A NEW LOOK AT HONING

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abstract

Honing is an abrasive bore sizing and finishing process which, with properly selected tools and equipment, improves both bore geometry and surface finish while correcting most common bore errors with the least amount of stock removal.

With the introduction of suberabrasives, plated tools, and the technological advances in machine design, two new concepts in honing and bore sizing and finishing have been introduced: In the '80's it was the Single Stroke Honing® process and now with the dawn of the new decade, it's the CrossGrinding™ process.

This paper will focus largely on "Honing" as a bore sizing and finishing process, but it will also touch on both the Single Stroke Honing and CrossGrinding processes.

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Boring
Finishing
Flexible Mfg. System
Grinding
Holes
INTRODUCTION

Honing is an abrasive machining process, which is designed to improve the accuracy of cylindrical, usually internal, surfaces. It is characterized by large areas of abrasive contact, low cutting pressure, low velocity, floating part or tool, and automatic centering of the tool by expansion inside the bore.

Boring, on the other hand, is a machining process which is designed to enlarge holes, usually to improve the accuracy of a drilled hole. It is characterized by small area of contact, high pressure; fixed part and tool; and the ability the move or change the centerline.

Both processes have valid applications depending on your particular needs. One or the other method may be better suited for your requirements. In some cases both processes may be used – first boring to remove large amounts of stock and to establish or move the centerline, followed by honing to improve bore geometry and provide a particular surface finish and crosshatch pattern.

There is a new concept of bore resizing and finishing - the CrossGrinding™ process, which will be covered in detail later in this paper.

Illustrated in Figure 1 are Ten Common Bore Errors which are normally associated with machining, heat treating or chucking. The Honing process and the CrossGrinding™ process can correct all of these Errors with the least possible amount of material removal when compared to other machining processes. In addition, honing is also beneficial for an eleventh error – Surface Integrity.
Surface integrity refers to the quality of the surface of the metal after machining. As illustrated in Figure 2, most machining processes are abusive to the material being machined and may fracture the crystals of metal to a depth of about 0.002 of an inch (0.05mm).

On the other hand, Honing and the CrossGrinding™ process have been found to be relatively gentle to the material being worked, thus providing a sound base metal surface finish as illustrated in Figure 3.

Since this paper is about Honing, it will concentrate on the Honing process with some reference to the Single Stroke Honing and CrossGrinding processes, which are closely related to the Honing process.

Basically, the Honing and CrossGrinding processes apply three forces to the part being honed - as illustrated in Figures 4 and 5:

- **Stone expansion** forces abrasive against the wall of the part.
- **Rotation** of the honing tool (or part), combined with . . .
- **Stroking**, removes material and creates the characteristic crosshatch pattern – which will be addressed in greater detail later in this paper.

The **Honing Processes** require no chucking or alignment. The Honing process allows the part to float on the tool, aligning itself with the tool and being supported by the tool. In this way, the Honing process can remove the bore errors caused by other, less accurate machining processes.
HONING TOOL - DESIGN

The design of the honing tool is very important. The use of a rigid honing tool helps to prevent the tool from following an out-of-round or non-straight condition which may exist in the bore.

Furthermore, in the design of the honing tool close attention must be paid to the angular spacing of the contact lines for the guide shoes and stones. If these contact lines are evenly spaced, a rhythmic motion and sound called chatter will be produced, which would generate an out-of-round bore. Or if the angles between the contact lines are improper, a higher frequency chatter will be created, which will result in noise, also poor stone life and a corduroy-pattern finish (routher than normal) in the bore.

Figure 6 is an illustration of a typical honing tool. Note the great stone length and the rigidity made possible by supporting a row of relatively short stones by a common wedge, and the fact that only the row of stones moves, while the guide shoes are stationary.

By looking at this same tool, in an end view, as illustrated in Figure 7, you can see the unevenly spaced three-line contact incorporated into its design. This design helps to stabilize the tool and to create round and straight bores by selective stock removal.

Selective stock removal, as illustrated in Figure 8, means that the big areas of an inaccurate bore will be touched by the honing stone only after the tight areas have been honed as large as the big areas. This process of removing stock is referred to as Cleaning-Up a bore.

