2 SPUR GEARS AND PARALLEL AXIS HELICAL GEARS

2.1 GEAR DRIVE

A gear drive is a mechanical drive which transmits power through toothed wheels called as gears. In this drive driving wheel is in direct contact with the driven wheel in contrast with the other mechanical devices such as belt drives and chain drives, where an intermediate link like belt or chain is needed to connect the driven wheel with the driving wheel. Gears are transmitting power from one wheel to other by means of positive contact of successively engaging teeth.

2.2 ADVANTAGES

1. Gear drives are compact than belt and chain drives.
2. Gear drives are having high efficiencies.
3. They have very long service life and high reliability.
4. Gear drives can transmit more power than other drives.
5. They have greater range of speed ratios.
6. They have constant speed ratio owing to the absence of slipping.
7. Metal gears do not deteriorate with age, heat and oil.

2.3 DISADVANTAGES

1. Design and manufacturing of gears is complicated.
2. It produces noise at high velocities.
3. For long centre distance power transmission gears cannot be operated.
4. They require careful maintenance and proper lubrication.

2.4 CLASSIFICATION

1. Based on the position of the gear shafts
   a. Parallel-spur, helical and herring bone gears.
   b. Intersecting- Bevel gears- Straight and spiral.
   c. Non intersecting and Non parallel-crossed helical, worm gears, hypoid, spiroid, planoid, bebveloid, helicon, face gear etc.
2. Based on type of engagement.
   a. External gearing
   b. Internal gearing
   c. Rack and pinion

3. Based on the position of teeth on the wheel rim.
   a. Teeth parallel to the axis of gear Eg-Spur gear.
   b. Teeth inclined to axis of geasEg-Helical,Herring bone gears.

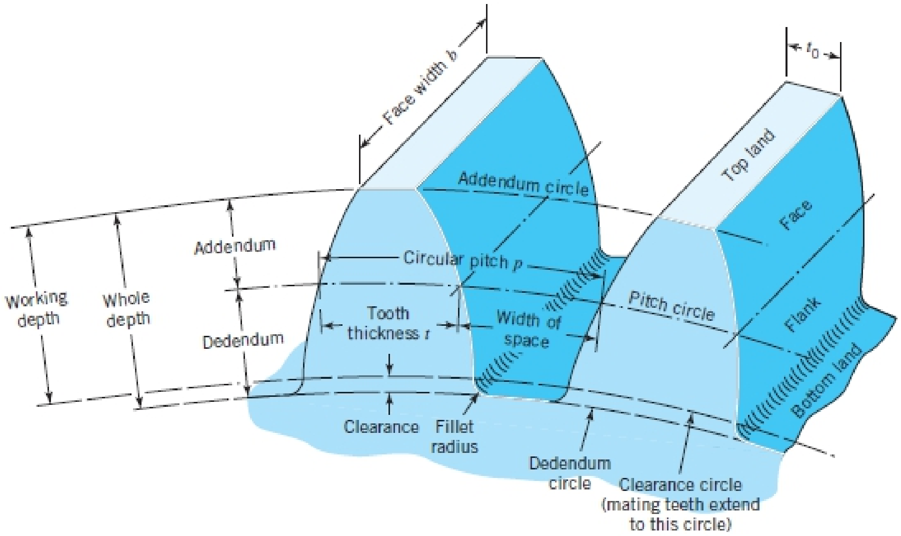
   c. Curved teeth on wheel-Eg-Spiral.
4. Based on the peripheral speed of gears.
   a. Low speed gears V< 3 m/s.
   b. Medium speed gears 3 m/s <V< 15 m/s.
   c. High speed gears V> 15 m/s.

