Introduction to Surface Finish & Mechanical Design

Surface finish (also called: *Texture*) is a non-trivial subject. This paper provides only a general overview of the subject. It is not intended to replace a more specific study of the subject necessary for advanced application of surface conditioning. It is an introductory overview and should not be taken for more.

The most common application of surface finish measures only the arithmetic average of the roughness of a surface. This is measured in micro-inches (µ-in) or micro-meters (µm) and identified as the value Ra. There are many additional measures of surface roughness used in particular instances, but the other ones most commonly used are: Rq, the *Root Mean Square* (RMS) of a surface's roughness; and Rz, the average of the highest and lowest points (the means of determining them vary according to the specification being employed). Anyone needing more information on this subject is encouraged to read ASME/ANSI Y14.36M-1996 (R2008) *Surface Texture Symbols*, ASME/ANSI B46.1-2002 *Surface Texture, Surface Roughness, Waviness and Lay*, and ISO 1302:2002 *Geometric Product Specifications*. They are the source authority for this subject. This paper focuses on the ASME/ANSI specification system and ignores the ISO system for the most part.

General Overview of Surface Roughness:

There is something inherently pleasing in a smoothly polished surface. It appeals to our sense of quality and fineness. It takes time and effort, and hence cost, to produce such a surface. French-polishing of pianos and other fine furniture is just one example of the appeal of this type of surface. However, if this is applied to the handle of a knife, it can make it slippery and hard to hold for use. Mirror polished stair treads are death looking for a place to happen when they are wet. These are just some of the reasons we may **not** want a smoothly polished surface (beyond the cost of manufacture). These are considerations a well trained designer considers when specifying a surface finish – others are discussed later.

Surface Roughness by Manufacturing Process:		
Ra (µ-in):	Ra (µm):	Process:
2000	50	High-speed Flame or Plasma Cutting
1000	25	Flame Cutting
500	12.5	Open Jaw Shearing, Rough Machining
250	3.2	Rough Machining, Sawing, Hydraulic Chopping, Plasma Cutting
125	1.6	Blanking, EDM, Cold Sawing, Planing/Shaping, Milling, Turning
63	0.8	Milling, Turning, Rolling/Swaging, Fineblanking, ECM
32	0.4	ECM, Tumble Polishing, Reaming, Broaching, Buffing
16	0.2	Buffing, Fine Abrasives, Electrolytic Polishing
8	0.1	Electrolytic Polishing, Burnishing, Lapping
4	0.05	Lapping, Superfinishing
1	0.025	Superfinishing, Electropolishing

Table 1: Common Ra Values & Processes

An Ra finish of 125 µ-in (1.6 µm) is the basis for fatigue life cycle testing and analysis for automotive and aerospace parts. An Ra finish of 63 µ-in (0.8 µm) is mostly used for sliding fits such as shaft and bearing type fits and some static pressure seal surfaces. An Ra finish of 32 µ-in (0.4 µm) is common for higher pressure static sealing surfaces and dynamic sealing surfaces. Care must be taken in assigning Ra values to sealing surfaces as a rougher (larger Ra value) surface is often needed to assure lubrication of the seal. A surface with an Ra of 16 μ-in (0.2 μm) is used in some ultra-high-pressure sealing.

Ra finishes finer than 16 μ-in (0.2 μm) is pretty much limited to optical components, ultra-laminar fluid flows, and medical components. The cost of processing nearly triples each time the Ra surface finish value is halved. That is a traditional statement. Milling and lathe technologies have improved since the last major finish/cost study was done and I know that I routinely produce finishes today that would have been post-machine processed to achieve in the 1960's. Similarly, abrasives and chemical processing has improved incredibly over that same period. However, one rule that is likely never to change is the one that states, *No finish will ever be better than the surface over which it is laid*. Any additional finish such as painting or plating added to the surface will need a finer finish onto which it is laid to meet the basic Ra requirements.

Surface Roughness Symbology:

The designer must communicate to the shop the surface finish requirements of the parts to be made. The language of this communications is a set of symbols defined for American usage under the ASME/ANSI Y14.36 standard. They are:

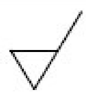
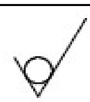
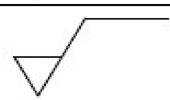
	General Surface Texture Symbol	Note 1.
	Machined Surface Texture Symbol	Note 2.
	As-Cast Surface Texture Symbol	Note 3.
	Extended Requirement Surface Texture Symbol	Note 4.

