Technology II

Manufacturing methods
Gears Machining

GEAR TYPES

• Cylindrical gears:
  - spur
  - helical

• Bevel gears:
  - straight
  - curved (spiral)

• Worm wheels and worms
**Spur and helical gears cutting**

**METHODS:**

- **form milling** – using a **cutter** (with the same **edge profile** as the shape of the tooth space) and a **dividing device**
- **hobbing** – using a **hob** and a **generating process** for creating a tooth profile
- **shaping** – using a **shaper cutter** and a **generating process** for creating a tooth profile
- **broaching**
Gear machining – form milling (single gear tooth cutter)

Fig. 10.1. Basic method of machining gears by form milling.
Gear machining – form milling
## Gear milling – tolerances and surface finish

<table>
<thead>
<tr>
<th>Type of cut</th>
<th>IT</th>
<th>Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Form milling – shape mill</td>
<td>9–11</td>
<td>3,2 - 6,3</td>
</tr>
<tr>
<td>End milling</td>
<td>8–9</td>
<td>3,2 - 6,3</td>
</tr>
</tbody>
</table>
Gear machining - hobbing

- **Hob** – a tool designed as a *worm shaped cutter*, which acts by the cutting *as a worm cooperating with the machined gear wheel*. 

![Diagram of a hob and a machined gear wheel.]
Hobbing cutter
Gear hobbing
Gear hobbing

Fig. 10.3. The set of the axis of the hob to the axis of the gear blank in hobbing:
(a) spur, and (b) helical gears.

Fig. 10.4. Generating action of a tooth in hobbing.
Gear hobbing machine tool

Fig. 10.5. Hobbing machine.
Gear hobbing machine tool
Gear hobbing – kinematic schema
Gear machining - shaping

• circular shaper cutter

• rack shaper cutter

Fig. 10.7. Rack shaper cutter.
Gear shaping – a circular cutter
Gear shaping – a circular cutter
Gear shaping – the principle

**Spur gears**
- Cutter
- Shaper
- Workpiece
- Approach
- Return stroke
- Cutting
- Back-off

**Helical gears**
- Cutting motion
- Feed
- Generating
Gear shaping – a circular cutter
Gear shaping – a rack cutter
Gear shaper with the rack cutter
## Tolerances and surface finish

<table>
<thead>
<tr>
<th>Type of cut</th>
<th>IT</th>
<th>Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hobbing</td>
<td>5 - 7</td>
<td>0,8 – 3,2</td>
</tr>
<tr>
<td>Shaping – circular cutter</td>
<td>5 – 6</td>
<td>0,8 – 1,6</td>
</tr>
<tr>
<td>Shaping – rack cutter</td>
<td>4 - 5</td>
<td>0,8 – 1,6</td>
</tr>
</tbody>
</table>
Broaching

• Very productive method
• Broach has the shape of gear
• Ideal for internal gears
  – Tooth gaps one after another
  – All gaps simultaneously

Desc.:
1 – elongated body, 2 – teeth, 3 – gullets, 4 – teeth gaps, 5 – axis, 6 – follower end, 7 – pull end, 10 – outside shape of broach
Broaching

• From a premachined hole a final gear is made
## Broaching

<table>
<thead>
<tr>
<th>Type of cut</th>
<th>IT</th>
<th>Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roughing</td>
<td>5 – 6</td>
<td>0,8 – 1,6</td>
</tr>
<tr>
<td>Finishing</td>
<td>4 – 5</td>
<td>0,8 – 1,6</td>
</tr>
</tbody>
</table>
Spur and helical gears finishing

METHODS:

• **shaving** – for gears **without** heat treatment
• **grinding** – mostly for gears **after** heat treatment
  - form grinding
  - involute - generating grinding
• **lapping**
• **teeth rounding** – creating a shape of tooth (in the direction parallel to the axis of rotation) to make changing gears easier
A gear wheel being shaved is run in contact with a shaving cutter

Shaving cutter – HSS tool; teeth with **serrations**, which are acting in the shaving

**Fig. 10.12** Shaving cutter.

**Fig. 10.13** Tooth of the shaving cutter.
GEAR WHEELS SHAVING

The gear and the cutter are run in mesh with their axes crossed at a small angle. During the rotation the gear is reciprocated longitudinally across the cutter. This "shaving" process causes very fine chips are cut from the tooth surface (process requires less than 1 minute).
Form gear grinding

Fig. 10.15. Form gear grinding.
Form splining grinding
Involute-generating grinding

Fig. 10.16. Straight-sided grinding wheels with a dresser.