This Cleaning-Up process can be seen by looking into a partially honed bore as illustrated in Figure 9, and observing the difference in appearance between the honed and un honed areas.
HONING TOOL - SELECTION

Honing Tools can be divided into three groups; Conventional Multi-Stroke Tools, plated Single Stroke Honing® Tools, and plated super-abrasive CrossGrinding™ Tools.

Conventional Multi-stroke Tools are further divided into the following sub-groups: Single-Stone, Multiple-Stone, Wide-Stone, and Multiple-Point.

Single-Stone Tools are commonly used for small bores, about 0.060 to 1.0 in. (1.5 to 25mm) in diameter (see Figure 10). Longer stones and longer shanks are available for longer or recessed bores.

Multiple-Stone Tools are used for larger bores, about 0.625 to 6.0 in. (16 to 150mm) in diameter (see Figure 11). Longer tools are available, with more stones in line.

Wide-Stone Tools are used for honing over keyways and splines (see Figure 12), for bores from 0.250 to about 4.0 in. (6 to 100mm) in diameter.

It should be noted that the parts suitable for honing with all of the honing tools listed so far are usually light enough to float on the rigidly mounted rotating tool.

Multiple-Point Honing Tools are used for large bores, about 2.9 to 12.0 in. (73 to 305mm) in diameter (see Figure 13). In large diameter parts it is more practical to use a tool that has multiple contact points in order to provide faster stock removal.

Single Stroke Honing® Tools are used for bores from 0.235 to 2.0 in. (6 to 50mm) in diameter (see Figure 14). They are very fast and accurate, but limited in metal removal. Light parts can float; heavy parts will have to be positioned accurately (within 0.001 in. or 0.03mm), then locked in place. This is a significant departure from conventional multi-stroke honing procedure.

The Single Stroke Honing Tool consists of an expandable diamond plated sleeve on a tapered arbor. During set-up the abrasive-coated sleeve is expanded by being pushed up the tapered arbor. The process is a fast and accurate method of honing a bore to final size, because the rotating tool is pushed through the bore only once unlike conventional honing where the part is stroked repeatedly over the rotating honing tool. Repeatability of size is very good, because all size adjustments are made during set-up.
Size adjustment is infrequent because the tool is plated with diamond abrasive. As many as 100,000 parts can be honed with one tool. This means the operator need only to load, unload, and monitor the operation, thus freeing him or her for other responsibilities. This also lends itself to automated lines and robotized machines.

One factor which is very important with the Single Stroke Honing process is that the volume of chips to be removed has to be kept relatively small. Unlike conventional multi-stroke honing tools, the Single Stroke Honing Tool cannot carry more chips out of the bore than there is room for between the diamond grits of the tool itself. Therefore, jobs requiring large amounts of stock to be removed or jobs involving long parts with uninterrupted bores, a conventional multi-stroke honing tool is still the most logical choice.

To help you better make the determination between conventional multi-stroke honing and Single Stroke Honing, here are a few facts regarding the materials to be honed. Interrupted and short bores produce a low overall volume of chips, allowing the honing oil to wash the chips out of the bore and off the tool during the stroke. Cast iron makes short, non-stringy chips which can be carried off by the honing oil relatively easily. On the other hand, soft steel, bronze, and aluminum produce stringy chips which are more difficult for the honing oil to wash free of the tool, thus reducing the amount of stock that can be removed from these materials with one pass.

The best features of conventional multi-stroke honing tools and Single Stroke Honing Tools are combined in a new multi-stroke superabrasive CrossGrinding™ Tools (see Figure 15).

The New CrossGrinding™ Tools are used for bores from 0.375 to 1.25 in. (9.5 to 32 mm) in diameter. They are very fast and accurate, and limited in metal removal in one operation only by the range of the tool. Parts can either float or be locked in place depending mainly on the weight of the workpiece.

This new concept in tool design is similar to that of a Single Stroke Honing Tool, but with the added flexibility of being able to expand, much as a conventional multi-stroke honing tool, during the actual honing operation.

