LATEST FINDINGS OF THE ORNAMENTAL AND ROSE ENGINE LATHES

G. Phil Poirier
Poirier Studio/
Bonny Doon Engineering
Taos, NM

Brief History
The lathe is understood to be the "mother of all machine tools" due to the fact that all machine tools are derived from the lathe, and most machine tool parts are made on a lathe, along with the fact that the lathe is the only machine tool that can replicate itself.
The earliest versions of a lathe, which could manipulate a piece of clay or wood by spinning it on an axis supported at either end, was at least 3000 years ago. Definitive work using a lathe was found in Celtic burial sites around 700 B.C., and Etruscan turned vessels were numerous in sites dating to 6th Century B.C. One piece of turned work was found at an Egyptian site dating 1100-1400 B.C.[1]

The earliest evidence of the evolution of a plain lathe into an ornamental lathe dates back to the middle of the 16th century.[2]
More than two centuries before the Industrial Revolution, the royal courts of Europe were competing to understand and master the art of ornamental turning.[3]

So what are the latest uses of the mother of all machine tools with regards to make rings, bracelets, earrings, and other objets d'art in the jewelry industry? We'll start with a look at the recent practice of using modern controllable motors to mechanize and automate some of the processes, followed by a recent reimagining of using a rose engine for lapidary work on gemstones.

Part 1: Mechanization vs automation
These two terms are defined in modern dictionaries as having to do with human interaction with machine tools.
The term mechanization is used to refer to the simple replacement of human labor by machines, automation implies the integration of machines into a self-governing system displacing human thought or mental labor.

With these definitions we can categorize many of our jewelry production machines, including most CNC (computer numeric code) machining of jewelry items, as mechanized machines. A few of the most advanced machines that load and unload the parts of a self-regulating machine may be categorized as automation, where no human thought or labor is required. Unfortunately this description of automation does not take into account all of the advanced engineering involved with the initial programing of the machine such as the initial design in CAD (computer aided design) and the follow up engineering of the strategy to run the machine using CAM (computer aided manufacturing).

The 19th century ornamental lathes required both human labor and human thought. As we move into the 21st century we now can add a variety of mechanization and automation to these lathes.

Digital Gears and Motion Control on an Ornamental Lathe
One of the more recent evolutions of the ornamental lathe is to add stepper or servo motors to the many axes of the ornamental lathe. This has been standard for more than 70 years with plain lathes. Most of the large scale jewelry production companies have been using CNC lathes and mills in their shops for many years. Use of the ornamental lathe does not supplant these modern machines but in fact adds to the overall variety of design and manufacturing possibilities. Let's first go over the axes of a lathe. Shown in Figure 1 are the three main axis of an ornamental lathe.

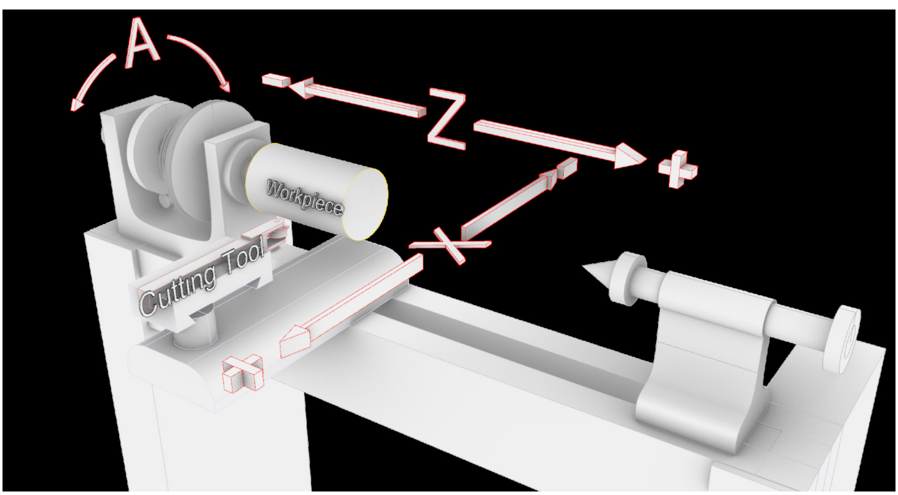

Figure 1: Showing the X, Z, and A Axes

Note that the cutting tool can move along the Z axis and along the X axis while the work rotates around the A axis. The cutting tool

moving in the X- direction will plunge the cutter into the work and in the X+ direction it will move away from the work.
The ornamental lathe was typically outfitted with numerous accessories, many of which would add additional axes of motion to the lathe. These would include such apparatuses as the spherical slide rest, the undulator, the reciprocator, the elliptical chuck, the geometric or epicycloidal chuck, the spiral apparatus and many many more.
Many of these add-ons would require a gear train in order to connect the rotation of the spindle and work to the movement of the cutter slide or compound. When using the spiral apparatus the gear train is assembled to create a synchronized movement so when the cutting tool is moved along its Z axis (Figure 2) the spindle with the work would rotate a specified amount around the A axis.