Fig. 10.17. Straight-sided grinding wheel and involute-generation.
Involute-generating grinder

Fig. 10.19. Involute-generating grinding with a worm grinding wheel.
Involute-generating grinder
# Gear finishing – tolerances and surface finish

<table>
<thead>
<tr>
<th>Type of cut</th>
<th>IT</th>
<th>Ra</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shaving</td>
<td>5 - 6</td>
<td>0.4 – 0.8</td>
</tr>
<tr>
<td>Form grinding</td>
<td>5 – 7</td>
<td>0.2 – 1.6</td>
</tr>
<tr>
<td>Involute-generating grinding with straight-sided</td>
<td>2 - 4</td>
<td>0.2 – 0.4</td>
</tr>
<tr>
<td>grinding wheels</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Involute-generating grinding with a worm grinding</td>
<td>3 - 5</td>
<td>0.2 – 0.8</td>
</tr>
<tr>
<td>wheels</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Gear lapping

- On finished, shaved and hardened gears.
- The gear runs in contact with one or more cast iron lapping gears.
- Flow of oil with abrasive is used.
- Improves surface quality at low costs then grinding.
- $Ra = 0.1 - 0.2$
Teeth rounding

Fig. 10.21. Teeth rounding by milling cutter.
Teeth rounding

Abdachen Außenverzahnung

Abdachen Innenverzahnung

Einseitig Anfasen/Entgraten Stirnräder
Anfasen/Entgraten Kegelräder
Kurzverzahnungen Wälzabdachen
Kurzverzahnungen Wälzabdachen
Straight bevel gears cutting

METHODS:

• **form milling** – using a **cutter** (with the same form as the tooth face) and creating first one, than the opposite **face flank of the tooth**

• **involute-generating milling** – using two **cutters** representing one tooth of a rack and a **generating process** for creating a tooth profile

• **shaping** – using a **shaping rack tool** and a **generating process** for creating a tooth profile

• **broaching** – using **rotational broach**
Straight bevel gears

involute-generating milling

Fig. 10.23. Involute-generating milling.
Straight bevel gears - shaping

Fig. 10.25. The basic kinematics of straight bevel gear shaving.
Straight bevel gears - broaching

Fig. 10.28. Strait bevel gears broaching (Revacycle method).
Straight bevel gears - broaching
Curved bevel gears cutting

METHODS:

• **Gleason** – teeth curved in the form of circle
• **Oerlikon** – teeth curved in the form of epicycloid
• **Klingelnberg** – teeth curved in the form of involute
Gleason method

Tool is a composition of a round body and cutting tools. The can be adjusted separately.
Curved bevel gears - Oerlikon

Fig. 10.31. Continuous involute-generating Oerlikon method.
Worms and worm gears

Worms – produced by turning or form milling

Fig. 10.38. Worm producing by turning.

Fig. 10.39. Globoid worm producing by form milling.
Worms and worm gears

Worm gears – produced by hobbing
Worm hob has a small diameter
In feed machining
CNC machines

Dedicated hobbing machine:
- Expensive machine
- Limited in size (modulus)
- Limited in shape (kinematics)
- used to be only option

CNC lathe with a special tool and cycle in control system
- Economical benefit
- One-step machining including gear
- Easy setup
CNC machining of gears

•Sandvik Coromant

Milling in soft and hard state of material!
*Method Up-Gear® Technology for milling of gears*
CNC machining of gears

• Sandvik Coromant

Milling in soft and hard state of material!
*InvoMilling method multiprocesssing machining centers*

- dry cutting
- multiaxis machining
- costs reduction
CNC machining of gears

- Sandvik Coromant

Milling in soft and hard state of material!

InvoMilling method multiprocesssing machining centers
CNC machining of gears

- Seco Tools
  Gear roughing

Roughing of external gears
CNC machining of gears

- Seco Tools
  - Finishing of gear profiles external
  - Finishing of gear profiles internal
CNC machining of gears

• Seco Tools
  Hobbing cutter with indexable inserts
CNC machining of gears

- Seco Tools
  Two screw threaded hobbing cutter for gears with inserts

http://www.mmspektrum.com/clanek/nastroje-pro-frezovani-ozubeni.html
CNC machining of gears

GEAR SKIVING (POWER SKIVING) like hobbing
- hob is helical, and slow - skiving is spur and high speed
- → high quality, productivity (high vc) one machine machining
- straight and helical gears
Power skiving

https://www.youtube.com/watch?v=2jdPvsH9234