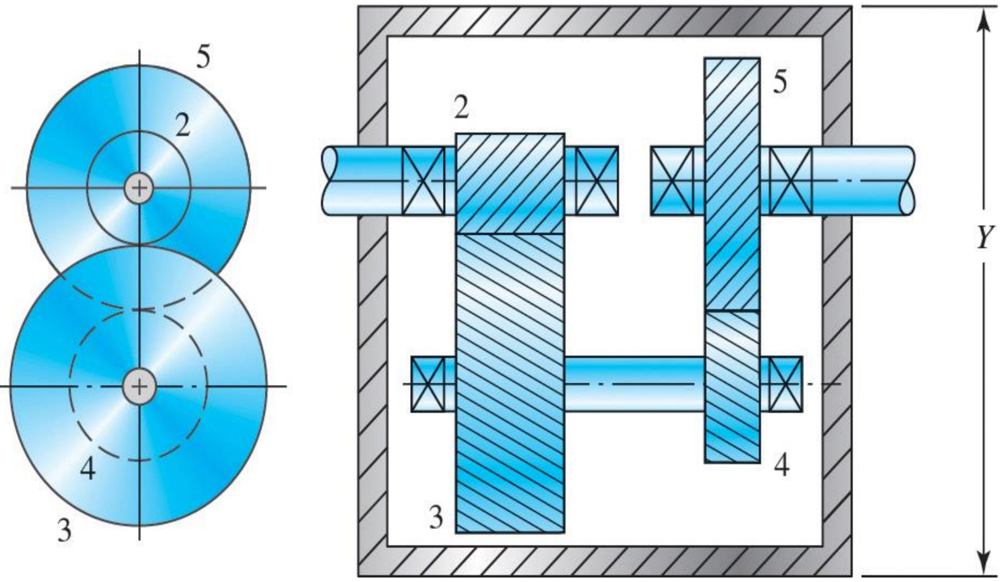
Power Transmission Case Study



Compound Reverted Gear Train

- Transmission of power from a source (engine or motor) to output actuation is an essential task of many machines.
- An efficient means of transmitting power is through the rotary motion of a shaft that is supported by bearings.
- Gears, belt pulleys, or chain sprockets may be used to provide for torque and speed changes between shafts.
- The design of a system to transmit power requires proper selection and design of individual components (gears, bearings, shafts, etc.)
- The design and selection of each component is dependent on the other.

- The nature of the course so far has been to work on design and selection of each component separately. This **power transmission case study** involves incorporating the details of each component into an overall design process.
- The individual components of a **compound reverted gear train** needs to be selected to meet certain design specifications which will be provided.

Typical Design Specifications

Compound Reverted Gear Train

Design Requirements

Power to be delivered: 20 hp.

Input speed: 1750 rev/min.

Output speed: 85 rev/min.

Targeted for uniformly loaded applications, such as conveyor belts, blowers, and generators.

Output shaft and input shaft in-line.

Base mounted with 4 bolts.

Continuous operation.

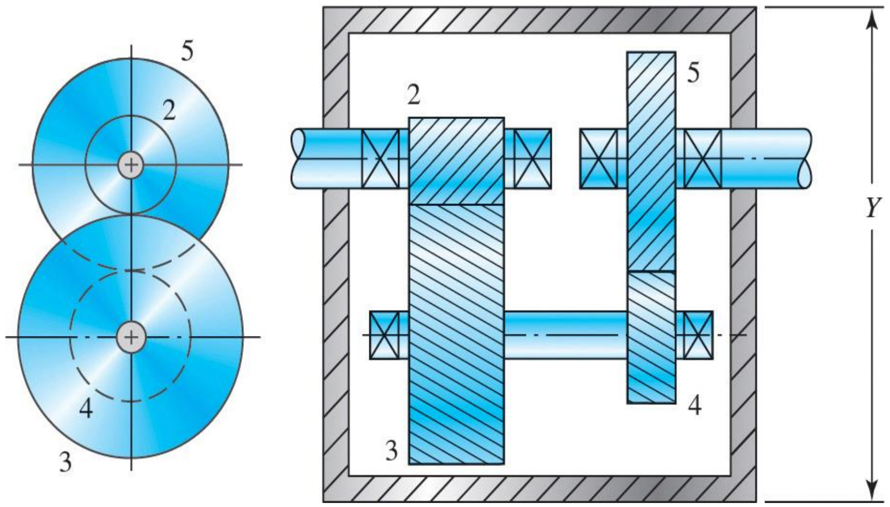
6-year life, with 8 hours/day, 5 days/wk.