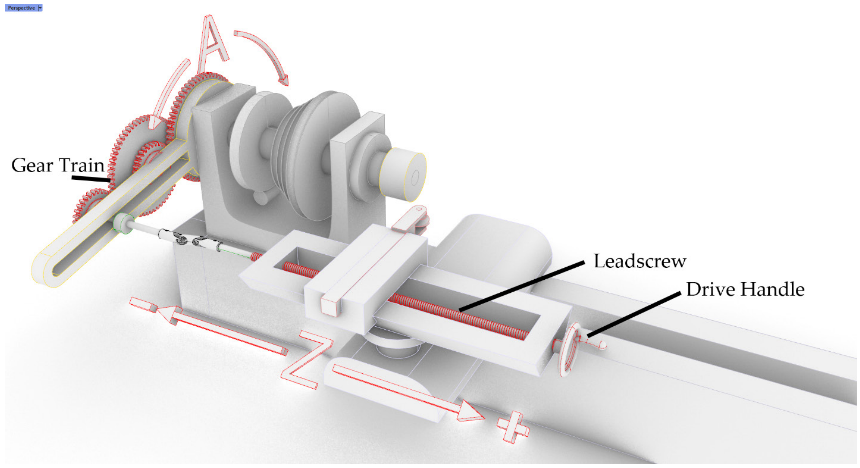

Figure 2: and the process of connecting two axes to move together

An example using Figure 2 might look like this: we would turn the Drive Handle which turns the Leadscrew moving the cutting tool along the Z axis which is connected to, and turning, the Gear Train which is rotating the spindle around the A axis. This combined action results in a spiral cut in the workpiece.

This might be used to cut a spiral in a ring as shown in Figure 3, or a bracelet, or a vessel.

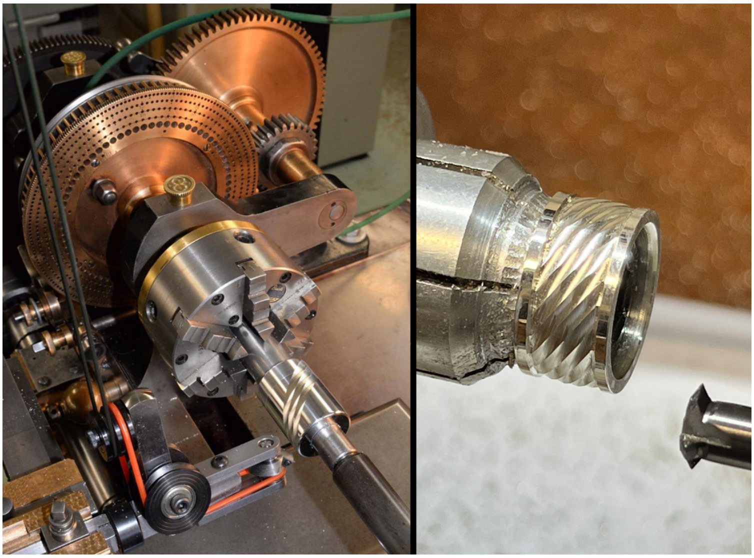

Figure 3: which shows both a small vessel and a finger ring cut in a spiral pattern

Another common example would be in the making of screws where the Z axis might travel 1” while the A axis rotated 16 full turns, this would create a screw with a pitch count of 16 threads per inch. Shown in Figure 4 is a group of parts for a hip flask in sterling silver with 16 threads per inch.

Figure 4: note the threads cut into the sterling silver sand castings

In all cases like these the operator must construct a gear train to synchronize the two axes that are moving together as one. This process requires a collection of gears to allow for the cutting of different thread pitches or spirals. If a large number of differing thread pitches or differing styles of spirals are required then consequently a large number of gears would also be required (Figure 5). Most modern plain lathes work on this same principle for cutting threads and spirals.

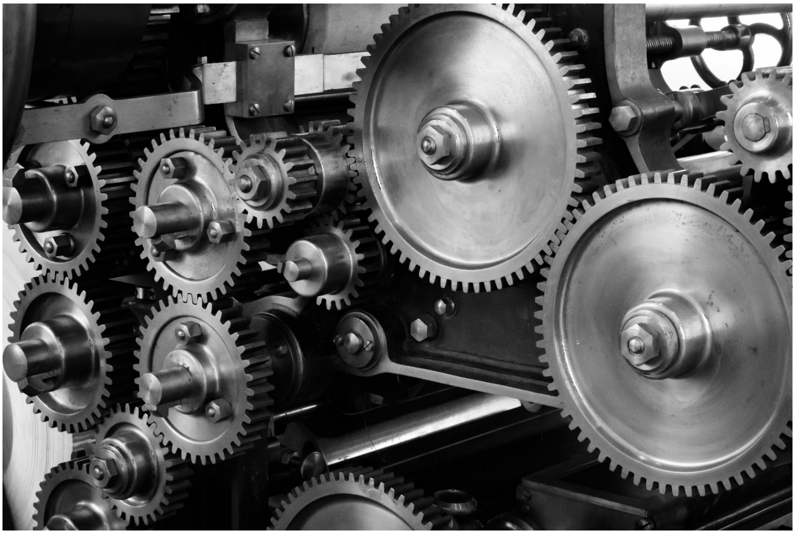

Figure 5: Just one setup for a specific spiral on a lathe

With modern motors and electronics we can now get rid of all the gears required and substitute stepper motors (Figure 6) or servo motors in their place. By doing so we eliminate all the required gears and can produce an unlimited number of different pitches for the spiral example above. Understanding that if one needed an infinite number of thread pitches one would require an infinite number of gears to be available!

By eliminating all of the gears we can now synchronize movement of 2, 3, 4, or even 5 axes of an ornamental lathe and its multiple accessories.

