CLEANING AND SURFACE TREATMENTS

- Chemical Cleaning
- Mechanical Cleaning and Surface Preparation
- Diffusion and Ion Implantation

Overview of Industrial Cleaning

- Almost all workparts must be cleaned one or more times during their manufacturing sequence
- Chemical and/or mechanical processes are used to accomplish this cleaning
  - Chemical cleaning methods use chemicals to remove unwanted contaminants from the work surface
  - Mechanical cleaning involves removal of contaminants from a surface by various mechanical operations
Reasons Why Manufactured Parts (and Products) Must be Cleaned

• Prepare the surface for subsequent processing, such as a coating application or adhesive bonding
• Improve hygiene conditions for workers and customers
• Remove contaminants that might chemically react with the surface
• Enhance appearance and performance of the product

Important Factors in Selecting a Cleaning Method

• Contaminant to be removed
• Degree of cleanliness required
• Substrate material to be cleaned
• Purpose of the cleaning
• Environmental and safety factors
• Size and geometry of the part
• Production and cost requirements
Contaminant to be Removed

- Various contaminants build up on part surfaces, either due to previous processing or factory environment.
- Principal surface contaminants found in the factory:
  - Oil and grease, e.g., lubricants in metalworking
  - Solid particles such as metal chips, abrasive grits, shop dirt, dust, etc.
  - Buffing and polishing compounds
  - Oxide films, rust, and scale

Degree of Cleanliness

Refers to the amount of contaminant remaining after a given cleaning operation.
- A simple test is a *wiping method*, in which the surface is wiped with a clean white cloth:
  - Amount of soil absorbed by the cloth is observed
  - Non-quantitative but easy to use
Other Factors in Selection of Cleaning Method

• The substrate material must be considered, so that damaging reactions are not caused by the cleaning chemicals
  – Examples:
    ▪ Aluminum is dissolved by most acids and alkalis
    ▪ Steels are resistant to alkalis but react with virtually all acids
• Cleaning methods and associated chemicals should be selected to avoid pollution and health hazards

Chemical Cleaning Processes

• Alkaline cleaning
• Emulsion cleaning
• Solvent cleaning
• Acid cleaning
• Ultrasonic cleaning
• In some cases, chemical action is augmented by other energy forms
  – Example: ultrasonic cleaning uses high-frequency mechanical vibrations combined with chemical cleaning
Alkaline Cleaning

Uses an alkali to remove oils, grease, wax, and various types of particles (metal chips, silica, light scale) from a metallic surface

• Most widely used industrial cleaning method
• Alkaline solutions include sodium and potassium hydroxide (NaOH, KOH), sodium carbonate (Na₂CO₃), borax (Na₂B₄O₇)
• Cleaning methods: immersion or spraying, usually at temperatures of 50-95°C (120-200°F), followed by water rinse to remove residue

Emulsion Cleaning

Uses organic solvents (oils) dispersed in an aqueous solution

• The use of suitable emulsifiers (soaps) results in a two-phase cleaning fluid (oil-in-water), which functions by dissolving or emulsifying the soils on the part surface
• Can be used on either metal or nonmetallic parts
• Must be followed by alkaline cleaning to eliminate all residues of the organic solvent prior to plating
Solvent Cleaning

Organic soils such as oil and grease are removed from a metallic surface by means of chemicals that dissolve the soils

- Common application techniques: hand-wiping, immersion, spraying, and vapor degreasing
- **Vapor degreasing** (a solvent cleaning method) uses hot vapors of chlorinated or fluorinated solvents
  - Because the chemicals are hazardous, vapor degreasing has been largely discontinued as an industrial cleaning process, at least in the U.S.

Acid Cleaning

Removes oils and light oxides from metal surfaces using acid solutions combined with water-miscible solvents, wetting and emulsifying agents

- Common application techniques: soaking, spraying, or manual brushing or wiping carried out at ambient or elevated temperatures
- Cleaning acids include hydrochloric (HCl), nitric (HNO₃), phosphoric (H₃PO₄), and sulfuric (H₂SO₄)
Acid Pickling

A more severe acid treatment to remove thicker oxides, rusts, and scales
- The distinction between acid cleaning and acid pickling is a matter of degree
- Generally results in some etching of the metallic surface which serves to improve organic paint adhesion

Ultrasonic Cleaning

Mechanical agitation of cleaning fluid by high-frequency vibrations (between 20 and 45 kHz) to cause cavitation - formation of low pressure vapor bubbles that scrub the surface
- Combines chemical cleaning and mechanical agitation of the cleaning fluid
- Cleaning fluid is generally an aqueous solution containing alkaline detergents
- Highly effective for removing surface contaminants
Mechanical Cleaning and Surface Preparation

