001
J	.0002	.002 – .005[1]	.001
K	.0005	.002 – .005[1]	.001
L	.001	.002 – .005[1]	.001
M	.002 – .005[1]	.002 – .005[1]	.005
U	.005– .012[1]	.005– .010[1]	.005
N	.002 – .010[1]	.002 – .004[1]	.001

[1] The tolerance depends on the size and shape of the insert, see page A 379 for specific references.

3 Tolerances, metric

Tolerance, class	s	iC / iW
G	±0.13	±0.025
M		±0.05 – ±0.15[1]
U		±0.08 – ±0.25[1]

[1] Varies depending on the size of *iC*. See below.

Inscribed circle *iC* mm	Tolernace class M	U
3.97 5.0 5.56 6.0 6.35 8.0 9.525 10.0	±0.05	±0.08
12.0 12.7	±0.08	±0.13
15.875 16.0 19.05 20.0	±0.10	±0.18
25.0 25.4	±0.13	±0.25
31.75 32.0	±0.15	±0.25

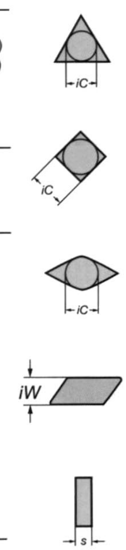
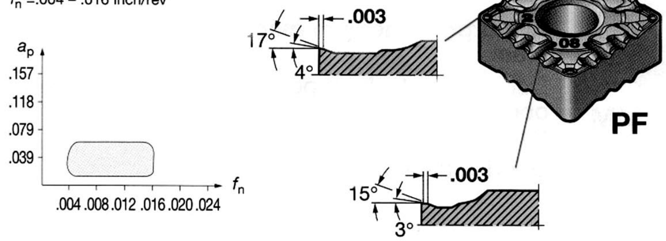


Figure 2: ANSI and ISO Code designations for insert style tools

Courtesy Sandvik Coromant USA.

BASIC GEOMETRIES

CNMG 432-PF
a_p = .012 – .059 inch
f_n =.004 – .016 inch/rev



P

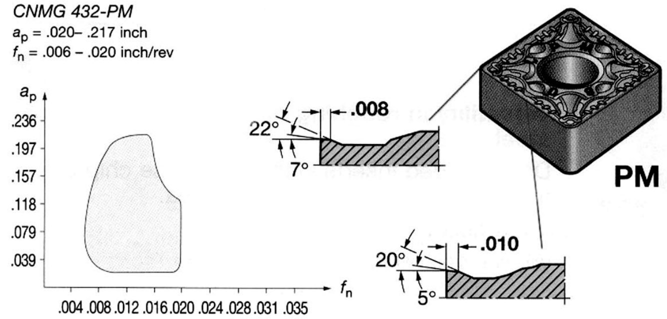
Finishing in steel

Smooth and accurate chip flow in axial and radial turning, copying, chamfering and back facing operations.

Low cutting forces.

Very good surface finish and close tolerances.

CNMG 432-PM
a_p = .020– .217 inch
f_n = .006 – .020 inch/rev



P

Medium machining in steel

Versatile, all purpose chip breaker.

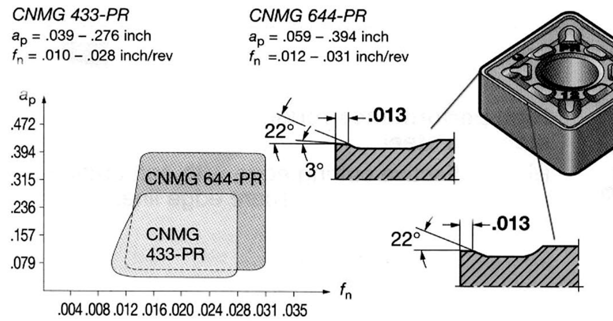
From semi-finishing to light roughing.

High productivity and trouble-free machining.