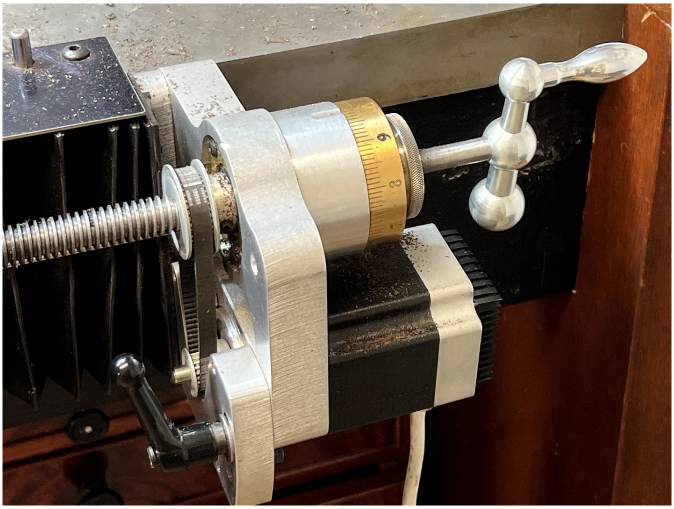

Figure 6: showing a stepper motor with 3:1 gear reduction added to the slide of an OT lathe

Most modern machine tools like lathes and mills use stepper or servo motors. These are motors which are user programmable to move at very specific RPM's and rotate a specific number of revolutions or portions of a revolution. When these motors are coupled to a linear or radial axis of a machine the motion of the machine can be controlled precisely, common machines are accurate to .0002" or better and repeatability is similar.

Stepper motors were invented over 100 years ago with the earliest patent dating 1918. They were first used by the Royal Navy in the HMS Hood in 1930 to more precisely aim their guns. Nowadays they are ubiquitous in daily life, from all forms of manufacturing machines, cutting mills and lathes to pick-and-place robotics and sorting machines to the vent doors in your car.

They are named "stepper motors" due to their design which will produce 200 steps per revolution of the motors spindle, or 1.8 degrees per step. Most modern stepper motors are made to be further divided into microsteps of 4, 8, or up to 256 times per step. As an example: if a 200 step motor has 8 microsteps (200 X 8=1600 steps per rev), and a leadscrew on a lathe requires 10 rotations per inch, then the resulting resolution would be 0.00006" per step, or 60 millionths of an inch, or 1.5micron. This resolution should be plenty fine for jewelry manufacturing work. If we need finer resolution then further adding a gear reduction of 3:1 (Figure X) will reduce the resolution to .00002 or .5 micron.

By adapting this early 20th century invention to a 19th century ornamental lathe a modern jewelry designer or manufacturer can now utilize multiple axes of motion to achieve an infinite number of designs or patterns for their jewelry.

By adding mechanization via stepper motors to an OT lathe we gain advantage with all the ornamental lathe has to offer such as a spindle that slides from left and right, rocks back and forth, and can use rosettes to complicate the motion and the pattern produced.

We also have the advantage of adding all the motions of all of the accessories stated above. This gives us the benefit of multiple movements along many different axes, unlike adding stepper or servo motors to a plain lathe.

CAD-CAM Programing, Pro's and Con's

One very common question is why can't we do all of this fancy work in a modern mill or multi-axis lathe? Yes, it can be achieved but with varying levels of success. Using a 3, 4 or 5 axis mill is the best way to achieve many jewelry designs but like all processes it has its limitations.

One issue is the CAD-CAM that is required for these machines and how they perceive a 3 dimensional object such as a ring or bracelet. Figure 7 is a screen shot of toolpaths required for a 4 axis mill in order to shape a tapered ring shank.

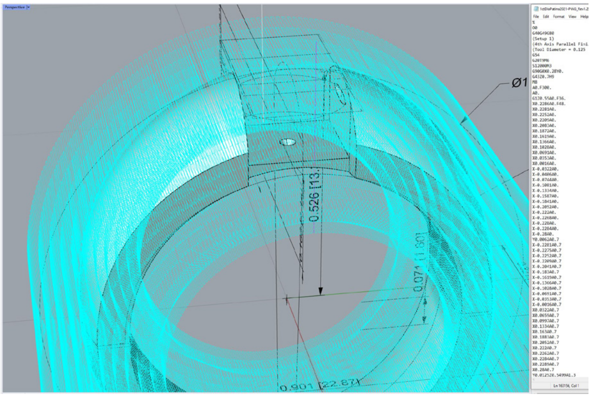

Figure 7: showing the toolpaths in blue needed for a tapered ring shank

This program is over 150,000 lines in length which means editing is practically impossible. If we needed a different size then we would have to reprogram the CAD and the CAM. CAM software capable of creating 5 axis toolpaths tends to be very expensive and requires vast amounts of skill and knowledge to operate. This is fine for the large manufacturers with big budgets but not possible to the smaller manufacturers.

Figure 8 is the toolpath of a simple spiral design on a ring, here the toolpath was created with a large stepover for visual ease in this example. This style of programming can be written with CAM programs that are much less costly and easier to learn and operate.

