Manufacturing Processes for Engineering Materials

ABRASIVE-GRINDING

SUTOPO
PENDIDIKAN TEKNIK MESIN FT-UNY
Maret 2012

Abrasives

- Abrasives umumnya terdiri atas:

1. **Conventional abrasives**
   a) *Aluminium oxide*
   b) *Silicon carbide*
2. **Superabrasives**
   a) *Cubic boron nitride*
   b) *Diamond*

- Abrasives adalah lebih keras daripada conventional cutting-tool materials.

Knoop Hardness Range for Various Materials and Abrasives

Common glass	350–500	Titanium nitride	2000
Flint, quartz	800–1100	Titanium carbide	1800–3200
Zirconium oxide	1000	Silicon carbide	2100–3000
Hardened steels	700–1300	Boron carbide	2800
Tungsten carbide	1800–2400	Cubic boron nitride	4000–5000
Aluminum oxide	2000–3000	Diamond	7000–8000

Abrasives

- **Friability** is the ability of an abrasive grain to fracture into smaller pieces.
- High friability indicates low strength or low fracture resistance of the abrasive.
- **Shape** and **size** of abrasive grain affect its friability.

Types of abrasives:

1. Synthetic aluminum oxide
2. Silicon carbide
3. Cubic boron nitride
4. Diamond

Abrasives

Grain size

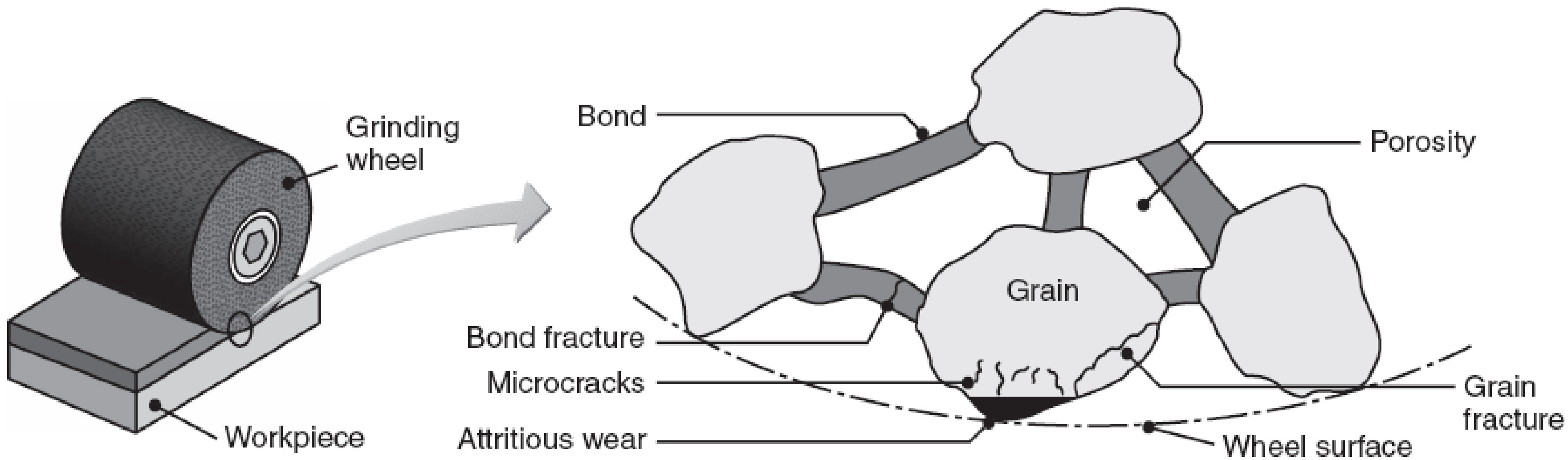
- Very small size.
- Abrasives berfungsi sebagai pemotong (pahat)
- **Grit number** (kasar s.d sangat halus)

UKURAN BUTIRAN ABRASIVES (μm)…

1. Coarse : 1700, 1400, …, 630
2. Medium : 500,…, 250
3. Fine : 220,…, 125
4. Very fine : 106,…, 58
5. Flour size : 52,…, 26

Perekat Abrasive

- High rates of material removal can be achieved.
- It is in the form of a **grinding wheel** and abrasive grains are held together by a **bonding material**.



