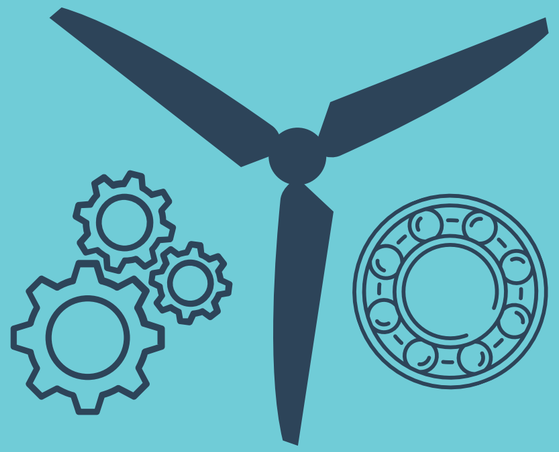
T-shore Education

Gearbox and Bearing Maintenance

Theory Presentation



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01	11.12.2024	New presentation created	Krzysztof Komorowski

Aims and Objectives of Gearbox & Bearings theory

Main Aim

The aim of this theory material is to provide an introduction to the technical knowledge related to gears, bearings, and gearboxes. Additionally, it includes elements of safety when working with mechanical devices and specialized knowledge on the use of gearboxes in wind turbine generators, as well as the topic of gearbox maintenance within the wind energy industry.

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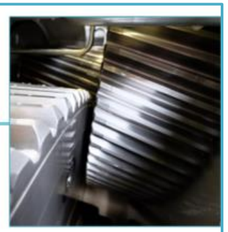

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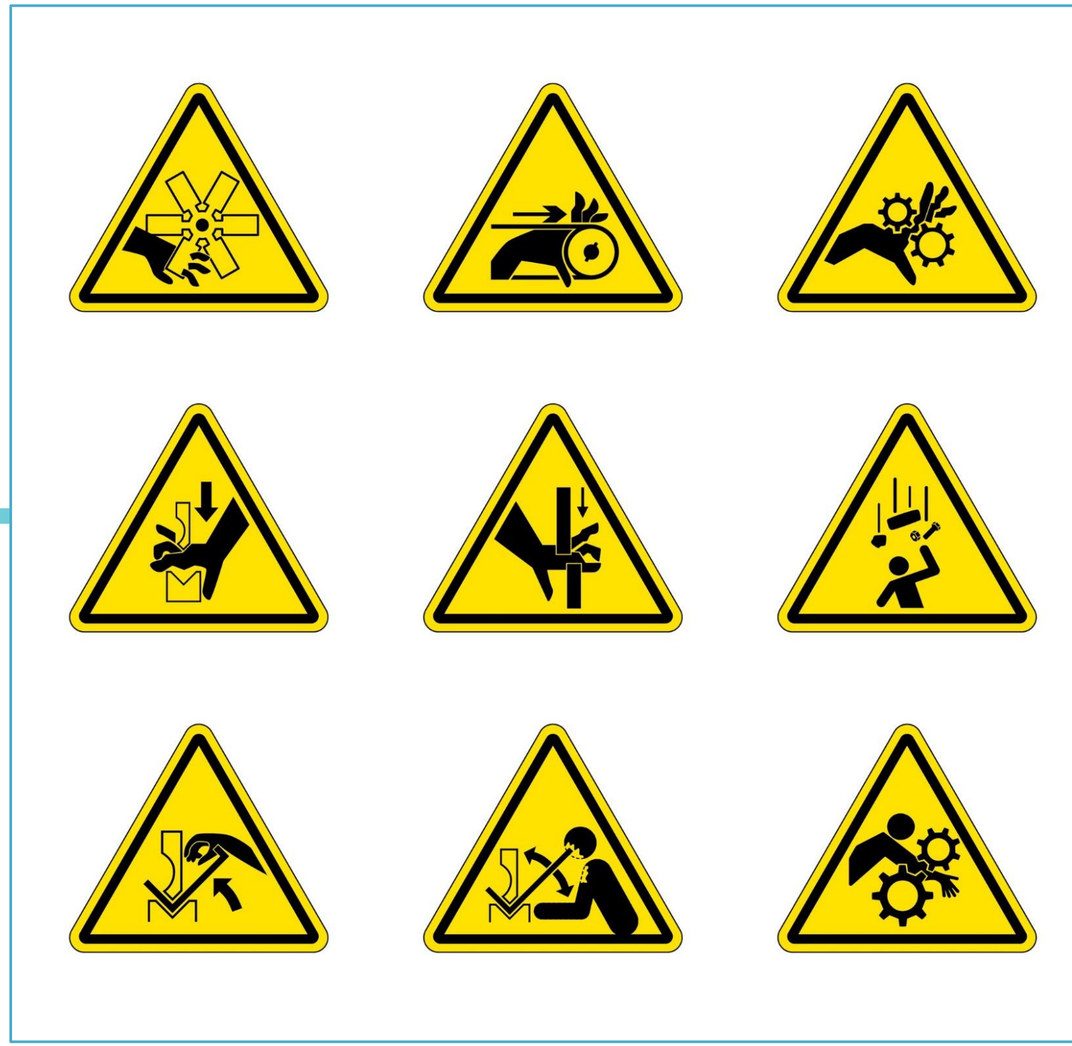
Mechanical Safety

Lesson 1



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Importance of Approved Working Practices

- Safety First
- Doing it Right
- Consistency
- Building a Safety Culture
- Regular Training and Updates

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Safety data sheets

Material Safety Data Sheets (SDS)

(g) Safety Data Sheet Format

1. **Identification of the substance or mixture and of the supplier**
2. **Hazards identification**
3. **Composition/information on ingredients**
4. **First-aid measures**
5. **Fire-fighting measures**
6. **Accidental release measures**
7. **Handling and storage**
8. **Exposure controls/personal protection**
9. **Physical and chemical properties**
10. **Stability and reactivity**
11. **Toxicological information**
12. *Ecological information (non-mandatory)*
13. *Disposal considerations (non-mandatory)*
14. *Transport information (non-mandatory)*
15. *Regulatory information (non-mandatory)*
16. **Other information, including date of preparation or last revision**

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Safety signs

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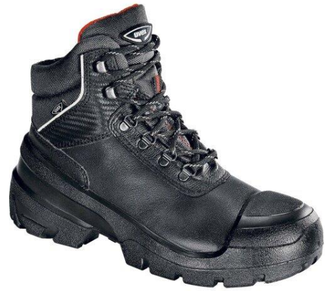
PPE when working with mechanics

Main mechanical PPE equipment:

- Head Protection (Helmets)
- Eye and Face Protection (Safety Glasses and Shields)
- Hearing Protection (Earplugs or Earmuffs)
- Hand Protection (Gloves)
- Foot Protection (Safety Shoes)
- Respiratory Protection (Masks or Respirators)
- Body Protection (Work Clothing and Aprons)
- Fall Protection (Harnesses and Lanyards)

Personal Protective Equipment (PPE) is essential in providing a barrier between the worker and hazards in the mechanical work environment



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Lockout-tagout procedure

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The importance of appropriate isolation

The importance of emergency stop buttons...why are they there and when should they be used?

- Impact of e-stop on mechanical systems (video)

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Introduction to Gears

Lesson 2

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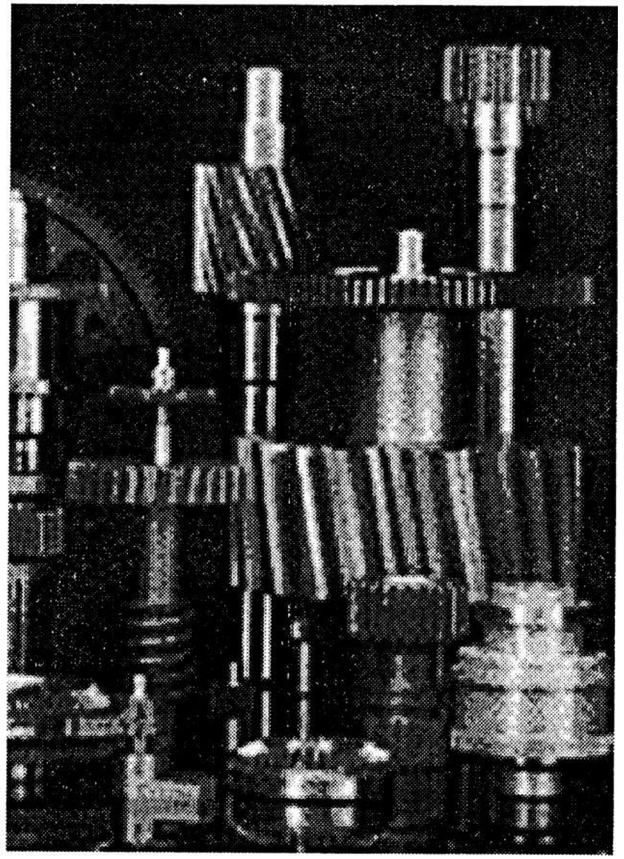
Gear definition

Power transmission is a crucial aspect of turbine design.

Gears are...

- mechanical devices designed to transmit power between shafts.
- Rolling cylinders or cones with teeth that engage with another cylinder or cone with teeth.



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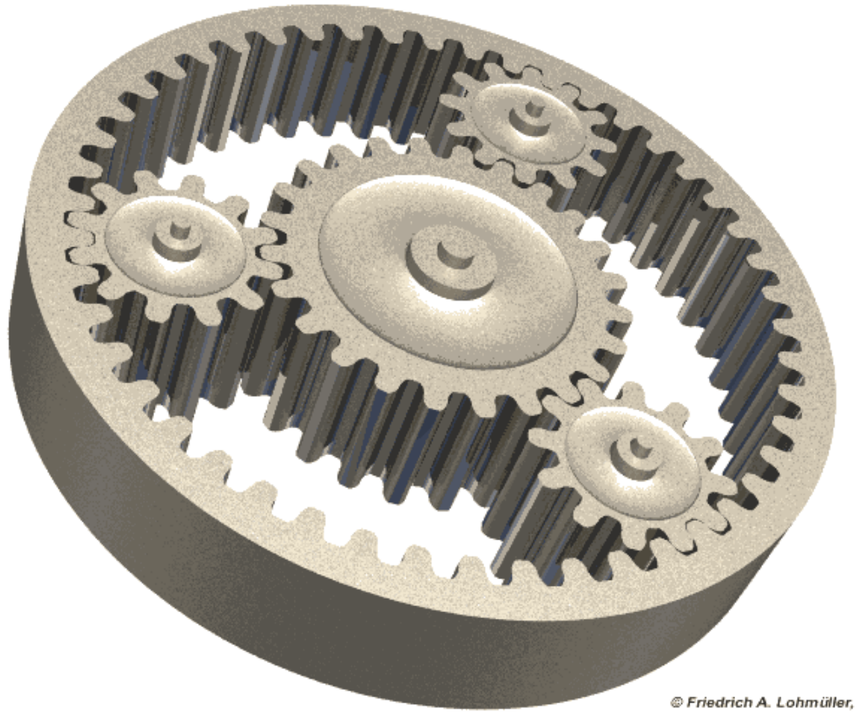
Gears function

Forces are transmitted continuously as teeth engage at a constant angle.

Transfers forces between shafts while changing:

- Rotational speed
- Torque
- Direction of rotation

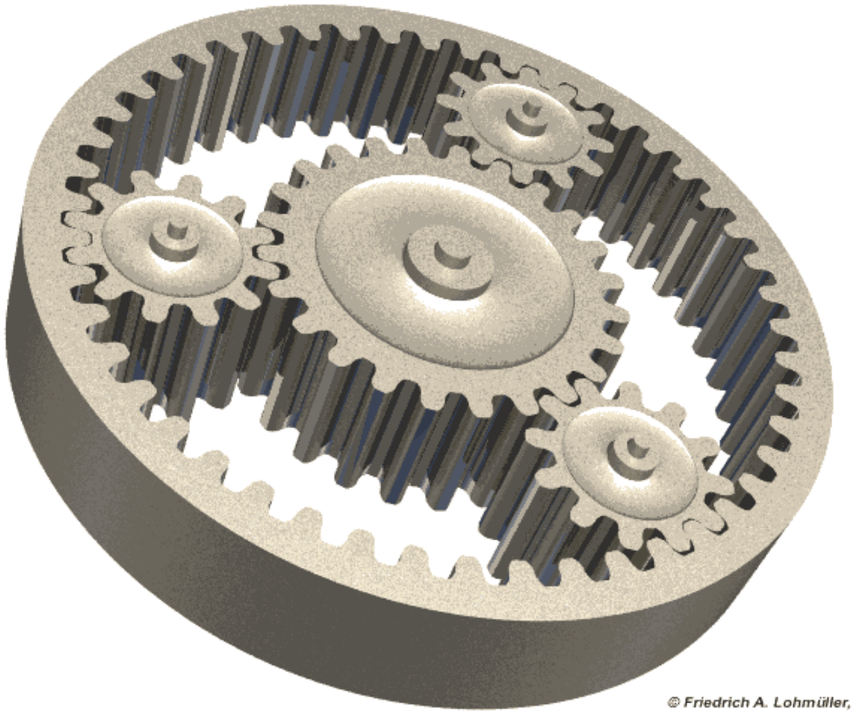
Gear application depends on shaft positioning.



Gears purpose

Gears purpose:

- To change the direction of rotation
- To modify rotational speed
- To drive multiple machines or outputs
- To synchronize processes
- Used in hydraulics and lubrication pumps



Types of drive systems

Open gear:

- Exposed to external contamination.
- Covers may provide some protection.
- Grease-lubricated, typically used in motors, lathes, textile machines, conveyors, and packaging machines.

Closed gear

- Enclosed in a casing.
- Has a sealed lubrication system.
- Protected against external contamination.
- More durable than open gears.

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Gears functionality

Smallest gear = Pinion.

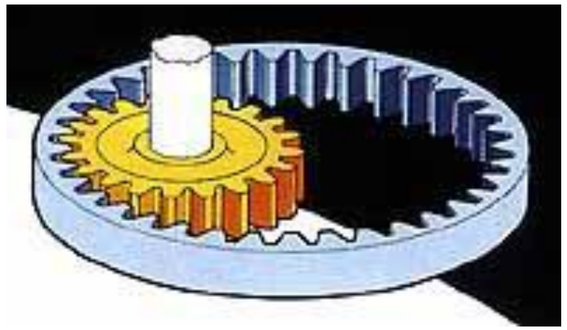
Largest gear = Gear.

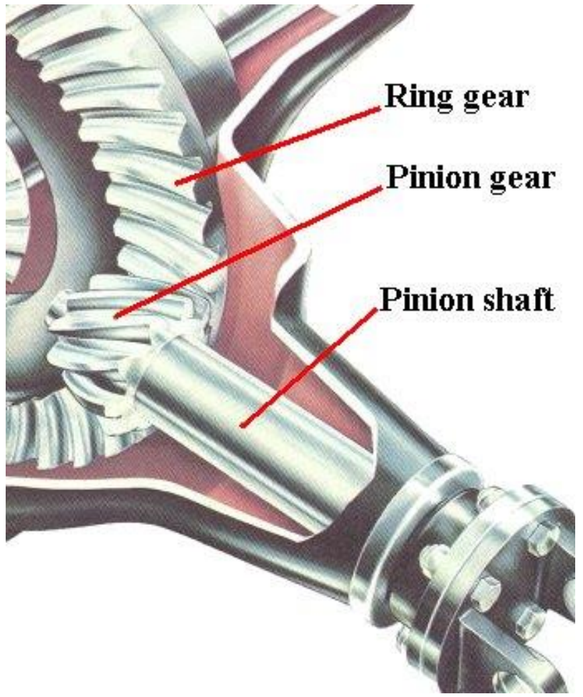
High gear - when a gear drives a pinion.

