Surface Finish Charts

Surface Finish Affects Performance

The surface finish of process vessels, piping and related components can be a critical factor in their performance, maintenance costs, and service life. Until recently, specifying and measuring surface finish involved varying degrees of speculation. Today, it is more likely that this characteristic will be influenced by industry standards, which manufacturers and processors must satisfy.

Increasingly stringent specifications are creating greater demand for improved surface finish on most metal components that are part of process equipment. In particular higher purity requirements for pharmaceutical and biotechnology products are dictating the characteristics of surfaces in contact with process fluids. Increasingly, process equipment components must meet requirements in the ASME Bio-processing equipment standard, ASME-BPE-2009.

This standard provides specifications for the design, manufacture and acceptance of vessels, piping and related components for application in equipment used by the biotechnology, pharmaceutical, and personal care product industries. It includes aspects related to sterility and cleanability, materials, dimensions and tolerances, surface finish, material joining, and seals. Meeting the surface finish requirements of this standard is rapidly becoming a universal necessity in the manufacture of other fluid process equipment. As a result, suppliers of equipment and components are often required to quantify the surface roughness of their finished products.

Some additional standards and specifications that directly or indirectly affect surface finish requirements include:

- ASME B46.1-2002 - Surface Roughness, Waviness, and Lay
- ISO 4287 and 4288 - Geometrical Product Specifications (GPS)
- DIN ISO 1302, DIN 4768 - Comparison of Roughness Values
- ASME Y14.36M - Surface Texture Symbols
- ASME B16.5 - Pipe Flange Face Roughness
- DIN 7079 Standard for Fused-Glass Sight Glasses in Metal Frames

Such standards have come into play because process engineers realize that the surface finish of vessels, piping and related components can have profound effects on how well a fluid system performs. Typically, surface roughness is a critical parameter in the assessment of surface finish on fluid system components. This parameter can affect fluid flow resistance (friction), adsorption/desorption, the build-up of chemicals from a process fluid, corrosion formation, pressure drop, etc. Ultimately, surface finish can affect service life and maintenance costs.

Surface Finish Measurements and Charts

All manufactured components have some form of surface texture, which has elements of lay (the machining or forming pattern), surface roughness, and waviness. In addition, inherent material properties may contribute to surface porosity, inclusions, and residual elements. The parameters of texture are vertical amplitude variations, horizontal spacing variations, or some hybrid combination of these. Surface roughness is an expression of finely spaced vertical surface irregularities, as opposed to waviness, which is irregularities with spacing greater than surface roughness.

Depending on conventions in different countries, industries, applications, etc. the units used to express surface finish or roughness will vary. Likewise, various industry standards are used to specify the degree of roughness allowed or recommended in different applications. These standards include those published by ANSI, ASME, SAE, ISO, and other organizations.

Commonly used expressions of finish include:

- **Standard grit reference** - refers to the grit of a surface finishing medium or method, which does not provide a consistent measure of roughness, since results depend on a part's material, finishing method, lubricant used (if any), and applied work pressure.
- **N** - New ISO (Grade) Scale numbers. These are used on manufacturing drawings that specify surface finish in terms of an ISO standard. Each roughness grade number can be correlated to a specific Ra number that is expressed in microns.
- **Ra** - Roughness average, most commonly expressed in micrometers (microns). This is the most universally recognized and used international standard of roughness measurements. It is the arithmetic mean of the absolute departures of a roughness profile from the mean line of the measurement. Ra may also be expressed in microinches.
- **CLA** - Center Line Average in micro-inches. This is a conversion using Ra(µm) x 39.37.
- **RMS** - Root Mean Square in micro-meters or micro-inches; i.e., the average of peaks and valleys of a material's surface profile as calculated from a number (n) of measurements (x) along the sampling length:
  $$x_{\mathrm{rms}} = \sqrt{\frac{1}{n}\left({x_1}^2 + {x_2}^2 + \cdots + {x_n}^2\right)}$$
- **Rp** - Maximum profile peak height.
- **RSm** - The mean spacing between profile peaks on the mean line, measured along the sampling length.
- **Rt** - The total height of a roughness profile, typically expressed in microns, is the maximum peak-to-valley height along the assessment length.

