446.305A MANUFACTURING PROCESSES

Chapter 9. Material-Removal Processes: Abrasive, Chemical, Electrical, and High-Energy Beams

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Grinding (연삭) (1)

- Hardness
- Friability (깨짐성)
 - Self sharpening (자생작용)
 - Grain fragments rapidly
- Grain size (입도)
 - Grit number (입도지수)
 - 10>100>500





FIGURE 9.5 The grinding surface of an abrasive wheel (A46-J8V), showing grains, porosity, wear flats on grains (see also Fig. 9.9), and metal chips from the workpiece adhering to the grains. Note the random distribution and shape of the abrasive grains. Maenification: $50\times$.

S. Kalpakjian, "Manufacturing Processes for Engineering Materials", $3^{\rm rd}\!/\!4^{\rm th}$ ed. Addison Wesley

Ref.

Grinding (연삭) (2)

- Irregular geometry of grains.
- Highly negative rake angle : -60° or even lower.
- The radial positions of the grains in a grinding wheel vary.
- High cutting speed : ~30m/s







Residual stresses







Surface Grinding (평면연삭)



FIGURE 9.12 Schematic illustrations of surface-grinding operations. (a) Traverse grinding with a horizontal-spindle surface grinder. (b) Plunge grinding with a horizontal-spindle surface grinder, producing a groove in the workpiece. (c) Vertical-spindle rotary-table grinder (also known as the *Blanchard-type* grinder).

Ref.

S. Kalpakjian, "Manufacturing Processes for Engineering Materials", 3rd/4th ed. Addison Wesley

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Cylindrical Grinding (원통연삭)



Internal Grinding (내면연삭)



Centerless Grinding (무심연삭)



FIGURE 9.16 Schematic illustrations of centerless-grinding operations.

Ultrasonic Machining (초음파가공)



the ultrasonic-machining process by which material is microchipping and erosion. (b) and (c) Typical examples of holes produced by ultrasonic machining. Note the dimensions of cut and the types of workpiece

Finishing Operations (마무리공정)

- Honing (호닝) Stone Spindle Superfinishing 3.07 FIGURE 9.21 Schematic Nonabrading illustration of a honing tool bronze guide to improve the surface finish of bored or ground holes. Holder Workpiece Oscillation (traverse if necessary) Stone Stone Rotation FIGURE 9.22 Schematic illustration of the superfinishing process for a cylindrical part: (a) cylindrical microhoning; Motor Rolls (b) centerless microhoning. Workpiece (b) (a)
- Lapping (래핑)

• Polishing (연마) / Buffing (버핑)

Ref.

Lapping





FIGURE 9.23 (a) Schematic illustration of the lapping process. (b) Production lapping on flat surfaces. (c) Production lapping on cylindrical surfaces.



Chemical Machining (화학적가공)





FIGURE 9.25 (a) Missile skin-panel section contoured by chemical milling to improve the stiffness-to-weight ratio of the part. (b) Weight reduction of space launch vehicles by chemical milling of aluminum-alloy plates. These panels are milled after the plates have first been formed into shape, such as by roll forming or stretch forming. The design of the chemically machined rib patterns can readily be modified at minimal cost. *Source: Advanced Materials and Processes*, ASM International, December 1990, p. 43.

Electrochemical Machining / Grinding

■ ECM (전해가공)

■ ECG (전해연삭)



(b)

FIGURE 9.31 (a) Schematic illustration of the electrochemical-grinding process. (b) Thin slot produced on a round nickel-alloy tube by this process.

Ref.

Electro Discharge Machining (EDM)

■ EDM (방전가공)



FIGURE 9.33 (a) Examples of cavities produced by the electrical-discharge-machining process, using shaped electrodes. The two round parts (rear) are the set of dies for extruding the aluminum piece shown in front. *Source*: Courtesy of AGIE USA Ltd. (b) A spiral cavity produced by a rotating electrode. *Source: American Machinist.* (c) Holes in a fuel-injection nozzle made by electrical-discharge machining. Material: Heat-treated steel.

Ref.

S. Kalpakjian, "Manufacturing Processes for Engineering Materials", 3rd/4th ed. Addison Wesley

FIGURE 9.34 Stepped cavities produced with a square electrode by EDM. The workpiece moves in the

two principal horizontal

synchronized with the

directions, and its motion is

downward movement of the electrode to produce various cavities. Also shown is a round electrode capable of producing round or elliptical

cavities. Source: Courtesy of AGIE USA Ltd.

Micro ECM / EDM





Wire EDM



■ Wire EDM (방전와이어 커팅)



FIGURE 9.35 Schematic illustration of the wire EDM process. As much as 50 hours of machining can be performed with one reel of wire, which is then discarded or recycled.



Laser beam machining (LBM)

Light Amplification by Stimulated Emission of Radiation (LASER)



Ref.



First Ruby Laser



Applications of Laser









Cutting

Heat treating

Welding

Table 9.5 General Applications of Laser in Manufacturing

Applications	Workpiece materials	Laser type
Cutting	Metal	PCO ₂ , CWCO ₂ , Nd:YAG, ruby
	Plastics	CWCO ₂
	Ceramic	PCO ₂
Drilling	Metal	PCO ₂ , CWCO ₂ , Nd:glass, ruby
	Plastics	Excimer
Marking	Metal	PCO ₂ , Nd:YAG
	Plastics	Excimer
	Ceramic	Excimer
Surface treatment	Matal	CWCO ₂
Welding	Matal	PCO ₂ , CWCO ₂ , Nd:YAG, Nd:glass, ruby





Focused Ion Beam System (1)



Schematics of FIB System

What is Focused Ion Beam ?

- Nanoscale Hybrid Fabrication Tool
 - Sputtering
 - Deposition

FIB Components

- Ion Gun (10⁻⁷ torr)
 - Liquid Metal Ion Source (LMIS)
- Ion Optical Column
 - Electrostatic Lens
 - Variable Aperture
- Vacuum Chamber (10⁻⁶ torr)
- Specimen Stage
 - Eucentric Stage
- Gas Nozzle
 - Carbon
 - Platinum
 - Tungsten

Focused Ion Beam System (2)

Hybrid Fabrication Methods







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Case study: Stent





FIGURE 9.43 Evolution of the stent surface. (a) MULTI-LINK TETRATM after lasing. Note that a metal slug is still attached. (b) After removal of slag. (c) After electropolishing.

FIGURE 9.42 Detail of the 3-3-3 MULTI-LINK TETRA™ pattern.

Notes: a. 0.12 mm (0.0049 in.) section thickness to provide radiopacity b. 0.091 mm (0.0036 in.) thickness for flexibility

Ref.