ABOVE AND BEYOND **HONING**

Sunnen® Honing Techniques

DATA FILE: #104

OBTAINING SPECIFIED FINISHES BY HONING

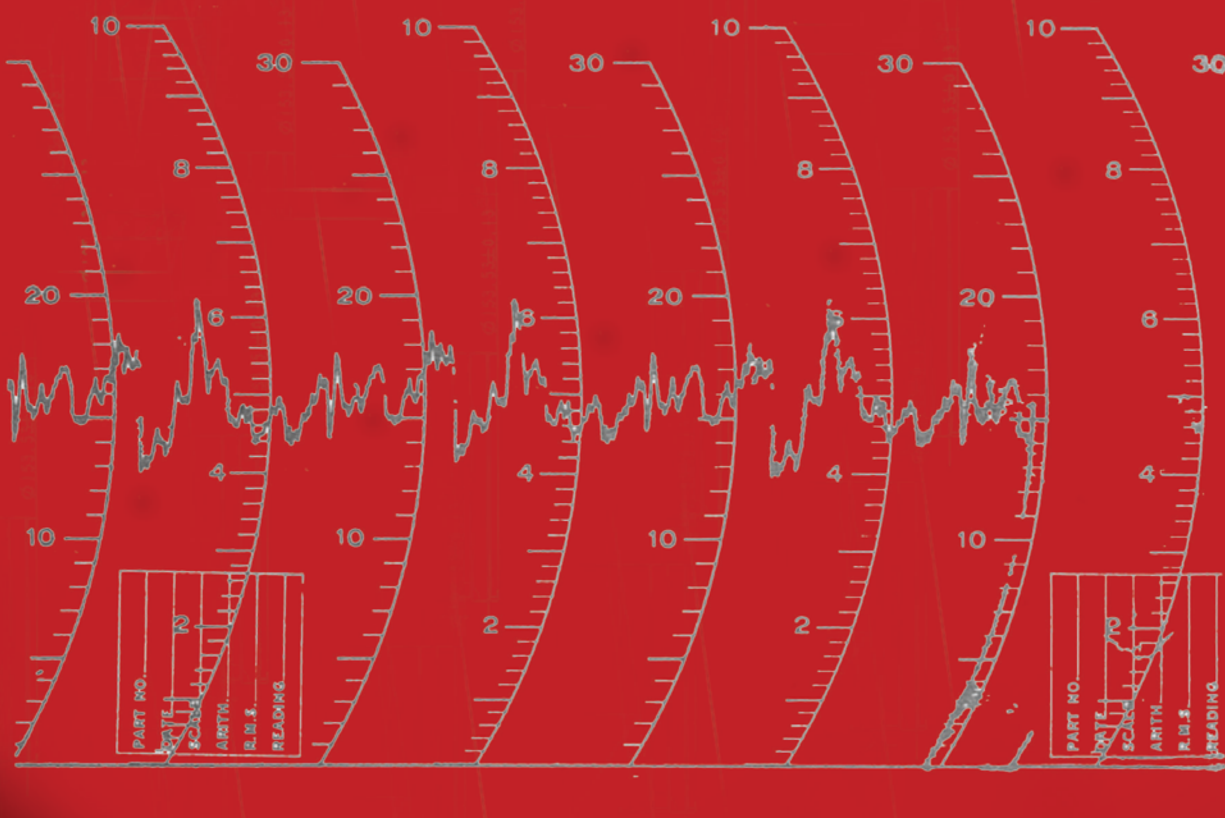


PHOTO STORY OF HOW HONING IMPROVES SURFACE FINISH IN HARDENED STEEL

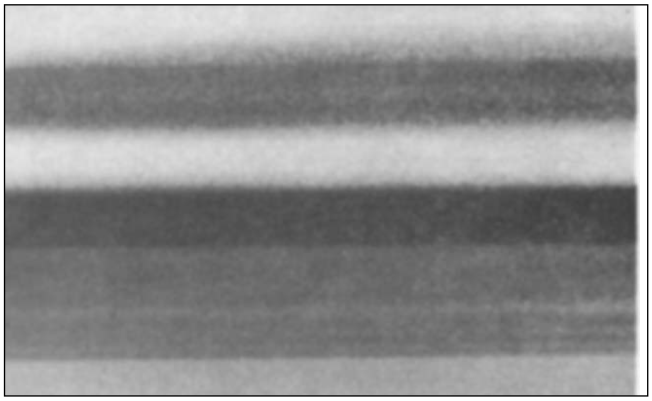


Figure 1 - Finely ground surface. Looks good. Highly reflective surface finish.