- Less torque, but more speed
- Speed increases.

Low gear - when a pinion drives a gear.

- Less speed, but more torque.
- The speed is reduced.

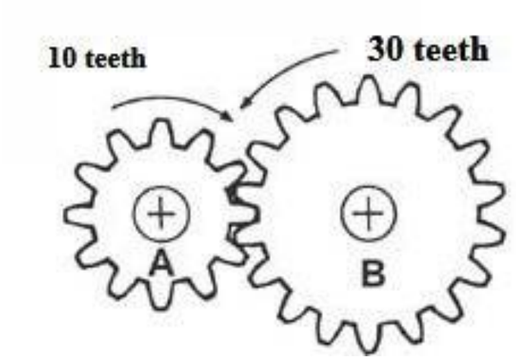




Gears specification

Gears and teeth

- They have the same size and tooth design.
- They are manufactured together.
- They are intended to be used together.

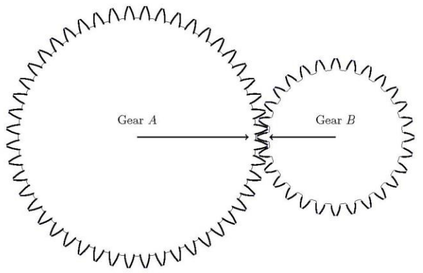


Internal gears

- The teeth are located on the inner diameter.
- Multiple teeth are in contact at the same time.
- The teeth can be Spur (cylindrical) or Helical (screw-shaped).

Mechnical advantages

- A reduction in speed leads to an increase in torque.
- Large gears provide a mechanical advantage over smaller gears.
  - They rotate over larger surfaces.
  - A greater radius offers larger surfaces to distribute forces.



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Gears movement

Radial Shafts

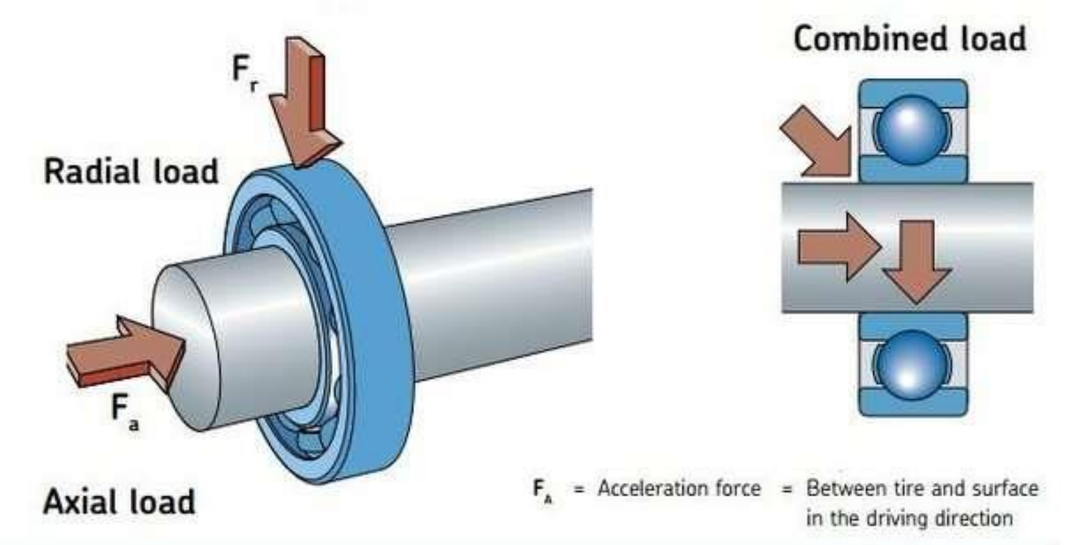
- Refers to the centerline of the gear or shaft.

Axial movements

- Occurs when a gear or shaft can move axially (along its axis) within the bearings.

Axial and Radial

- Axial movement should ideally be less than zero to maintain stability.
- Support bearings are used to manage both axial and radial forces.



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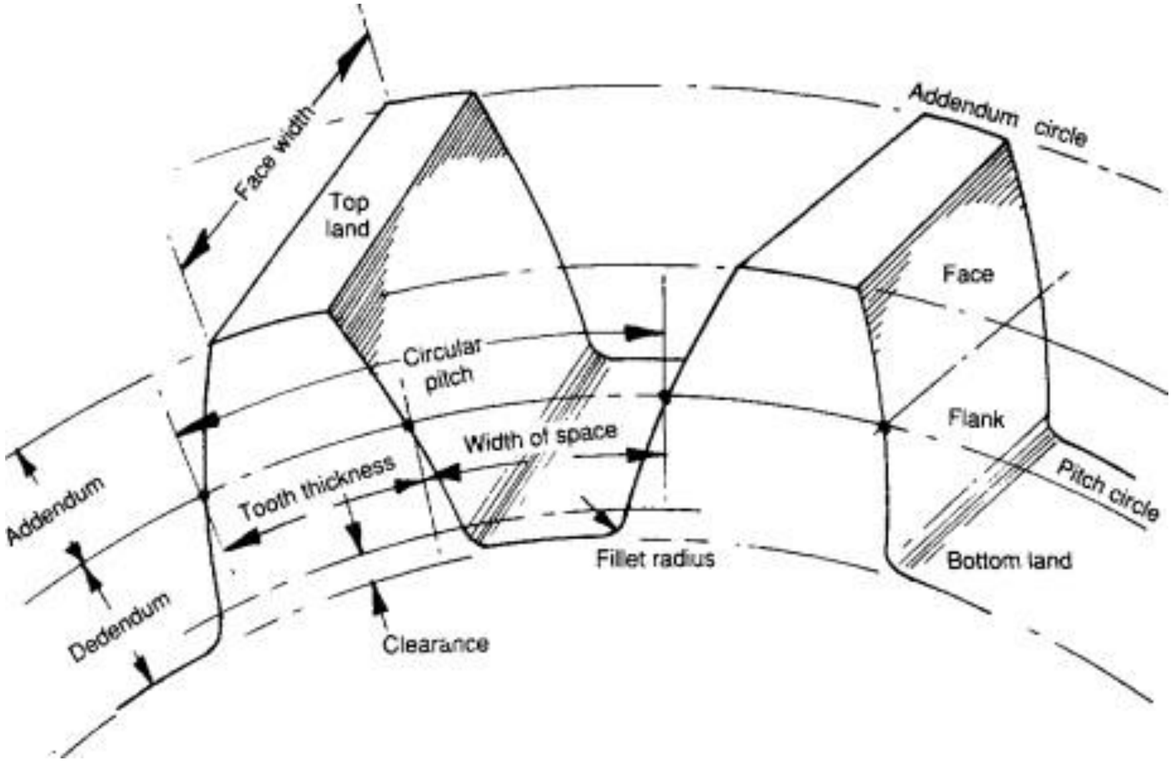
Gear tooth profile

Tooth profile - the profile or design of the tooth is the most important aspect of a gear.

- The profile of the tooth is based on the force curve in the gear.
- The profile also helps to place the forces where the tooth can absorb large forces.
- This contributes to transferring forces between shafts in a smooth manner.
- It also helps extend the lifespan of the gear



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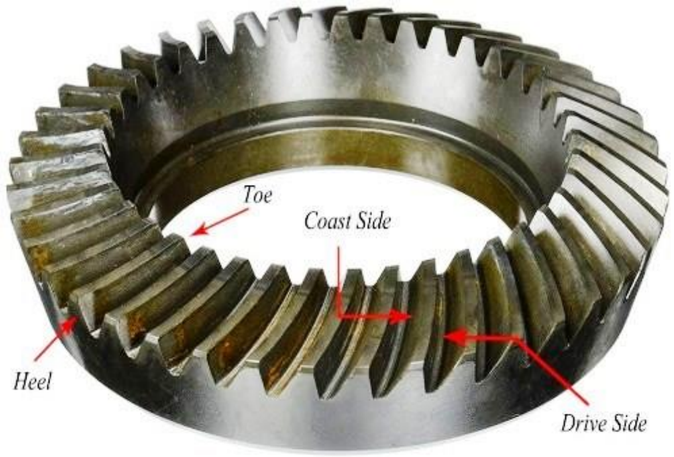
Gears movement

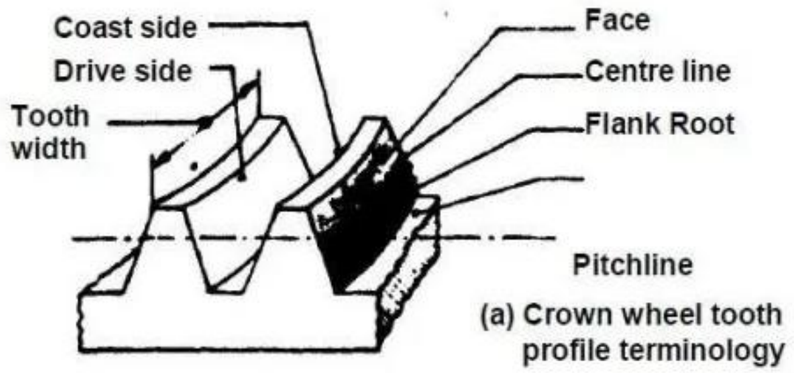
Free side of a tooth (coast side)

- The side of the tooth that does not drive the engaging tooth.



Driving side of a tooth

- The side of the tooth that drives the engaging tooth.
- The pattern on the contact surface provides a good indication of the gear's position and/or wear.



The contact surface can be checked using a pain specifically designed for this purpose.

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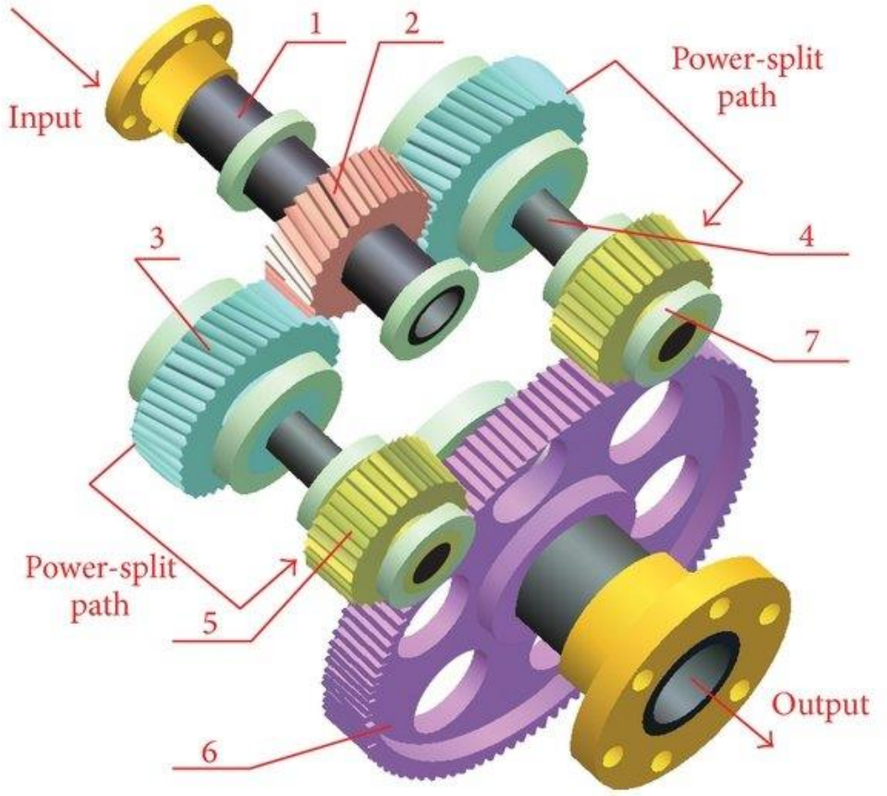
Power transmission

Gears can consist of one or more parts. The function is to transfer movement from one shaft to another - Increasing or reducing the revolutions between shafts.

- Changing the direction between shafts may also be desirable.
- Gear transmission is designed based on the placement of shafts and the required gear ratio.
- Often, there is a need to add more gears instead of larger gears



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Gears ratio change

Direct transmission

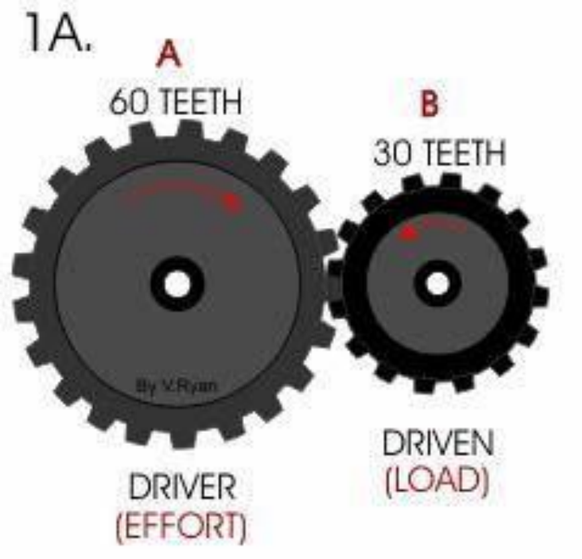
- When the input rotational speed is the same as the output rotational speed.

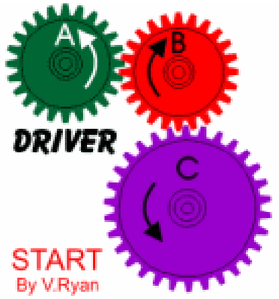
Driver.

- Power in
- Input gear - engages with the driven gear, causing it to rotate.

Driven.

- Power out.
- Output gear - rotates as a result of the input gear.





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Gears ratio change

Increase in Rotational Speed (RPM)

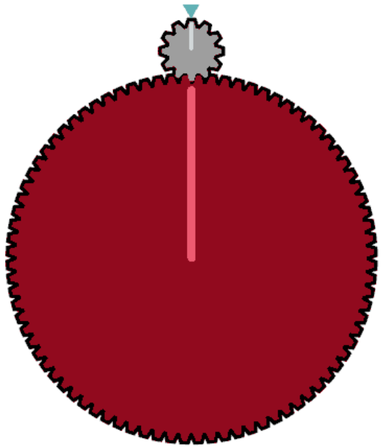
For gears, the number of teeth is used to calculate the gear ratio

D in (Input gear diameter) = Ø400 and D out (Output gear diameter) = Ø50.

Gear ratio = $\frac{D\ in}{D\ out} \sim \frac{400}{50} = \frac{8}{1}$

Output RPM Formula:

Output RPM = Input RPM × Gear Ratio



Example calculations

- If **input RPM = 250**, what is the output RPM?

  Output RPM = 250$* \frac{8}{1} = 2000\ rpm$

- If **output RPM = 1500**, what is the input RPM?

