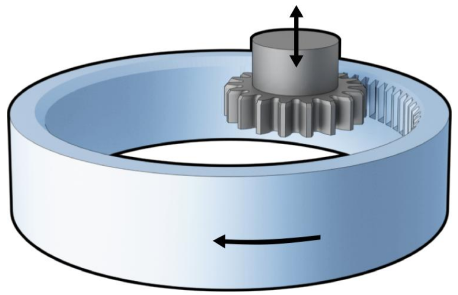
Gear Manufacturing Process

Catalog

1. Gear Shaping

Gear Shaping (Shaping) uses the gear meshing principle. The gear-shaped cutter performs a vertical reciprocating stroke, while the cutter and workpiece roll relative to each other according to the gear engagement relationship (indexing/ generating motion).

As the cutter feeds radially to the full tooth depth, the workpiece rotates to generate a continuous tooth profile.



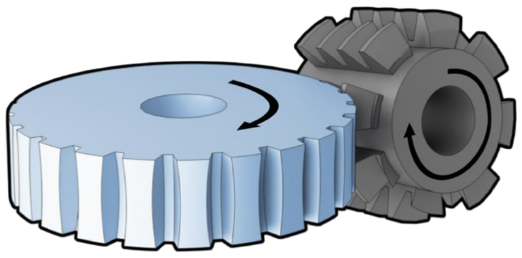
Key Features

- Machines spur gears, helical gears, internal gears, and compound gears (complex tooth forms).
- Good tooth flank finish: Ra 1.6–3.2 μm.
- Suitable for small to medium batch production.
- Lower efficiency due to intermittent cutting.
- Generally not recommended for large modules(> 6 mm).

2. Gear Hobbing

Gear Hobbing (Hobbing) is a generating process based on the worm–gear meshing principle. The cutting tool (hob) resembles a worm and has multiple cutting edges along its helical flutes.

The hob’s lead/helix is matched to the gear’s module and geometry to generate the tooth form.



① Primary motion: High-speed hob rotation (cutting motion).

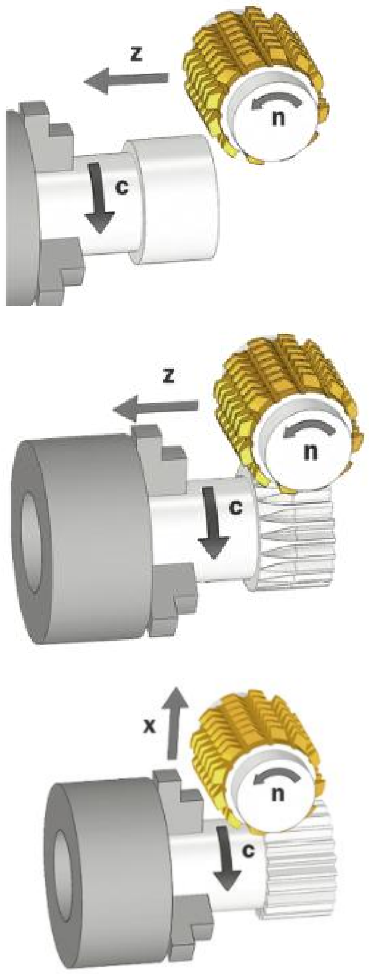
② Generating / indexing motion: The workpiece and hob rotate synchronously at the required gear ratio (tooth indexing).

③ Axial feed: The hob moves along the gear axis to cut the full face width.

④ Radial feed (infeed): Controls cutting depth to reach the full tooth depth.

Key Features of Gear Hobbing

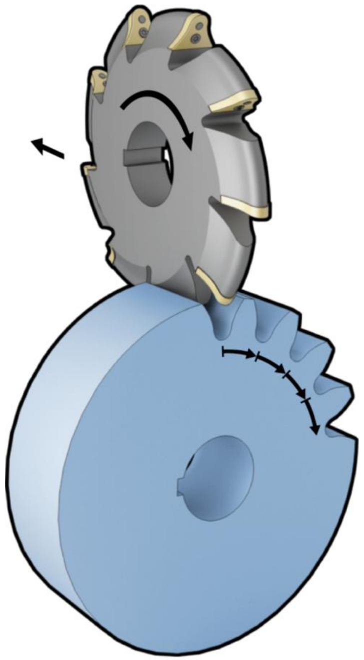
- High productivity: Continuous cutting, ideal for high-volume production(typically 3–5× faster than gear shaping).
- Good accuracy: Commonly achieves IT6–IT8(widely used as a pre-grinding process).
- Versatile: Suitable for spur gears, helical gears, worm wheels, and small-module gears.
- Good surface finish:Ra 1.6–3.2 μm, generally better than gear milling.
- Limitation:Internal gears cannot be hobbed(gear shaping is a common alternative).