Most expressions of roughness can be converted from one form to another. For example, CLA (microinches) = Ra(µm) x 39.37(inches/meter)

Other conversions use factors that have been establish as generally acceptable over time. In the case of RMS, a range of factor values from 1.1 to 1.7 can be acceptable. A factor of 1.1 is probably use most often, i.e., RMS(µin.) = CLA(µin.) x 1.1. Table 1 lists conversions for some commonly used roughness expressions and values.

Table 1. Conversion chart for equivalent expressions of roughness.

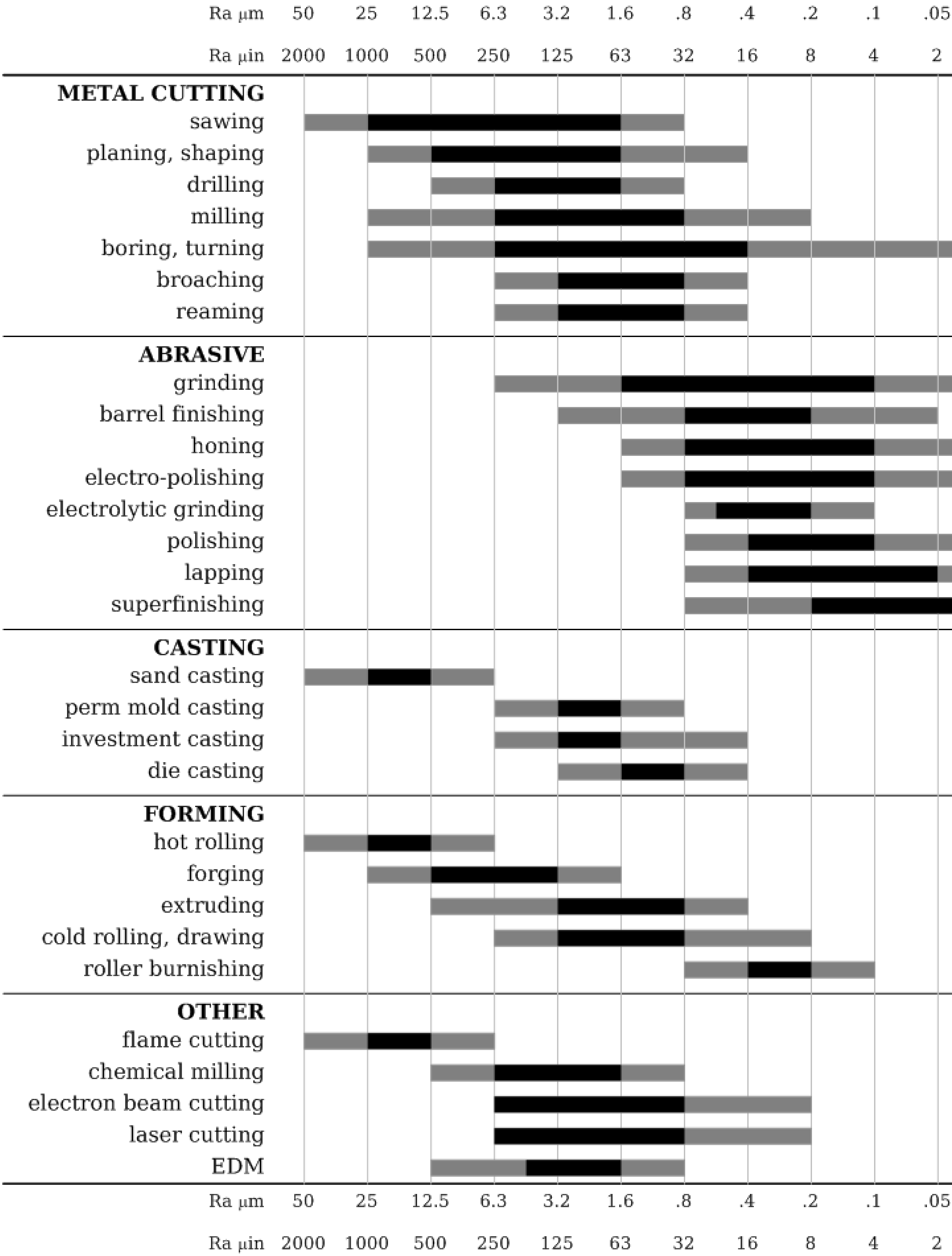
Grit No.	ISO No.	Ra (µm)	Ra (µin.)	CLA (µin.)	RMS (µin.)[1]	Rt (µm)[2]
-----------	N12	50	2000	2000	2200	200
-----------	N11	25	1000	1000	1100	100
-----------	N10	12.5	500	500	550	50
60	N9	6.30	250	250	275	25
-----------	N8	3.20	125	125	137.5	13
80	-----------	1.80	71	71	78	9.0
-----------	N7	1.60	63	63	64.3	8.0
120	-----------	1.32	52	52	58	6.6
150	-----------	1.06	42	42	46	5.3
-----------	N6	0.80	32	32	32.5	4.0
180	-----------	0.76	30	30	33	3.8
220	-----------	0.48	19	19	21	2.4
-----------	N5	0.40	16	15	17.6	2.0
240	-----------	0.38	15	12	17	1.9
320	-----------	0.30	12	9	14	1.5
400	-----------	0.23	9	8	10	1.3
-----------	N4	0.20	8	4	8.8	1.2
500	N3	0.10	4	2	4.4	0.8
-----------	N2	0.05	2	1	2.2	0.5
-----------	N1	0.025	1	1	1.1	0.3