CNMG 433-PR
a_p = .039 – .276 inch
f_n = .010 – .028 inch/rev

CNMG 644-PR
a_p = .059 – .394 inch
f_n =.012 – .031 inch/rev

Double sided



P **M**

Economy roughing in steel

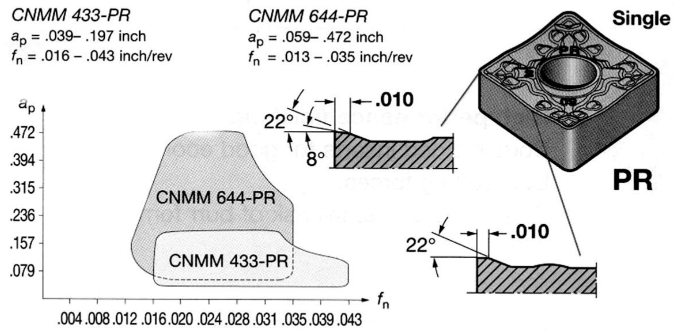
Double sided positive geometry for best economy and superb roughing performance, even on slender components.

All purpose chip breaker with the broadest possible working area.

CNMM 433-PR
a_p = .039– .197 inch
f_n = .016 – .043 inch/rev

CNMM 644-PR
a_p = .059– .472 inch
f_n = .013 – .035 inch/rev

Single sided



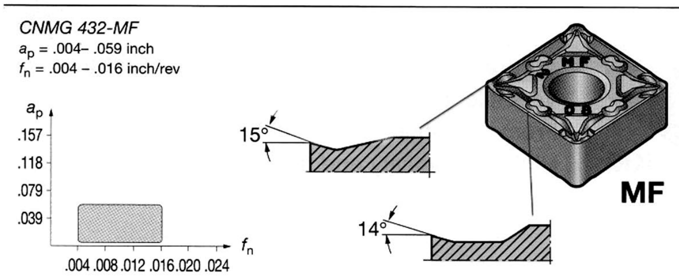
P

Versatility in roughing operations in steel

Single sided, positive geometry for best combination of security and low cutting forces.

All purpose chip breaker with the broadest possible working area.

CNMG 432-MF
a_p = .004– .059 inch
f_n = .004 – .016 inch/rev



M **S**

High performance finishing in stainless steel

Double sided, sharp positive cutting edges giving clean cuts and little risk of built-up edge.

Close tolerances and good surface finish.

Figure 3: Descriptions of Different Chip Breaking Surfaces on Insert Faces
Courtesy Sandvik Coromant USA.

Reliable cutting parameter data for use with platinum and PGM's has also been almost impossible to come by from most major tooling manufacturers. Most of the tooling geometries designed for the high-nickel and stainless alloy steels has, in my experiences, worked well in platinum machining. So it would make sense that some of the cutting condition parameters that would be suggested for these austenitic stainless steel alloys should work quite well for platinum machining. My experiences have shown that a good starting point for figuring the proper speeds and feeds for cutting platinum have been between 150-200 surface feet per minute removal rate. Of course machine rigidity and horsepower ratings figure greatly into the success or failure in any given scenario. For those not familiar with how to calculate surface footage removal rate, I would like to reference the conversion formula to find the spindle R.P.M. and feed rate as follows:

For inch units only:

$$N = \frac{12V}{3.14\ D}$$

Where N = Spindle Speed; rpm
V = Cutting Speed; fpm
D = Diameter; inch

(For turning D is the outside diameter of the work piece. For milling, drilling or reaming, D is the diameter of the cutter.)

Other parameters contributing to cutting process success include but are not limited to insert tool selection, insert coatings, chip breaker geometry and tool holder style. These tips should give some insight into the methods by which one can achieve platinum machining success.

Polycrystalline Diamond (PCD) Tooling – While standard carbide insert tooling processes can be adapted for cutting platinum, it is well known that the selections made in carbide will only last for a limited time in machining platinum. For the optimum in production process efficiency the ultimate in wear resistance is achieved with the employment of PCD or polycrystalline diamond tooling. Diamond is of course the hardest natural substance. So it would stand to reason that a cutting tool employing this hardness would last a great while. The cost however associated with a single crystal diamond tip can be prohibitive. While the ability to endure abrasion resistance is desired, the single crystal diamond is also hard to shape into controllable geometry.

To alleviate some of the issues associated with single crystal diamond tools, the polycrystalline synthetic diamond process produces a diamond and substrate composite wafer that can easily be cut into various shapes and sizes for all kinds of tooling applications. A representation of the process can be seen in the diagram below.