Low maintenance.

Competitive cost.

Nominal operating conditions of industrialized locations.

Input and output shafts standard size for typical couplings.



Compound Reverted Gear Train

Note: A <u>compound reverted gear train</u> is a compound gear train in which the input shaft is in-line with the output shaft. See the figure above.

Design Sequence for Power Transmission

Power and torque requirements.

Gear specification.

Shaft layout.

Force analysis

Shaft material selection

Shaft design for stress (fatigue and static)

Shaft design for deflection

Rotating shaft dynamics

Bearing selection

Final analysis

Note: The above list is a general list. Remember that design is an iterative process. There is no one set sequence of steps to achieve your final goal.

Power and Torque Requirements - determines the overall sizing needs of the entire system

- In ideal case, neglecting losses, power in equals power out.

Power is product of torque and speed. $T_i \omega_i = T_o \omega_o$

- With a constant power, a gear ratio to decrease the angular velocity will simultaneously increase torque. The equation for gear ratio or train value is given below.

- Gear ratio, or train value, $e = \omega_o / \omega_i = T_i / T_o$

- A typical power transmission design problem will specify the desired power capacity, along with either the input and output angular velocities, or the input and output torques. There will usually be a tolerance specified for the output values.

Gear Specification

- The train value is also given by $e = \dfrac{product\ of\ driving\ tooth\ numbers}{product\ of\ driven\ tooth\ numbers}$

- The minimum number of teeth on the pinion for $\Phi = 20^0$ is given by

$$N_p = \frac{2}{(1+2m)\sin^2\phi}\left(m + \sqrt{m^2+(1+2m)\sin^2\phi}\right) \qquad m = \frac{N_g}{N_p}$$

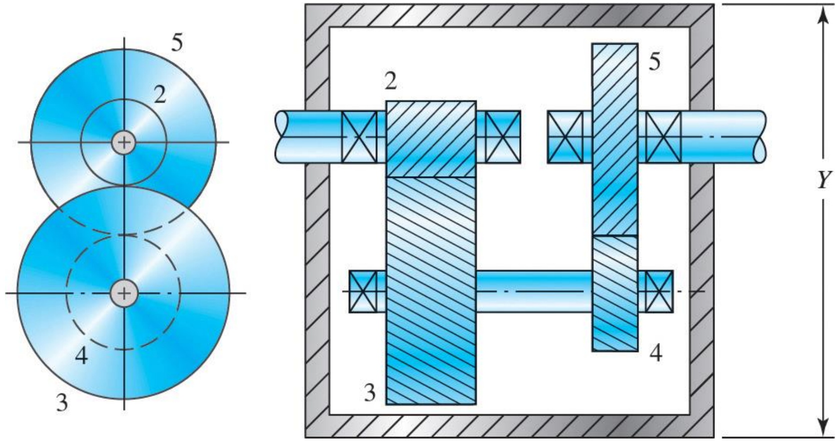
N_g: Number of gear teeth

N_p: Number of pinion teeth

- For the input shaft and the output shaft of a two-stage compound gear train to be in-line,

Minimum pitch, $P_{\min}$

$$P_{\min} = \frac{\left(N_3 + \dfrac{N_2}{2} + \dfrac{N_5}{2} + 2\right)}{(Y - \text{clearances} \; - \; \text{wall thickness})}$$



