DI04019041: Fabrication Technology - Unit 5

GTU Course Presentation

July 24, 2026

Course Contents I

1. Lecture 38: Surface preparation methods
2. Lecture 39: Manual and motorized Emery papering
3. Lecture 40: surface color coating methods
4. Lecture 41: spray application

Introduction to Surface Preparation I

5.1 Surface preparation methods: Why surface preparation is critical in manufacturing and coating applications.

Introduction to Surface Preparation II

Key Points

- Removal of mill scale, rust, oxide films, weld spatter, and organic contaminants is essential to guarantee mechanical adhesion of coatings.
- Surface profile (roughness) directly influences the mechanical interlocking mechanism described by ASTM D4417.
- Poor preparation accounts for over 80% of premature coating failures under aggressive environment exposure.
- Primary classification: Mechanical (blasting, grinding, brushing), Chemical (pickling, degreasing), and Thermal preparation.

Abrasive Sand Blasting: Process & Standards I

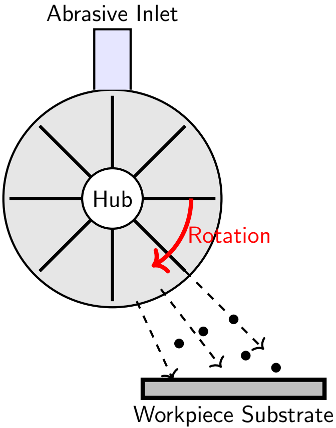
Pneumatic acceleration of abrasive media to clean and profile substrates.

Abrasive Sand Blasting: Process & Standards II

Key Points

- Mechanics: Compressed air (6 to 7 bar) accelerates media like silica sand, coal slag, or garnet through a venturi nozzle.
- Environmental & Health: Silica sand is highly restricted due to silicosis hazards (OSHA regulations), prompting transitions to garnet, staurolite, or copper slag.
- Cleanliness Standards: Reference ISO 8501-1 / SSPC-SP classifications: SP-5 (White Metal), SP-10 (Near-White Metal), SP-6 (Commercial), SP-7 (Brush-Off).
- Anchor Profile: Peak-to-valley height typically targeted between 37 to 75 $\mu m(1.5to3.0mils)forindustrialliquidcoatings$.

Centrifugal Shot Blasting Machine I



Centrifugal Shot Blasting Machine II

Key Points

- Centrifugal wheel blasting uses a high-speed rotating impeller to mechanically propel steel shots or grit without compressed air.
- Impact mechanics: Kinetic energy transfer compresses the surface, creating beneficial compressive residual stresses (similar to shot peening).
- Media selection: Spherical steel shots (cast steel) clean by impact hammer action; angular steel grits clean by shearing and scraping action.
- High-capacity production: Typically deployed in closed-loop conveyor systems for structural steel descaling and de-sanding of castings.

Surface Grinding Mechanics I

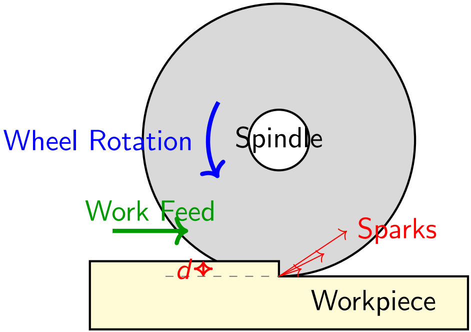
Precision machining utilizing a rotating abrasive wheel to remove material and establish a planar surface.

Surface Grinding Mechanics II

Key Points

- Kinematics: Horizontal spindle reciprocating table is the most common configuration for flat, precise engineering surfaces.
- Material Removal: Thousands of microscopic abrasive grains (Al_2O_3, SiC, CBN, or Diamond) act as single-point cutting tools, creating micro-chips.
- Thermal Effects: High localized temperatures can cause thermal damage, phase transformation (martensite formation), and tensile residual stresses.
- Cooling: Copious flood cooling with water-soluble synthetic fluids is required to control thermal expansion and prevent work-piece burning.