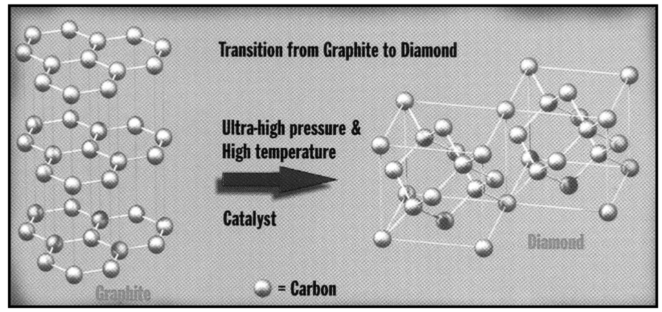


Figure 4: Diagram of the Molecular Differences in the Graphite to Diamond Process
Courtesy Polytech Diamond Tool Co.

PCD is formed by applying ultra high pressure and high temperature to diamond powder. The metallic second phase material infiltrates from a cemented carbide substrate during the sintering process. This molten metal acts as a solvent/catalyst to bond the diamond grains together. The resultant polycrystalline material exhibits the extreme wear resistance of diamond and is complemented by the toughness of the metallic second phase material. Due to the random orientation of its diamond crystals, the properties of PCD are uniform in all directions.

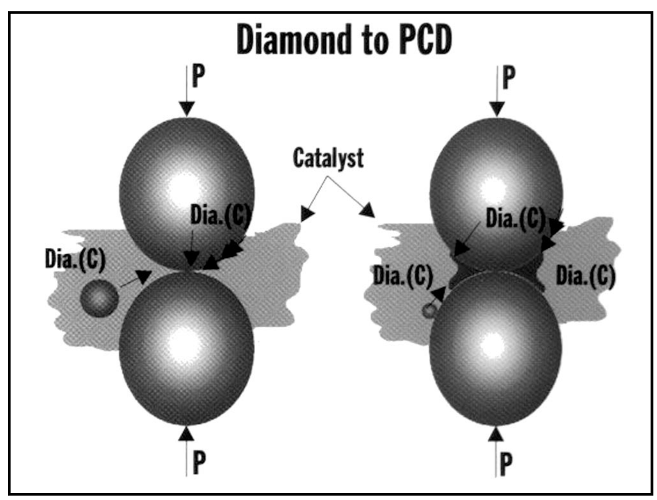


Figure 5: Diagram of the Diamond Powder to Poly Crystalline Process
Courtesy Polytech Diamond Tool Co.

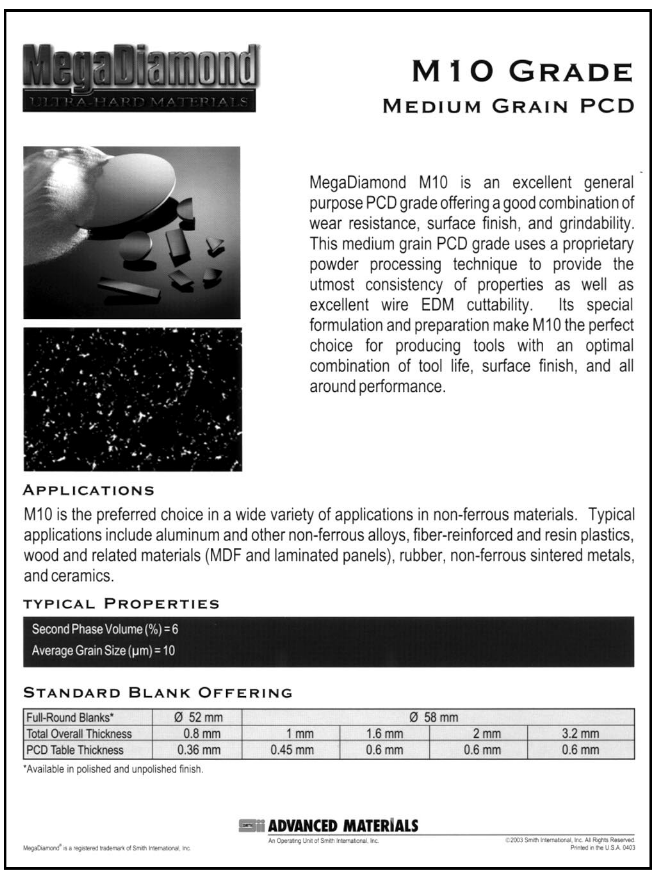
The extended tool life and increased productivity provided by PCD tooling are usually welcome offsets to the higher initial cost per edge. Further extending the life of a PCD insert by re-sharpening or re-lapping brings the PCD tooling life span to between 20-35 times the lives of its standard coated carbide counterpart.