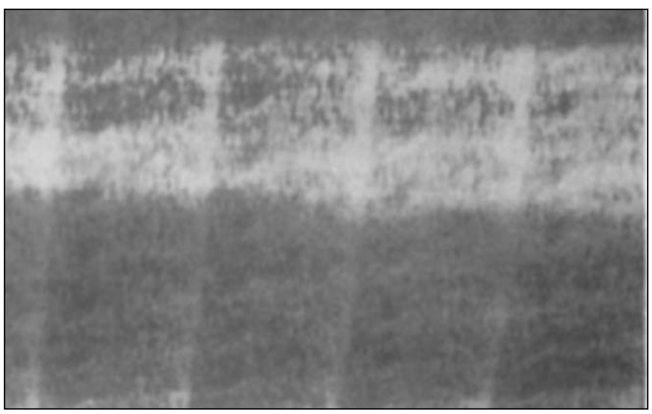


Figure 2 - The same surface, lightly oxidized and lightly honed, reveals grinding spirals.

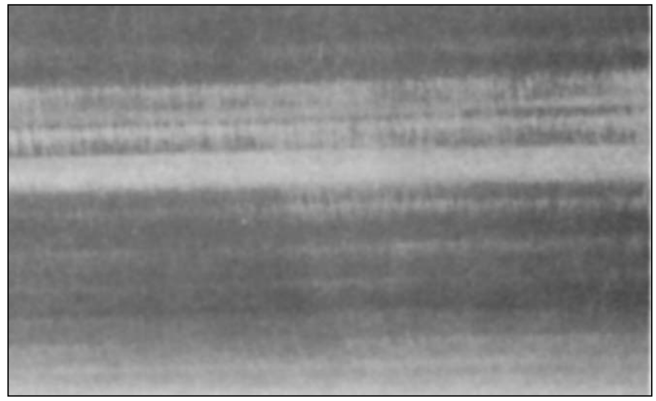


Figure 3 - The same surface, rough honed. The grinding spirals have been removed, but faint lengthwise grinder chattermarks are exposed. These marks were caused by vibrations in the grinding machine itslef or transmitted through its foundation.

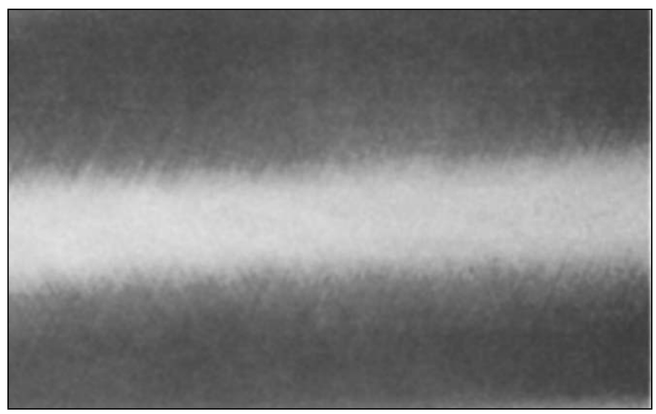


Figure 4 - The same surface, finish honed to specifications..

HONING TECHNQUES
OBTAINING SPECIFIED FINISHES BY HONING

GENERAL

Since surface finish measurements became recognized and standardized in mechanical engineering specifica-tions, more and more blueprints specify surface finishes based on actual measurement. Likewise, inspection departments are now equipped to check surface finishes by actual measurement.

There are several makes of surface analyzers in use. In general terms, such an instrument is a recording oscillograph. The measurement is made by moving the point of a pick-up stylus back and forth over a portion of the surface being measured *(see Figure5)*. The stylus is connected to a recording mechanism that produces a "microinch chart" *(see Figure6)*.