Surface Grinding Process Geometry I



Surface Grinding Process Geometry II

Key Points

- Depth of cut (d) typically ranges from 5 to 50 $\mu mperpassinprecisiongrindingapplications$.
- The chip formation occurs in three phases: elastic deformation (rubbing), plastic deformation (ploughing), and actual chip cutting.
- Wheel dressing: Frequent dressing with a diamond tool is critical to remove loaded metal chips and expose fresh, sharp abrasive grains.
- Surface finish achieved: Average roughness (R_a) typically ranges between 0.1 to 0.8 $\mu m(N4toN6grade)$.

5.2 Surface finishing methods: Post-machining processes to refine texture, reduce friction, or enhance aesthetics.

Surface Finishing Methods & Classifications II

Key Points

- Honing: Low-speed abrading process utilizing bonded abrasive sticks to produce cross-hatched surface patterns (critical for engine cylinder walls).
- Lapping: Free abrasive process utilizing a slurry with loose grains (e.g., diamond paste, alumina) between a lap plate and work-piece for ultra-flatness.
- Polishing & Buffing: Polishing removes minor scratches using fine abrasives; buffing uses soft wheels with compound to achieve a mirror finish.
- Superfinishing: Micro-honing process using very light pressure and rapid short-stroke oscillations to remove amorphous smear layers.

Metrology & Engineering Selection Criteria I

Evaluating finished surfaces for performance compliance.

Metrology & Engineering Selection Criteria II

Key Points

- Roughness Parameters: R_a (arithmetical mean deviation), R_z (maximum height of profile), and R_q (root mean square) measured using stylus profilometer.
- Functional Performance: Surface topography controls oil retention, fatigue life (via residual stress management), and coefficient of friction.
- Cost vs. Finish: Superfinishing and lapping exponentially increase manufacturing costs; target the coarsest finish acceptable for design lifetime.
- Corrosion Correlation: Smoother surfaces have fewer microscopic crevices, preventing localized cell concentration and stress corrosion cracking.

Manual and Motorized Emery Papering I

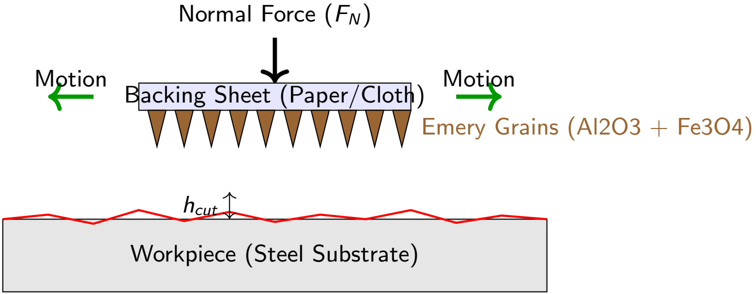
Emery papering is a micro-abrasive process using emery (a natural composite of corundum/Al_2O_3 and magnetite/Fe_3O_4) glued to paper or cloth backing to remove surface oxides, mill scale, and achieve targeted surface roughness (R_a) before coating or welding.

Manual and Motorized Emery Papering II

Key Points

- Manual emery papering is performed in multi-directional or cross-hatch patterns to prevent deep unidirectional grooving, transitioning from coarse grit (e.g., 80-120 grit for heavy descaling) to fine grit (up to 600-1000 grit for pre-polishing).
- Motorized emery papering utilizes orbital sanders, belt grinders, or rotary discs, significantly increasing material removal rate (MRR) and ensuring uniform contact pressure (typically 15-30 kPa) through pneumatic or electric regulation.
- Wet emery papering (using water or light oils as cutting fluids) reduces friction heat, prevents loading (clogging of abrasive spaces with debris), and flushes away detached metal particles.
- Standard compliance: Abrasives are graded according to

Mechanics of Emery Papering I



Mechanics of Emery Papering II

Key Points

- Abrasive grain interaction: Grains act as micro-cutting tools with highly negative rake angles, causing micro-plowing and micro-cutting of the workpiece surface.
- Normal force (Fn) controls the depth of cut (h_cut), directly impacting the material removal rate and the resulting surface roughness profile.
- Frictional heating during motorized operations can induce localized tempering; proper coolant flow or intermittent contact is required to prevent thermal degradation of the grain structure.