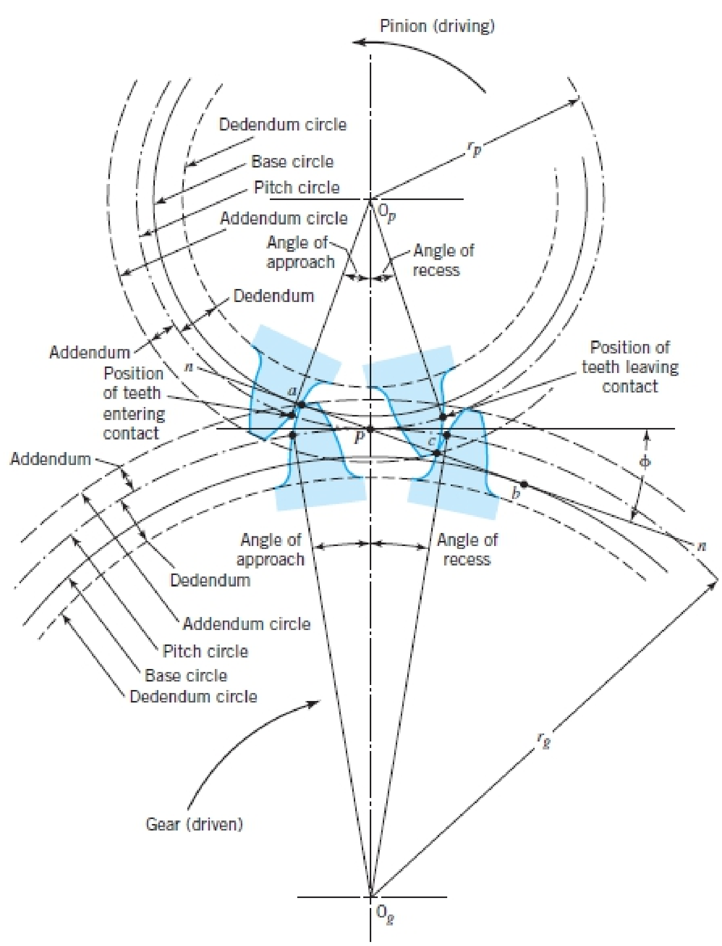
5. Based on profile
   a. Invoulte profile
   b. Cycloid profile
6. Based on pressure angle
   a. Gear with 20°pressure angle
   b. Gears with $14\frac{1}{2}°$pressure angle
7. Based on tooth height (or) working depth
   a. Full depth gears.
   b. Stub gears

2.5 COMMON TYPE OF GEARS

1. Spur gears
2. Helical gears
3. Bevel gears
4. Worm gears

2.6 NOMENCLATURE OF A GEAR





1. **Pitch circle**
   It is the imaginary circle of gear that roll without slipping over the pitch circle of its mating gear. The diameter of this circle is the most predominant parameter for the design
2. **Gear centre**
   It is the centre of the pitch circle.
3. **Addendum circle**
   This circle coincides with the crests (or) tops of teeth and diameter of this circle is maximum diameter of gear.
4. **Dedendum circle**
   This circle coincides with the roots (or) bottoms of the teeth and the diameter of this circle is the minimum diameter of gear.
5. **Point of contact**
   It is a point at which two profiles touch each other. it is also called pitch point.
6. **Pressure angle**
   It is the angle made by the line of action with common tangent to the pitch circle of mating gears. For involute system of gears the pressure angle is constant and it may be $14\frac{1}{2}°$ (or) 20°
7. **Module (m)**
   It is the ratio of pitch circle diameter to the no of teeth.
   i.e. m = d/z
   d = pitch circle diameter.
   z = No of teeth.
8. **Circular pitch**
   It is the distance along the pitch circle between corresponding points of adjacent teeth.
   $P_c = \pi\ p/z$
9. **Diameteral pitch**
   This is the ratio of the number of teeth on the gear to the unit length of diameter of the pitch circle. This is the reverse ratio of module.
   $P_d = z/d = 1/m$
10. **Addendum**
    It is the radial distance between the tip circle and pitch circle. Usually addendum value may be taken equal to one module.
11. **Dedendum**
    It is the radial distance between pitch circle and root circle.

MATERIAL

1. Cast iron
2. Alloy steel
3. Carbon steel,Alloy steels with Mn.

DESGIN PROCEDURE

STEP-1

From the statement of problem note down the power to be transmitted, pinion speed, gear ratio etc.

STEP-2

Select the material, usually pinion is subjected to more loading cycles than gear and hence the material selected for pinion should be stronger than gear material. **(PSG 8.4 or 8.5)**

STEP-3

Note the design surface compressive stress and bending stress for the selected material from **(PSG 8.5)** or using formula **(PSG 8.16)**

STEP-4

Determine the minimum centre distance required for the gear drive **(PSG 8.13)**

STEP-5

Based on the beam strength or bending stress determine the minimum module

(PSG 8.13a)

STEP-6

After calculating minimum module, select the next standard module **(PSG 8.2)**

STEP-7

Correct the number of teeth on pinion **(PSG 8.22)**

STEP-8

Find out the pitch circle diameter for pinion and gear.

