MEASURING SURFACE FINISHES

Methods used to measure and record surface finishes, describes surface finish values, and explains how to specify surface finishes for machined parts.

Technical Report

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1.0 INTRODUCTION

The performance of BAL™ Seals in dynamic sealing application is affected by numerous factors, such as alignment of moving parts, shaft or bore material and hardness, use of lubricant films, seal material flexibility, friction and wear properties, etc. The surface finish of the counterface in contact with a BAL Seal can have a significant effect on seal performance.

This report discusses surface finishes and factors to consider when specifying surface finishes to use in contact with seals. These include:

- Surface finish values systems
- Surface finish measuring instruments
- How to specify surface finishes
- How the counterface surface finish affects BAL Seal performance

2.0 SURFACE FINISH VALUES

There are several roughness value systems in use. The arithmetic average roughness system measures the arithmetical average deviation of the actual surface from the surface profile mean. The geometric average roughness system measures the geometric average deviation from the same mean.

2.1 Arithmetic average roughness (Ra, AA, and CLA)

Ra = Roughness by arithmetic average
AA = Arithmetic average
CLA = Centerline average

These terms use the same principle in calculating the average surface roughness. Arithmetic average values are explained in Figure 1 with a few sample calculations. The wavy line, A-B, represents a typical cross section of a machined surface when magnified. The arithmetical average deviation from the mean is determined by first drawing the mean, or nominal surface line, for reference. The mean line is positioned parallel to the plane of the surface being measured at such a position that the areas between it and the wavy surface contour are equal above and below the line. The mean line is then marked off into a series of equal division (a, b, c, etc.). At each of these marks, a measurement is made perpendicular to the mean line, from the mean line to the irregular surface (line A-B). These values are tabulated and totaled and then divided by the number of measurements taken.

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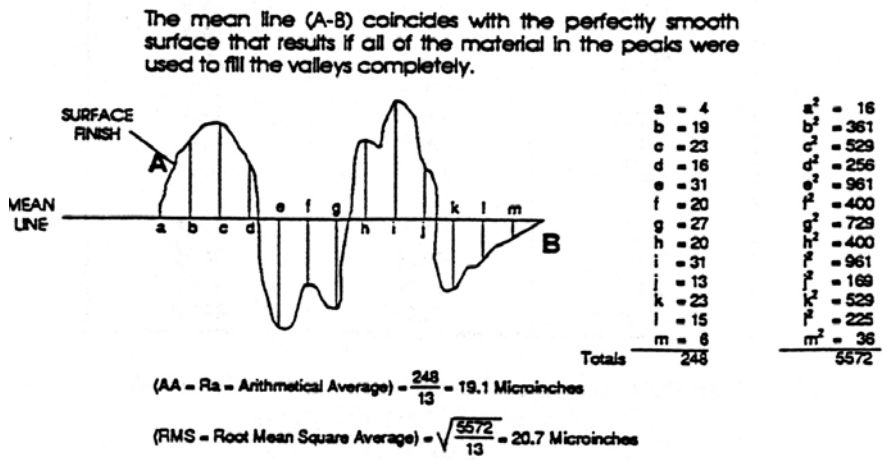


Method Used to Calculate Arithmatic Average Roughness and Geometric Roughness
FIGURE 1

2.2 Geometric average roughness (RQ and RMS)

RQ = Geometric average roughness
RMS = Root mean square

These terms use the same principle to calculate the average surface roughness. RMS or RQ is calculated by taking the same measurements as given for Ra, squaring them, dividing the total by the number of measurements, and taking the square root of the result. The resulting value is approximately 11% higher than the Ra value for the same surface. RQ and RMS are sensitive to occasional highs and lows, making them a valuable complement to Ra.