Bond types (perekat)

- Macam-macam Perekat:

1. **Vitrified – use glass/ceramic as bonder (waterglass)**

- Menghasilkan batu yang strong, stiff, porous tetapi brittle.
- Kurang tahan terhadap mechanical dan thermal shock.

2. **Resinoid – adhesive bonding**

- Bahan perekat adalah *thermosets.*
- **Reinforced resinoid wheels** untuk memperkuat ikatan

Bond types

3. Rubber

- Adalah perekat yang paling flexible.
- Dapat digunakan untuk perekat batu gerinda yg tipis (pemotong)

4. Metal bonds – menggunakan powder metallurgy (PM)

- Mampu bekerja pada pressure dan temperature yang tinggi

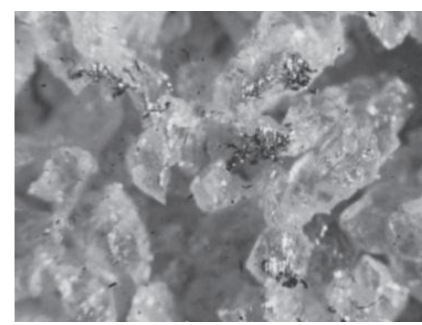
Mechanics of Grinding

- Butiran abrasive secara individual berfungsi sebagai Cutting tool
- Perbedaan antara kinerja single grain dari single-point cutting tool adalah:

1. individual grain memiliki geometry yg irregular
2. Rata-rata sudut rake adalah negative
3. grinding wheel have different radial positions
4. cutting speeds dari grinding wheels adalah sangat tinggi

Typical Ranges of Speeds and Feeds for Abrasive Processes

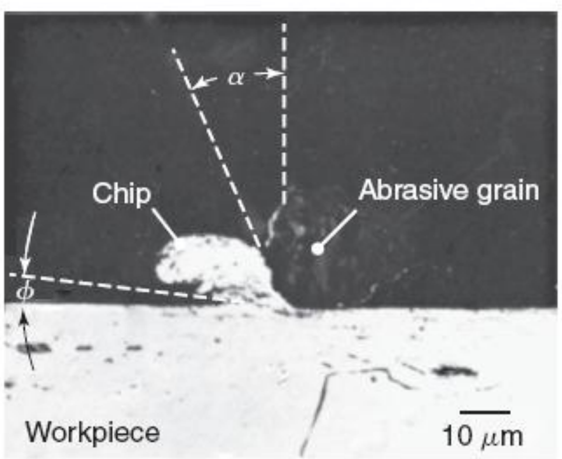
Process variable	Conventional grinding	Creep-feed grinding	Buffing	Polishing
Wheel speed (m/min)	1500–3000	1500–3000	1800–3600	1500–2400
Work speed (m/min)	10–60	0.1–1	—	—
Feed (mm/pass)	0.01–0.05	1–6	—	—

