Fits, Tolerance and surface roughness

Definitions of Terms:

There are some important terms needed to know in tolerance dimension according to [ANSI Y14.5M-1982] such as:

- **Nominal Size:** The designation that is used for the purpose of general identification is usually expressed in common fractions.
- **Basic Size or Dimension:** The theoretical size from which limits of size are derived by application of allowances and tolerances, the basic size is the decimal equivalent to the nominal size.
- **Actual Size:** The measured size of the finished part.
- **Tolerance:** The total amount by which a given dimension may vary, or the difference between the maximum and the minimum.
- **Limits:** The maximum and minimum sizes indicated by a tolerance dimension.
- **Allowance:** The minimum clearance space (or maximum interference) intended between the maximum material condition (MMC) of mating parts. Allowance represents the tightest permissible fit and is simply the smallest hole minus the largest shaft. For clearance fits, this difference will be positive, while for the interference fits it will be negative.

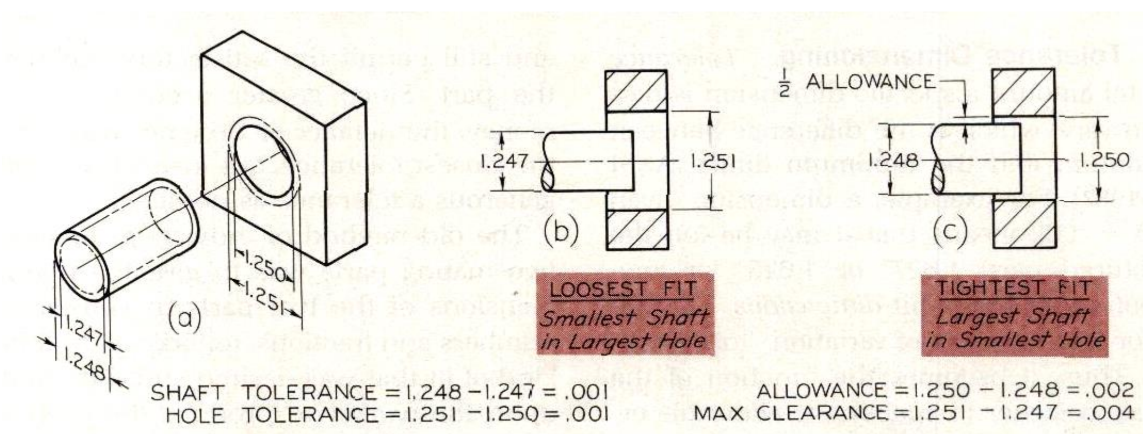

Fig-1 Limit dimensions.

Fits Between Mating Parts:

Fit is the general term used to signify the range of tightness or looseness that may result from the application of a specific combination of allowances and tolerances in mating parts. [ANSI Y14.5M-1982] There are four general types of fits between parts.

- **Clearance Fit:** In which an internal member fits in an external member (as a shaft in a hole), and always leaves a space or clearance between the parts. This space is the allowance, and in a clearance fit it is always positive.
- **Interference Fit:** In which the internal member is larger than the external member such that there is always an actual interference of metal. This interference is the allowance, and in an interference fit it is always negative.

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- **Transition Fit:** In which the fit might result in either a clearance or interference condition, the smallest shaft will fit in the largest hole with positive space, but the largest shaft will have to be forced in the smallest hole with an interference of metal (negative allowance).
- **Line Fit:** In which limits of size are so specified that a clearance or surface contact may result when mating parts are assembled.

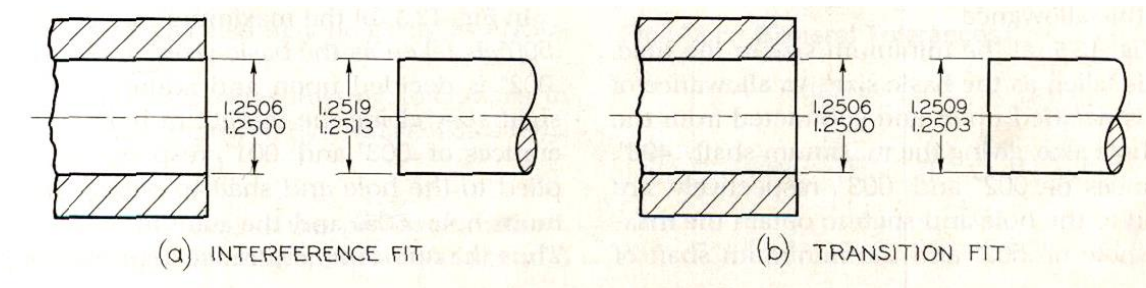

Fig-2 Fits between parts.

Basic Hole System:

Toleranced dimensions are commonly figured on the so-called basic hole system which the minimum hole is taken as the basic size, an allowance is assigned, and tolerances are applied on both sides of, and away from, this allowance.

The basic hole size can be changed to the basic shaft size by subtracting the allowance for a clearance fit, or adding it for an interference fit. The result is the largest shaft size, which is now the basic shaft.

Basic Shaft System:

This system should be used only when there is a reason for it, for example, it is advantageous when several parts having different fits, but one nominal size are required on a single shaft. In this system, the maximum shaft is taken as the basic size, an allowance for each mating part is assigned, and tolerances are applied on both sides of, and away from, this allowance.

The basic shaft size may be changed to the basic hole size by adding the allowance for a clearance fit or by adding the allowance for a clearance fit or subtracting it for an interference fit. The result is the smallest hole size which is now the basic size.

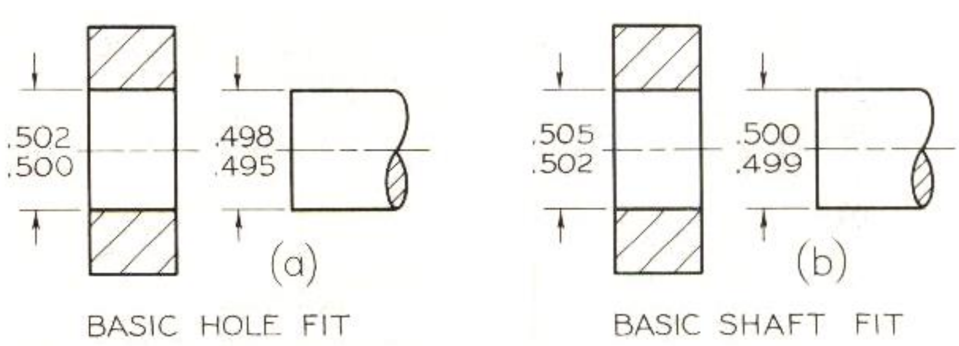

Fig-3 Basic hole and basic shaft system.

