End Effector Selection and Design

• End Effector Types
• General Design Practices
• Specific Design Criteria
• Case Studies
End Effector Types

- Mechanical Grippers
- Negative Pressure (vacuum)
- Magnetic
- Hooks
- Ladles (scoops liquid or powder)
- Others (electrostatic)
End Effector Types - Mechanical Grippers

- Parallel Grippers
  - Most common
  - More accurate
End Effector Types - Mechanical Grippers

- **Parallel Grippers**
  - Most common
  - More accurate

- **Angular Gripper**
  - Limited space
  - Clearance

- **Toggle Gripper**
  - High mechanical advantage
  - Over centering
End Effector Types- Mechanical Grippers

- External Grippers
- Internal Grippers
End Effector Types - Negative Pressure

- Vacuum
  - Suction Cups
  - Edge grip
  - Specialty

Flat

Shaped

Bellows

Rough Surfaces
End Effector Types- Negative Pressure

- Vacuum
- Bernoulli (non-contact)
End Effector Types- Negative Pressure

• Vacuum
• Bernoulli
• Coanda (high flow, low pressure)
End Effector Types- Negative Pressure

- Vacuum
- Bernoulli
- Coanda (high flow, low pressure)
- Specialty
  - Vacuum/pressure (Coreflow)
  - Vacuum/ultrasonic (Zimmerman-Schlip)
General Design Practices

• Minimize weight - affects robot performance
  – Material selection
  – Lightening holes

• Minimize size
  – Helps minimize weight
  – Reduce cantilever load and moment of inertia
  – May conflict with flexibility

• Maximize rigidity
  – Improves positional accuracy and repeatability
  – Reduce vibrations

• Maximize holding force
  – Reliably hold part (without damage)
  – Orient part to maximize force in direction of motion

• Maintenance and form factor change considerations
Specific Design Criteria

- Work piece analysis (objects to be handled)
- Process Analysis
- Design Considerations
Work Piece Analysis

- Work piece Dimensions and tolerances
  - Determines size and weight of end effector
    - Material, stiffness, cost
  - Can single tool handle size and shape variation of work piece?
  - Is compliance required?
    - PV Wafer stack not parallel due to wedge shape of wafers
Work Piece Analysis

- Material and physical properties
  - Use gripper, vacuum or magnet?
  - Permissible contact points
    - Semiconductor: 3mm exclusion zone
    - Hard disk: ID clamp zone, OD chamfer
    - PV wafers: contact top surface but minimal edge contact
  - Permissible grip forces
    - High force on PV wafer surface creates micro-cracks
    - Need to control force and clamping speed?
  - Weight and balance of part
    - Quantity and location of grip points
  - Surface finish and shape
    - Vacuum for smooth flat surfaces, mechanical gripper for round parts
    - Surface texture and condition (oily, sticky)
Process Analysis

- Manual or automated
  - Take tool to part or part to tool?
- Range and quantity of parts
  - Hard disk tools require multiple form factors (48, 65, 78, 84, 95mm)
  - Automated or manual tool change
- Presentation and disposition
  - Position and orientation at pickup and drop-off
  - Dimensional clearances to avoid interferences
Process Analysis

• Sequence of events and cycle time requirements
  – Number of end effectors
  – Batch processing

• Environment
  – Cleanliness
  – Temperature (environment or workpiece)
  – Atmospheric or Vacuum
  – Chemicals
  – Vibration and shock

• In process inspection requirements
  – Add gauging to end effector
  – Compatibility with inspection process
Design Considerations

- Cost
- Flexibility
- Changeover
- Safety (lost of power, collision)
- Handling of damage product
- Sensing
  - Part sensing
Case Studies
Case Studies

• Vacuum end effector- Hot wafers
• Bonded wafers
• Picking wafer from blind pocket
• PV cell handling- high speed
• PV cell handling- perforated wafers
Hot Wafers- Vacuum End Effector

- Problem: How to pick up a hot wafer with a cold vacuum end effector?
  - Wafer deforms (warps) due to temperature gradient and breaks vacuum.
- Solution: a paddle type end effector with a low thermal mass insert made from low thermal conductivity material.
Hot Wafers- vacuum end effector

Spring

Quartz Insert

O-ring
Warped Wafers- vacuum end effector

- Problem: Bonded wafers are often deformed (warped or bowed).
  - Edges are sharp and brittle and cannot be handled with edge grip end effectors
  - Will not hold vacuum with rigid vacuum pads
- Solution: compliant vacuum pads
Warped Wafers- vacuum end effector

Pad snaps onto a ball shaped receptor and “rocks” +/-1deg

Vacuum pads
Top Surface, Non-contact Pick-up

- Problem: How to pick up a wafer from a blind pocket- without touching top surface
- Vacuum will not work

- Solution:
  - Bernoulli gripper creates low pressure for pickup
  - Edge support prevents contact with wafer surface
Top Surface, Non-contact Pick-up

- Housing
- Bernoulli gripper
- Wafer contacts housing only at the edge
PV wafer handling

Problem: How to pick up and drop off PV wafers at 3600pph without damage
  - Off flat belt
  - Off stationary coinstack
  - Cycle time is limited by pickup and dropoff- not robot speed

Solution:
  - High flow low vacuum, generate at point of use
    • Rapid pickup, low stress on wafer
  - Built-in blowoff for quick release of wafer
  - Rigid, large contact surface for high holding force with non-marking wafer support
PV wafer handling

- Videos
  - High speed pickup and dropoff
  - Slow motion of pickup and dropoff
  - 7200pph (for alternative substrate)
PV wafer handling- Fragile

- **Problem:** Pick up highly fragile partially perforated wafers off coinstack.
  - Wafers stick together through surface tension
  - Vacuum applied on top wafer leaks through and holds on to wafers below

- **Solution:**
  - Add blowoff nozzle to separate cells
  - Change vacuum pattern with compliant seal in non-perforated cell area