Notes:
1. A factor of 1.1 X CLA is used throughout this table to calculate RMS(µin.)
2. Typically, for values of Ra from 50µm to 3.2µm, the conversion factor for Rt (µm) is 4. As surface roughness decreases from 3.2µm, the conversion factor increases, reaching 12 at 0.025µm. This is reflected in the table above.

Manufacturing Processes

Primary manufacturing processes establish the initial surface characteristics of components and their roughness values. In the case of metallic components, additional finishing processes may be used to reduce the degree of roughness to fit a specific application. Table 2 lists typical Ra values for various metal finishing methods. In the case of fluid system components, the motivation to reduce surface roughness could be to reduce flow resistance and pressure drop, improve sealing, reduce build-up of process chemicals on the metal surface, improve corrosion resistance to increase life, etc. In sight glasses, for example, the surface roughness of both the glass and the metal mounting ring are critical for achieving a good seal in the installation.

Table 2. Typical range of Ra surface roughness values in various metal forming operations.



Ra μm 50 25 12.5 6.3 3.2 1.6 .8 .4 .2 .1 .05
Ra μin 2000 1000 500 250 125 63 32 16 8 4 2
METAL CUTTING
sawing
planing, shaping
drilling
milling
boring, turning
broaching
reaming
ABRASIVE
grinding
barrel finishing
honing
electro-polishing
electrolytic grinding
polishing
lapping
superfinishing
CASTING
sand casting
perm mold casting
investment casting
die casting
FORMING
hot rolling
forging
extruding
cold rolling, drawing
roller burnishing
OTHER
flame cutting
chemical milling
electron beam cutting
laser cutting
EDM
Ra μm 50 25 12.5 6.3 3.2 1.6 .8 .4 .2 .1 .05
Ra μin 2000 1000 500 250 125 63 32 16 8 4 2

Source: Wikipedia: http://en.wikipedia.org/wiki/Surface_finish