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Specification of Tolerances:

Several methods of expressing tolerances in dimensions are approved by [ANSI Y14.5M-1982] as follows:

1. **Limit Dimensioning:** the maximum and minimum limits of size and location are specified.
2. **Plus and Minus Dimensioning:** the basic size is followed by a plus and minus expression of tolerance resulting in either a unilateral or bilateral tolerance.
   - **The unilateral system of tolerances:** allows in only one direction from the basic size.
   - **The bilateral system of tolerances:** allows variation in both directions from the basic size.
3. **Single-Limit Dimensioning:** it is not always necessary to specify both limits. MIN or MAX is often placed after a number to indicate minimum or maximum dimensions desired where other elements of design determine the other unspecified limit.
4. **Angular Tolerances:** are usually bilateral and in terms of degrees, minutes, and seconds.

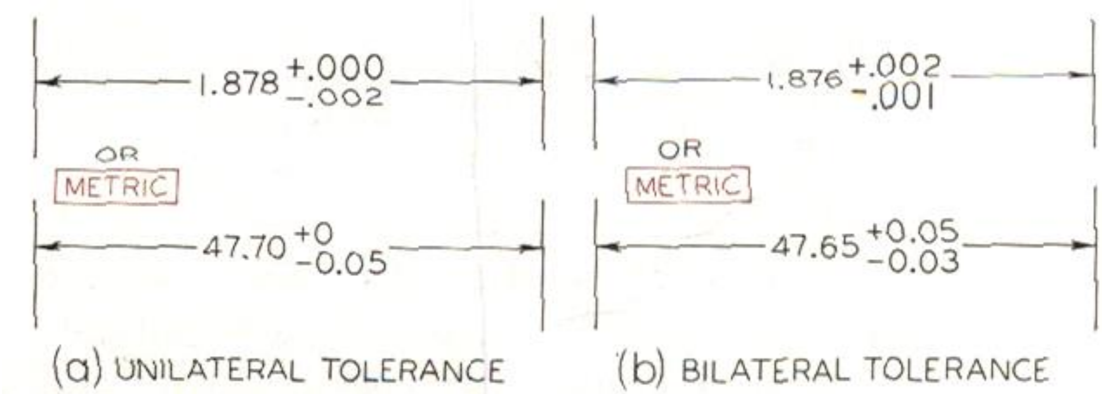

Fig-4 Plus and minus dimensioning.

Fits, Tolerance and surface roughness

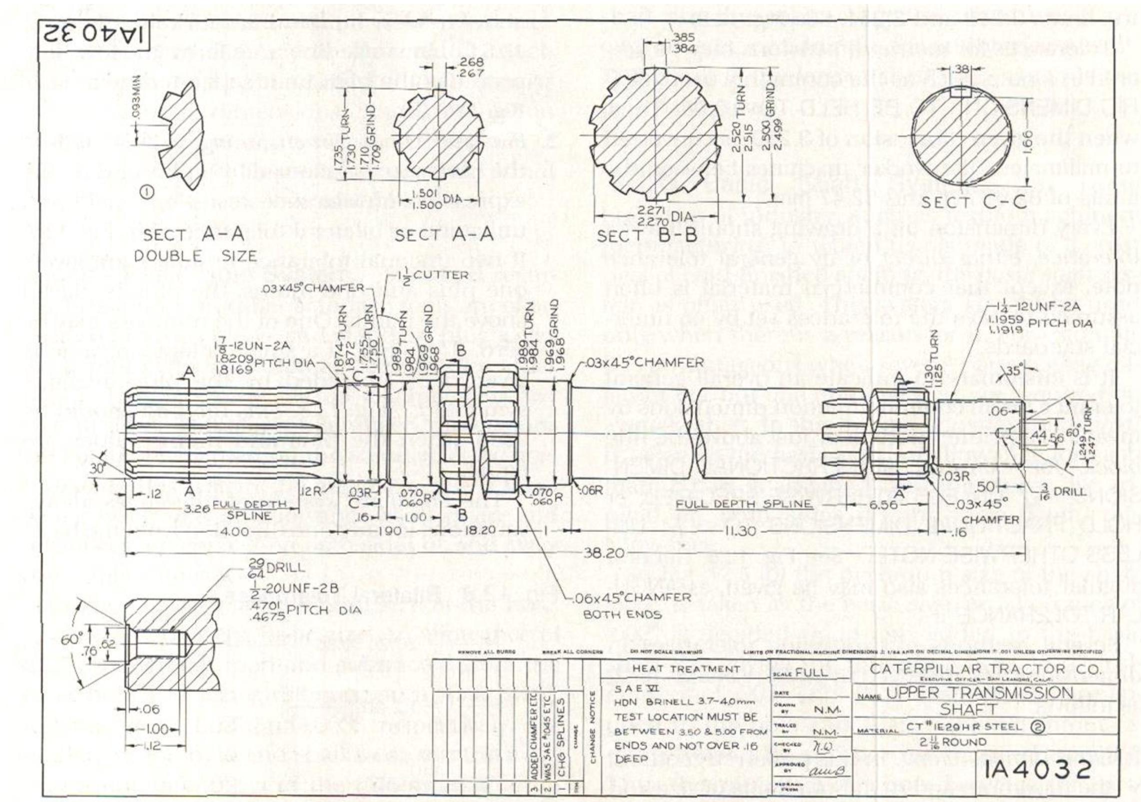

Fig-5 Limit Dimensions.

American National Standard Limits and Fits:

It has issued the [ANSI B4.1-1967 (R1979)], "Preferred Limits and Fits for Cylindrical Parts", defining terms and recommending preferred standard sizes, allowances, tolerances, and fits in terms of the decimal inch.

Specification of Fits:

Letter symbols to identify the five types of fits are:

RC	Running or Sliding Clearance Fits
LC	Locational Clearance Fits
LT	Transition Clearance or Interference Fits
LN	Locational Interference Fits
FN	Force or Shrink Fits

- **Running and Sliding Fits:** are intended to provide a similar running performance, with suitable lubrication allowance, throughout the range of sizes. The clearance for the first two classes, used chiefly as slide fits, increase more slowly with diameter than the other classes, so that accurate location is maintained even at the expense of free relative motion.
- **Locational Fits:** are fits intended to determine only the location of the mating parts; they may provide rigid or accurate location, as with interference fits, or provide some freedom of location, as with clearance fits. Accordingly they divided into three groups: clearance fits, transition fits, and interference fits.

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- **Force Fits:** Force or shrink fits constitute a special type of interference fit, normally characterized by maintenance of constant bore pressures throughout the range of sizes. The interference therefore varies almost directly with diameter, and the difference between its minimum and maximum value is small, to maintain the resulting pressures within reasonable limits.

Metric System of Tolerances and Fits:

A system of preferred metric limits and fits by the International Organization for Standardization (ISO) is in the [ANSI B4.2-1978] standard.

