Loosė Abrasive Flat Machining Techniques

Loose abrasive flat machining techniques fit into three basic categories:

Lapping
Free Abrasive Machining
Polishing

All three of the above classifications involve the mechanical abrading of a surface, i.e. the flat face of a pump housing "rubbing" against the surface of a lapping, free abrasive machining, or a polishing plate. Typically, free abrasive machining connotes a roughing operation wherein as much as .040" of stock can be removed. Lapping normally brings to mind an intermediate step between free abrasive machining and polishing with up to .005" material removal. Polishing is usually considered to merely burnish a surface and remove less than .0005" of material.

Most recently, lapping and free abrasive machining terminology is used interchangeably. Free abrasive machining introduced a key process control necessary for consistency of material removal in production applications. Water cooling of the lapping/free abrasive machining plates allowed use of greater pressures bearing down on the piece parts being machined and also allowed use of coarser abrasives to "hog" material. Prior to water cooling of the lapping/free abrasive machining plates, heat build-up would cause two detrimental phenomina:

- Drying of the vehicle suspending the abrasive particles, thereby slowing down the machining process as the frictionally heated vehicle lost all suspension capabilities;
- The gravitation of the residual heat created by the rubbing of the parts being machined, to the center of the lapping/free abrasive machining plate. This thermal build-up would cause the plate to swell, creating erroneous lap plate flatness readings when the machine cycle stopped and the lapping/free abrasive machining plate cooled. Convex plates could conceiveably become concave.

Lapping, free abrasive machining and polishing involve the same key components:

A MACHINING PLATE

This typically is an alloyed cast iron or hardened steel material which wears away much as a grinding wheel, but at a much slower rate. Cast plates offer the most versatility and greatest cost effectiveness for the following reasons: virtually all materials can be machined on cast iron alloy plates; cast plates use their open matrix to hold the abrasive used in the process much like the bond material in a bonded grinding wheel. Hardness of the steel varies as the plate wears, creating a variable which can cause minor cutting rate variances. Abrasive and vehicle are not held on the plate surface, creating higher abrasive and vehicle costs. Cutting rates are further impeded as, in the machining of soft materials, abrasive imbeds in the parts being machined, creating a machine load of "little grinding wheels" cutting at the machining plate. In the machining of hard materials on a hard plate, abrasive gets crushed between the surfaces of the piece parts and the machining plate. This creates low edges on the piece parts where full abrasive grains cut at the outer edges of piece parts and finer crushed particles cut at the inner areas of piece parts.

CONDITIONING RINGS

These rings retain the parts during the machining operation, and help keep the machining plate in a planar condition, assisting in the distribution of abrasive slurry across the surface of the machining plate.

ABRASIVE SLURRY

Abrasive slurry is composed typically of two components. A vehicle, oil base or water base which acts as a carrier for the second slurry component, which is the abrasive powder. Abrasive is most often a silicon carbide or a form of aluminum oxide (fused alumina or calcined alumina). Other abrasives which are used include boron carbide, diamond, garnet, zirconium oxide, chrome oxide and others. Abrasive is mixed with the vehicle to form the slurry which provides the "cutting" when flowed onto the lapping/free abrasive machining plate. Slurry flow rates vary depending on the application.

Controllable variables in the lapping/free abrasive machining and polishing process consist of: the abrasive type, particle size and concentration in the slurry mix; the vehicle type, oil base or water base; viscosity, lubricity characteristics, and concentration in relation to the abrasive: the downward pressure applied to the piece parts; the material composing the lapping/free abrasive machining plate; the rotational speed of the lapping/free abrasive machining plate; temperature control of the lapping/free abrasive machining plate; and the type of tooling utilized.

Tooling (Workholders). In most cases tooling is in the form of a plastic workholder disc (other materials can be used), which in the case of a single sided machining is the diameter of the inside diameter of the conditioning ring. Holes are cut in the workholder disc to accommodate piece parts. Workholder discs are thinner than the pieces being machined. For double sided applications workholder discs are in the form of toothed carriers, also having holes in them to accommodate piece parts and being thinner than the pieces being machined.