The CrossGrinding process is a fast and accurate method of sizing large numbers of parts to final size. It is fast because the tool rotates at speeds much greater than conventional multi-stroke honing tools – 500 to 5000 rpm. Repeatability of size is very good because, like a Single Stroke Honing Tool it incorporates a plated superabrasive sleeve, which wears extremely slowly, allowing a greater number of parts to be sized with only periodic size adjustments to compensate for tool wear.

Since the tool is plated with superabrasive, only one initial and occasional periodic adjustments for wear are required; allowing numerous parts to be resized with one tool. This means when the CrossGrinding System is used, the operator needs only to make the initial set-up, loads the workpiece magazine, and monitors the operation, thus freeing him or her for other responsibilities.

One factor which was very important with Single Stroke Honing was the volume of chips which had to be kept relatively small. With the new CrossGrinding Process; and the use of a multi-stroke tool and with a relatively small volume of chips being removed per stroke, chips are no longer a limiting factor. Therefore, for jobs requiring large amounts of stock to be removed or jobs involving parts with interrupted bores, the new CrossGrinding Process can be used alongside or in place of conventional multi-stroke honing.

Again, to help you better make the determination between conventional multi-stroke honing, Single Stroke Honing and the new CrossGrinding process, the major factors to consider are: If your parts fall within the range of the CrossGrinding Tools and you process a large volume of parts, but not the volume to justify a custom built machine, then it may be to your advantage to look into the new CrossGrinding System.
HONING STONE – ABRASIVE

Honning stones are normally divided into groups according to the type of abrasive grit and the type of bond used to hold the grits together. The stones in each of these groups are then rated according to Hardness.

Most honing is done with conventional abrasives because of their low price. However, the use of superabrasives is increasing rapidly, because high abrasive price does not necessarily mean high cost of honing.

The effective Hardness Rating (see Figure 16) of a honing stone is determined by the type and quantity of bond as well as the closeness of the grain spacing (or density) and, of course, the abrasion resistance of the type of abrasive grit.

The abrasion resistance of each type of abrasive grit is not always proportional to its hardness. For instance, diamond, being the hardest of all materials, might be assumed to be good for honing steel. However, diamond does not always perform well in steel. Theory has it that because of steel’s affinity for carbon, the diamond, being carbon, is actually dissolved into the carbon-poor steel. While this theory holds for most applications of diamond in steel, the bond being used to hold the abrasive must also be considered before making a final judgement as to the appropriateness of the particular abrasive. For instance, because of its superior strength, diamond is used on plated Single Stroke Honing and Cross-Grinding Tools for honing steel, but is not used in bonded abrasive sticks for conventional multi-stroke honing of steel.

It should be noted, that the Hardness Ratings of honing stones is not a measure of the stone’s quality. The best stone for a job is one hard (or strong) enough to hold each abrasive grit in place just long enough to wear down its sharp cutting edge, and then allow that dulled grit to drop out, permitting the sharp grit underneath to take its place. Furthermore, different materials respond differently to each of the various abrasive grits; therefore, each type of abrasive grit and the material to be honed should be viewed individually.

The Abrasive Grits are normally separated into two groups: Conventional Abrasives such as aluminum oxide and silicon carbide, and Superabrasives such as Borazon® (CBN – Cubic Boron Nitride) and diamond.

Aluminum Oxide is best suited for stock removal in steel.

Silicon Carbide works best on cast iron, bronze, brass, aluminum and for fine finishing steel, and on some non-metallic materials, such as: Acrylic, Dapon, Delrin, epoxy, graphite, Kel-F, Lucite, nylon, phenolic, Plexiglass, polycarbonate, polyethylene, Teflon, Torlon, Zytel, etc.

Borazon, in metal bond, is useful for honing cast iron and any kind of steel - hard or soft, high or low alloy.

And finally Diamond. Diamond is the only abrasive that works for tungsten carbide, glass and ceramics, and it is also effective in cast iron.

Unlike abrasive grits, Bonds are divided into groups according to the agent used in the bonding process. The various types of bonding agents are vitrified, resin and metal.

Vitrified Bond is most commonly used for conventional abrasive. A type of clay is mixed with the abrasive grits and then fired in a furnace to a glass-like (vitreous) consistency.