Compound Reverted Gear Train

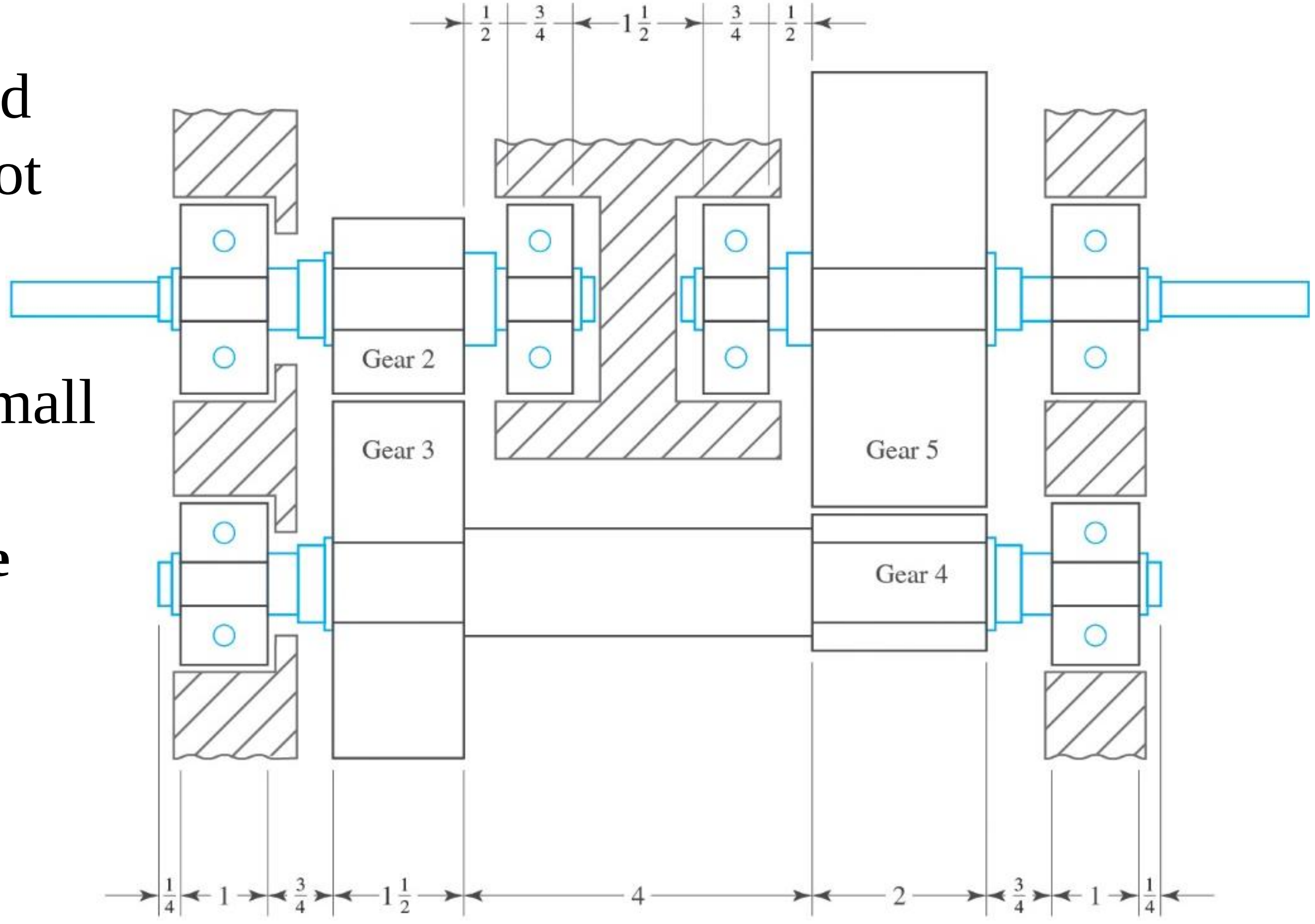
Gear Specification

- Complete the gear analysis (see the following)

- Find the number of gear teeth on each gear
- Find the gear diameters
- Typical spur gears are available with ***face widths from 3 to 5 times the circular pitch***
- Assume/Assign the gear material. Choose appropriate grade of steel.
- Conduct gear tooth bending analysis
- Assess the safety of the gears. Achieve a reasonable factor of safety (2 to 3)