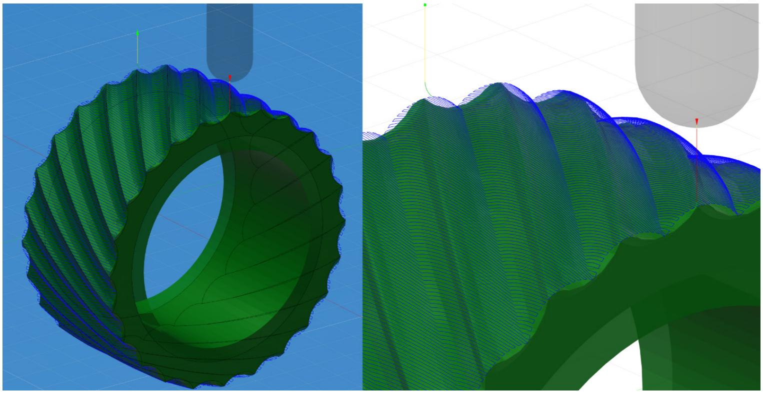

Figure 8: Toolpath shown in blue needed for a spiral ring with close-up at right

But note that the toolpaths are crossing up and down through the troughs of the desired spiral cuts. This might not be ideal for the finish of the ring, rather, it would be best to reprogram this ring to follow the spiral troughs directly as shown in Figure 9. This will also require us to find a ballmill with the correct radius to match the intended design.

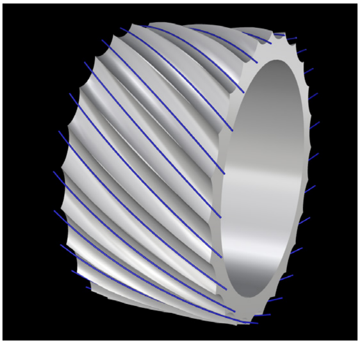

Figure 9: showing the toolpath in blue to cut in the troughs of a spiral

This would reduce the length of the program but it would still be a few hundred lines of code which might still be a challenge to modify or edit. Let's simplify the program even further to make it capable of any size ring by programming just one of these curves and then use a repeat cycle on the machine. Examples are discussed further along in this paper.

A second issue is the cutting direction of the cutting tool. Ornamental lathe tools are quite different than the tools for modern mills and lathes. The example in Figure 10 shows a ballmill in use which would be the tool of choice in a mill. The direction of the cut is all-important when cutting precious metals. Not only are high speeds required but orienting the tool and cut in the metal has widely differing results depending upon the tool path through the metal. A direct vertical cut in a mill with a ballmill will expose the problem that the tip of a ballmill does not cut, it ends up leaving a telltale artifact in the work. In Figure 10 at left the ballmill will end up leaving a smudge line down the middle of each cut.

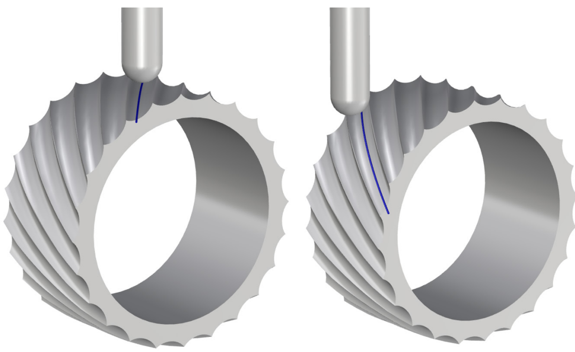

Figure 10: Cutting with the tip at left vs. cutting on the tangent of a ballmill at right

The programing must be rearranged to place the side of the ballmill in the cut rather than the tip. Ideally placing the ballmills 30-45deg tangent point at the deepest part of the cut as shown in Figure 10 right.

By utilizing an ornamental lathe in this process we can take advantage of the much wider array of cutting tools available. This spiral ring could be made with a vertical cutting frame, which spins a flycutter vertically (Figure 11), an ornamental drill, or a universal cutting frame which can tilt the angle of the cutting tool to match the desired effect (Figure 12).

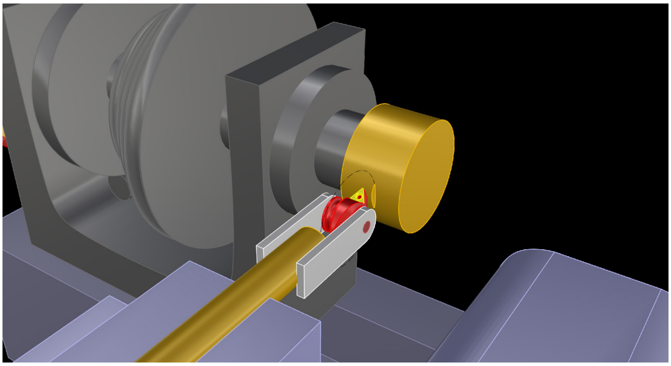

Figure 11: A vertically oriented cutter

The flycutter can have an unlimited number of shapes, shown in Figure 10 is a common triangle carbide insert. Note the cut in the work piece. If we use a universal cutting frame we can angle the cutter from vertical to horizontal in unlimited steps (Figure 12). Again, note the cut in the workpiece.