2.3 English and metric roughness values

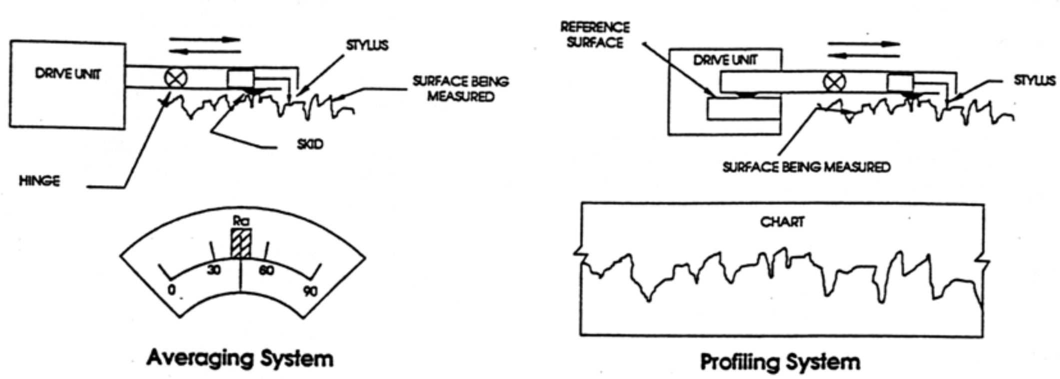
There are two valid units for average roughness, the microinch and the micron. Microinches are millionths of an inch (0.000001 inch). Microns are millionths of a meter (0.000001 meter). The microinch was selected as the original basic unit of measurement because the roughness irregularities of ordinary machined surfaces were of such a magnitude that their average roughness could be expressed in simple whole numbers (e.g.: 4, 8, 16, 32 microinches, etc.). The approximate metric equivalents to these values are now becoming the accepted and preferred values (e.g.: 0.1, 0.2, 0.4, 0.7, 0.8 micrometers, etc.). The chart in Figure 2 gives a comparison of these designations as well as RMS values. The American Standard for Surface Texture in ANSI B46.1-1978 gives Ra as the standard surface finish designation. In most applications where RMS is called out. The same figure can be expressed in Ra without changing the degree of roughness. (e.g.: 8 microinches RMS = 8 microinches Ra).

RMS, RQ (microinches)	Ra, AA, CLA ENGLISH (microinches)	Ra, AA, CLA Metric (microns)
1.00	0.90	0.023
1.11	1.00	0.025
2.00	1.80	0.046
2.22	2.00	0.051
4.00	3.60	0.091
4.44	4.00	0.102
6.00	5.41	0.137
8.00	7.21	0.183
8.88	8.00	0.203
12.00	10.81	0.275
16.00	14.41	0.366
17.76	16.00	0.406
32.00	28.83	0.732
35.52	32.00	0.813
63.00	56.76	1.442
69.93	63.00	1.600

Figure 2

3.0 SURFACE FINISH MEASURING INSTRUMENTS

There are two basic types of instruments used to measure surface finish: skid, or averaging instruments, and skidless, or profiling instruments (See Figure 3).



Surface Finish Measuring Instruments
FIGURE 3

3.1 Averaging instruments

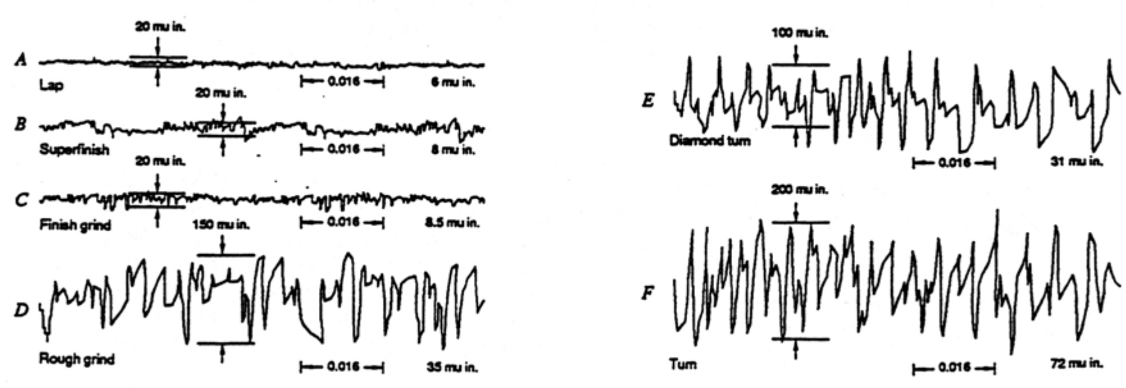
Averaging instruments are not sensitive to surface waviness and respond only to roughness. In operation, both the stylus and a skid ride on the surface measured. This design does not monitor waviness, which is filtered out to some extent by the skid. Roughness values are indicated on a meter.

3.2 Surface profiling instruments

A profiling instrument has an integral reference surface that allows the stylus to record waviness deviations as well as roughness. With skidless equipment, the stylus moves relative to a precision reference surface built into the instrument. The stylus is the only limiting factor in following the irregularities on the surface being measured. The surface profile is represented by a chart recorder printout, which provides more accurate data than an averaging meter. The surface texture can then be analyzed from the printout.

3.2.1 Surface profile records of various machined surface

Figure 4 shows some typical profile recordings of various machined surfaces attained with surface profiling instruments. Note the sawtooth pattern of rougher surface finishes. As roughness values decrease, abrasive wear on Bal Seal decreases.