Physical removal of soils, scales, or films from the work surface by means of abrasives or similar mechanical action

- Often serves other functions also, such as deburring, improving surface finish, and surface hardening
- Processes:
  - Blast finishing
  - Shot peening
  - Mass finishing processes

Blast Finishing

High velocity impact of particulate media to clean and finish a surface

- The media is propelled at the target surface by pressurized air or centrifugal force
- Most well-known method is sand blasting, which uses grits of sand as the blasting media
- Other blasting media:
  - Hard abrasives such as aluminum oxide ($\text{Al}_2\text{O}_3$) and silicon carbide ($\text{SiC}$)
  - Soft media such as nylon beads
Shot Peening

High velocity stream of small cast steel pellets (called shot) is directed at a metallic surface to cold work and induce compressive stresses into surface layers

- Used primarily to improve fatigue strength of metal parts
- Purpose is therefore different from blast finishing, although surface cleaning is accomplished as a byproduct of the operation

Mass Finishing

Finishing parts in bulk by a mixing action in a container, usually in the presence of an abrasive media

- The mixing causes the parts to rub against the media and each other to achieve the desired finishing action
- Parts are usually small and therefore uneconomical to finish individually
- Processes include:
  - Tumbling
  - Vibratory finishing
Tumbling

Use of a horizontally oriented barrel of hexagonal or octagonal cross-section in which parts are mixed by rotating the barrel at speeds = 10 to 50 rev/min

- Finishing by "landslide" action - media and parts rise in the barrel as it rotates, then top layer tumbles down due to gravity
- Drawbacks: slow, high noise levels, and large floor-space required

Figure 28.1 - Diagram of tumbling (barrel finishing) operation showing "landslide" action of parts and abrasive media to finish the parts
Vibratory Finishing

• An alternative to tumbling
• Vibrating vessel subjects all parts to agitation with the abrasive media, as opposed to only the top layer as in barrel finishing
  – Consequently, processing times for vibratory finishing are significantly reduced
• The open tubs in this method permit inspection of the parts during processing, and noise is reduced

Mass Finishing Media

• Most are abrasive; however, some media perform nonabrasive finishing operations such as burnishing and surface hardening
  – Natural media (corundum, granite, limestone) - generally softer and nonuniform in size
  – Synthetic media (Al₂O₃ and SiC) - greater consistency in size, shape, and hardness
  – Steel - used for burnishing, surface-hardening, and light deburring operations
Processes to Alter Surface Chemistry and Properties

- Two processes that impregnate the surface of a substrate with foreign atoms:
  - Diffusion
  - Ion implantation
Diffusion

Alteration of surface layers of a material by diffusing atoms of a different material (usually an element) into the surface, usually at high temperatures

• The surface still contains a high proportion of substrate material
• The diffused element has maximum percentage at the surface and rapidly declines with distance below surface
• Applications in metallurgy and semiconductor manufacture

Figure 28.3 - Characteristic profile of diffused element as a function of distance below surface in diffusion.
The plot given here is for carbon diffused into iron
Metallurgical Applications of Diffusion

• Surface hardening treatments to increase hardness and wear resistance
  – Carburizing, nitriding, carbonitriding, chromizing, and boronizing
• Surface treatments to increase corrosion resistance and/or high-temperature oxidation resistance
  – Aluminizing - diffusion of aluminum into carbon steel, alloy steels, and alloys of nickel and cobalt
  – Siliconizing – diffusion of silicon into steel part surface

Semiconductor Applications

• In semiconductor processing, diffusion of an impurity element into the surface of a silicon chip is used to change the electrical properties at the surface to create devices such as transistors and diodes
• Called doping in semiconductor processing
Ion Implantation

Embedding atoms of one (or more) foreign element(s) into a substrate surface using a high-energy beam of ionized particles
- Result is an alteration of the chemistry and physical properties of the layers near the substrate surface
- Produces a much thinner altered layer and different concentration profile than diffusion
- Alternative to diffusion when the latter is not feasible due to high temperatures required

Figure 28.4 - Profile of surface chemistry as treated by ion implantation
Shown here is a typical plot for boron implanted in silicon
Note the difference in profile shape and depth of altered layer compared to diffusion coating in Figure 28.3
Advantages of Ion Implantation

- Low temperature processing
- Good control and reproducibility of impurity penetration depth
- Solubility limits can be exceeded without precipitation of excess atoms
- No problems with waste disposal as in electroplating and many coating processes
- No discontinuity between coating and substrate as in coating processes

Principal Applications of Ion Implantation

- Modifying metal surfaces to improve properties
- Fabrication of semiconductor devices