Manual and Motorized Wire Brushing I

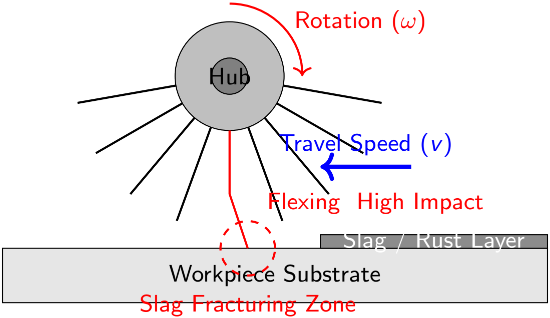
Wire brushing is a mechanical surface preparation method that uses high-strength metal filaments to remove surface contaminants like slag, rust, weld spatter, and old coatings, without significantly altering the base metal dimensions.

Manual and Motorized Wire Brushing II

Key Points

- Filament materials are selected based on metallurgical compatibility: carbon steel brushes for carbon steels, stainless steel (typically Grade 302 or 304) for stainless steel and aluminum to prevent galvanic corrosion and cross-contamination.
- Manual wire brushing uses handheld wooden-back or plastic-handled brushes, primarily applied to inter-pass weld cleaning in pipe welding to remove slag and prevent inclusions.
- Motorized wire brushing employs pneumatic or electric angle grinders rotating cup brushes or wheel brushes at speeds of 6,000 to 12,000 RPM, where the centrifugal force stiffens the wire filaments for aggressive impact.
- Filament configurations: Knot-wire (twisted) brushes provide high impact for heavy corrosion/slag removal;

Wire Brushing Setup and Mechanics I



Wire Brushing Setup and Mechanics II

Key Points

- Centrifugal rigidity: As rotation speed increases, the filaments align radially, converting the rotational kinetic energy into repetitive micro-impacts on the workpiece surface.
- Weld cleaning zone: The high-speed impact of wire tips shatters brittle slag and oxide coatings, separating them from the ductile base metal.
- Wire flexure: Dynamic bending of the wires prevents gouging of the base metal, keeping the bulk substrate intact while removing superficial layers.

Buffing Wheel Machining & Polishing Compounds I

Buffing is a finishing process using a rotating cloth wheel impregnated with fine abrasive compounds to generate a highly reflective, mirror-like surface (low Ra, e.g., < 0.1 microns) by flowing and leveling micro-asperities.

Buffing Wheel Machining & Polishing Compounds II

Key Points

- Buffing wheels (mops) are made of soft materials such as cotton, flannel, sisal, or wool, constructed as pleated, spiral-sewn, or loose discs to control flexibility and cooling air flow.
- Polishing compounds consist of micro-sized abrasives suspended in a binder of grease, wax, or stearic acid. Common abrasives include Tripoli (silica) for cutting down, and aluminum oxide or rouge (iron oxide) for color buffing.
- Process stages: Cut buffing utilizes coarser compounds and firm wheels to remove minor scratches; color buffing uses very fine compounds and loose flannel wheels to develop high reflectivity.
- Operating parameters: Buffing is performed at high surface speeds, typically 1500 to 2500 m/min (SFPM

Solvent Cleaning Processes in Fabrication I

Solvent cleaning is a pre-treatment process to remove organic contaminants (greases, cutting oils, drawing lubricants, anti-rust compounds) from metal surfaces, preventing downstream weld defects, poor coating adhesion, or chemical reactions.

Solvent Cleaning Processes in Fabrication II

Key Points

- Acetone (C3H6O): A fast-evaporating, highly polar solvent. Used for precision degreasing of critical components, such as cleaning aluminum weld joints immediately before Gas Tungsten Arc Welding (GTAW) to prevent hydrogen porosity.
- Kerosene: A slow-evaporating, aliphatic hydrocarbon solvent. Effective for dissolving heavy grease, tar, and high-viscosity protective oils. Leaves a thin residual film that provides temporary corrosion protection, which must be removed before welding or painting.
- Petrol (Gasoline): High solvency power for oils and waxes, but extremely hazardous due to its low flash point (<-40 C), volatility, and risk of vapor-air explosive mixtures. Strictly avoided in industrial fabrication lines.
- Diesel: A heavy distillate hydrocarbon. Excellent for

Health, Safety, and Environmental (HSE) Protocols I

Mechanical and chemical surface preparation methods involve significant industrial hazards, including airborne particulate matter, fire risks, toxic vapors, and physical injury, requiring strict compliance with OSHA and regional safety codes.