Profile Recordings of Various Machined Surfaces
FIGURE 4

4.0 HOW TO SPECIFY SURFACE FINISHES

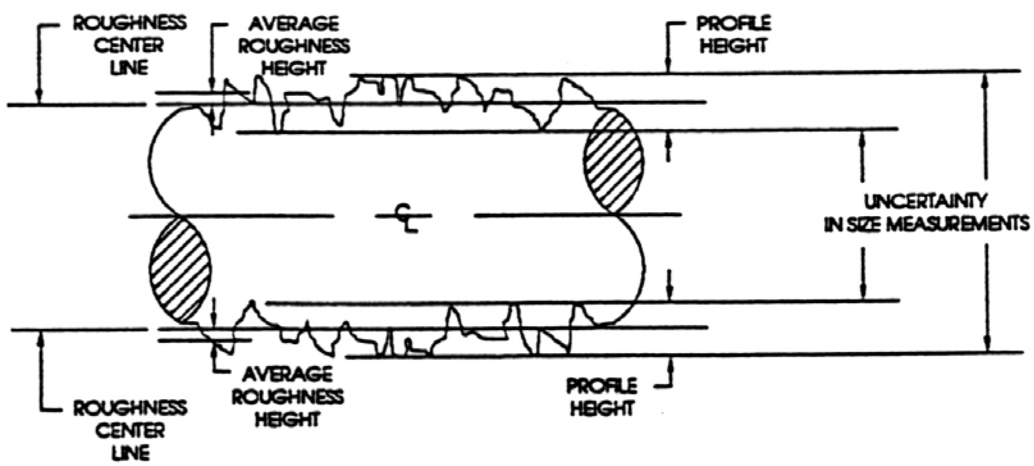
Selection of surface finish values for a specific sealing application must take into consideration the service conditions, shaft or bore materials, cost, performance requirements, and methods of attaining a good surface finish. It is also necessary to have an understanding of the various roughness values currently in use. The basic reference document in the United States for all matters concerning the designation, measurement and control of surface texture is ANSI B46.1-1978 Surface Texture Standard (formerly ASA B46.1-1962). This document standardizes terminology and measurement of the various aspects of surface texture, defines characteristics of stylus instrumentation for measuring roughness, standardizes surface texture symbols for drawings, etc. It is recommended that the reader obtain a copy of this standard for more details on the subject of surface texture.

4.1 Selection of sample area for measurement

The sample area is the specified distance over which a roughness assessment is taken on the surface of a part. The sample selected for Ra measurement must be large enough to provide an adequate amount of information, yet small enough so that it does not include waviness deviations, which would distort an Ra reading. According to ANSI B46.1-1978, six different sample lengths can be specified, ranging from 0.003 inch to 1.000 inch. In general, if the roughness average of a surface is between 10 and 120 microinches Ra, a sample of 0.030 inch is used. For a finer surface, a 0.010-inch sample length is sufficient. For a roughness below 2 or 3 microinches Ra, a 0.003-inch sample length should be specified.

4.2 Surface finish in relation to dimensional tolerances

On most machined parts, the combined profile height, as shown in Figure 5, is about four times the average roughness. Therefore, the specified tolerance on a diameter should be at least eight times the Ra value called out for the surface of the part. Otherwise, the deviation in surface roughness alone can exceed the allowable dimensional tolerance.



Relationship of Surface Finishes to Dimensional Tolerances
FIGURE 5

5.0 HOW THE COUNTERFACE SURFACE FINISH AFFECTS BAL™ SEAL PERFORMANCE

The finish of a counterface can have a substantial affect on the BAL Seal's performance. Better seal performance may be obtained by finishing the counterface from 2 to 10 microinches Ra. In some light duty applications, a rougher surface finish may be specified to avoid unnecessary expense. However, a counterface made from a harder material with a better surface finish will help improve BAL Seal performance and reliability and should be specified when warranted by the application.

6.0 SUMMARY

The surface finish of a part can be measured using one of two roughness value systems: arithmetic average roughness or geometric average roughness. The roughness by arithmetic average (Ra) is the accepted standard and can be measured in English (microinches) or metrics (microns) units. Surface finishes are measured using averaging or profiling instruments. Averaging instruments cannot measure waviness and typically display surface finish values on a meter. Profiling instruments display surface finish values on a chart recorder printout, which represents the profile of the surface, and give more accurate data for analyzing the surface texture. The surface texture standard, ANSI B46.1 – 1978, provides detailed information about the specification of surface finishes. Dynamic surfaces in contact with BAL Seals should have a specified finish. The finish of a counterface can have a significant effect on seal performance. In critical applications, BAL Seals perform better when in contact with surfaces having a finish of 2 to 8 microinches Ra.

7.0 REFERENCES

"Control of Surface Quality" by Surface Checking Gage Co., Hollywood, CA.

"Surface Texture – ANSI B46.1-1978," Published by American Society of Mechanical Engineers, United Engineering Center, New York, NY.

"Tool Engineer's Handbook" by ASTE Handbook Committee, McGraw-Hill, NY 19149.