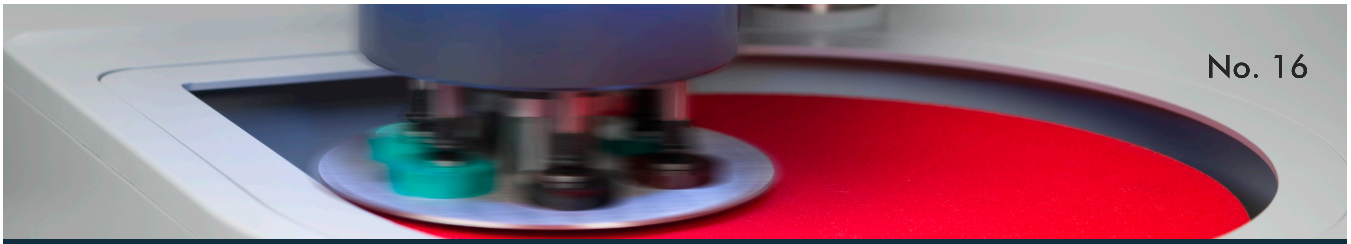


No. 16

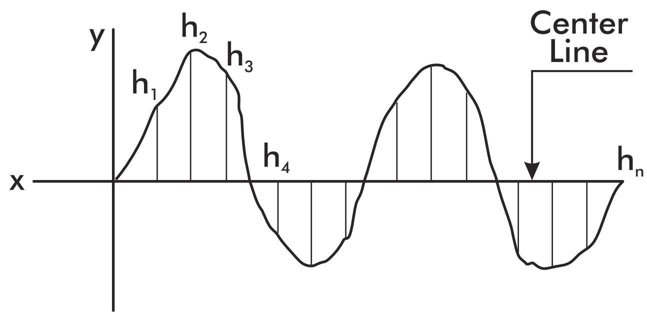
LECO MET-TIPS Ideas for Metallographic Procedures

Surface Roughness

The term "surface roughness" is more applicable to the mechanical field than to the metallurgical field and, in general, refers to machined parts that have working surfaces. For example, bearings, gears, and pistons have surfaces that work against the surfaces of another part. Working parts where close tolerances are specified require a close control of surface roughness, and blueprints will indicate the degree of finish required by a machining operation.

Surface roughness values are expressed in microinch units. A microinch is one-millionth of an inch (0.000001) and is abbreviated as (μin.). The American Standard specifies surface roughness measurements as an arithmetical average (AA) deviation from the mean surface. This average is somewhat less than the root mean square (RMS) average deviation which was formerly in wide use. Mean surface is the perfect surface (i.e., a surface having no asperities). It is also referred to as the center line, and the roughness values obtained around this center line are referred to as center line averages (CLA).

AA values can be obtained by an instrument using a very fine stylus that is moved over the surface of the part. It takes a great many measurements of the heights of the peaks and valleys of the surface (measured around the mean surface) and averages them. The path of the stylus can be plotted on a thin strip of graph paper or be indicated on a gauge. A hypothetical profile of a surface is shown in the following diagram.



Arithmetical average roughness is obtained by adding all the ordinates (h) in the y direction, without regard to sign, and dividing the sum by the number of ordinates added (n).

$$\text{AA Average} = \frac{h_1 + h_2 + h_3 + h_4 + \cdots + h_n}{n}$$

The root mean square is derived as follows.

$$\text{RMS Average} = \sqrt{\frac{(h_1)^2 + (h_2)^2 + (h_3)^2 + (h_4)^2 + \cdots + (h_n)^2}{n}}$$

Roughness measuring instruments calibrated to give RMS values will read approximately 11% higher for a given surface than instruments calibrated for AA values. This is because of the large numbers obtained when squaring the (h) ordinates. Inspection of surfaces by instruments calibrated to give AA values to blueprint specifications given in RMS values theoretically would allow acceptance of surfaces having up to 11% greater roughness than originally intended. As a consequence, the trend is to adopt the American Standard where surface roughness is specified in arithmetical average (AA) deviation values.

As mentioned earlier, surface roughness is seldom considered in metallographic practices, at least as far as actual values are concerned. One is aware that in the grinding steps the coarser the grit being used, the rougher the sample surface will be. Grinding with succeedingly finer grit sizes will ultimately produce a surface suitable for the polishing steps. However, there is always the nagging question of just what is the surface roughness obtained from the various silicon carbide grit sizes used in a metallography laboratory, and does surface roughness play any role in determining what polishing steps are to be used. Experimental studies were conducted using both manual and automatic grinding techniques to determine the relative surface roughness of samples after being ground through the various grit sizes and to determine if heavy pressure has any effect on surface roughness.