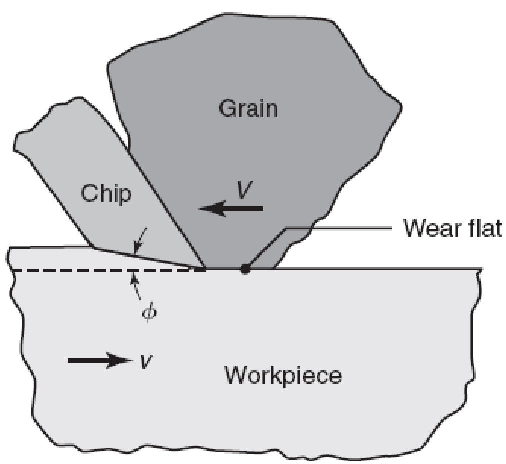


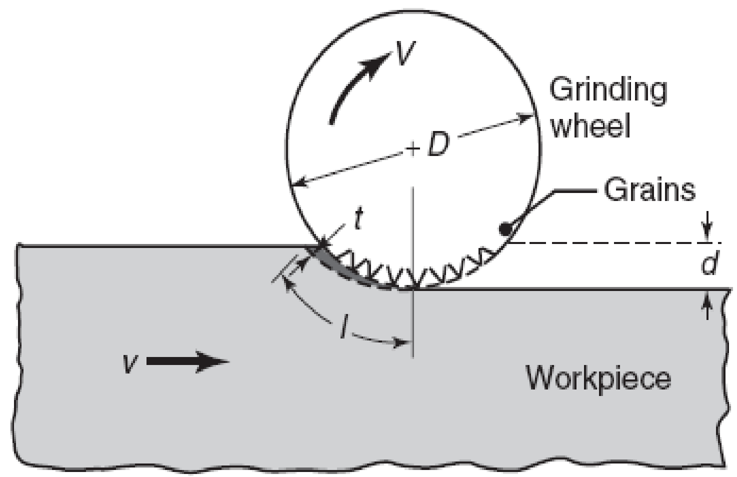
Mechanics of Grinding

- For the condition of v<<V, the *undeformed-chip length* is:

$$l \approx \sqrt{Dd}$$







Mechanics of Grinding

- For *external (cylindrical) grinding,* $l = \sqrt{\dfrac{Dd}{1 + \left(D/D_w\right)}}$
- For *internal grinding,* $l = \sqrt{\dfrac{Dd}{1 - \left(D/D_w\right)}}$
- Volume of chip with rectangular cross-sectional area and constant width is

$$Vol_{chip} = \frac{wtl}{2} = \frac{rt^2 l}{4}$$

- Undeformed chip thickness in surface grinding is

$$t = \sqrt{\frac{4v}{VCr}\sqrt{\frac{d}{D}}}$$

Example 9.1
Chip dimensions in grinding

Estimate the undeformed chip length and the undeformed chip thickness for a typical surface-grinding operation. Let D = 200mm, d = 0.05mm, C = 2 per mm^2 and r = 15.

Solution

Undeformed length is: $l = \sqrt{Dd} = \sqrt{(200)(0.05)} = 3.2\,\text{mm}$

From Table 9.2, v = 0.5m/s and V = 30m/s. Thus thickness is:

$$t = \sqrt{\frac{4v}{Vcr}\sqrt{\frac{d}{D}}} = \sqrt{\frac{4(0.5)}{(30)(2)r}\sqrt{\frac{0.05}{200}}} = 0.006\,\text{mm}$$

Grinding forces

- Relationship of **relative grain force** is

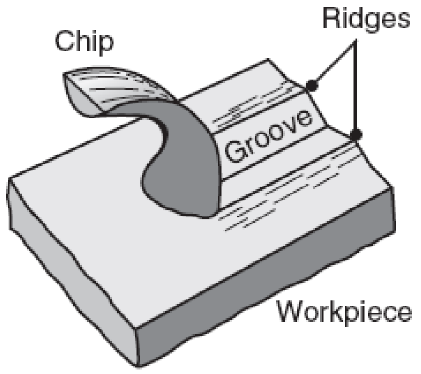
$$\text{Relative grain force} \propto \frac{v}{VC}\sqrt{\frac{d}{D}}$$

- **Specific energy** consumed in producing a grinding chip consists of 3 components:

$$u = u_{chip} + u_{plowing} + u_{sliding}$$

- Specific-energy requirements in grinding depends on:

