Abrasive Selection and Control in Lapping Processes

by

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In order for a lapping operation to achieve optimum results careful consideration must be given to all the factors which influence the efficiency of the process. The factors include the machine's design compatibility with the workpiece's requirements, the establishment and maintenance of machine operational parameters such as flatness and pressure limits and fixturing of the workpiece, the abrasive, the vehicle (the liquid which carries the abrasive particles), and the delivery and control of the abrasive and vehicle. The best result when you select the proper abrasive to do the job, surround it with a fluid exhibiting the proper lubrication, cooling, film thickness, and workpiece compatibility, deliver the abrasive compound to the work site, keep it there until it is worn out or has been broken down completely, and remove the spent abrasive and debris generated from the worksite.

The best abrasive to use is often the softest abrasive which is still effective in machining the hardest part to be addressed with a given lapping machine. If an abrasive is chosen which is too soft for some of the parts to be lapped then it will take too long to do the machining operation, but if the abrasive is excessively hard or tough then there exists the possibility of embedding particles in the machined surface. Aluminum oxides are generally the choice for lapping aluminum or brass parts, crystalline materials, and most steel parts. Silicon carbide is the abrasive choice for metal parts with hardnesses above approximately 60-65 on the Rockwell "C" scale. For very hard materials boron carbide or diamond may have to be used. CBN has found a home in fixed abrasive applications, but is very seldom used in loose abrasive operations. There is no substitute for experimentation in confirming the machining effectiveness of a given abrasive.

In choosing the proper size of abrasive to give the desired machining result several aspects must be considered. If the abrasive has been graded to a given "grit size" the grading specification must be known. Most manufacturers are now using FEPA (Federal Europenne des Fabricants de Produits Abrasifs), but you may also encounter ANSI (American Society B74.10-1977). The FEPA grades are more tightly controlled, and, in the smaller sizes, slightly finer. The result is that in comparing an abrasive from one source with another there exists a possibility of semantic confusion. When reference is made to an abrasive by its "micron size" it must be recognized that there are no standards to absolutely characterize nomenclature. The individual manufacturers who use micron size designations generally have developed good batch-to-batch production uniformity, but comparing the material from one manufacturer to another should be confirmed with particle size analyses to verify the average, mean, and distribution of sizes within a given size designation.

It is worth noting that the selection or disqualification of an abrasive powder should never be done on the basis of a statistical overview of particle size characterization. For most lapping applications the average size is an adequate indicator only to make a preliminary determination of expected performance. With the exception of the most sophisticated laboratories particle size distribution or population studies are totally inadequate to determine, for example, whether or not a given powder will cause scratches due to outsized particles or contamination. It is easy to demonstrate the analytical precision required to detect outsized particles, and it is worth the exercise to give a better perspective to the subject of particle size analysis. The problem may be restated as "determine the minimum percentage of outsized material which would cause scratching in every load of parts run." If we consider an operation where the lapping cycle is known, and the amount of compound used is known then the amount of outsized material which could not be tolerated may be approximated.

Let's use the following parameters:

- **LAP CYCLE:** 1 minute
- **COMPOUND USED/CYCLE:** 10 cc.
- **ABRASIVE TYPE:** Aluminum Oxide (Density: 3.97 g/cc.)
- **AVERAGE PARTICLE SIZE:** 10 microns
- **COMPOUND BATCH SIZE:** 55 gallons (400 lbs.) (208,175 cc.)
If one outsized particle is introduced to the lapping surface during this operation it will scratch one or more parts resulting in unacceptable parts.

# OF OUTSIZED PARTICLES WHICH WILL CAUSE REJECTS IN EVERY LOAD OF PARTS: 20,818 particles
(of course zero rejects requires ZERO outsized particles).

Assume that the abrasive particles are spherical for mathematical facility, then each 10 micron particle will weigh approximately:

\[ 4(3.14159)(0.0005 \text{ cm})(0.0005 \text{ cm})(0.0005 \text{ cm})/3 \times 3.97 = 0.0000000020785 \text{ g} \]

and 20,818 particles will weigh 0.00004327 g

If the 400 lb. drum is 15% abrasive then the amount of abrasive in the drum of compound is:

\[ 400 \text{ lb.} \times 454 \frac{\text{g}}{\text{lb}} \times .15 = 27,240 \text{ g} \]

and the percentage of outsized material which would cause rejects in every load of parts if homogeneously dispersed would be:

\[ 0.00004327 / 27,240 \times 100 = 0.0000015884\% \]

It is an exceptional laboratory that considers 0.01% a significant amount, but to anyone holding an expensive scratched part 0.0000001% is very significant.