Pressure equalizers. In single sided applications, felt pads the diameter of the inside of the conditioning ring are placed on top of the piece parts to uniformly distribute the pressure applied through gravitationally weighted pressure plates placed on top of the piece parts or pressure plates which are pneumatically pressurized. (This occurs on machines equipped with pneumatic pressure controls.)

Where to Use Lapping/Free Abrasive Machining

The following examples of lapping and free abrasive machining applications include short run as well as high volume flat surfacing programs. Lapping/free abrasive machining eliminates costly set up and high labor costs which are otherwise incurred by excessive parts handling and close tolerance requirements found while attempting to achieve exacting flatness and surface finish tolerances with alternative machining techniques.

THIN SECTION PARTS:

(All piece parts subject to clamping distortion, or magnetic chucking distortion requiring flat surfacing and a reasonable or better surface finish.) Lapping/free abrasive machining can replace milling, grinding or facing operations.

BAD BACK PARTS:

Lapping/free abrasive machining machines parts with the surface to be machined face down on the machining plate. This eliminates the need for expensive tooling for those "bad back" castings or fabrications that need flat surfaces for sealing purposes, or referencing surfaces for assembly or subsequent boring or drilling operations. Machining starts with rough castings, eliminating the need for prior milling, facing or grinding operations. Present the roughest surface (as cast) as possible to the lapping/free abrasive machining operation as this speeds up the material removal. Blending in the material peaks makes for faster material removal than machining solid surface. This eases prior machining operations when they are used, as you no longer need to generate a fine RMS with a milling or turning cutting tool and no longer need multiple grinding steps.

NONMAGNETIC MATERIALS:

Lapping/free abrasive machining is ideal for parts that cannot be magnetically chucked. Aluminums, stainless steels, zinc die castings, copper, bronze, tungsten carbides, ceramics, glass, granite, diamond, ferrites, plastics, and all semiconductor materials including silicon, sapphire, gallium arsenide, gallium phosphide, GGG, quartz, germanium and many others.

OTHER USES:

Lapping/free abrasive machining is a process which often replaces hand scraping of large sections requiring flat surfacing.

Machining of dissimilar materials on the same piece part surface with virtually uniform abrading action.

Machining of brittle materials which may chip or break as a result of stress or shock generated by other machining processes.

Residual Benefits of The Process

- Deburring of the machined surface during the operation.
- Simplifying of prior machining operations.
- Eliminating or simplifying tooling.
- No piece part distortion.
- No burning of the pieces being machined.
- Machining several different parts (even different materials) on the same machine at the same time.
- Increasing part quality and consistency.
- Reducing piece part cost.
- Combining several lapping/free abrasive machining tolerance goals in a single operation.

Surface Finish Control

Surface finish control is accomplished by selecting the correct abrasive (material and grain size), vehicle, machining plate material, and slurry feed rate. Down pressure on the piece parts also plays a role in surface finish control, as too much pressure can preclude the abrasive from working its way underneath the parts being machined, or eliminate completely the abrasive from beneath the work. Too little pressure, on the other hand, may reduce the efficiency of the abrasive being used. Optimum pressure is usually in the range of 3-5 lbs. per sq. inch on the area of the work being machined. This may vary for special applications.

Flatness Control

Flatness control of the main machining plate is critical for close tolerance work. In this machining process the pieces being machined mirror a percentage of the area of the surface of the machining plate being used. (i.e.

a part 5" in diameter being machined on a 24" diameter machining plate requires a closer machining plate flatness than a part 5" in diameter being machined on a 40" diameter machining plate). Most often parts that are machined to a concavity have been machined on a convex machining plate and parts machined to a convexity have been machined on a concave machining plate. This factor can be used to control convexity or concavity in the pieces being machined as well as to control flatness tolerance. Machining plate flatness should be checked at least once per shift to determine concave or convex wear patterns on the machining plate. Flatness is easily checked by placing a straight edge O.D. to O.D. on the cleaned surface of the machining plate and checking with "feeler gauges" to determine if the plate has worn to an undesirable direction, or by using one of the piece parts or a test part as a flatness reference sample (other mechanisms can be used for checking plate flatness).

