Lecture 11

Chapter 21
Fundamentals of Machining

Fundamentals of Machining

- Machining (Cutting)
  - Process of the removal of material from the surface of a workpiece by production of chips
- Turning
  - Cutting tool removes a layer of material from a rotating workpiece
- Cutting-off
  - Tool moves radially inward on workpiece making two piece
- Slab-milling
  - Rotating cutting removes layer of material
- End-milling
  - Rotating cutter produces a cavity
Cutting Process

- Depth of cut ($t_o$)
- Feed rate
  - Distance tool travels per unit revolution
- Chip production
  - Plastic deformation and shearing

Cutting Variables

- Independent
  - Tool material and coatings
  - Tool Shape, surface finish, and sharpness
  - Workpiece material and condition
  - Cutting speed, feed and depth of cut
  - Cutting fluids
  - Characteristics of the machine tool
  - Workholding and fixturing

- Dependent
  - Type of chip produced
  - Force and energy dissipated
  - Temperature rise in workpiece, the tool and the chip
  - Tool wear and failure
  - Surface finish and surface integrity of the workpiece
Factors Influencing Machining Operations

TABLE 20.1

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Influence and interrelationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting speed, depth of cut,</td>
<td>Forces, power, temperature rise, tool life, type of chip, surface finish.</td>
</tr>
<tr>
<td>Feed, cutting fluids</td>
<td></td>
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<tr>
<td>Tool angles</td>
<td>As above; influence on chip flow direction; resistance to tool chipping.</td>
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<tr>
<td>Continuous chip</td>
<td>Good surface finish; steady cutting forces; undesirable in automated machinery.</td>
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<tr>
<td>Built-up edge chip</td>
<td>Poor surface finish; thin stable edge can protect tool surfaces.</td>
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<tr>
<td>Discontinuous chip</td>
<td>Desirable for ease of chip disposal; fluctuating cutting forces; can affect surface finish and</td>
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<tr>
<td></td>
<td>cause vibration and chatter.</td>
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<tr>
<td>Temperature rise</td>
<td>Influences tool life, particularly crater wear, and dimensional accuracy of workpiece; may</td>
</tr>
<tr>
<td></td>
<td>cause thermal damage to workpiece surface.</td>
</tr>
<tr>
<td>Tool wear</td>
<td>Influences surface finish, dimensional accuracy, temperature rise, forces and power.</td>
</tr>
<tr>
<td>Machinability</td>
<td>Related to tool life, surface finish, forces and power.</td>
</tr>
</tbody>
</table>

Modeling the Cut

(a) Rake angle, a

(b)
Modeling the Cut

- Cutting ratio (r)
  - \( \frac{t_o}{t_c} = \frac{\sin \phi}{(\cos \phi - \alpha)} \)

- From mass continuity
  - \( V_{t_o} = V_c t_c \)
  - \( V_c = V_r \)
  - \( r = \frac{V_c}{V} \)
  - \( V_c = V \sin \phi / (\cos \phi - \alpha) \)

Types of Chips

Figure 20.5  Basic types of chips and their photomicrographs produced in metal cutting: (a) continuous chip with narrow, straight primary shear zone; (b) secondary shear zone at the chip-tool interface; (c) continuous chip with large primary shear zone; (d) continuous chip with built-up edge; (e) segmented or nonhomogeneous chip and (f) discontinuous chip. Source: After M. C. Shaw, P. K. Wright, and S. Kalpakjian.
Hardness Profile of Workpiece During Cutting

- Higher hardnesses indicate a larger amount of work hardening (more plastic deformation)

Methods to Break Chips

- Chip breaker
- Rake face
- Clamp
- Tool
- Workpiece
Forces Generated During Cutting

- $F_c$ = Cutting Force
- $F_t$ = Thrust Force
- $F$ = Friction Force
- $N$ = Normal Force
- $F_s$ = Shear Force
- $F_n$ = Normal Force

Merchant’s Circle

- $F_c$, $F_t$, $F$, $N$, $F_s$, $F_n$
Results from Merchant’s Circle

- Friction Force = $F_c \sin \alpha + F_t \cos \alpha$
- Normal Force = $F_c \cos \alpha - F_t \sin \alpha$
- $\mu = F/N$ and $\mu = \tan \beta$ (typically 0.5 – 2)
- Shear Force = $F_s = F_c \cos \phi - F_t \cos \phi$
- Force Normal to Shear Plane $F_n = F_c \sin \phi + F_t \cos \phi$

Material Removal Rate (MRR)

- Material Removal Rate (MRR)
  - MRR = Volume Removed / Time
- Volume Removed = $L \cdot w t_o$
- Time to move a distance $L = L/V$
- MRR = $L \cdot w t_o / (L/V) = V \cdot w t_o$