  Input RPM = $1500 \div \frac{8}{1} = 187.5\ rpm$

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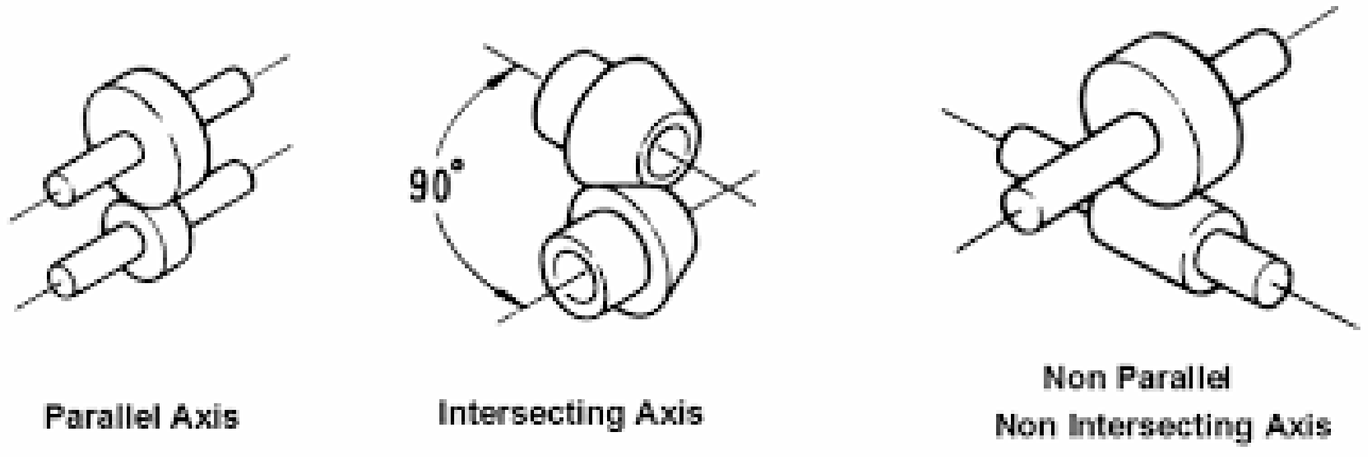
Location of axles

Gears can be classified based on the positioning of the shafts and how the shafts are connected:

- **Parallel shafts:** Cylindrical gears, helical gears, herringbone gears.
- **Intersecting shafts:** Angled teeth.
- **Non-parallel, Non-intersecting shafts:** Screw versus spiral/helical gears, hypoid gears.



Gears type

Common types of gears:

- Spur: Cylindrical gears with straight teeth.
- Bevel: Angled teeth for intersecting shafts.
- Worm: Screw-like gears for high reduction ratios.
- Helical: Spiral-shaped or angled teeth.
- Herringbone: Double helical (fishbone) gears.
- Hypoid: Gears for non-parallel, non-intersecting shafts.


Worm Gear


Helical Gear


Double Helical Gear
(Herringbone Gear)


Spiral Bevel Gear


Miter Gear


Straight Bevel Gear


Internal Gear


Spur Gear


Rack and Pinion

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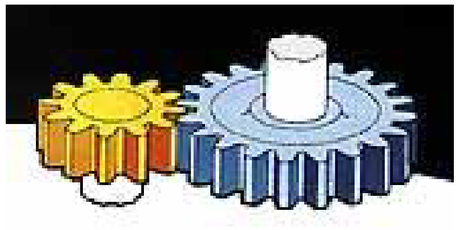
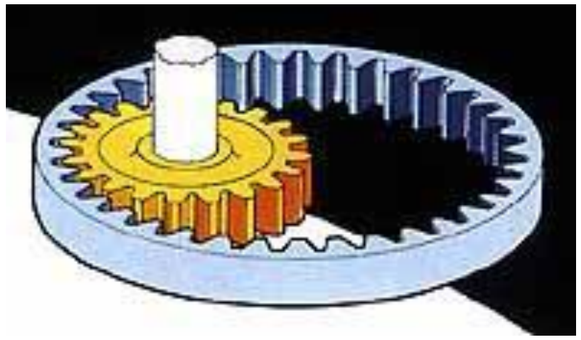
Cylindrical gears

- This is the most common type of gear.
- Used to transfer power between parallel shafts at moderate speeds.
- Rotational speed: approximately 1000–1500 RPM.
- Features straight teeth that are parallel to the axis of rotation.
- These can be used on both external and internal gears.





Spur gear

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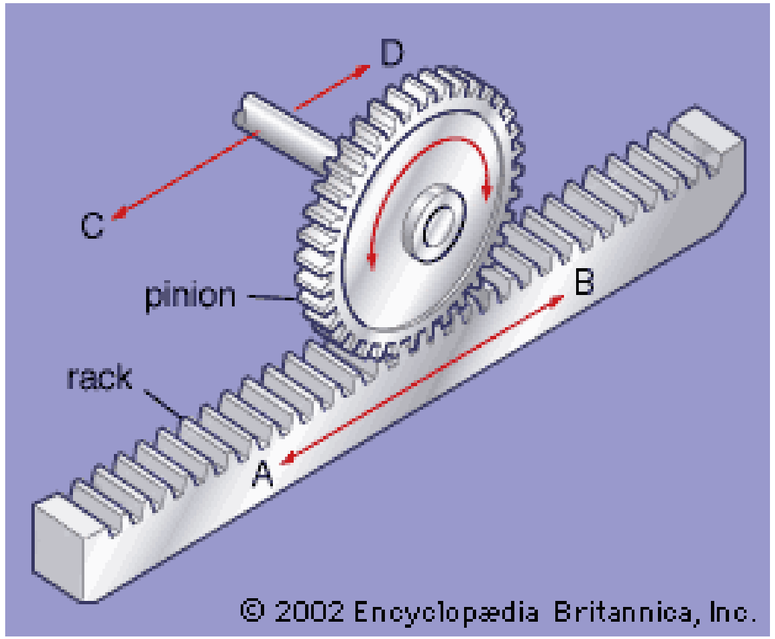
Cylindrical gears

Rack and pinion

- Used to transfer linear forces to rotary forces



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Cylindrical gears

Bevel gear

- Often used where shafts cross each other.
- Usually perpendicular

Straight

Spiral

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Cylindrical gears

Bevel gear

- Develops axial forces and radial forces
- Requires bearings to handle both types of load
- Difficult to set up
  - **Stable mounting**: The shaft is supported by a bearing at each end.
  - **Unstable mounting**: The shaft is supported by a bearing at one end.

Cylindrical gears

Hypoid gear - a variant of the bevel gear, Where the teeth are spiral instead of straight.

- Spiral teeth distribute the load over multiple teeth at once.
- This provides smoother operation.
- Transfers forces between two intersecting, non-parallel shafts.
- Bearings are most often pressed onto the shafts.
- Requires extensive lubrication.

FIGURE 6.14 Hypoid gears. (Courtesy of Gleason Works.)

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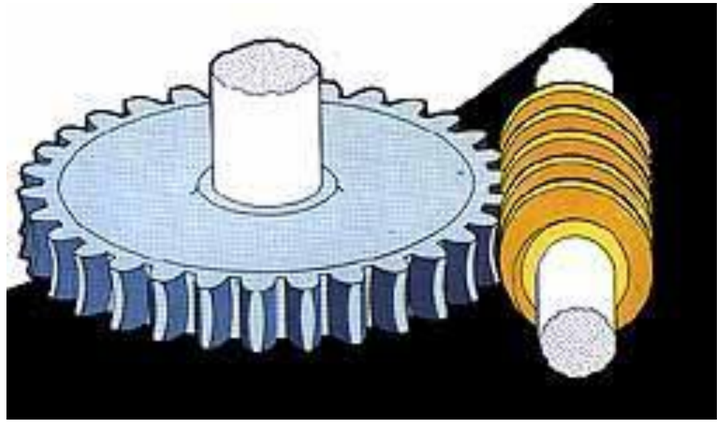
Worm gears

Worm gear - These are used to transfer power between non-intersecting shafts at right angles.

- Teeth on the worm wheel (gear) have the same profile as cylindrical gears.
- Used for high gear ratios: 7:1 to 70:1 RPM



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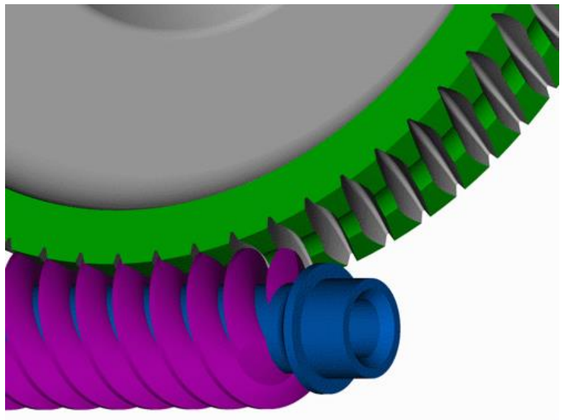
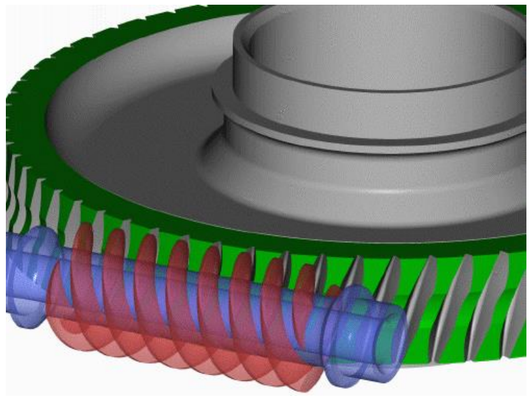
Worm gears

Worm gear specification

- The power comes through the shaft.
- The screw and wheel have teeth that fit together.
- The screw motion of the shaft provides a completely smooth and even output without vibration.
- The sliding of the teeth against each other creates friction, heat, wear, and power loss.
- Greater speed reduction (gear ratio) results in more power loss.60% power loss at a 70:1 gear ratio.
- Requires extensive lubrication.
- Speeds of 3600–6000 FPM.
- The load should not be able to drive the shaft backward.



To determine the gear ratio: One rotation of the screw results in one tooth advancement.



Helical/spiral gears

Helical gear - These are used to transmit forces when the shafts are parallel.

- Spiral Angle:
  - The angle of the teeth ranges from 7° to 23°.
  - The larger the angle, the more teeth are engaged simultaneously.
  - The larger the angle, the greater the axial forces become.
  - Axial or tapered bearings must absorb these forces.
- Multiple teeth are engaged simultaneously.
  - This provides better load transfer and smoother, quieter operation.
  - The most common speed range is from 2000 to 2500 RPM.
  - Lubrication under pressure is recommended

Herringbone gears

Herringbone gear – there are used to transmit forces between parallel shafts.

- There are two rows of inclined teeth, each pointing in a different direction.
- The angle of the teeth is usually 30°.
- These are designed to avoid axial forces.
- They are best suited for high speeds and heavy loads.

Introduction to Bearings

Lesson 3

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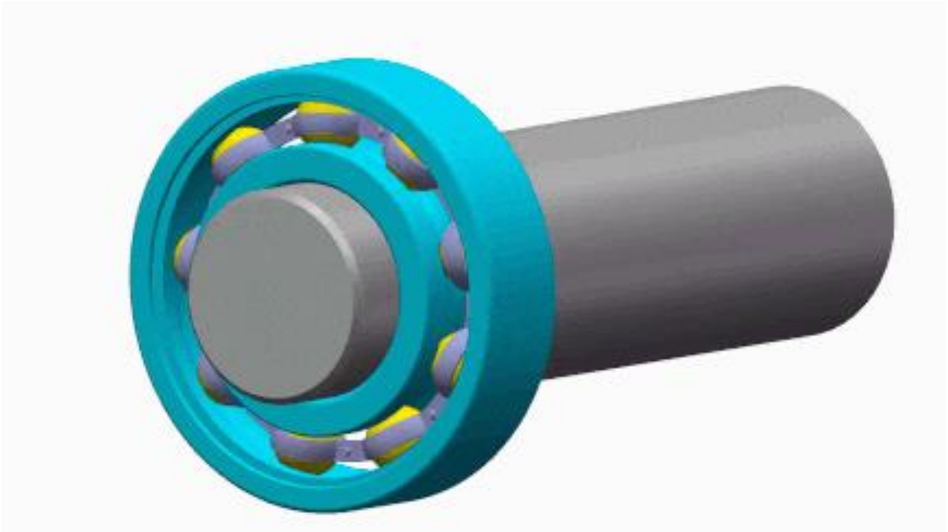
Bearings definition

Bearings are...

- Machine components designed to reduce friction between moving parts, allowing for smoother motion.
- Bearings support the rotating shafts of the wheels, gears, turbines, rotors, etc. in those machines, allowing them to rotate more smoothly.



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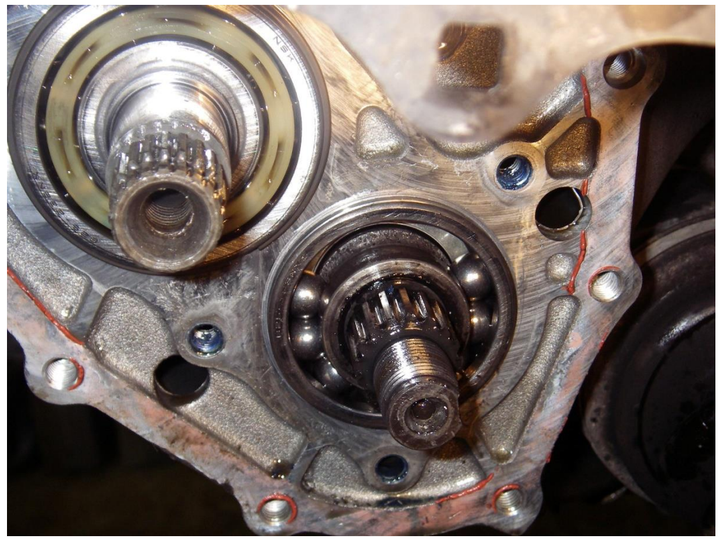
Bearings purpose

Function 1: Reduce friction and make rotation more smooth

The main purpose of bearings is to prevent direct metal-to-metal contact between two elements that are in relative motion. This prevents friction, heat generation and ultimately, the wear and tear of parts. It also reduces energy consumption as sliding motion is replaced with low-friction rolling.



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Bearings purpose

Function 2: Protect the part that supports the rotation, and maintain the correct position for the rotating shaft

A large amount of force is needed between the rotating shaft and the part that supports the rotation. Bearings perform the function of preventing damage from being done by this force to the part that supports the rotation, and also of maintaining the correct position of the rotating shaft.

This function of bearings is what allows us to use our machines over and over again for an extended period of time.