Parallelism and Sizing (Single-Sided Machines)

Steps to achieve parallelism and sizing when using the lapping/free abrasive machining process:

1. With no parts in the machine, machine the pressure pads against the maching plate to achieve opposed parallel surfaces.
2. Place the parts within the conditioning rings.
3. Run machine.
4. Transpose parts within a conditioning ring. Random movement of several parts within a given ring will redirect the pressure pad when it is again lowered against the work. Should parallelism as well as sizing correction be desired, turn the parts over during the transposing function. Short machining cycles between transpositions as thickness tolerance approaches requirement will create closer size and parallel control. This type of correction requires that at least four pieces fit within a conditioning ring.
5. Run machine. Repeat transposition and machine cycle to the required tolerance. Typically, correction of size and parallelism to .0001" is attainable.

Machining for Flatness Only, Maintaining Thickness Spread of Parts Being Machined

Where machining for flatness and surface finish are the only requirements, a pressure equalizer is inserted between the bottom surface of the pressure pad and the top side of the pieces being machined. This felt or neoprene pad compensates for the piece part height differences and allows the downward pressure applied by the pressure pad to be distributed evenly across all pieces being machined. Thus all pieces "clean up" in the same time.

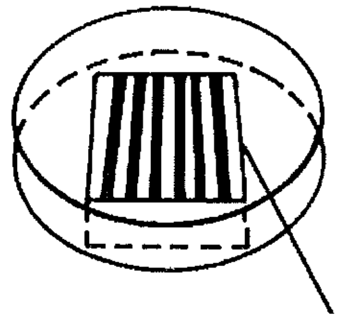
Squareness

Typically, squareness is not a standard function of the lapping/free abrasive machining process. Squareness is achieved by generating qualifying surfaces using this process and referencing from these flat surfaces for subsequent machining operations (i.e. drilling, boring, grinding, etc.). Squareness can be achieved where the I.D. or O.D. surface of the piece part is used as a reference surface and is held to a reference plate during the lapping operation (requires special tooling).

Checking Piece Part Flatness Using Optical Flats and a Monochromatic Light Source

1. Polish piece part surface to be checked, removing lapped matte finish.
2. Clean part and carefully clean optical flat surface, removing all residue and dust particles.
3. Place part with surface to be checked facing up beneath light (light should be switched on).
4. Carefully place optical flat on piece part surface to be checked.
5. Bands will appear when looking through the optical flat onto the surface of the piece part.
6. Use the reflection of the straight vertical line scribed into the monochromatic light lens to establish a reference line for reading the correct flatness. If no line exists, mentally visualize a line bisecting your piece part surface. Bands on the part should be parallel to this line.
7. Use pressure contact with your finger near one edge of the optical flat to apply light pressure. Bands migrating around your finger indicate a convex part. Bands curving away from your finger indicate a concave part. When a "bulls eye" pattern appears when pressure is applied near the edge of the optical flat, the bulls eye pattern will move toward the point of pressure if the part is convex. If the part is concave, pressure applied at the center of the optical flat will cause the circular bands to widen and decrease in number.
8. The number of bands crossing your reflected or imaginary line indicate the flatness of the piece part. Each band crossing the line represents .000011", therefore, two bands crossing the line will indicate .000022" concave, or convex.
9. Some parts may be flat within one light band but may exhibit slight edge "roll off" as a result of hand polishing prior to checking.
10. Part surfaces that give no line pattern on portions of the surface may not have a completely lapped and or polished surface, or may have dirt on the surface.

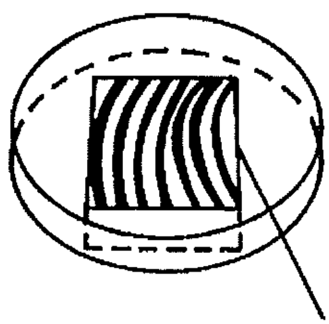
Light Band Measurement of Flat Surfaces



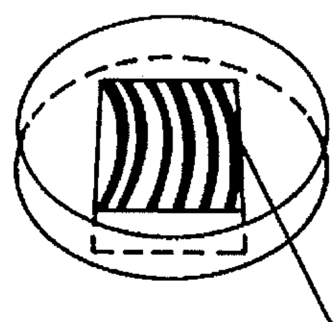
LINE OF CONTACT

Straight bands equally spaced and parallel, indicate that the surface is flat within 11.6 millionths of an inch.