Johnson Matthey has invested heavily in a full complement of PCD inserts and other PCD tooling and maintains a tool re-lapping program to make the most from our investment. The volumes of platinum that we machine in a year would never be possible without this heavy utilization of diverse PCD tooling.

Tooling Geometry For Platinum –There are many theories about tooling design that manufacturers have come to adopt based on lab trials and information gleaned from applications engineers who work in a wide variety of metals. Once again very few, if any, have developed tooling designs to work congruently with platinum and its alloys.

Figure 6: Assortment of Different Negative Rake Inserts
Courtesy Sandvik Coromant USA.

Positive Rake Angles Are Best For Platinum – When machining some of the toughest steel alloys neutral or negative tooling angles are generally stronger, however they can certainly contribute to premature tool failure when applied to platinum. The success of any machining operation is the ability to separate the chip from



MegaDiamond
ULTRA-HARD MATERIALS

M10 GRADE
MEDIUM GRAIN PCD

MegaDiamond M10 is an excellent general purpose PCD grade offering a good combination of wear resistance, surface finish, and grindability. This medium grain PCD grade uses a proprietary powder processing technique to provide the utmost consistency of properties as well as excellent wire EDM cuttability. Its special formulation and preparation make M10 the perfect choice for producing tools with an optimal combination of tool life, surface finish, and all around performance.

APPLICATIONS

M10 is the preferred choice in a wide variety of applications in non-ferrous materials. Typical applications include aluminum and other non-ferrous alloys, fiber-reinforced and resin plastics, wood and related materials (MDF and laminated panels), rubber, non-ferrous sintered metals, and ceramics.

TYPICAL PROPERTIES

Second Phase Volume (%) = 6
Average Grain Size (μm) = 10

STANDARD BLANK OFFERING

Full-Round Blanks*	Ø 52 mm	Ø 58 mm			
Total Overall Thickness	0.8 mm	1 mm	1.6 mm	2 mm	3.2 mm
PCD Table Thickness	0.36 mm	0.45 mm	0.6 mm	0.6 mm	0.6 mm

*Available in polished and unpolished finish.

ADVANCED MATERIALS
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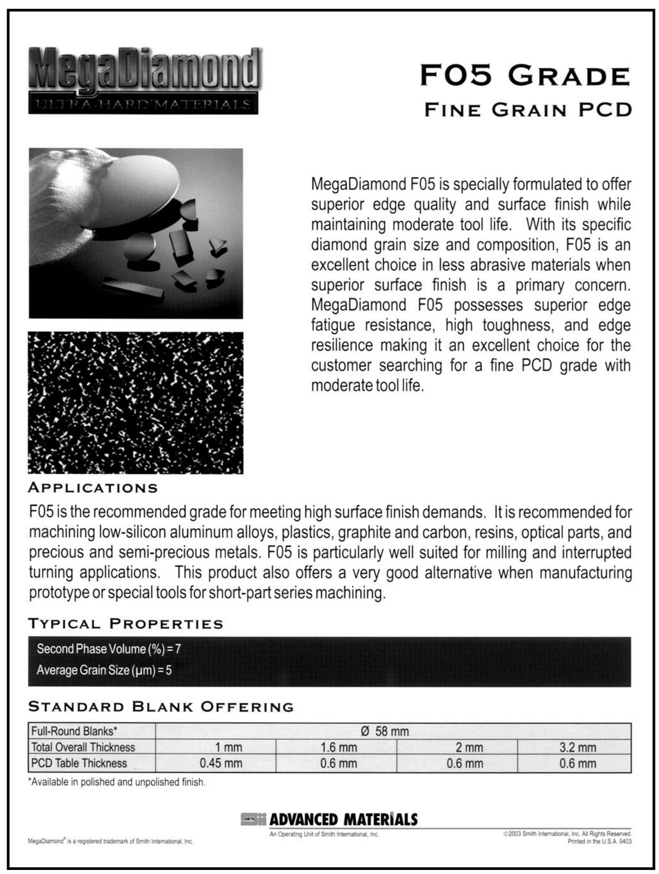

MegaDiamond
ULTRA-HARD MATERIALS

F05 GRADE
FINE GRAIN PCD

MegaDiamond F05 is specially formulated to offer superior edge quality and surface finish while maintaining moderate tool life. With its specific diamond grain size and composition, F05 is an excellent choice in less abrasive materials when superior surface finish is a primary concern. MegaDiamond F05 possesses superior edge fatigue resistance, high toughness, and edge resilience making it an excellent choice for the customer searching for a fine PCD grade with moderate tool life.