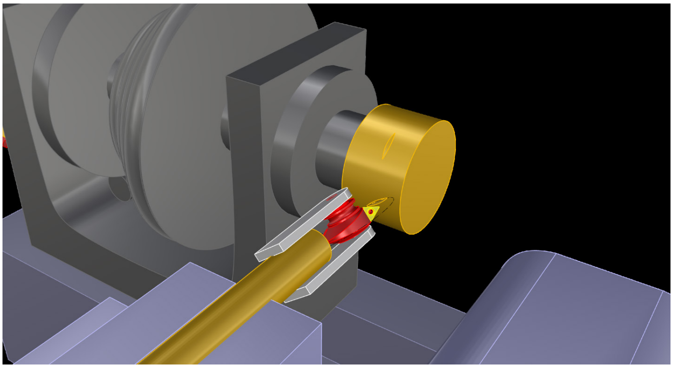

Figure 12: A universal cutting frame tilted 60 degrees

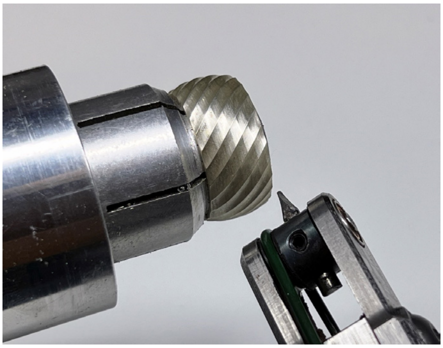

Figure 13: a universal cutting frame tilted to 60 degrees

Figure 13 is an example of a universal cutter tilted 60 degrees to the right for a wider cut. If we tilted the cutter 60 degrees to the left the result would have been a much narrower cut.

This is just one of numerous shapes we could use in this cut. Cutter inserts can be shaped for custom form cuts, and shank type tools can be used which also can be shaped into an unlimited variety of forms to create an unlimited number of patterns in the metal. These forms can range from a deep V groove, a shallow U groove, or a multiple tip cutter which would create a Florentine like finish. The possibilities are only limited by the imagination applied.

Direct Programing and the Basics of G-code

By programing directly without the use of CAM we can achieve a clean simple toolpath which can be easily edited for numerous design variables including size, width, and pattern. Numerous patterns can be created by simple repeated motions of the ornamental lathe and its many axes. The best place to start is to breakdown the movements into the simplest part. Rather than programing all of the many cuts in the previous example of the spiral ring we can program just one cut and ask the controller to repeat the move around the ring a given number of times. A great benefit to this strategy is that we can now cut any size ring or bracelet with a simple edit of two or three words in the program.

First let's cover the basics of direct programing. Most all motor controllers use a form or dialect of what is called "G-code". G-code uses a simple text file known as plain text, this would include the program "Notepad" on a PC. Notepad is the simplest of text formats using only 256 characters. G-code is written using standard Cartesian coordinates. Basic G codes include G00 which tells the control to move the motors at a rapid rate to a given coordinate. G01 tells the control to move to the new coordinate location at a specified feed rate following the coordinate.

Example: if you want the X axis to quickly move 1" you might simply type in the following "G00 X 1.0". If you want to go the opposite direction you would type "G00 -X 1.0". If you want to move slowly, as in when you are cutting material, you would type "G01 X1.0 F5", where the F5 represents the travel speed of 5" per minute.

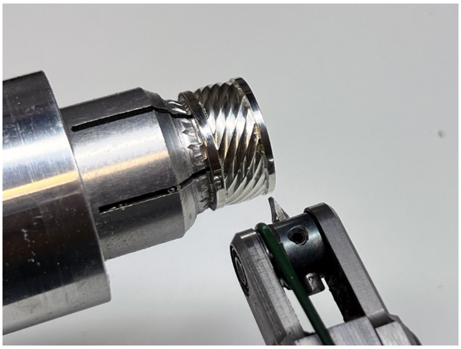

Figure 14: a simple spiral cut ring

In the case of our spiral ring in Figure 14 the code might look like this:
G01 X.3 A60 F20

This would move the X axis and the A axis simultaneously so they arrive at the destination at the same time, thereby cutting a spiral at 20” per minute.

Next we would repeat this line 24 times for 24 cuts around the circumference of this ring. We do so by typing a line that reads L24 before the line above.

L24

G01 X.3 A60 F20

This tells the control to “loop” the following line 24 times. Now so far this explanation has been simplified, but not by much. We’ll also want to tell the tool to plunge into the work at the beginning of the cut, and at the end of the cut we need the tool to retract from the cut.

The complete program can be written with fewer than a dozen lines of code and the program can be used for any size ring or bracelet. It is easily editable to allow for many variations of design patterns. By changing one or two words in the program we can readily change the pitch, the angle of the spiral, and the number of cuts around the circumference. By changing the L24 word to L36 we end up with 36 cuts around the ring. We can cut more or fewer cuts around the ring by simply changing that one command. By changing the A60 command to A90 or A120 we would get different styles of spiral, or we can change the sign of the coordinate by typing A-60 which will cut the spiral in the opposite direction around the cylinder. In Figure 15 note that the diamond shapes were cut by overlapping spirals going in opposite directions.

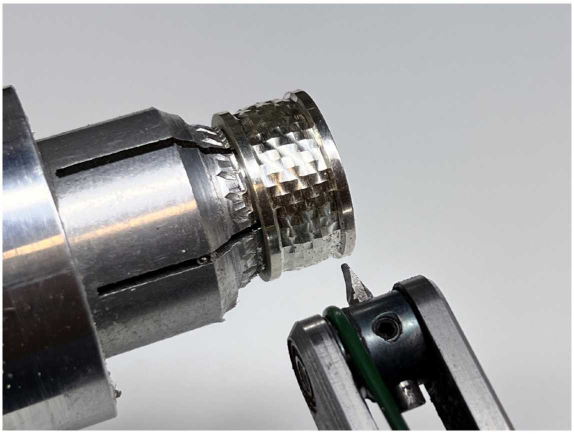

Figure 15: Cutting spirals in opposite directions

If we change the X command we would cut a shorter or longer path allowing for narrow or wide rings, bracelets, earrings etc...