Method for Determining Which Way Part Is Out of Flat



Line of Contact
CONVEX



Line of Contact
CONCAVE

How to Judge Proper Abrasive Slurry Mix and Feed

1. Look for a uniform covering of slurry on the machining plate surface.
2. Check for uniform surface finish quality on the piece part surface being machined.
3. Check for optimum stock removal rate.
4. Check surface of the machining plate for "galling".
5. Check to see top surface of machining plate is level for uniform slurry feed to all stations.

Remedies For Improper Slurry Feed

1. Increase the ratio of abrasive to vehicle. Do not introduce too much slurry, as this may impede cutting rates and increase cost.
2. Increase or decrease the flow rate of slurry being fed onto the surface of the machining plate. Watch edge of machining plate for slurry "wash off". Excessive amounts should not "sling" from the machining plate.
3. Check for overloading the down pressure on the piece parts. Too much pressure will force the parts to wipe the slurry from the machining plate surface.
4. Top of machining plate surface must be level for equal distribution of slurry to all work stations.

Common Process Characteristics

The Effect Of Magnetism

When machining ferrous materials, it is important to demagnetize the piece parts being machined. Parts can be checked for magnetism with a hand held residumeter (field indicator) which will show the extent of residual magnetism in the parts. This magnetism gets transferred to the machining plate during the machining process. Each segment of the machining plate becomes an opposing pole, thereby pushing and pulling at the parts as the plate passes beneath them during lapping/free abrasive machining. This fluttering of the parts causes unusual surface finish patterns as well as difficult-to-control flatness tolerances. Demagnetizing is performed with a simple degaussing device.

Edge Rolloff

Low edges on piece parts being machined can often be traced to too much abrasive action at the outer edges of piece parts being machined. This problem can be remedied by the following:

A. Using an abrasive of a smaller particle size or one which is less friable.

B. Breaking up the surface of the machining plate by adding more grooves, thus allowing the abrasive particles to be more evenly distributed across the surface of the parts being machined.

C. Backing off on some of the downward pressure being applied to the piece parts.

Too Much Heat

Lapping/free abrasive machining is a cool process. However, when coarser abrasives are used, and greater downward pressures are employed when achieving high stock removal rates or during continuous production runs, thermal build-up can be a problem. This thermal problem is rectified by using a machine with a built in water-cooled machining plate. All Flat-Tech machines equipped with pneumatic down pressure systems also have a standard water-cooled machining plate system. Water cooling means:

A. Cool parts for the operator to handle.

B. Accurate plate flatness readings.

C. Uniform stock removal rates from load to load.

How to Fill a Conditioning Ring

When filling a conditioning ring with parts while not using a phenolic workholder/spacer, make sure that the load is balanced within the ring. Part loads must fill the ring, but must not be positioned so as to fit so tightly that they lock one another in a fixed position within the ring. A little "sloppiness" between the parts is necessary.

When using a phenolic workholder/spacer, holes to receive the parts must be placed in the workholder disc so that a balance load condition is created. Place holes as close to the circumference of the workholder disc as possible, allowing for some space to retain the strength of the workholder. Then add holes as needed to maximize capacity.

How Much Down Pressure?

Pressure application in the lapping/free abrasive machining process can be a great assist in increasing stock removal rates. Too much pressure can reduce stock removal rates as well as distort fragile parts being machined. Typical pressure applied is in the range of 3 lbs./sq. in. to 5 lbs./sq. in. This general rule applies to parts sturdy enough to withstand this pressure and refers to lbs./sq. in. on the surface of the work being machined.

Low Corners on Rectangular Parts

It may be necessary to restrict the rotation of the piece part within the conditioning ring or the workholder being used. This can be accomplished by cutting holes in the workholder that duplicate the footprint of the part being machined, rather than fitting the part into a cut round hole. Allow clearance for the part to fit into the workholder cavities which receive the parts.