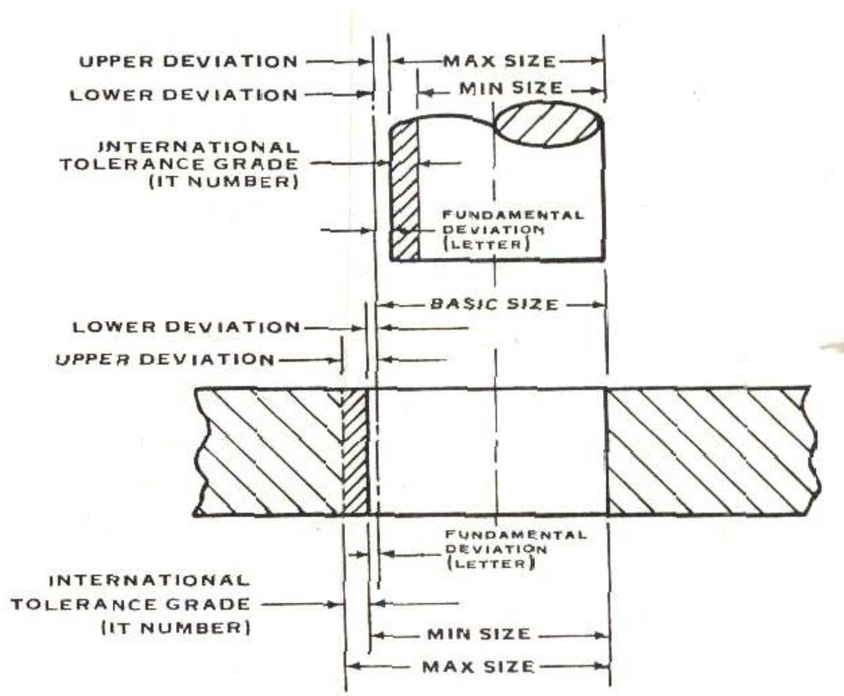

Fig-6 Terms related to Metric Limits and Fits [ANSI B4.2-1978].

The following terms for metric fits are illustrated in the following:

- **Basic Size:** The size from which limits or deviations are assigned. Basic sizes, usually diameters.
- **Deviation:** The difference between the basic size and the hole or shaft size. (This is equivalent to the tolerance in the decimal-inch system).
- **Upper Deviation:** The difference between the basic size and the permitted maximum size of the part. (This compares with the maximum tolerance in the decimal-inch system).
- **Lower Deviation:** The difference between the basic size and the minimum permitted size of the part. (This compares with the minimum tolerance in the decimal-inch system).
- **Fundamental Deviation:** The deviation closest to the basic size. (This compares with the minimum allowance in the decimal-inch system).
- **Tolerance:** The difference between the permitted minimum and maximum size of a part.

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- **International Tolerance Grade (IT):** A set of tolerances that varies according to the basic size and provides a uniform level of accuracy within the grade. For example, in the dimension 50 H8 for a close-running fit, the IT grade is indicated by the numeral 8. (The letter H indicates the tolerance is on the hole for the 50 mm dimension.) In all there are 18 IT grades—IT01, IT0, and IT1 through IT16.

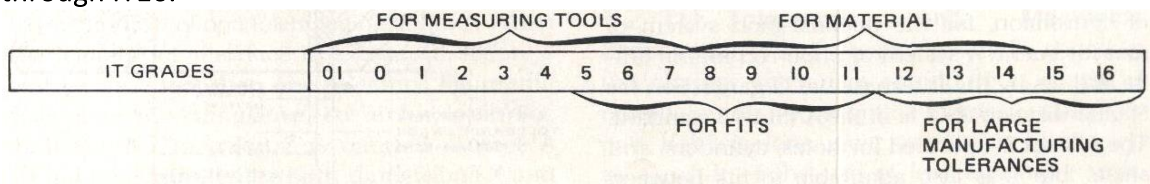

Fig-7 Practical use of IT.

- **Tolerance Zone:** The tolerance and its position in relation to basic size.
- **Hole-Basis System of Preferred Fits**: fits A system based upon the basic diameter as the minimum size. For the generally preferred hole-basis system, the fundamental deviation is specified by the uppercase letter H
- **Shaft-Basis System of Preferred Fits:** A system based upon the basic diameter as the maximum size of the shaft. The fundamental deviation is given by the lowercase letter h.
- **Interference Fit:** A fit that results in interference fit between two mating parts under all tolerance conditions.
- **Transition Fit:** A fit that results in either a clearance or an interference condition between two assembled parts.
- **Tolerance Symbols:** Symbols used to specify the tolerances and fits for mating parts.

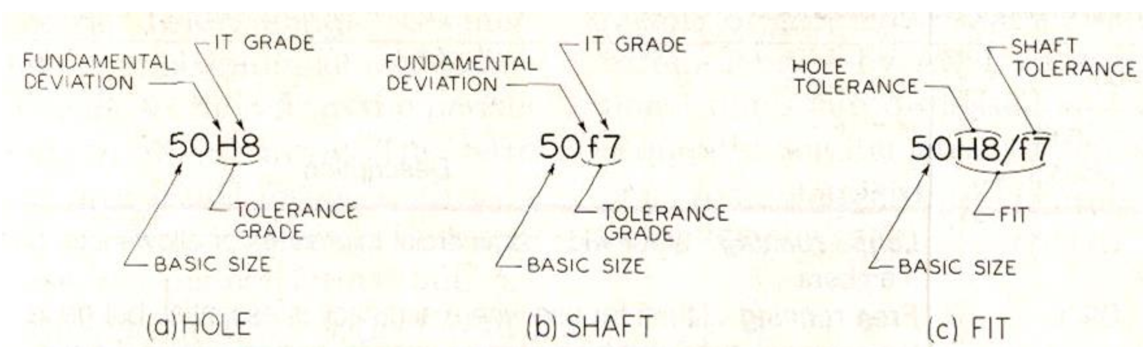

Fig-8 Application of definitions of symbols to holes and shafts [ANSI B4.2-1978].