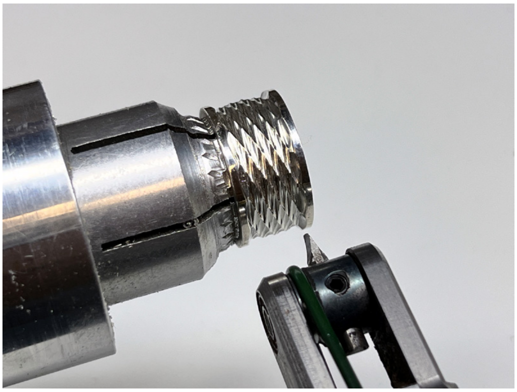

Figure 16: Cutting the spiral pattern with a rosette engaged on the Rose Engine

If we engage a rosette while cutting the same ring as shown in Figure 16 then the result is something that looks like a double spiral.

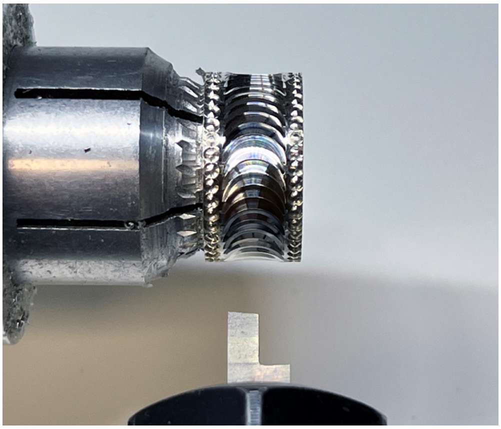

Figure 17: Simple plunge cuts with repeat

In Figure 17 a ring has been cut with a simple plunge and repeat program which we will dissect now. In this case the cutter is a custom cutting tool designed by the author and made by Chris Ploof Designs. It has an eccentric cutting point with a 150 degree angle. The goal is to repeat this cut into the work 48 times around the cylinder which could be a ring, bracelet, or earring. First let's write the location of the starting position.

G00 X.05 A0 Z0

This is where we will start and finish each cut. Note that X.05 is 50 thousandths of an inch clear of the workpiece, and Z0 is at the edge of the workpiece.

Plunging the cutter into the workpiece is a – direction move on the X axis. So we'll add the plunge move in X and a retract move at the end of the cut. Note that the + sign is not needed to command a positive direction.

G00 X.05 A0 Z0 (starting place)

G01 X-.02 F3 (plunge into the work)

X.05 (retract away from the work)

So far this will make one cut into the work. Let's now take this block of commands and program it to repeat the desired times around the A axis. The best way to do this is to take this block and turn it into a subprogram or subroutine that we will then ask to be repeated. A subprogram or subroutine is simply a group of codes that are contained within the larger program.

M98 is G-code for Start a subprogram, M99 is the code that ends a subprogram. We will also need a name for the sub program, in this case I'll call it "Repeat". We will use the code "P" to identify the name of the subprogram that we want to use, and we will use the "O" code to signify the beginning of the named subprogram. You can have any number of subprograms in one program.

So now it'll look like this:

M98 PRepeat L48 (find the subprogram named "Repeat" and loop it 48 times)
ORepeat (this is the start of the subprogram that is named "Repeat")
G00 X.05 A0 Z0 (starting place)
G01 X-.02 F3 (plunge into the work)
X.05 (retract away from the work)
G91 (move in incrementally or relative coordinates)
G00 A7.5 (rotate the A axis 7.5 degrees)
G90 (move in Absolute coordinates)
M99 (end of subprogram)

This program is only 9 lines in length, short and direct enough to allow the user to change the most important moves easily to attain different outcomes and patterns.

A variation of this program can be used to make multiple plunges across a part, be it a ring or similar. This would result in a design as shown in Figure 18.

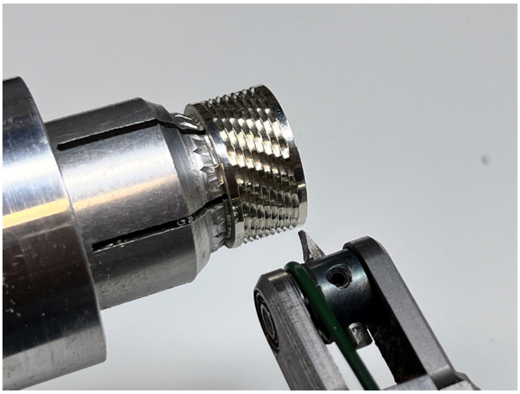

Figure 18: Using a simple program to cut multiple plunge cuts around a ring

By adding another two lines in the program which will shift the A axis a few degrees and shift the cutter over just a small amount in the Z direction we get what is seen in Figure 18. This version can be easily edited to give thousands of variations by just changing one or two key words. If we change the style of cutter using this same program we get what is shown in Figure 19, a very different look.

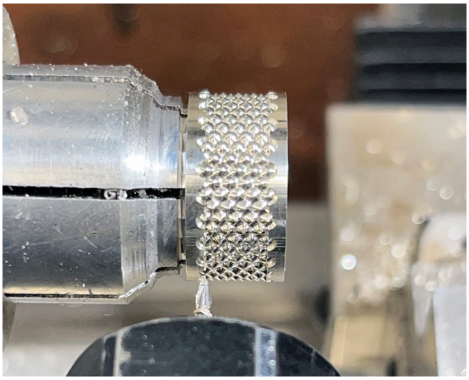

Figure 19: Simple repeated plunge cuts with a corner rounding cutter

One of the issues with mechanizing an ornamental and/or rose engine lathe is cost of entry for the smaller jewelry studios. Current available systems are close to $4000.00 in cost, with many extras needed in order to get a lathe up and running. This was seen as a limiting factor that could be improved. This idea was tackled by the author, Fred Armbruster, and Eddie Bell at a workshop get-together in Albuquerque, NM in December of 2023. Shown in Figure 20 is the kit we assembled for less than $400.00. All parts were purchased as off-the-shelf parts from Amazon and similar online stores. It took a 6-8 hours to wire and assemble including the cables to the motors.