Resin Bond used to be shellac, but now is usually plastic. Its use in honing is limited to very fine polishing.
Metal Bonds can be brass, steel, nickel or carbide based. Metal can be used to make Bonded Sticks (see Figure 17) or Plated Products (see Figure 18). A bonded stick is composed of bond matrix and abrasive grains. It is designed so that as the abrasive grains in the top layer wear, they break out and expose sharp new grains further down in the stick. Plated products consist of a single layer of abrasive grains attached to the surface by electrolytic plating. Figure 17 and 18 should clarify the differences between the two bonding systems. The single layer plated surface is used on the Single Stroke Honing® Tools, the CrossGrinding™ Tools, and on conventional multi-stroke honing tools for long-life guide shoes.

**HONING FLUIDS SELECTION**

Commonly, the fluids used for honing are referred to as "coolants". This is a misnomer, because cooling is not one of the major functions of any honing oil or water-based product. By far the most important reason for using a honing fluid is its chemical activity.

A good honing fluid must be inactive at normal temperatures, so it does not corrode anything. But it must instantly become active when the temperature comes close to the melting point of the metal being honed. This high temperature occurs in microscopic spots at the points of cutting action and would result in welding of the metal guide shoe to the metal being honed. These tiny weld spots would be torn apart by the force of the honing machine, and the results would be rough surface finish and rapid wear of honing stone and guide shoe. However, capable "coolant" will prevent welding by chemically changing the hot spots from metal to a non-metallic compound, which can not be welded. This welding problem is especially likely to happen with high-alloy materials, such as stainless steel.

Honing Oils: It should be noted that, although it is considered desirable by some to refrigerate the honing oil, tests have shown that the honing action is actually faster when the oil is hot. Another idea was that cold oil would guarantee exact size of the finished part, without having to consider the shrinking of the bore diameter when the part cools off. This was also unsuccessful, because the input of heat during rapid honing is vastly greater than the very limited cooling ability of oil.

Another common myth is that honing tools without guide shoes are immune to welding problems. But, here again it is a honing fluid problem. For if the honing fluid does not have enough chemical activity it will permit stone loading, which means that metal chips created by the cutting action of the honing stones stick to the stone surface. Therefore, when there is stone loading, there will be metal-to-metal contact and welding, with the same undesirable results as when using a honing tool with metal guide shoes.

**Water-Based Honing Fluids:** With tighter government regulations and greater concern for safe, biodegradable products, water-based honing fluid technology has come up with new products that seem to offer an alternative to the more conventional oil-based honing fluids. Tests on specially developed water-based honing fluids in the new CrossGrinding Machine and conventional honing machines look very promising. Unlike traditional water-based products used for grinding or cutting, these new products were developed for use in honing and CrossGrinding Machines. But before deciding to use water-based honing fluids, consider the fact that water-based fluids need occasional replacement, and the cost of legally disposing used fluids is rising rapidly. Honing oils, on the other hand, don't need changing. Just separate the honing swarf from the oil by using filters, magnetic separators, or simply gravity.

Simply stated, always use a honing fluid (oil or water-based) which was properly blended for the process being used. Years of research, blending, testing, reblanding, and evaluating have gone into the development of quality honing fluids.
HONING MACHINE – SELECTION

Both horizontal and vertical honing machines are available. In general honing, no proof is available that one type of machine gets better results than the other, neither in speed nor in accuracy attainable. There are, however, some obvious limitations. For instance, to hone a ten-foot (about three meters) long tube, a vertical machine would have to be at least 26 feet (about eight meters) tall, and it would be difficult to find a building to fit it in. On the other hand, short heavy parts, for example with a 6 in. (about 150mm) bore by 10 in. (about 250mm) long, are better suited to vertical machines. This is because it is easier for the operator to lift the tool in and out of the bore and support the weight of the tool.

Honing machines are available, ranging from the simplest, basic honing machine to automated, robotized versions, selling for a hundred times as much. There are four common types of honing machines:

With the Basic Hone shown in Figure 19; the operator is required to hold the part in his or her hand while stroking the part back and forth over the honing tool.

With the Power Stroked Machine shown in Figure 20; the operator puts the part into a fixture, starts the spindle, the machine hone the part, then the operator stops the machine, and unloads the finished part.

Another improvement is the Automatic Honing Machine shown in Figure 21; the machine gages the bore diameter while it is being honed, and stops the honing operation when size has been reached.