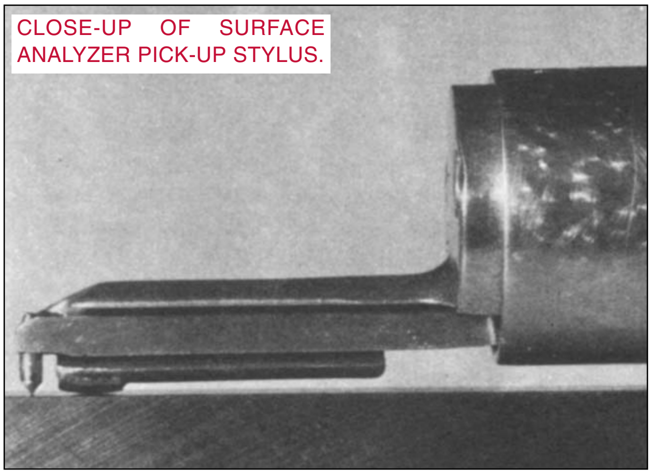
A microinch chart is a highly magnified surface profile obtained by instruments and recorded on a moving, calibrated chart, with the peaks and valleys above and below the centerline representing deviations calibrated in millionths of an inch - "microinches." The less the height of the peaks or the depth of the grooves, the finer the surface finish.

One method of assigning <u>average</u> microinch values to such a chart is to include any occasional extra high peak or extra low valley into the normal deviation. This is done in establishing RMS (Root Mean Square) values *(see Figure7)*.

The other and more recent method in computing an average value is to consider an occasional deeper scratch or extra-wide deviation as a flaw, and to use only the normal ups and downs for computing the <u>average</u> value *(see Figure8)*. This is the "AA" method (Arithmetical Average Height) in general use today by the American Standard Assn., ASA.

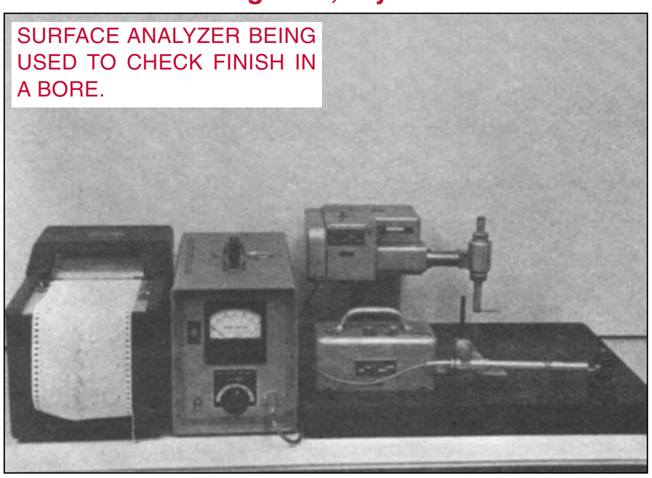
The microinch values arrived at when measuring honed surfaces differ very little between the two methods, and either is used in specifying honed finishes. For instance, a 20-microinch "AA" value would figure about 22 microinch "RMS", a difference of about 10%.

The symbol $50\surd$ specifies a finish with roughness of 50 microinches AA or better. The symbol $^{50}_{15}\surd$ specifies a maximum roughness of 50 AA and a minimum of 15.



CLOSE-UP OF SURFACE ANALYZER PICK-UP STYLUS.

Figure 5, Stylus



SURFACE ANALYZER BEING USED TO CHECK FINISH IN A BORE.

Figure 6, Analyzer

Mechanical equivalent of stylus and ink pen. The longer the dimension 'Y' with respect to “X”, the greater the magnifications of the surface profile.