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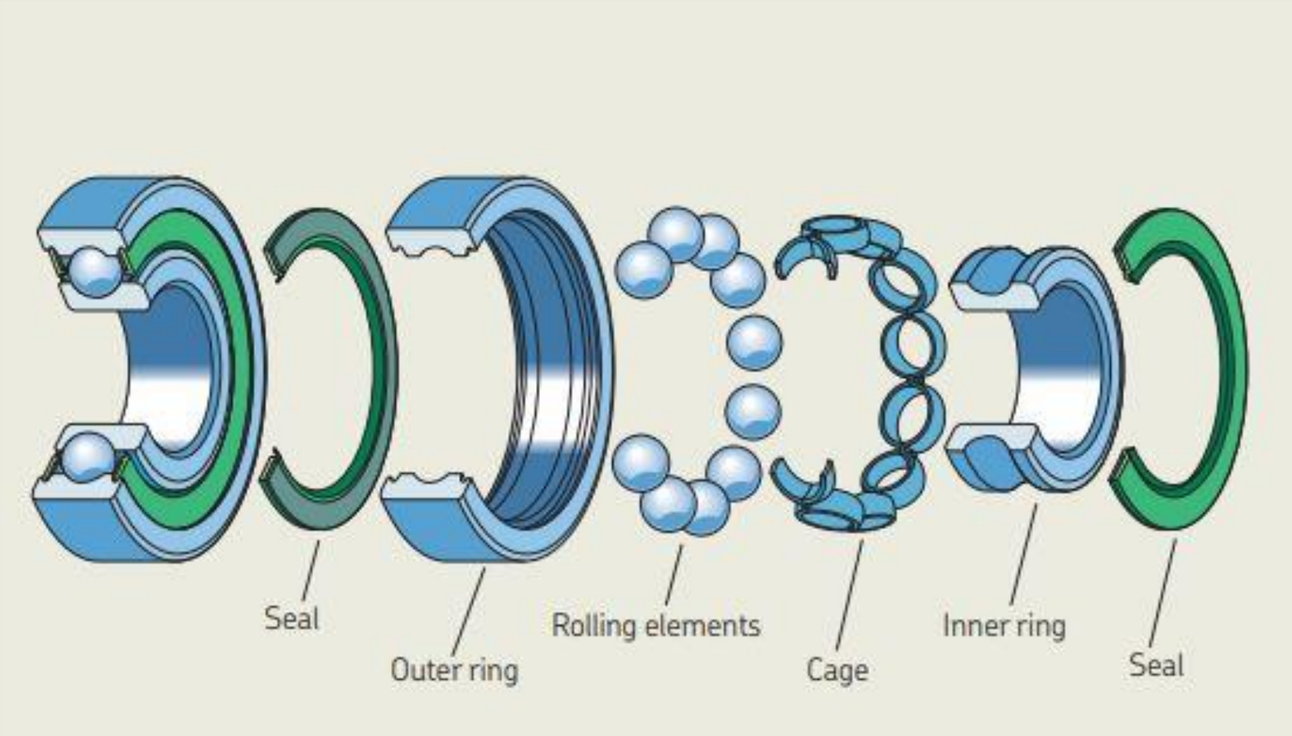
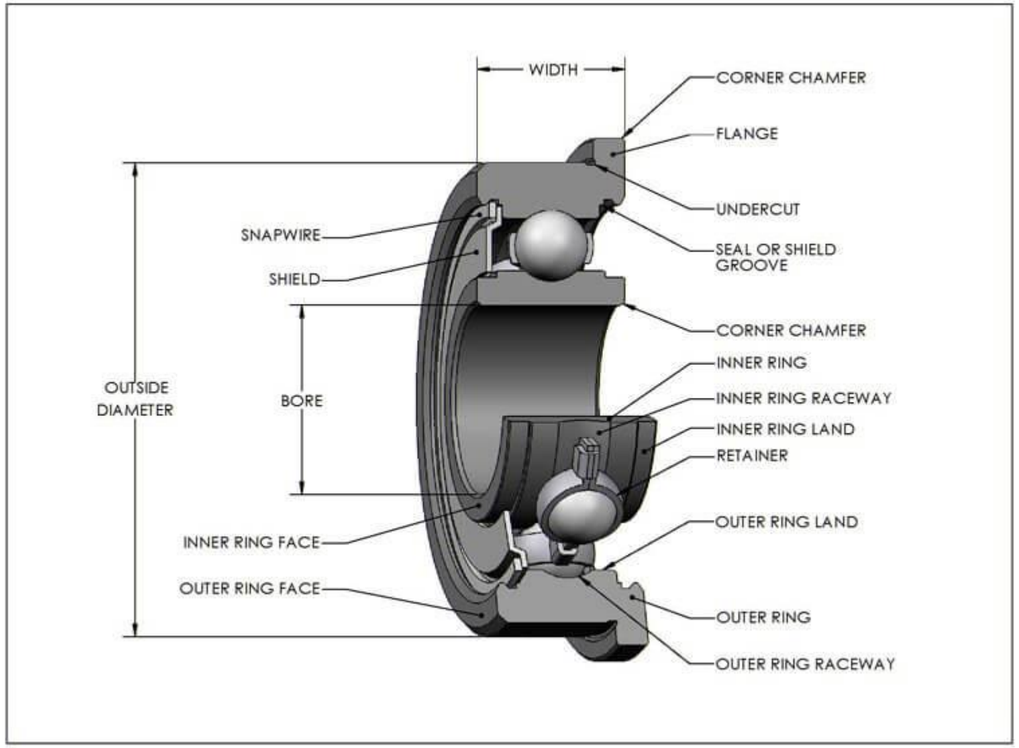
Bearings structure

Simple structure



Detailed structure



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Inner Ring / Outer Ring

The inner and outer ring are usually made from a special high-purity, chrome alloy steel. This material has the necessary hardness and purity – both important factors for a high load rating and a long service life.

Special materials such as ceramic and plastics are also used. Although plastics cannot withstand extremely high temperatures, they are considerably lighter than steel. This makes them invaluable in sectors such as the automotive industry, where every gram matters.

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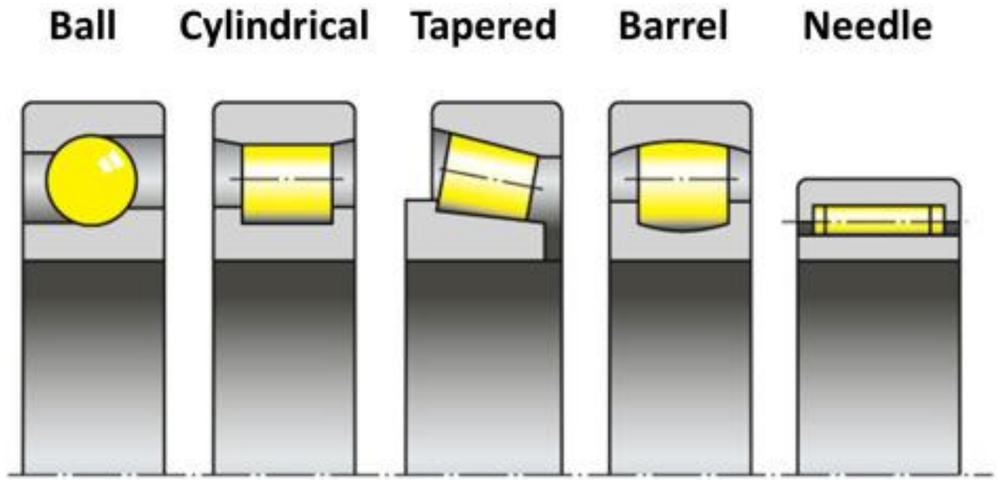
Rolling elements

Rolling elements are either balls, rollers, cones, spheres or needles.

They are usually made from a special high-purity, chrome alloy steel.

Special materials such as ceramic and plastics are also used.

The rolling elements roll on the specially formed raceways of the rings or discs and are kept apart and guided by the cage.



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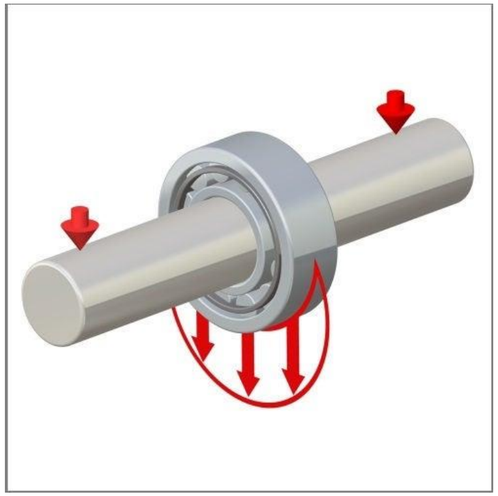
Bearings movement

Radial bearings / Axial bearings

- Bearings can transmit loads in a radial direction or an axial direction (thrust) and in many cases there is a combination of both radial and axial loads to transmit.

Radial Bearing



Axial Bearing

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Bearings movement

Rolling bearings:

- use rolling elements like balls or rollers to reduce rotational friction, making them ideal for high-speed, low-load applications such as motors and precision machinery
- require minimal maintenance due to their sealed lubrication systems

Sleeve bearings:

- rely on sliding motion and are better suited for low-speed, high-load applications like industrial pumps and automotive transmissions.
- Due to large contact area need frequent lubrication and replacement under high friction conditions.

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Bearings types

Source: The Engineers Post youtube channel

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Mounting of bearings

Bearings can be fitted by the following methods depending on the size and fit of the bearings

Mounting in a cold condition

- Using a hammer and a length of pipe
- Using hydraulic press

Mounting using heat

- Induction heating

Around 16% of all premature bearings failures are a result of poor fitting or using incorrect mounting techniques

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Causes of bearing failure

- Improper lubrication – 43%
- Improper mounting - 27%
- Other lubrication causes – 21%
  - Separation in storage
  - Temperature limit exceeded
  - Moisture contamination
- Fatigue – 9%

Most bearings fail due to some for of **CORROSION**

T-shore Education

Introduction to wind turbine Gearbox

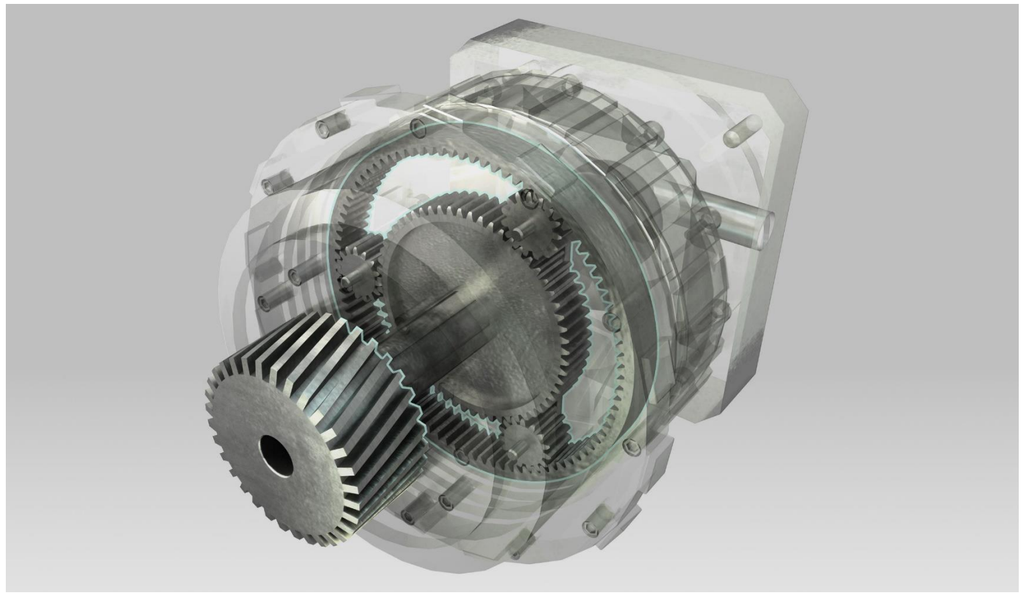
Lesson 4

T-shore Education

Gearbox definition

Gearbox (also called a transmission) is a mechanical device that that is used to increase the output torque or change the speed (RPM) of the motor.

- mechanical unit or component consisting of a gear train or set of gears embedded in a housing – **box containing gears**



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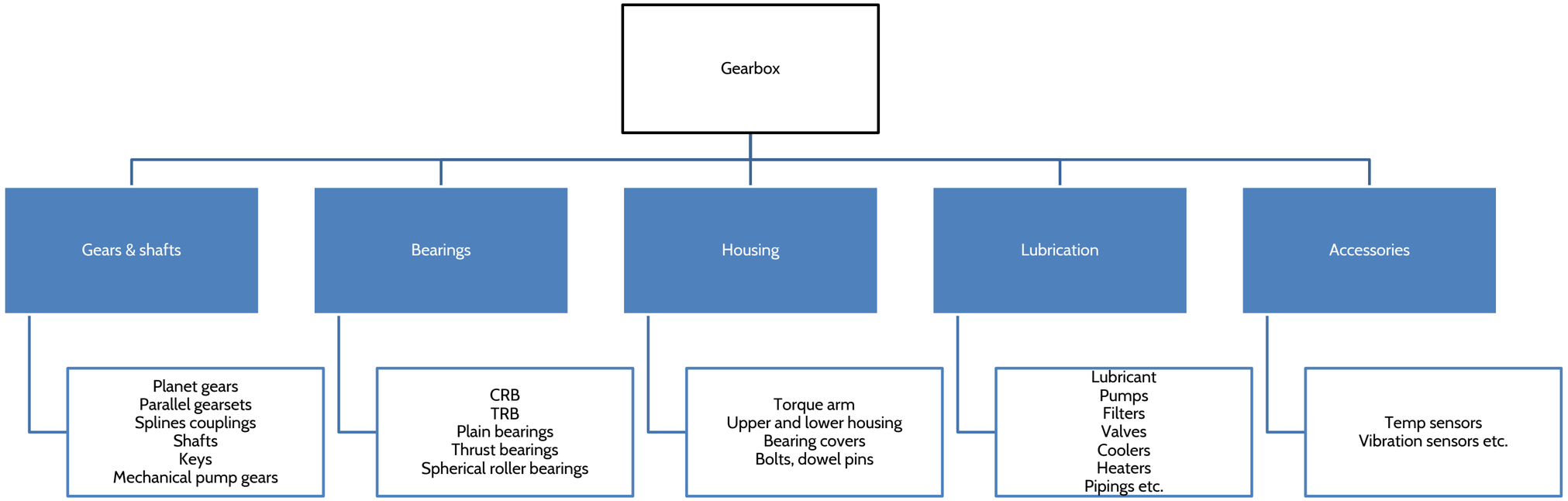
Gearbox building elements



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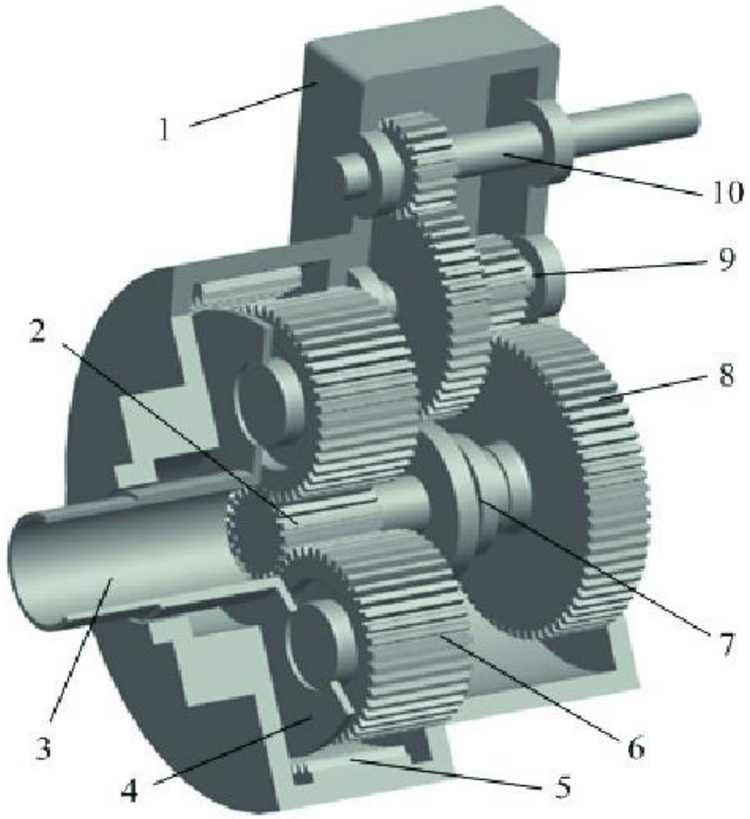
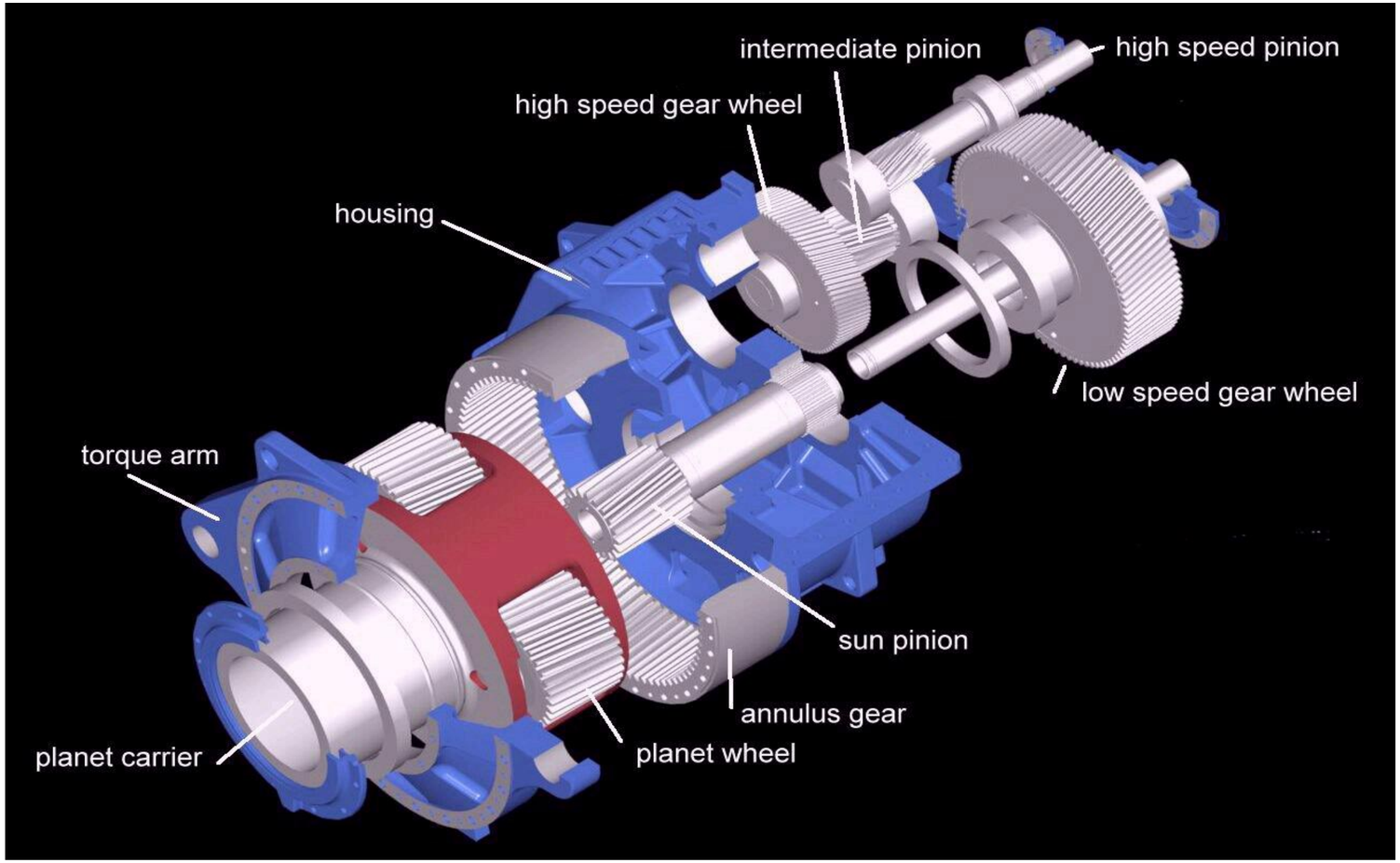
Gearbox structure