3. Gear Milling

Gear Milling (Milling) is a form-cutting method for gears. It is a discrete machining process (not a continuous generating process), making it suitable for single-piece / small-batch production or large-module gears.

- Tooling: Uses form cutters (disc-type or end mill type) whose cutting edge profile matches the gear tooth space.
- Process: The cutter rotates to machine one tooth space per pass; the workpiece is then indexed to the next position and the next tooth space is cut.



Key Features of Gear Milling

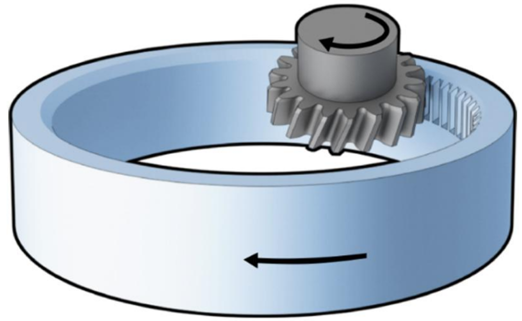
- Suitable for large modules (e.g., m > 10 mm), where hobbing/shaping is often less practical or less economical.
- Can machine spur gears, helical gears, bevel gears, and non-standard tooth forms (e.g., sprockets, ratchets).
- Can be done on a conventional milling machine—no dedicated gear machine is required.
- Not cost-effective for high volume: each tooth space requires individual indexing.
- Higher profile error risk (depends heavily on cutter accuracy and the indexing mechanism).
- Typical surface finish: Ra 3.2–6.3 μm; often requires secondary finishing (e.g., gear grinding) for higher accuracy.

4. Gear Skiving

Gear Skiving (Power Skiving) is a high-efficiency, high-precision gear cutting method that combines principles of turning and gear shaping.

It is well suited for batch production of internal gears, external gears, and complex tooth forms.

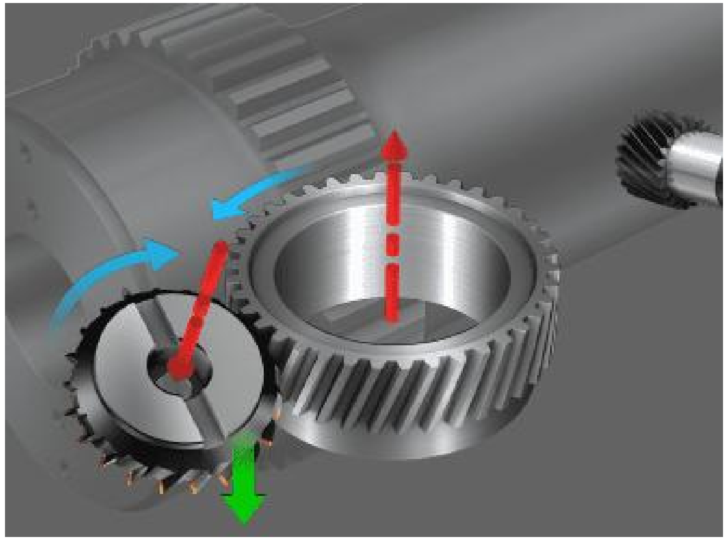
Tool (Skiving Cutter)



- Gear-like cutter (similar to a helical gear) with carbide cutting edges.
- The cutter helix angle is matched to the workpiece; a typical range is 20°–30°.
- Material is removed by continuous cutting during rotation.

Motions

- Primary motion: High-speed cutter rotation (cutting motion).
- Synchronous generating motion: Cutter and workpiece rotate in a fixed gear ratio (generating action).
- Radial infeed: Cutter feeds radially to reach full tooth depth.
- Axial feed: Cutter moves along the gear axis to complete the full face width.



Key Features of Gear Skiving

High productivity: Continuous cutting; machining time is typically 50–80% shorter than gear shaping.

High accuracy: Can reach IT5–IT7(approaching ground-gear levels in many applications).

High flexibility: Suitable for internal gears, external gears, helical gears, and asymmetric tooth forms.

Excellent surface finish:Ra 0.4–1.6 μm, reducing the need for secondary finishing.

Higher tooling cost: Dedicated skiving cutters are custom and expensive.