1. **Size effect**
2. **Wear flat**
3. **Chip morphology**



Example 9.2
Forces in surface grinding

Assume that you are performing a surface-grinding operation on a low-carbon steel workpiece using a wheel of diameter D = 25.4 cm that rotates at N = 4000 rpm.
The width of cut is w = 2.54 cm, depth of cut is d = 0.00508 cm, and the feed rate of the workpiece is v = 152.4 cm/min. Calculate F_c and F_n

$$MRR = dwv = (0.00508)(2.54)(152.4) = 1.966 \text{ cm}^3\text{/min}$$

Solution

Material rem

Approximate Specific-Energy Requirements for Surface Grinding		
Workpiece material	Hardness	Specific energy W-s/mm^3
Aluminum	150 HB	7–27
Cast iron (class 40)	215 HB	12–60
Low-carbon steel (1020)	110 HB	14–68
Titanium alloy	300 HB	16–55
Tool steel (T15)	67 HRC	18–82

$$Power = (u)(MMR) = (682.581)(1.966) = 1342 \text{ W} \times 6.1183 \text{ kg-m/min} = 8210.76 \text{ m-kg/min}$$

Power consumed is

Example 9.2
Forces in surface grinding

Solution

Since power is defined as

$$Power = T\omega$$

$$8210.76 = F_c\left(\frac{25.4}{2}\right)(2\pi)(4000)$$

$$F_c = 25.8\,\text{kg}$$

Since thrust force is about 30% higher than the cutting force,

$$F_n = (1.3)(25.8) = 33.54\,\text{kg}$$

Temperature

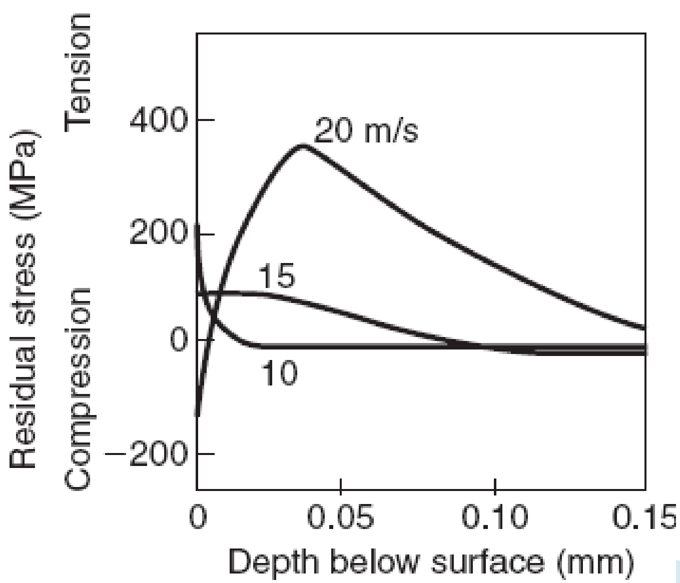
- *Temperature rise* adversely affect surface properties and cause residual stresses on the workpiece.
- In *surface grinding*, $\Delta T \propto \dfrac{uwLd}{wL} \propto ud$
- Introduce size effect and assume that *u* varies inversely with *t*,