The size designations for polishing abrasives are even less standardized than industrial grades of aluminum oxide and silicon carbide. Whatever the characterization of the material there should always be some skepticism when relating one source of material to another, or one type of powder to another. For some polishing applications the type of abrasive is more important than precision sizing. For some applications the particle-to-particle uniformity is the overwhelming consideration. Internal standards used by each manufacturer are applied to their products based on performance criteria under specific use conditions for a specific application, and although the designations may seem to be similar to those used for prefinishing operations the manufacturing specifications must be compared, and extreme caution must be used to avoid serious contamination problems in a polishing operation or a great deal of wasted R & D effort on a misapplied powder. In addition to "micron," "grit," and "mesh" sizes, "square meters per gram" and meaningless numerical designations are also commonplace.

Abrasive candidates for a given application can easily be evaluated using hand lapping methods. Even when a production procedure cannot be approximated with hand lapping, a little intimacy with the powder or compound can yield valuable information. The strongest case for doing a little personal hand lapping is the cost involved. Consider starting with only the abrasive powder or compound. To do a preliminary evaluation of the material by hand lapping you need either one of your pieces to be lapped (if your workpiece is unavailable or not suited to hand lapping a common washer from the toolroom or hardware store will work well), and a lap plate (if no lap is handy or you don't want to contaminate a lap place with some unknown material, I suggest trying a small metal panel, or a small piece of plate glass). Mix a little powder with your carrier, and simply move your workpiece in a circular or "figure 8" motion on your lap. You can vary pressure and get a pretty good idea as to how well your vehicle wets the abrasive, how well the compound stays between the workpiece and the lap, the finish you can expect, the aggressiveness of the abrasive, and the general cleanability of the soil generated.

The vehicle or carrier used in conjunction with the abrasive is always an important consideration. Vehicles are as varied as the types of abrasives and sometimes must be custom tailored to an application. There are liquids and pastes and, with either, a great variety of options such as oil bases, emulsions, water bases, non-suspending liquids, full suspension liquids, and custom considerations to provide the proper lubrication, wetting, dispersion, and cleaning characteristics. Only a supplier who is capable of employing all of these alternatives would be able to provide the necessary support to sort through the
options. Routine operations do not necessarily require a special lapping oil, and some operations are actually improved by changing to an inexpensive easily obtained light oil. There, of course, are many operations which need all of the help that specialty lapping oils provide. Water-based vehicles could solve many of your plants' problems, but caution should be used to avoid replacing the old problems with new problems.

Some generalized guidelines may be helpful to anyone considering conversion of an oil based lapping operation to a water based operation.

1. Water based compounds do not necessarily produce a soil which is easier to clean. You must use the proper cleaners and equipment with any soiled part.

2. It may be helpful, or even necessary, to keep lapping parts wet as they are taken from the lap to facilitate cleaning water based lapping soils.

3. The waste products from water based lapping are not generally a disposal problem unless the workpiece contributes troublesome elements.

4. Conversion must be controlled to avoid "production shock." Care should be taken to allow operators and supervisors to provide opinions and practical advice.

5. Corrosion prevention must be considered when using water based lapping vehicles. The machine must be protected as well as any parts sensitive to oxidation.

6. Both oil and water vehicles are flexible enough to provide the proper lubrication, cooling, abrasive dispersion, and suspension required for most applications. The finishes possible and cutting rates are essentially the same for both oil and water bases.

The oldest method for handling abrasive compounds is hand application, and it is still one of the better options for some procedures. Paste compounds are generally hand applied as are some liquids in smaller or difficult operations. Most lapping in a medium or high volume production scheme will require some degree of control and automation. There are at least two levels of abrasive control to consider.

The standard method of handling abrasives has been to employ the semi-automated delivery systems supplied with most conventional lapping machines. These systems commonly require that the vehicle be measured into a mixing container, and that the dry abrasive be added with agitation. The resulting mixture is then pumped or otherwise conveyed to the lapping site. The range of efficiency provided by all of the semi-automated systems is very wide. The composition of the compound is most often left to the machine operator. Variance and machining conditions may vary from operator to operator, and are subject to distractions and the daily disposition fluctuations of some operators. There is often a tendency of the abrasive to separate from the vehicle during transport from the agitated mixing tank to the lapping plate resulting in inconsistent flow, clogged lines, fouled valves, and associated problems in lapping. Fine abrasives and small machines are generally less likely to be adversely affected by abrasive settling.

Completely automated abrasive control is provided by fully suspending the abrasive in the vehicle at a precise concentration, and delivering the suspended, homogeneous mixture to the lapping site using positive displacement metering equipment. An extra measure of control and flexibility is afforded by metering an abrasive concentrate to the lapping site, and diluting the concentrate with oil or water provided by a second metering pump, and after a brief in-line mix of the concentrate and diluent, the controlled mixture is introduced to the lap. By metering both the diluting fluid and the abrasive concentrate the total flow as well as the amount of abrasive is controlled with automated precision. The optimum amount of fluid for lubrication and flushing may be kept to a minimum insuring that good abrasive is not washed from the table by a flood of vehicle. Operating costs are minimized as efficiency is increased. Increased efficiency improves productivity. The only completely automated abrasive delivery system has been patented, and is available only through Chemical-ways Corporation, 901 Sherwood Drive, Lake Bluff, Illinois 60044.