For the studies, eighteen samples were sectioned from an annealed, 1.25-inch diameter, austenitic 304 stainless steel bar. Austenitic stainless steel was selected because of its homogeneous microstructure. The eighteen samples were divided into three groups, six samples per group. Samples in Group I were ground manually; samples from Group II were ground automatically using LECO's Automatic Polisher for 60 seconds at 45 psi, with a grinding wheel rotation of 300 rpm. Samples from Group III were initially ground in the same manner as those from Group II, then ground an additional 30 seconds at 30 psi, with a wheel rotation of 200 rpm. All samples in each group started with a 120-grit grind, and as grinding proceeded through the succeedingly finer grit sizes, one sample was dropped out after each grind. For example, the sixth sample, which had a 600-grit grind, was ground through all six grinding steps being evaluated. Each sample from Group I was ground on a fresh, unused paper, and grinding at each step continued until all scratches were uniform and unidirectional. Samples ground automatically were processed six at a time and the scratches were random. Ordinary tap water was used as a coolant, and after each grinding step, the samples were ultrasonically cleaned, rinsed in ethyl alcohol, and dried in a stream of air.

Surface roughness measurements were obtained across the diameter of each sample using an instrument which produced a hard copy of the peaks and valleys of the surface texture. Standard calibration blocks were used to check the sensitivity of the instrument. The results are contained in the following table.

SiC Grit Size	Group I[(a)]	Group II[(b)]	Group III[(c)]
120	9	8	7
180	5	3	3
240	4	5	4
320	4	3	2
400	2	1	1
600	2	1	1

(a) Manually ground
(b) Automatically ground—60 seconds, 300 rpm, 45 psi
(c) Automatically ground—same as above, plus an additional 30 seconds, 200 rpm, 30 psi (use of extension mode)

An analysis of the experimental data indicated that, generally, the surfaces were finer on samples from Group II and Group III. Interestingly, there was no apparent difference between the 240 and 320-grit grinds on samples from Group I, but more interesting was the 240-grit grind produced tougher surfaces than the 180-grit grind on samples from Groups II and III. Further analysis of the data obtained on samples from Group II and Group III would seem to indicate that the 240-grit grind could be eliminated without a sacrifice in surface quality; and since there was no difference between the 400 and 600-grit grind, the 400-grit grind could be eliminated—thus having a grinding sequence of 180, 320, and 600. Data obtained from these experimental studies substantiated data obtained from earlier experiments whereby the effects of varying pressure versus the rate of metal removal was studied using automatic grinding procedures. In these earlier studies, analysis of the experimental data showed there was not a significant difference in the amount of metal removed from steel samples subjected to a 180 and a 240-grit grind, and very little difference between the 400 and 600-grit grind. Experiments were then performed with ferrous and nonferrous alloys whereby the grinding sequence consisted of 180, 320, and 600-grits only—the 240 and 400 grits were eliminated. The subsequent polishing steps were normal for the particular material being prepared. Extensive microscopic examination of the specimens in the as-polished and etched conditions revealed flatter edges, less disturbed metal, and flatter inclusions than in specimens which were manually prepared using all the grinding steps and then polished. Furthermore, taper sections taken on the plane perpendicular to the original plane of polish revealed considerably less deformation in the automatically prepared specimens than in the manually prepared specimens.

The results of the two experimental studies show that with automatic grinding and polishing procedures, several grinding steps can be successfully eliminated without a sacrifice in quality. Moreover, since there is less deformation introduced by automatic grinding, quality can be improved and subsequent polishing steps will require less time.

It is recommended that none of the grinding steps be skipped when manual grinding is performed. Since the depth of deformation is greater when manual grinding is performed, each grinding sequence is required to remove the deformation introduced by the preceding grind.

LECO Corporation would like to thank Dr. Lee Dillinger for his contributions to this project.

LECO Corporation
3000 Lakeview Avenue | St. Joseph, MI 49085 | 800-292-6141 | Phone: 269-985-5496
info@leco.com | www.leco.com | ISO-9001:2015 Certified | LECO is a registered trademark of LECO Corporation.