"Galling"

This "gouging" of material occurs most often when machining stainless steels or exotic metals. Key elements to note are:

A. The concentration of the slurry mix. It may be necessary to increase the concentration of abrasive.

B. The lubricity of the slurry. It may be necessary to add an antigalling agent (Flat-Tech JL-40).

C. The amount of pressure being applied. Fewer psi may be required.

D. The amount of slurry flowing onto the table. It may be necessary to increase the flow rate.

E. The material of the machining plate being used. Machining plates which are too hard and/or "gummy" may be the problem.

Irregular Machining Plate Wear

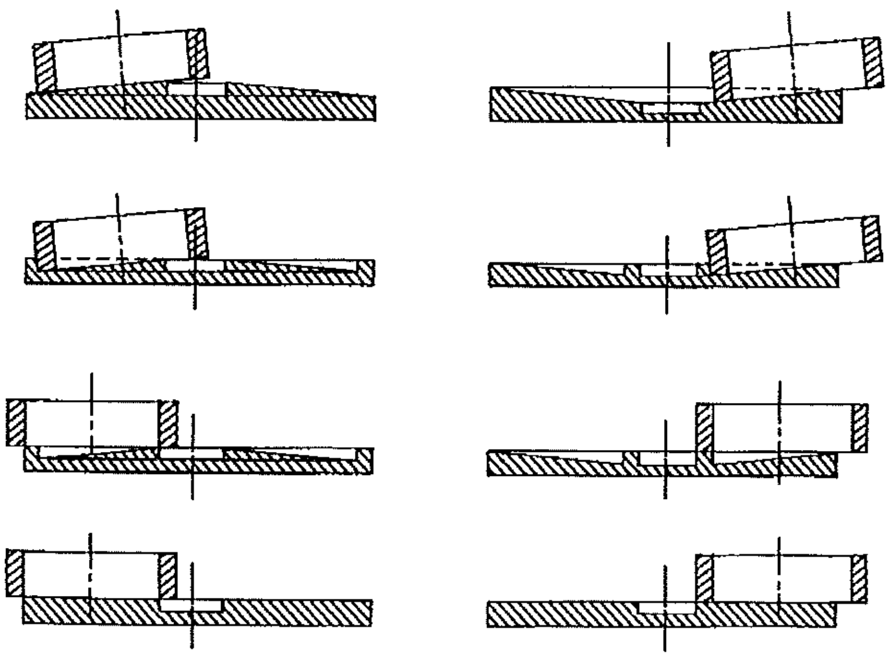
A. Generating a convex condition on the machining plate when the conditioning rings are programmed for concavity or flat. This can be caused by insufficient friction driving the ring (ring slips or hesitates from rotating). Increase slurry flow rate, or try coarser abrasive size.

B. Machining plate is too far convex to correct by conventional means. A hill developed on the machining plate causes the weight of the conditioning ring to follow the contour (slope) already developed. To solve this problem use special dressing techniques (as illustrated) or have maching plate surface ground.

C. Generating concavity on the machining plate when the conditioning rings are programmed to correct concavity. This can be caused by a machining plate that has been allowed to become too concave. Thus, the conditioning rings follow the contour of the machining plate. To correct this condition see illustration, or have machining plate surface ground.

Machining Plate Flatness Correction For Extreme Conditions

Conditions are exaggerated.



CONVEX CONCAVE

Random High and Low Spots on Machining Plate Surface

Irregular machining plate wear is a condition where high and low conditions occur in random positions on the surface of the machining plate. This condition can be caused by the pattern created by piece parts being machined, incorrectly filled conditioning rings or magnetism in the machining plate.

The condition can be corrected by:

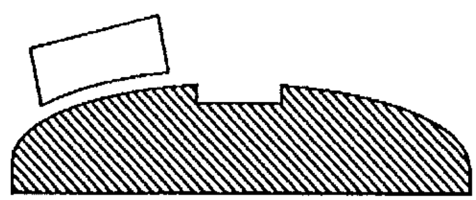
A. Demagnetizing the machining plate.

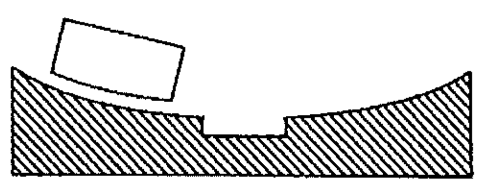
   Use a solid disc (ideally cast iron, aluminum or steel) the diameter of the inside of the conditioning ring; within the conditioning ring to "dress" the machining plate. Parts of a smaller diameter within the conditioning ring will "ride over" the irregular surface on the plate.