Shaft Layout

- The general layout of shafts, including axial location of gears and bearings must be specified to proceed with the analysis.
- The shaft layout is used to conduct the free body analysis, and to obtain the shear force and bending moment diagrams.
- A free-body force analysis can be conducted without knowing shaft diameters, but can not be performed without knowing the axial distances between gears and bearings
- It is important to keep the axial distances small to avoid excessive deflections
- See the rough shaft layout. **Note: At this stage**
  - **Gear widths are known**
  - **Bearing widths are guessed**
  - **Other dimensions are reasonably guessed.**



Force Analysis

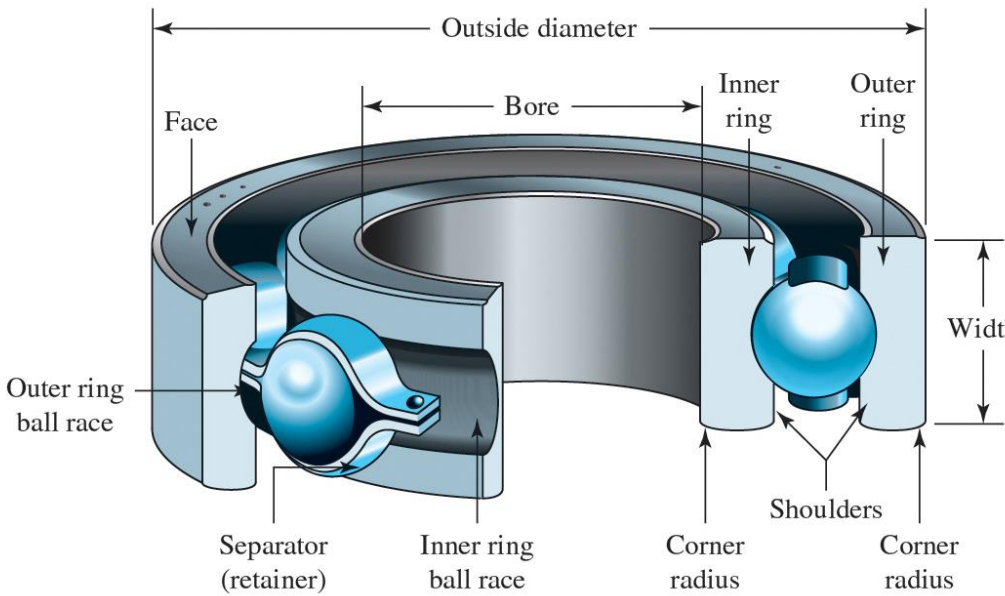
- Once the gear diameters are known, and the axial location of the components are set, the free body diagrams and shear force and bending moment diagrams for the shafts can be produced.
- With the known transmitted loads, determine the loads through the gears.
- From the summation of forces and moments on each shaft, reaction forces on the bearing can be determined
- For shafts with gears, the forces and moments will usually have components in two planes along the shaft.
- For rotating shafts, usually only the resultant magnitude is required, so force components at bearings are summed as vectors.
- Shear force and bending moment diagrams are usually obtained in two planes, then summed as vectors at any point of interest.
- A torque diagram should also be generated to visualize the transfer or torque from an input component, through the shaft, and to an output component.

Shaft Analysis

- Select a trial shaft material and change it later if necessary
- Estimate the appropriate diameters for each section of the shaft based on the bending stresses in the shaft
- Conduct dynamic analysis on the three shafts to find the critical speed of rotation. Predict the safety of the shafts.

Bearing Selection

- With the bearing reaction forces and approximate bore diameter known, the bearing selection is now straightforward.
- Rolling contact bearings are available with a wide range of load capacities and dimensions.
- If the bore diameter of the selected bearing is smaller or larger than the shaft diameter, a stepped shaft might have to be used. Stepping results in stress concentration at the regions where there is change in geometry. Conduct a stress concentration analysis.



Source: Based on General Motors Corp., GM Media Archives

Final Analysis

- Check every step of the design for accuracy
- Check if your design meets the requirements