The Single Stroke Honing Machine shown in Figure 22 offers a fast, accurate, and relatively inexpensive alternative to conventional multi-stroke honing in limited applications. But it still is not a logical choice for most honing applications.
Up until now, the only other alternative was an expensive Custom-Built Honing Machine, such as the one shown in Figure 23, that would do everything, including loading, gaging, and unloading; and some that would even segregate the parts according to minute differences in size, label them and present management with a printout of statistical quality control.

But with the introduction of the new CrossGrinding™ Machine, the price and application gap between conventional honing machines and Custom-Built Machines has been filled. The CrossGrinding Machine shown in Figure 24, combines the best of Single Stroke Honing and conventional multi-stroke honing with the features previously only found on Custom-Built Machines.

This new machine uses a new design of super-abrasive CrossGrinding Tool similar to a Single Stroke Honing Tool, but this tool expands and collapses during the CrossGrinding process, much like a conventional multi-stroke honing tool.

This machine also incorporates all sorts of interesting features, such as: Computer Numerical Control (CNC) with Touch Screen Programming, allowing you to enter information like the part's starting and desired finished diameters, etc. on the Touch Screen. Then the machine will automatically set itself up to the proper spindle speed, stroke length, stroke rate, feed rate, crosshatch angle, sparkout time and tool retraction, as well as recommend the proper CrossGrinding Tool to use. From then on the process is completely automatic. And the machine will remember up to 100 such setups.

These new machines, tools and related accessories create a CrossGrinding System within the price reach of most shops.

**HONING MACHINE – SETTINGS**

Whether you are using the highest priced machine available or the least expensive one, you must consider several factors when honing: Spindle speed, stroke rate, stroke length, and cutting pressure.

**Spindle Speed:** Compared to grinding, honing surface speeds are quite slow. Grinding wheels run at up to 7500 surface feet per minute (about 38 meters per second). A test, reported by W. König, Kemal Yegenoglu and Bernd Stuckenholz of the Aachen Technical University in West Germany, was even successful at 23500 surface feet per minute.

<table>
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<tr>
<th>INCHES</th>
<th>MILLIMETERS</th>
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<tr>
<td>700 DIA. IN INCHES = rpm</td>
<td>17500 DIA. IN MILLIMETERS = rpm</td>
</tr>
<tr>
<td>EXAMPLE 6 Inches</td>
<td>150 millimeters</td>
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| \[
\frac{700}{6} = 117 \text{ rpm} \\
\frac{17500}{150} = 117 \text{ rpm}
\] |

**FIGURE 25, Spindle Speed**
minute (120 meters per second). Honing speeds run at about 175 surface feet per minute (less than one meter per second). To find the correct spindle speed for a given diameter, refer to the Formulas shown in Figure 25. Slow honing surface speed does not result in slow metal removal; large stone area and fast stroke make up for slow surface speed.

**Stroke Rate:** A characteristic feature of a honed surface is the crosshatch pattern which is seen in Figure 26. The pattern is generated on the bore surface as the part is stroke back and forth over the rotating honing tool. The faster the stroking rate (spm) in relation to the tool rotation (rpm), the larger the crosshatch angle. Limitations in the stroke speed capability of the honing machine will make it highly unlikely that the crosshatch angle will be too large. Although exact crosshatch angles can be calculated by controlling the ratio of spindle speed to stroke rate, using the formula shown in Figure 27; most blueprints have ignored this angle. Regardless of whether or not the crosshatch angle is called out on the blueprint, it should be pointed out that the pattern created makes for excellent oil retention and bearing surface.

**Stock Removal Rates:** The formulas shown in Figure 27 can be used to estimate the amount of time in minutes it will require to remove a given amount of stock, using a honing machine which provides three horsepower at the spindle. For small diameter parts it is more difficult to predict honing times than it is for larger diameters. But the honing time for small parts is usually just a few seconds, so it is not as important as for big workpieces.