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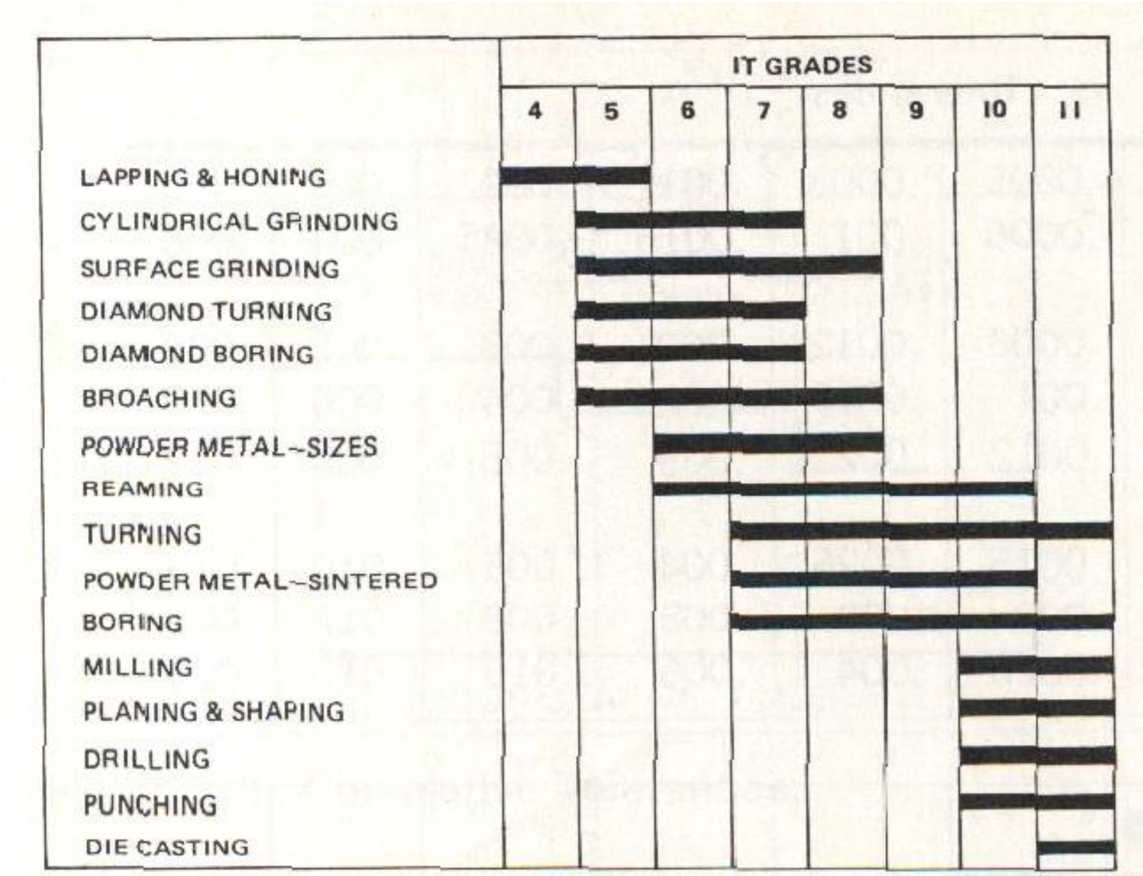

Fig-9 International tolerance grades related to machining processes [ANSI B4.2-1978].

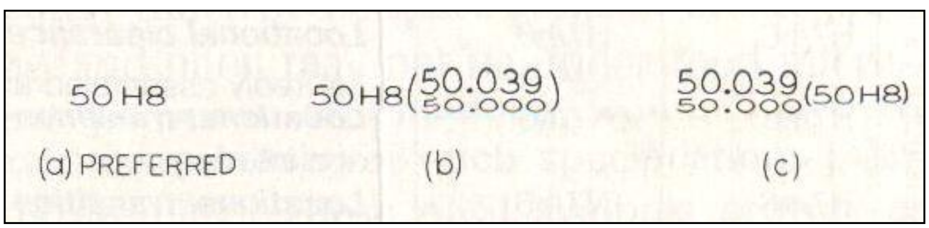

Fig-10 Acceptable methods of giving tolerance symbols [ANSI B4.2-1978].

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Preferred Fits:

	ISO Symbol		Description	
	Hole Basic	**Shaft Basic**		
Clearance Fits	H11/c11	C11/h11	**Loose running** fit for wide commercial tolerances or allowances on external members.	More clearance
	H9/d9	D9/h9	**Free running** fit not for use where accuracy is essential, but good for large temperature variations, high running speeds, or heavy journal pressures.	
	H8/f7	F8/h7	**Close running** fit for running on accurate machines and for accurate location at moderate speeds and journal pressures.	
	H7/g6	G7/h6	**Sliding fit** not intended to run freely, but to move and turn freely and locate accurately.	
Transition Fits	H7/h6	H7/h6	**Locational clearance** fit provides snug fit for locating stationary parts; but can be freely assembled and disassembled.	
	H7/K6	K7/h6	**Locational transition** fit for accurate location, a compromise between clearance and interference.	
	H7/n6	N7/h6	**Locational transition** fit for more accurate location where greater interference is permissible.	
Interference Fits	H7/p6	P7/h6	**Locational interference** fit for parts requiring rigidity and alignment with prime accuracy of location but without special bore pressure requirements.	
	H7/S6	S7/h6	**Medium drive** fit for ordinary steel parts or shrink fits on light sections, the tightest fit usable with cast iron.	
	H7/u6	U7/h6	**Force** fit suitable for parts which can be highly stressed or for shrink fits where the heavy pressing forces required are impractical.	More interference

[a]The transition and interference shaft basis fits shown do not convert to exactly the same hole basis fit conditions for basic sizes in range from Q through 3 mm. Interference fit P7/h6 converts to a transition fit H7/p6 in the above size range.

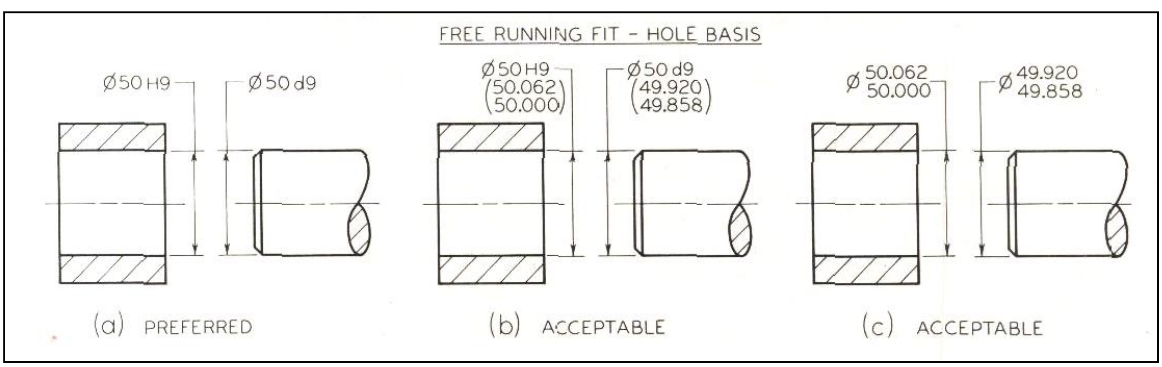

Fig-10 Methods of specifying tolerances with symbols for mating parts.