Structure of wind turbine gearbox

1. housing
2. sun gear
3. wind turbine's rotor
4. planetary arm
5. ring gear
6. planetary gear (there are a total of three planets gears)
7. sun shaft
8. wheel,
9. middle shaft
10. high-speed shaft



Gearbox structure



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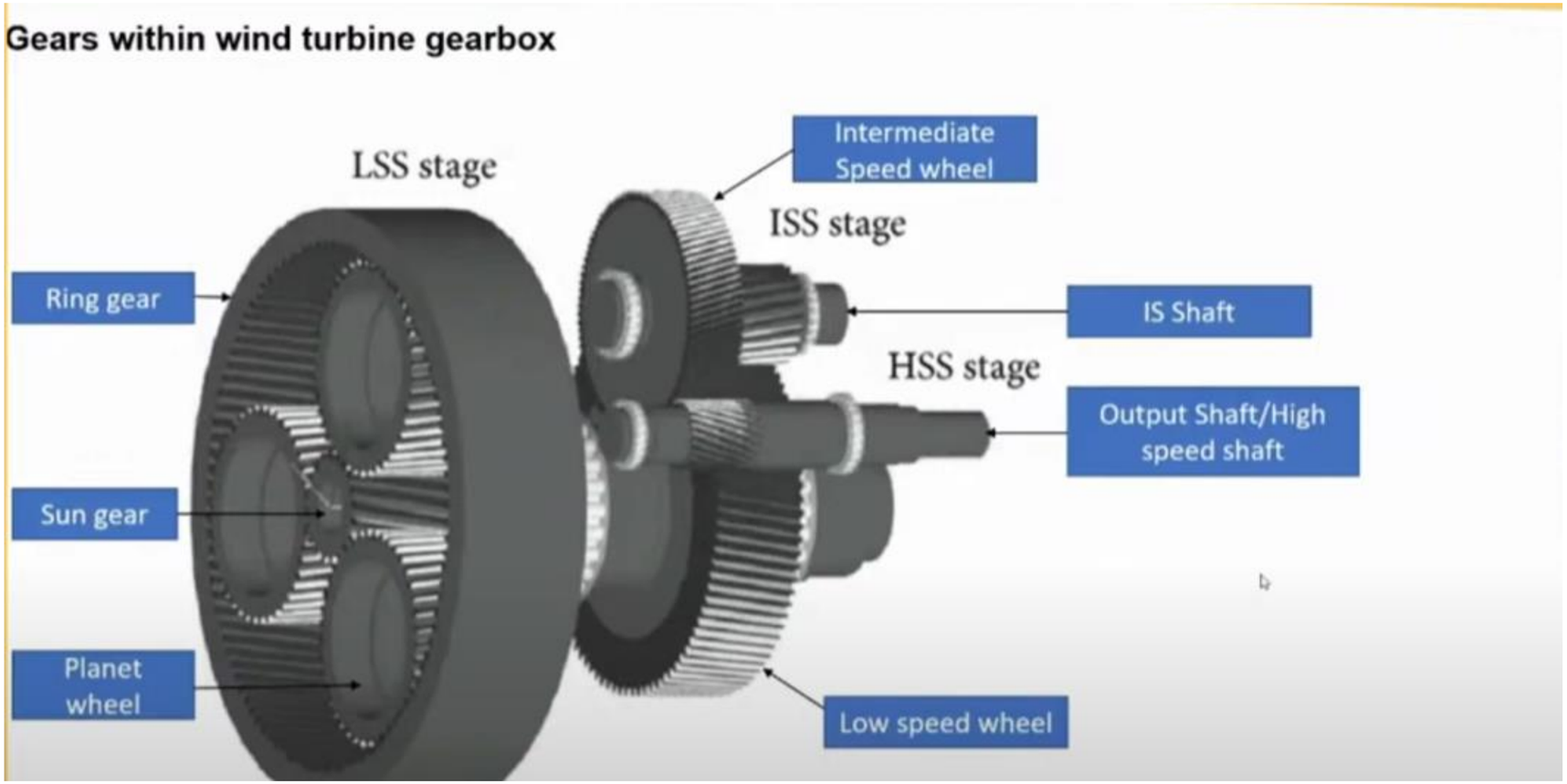
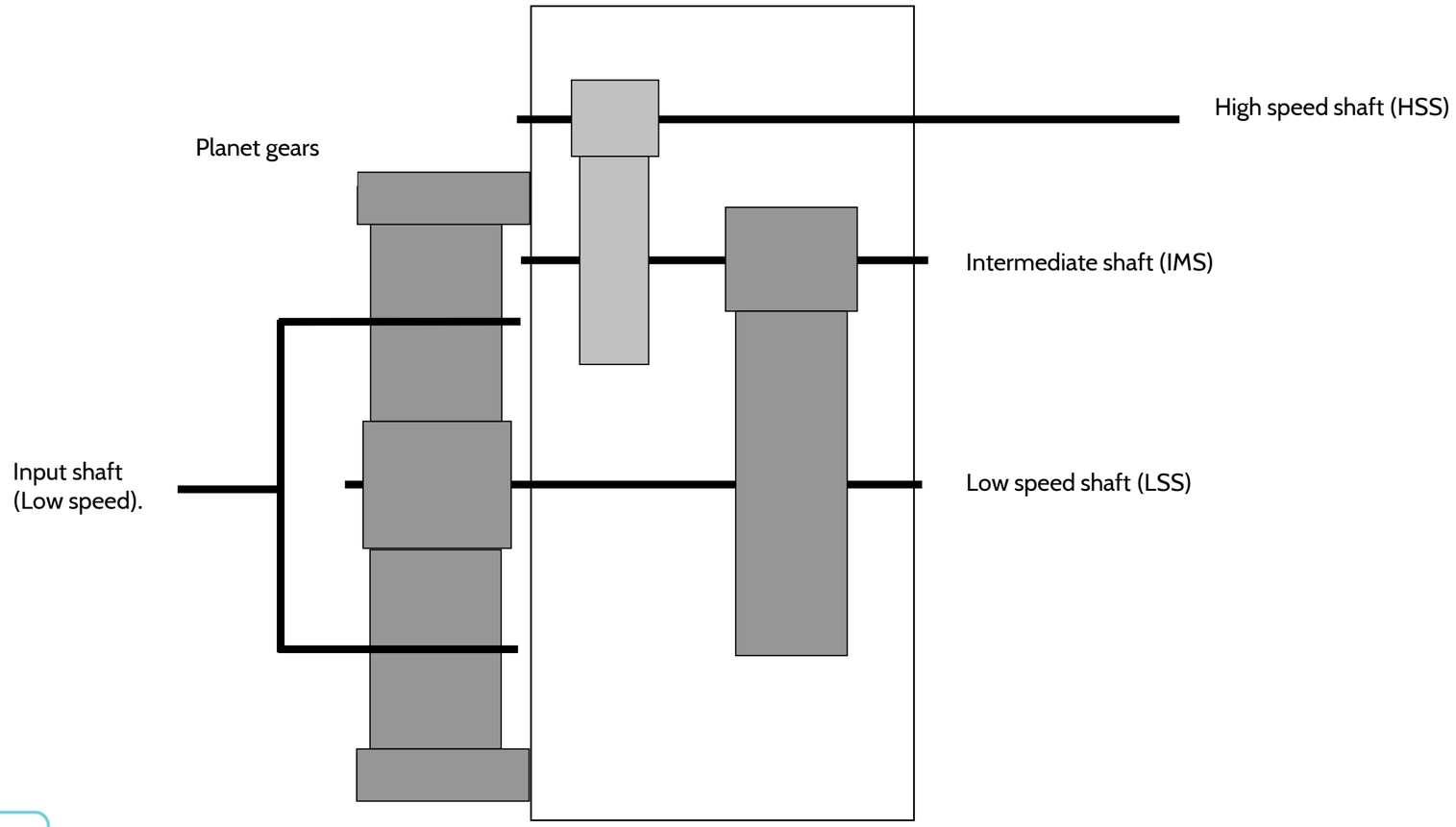
Gearbox structure



Gearbox structure

Shafts in gearbox



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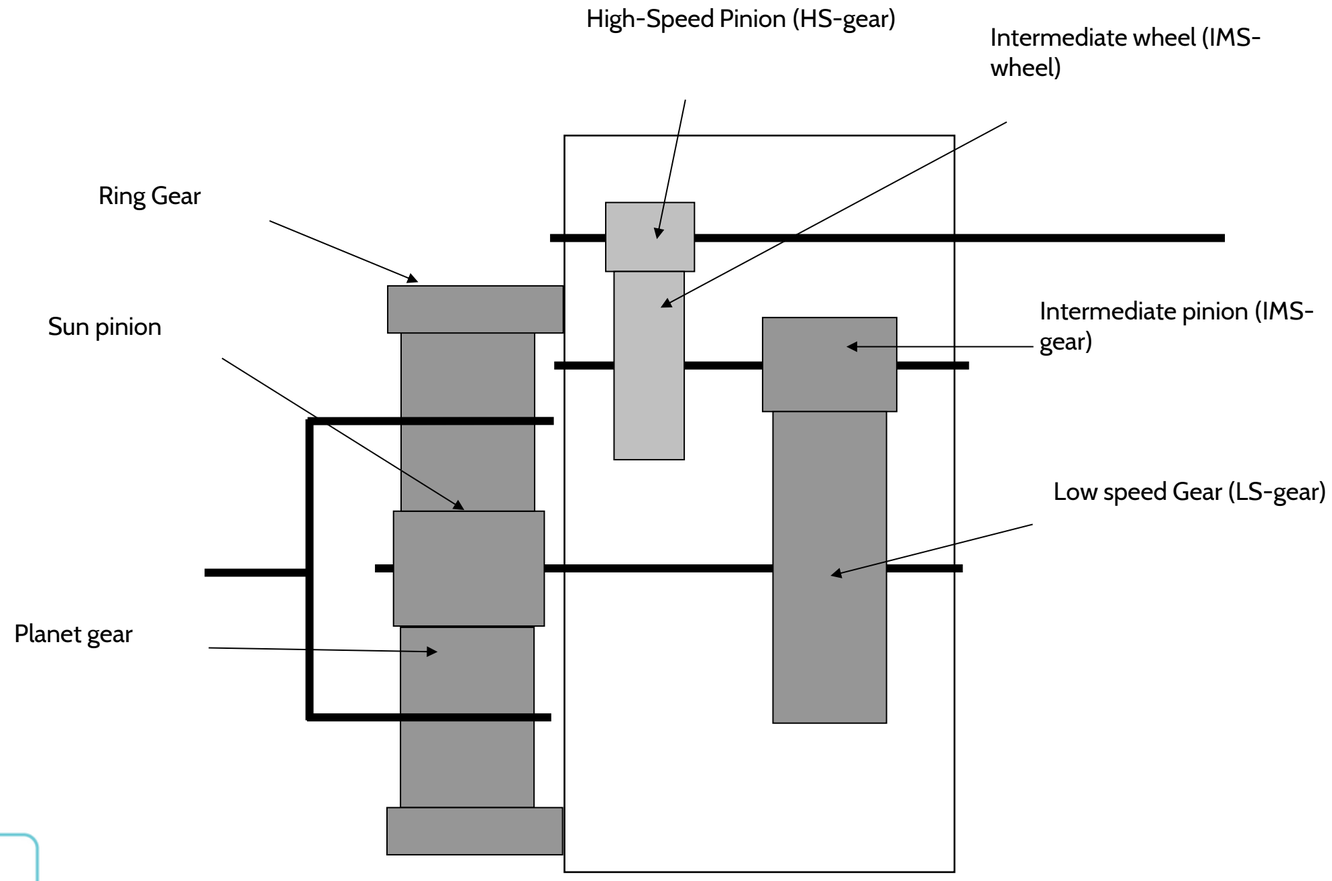
Gearbox structure