Table 2: Surface Finish Symbols

Note 1: This symbol is the general purpose symbol. It requires no machining if the surface of the part meets the defined surface roughness (etc.) requirements.

Note 2: This symbol requires that the surface of the part be machined and meet the defined surface roughness (etc.) requirements.

Note 3: This symbol requires that the surface of the part (as cast, forged, or rolled) meet the defined surface roughness (etc.) requirements with no additional machining or processing.

Note 4: This symbol is used when requirements in addition to Ra values be met.

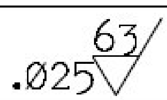
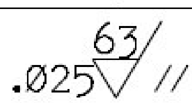
	63 micro-inch Ra Finish Specified.	Note 5.
	.025 inch Maximum Clean-up Specified.	Note 6.
	Parallel Texture Lay Specified.	Note 7.

Table 3: Surface Finish Symbols

Note 5: The position *in the vee* specifies the Ra roughness value. If only one value is given, it means that a surface of this value or finer (lessor Ra value) is acceptable. If a stacked set of values is given, then the Ra roughness value of the surface must be no coarser (larger numeric value) than the *upper* value **and** that the Ra roughness value of the surface be no finer than the *lower* value. Such dual-value roughness requirements are most common in sealing surfaces where lubrication must be maintained.

Note 6: The .025 value placed in the *outside lower left* position states that no more than .025 inch be removed from the surface of the part while machining to meet the Ra surface roughness value.

Note 7: The symbol placed in the *outside lower right* position defines the *lay* of the surface roughness.

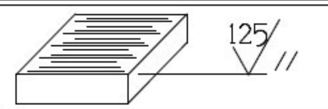
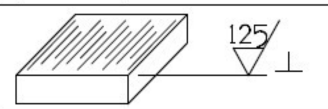
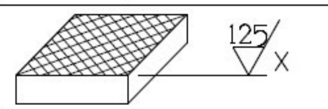
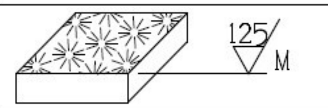
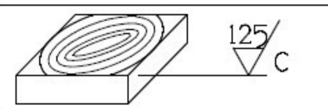
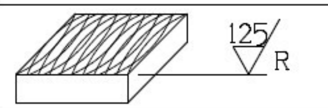
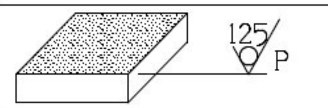
Parallel		**Texture to lay parallel to indicated edge. Typical Manufacture: Shaping, Side Milling, Rolling, Grinding, or Lapping.**	**Note 8.**
Perpendicular		**Texture to lay perpendicular to indicated edge. Typical Manufacture: Shaping, Side Milling, Rolling, Grinding, or Lapping.**	**Note 9.**
Crosswise Hatch		**Texture to lay crosswise to indicated edge. Typical Manufacture: Fly Cutting, Shaping, Grinding, or Lapping.**	**Note 10.**
Multi-Directional		**Texture to lay without clear direction to indicated edge. Typical Manufacture: Orbital Grinding, or Random Pattern Milling.**	**Note 11.**
Circular		**Texture to lay circularly to indicated edge. Typical Manufacture: Turning, Rotary Table Milling, or Blanchard Grinding.**	**Note 12.**
Radial		**Texture to lay radially to indicated edge. Typical Manufacture: Fly Cutting, Blanchard Grinding, or Face Milling.**	**Note 13.**
Particulate, Non-Directional		**Texture to lay parallel to indicated edge. Typical Manufacture: Sand Casting, Die Casting, or EDM/ECM.**	**Note 14.**

Table 4: Surface Finish Symbols

Note 8: The texture of the surface roughness shall lay parallel to the indicated edge of the part. This is most often achieved through face milling, shaping/planing, rolling, grinding, or lapping. It may be used to provide a specific sliding part orientation.

Note 9: The texture of the surface roughness shall lay perpendicular to the indicated edge. It is made in the same manner as parallel lay orientation, just 90° from that edge position. It may be used to provide a specific sliding part orientation.

Note 10: A crosswise hatch texture/lay is often used to increase grip of a surface or retain lubricant on sliding surfaces.