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Geometric Tolerances:

	Type of Tolerance	Characteristic	Symbol
For individual features	Form	Straightness	—
		Flatness	▱
		Circularity (roundness)	○
		Cylindricity	/○/
For individual or related features	Profile	Profile of a line	⌒
		Profile of a surface	⌓
For related features	Orientation	Angularity	∠
		Perpendicularity	⊥
		Parallelism	//
	Location	Position	⌖
		Concentricity	◎
	Runout	Circular runout	↗ [a]
		Total runout	⇗ [a]

[a] Arrowhead(s) may be filled in.

Term	Symbol
At maximum material condition	Ⓜ
Regardless of feature size	Ⓢ
At least material condition	Ⓛ
Projected tolerance zone	Ⓟ
Diameter	∅
Spherical diameter	S∅
Radius	R
Spherical radius	SR
Reference	( )
Arc length	⌒

(a) (b)

Fig-11 (a) Geometric characteristics and (b) modifying symbols, [ANSI Y14.5M-1982].

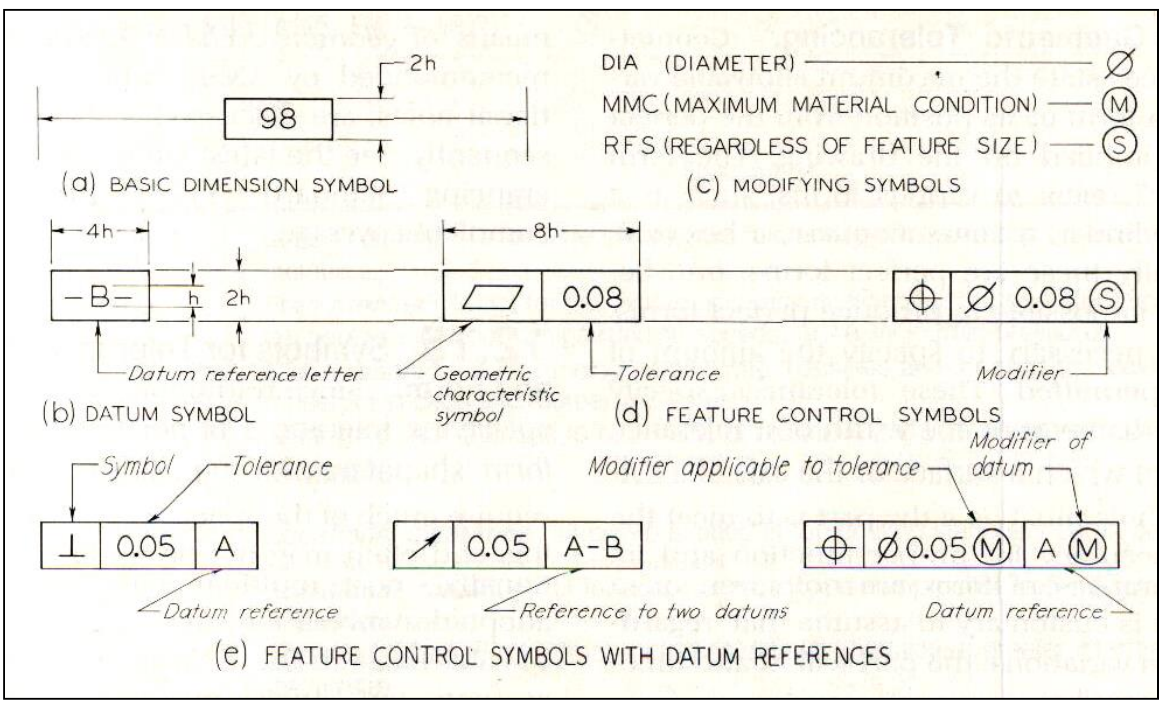

Fig-12 Use of symbols for tolerance of position and form, [ANSI Y14.5M-1982].

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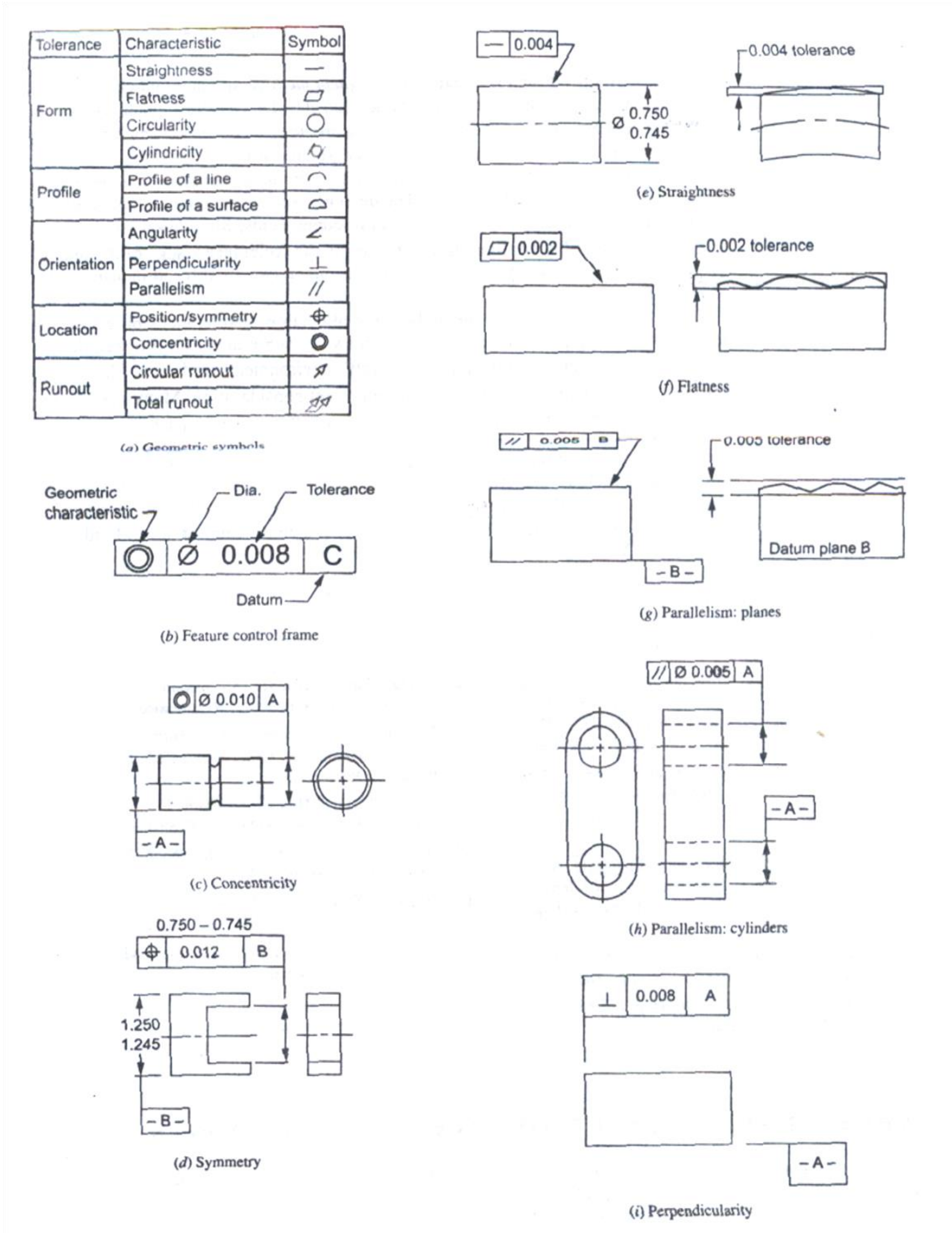

Fig-13 Geometric tolerance.