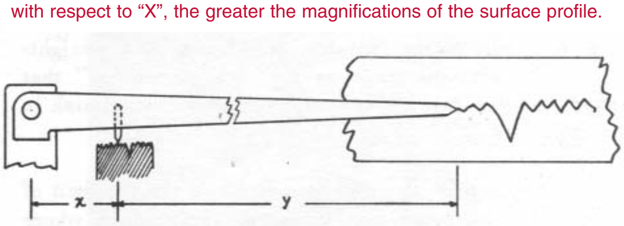


Figure 7, Stylus & Pin

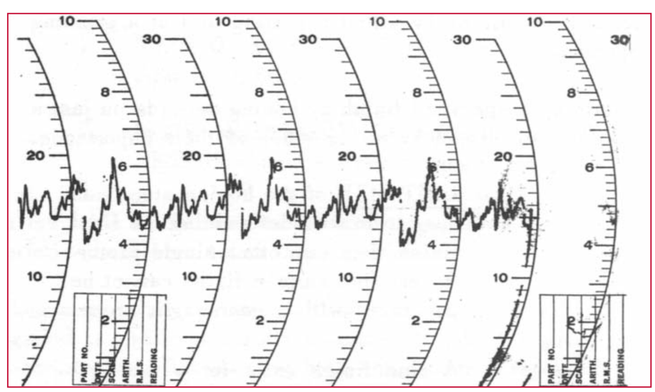


Figure 8, Typical Graph

PLANNING TO MEET SURFACE SPECIFICATIONS

Today, in planning a machining procedure for work where surface finish affects the function of the part, we have not only tolerances for size, roundness, and straightness, but also tolerance on a "fourth dimension" that must be taken into consideration - the surface finish in microinches.

As a general rule, the specified finish is the top limit of allowable roughness, but there are applications where the minimum as well as the maximum finish must be met. An example is the finish of cylinder walls in reciprocating engines and pumps where neither too fine nor too coarse a finish is desired. In some cases specific "roughness" is necessary to seat new piston rings pro-perly, and too fine a surface finish is not desirable. A lubricant film often will not adhere to a highly polished surface. A crosshatch surface, such as honing generates, has thousands of microscopic pockets which are ideal for supporting a uniform lubrication film.

HONING (THE SIMPLE WAY TO CONSISTENT RESULTS)

Honing, long accepted as a dependable method for meeting close tolerances on roundness, straightness, size, and for duplicating piece to piece in cylindrical work, is also the most dependable method for meeting this "fourth dimensional" tolerance - a specified surface finish. Honing, as a rule, is a secondary operation, following primary machining by either a cutting tool or a grinding operation.

Obtaining a specified finish by honing depends on just a few factors, listed below in order of their importance *(see Figure 9)*.

1. GRIT SIZE of the honing stone has more to do with determining the final finish than any other single factor. A very fine surface finish cannot be generated with a coarse grit stone.

A fine finish calls for a fine grit stone because the grit size determines the size of abrasive's cutting teeth. One of the advantages of honing is that the surface finish can be "predicted" and held to close limits by selection of the correct honing stone.

2. NATURE OF WORK MATERIAL: The materials comparative hardness, density and toughness are also determining factors. The degree of penetration made by the abrasive grit determines the "depth" of the scratches.

3. TYPE OF GRIT: All three of the abrasive types in common use (alu-minum oxide, silicon carbide, and diamond) are of crystalline structure, each having its own cleavage line. After being crushed and screened, each type grain differs from the other in general shape. One type will crush into rugged burr shapes while another takes the shape of splinters.

Fig. 12 - Two forces are required for cutting. A honing stone is like a file in many respects. A downward force and a crosswise force are both necessary to remove stock. The size of the grit is usually important, just as is the size of the file teeth. Coarse file teeth can be used for fast stock removal, but it always takes small teeth (or fine grit) to obtain a fine finish.

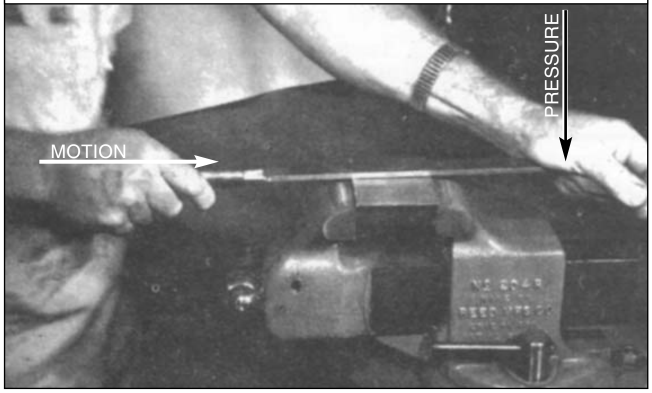


Figure 10, Stacking (Loose)

The abrasive types also have distinct differences as to degree of hardness and brittleness, which have a bearing on how long the abrasive will hold a cutting point. These differences affect the surface finish.