Health, Safety, and Environmental (HSE) Protocols II

Key Points

- Inhalation hazards: Wire brushing and emery papering generate metal dust and mineral particles. Dry buffing creates fiber and compound dust. Local exhaust ventilation (LEV) and N95/N100 particulate respirators are mandatory.
- Flammability and explosion risks: Acetone, petrol, and kerosene present severe fire hazards. Petrol must never be used for open degreasing. All solvent operations must be isolated from welding areas to prevent ignition by electric arcs or sparks.
- Personal Protective Equipment (PPE): Safety glasses with side shields and face shields are required during motorized brushing and buffing to protect against flying wires or debris. Nitrile or chemical-resistant gloves are mandatory for solvent handling.

Overview of Surface Color Coating Methods I

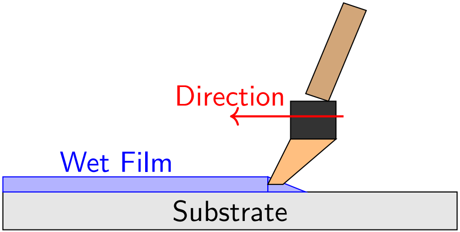
Surface color coating serves dual functions in mechanical fabrication: protecting the substrate from corrosion and environmental degradation, and achieving specified engineering aesthetics. Method selection depends on part geometry, viscosity, wet film thickness (WFT) targets, and production volume.

Overview of Surface Color Coating Methods II

Key Points

- Primary coating roles: Corrosion mitigation (barrier control), wear resistance, and aesthetic finishing.
- Key parameters: Wet Film Thickness (WFT), Dry Film Thickness (DFT), coating viscosity (ASTM D1200), and adhesion (ASTM D3359).
- Application techniques: Manual brush application, industrial roller application, and precision cotton dab/swab application.

Brush Application: Process Mechanics I



Brush Application: Process Mechanics II

Key Points

- Mechanics: Fluid is loaded into the brush bristles by capillary action and transferred via shear-induced flow during stroke application.
- Shear Thinning: Brush friction introduces shear, temporarily lowering viscosity of thixotropic coatings to allow smooth flow.
- Geometry Suitability: Ideal for complex structural joints, bolts, welds, and small-batch custom metal components.
- Leveling: Viscous force vs surface tension dictates leveling; proper wet film must self-level before solvent flash-off.

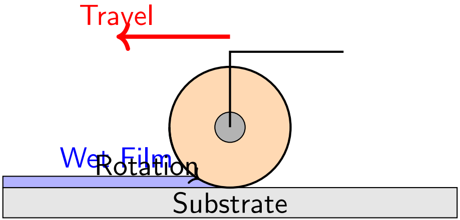
Brush application is widely used for stripe coating on edges and welds to ensure complete coverage, preventing early failure. Proper bristle selection and viscosity control are vital.

Brush Application: Industrial Practices & Defects II

Key Points

- Bristle Selection: Natural bristles (hog hair) for oil-based/solvent coatings; synthetic filaments (nylon/polyester) for water-borne coatings.
- Stripe Coating: Application of paint to welds, corners, and bolts before full spray coats (ISO 12944-5) to guarantee minimum DFT.
- Common Defects: Brush marks (ropiness due to high viscosity/poor leveling), sags and runs (low viscosity/thick application), and bristle shedding.
- Standardization: Viscosity evaluation using Ford Cup No. 4 and brushability assessment via ASTM D5068.

Roller Application: Principles and Mechanics I



Roller Application: Principles and Mechanics II

Key Points

- Process Dynamics: A rotating cylindrical core with a fabric nap cover transfers paint from a tray onto flat, broad surfaces.
- Nap Selection: 3/16 to 1/4 inch nap for smooth metal surfaces; 3/8 to 1/2 inch nap for semi-rough panels.
- Film Splitting: Splitting of the wet paint film between the roller cover and substrate leaves a textured stipple pattern.
- Coating Transfer Rate: Much faster deposition than brush application; highly efficient for flat sheets, tanks, and structural panels.