Higher machine investment: Requires high-precision CNC skiving/turning centers with tight synchronization control.

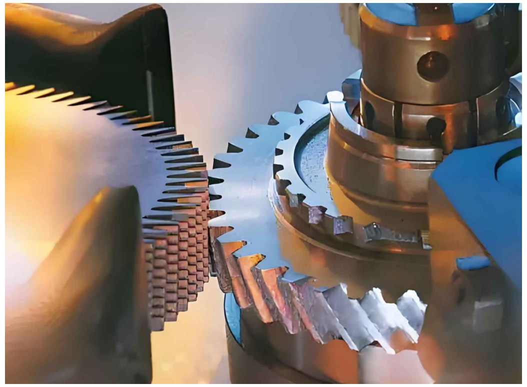
Narrower module window: Commonly used for m ≈ 0.5–6 mm.

5. Gear Shaving

Gear Shaving (Shaving) is a finishing process used to improve tooth profile accuracy, surface finish, and meshing performance.

It is commonly applied as a semi-finishing or finishing step after hobbing or gear shaping. The process is based on the meshing of a crossed-axis helical gear pair.

Tool (Shaving Cutter)



- A high-precision helical-gear-like cutter with dense serration/slot grooves on the tooth flanks (chip pockets).
- Typically made of HSS (high-speed steel) or carbide, with hardness higher than the work gear.

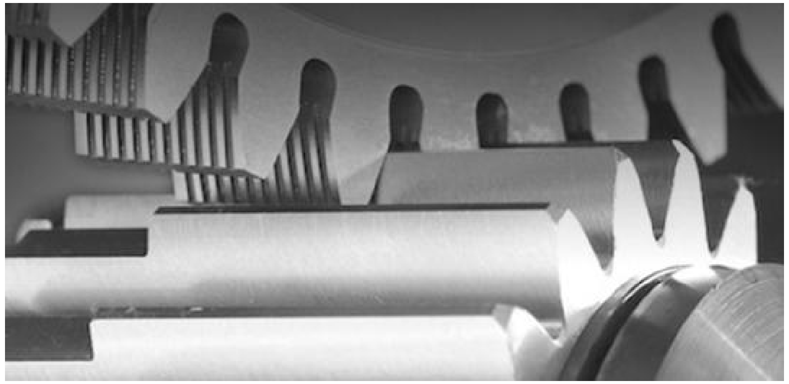
Motions

•Primary motion: High-speed cutter rotation (cutting motion).

•Radial feed / pressure: The cutter is pressed into the gear to remove a small amount of material (~0.01–0.1 mm).

•Axial / longitudinal feed: The workpiece or cutter moves along the tooth direction to ensure uniform finishing across the full face width.

•Crossing angle (Σ): Typically 15°–30°, creating point-contact cutting between cutter and workpiece.



Key Features of Gear Shaving

- High accuracy: Can improve gear accuracy to IT6–IT7(typical hobbing output is often IT8–IT9).
- Excellent surface finish: Can achieve Ra 0.4–0.8 μm, helping reduce noise and wear.
- High productivity: Cycle time ranges from seconds to minutes per part, suitable for mass production.
- Correction capability: Helps correct profile and lead deviations, improving smooth meshing.
- Limited to “soft” gears: Workpiece hardness typically ≤ HRC 32(hardened gears usually require grinding).
- Not suitable for internal gears: Shaving requires external meshing between cutter and gear.
- Higher tooling cost: Shaving cutters are custom and involve regrinding/resharpening cost.

6. Gear Grinding

Gear Grinding (Grinding) is an ultra-precision finishing process in gear manufacturing. It is mainly used for hardened gears (HRC ≥ 45) and can achieve IT3–IT5 accuracy.

(1) Form Grinding

- Principle: Uses a form grinding wheel whose profile matches the tooth space; the gear is ground tooth-by-tooth.
- Best for:Large-module gears(e.g., m > 6 mm) and gears requiring modifications (e.g., crowning).