APPLICATIONS

F05 is the recommended grade for meeting high surface finish demands. It is recommended for machining low-silicon aluminum alloys, plastics, graphite and carbon, resins, optical parts, and precious and semi-precious metals. F05 is particularly well suited for milling and interrupted turning applications. This product also offers a very good alternative when manufacturing prototype or special tools for short-part series machining.

TYPICAL PROPERTIES

Second Phase Volume (%) = 7
Average Grain Size (μm) = 5

STANDARD BLANK OFFERING

Full-Round Blanks*	Ø 58 mm			
Total Overall Thickness	1 mm	1.6 mm	2 mm	3.2 mm
PCD Table Thickness	0.45 mm	0.6 mm	0.6 mm	0.6 mm

*Available in polished and unpolished finish.

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the stock with a maximum mean time between failures. Most neutral or negative chip breaking geometries actually try to force the chip back into the stock encouraging the chip to break and be flushed away. The inherent “gumminess” of a platinum chip in this neutral or negative rake angle situation will actually fuse back onto the stock. Given the propensity of the cutting forces to generate heat, this constant re-cutting of the chips will lead to premature tool failure.

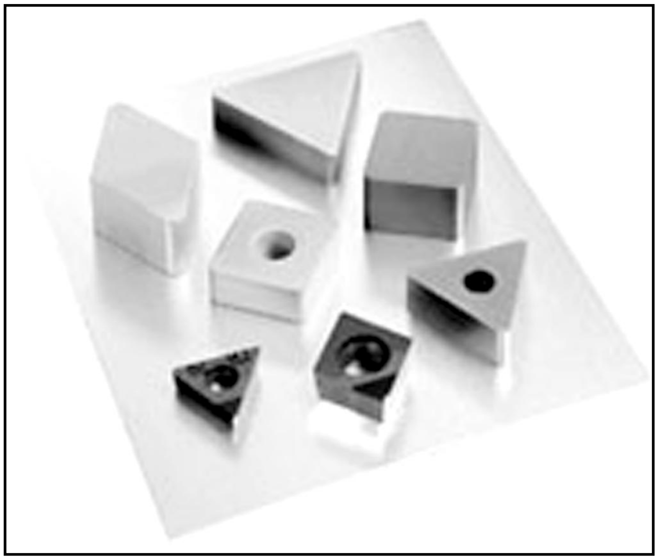

Figure 7: Assortment of Specialty Inserts
Courtesy Sandvik Coromant USA.

Conversely positive tooling rake angles are generally the weakest for machining steel and its alloys and this has led to the application of positive rake tooling for fine finishing cuts or light cutting passes. High positive geometries are also widely reserved for aluminium, plastics, or any other soft gummy material. This last application is precisely why positive rake tooling works very well in platinum machining. Although the process will be limited as to what speeds, feeds, and depth of cuts can be tolerated, I have been very successfully employing high positive rake angle inserts in our roughing operations. The fact that this type of geometry pulls the chip with its inherent heat away from the stock, allows the cut zone to be adequately cooled preventing premature tool edge degradation.

A general rule with regards to tooling geometries is to obviously understand implicitly the properties of the metal you are working with and trying to cut. Any tooling that is slanted towards a gummy type of material with an emphasis on chip separation will usually work well on machining platinum. Just remember to apply the cutting forces, or speeds and feeds, judiciously.

• Strategies for Effective Recovery of Precious Metal.

When designing manufacturing processes for our platinum machining facilities, it helps to look at the entire process and not just making the part. There are many strategies that can be employed to better utilize the metal of any precious metal manufacturing operation.

Waste Not Want Not – When it comes to manufacturing anything out of platinum, there is never the luxury of having plenty of material to work with. The real trick to getting an efficient machining operation is to start with no more metal than you need. Our ring blank manufacturing is an excellent example of this. Johnson Matthey currently produces 220 different part numbers of ring blanks. To begin our operation the starting stock sizes are carefully calculated to allow enough material to machine a fine surface finish and just enough length to produce the required amount of rings in the order and no more. This policy has produced 36 different intermediate starting stock sizes to make the various part numbers from. We have tried hard to maintain an 80% or better yield from metal received in to the operation versus finished parts produced. A major benefit from this is the fact that there is very little left in the bottom of the machine to clean out.