**Stroke Length:** The stroke length is not very important if the honing stone length is greater than the diameter of the bore being honed. On the other hand, honing tools used for large diameter bores are very sensitive to stroke length, probably because the geometry of large diameter honing tools is designed more for high-volume material removal than for accuracy obtainable with the three-point contact of the small-bore honing tool. Changing the stroke length in large diameter bores by as little as 1/8 in. (3 mm) on each end can make the difference between bellmouth and barrel shape (Figure 28).

**Overstroke:** When adjusting the stroke length for any honing job, the stone must cover the entire length of the bore plus a little extra on each end, which is called the overstroke (Figure 29). Overstroke each end by about 1/4 of the bore length or stone length, whichever is shorter.
<table>
<thead>
<tr>
<th>CUTTING PRESSURE</th>
<th>SECONDS FOR 0.004 IN. STOCK REMOVAL</th>
<th>STONE WEAR PER PART</th>
<th>STONE COST PER PART</th>
<th>LABOR PER PART AT $0.01 / SEC.</th>
<th>TOTAL COST PER PART</th>
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<tr>
<td>2</td>
<td>30</td>
<td>0.0001</td>
<td>$0.01</td>
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<tr>
<td>2.50</td>
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<td>0.0015</td>
<td>$0.15</td>
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</table>

**FIGURE 30, Cutting Pressure vs Cost**

Cutting Pressure: It is very important to find the correct cutting pressure and rate of feed for the stone being used. Use the lowest cutting pressure that gives good cutting action. To determine which cutting pressure will result in the lowest cost when doing production honing, try different pressure settings and tabulate the results, as shown in the example in Figure 30. As can be seen, a cutting pressure of 3 produced the best total cost per part in this example.

**HONING FIXTURE - SELECTION**

In addition to selection of the honing tool, stone, oil, and machine, your choice of and method of fixturing or holding your part must be considered in terms of safety, ease of loading and unloading, cost, etc.

Generally, Fixtures for honing are quite simple, because it is not necessary to locate the part accurately, and the forces used to hone are usually quite low.

A lot of honing is still done manually. The operator moves the part back and forth over the honing tool by hand. The Fixture can be as simple as a loop if emery cloth wrapped around the part and held in a clamp to absorb the torque of honing as is illustrated in Figure 31.

This same simple Fixture can also be used to hold a part for use in a power stroked machine as is shown in Figure 32.

But the larger and heavier the parts you hone the more concerned you will need to be with the design of the Fixture. Figure 33 shows an example of a Fixture for a heavy part which was to be honed on a vertical machine, where the tool was to float, while the part was to remain locked in place. The Fixture was designed with end clamps, which are less likely to distort the part when tightened than a fixture which would chuck on the outside diameter of the part. It is also safer, since the part couldn't jump out of the Fixture, even if loose nuts would permit the part to spin in the Fixture.

Because of the varieties of machines, types of parts one may be honing, Fixtures should be designed based on the part, ease of loading and unloading, and related job requirements.
### Approximate Surface Finish in Micronches (\(\mu\)) Ra

<table>
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<tr>
<th>MATERIAL</th>
<th>ABRASIVE TYPE</th>
<th>GRIT SIZE</th>
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<th>150</th>
<th>220</th>
<th>280</th>
<th>320</th>
<th>400</th>
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<tr>
<td></td>
<td>CBN (BORazon®)</td>
<td>-</td>
<td>55*80</td>
<td>45</td>
<td>30</td>
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<td>-</td>
<td>20</td>
<td>-</td>
<td>7</td>
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<td>-</td>
<td>95</td>
<td>70</td>
<td>-</td>
<td>-</td>
<td>30</td>
<td>-</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

* IF TWO VALUES ARE SHOWN: THE FIRST NUMBER IS FOR SMALL PARTS, HONED ON MACHINES WITH ONE HORSEPOWER OR LESS; THE SECOND NUMBER IS FOR LARGE PARTS, HONED ON MACHINES WITH TWO OR MORE HORSEPOWER.