4. TYPE OF BOND: The bulk of all honing is done with vitrified bond stones. The reason for this is that vitrified bond is friable (crumbly) to give the stone self-dressing qualities so that new sharp cutting points are presented to the work at the proper time.

Occasionally, when extremely fine finishes are required in soft materi-als, the bonding materials used in the abrasive may cause minute scratches in the surface being honed. For these applications a cork bond stone is available. The bonding material in this stone is pulverized cork, held together with a plastic-like binder. This "stone" will pro-vide an extremely high finish but will not correct geometric inaccuracies.

5. STRENGTH OF BOND or hardness of stone is not extremely critical but can affect the finish in some cases. When the stone is so hard that it will "load" or "glaze" rather than breakdown, the "loaded" stone stops cutting but may cause scratches in the surface. The correct stone will remain sharp and cut uniformly. A still softer stone will cut more deeply but wear faster and, if too soft, will crumble away. Just a little "dulling" of the abrasive grits (bond slightly on the hard side) may improve surface finish under some conditions. In most cases a wide range of hardnesses will produce a satisfactory finish; but *to achieve high production rates at low cost, the correct stone hardness is all-important*.

6. HONING OIL: Many coolants do just what the name implies -- cool the tools and the work. Honing oil must do much more, and Sunnen Honing Oil is specif-ically blended for use with Sunnen Honing Tools. In the case of fine surface finishes, the Honing Oil must

lubricate the metal guide shoes and prevent galling. It must keep the stone clean to avoid loading. It must wash away chips and loose abrasive grits to prevent scratching. The use of the proper honing Oil is essential to do all these jobs. *Many surface finish problems are caused by the use of improper oil or coolants.*

In seeking fine surface finishes the honing oil must have a 'body'; that is, a viscosity that is just right to limit grit point penetration under light hon-ing pressure - but not of a degree to interfere with stock removal when sufficient pressure is used.

<u>7. STONE CUTTING PRESSURE:</u> The honing pressure used also has some effect on the surface finish produced. A given grit size, under high pres-sure, will bite more deeply into the work being honed, resulting in some-what rougher finish than if a light or medium pressure is used.

The design of the honing pressure system in the Sunnen machine provides for a "feathering out" of cutting pressure as final size is reached. This occurs as the indicator on the honing dial approaches "0". This "feathering out" feature is a great help in producing fine finishes.

<u>8. THE OPERATOR:</u> There are areas, too, in which the operator can affect the final result through various tech-niques. These will be discussed later.

SELECTING HONING STONES

In theory, a certain grain size should give the same finish in all materials, considering the factors previously discussed.

In compiling specifications as to proper stones for obtaining certain finishes in various materials, these characteristics of the work material must be taken into account:

1. TYPE OF WORK MATERIAL (Steel, Bronze, Aluminum, etc.)

2. WORK MATERIALS DEGREE OF HARDNESS (Resistance to penetration by pressure)

In the table of finishes on the next page, these characteristics have been taken into consideration.

When a stone of specified grit size and type is recommended to obtain a certain measured finish in a given material, these figures have been obtained from repeated experience with a free-cutting honing stone. The surface finish values are considered typical for the general classes of materials listed.

Three different types of abrasive grain are in general use - aluminum oxide, silicon carbide, and diamond. In many materials, all three abrasives will produce approxi-mately the same finish; and other factors such as speed of stock removal and cost determine which abrasive should be used. An example would be the honing of carbon steel of Rockwell C 45 hardness. Diamond, aluminum oxide, or silicon carbide could be made to cut this ma-terial and equal grain sizes would give something like equal finish. However, in practice, aluminum oxide has been found to be the most economical for this particular material.