Gears and pinions in gearbox



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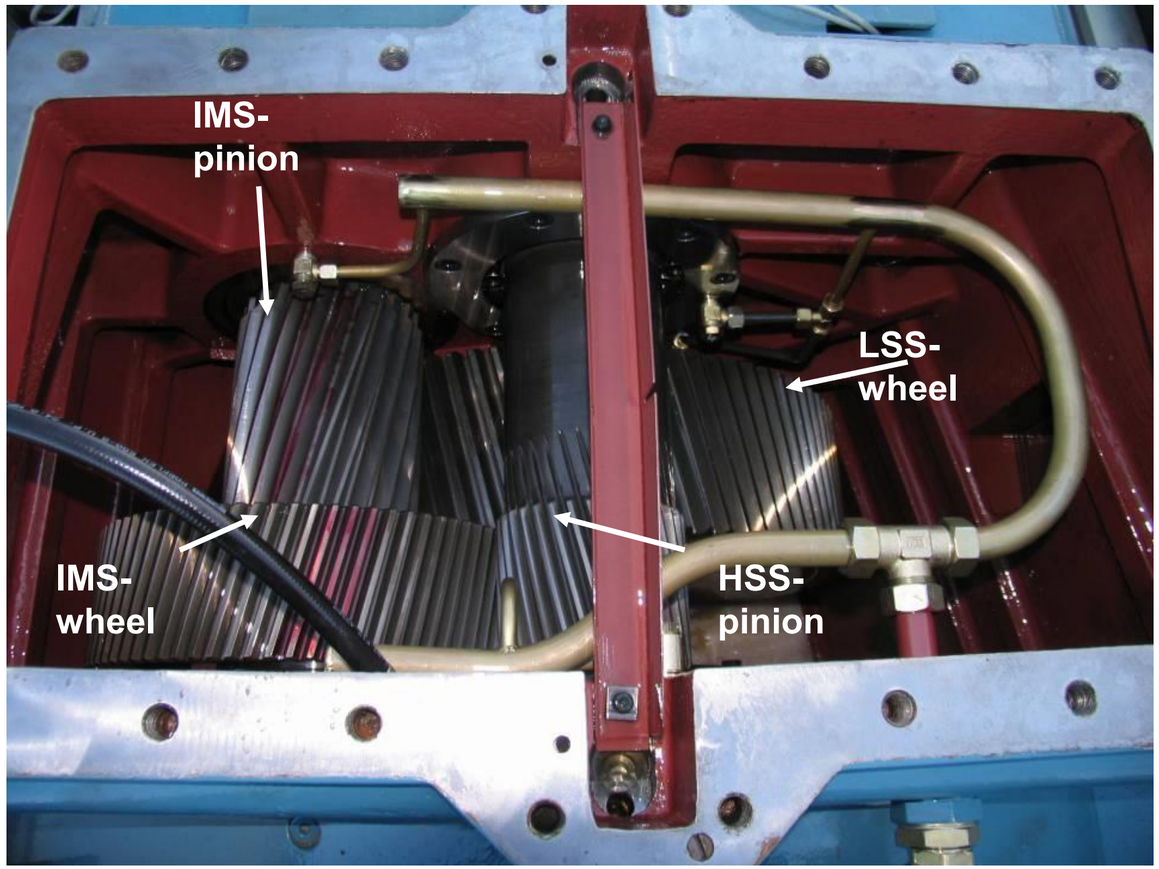
Gearbox structure

Gears and pinions in gearbox



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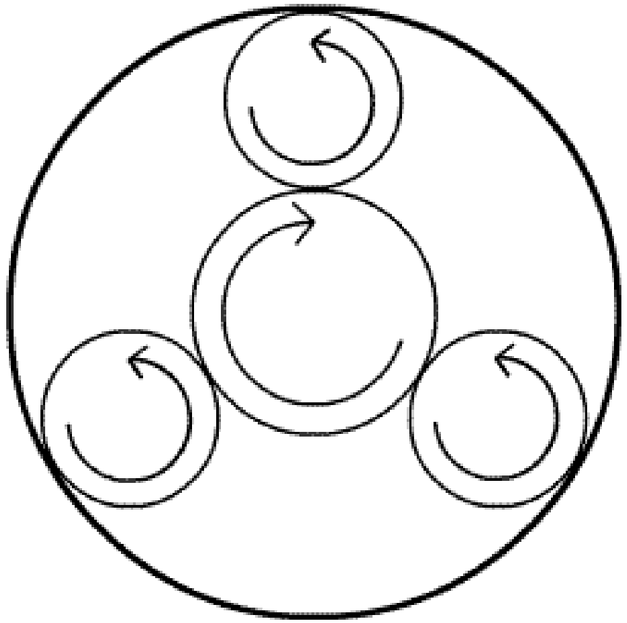
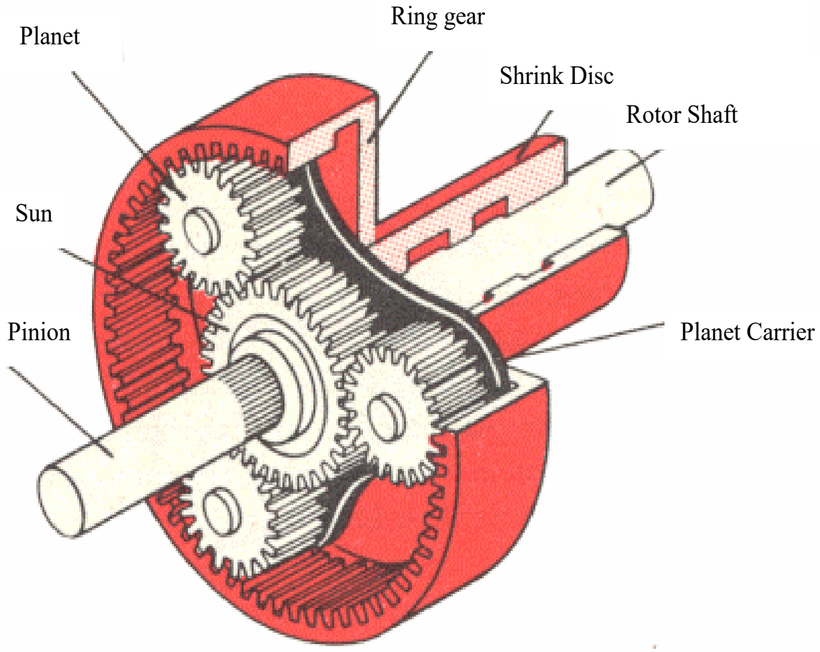
Gearbox structure

First stage planetary gears





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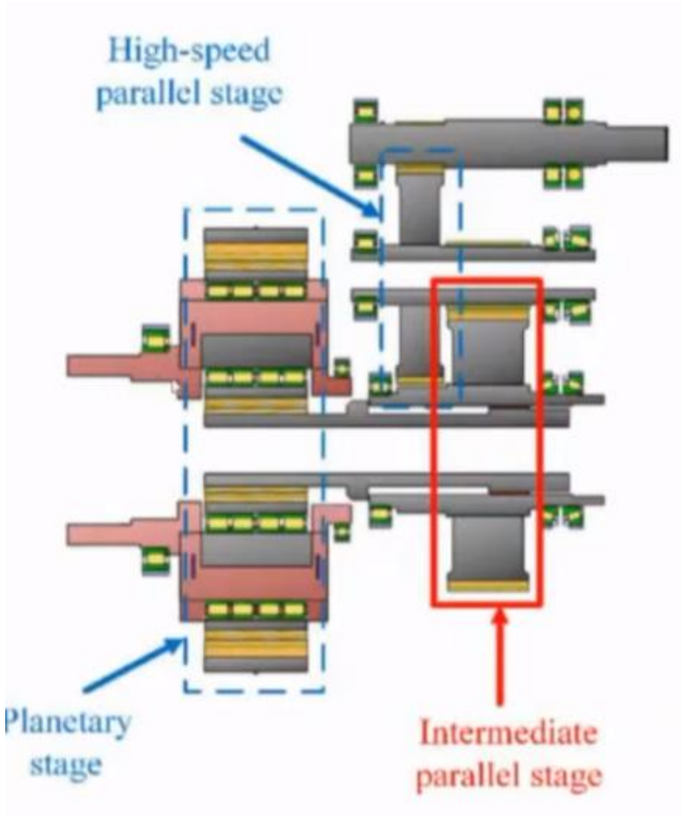
Gearbox structure

Intermediate and High-speed parallel stages



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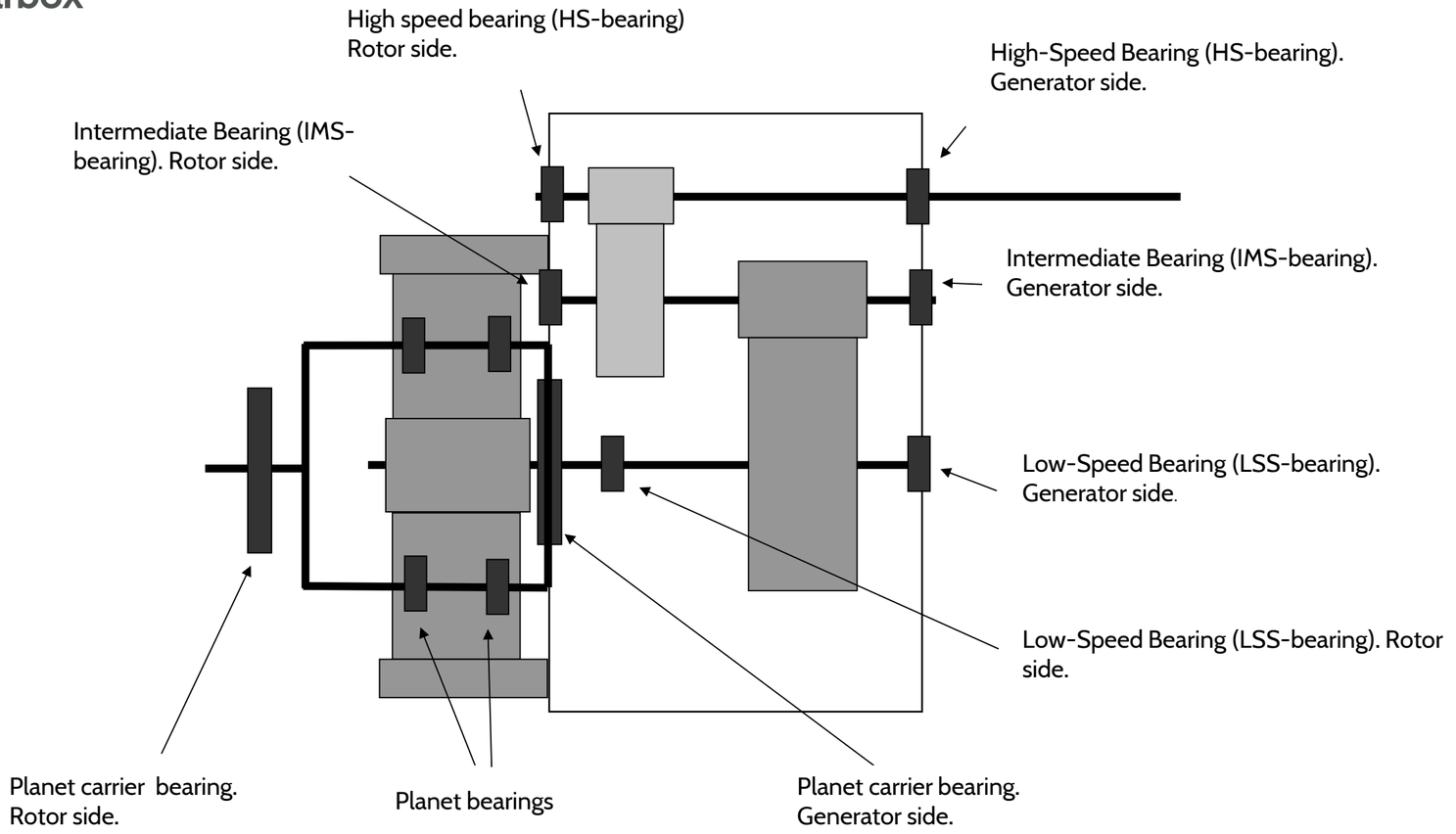
Gearbox structure

Bearings in gearbox



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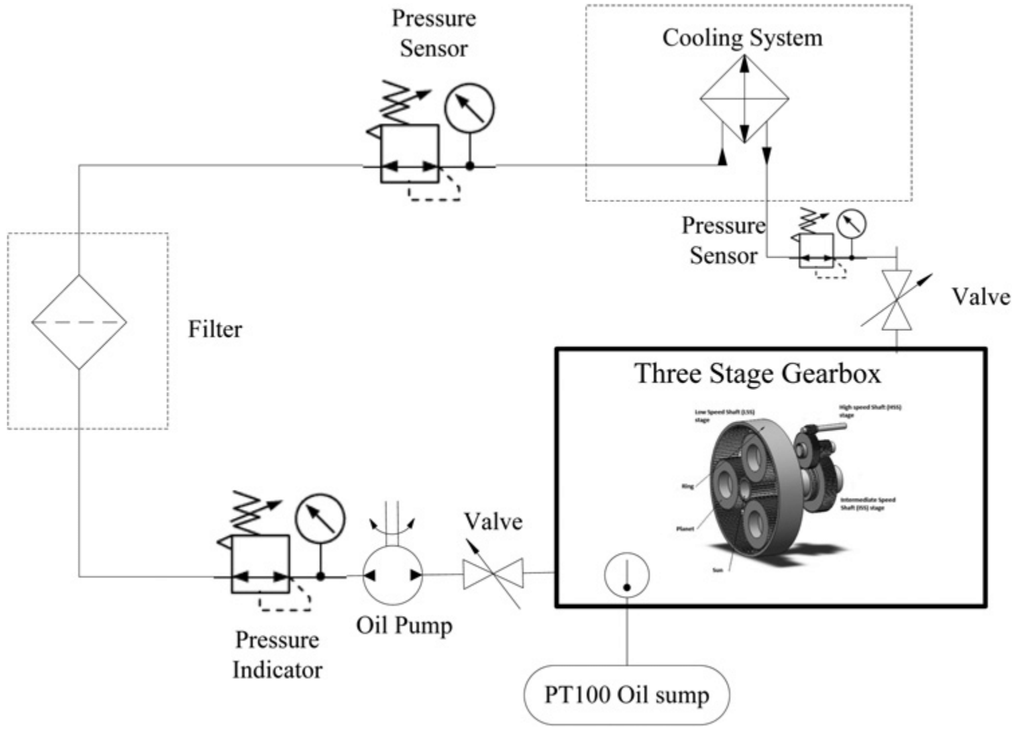
Lubrication and cooling system

Main function of lubrication and cooling system

- Reduces friction and wear by introducing a lubricating firm between moving parts
- Helps to dissipate heat away from the critical parts of the equipment
- Facilitates smooth operation of equipment by removing suspending products
- Protection: prevents metal damage due to oxidation and corrosion



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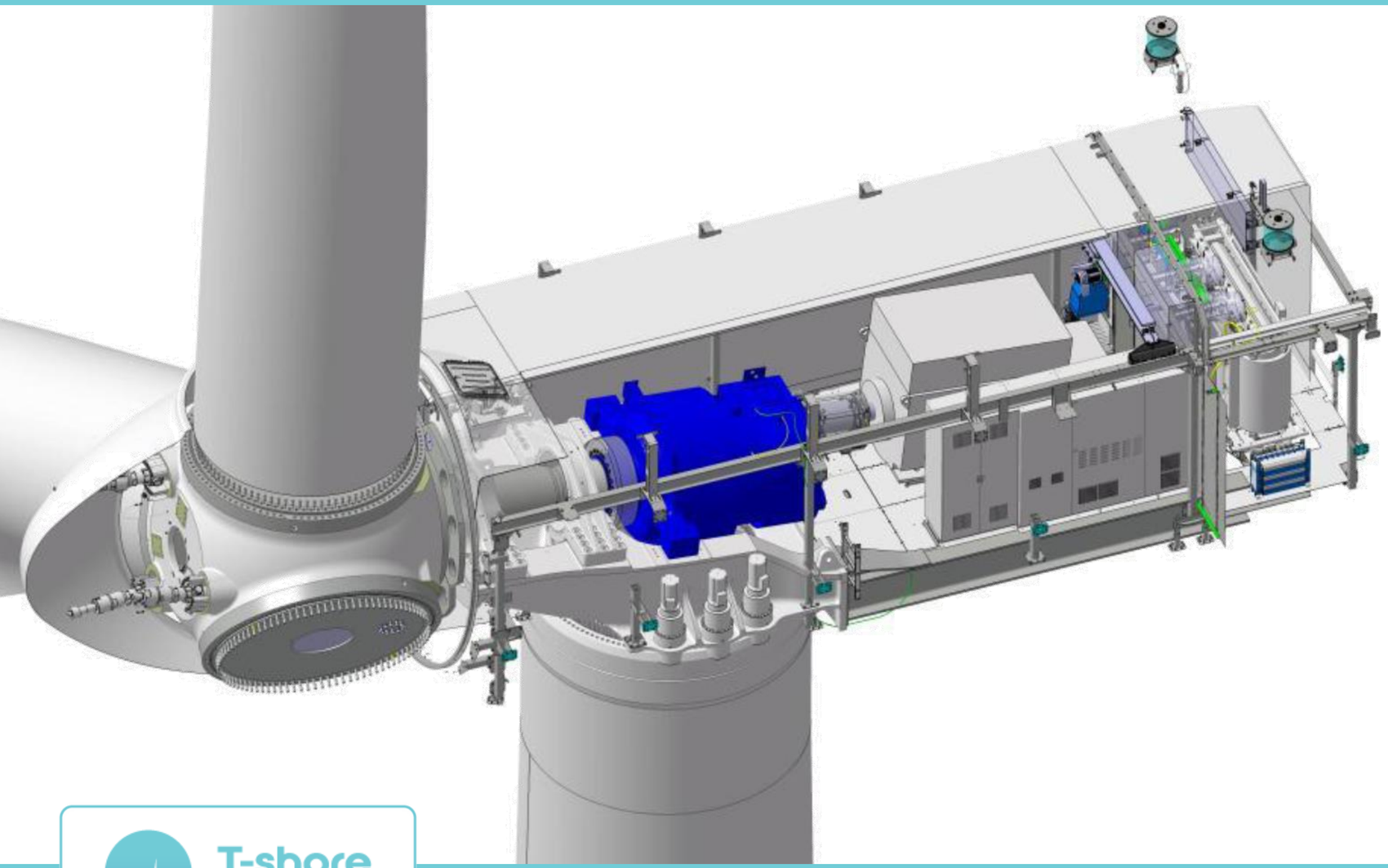
Gearbox in wind turbine