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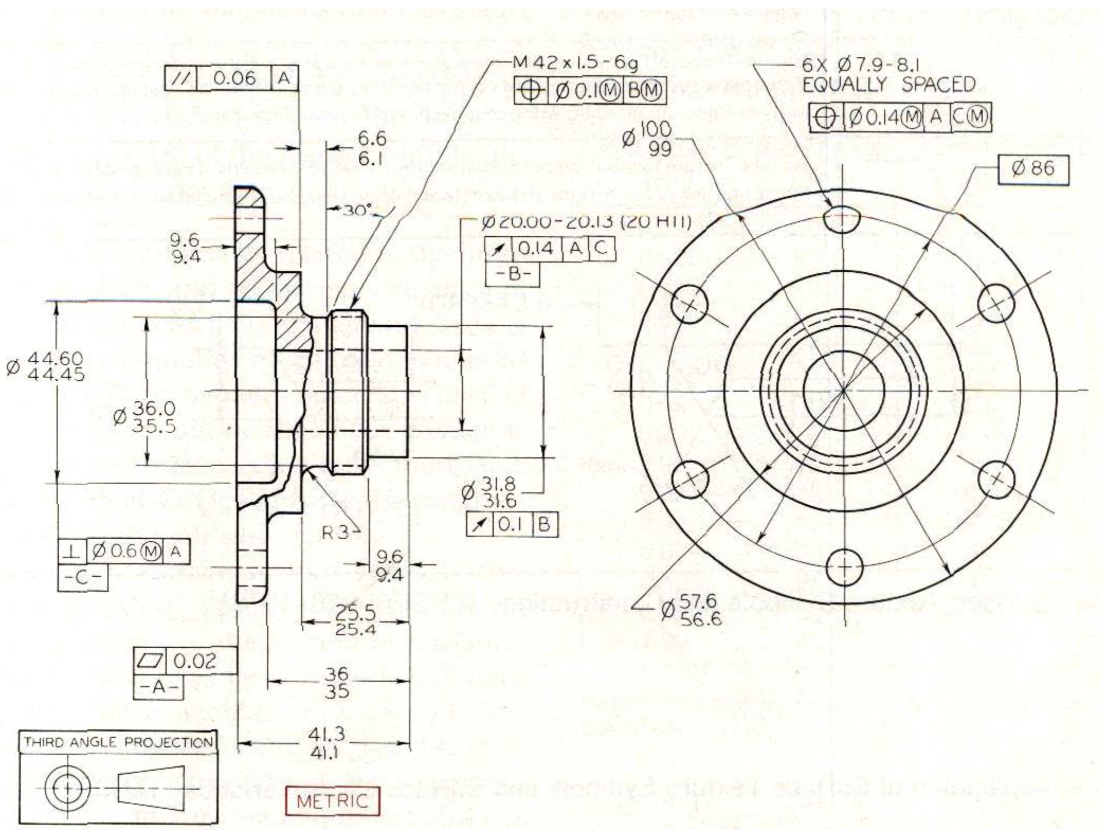
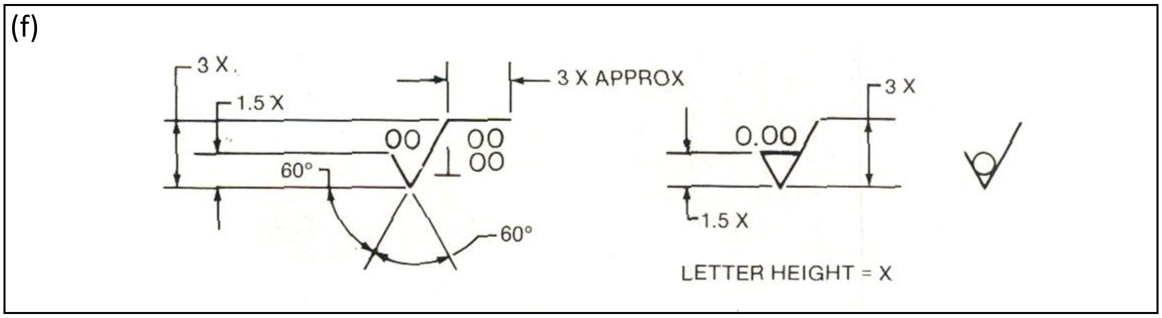


Fig-14 Application of symbols to position and form tolerance dimensions [ANSI Y14.5M-1982].

<u>Surface Roughness, Waviness, and Lay [ANSI Y14.36-1978]:</u>

Symbols	Meaning
(a)	**Basic Surface Texture Symbol.** Surface may be produced by any method except when the bar or circle, (b) or (d), is specified.
(b)	**Material Removal By Machining Is Required.** The horizontal bar indicates that material removal by machining is required to produce the surface and that material must be provided for that purpose.
(c) 3.5	**Material Removal Allowance**. The number indicates the amount of stock to be removed by machining in millimeters (or inches). Tolerances may be added to the basic value shown or in a general note.
(d)	**Material Removal Prohibited.** The circle in the vee indicates that the surface must be produced by processes such as casting, forging, hot finishing, cold finishing, die casting, powder metallurgy or injection molding without subsequent removal of material.
(e)	**Surface Texture Symbol.** To be used when any surface characteristics are specified above the horizontal line or to the right of the symbol. Surface may be produced by any method except when the bar or circle, (b) or (d), is specified.