Note 11: No consistently discernible orientation shall exist to the lay. This is also used to denote a surface that will be scraped. It is often used to establish a *matte* surface for additional finish or to retain lubricant on sliding surfaces.

Note 12: This texture is sometimes used to provide a circular alignment or slide direction between parts.

Note 13: This texture is often used to demonstrate the flatness of a machined plane. It may also be used to retain lubricant between sliding parts.

Note 14: This texture is often used to mask surface imperfections in cast or forged parts. The pattern is often chemically etched (ECM) or spark eroded (EDM) into a die surface. It is most commonly used with the *no machining allowed* surface symbol for cast or forged parts.

Additional Considerations: Epoxy or urethane adhesive bonded surface benefit from a rougher finish texture. A 250/125 (µ-in – 3.2/1.6 µm) surface roughness adds to the strength of the bond. Orientation of the lay may be used to gain directional strength in this type of joint. Similar considerations apply to surfaces that will be sealed, painted, or chemically treated. Careful consideration and testing of surface roughness can improve a design. Blithely applying an unneeded surface finish adds to cost. Improperly considered surface finish may well detract from a product's functionality.

The Extended Requirement Surface Texture Symbol:

Although not commonly used, the extended requirement surface texture symbol provides finer definition of a surface finish.

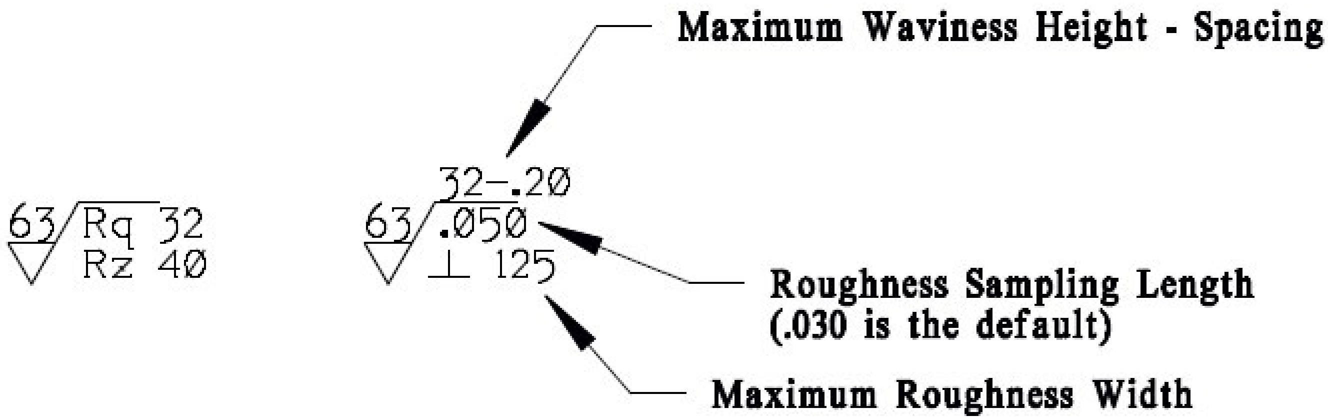


Figure 5: Extended Requirment Surface Finish Symbols

The left-hand example shows the application of Rq and Rz requirements to an otherwise typical surface finish symbol. The right hand example shows the application of *Maximum Waviness Height Spacing*, *Maximum Roughness Width*, and *Roughness Sampling Length* requirements to a surface finish symbol. Details of these applications are beyond the scope of this introduction and a reader wishing to use them in their work should review ASME/ANSI Y14.36M-1996 (R2008) *Surface Texture Symbols*, ASME/ ANSI B46.1-2002 *Surface Texture, Surface Roughness, Waviness and Lay*, *Machinery's Handbook*, and ISO 1302:2002 *Geometric Product Specifications* for more information.

Measuring Surface Roughness:

Surface roughness is usually measured electro-mechanically or optically. Electro-mechanical devices usually operate on a process similar to a phonograph. A very fine “needle” is slowly dragged across the surface to be measured and the amplitude of the needle's movement recorded and analyzed. These types of devices usually output: Ra, Rq, and Rz values. Optical devices use diffracted light to make these measurements. Metrology equipment dealers are usually happy to demonstrate them so long as you are up-front with your purpose in visiting them. Any design engineer, draftsman, or machinist who needs to work with surface finish requirements would do well to make such a visit.