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Role of gearbox in wind turbine

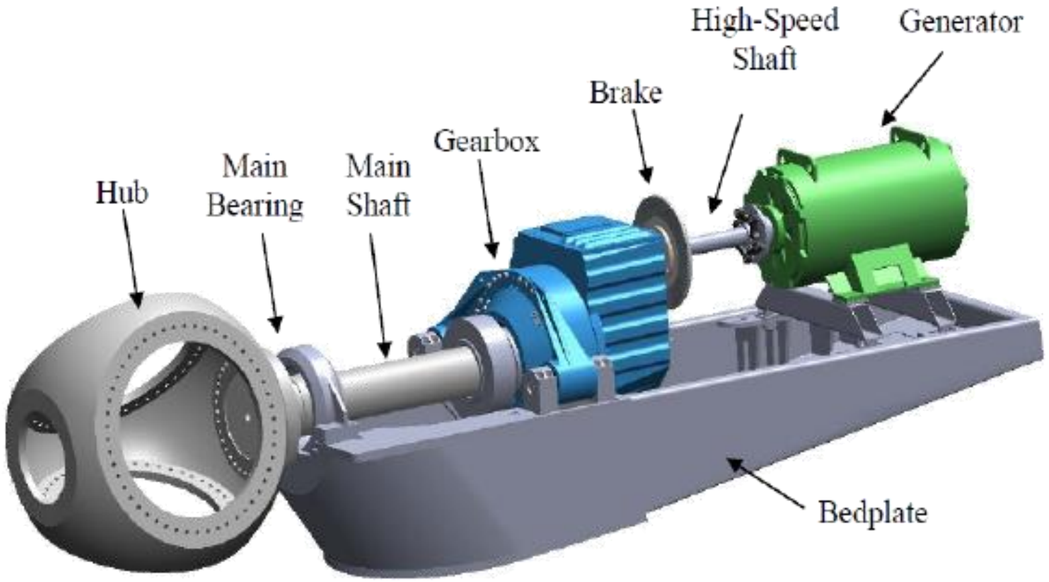
- To multiply the slow speed of the turbine blades (typically 5-15 rotations per minute) to the high speeds (1000 – 1800 rotations per minute) needed to generate electricity using a high speed induction generator
- To transfer power from the low speed turbine shaft at high torque to the high speed generator shaft at low torque

Speed multiplier

How turbine work

Conversion of energy

- **Rotor Rotation** - The rotating blades turn the rotor connected to the main shaft
- **Gearbox** - increase the rotational speed of the slower-moving main shaft
- **Generator** - the generator converts the mechanical energy from the rotating shaft into electrical energy.
- **Electrical Output** – generated electrical power is sent to the power grid for distribution



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Gearbox in wind turbine

Source: Real Engineering youtube channel

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Example of gearboxes in wind turbine

- 1,3 MW Gearbox in SWT

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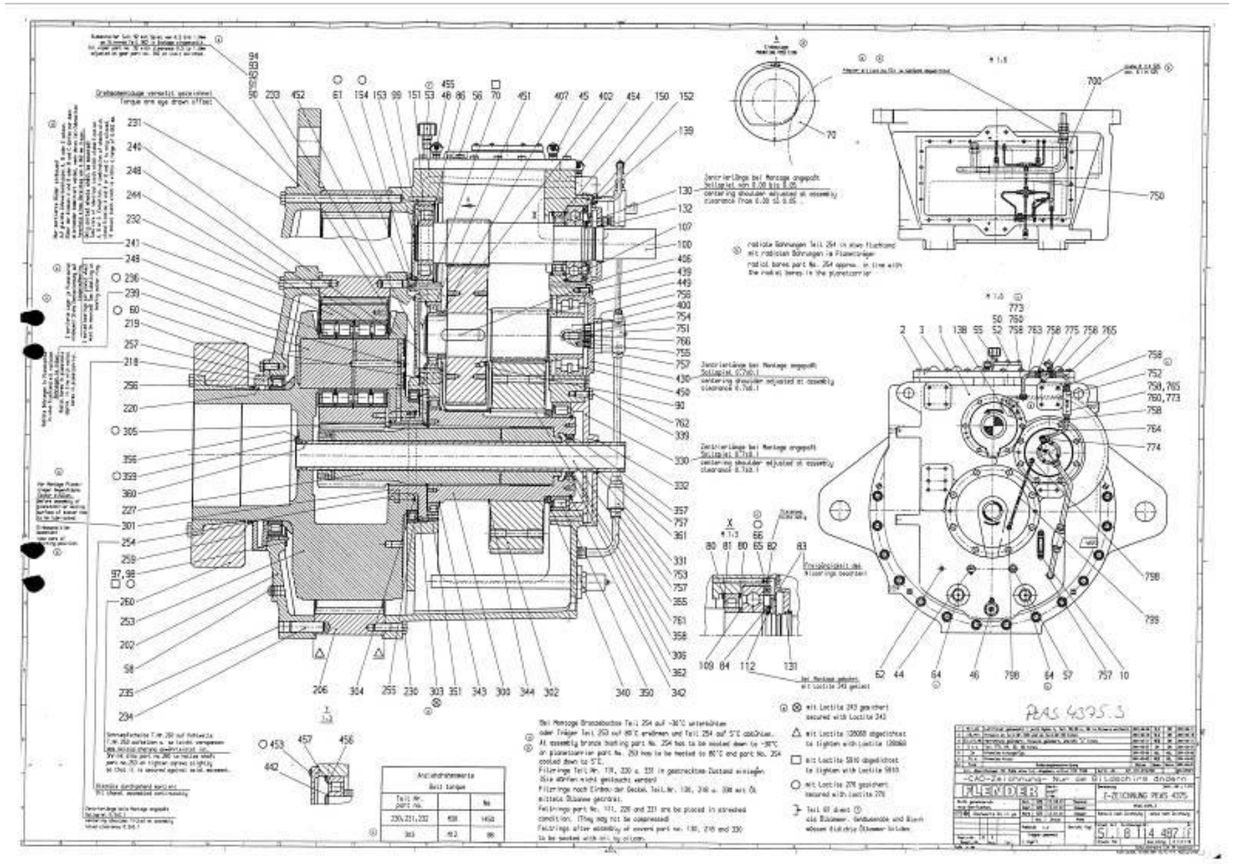
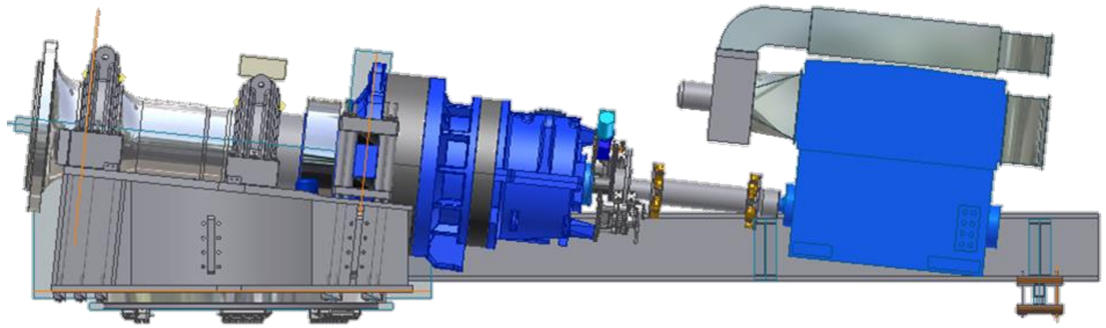
Example of gearboxes in wind turbine

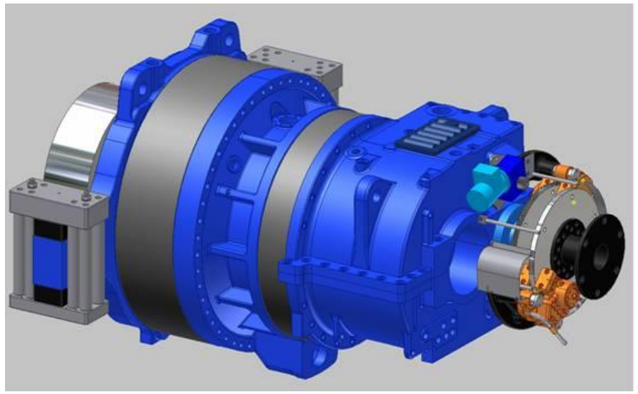
- 1,3 MW Gearbox in SWT



Example of gearboxes in wind turbine

- SWT 3,6-107 (3.6MW) gearbox





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Example of gearboxes in wind turbine

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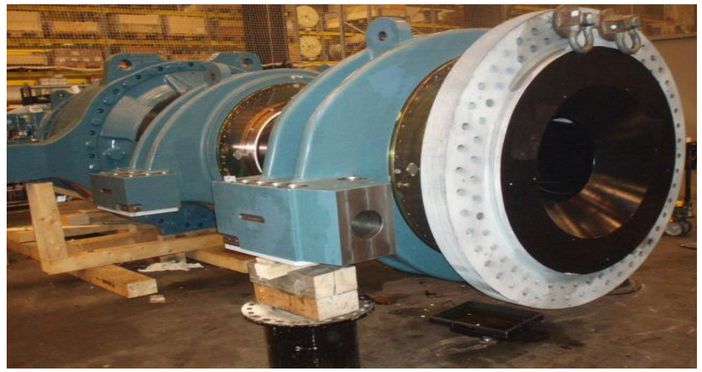

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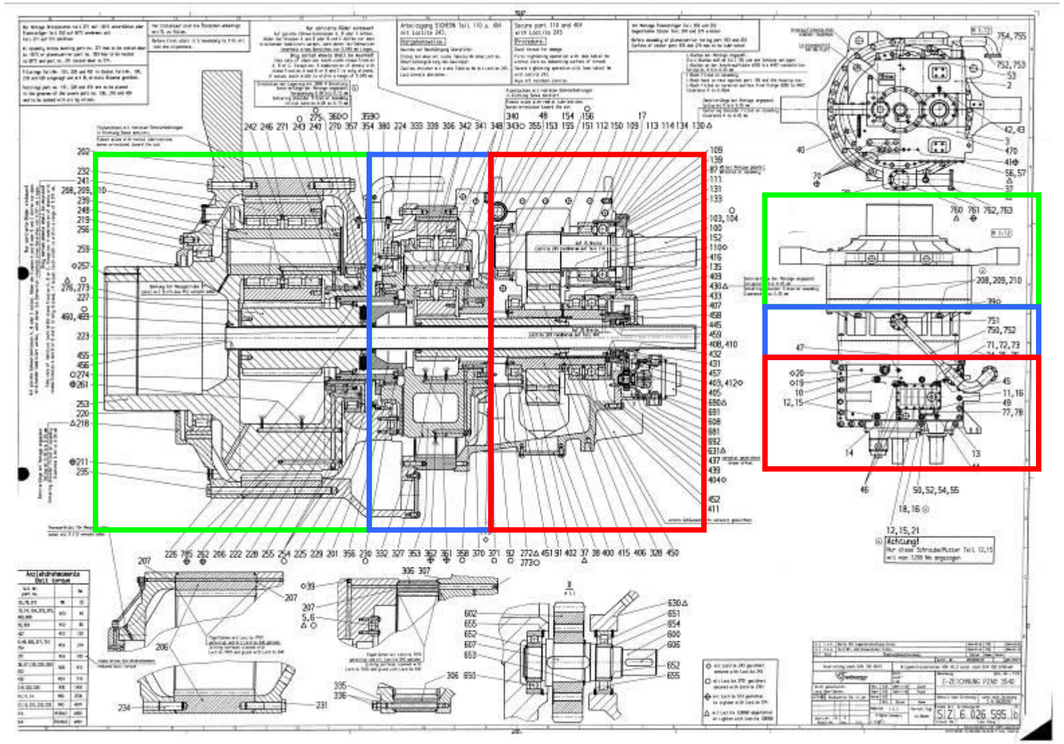
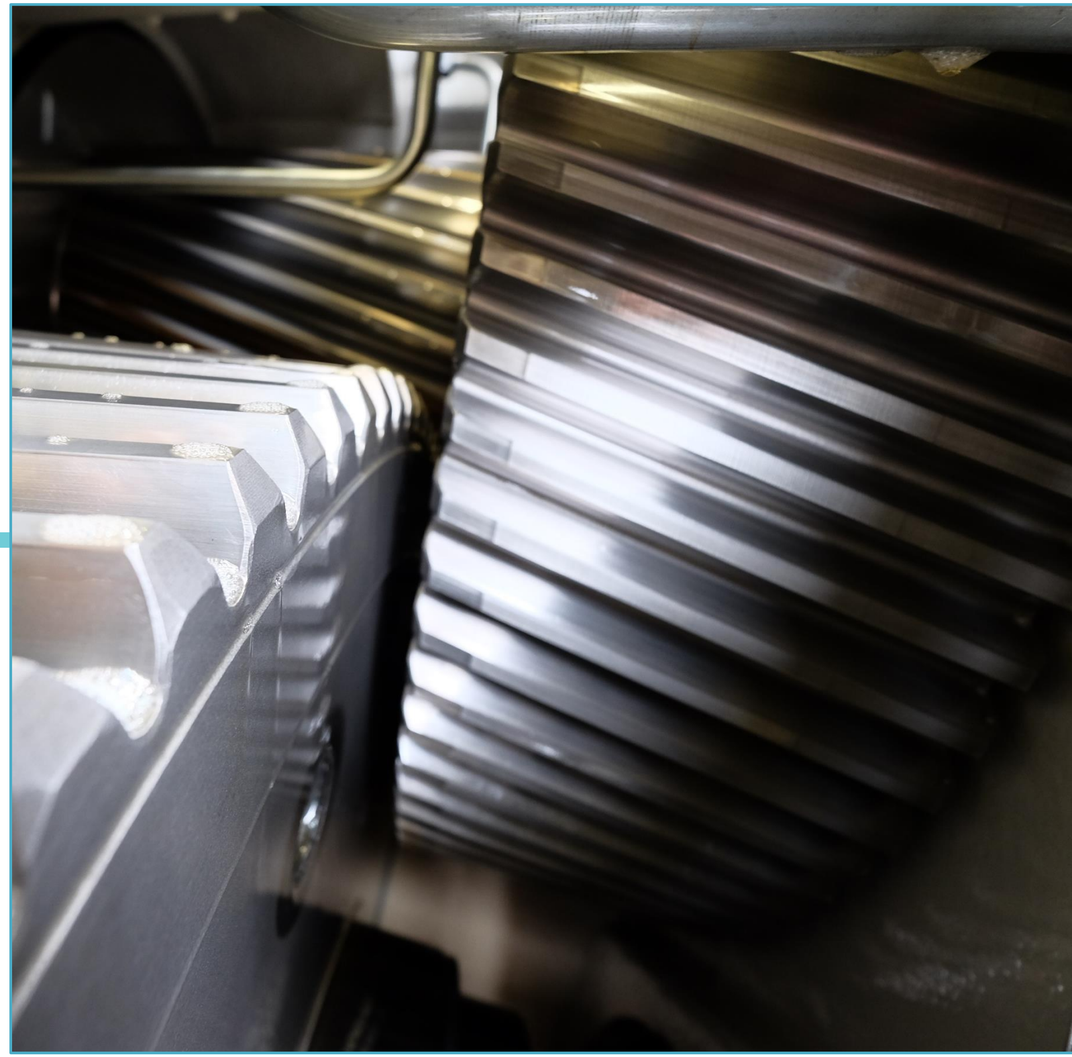
Example of gearboxes in wind turbine