Figure 20: a 4 axis Control box and 4 stepper motors using off-the-shelf parts

Part 2: Lapidary use of the Ornamental Lathe

Lapidary, the cutting of gemstones, has recently seen advances in the use of non-traditional machine tools being utilized for the cutting of gemstones both opaque and transparent. Rose engine cut gems have a unique optical effect and light movement that cannot be obtained through conventional faceting or fantasy cutting. The use of rose engine ornamental lathes is not new but in fact goes back at least a generation or more, and possibly back to the 18th century. That said, the current range and execution of gemstone cutting on an ornamental lathe goes well beyond what has come before. Shown in Figure 21 and Figure 22 are boxes from the book of the Gilbert Collection of Gold Boxes3.

Figure 21 is dated 1819-1838, made in Paris and approximately 3-1/4” X 2-5/8” X 1-5/8” (83 X 67 X 42mm). Cut in bloodstone with gold and silver with diamonds and enamel.

Figure 21: a box made of bloodstone which appears to have been cut by *a rose engine*

Figure 22 is mid-18th century, probably German, and about 2-5/8” (66mm) in diameter made of agate with gold trimmings.

Figure 22: a small round box with Rose Engine designs cut into agate

The book with this collection states that these were both engine-turned designs. This might imply that the designs were fully cut on an ornamental or Rose engine lathe. This might also imply that the designs were laid out by using the OT or RE lathe and then further cut freehand on a carving machine much like the cutting of glass objects. To know exactly how these pieces were made will require much more detailed analysis.

By utilizing the many capabilities of an ornamental and/or a rose engine lathe lapidary work can be implemented on gemstones. One of the unique capabilities of ornamental lathes is being able to slow the spindle to fractions of a revolution per minute. Slow speed is absolutely necessary when cutting most gemstone material in order to keep the tool in its original optimum shape. If the tool is allowed to wear and dull then the process would have to stop while the tool is either sharpened or replaced.

In the 1990's the process of carving gemstone material with a rose engine was performed by a few craftspeople including Lew Wackler of Boulder, Colorado and Dale Chase of California. Figure 23 is a Citrine gem cut by Lew using a rose engine. You can easily see the design of the rosette used for this carving.

Figure 23: Rose engine cut Citrine by Lew Wackler

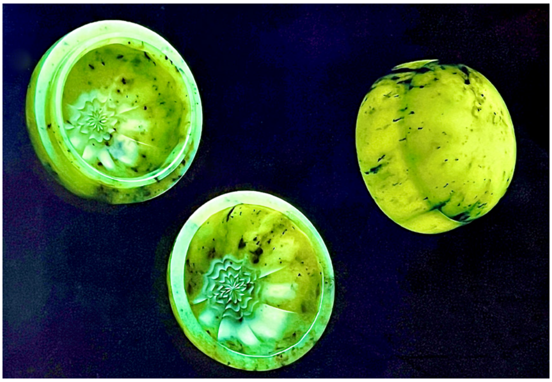

Figure 24: Nephrite Jade container by Dale Chase 1990's

Dale Chase was a student of Lew Wackler's, he has since passed away but some of his work and tools still survive. Figure 24 shows a jade container where you see the designs imparted by a rose engine lathe. Figure 25 is a collection of containers carved on a rose engine ornamental lathe into rock crystal.

Figure 25: Rock Crystal Containers by Dale Chase 1990's

Special tools were designed and built by Walter Balliet for Dale Chase (Figure 26). They consist of a drive motor connected by a timing belt to interchangeable lenticular discs of plated diamond. The discs have several small indentions in their periphery to allow for swarf to be moved out of the cutting action in the stone which helps in keeping the diamonds cool. The use of a coolant such as water or oil is typically utilized to keep the gem and the tool from heating up which would have negative results.

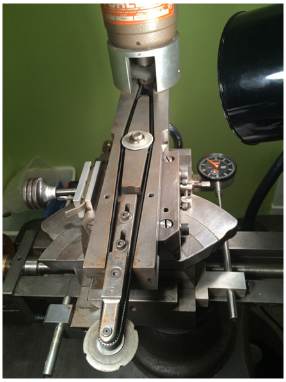

Figure 26: the diamond grinding tools used by Dale Chase, made by Walter Balliet

More recently several lapidarist are using ornamental and rose engine lathes to cut and facet gemstones. Many are also using modern machine tools such as manual and computer operated mills and lathes. We won't be discussing these machines in this paper, possibly the next, and will only cover the use of the ornamental and rose engine lathes.

Figure 27: Turquoise and amethyst by Nolan Sponsler

Nolan Sponsler is one of a small group of lapidary artists using an ornamental rose engine lathe with diamond cutting tools to effect wonderful new shapes and patterns in gemstones ranging from Turquoise (Figure 27) to Ametrine, to Tourmaline and more. Figure 26 shows a turquoise pendant carved using diamond tools on a rose engine ornamental lathe. The center gem is amethyst carved on the same rose engine.