Aluminum oxide crystals are "chunky"' in shape and therefore resist impact and breakage where the hole is rough and has buffs, as is typical for steel. Aluminum oxide honing stones are therefore always recommended for deburring.

Silicon Carbide abrasive, in the finer grit sizes, is specified for fine finishing because it is more brittle and the high points on the stone's surface will break off e with the surface. No occasional points will protrude produce deeper random scratches- In coarser grit sizes, silicon carbide's "needle -like", splintery shape is best for stock removal from aluminum, brass, bronze, cast iron, and other materials (except hard steel) because even with the low forces needed for cutting soft materials, the crystals fracture more easily than aluminum oxide and therefore constantly present new cutting edges.

Diamond abrasive is economical only when either of the other two available grains will not cut the work material, and in materials that are hard but of low shear strength -cemented carbides, glass, and ceramics. Diamond stones are costly but have very long life, are fast cutting, and economical in working the materials mentioned.

As indicated in the approximate finish table - a 4-microinch finish can be generated in hard steel, a 7 finish in soft steel, a 6 finish in cast iron -- all with a 500 grit stone. However, this same size grit will generate only a 14 microinch finish in aluminum or soft bearing bronze because of deep grit point pen-etration into these soft materials. All the stones list-ed in the finish table are of vitrified bond, glass-like and rigid. The bond will flake but not "give". Being rigidly held, the individual abrasive grains cannot sink back into the bonding mass under honing pressure.

PROCEDURES INFLUENCING SURFACE FINISH

Apparent or visual finish can be changed by speed of ro-tation in relationship to speed of reciprocation, but actual measured finish will change very little. As a rule, speed of rotation and rate of stroke are balanced to leave as steep a crosshatch as is practical. This steep cross-hatching allows a cutting action across the hills and valleys left by the opposite stroke, allows cutting with less pressure and, therefore, less heat generation. The average crosshatching in practice is something like 45 to 60 degrees.

SELECTION OF HONING STONE GRIT SIZE
to obtain specified microinch finishes in the various materials.

A. **Bold face** figures show AA surface finish readings obtained when It oning with normal cutting pressure. These finishes can be improved still further by "feathering out" cutting pressure at end of honing operation.

B. Figures in *light italics* give roughest AA finishes you can expect when using heavier cutting pressures for fastest stock removal.

NOTE: Surface readings are shown in microinches AA (arithmetic average). Where RMS (Root mean square) values are used, add 10% to convert figures in table to RMS readings.

GRIT NUMBER	HARD STEEL (Rockwell C50 or Harder)		SOFT STEEL (Less than Rockwell C50)		CAST IRON		NONFERROUS METALS MED. SOFT Forged Alum., Hard Bronze, Alum. Bronze, etc.		NONFERROUS METALS SOFT MAT. Cast Alum., Brass, Bear-ing Bronze, etc.		CARBIDE		CERAMIC		GLASS	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
4 (150 Grit)	**20**	*35*	**35**	*55*	**32**	*65*	**50**	*85*	**80**	*95*	**30***	*35**	**50***	*65**	**95***	*10**
5 (220 Grit)	**18**	*32*	**25**	*40*	**20**	*28*	**33**	*50*	**55**	*70*	**20***	*25**	**40***	*60**	**70***	*10**
6 (280 Grit)	**12**	*20*	**20**	*30*	**12**	*16*	**15**	*25*	**33**	*45*						
7 (320 Grit)	**10**	*15*	**15**	*24*												
8 (400 Grit)	**5**	*8*	**7**	*12*	**6**	*8*	**8**	*10*	**15**	*18*	**7***	*10**	**20***	*25**	**30***	*40**
9 (500 Grit)	**3**	*4*	**4**	*7*	**5**	*6*	**6**	*8*	**12**	*14*						
0 (600 Grit)	**(1)**	*(2)*	**(2)**	*(4)*	**(3)**	*(4)*	**(2)**	*(3)*	**(2)**	*(3)*	**3***	*4**	**15***	*20**	**15***	*30**

*Obtained with diamond stones in grit sizes shown.
Obtained with cork-bond stones usable for polishing only.