- SWT 3,6-107 (3.6MW) gearbox



Gearbox Inspection

Lesson 5



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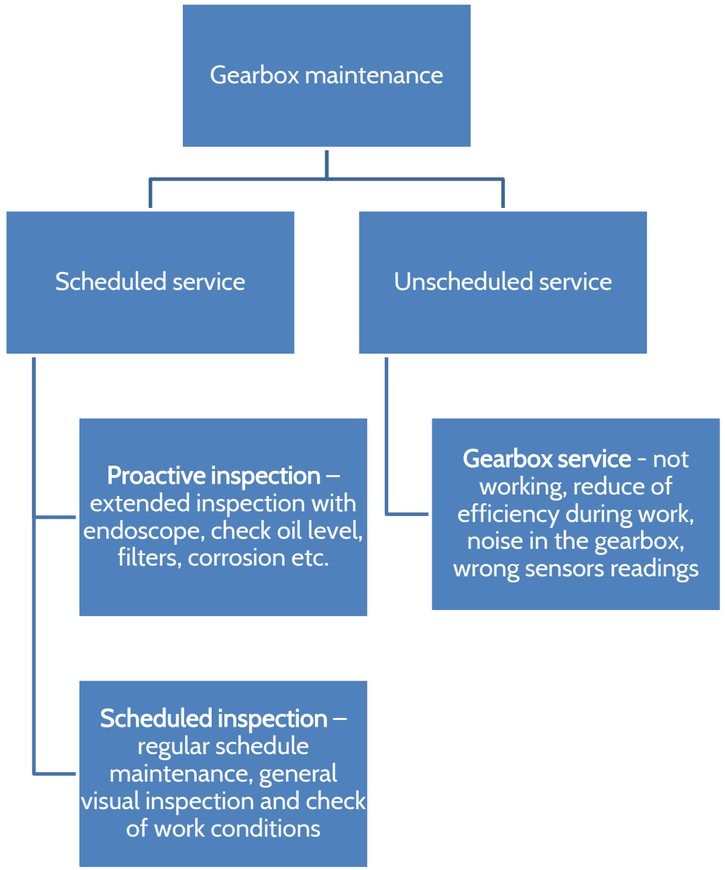
Gearbox maintenance

- Type of Gearbox maintenance



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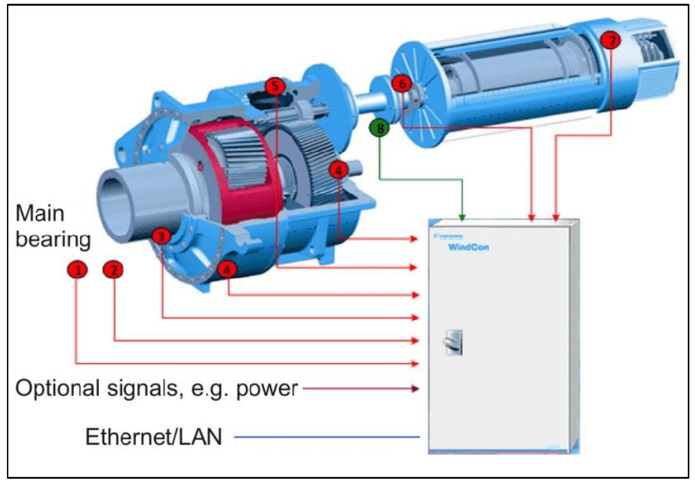
Gearbox unscheduled service

Unscheduled service

- Require advance skills, experience and knowledge to solve problem based on initial input and further investigation

Example service reason:

- Gearbox breakdown – not working
- Reduce working parameters of gearbox - reduce power generation by turbine
- CMS reading in wrong range – vibration sensor, oil temperature sensor etc.
- Noise in the gearbox during operation
- Other reason detected after gearbox scheduled inspection



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Gearbox scheduled service

Scheduled service

- Require intermediate skills, experience and knowledge to solve problem based on service instruction and manuals

Example service reason:

- **Proactive inspection**: Extended inspection to check gearbox condition and condition of specific parts and components. Executed with endoscope for internal parts. Looking for defects, corrosion, oil level, filters and housing.
- **Scheduled inspection**: regular schedule gearbox check periodicatly (sometimes combine with yearly inspection). General check of work conditions

Gearbox scheduled service

Reason of gearbox scheduled service

- Prevent major damage and long downtime for the turbine
- Warranty from the gearbox supplier
- Requirements from insurance companies
- Contract with owner of turbines

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Gearbox scheduled service

Example documentation of scheduled inspection

Example instructions

	9	**Gearbox**							
E	9.1	Check for leaking oil	x	O	x		Seal systems if necessary. Remove any escaped lubricants and clean the wind turbine.		
I			x	■			**MM70:** RENK Aerogear A60 BL 130: Inspection at the oil level indicator. The fill level should reach up to the center of the oil level indicator or dipstick (to be checked at rest 4 h after switching off the wind turbine whilst at operating temperature).	Refill volume [liters]	
I			x	■			**MM70/MM82A:** Eickhoff CPNHZ-217: Inspection at the oil level indicator. The fill level should reach the center of the oil level indicator.	Refill volume [liters]	
I			x	■			**MM82B:** RENK Aerogear A65 BL 150: Inspection at the oil level indicator. The fill level should reach up to the center of the oil level indicator or dipstick (to be checked at rest 4 h after switching off the wind turbine whilst at operating temperature).	Refill volume [liters]	
I			x	■			**MM82B:** Winergy PEAB 4480: Inspection at the oil level indicator (vertical). The distance between the top attachment screw and the fill level should be between 40 mm and 50 mm.	Refill volume [liters]	
I		Oil level inspection	x	■			**MM82B:** Moventas PLH-1700: Inspection at the oil level indicator. The fill level should reach the center of the oil level indicator.	Refill volume [liters]	
I	9.2	**Before checking the oil level:** Switch off pump wait approx. 30 min.	x	■			**MM82B/MM92/MM100:** Eickhoff CPNHZ-224 / EBN1209 / EBN1378 / EBN1510: Inspection at the oil level indicator. The fill level should reach the center of the oil level indicator.	Refill volume [liters]	
I			x	■			**MM92:** Winergy PEAB 4481: Inspection at the oil level indicator (inclined). The distance between the top attachment screw and the fill level should be between 140 mm and 150 mm.	Refill volume [liters]	
I			x	■			**MM92:** Bosch Rexroth GPV 508D: Inspection at the oil level indicator (vertical): The fill level should reach up to the center of the oil level indicator. You can determine the correct oil level with the gearbox at rest and the electrical lubrication pump running. **Caution!** A planetary gear must be in the 12 o'clock position (top)! The oil discharge hole of the hollow shaft of the planet carrier is then also in the 12 o'clock position.	Refill volume [liters]	
I			x	■			**MM82B/MM92/MM100:** Hansen EH854A: Inspection at the oil level indicator. The fill level should be between the two markings at the oil level indicator.	Refill volume [liters]	

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Gearbox scheduled service

Example documentation of scheduled inspection

Example instructions

G	9.3	Oil change	condition-based max. runtime 5 years				Oil	approx. 400 to 600 liters	Fill level in accordance with item 9.2
							The condition-based gear oil change is based on the results of the semi-annual oil analysis (see 9.4). More detailed information may be retrieved from the process instruction **GE-OMH-I-10-VA-EN**.		
I	9.4	Take an oil sample for oil analysis		O	x		**Only use oil sampling containers by Oelcheck** Oil samples must be taken from the drain tap of the Internormen filter block. Flush prior to sampling (min. 4 x, approx. 500 ml in total), label sample taken, only use specified containers, ensure cleanliness during and after sampling. Give oil samples to the responsible master service technician or coordinator. See also the current version of service manual **instruction for oil sampling at main gearbox.**		
I	9.5	Oil level monitor	x	■			If available, carry out a functional test of the oil level monitor via the cable bridge at the plug.		
I	9.6	Check ventilation filter		■			**Mahle paper filter: Replace the filter element**		
C				■			**Anselm oil bath filter**: For the oil change loosen the 3 fillister head screws M4 x 8 mm at the top filter cover and remove the cover. If necessary unscrew the filter from the gearbox using the 3 assembly holes offset by 120° and dispose of the oil. Refit the filter to the gearbox using Teflon tape near the thread and fill with fresh gear oil up to the oil level marking. The fill level marking is visible in the bevel screwed into the filter. Overfilling does not cause any harm. Refit the filter cover.		
E				■			**Internormen:** Replace the filter element		
E	9.7	Elastomer bearing condition	x	O	x		Check for cracks, separations and abrasion, deformation		
E	9.8	Gearbox cabinet		O	x		Visual inspection of the gearbox		x
E	9.9	Proximity sensors, sensor disk	x	O	x		Visual inspection of the fit and operation of the proximity sensors for speed measurement. Visual inspection of the condition and attachment of the sensor disk. Axial distance to the sensor loops: 2 mm (tolerance +1 mm)		x
	9.10	Grounding	x	O	x		Check the grounding for tight fit.		x
	9.11	Sensors, cables, plug connectors		O		x	Visual inspection of the sensors and their connections, check the screws for tight fit.		x
D	9.12	Slip indication on the clamping set	x	O	x		Check the slip markings between the shrink disk and the rotor shaft (where present) Place slip indication if necessary.		

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Gearbox scheduled service

How to take and oil sample for oil analysis

Source: Trico Corporation youtube channel

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Proactive inspection

Advance internal inspection - borescope

T-shore Education

Proactive inspection

Advance internal inspection – borescope inspection

Source: EVIDENT Industrial youtube channel

Proactive inspection

Advance internal inspection – example borescope inspection

Source: TCGM youtube channel

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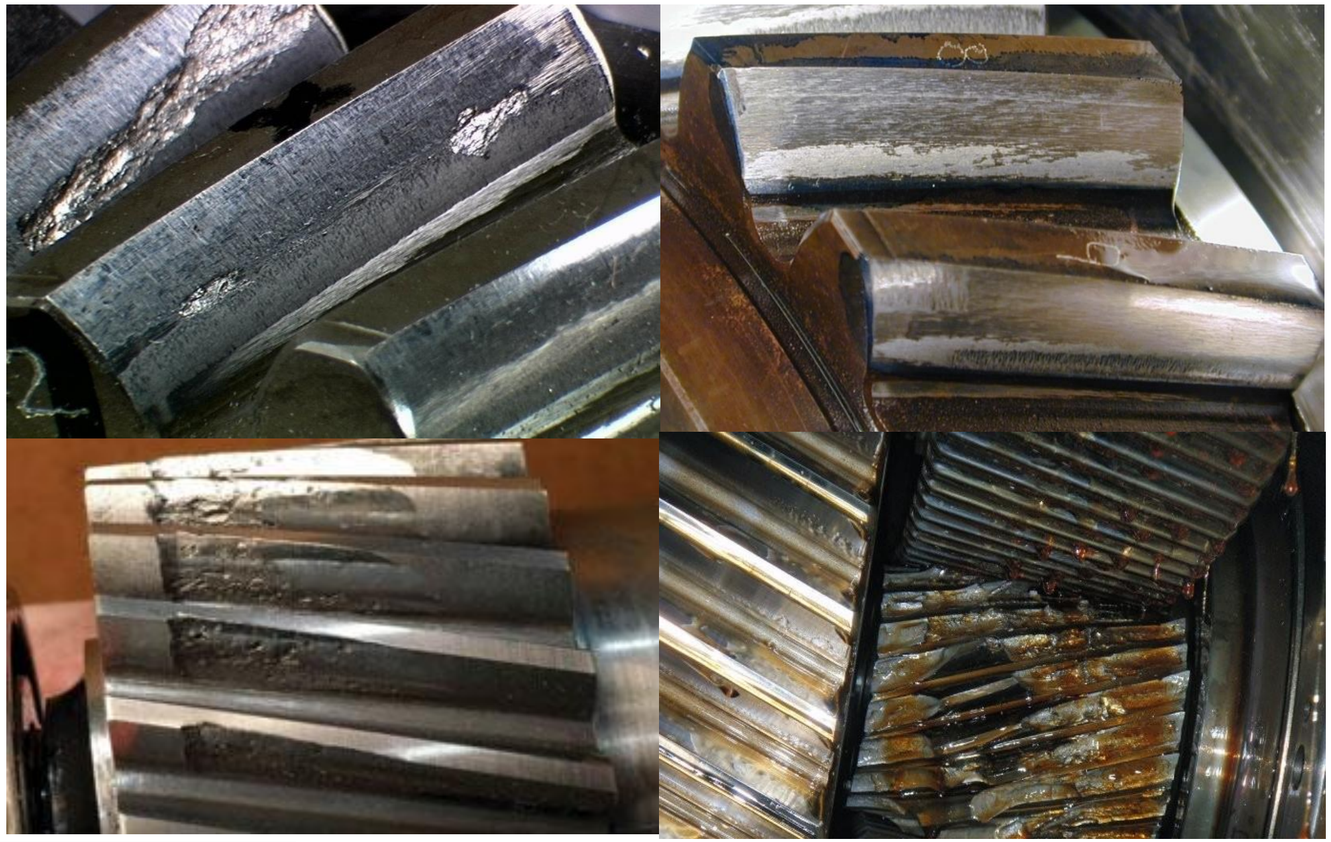
Proactive inspection

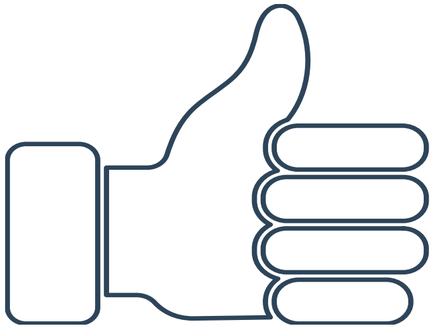
Findings example



Maintenance documentation

Suggestions how to fill out documentation correctly:

- Ensure all information is completed.
- Use pictures as supporting materials to communicate findings effectively.
- Use only objective and clear communication phrases.
- Double-check serial numbers, part numbers, and other identifiers.
- Use common words and simple expressions for clarity.
- Prioritize findings based on importance or urgency.



The customer receives

a report with all findings.

Thank you!

FAGSKOLEN ROGALAND

ENERGY INNOVATION

Dalane videregående skole

T-shore Education

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Enriching lives, opening minds.

Vocational education and training

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