For massive volume production, automated roll coaters (coil coating lines) continuously apply color coatings to metal coils at line speeds up to 200 m/min.

Roller Application: Coil Coating & Industrial Lines II

Key Points

- Coil Coating: Metal sheets are uncoiled, chemically pretreated, roller-coated, cured, and recoiled in a continuous, high-efficiency loop.
- Reverse Roll Coating: Applicator roll rotates in the direction opposite to the metal strip travel, producing a smooth, uniform finish.
- Direct Roll Coating: Applicator roll rotates in the direction of the metal strip travel; typically yields a thinner, textured coat.
- Defect Mitigation: Strict control of roll gap, roll-to-strip speed ratio, and temperature prevents defects like ribbing and cascading.

Cotton Application: Swabbing & French Polishing I

Cotton application uses a cotton core (fad) wrapped in lint-free fabric. Fluid release is controlled via compression and capillary action, delivering ultra-thin, highly leveled paint layers.

Cotton Application: Swabbing & French Polishing II

Key Points

- Mechanism: Fine capillary pressure dispenses thin, micro-level coatings without mechanical brush marks or stipple textures.
- Industrial Swabbing: Used extensively for localized chemical conversion coatings (such as Alodine per MIL-DTL-81706 on aerospace alloys).
- French Polishing: Traditional high-end finishing method using shellac, building hundreds of microscopic layers for deep luster.
- Advantages: Exceptionally smooth finish, zero brush line profile, minimal overspray, and high localized thickness control.

Process Selection & Comparative Evaluation I

Choosing the appropriate coating technique requires analyzing part geometry, dry film thickness (DFT) specifications, production speed, and volatile organic compound (VOC) emissions.

Process Selection & Comparative Evaluation II

Key Points

- Transfer Efficiency: Brush and cotton swab feature high transfer efficiency ($>$95%), whereas roller application yields 85% to 90%.
- Surface Texture: Brush leaves tool lines; roller creates a stipple (orange peel) texture; cotton swab provides a flat, leveled profile.
- Quality Codes: Strict adherence to SSPC-PA 2 for dry paint thickness measurement and ASTM D4541 for pull-off adhesion testing.
- Environmental Safety: Regulatory monitoring of VOC content in paint formulations according to EPA Method 24.

Industrial Spray Application Principles I

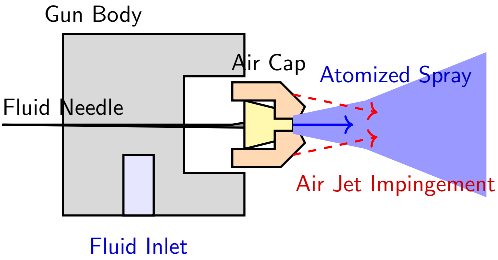
Overview of atomization and deposition mechanics in industrial spray coating systems.

Industrial Spray Application Principles II

Key Points

- Air Atomized Spraying: Uses compressed air (2.0 to 6.0 bar) to atomize liquid paint into a fine mist; offers exceptional finish quality but low transfer efficiency (30% - 40%).
- Airless Spraying: Forces coating material through a small nozzle orifice under high hydraulic pressure (100 to 350 bar); ideal for high-viscosity materials, achieving 50% - 60% transfer efficiency.
- HVLP (High Volume Low Pressure): Delivers high air volume at low atomizing pressure ($<$0.7 bar at the air cap); drastically reduces bounce-back and overspray, achieving transfer efficiencies up to 75%.
- Electrostatic Spraying: Imparts a negative charge (30 to 100 kV) to atomized paint droplets; attracted to grounded conductive substrates, minimizing

Air Atomized Spray Gun Mechanics I



Air Atomized Spray Gun Mechanics II

Key Points

- Fluid needle retraction regulates the paint flow rate exiting the fluid tip.
- Compressed air flows through the annulus of the air cap, shearing the fluid stream into micro-droplets.
- Horn air jets impinge on the spray stream from opposite sides to form the elliptical fan pattern.
- Crucial operator variables include target distance (150-250 mm), gun traverse speed, and paint viscosity (ASTM D1084).

The transition and relationship between wet-state and dry-state films in industrial applications.