As discussed earlier in connection with the Table of Surface Finishes, when a stone is specified for obtain-ing a certain surface finish in a given material, this selection is based on repeated experience with that particular stone. It is assumed that the stone will be used with full cutting pressure. However, finishes can be improved beyond the values obtained with a free-cutting honing stone, by "feathering out" the honing pressure as size is reached.

As an example, say we have a bore in a mild steel alloy for which we specify a 220 grit stone to obtain a 40-microinch finish. We expect the stone to produce this finish under full cutting pressure, at its maximum stock removal rate. When this 220 grit stone is used with lighter cutting pressure for finishing only; a finer finish (as low as 25 microinches) can be obtained.

If the specifications call for 18 or better finish in this same material, then a much finer grit stone must be used. We would specify 400 grit to obtain this finer finish, and we would probably get around 12 AA under production honing pressures. Again, the operator could "feather out" his cutting pressure as size is reached and possibly get 10 microinches.

When still finer finishes are speci-fied - and if there is also a considerable amount of stock to be removed or the starting finish is very rough - a third honing operation will be necessary, using a 500 grit stone, which would produce a finish of about 5 microinches. Each successive honing operation uses a pro-gressively finer grit stone and must go down to base metal -- below the depth of cut of the previous operation.

As a rule, a given grit size (honing pressure remaining constant) produces a finer finish in a harder material. As an example, the same stone just mentioned as producing a 12 AA or better finish in mild steel, would consistently produce 8 AA or better in a harder material. The depth of grain penetration is less in the hard material.

Occasionally, parts made of soft material like aluminum or bearing bronze must have a mirror-like finish. Such materials cannot be lapped with loose abrasive powder for they will take a "charge" of embedded grit. To get such a finish the final finish honing must be done with a fine grit, resilient bond type of stone. For this type of finish Sunnen has introduced the 600 grit "cork" bond stones mentioned earlier, which should properly be classified as polishing stones and are not suitable for stock removal.

To summarize, the finish obtained by honing is not af-fected by the condition of the honing machine, since vibrations are not transferred to the work as in cutting and grinding. The honing stones need not be diamond dressed to keep them trued and cutting. Finish, in honing, is primarily dependent on grit size; surface speeds and rate of stroking affect actual finish only slightly.

With very few factors controlling honed finishes, it is not difficult to specify a stone that will give a certain finish in a given material and have the work consistently come up to finish specifications.

In seeking super-fine finishes the mandrel used for roughing or stock removal should never be used for finishing because in honing, the mandrel's shoe surfaces take the same finish as the work. A separate mandrel should be reserved for such finishing operations.

CONCLUSIONS - HOW TO MEET SPECIFIED FINISHES

1. Heavy stock removal plus the need for a medium-fine or fine finish calls for more than one honing operation, and requires separate tooling to get the best results.

2. Inferior grade honing oils or other coolants will cause problems in stock removal as well as in finishing. Use only Sunnen Honing Oil to guarantee the proper performance of Sunnen honing tools. The oil must be kept clean and never diluted with solvents or other cutting agents. Oil should be changed and the machine cleaned out from time to time as needed.

3. A new honing stone must be radiused to the diameter of the bore being honed; the same holds true for new mandrel shoes. Use a truing sleeve of the same diameter.

4. Finishing work with fast, slow or very slow stroking will change the appearance of the surface, due to light reflection, but will not change the surface finish measurements.

5. Watch for "specks" of work material sticking to the stone. Wipe the stone face and inspect it occasionally between honing of parts - otherwise, 96 scratching" (galling or welding) of the work surface might result. A stone that has a tendency to "load" with "specks" has too hard a bond; a stone's surface must wear away slowly to stay "clean" and sharp. Use a softer stone, if necessary, to avoid loading.

6. Stone cutting pressure will change the surface measurements to some extent and as a rule should be "feathered out" on the final finishing stage of honing.

7. A change towards increased bore roughness in the last machining operation prior to honing may call for a change in honing procedure or even necessitate an added honing operation.

8. To "over-finish" is a waste of time - no need to generate a 10 microinch when a 40 AA or better is specified -a 30 or 35 AA finish will meet the spec's more economically.

data files

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