Figure 28: two rose engine cut citrine gemstones by Mike Donovan

Mike Donovan also uses a rose engine lathe to cut gemstones. Shown in Figures 28 are Citrine examples which show to good effect the numerous patterns that can be cut on such machines and their resulting optical play-of-light.

Figure 29 shows the in-process cutting on a rose engine, here with a piece of Citrine by Mike Donovan. An Amethyst is being cut using a drilling tool loaded with a round annular cutter of sintered diamonds. Note that he is using an Armbruster Ornamental Rose Engine lathe.

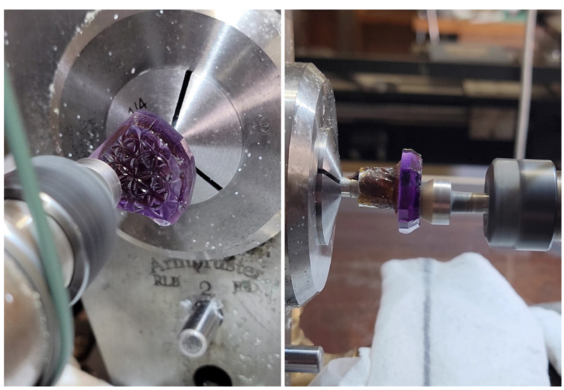

Figure 29: Amethyst being carved on a rose engine lathe

Derek Katzenbach is also using a rose engine lathe, this one being a Lindow Rose Engine made by David Lindow of Gravity, Pennsylvania. Here he has a preform shown in Figure 30 at left, and at right you see the initial cuts into a large block of Smokey Quartz.

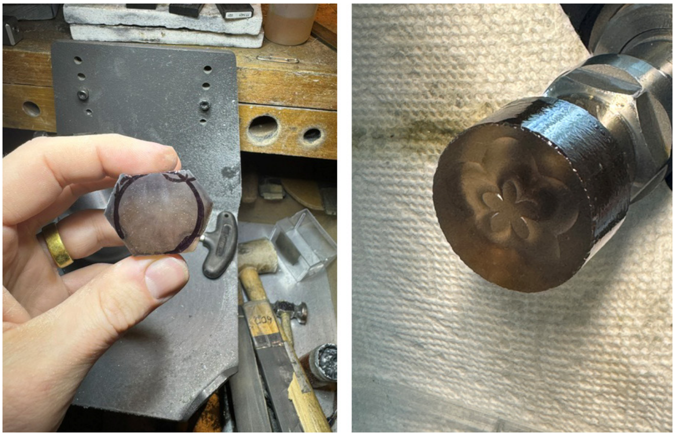

Figure 30: operations in cutting a large Smokey Quartz by Derek Katzenbach

In Figure 31 we see the finished gemstone of Smokey Quartz cut using a 5 lobed rosette with Multiple cuts which include the edge, or periphery, and 3 separate cuts on the face surface of the gemstone.

Figure 31: carved Smokey Quartz by Derel Katzenbach

Process & Technique

Mike Donovan has cut many gemstones on his rose engine with diamond tools that were hand-made by Chris Ploof. The tools were made by waterjet cutting the tool shapes out of a block of sintered diamond material (Figure 32) and welding onto a steel shank, then turning to shape on a lathe. In an interview with Chris he states that if the demand for these tools continues to grow it may be possible to do a production run in the future.

Figure 32: Sintered diamond cutting tools for gemstone carving made at Chris Ploof Designs

Sintered diamond has the benefit of longevity when compared to plated diamond tools but the cost involved to obtain custom shaped sintered diamond tools is much greater than plated diamond tools.

The predominant shapes of tools used to cut gemstone material on the rose engine are circle, or annular cutters, and V-shaped wheels with a 45 degree included angle around the edge along with cylinder shaped cutters.

Some of the issues that must be tackled with gem cutting this way is tool availability, the time required to fully cut the gemstone, the wear of the tooling which requires redressing the tool, and keeping the tool and stone well lubricated to prevent building up swarf, the fine dust and/or mud that comes from the cutting action.

Chipping of the stone material can result if the tool is pushed to fast into the material, or if the rotation of the rose engine is too fast. Micro-fractures just below the surface can be created by using too coarse of a diamond abrasive, or too much pressure, when rough cutting.

More experimenting must be performed in this area of gemstone cutting. New experiments would include using different shaped cutting tools and using different angles of tools, keeping in mind that the refractive optical qualities of the various families of transparent gemstones all have different refractive indexes and require specific cutting angles for the best optical effect. New ideas are forming to manufacture the cutting tools, and advances in the final polish, which is currently done with lots of handwork, will help in the growth of this field of uniquely cut gemstones.

Postscript
Charles Plumier was a 17th century historian that wrote and published the first in-depth book of turning in 1700, titled "L'Art de Tourner en Perfection". Today the Plumier Foundation is a non-profit that has been created to educate, encourage, and preserve the practices of ornamental turning and fine woodworking. Ornamental turning is an extraordinary collaboration between art and science that has created technical and aesthetic marvels over the past several centuries. The foundation is a source of learning for many craft fields including watchmaking and jewelry. Please visit Plumier.org and benefit from their work.

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Lew Wackler can be found at www.lewwackler.com

Mike Donovan can be found at http://www.mikeyddesigns.com/

Derek Katzenbach can be found at www.katzenbachdesigns.com

Nolan Sponsler can be found at https://deepriverjewelry.com

Chris Ploof Designs tools can be found at https://www.ornamentaltools.com/