Fits, Tolerance and surface roughness



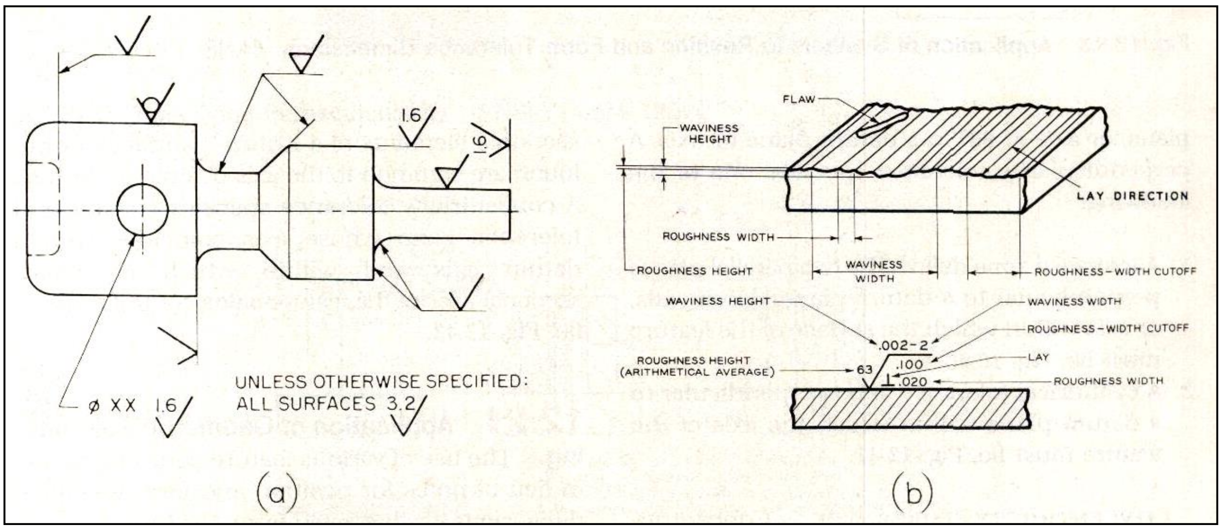
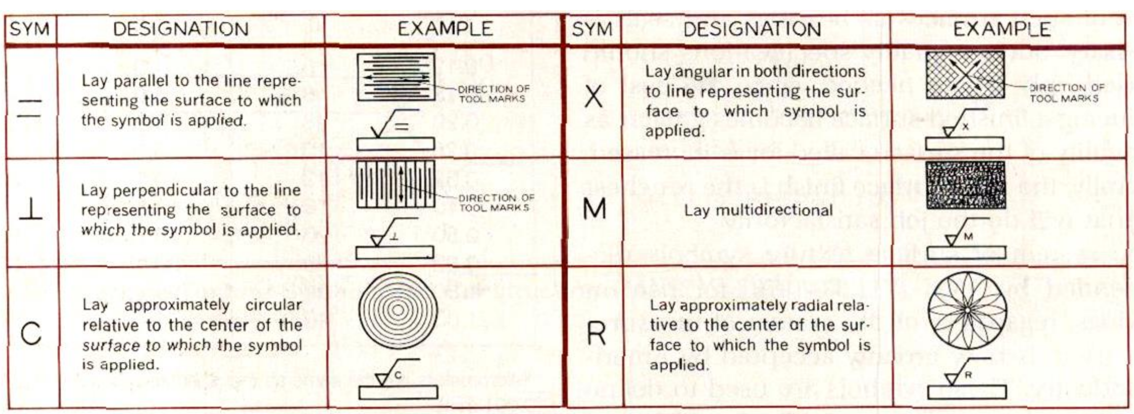


Fig-15 Application of surface texture symbols and surface characteristics [ANSI Y14.36-1978].



SYM	DESIGNATION	EXAMPLE	SYM	DESIGNATION	EXAMPLE
=	Lay parallel to the line representing the surface to which the symbol is applied.	DIRECTION OF TOOL MARKS	X	Lay angular in both directions to line representing the surface to which symbol is applied.	DIRECTION OF TOOL MARKS
⊥	Lay perpendicular to the line representing the surface to which the symbol is applied.	DIRECTION OF TOOL MARKS	M	Lay multidirectional	M
C	Lay approximately circular relative to the center of the surface to which the symbol is applied.	C	R	Lay approximately radial relative to the center of the surface to which the symbol is applied.	R

Fig-16 Lay symbols [ANSI Y14.36-1978].

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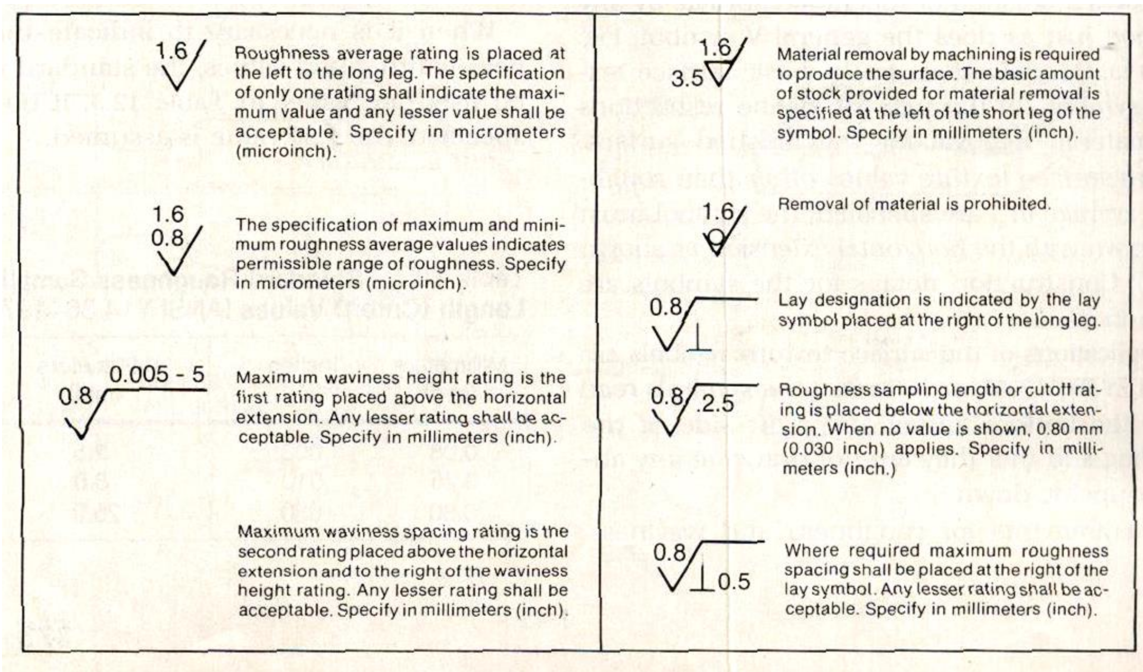

Fig-17 Application of surface texture values to symbol [ANSI Y14.36-1978].

Preferred Series Roughness Average Values (Ra) [ANSI Y14.36-1978].