Alloy Stream Purity – One of the biggest fiscal benefits to cleanouts after every job is the preservation of our alloy purities. Our machining operation can in any given week be tasked to machine any of 130 plus different precious group metal alloys. Although most jewelery manufacturers will only deal with about 10 different alloys or purity levels, the benefits of segregating scrap and swarf by like alloys or purity grades are many. Refinement of platinum scrap is expedited when the alloy and purity level can be certified. Johnson Matthey's facility affords our internal machining operation with a fast turnaround on scrap refinement. In a world where metal financing costs are sometime calculated by the hour, it helps to turn our scrap around quickly.

Planning And Forethought Can Make You Money – Since working in the platinum realm for some 12 years, I have come to completely change my manufacturing process way of thinking. Scrap and chip recovery are generally regarded by most manufacturers of equipment as a nuisance, and are dealt with in the same way. A quick look at equipment will show that such things as way covers, protective covers or doors, coolant troughs, chip removal systems, and indeed just the general fit and finish of a machine tool's cabinetry will reveal that scrap is usually not worried about. Platinum processing requires that the process designer pay careful attention to every nook and cranny of not only a machine tool, but the tooling and fixturing to be used in the operation. Fine mesh stainless steel screening, 10 micron or less filtration paper or bags, alloy specific shop vacs, and robust silicone caulking among other things can return their installation effort costs by 10 fold regarding platinum machining.

Figure 8: Assortment of Liquid Filtration Bags

• Process Automation for Ring Blank Production.

Johnson Matthey has spent 2 years developing our current ring blank manufacturing process. The road has not been an easy one. The trials have proven that efficient machining of ring blanks can be done with minimal operator intervention.

Programming innovation – Given the large number of current unique part numbers in our database, the task of writing over 220 (and expanding) different programs was not an option. Johnson Matthey programmers have employed a single ring blank program to encompass all 220 products by using a custom macro programming method. The CNC program is written in such a fashion to include variable expressions and mathematical calculations. When a new part program is desired the machine operator enters data defining features of the operation such as starting stock size, finish part dimensions, and tooling information. The program will re adjust based on the data list entered.

Tool Touch Probing – To increase production efficiency a process should be able to run with minimal or no operator intervention required sustaining the operation. Johnson Matthey has implemented a Renishaw touch probe system to safeguard against tool or operation failure. This is a small feedback touch probe to insure that the previous machining cycle has been completed successfully before allowing the machine to continue to make the successive part. Use of this style of probing system is commonplace in machining operations of all types. Our particular system can even be implemented to do a full part dimensional check before allowing the next part to be manufactured. This capability together with our operators' skill in inspecting dimensional and cosmetic features means our process is dimensionally consistent.

Automated Stock Feed – Our ring blank production process efficiency is further enhanced by our automated stock feed system. Normal feed systems for CNC lathes are usually large expensive bar feed attachments interfaced into the control of the machine. Since metal thrifting processes dictates that our stock is usually no longer than 12", Johnson Matthey opted for a single coolant operated bar stock pulling attachment. Mounted in the tool slide along with the other cutting tools, it is completely programmable, adjustable and repeatable via the CNC program. The cost for this attachment was less than $600 US versus over $10K US for a bar feed system.

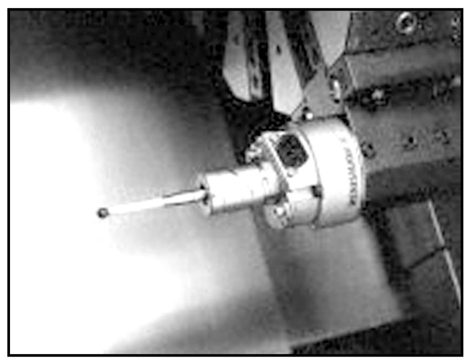

Figure 9: Renishaw Tool Touch Probe
Courtesy Renishaw Inc.

Figure 10: Daewoo Puma 160 Gang Tool Lathe
Courtesy DaewooMT.com

Summary & Conclusions

- CNC machines with conversational programming and linear slides improve efficiency & quality.
- Quick change PCD tooling provides longer tool life and better surface finishes
- Tooling with a positive rake angle is best for platinum but care must be taken with feed speeds.
- Planning for efficient scrap collection is as important as the machining process
- Any jeweller can benefit from any or all of these topics when adapted for their unique situation.
- Investigate all avenues of current technology and implement all you can afford.
- Keep investigating advances and - don't remain stagnant with old "prove" technology.