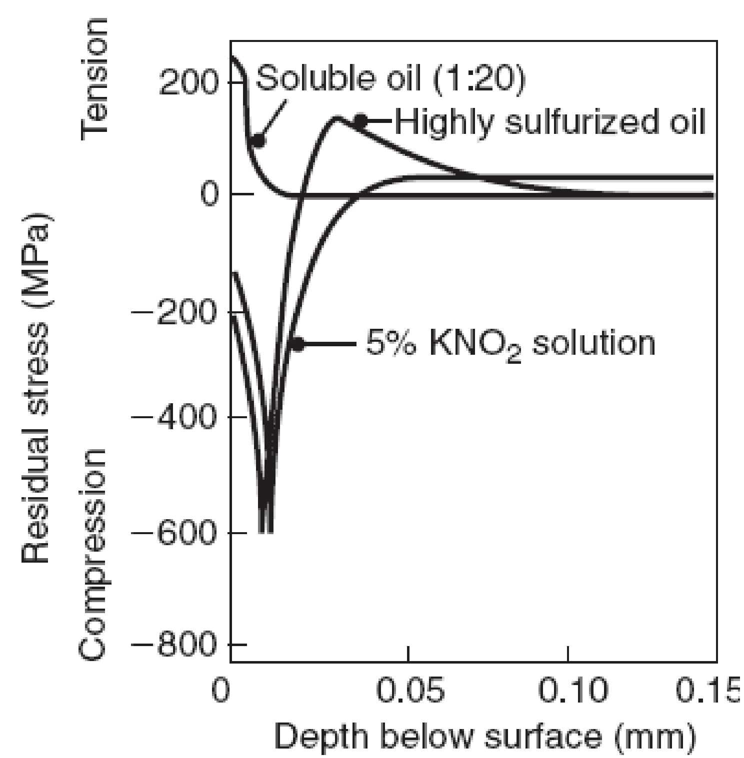
$$\text{Temperature rise} \propto D^{1/4} d^{3/4} \left(\frac{V}{v} \right)^{1/2}$$

Effects of temperature

- Major effects of temperature in grinding are

1. **Tempering**
2. **Burning**
3. **Heat checking**
4. **Residual stresses**





Grinding Wheel Wear

- Grinding wheels wear ada 3 mechanisms:

1. **Attritious wear**: caused by interaction of grain and workpiece
2. **Grain fracture**: caused by excessive attritious wear
3. **Bond fracture:** bond is too strong and grains cannot be dislodged

Grinding ratio

- *Grinding ratio* which is defined as:

$$G = \frac{\text{Volume of material removed}}{\text{Volume of wheel wear}}$$

- Grinding ratios tergantung pada tipe batu, workpiece material, grinding fluid dan pemilihan parameter pemotongan

Softor hard-acting wheels

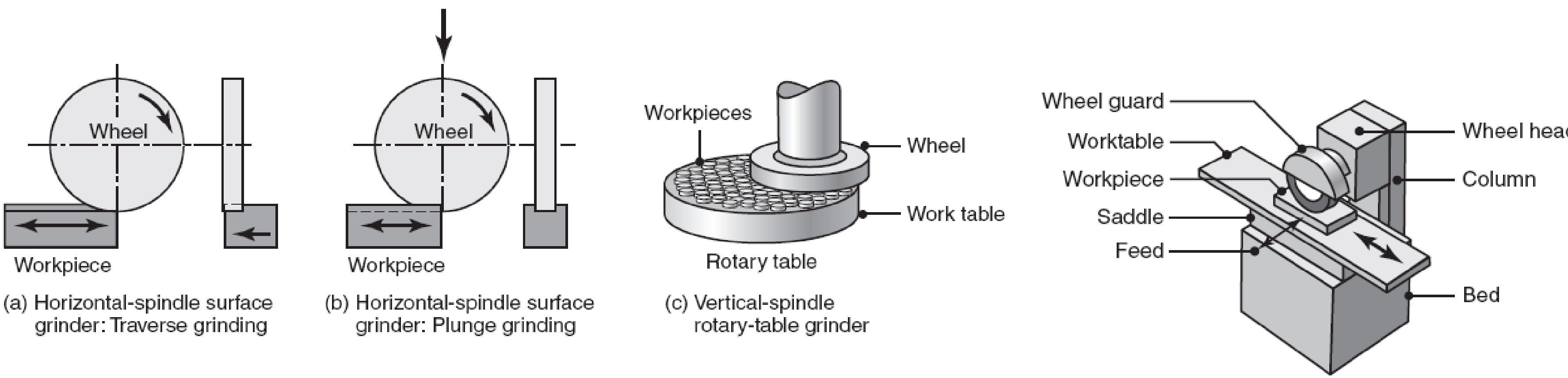
- Wheel may *act soft* (meaning wear rate is high) or *hard* (wear rate is low), regardless of its grade.