Micrometers (µm).	Mictroinches (µin).	Micrometers (µm).	Mictroinches (µin).
0.012	0.5	1.25	50
0.025	1	1.60	63
0.050	2	2.0	80
0.075	3	2.5	100
0.10	4	3.2	125
0.125	5	4.0	180
0.15	6	5.0	200
0.20	8	6.3	250
0.25	10	8.0	320
0.32	13	10.0	400
0.40	16	12.5	500
0.50	20	15	600
0.63	25	20	800
0.80	32	25	1000
1.00	40		

Preferred Series Maximum Waviness Height Values [ANSI Y14.36-1978].

Millimeters (mm).	Inches (in).	Millimeters (mm).	Inches (in).
0.0005	0.00002	0.025	0.001
0.0008	0.00003	0.05	0.002
0.0012	0.00005	0.08	0.003
0.0020	0.00008	0.12	0.005
0.0025	0.0001	0.20	0.008
0.005	0.0002	0.25	0.010
0.008	0.0003	0.38	0.015
0.012	0.0005	0.50	0.020

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0.020	0.0008	0.80	0.030

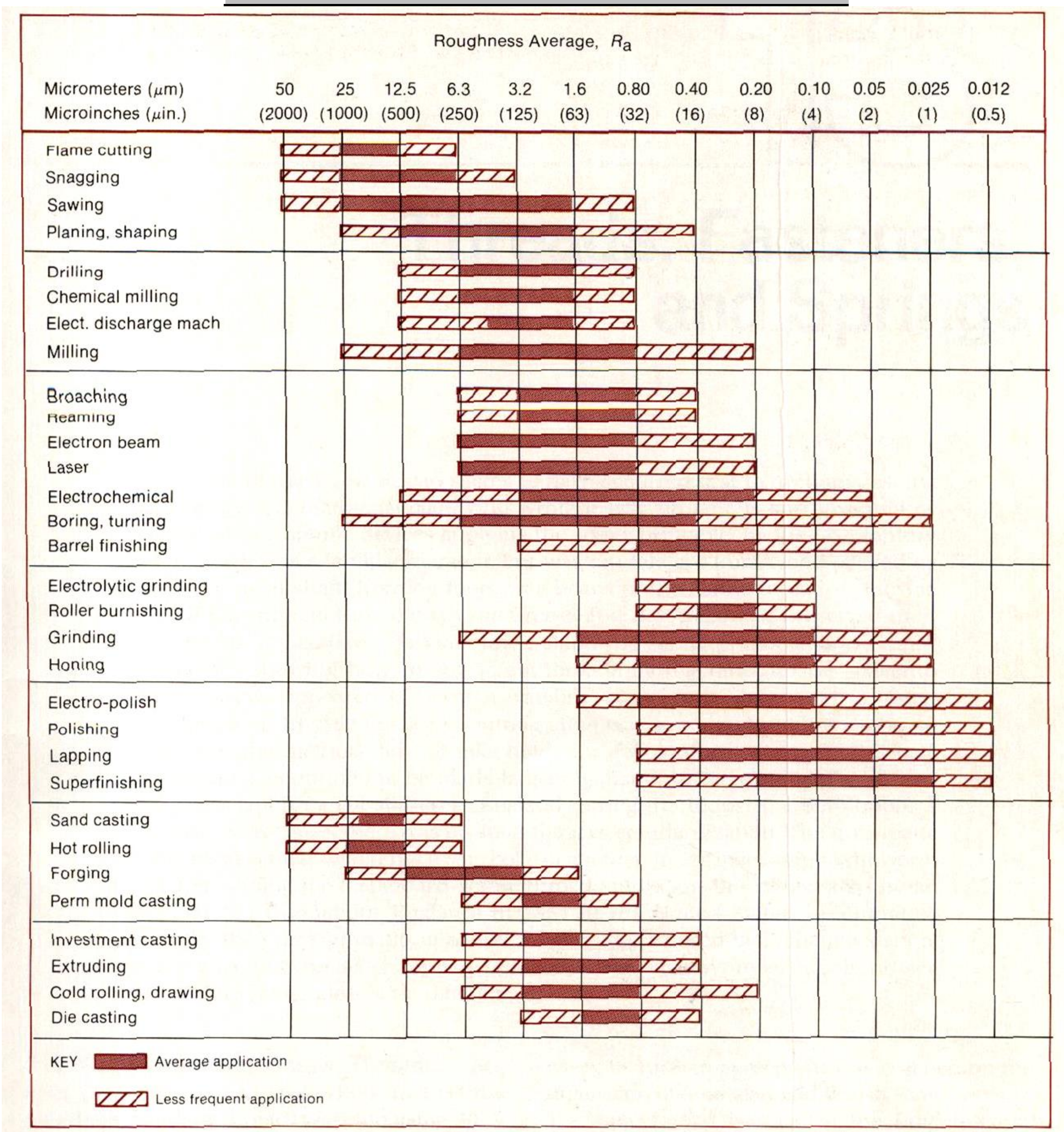

Fig-18 Surface roughness produced by common production methods [ANSI Y14.5M-1982]. The ranges shown are typical of the processes listed. Higher or lower values may be obtained under special conditions.

Classification of Machine Drawings:

- **Assembly Drawings:** shows the complete drawing of a given machine, indicating the relative positions of various components assembled together.
- **Part Drawings or Working Drawings:** illustrate the number of views of a single part of a machine required to facilitate it manufacturing. It should furnish all dimensions, limits and special finishing processes such as heat treatment, honing, lapping, surface finish.

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- **Shop Drawings:** may be defined as the complete drawing of an object comprising the number of drawings required to facilitate the fabrication of all parts of the object and their subsequent assembly into a complete product. A shop drawing will usually include both the assembly drawing and the part drawings.
- **Drawings for Catalogues:** only the outlines of assembly drawings are displayed for illustration purposes.
- **Drawings for Instruction Manuals:** consist of assembly drawings which are to be used when a machine. Shipped away in assembled condition, is nocked down in order to check all the components before being re-assembled and installed elsewhere.
- **Schematic Representation:** high level mechanization and automation which are the characteristics of modern technology have resulted in complicated machinery, utilizing different combinations of mechanical, electrical, pneumatic and hydraulic transmission systems.
- **Patent Drawings:** come into existence when designs are being invented.

Drawing Sheet Sizes:

Designation	Size (mm)	Designation	Size (mm)
A0	841 x 1189	A3	297 x 420
A1	594 x 841	A4	210 x 297
A2	420 x 594	A5	148 x 210

References

[1] Robert L. Mott, RE, **MACHINE ELEMENTS IN MECHANICAL DESIGN**, Fourth Edition, ISBN 0-13-061885-3.

[2] Budynas−Nisbett, **Shigley's Mechanical Engineering Design, Eighth Edition**, ISBN 0−390−76487−6.

With my best wishes

Eng / M.shehata