OR:

B. Have the table surface ground.

Piece parts being machined mirror a percentage of the flatness present on the surface of the machining plate. A convex machining plate will generate a part being machined which possesses a portion of the plate's convexity. This machining plate convexity will appear as concavity in the piece part. A concave machining plate will generate a part being machined which possesses a portion of the plate's concavity. This machining plate concavity will appear as convexity in the piece part.





Surface Finish Variance

Surface finish will vary when using the same abrasive grain size to machine soft and hard materials. As an example, a 20 micron abrasive particle size will yield a lower surface finish on a hardened steel piece part and a higher surface finish on an aluminum part. This is caused by the crushing effect created to a greater degree by the part of a harder, less porous material.

Surface finish for most lapped or free abrasive machined surfaces consists of a matte finish. This surface can be converted to a bright reflective finish by polishing or tumbling. Scratches which appear on the surface are in a random pattern and are of a typically inconsequential nature. These can be easily polished out. Scratch-free machining can also be accomplished through the selection of the proper abrasive.

Scratches on the surface of piece parts generated by the lapping or free abrasive machining process provide different readings than those generated by conventional surface grinding for a given RMS reading. This discrepency is created by the random nature of the scratch pattern on the lapped or free abrasive machined surface versus the repetitive line pattern generated by a grinding wheel on a vertical or horizontal spindle surface grinder.

Process Misconceptions

Misconception: Lapping and Free Abrasive Machining Are Only Finishing Processes.

FACT: This process is used to remove as much as .040" in some instances on softer materials. Removal of material in the area of .010"-.005" is quite common. This process affords the opportunity to incorporate what were formerly several machining operations into a single machining step.

Misconception: Lapping and Free Abrasive Machining are Slow Material Removal Processes.

FACT: Stock removal rates as much as .010" per minute have been achieved in some applications. Using the proper abrasives and the optimum down pressure can yield excellent material removal. This rate combined with the usually large capacities of the machines produce excellent (and competitive) part per hour rates.

Misconception: Certain Materials Cannot Be Machined Using Lapping or Free Abrasive Machining.

FACT: Every material, from the hardest to the softest, from ferrous to non-ferrous can be machined. Often combined materials can be machined, either as combinations on the surface of the same part or as conditioning ring loads of different parts of different materials on the same machine load.

Misconception: Some Parts Are Too Big or Too Heavy To Be Lapped or Free Abrasive Machined.

FACT: Machines can be easily tooled to receive parts larger than the I.D. of their conditioning rings. Therefore a machine size may not restrict the size of the part to be machined. Weight of the pieces to be machined exerting down presure of 3 psi-5 psi on the area of the surface against the machining plate can be machined regardless of overall part weight.

Misconception: Operators Must Be Highly Skilled To Generate Close Tolerances.

FACT: Minimal skill is required to produce the most exacting of tolerances, due to advanced machine controls in new equipment. Care must be taken as in any other machining operation.

Misconception: Only An Abrasive Expert Can Operate This Equipment.

FACT: Though abrasives perform differently in loose abrasive operations than in bonded or coated applications, great expertise is not necessary. Four or five abrasive grain sizes are used for 90% of all lapping and free abrasive machining applications.

Misconception: Lapping and Free Abrasive Machining Plate Surfaces Are Very Delicate.

FACT: The machining plate surface must not be contaminated with a particle sized larger than the abrasive grain which is being used. Particles harder than the abrasive being used also can cause scratching on piece parts where scratch-free surfaces are required. Therefore it is important to maintain a clean atmosphere in the area surrounding the machine.

The machining plate, which is typically grooved, is not destroyed if it becomes scratched or dented (stone all raised areas around indent). Remember that the parts being machined are passing over the machining plate grooves and in some cases over the I.D. and O.D. edges of the machining plate. If the scratches are deeper or wider than the grooves already in the machining plate, check the parts being machined to make sure they do not catch in the inclusions. Check cause of scratching on the machining plate surface to prevent scratching of parts requiring scratch free surfaces.