Wheel selection and grindability of materials

- Grinding process depends on part shape, part size, ease of fixturing and production rate required.
- Basic types of grinding operations are surface, cylindrical, internal and centerless grinding.
- Relative movement of the wheel are *traverse grinding, through feed grinding, cross-feeding* or *plunge grinding*.

Surface grinding

- *Surface grinding* involves grinding flat surfaces.
- Size of a surface grinder is specified by surface dimensions of length and width.



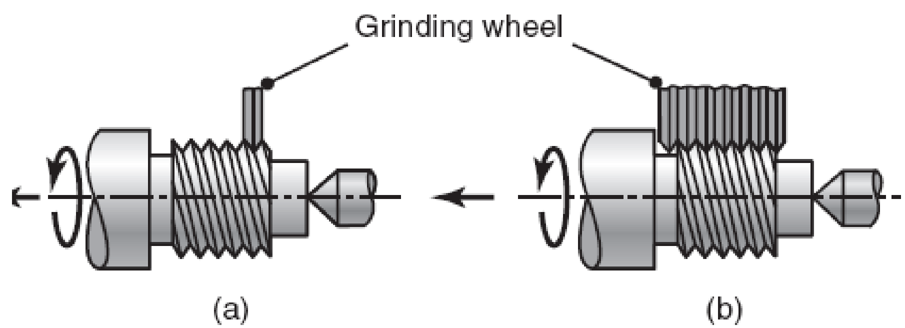
(a) Horizontal-spindle surface grinder: Traverse grinding

(b) Horizontal-spindle surface grinder: Plunge grinding

(c) Vertical-spindle rotary-table grinder

Cylindrical grinding

- **Thread grinding** is done on cylindrical grinders and centre-less grinders.
- Operation is costly, more accurately and threads have a very fine surface finish.



Grinding fluids

- **Usage of fluid is to:**

1. prevent excessive temperature rise.
2. improve surface finish and dimensional accuracy.
3. improve efficiency of operation.

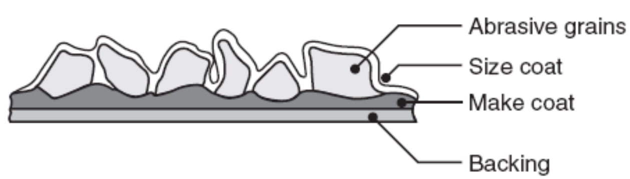
- Grinding fluids can be *water-base emulsions*, chemicals and synthetics.
- Water-base grinding fluids temperature rise as they remove heat from the grinding zone.
- Maintain even temperature by using a chiller where fluid is circulated.

Finishing Operations

- Commonly used finishing operations are:

1. Coated abrasives

- Sandpaper and emery cloth.
- Electrostatically deposited on flexible backing materials.
- Used in finishing flat or curved surfaces of metallic and non-metallic parts.
- Surface finish depends primarily on grain size.



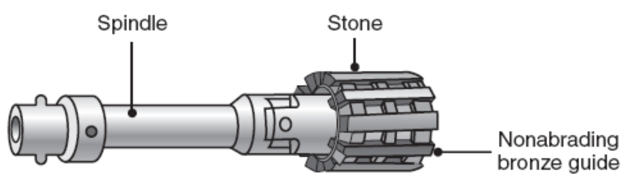
Finishing Operations

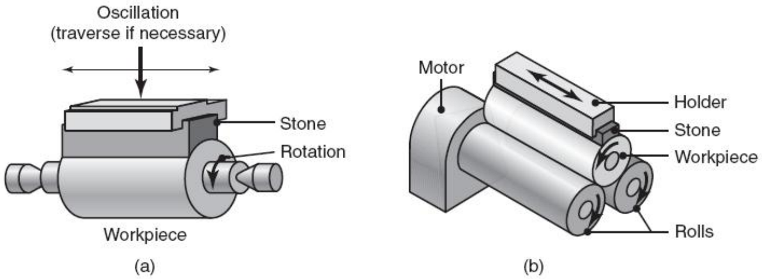
2. Wire brushing

- Produce fine surface texture and serve as a light material-removal process.