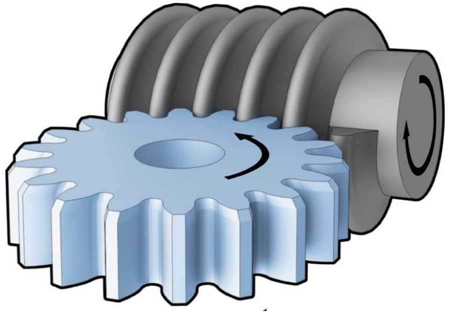
(2) Generating Grinding

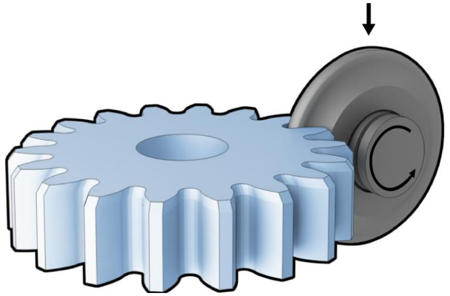
- Principle: Simulates the gear meshing (generating) motion; the grinding wheel and workpiece move relative to each other following the engagement relationship (similar to hobbing).

Main technologies

•Worm-wheel generating grinding (continuous generating): Highest productivity; best for small to medium modules.

•Disc-wheel grinding (Maag-type / dual-disc method):Ultra-high precision, but lower productivity.





Key Features of Gear Grinding

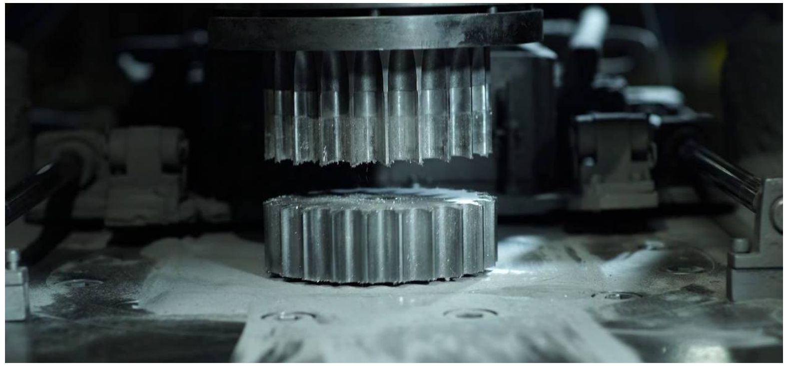
- Ultra-high accuracy: Typically IT3–IT5(profile error can be ≤ 3 μm in suitable conditions).
- Excellent surface finish:Ra 0.1–0.4 μm, helping reduce transmission noise.
- Strong modification capability: Precise control of profile/lead modifications (e.g., end relief, crowning, K-type modifications).
- High cost: Machine investment can be 5–10× that of a hobbing machine; grinding wheel maintenance/dressing costs are high.
- Lower productivity: Often 1/10–1/5 of hobbing (except for continuous worm grinding in some cases).
- Risk of thermal damage: Grinding heat can cause tooth flank burn; requires strict coolant and process control.

7. Alternative Gear Manufacturing Processes

① Powder Metallurgy (PM)

Powder Metallurgy is a near-net-shape process that forms gears by powder compaction + sintering. It is especially suitable for high-volume production of small-module gears with complex shapes.

Typical process flow:
Powder preparation → Compaction (pressing) → Sintering → Post-treatment (optional)



② Hot Forging

Hot-forged gears are produced by high-temperature plastic forming, offering high strength and excellent fatigue life. It is a key manufacturing route for heavy-duty gears (e.g., wind power and construction machinery).

Typical process flow:
Cutting/blanking & heating → Pre-forging + final forging → Trimming & piercing → Heat treatment → Finish machining

③ Cold Forging

Cold forging is a precision forming process performed at room or low temperature (below the recrystallization temperature).

It delivers very high material utilization, excellent surface quality, and work-hardening benefits, making it ideal for mass production of small to medium module gears.

Process Flow: Material Pre-treatment → Multi-Station Cold Forging → Post-treatment

Powder Metallurgy vs Hot Forging vs Cold Forging

Item	Powder Metallurgy (PM)	Hot Forging	Cold Forging
Accuracy	IT7–IT8	IT10–IT12	IT7–IT8
Surface finish	Ra 3.2–6.3 μm	Ra 12.5–25 μm	Ra 1.6–3.2 μm
Production rate	50–100 pcs/min	1–5 pcs/min	10–30 pcs/min
Strength	Medium	Highest	High

8. Typical Gear Process Accuracy (ISO Grade)

Process	Typical ISO Accuracy Grade
Standard hobbing	ISO 7–9
Finish hobbing	ISO 4–7
Gear milling	ISO 7–9
Gear shaping	ISO 7–8
Gear shaving	ISO 6–7
Power skiving (gear skiving)	ISO 5–8
Gear grinding	ISO 3–6
Hard honing (power honing)	ISO 3–6
Powder metallurgy (PM)	ISO 7–8

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