Coating Film Thickness Mechanics II

Key Points

- Wet Film Thickness (WFT): The dimensional thickness of a freshly sprayed wet coating immediately after application, measured prior to solvent evaporation.
- Dry Film Thickness (DFT): The thickness of the final cured coating film remaining after solvent evaporation and resin cross-linking.
- Volume Solids Ratio: The fundamental mathematical relationship is DFT = WFT * (Volume Solids % / 100). For example, 150 microns of a 60% volume solids paint yields 90 microns of DFT.
- Dilution Correction: If thinners are added to adjust viscosity, the formula becomes: DFT = [WFT * Volume Solids %] / [100 + % Thinner Added]. Under-thickness is common when thinning is ignored.

Wet Film Thickness (WFT) Measurement I

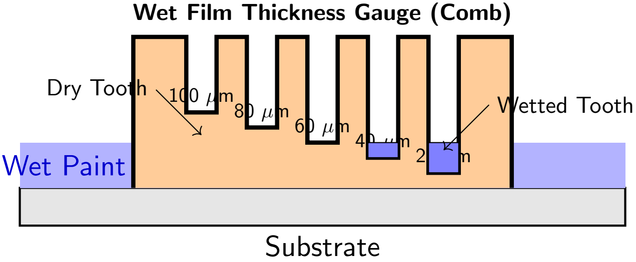
Non-destructive, real-time quality control checks to verify paint application parameters.

Wet Film Thickness (WFT) Measurement II

Key Points

- Standard Guidelines: WFT measurement methods are governed internationally by ASTM D4414 (comb gage) and ISO 2808.
- WFT Comb Gage (Notch Gage): A metallic plate with graduated teeth of different lengths. Pressed flat and perpendicular to the substrate, it measures the thickness between the wetted and dry teeth.
- WFT Wheel Gage (Interchemical): Uses three concentric wheels where the middle wheel is eccentric. Rolling the gage across the wet film leaves a mark at the point of contact to read thickness.
- Operational Value: Immediate verification allows spray operators to adjust traverse speeds or pressure settings, preventing sags, runs, or thin spots before the coating cures.

Principle of Wet Film Thickness Comb Gage I



Principle of Wet Film Thickness Comb Gage II

Key Points

- The outer support legs of the comb rest firmly on the substrate through the wet coating.
- Inner teeth have graduated clearances (e.g., 20, 40, 60, 80, 100 microns).
- Wetting occurs on all teeth with clearances less than the wet film thickness (20 and 40 microns in this diagram).
- The actual thickness value is documented as falling between the lowest dry tooth (60 microns) and the highest wet tooth (40 microns).

Dry Film Thickness (DFT) Measurement I

Nondestructive and destructive instruments for verifying dry, cured paint structures.

Dry Film Thickness (DFT) Measurement II

Key Points

- Magnetic Induction (ASTM D7091): Used for non-magnetic coatings (e.g., epoxies, polyurethanes) applied to magnetic/ferrous steel substrates.
- Eddy Current (ISO 2360): Measures non-conductive coatings applied on non-ferrous conductive metals (e.g., anodizing or paint on aluminum).
- Ultrasonic Testing (ASTM D6132): Uses ultrasound echo flight time to measure coatings applied on non-metal substrates like concrete, wood, and polymers.
- Destructive Testing (ASTM D4138): The Paint Inspection Gauge (PIG) cuts a V-groove through the coating; a microscopic scale measures the cut width to compute thickness.

Calibration and Quality Assurance Standards I

Adhering to international quality standards for thickness verification in metal fabrication.

Calibration and Quality Assurance Standards II

Key Points

- SSPC-PA 2 Standard: The preeminent standard specifying the frequency of DFT measurements and acceptable tolerances over structural areas.
- The 80/20 Rule: Under SSPC-PA 2, no single spot measurement may be less than 80% of the specified minimum thickness, and no spot may exceed 120% of the maximum.
- Calibration Verification: Operators must verify gauge calibration daily using certified shims placed on representative, unpainted steel profiles.
- Statistical Sampling: A typical procedure requires 5 spot measurements (each the average of 3 gauge readings in a 4 cm circle) per 10 square meters of coating.