3. Honing

- Give holes a fine surface finish.
- Surface finish controlled by type and size of abrasive used, speed of rotation and pressure applied.





Economics of Grinding and Finishing Operations

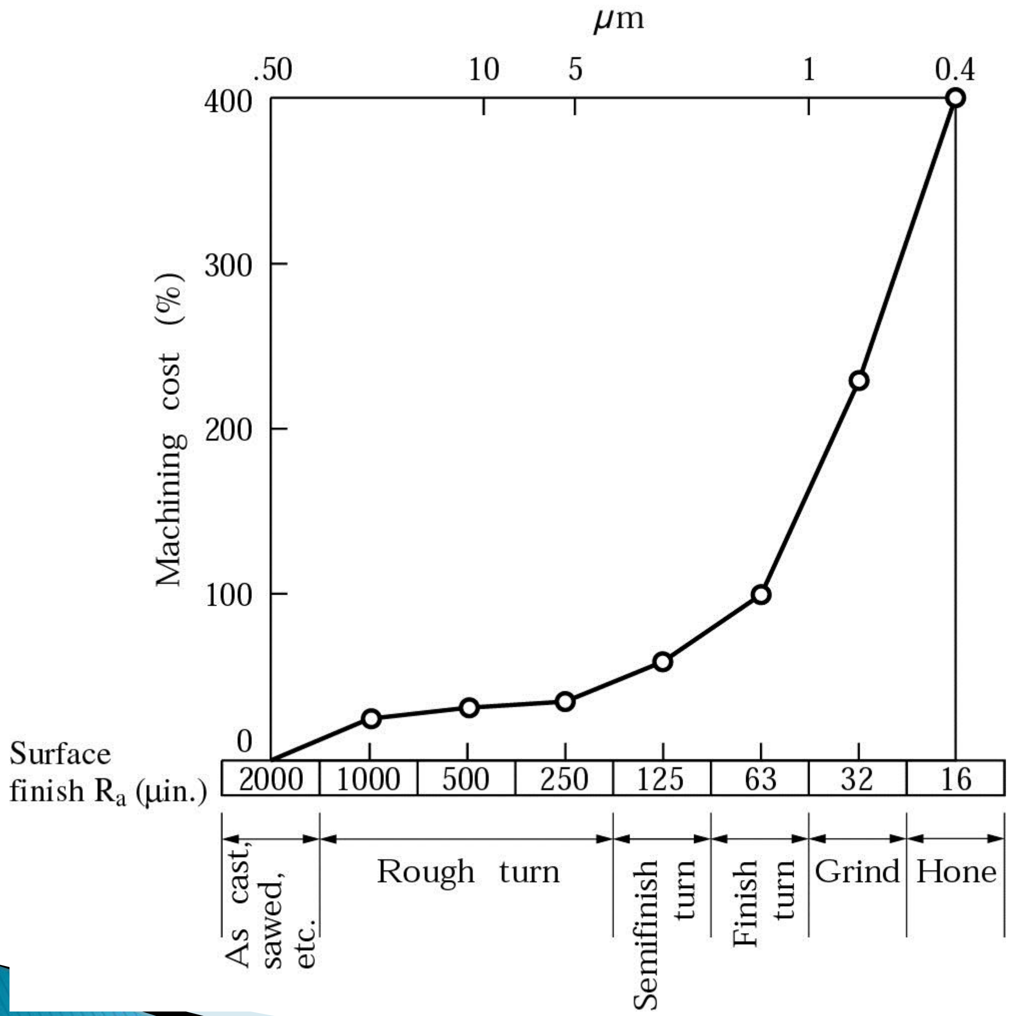


Figure 9.47 Increase in the cost of machining and finishing a part as a function of the surface finish required. This is the main reason that the surface finish specified on parts should not be any finer than necessary for the part to function properly.