**Figure 34, Approximate Surface Finish**

### Surface Finish in Micronches (\(\mu\)) Ra

**Existing Finish - Desired Finish**

\[
\text{SURFACE FINISH IN MICROINCHES (\(\mu\)) Ra} = \frac{\text{REQUIRED STOCK REMOVAL}}{100,000}
\]

**Example:** Existing Finish = 50 \(\mu\); Desired Finish = 10 \(\mu\)

\[
50 - 10 = 0.0004 \text{ in.}
\]

\[
\frac{0.0004}{100,000} = 0.00000004 \text{ in.}
\]

**Surface Finish in Micronches (\(\mu\)) Ra**

**Existing Finish - Desired Finish**

\[
\text{SURFACE FINISH IN MICROMETERS (\(\mu\)) Ra} = \frac{\text{REQUIRED STOCK REMOVAL}}{100}
\]

**Example:** Existing Finish = 1.25 \(\mu\); Desired Finish = 0.25 \(\mu\)

\[
1.25 - 0.25 = 0.01 \text{ mm}
\]

**Figure 35, Stock Removal for Surface Finish**

### Surface Finish

Surface Finish is measured by dragging a stylus across the honed surface of the workpiece and then averaging the reading of the peaks and valleys. Surface Finishes can be divided into two groups; conventional finish or plateau finish.

Unlike the crosshatch angle, blueprints often call out specific Surface Finish requirements.

As shown in Figure 34, the finer the grit of the honing stone, the finer the honed finish. But it should also be pointed out that the rougher the grit, the lower the cost of honing. Therefore, if there is a large amount of material to be removed and a fine surface finish is required, it is usually better to hone in two operations. The first operation would use a coarse grit stone for fast stock removal, while the second operation would be with the finer stone to obtain the specified surface finish.

The formulas shown in Figure 35 are provided as an aid in determining how much material to leave in the bore for finishing. As the example shows, if you want to go from an existing 50 microinch finish to a 10 microinch finish, you will need to remove 0.0004 of an inch of stock, as measured on the diameter. Removing less material will not produce the desired finish, and removing more is a waste of time.
Conventional Finish: Conventional Finish refers to what is produced by normal, conventional honing. A Conventional Finish is shown in Figure 36 - magnified 200 times.

Plateau Finish: Plateau Honing is a special process which has generated interest in the engine manufacturing and rebuilding market. This finish is shown in Figure 37 - also magnified 200 times. As you can see, the valleys are deep, and the peaks have been removed to form plateaus, thus the name Plateau Finish. The growing number of proponents of Plateau Finishing cite the following reasons for their support.

A cylinder wall has a Plateau Finish after the engine has been broken in. The peaks of the normally honed surface have been worn off by the piston rings, so you will get a plateaued surface eventually, so why not plateau hone originally, and leave the worn-off peaks of metal in the honing machine, instead of in the lubricating oil in the engine.

Furthermore, the valleys created when plateau honing act as oil reservoirs and provide lubrication during the critical moments when the engine has just been started, and the oil is not yet at full pressure. A smooth surface without these valleys does not have this ability to retain oil.

These claims are backed up by a test conducted by a piston ring manufacturer. Four 400 cubic inch Chevrolet engines were compared using a sophisticated radiometric oil consumption measurement technique. Three engines had been honed to produce conventional finishes (rough, medium, and fine); while the fourth engine was honed to have a plateau finish. The engine with the plateau finish consumed one-tenth the oil and had 80% less cylinder bore wear than the engines with conventional finishes.

To produce a Plateau Finish: First rough hone the part to the desired final size with a 70 to 100 grit stone. Then finish hone with a 600 grit stone for 15 to 45 seconds. The plateauing operation, with the 600 grit stone, removes so little metal that the diameter of the bore does not measurably increase. The amount of time used to hone with the 600 grit stone depends on the percentage of plateauing desired.

CONCLUSION

In Summary: Honing can improve both the bore geometry and surface finish. It can correct common bore errors with the least amount of stock removal. And the actual honing process can be relatively easy, when you select the right machine, holding fixture, honing fluid, and tool.

And with the advent of new equipment like the CrossGrinding™ Machine, large quantities of parts can be processed without having to invest in expensive custom built machines.
BIBLIOGRAPHY

Coes, Loring, Jr., Applied Mineralogy 1: Coes Abrasives, Spring-Verlag, New York, 1971


______, Technical Paper: A Long Look at Honing, Society of Manufacturing Engineers, Dearborn, 1986,


Lewis, Kenneth B., The Grinding Wheel, Grinding Wheel Institute, Cleveland, 1959

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