STEP-9

Correct the centre distance. **(PSG 8.22)**

STEP-10

Find out the face width $b=\psi a$ (or) $b= \psi_m .m$

STEP-11

Calculate the pitch line velocity and find out actual torque transmitted **(PSG 8.15)**

STEP-12

Determine the induced surface compressive stress and bending stress from **(PSG 8.13)**

STEP-13

Evaluate other parameters.

Example. Design a pair of spur gears to transmit 20 kW at a pinion speed of 1400 rpm. The transmission ratio is 4 assume suitable material and stress.

Given

Power to be transmitted P=20 kW = 20,000 W

Pinion speed n_1=1400 rpm

Gear ratio i= 4

Gear speed $n_2=n_1/i$ = 1400 / 4 = 350 rpm.

STEP-1-MATERIAL SELECTION

From **(PSG 8.5)**select the following

	Material	Design surface stress(N/mm^2)	Bending stress(N/mm^2)
Pinion	15Ni2 Cr Mo 15	950	320
Gear	C45	500	150

STEP-2-MINIMUM CENTRE DISTANCE

Minimum centre distance based on the surface compressive strength

$$a \geq (i+1)\left[\left\{\frac{0.74}{[\sigma_c]}\right\}^2 \frac{E[M_t]}{i\psi}\right]^{1/3}$$ **(PSG 8.13)**

E=young's modulus = $2.1\text{x}10^5$N/mm^2 **(PSG 8.14)**

σ_c= 500 N/mm^2 (Minimum value)

i= 4

ψ = b/ a = 0.3 (assumed) **(PSG 8.14) table 10**

Design twisting moment $[M_t] = M_t.k.k_d$ **(PSG 8.15)**

$$M_t = \frac{60.p}{2\pi.n_1} = \frac{60x20000}{2\pi x1400} = 136.4 \text{ N-m} = 136.4 \text{ x } 10^3 \text{ N-mm}$$

$[M_t] = 136.4\text{x}10^3\text{x}1.3 = 177.3\text{x}10^3$ N-mm

$$a \geq (4+1)\left[\left\{\frac{0.74}{500}\right\}^2 \frac{2.15x10^5 x177.3x10^3}{4x0.3}\right]^{1/3} = 206 \text{ mm.}$$

STEP-3-MINIMUM MODULE

$$m \geq 1.26\left[\frac{[M_t]}{[\sigma_b]\psi_m Z_1 y}\right]^{1/3}$$ **(PSG 8.13a)**

$[M_t]$ = 177.3 x 10^3 N-mm

$[\sigma_b]$ = 140 N/mm^2(minimum value)

Ψ_m=b/m = 10 (assumed) **(PSG 8.14)**

Z_1=20 (assumed)

y = 0.389 (corresponding to z_1=20) **(PSG 8.18)**

$$m \geq 1.26\left[\frac{177.3X10^3}{140X10X20X0.389}\right]^{1/3} \geq 3.2\ mm$$

Next standard module m= 4 mm **(PSG 8.2)**

STEP-4-CORRECT THE NUMBER OF TEETH

Number of teeth on pinion $z_1 = \frac{2a}{m(i+1)}$ = 2x206/ 4(4+1) = 20.6 ≈ 22 **(PSG 8.22)**

z_2=i x z_1 = 4 x 22 = 88 teeth

STEP-5-PITCH CIRCLE DIAMETERS **(PSG 8.22)**

Pitch circle diameter of pinion d_1= mz_1=4x22 = 88 mm

Pitch circle diameter of gear d_2=mz_2=4x88= 352 mm

STEP-6-CORRECTED CENTRE DISTANCE

$a = \frac{d_1+d_2}{2} = \frac{88+352}{2}$ = 220 mm **(PSG 8.22)**

STEP-7-FACE WIDTH

Face width b = ψa = 0.3 x220 = 66mmOrb = ψ_mm = 10x 4 = 40 mm

take higher value = 66 mm.

STEP-8-ACTUAL TORQUE TRANSMITTED

The actual values of load concentration factor (k) and dynamic load factor (k_d) are found out as follows

Now b/d_1=66/88=0.75

The corresponding value of k =1.05 **(PSG 8.15)**

Pitch line velocity 'v' = $\frac{\pi d_1 n_1}{60x1000} = \frac{\pi x88x1400}{60x1000}$ = 6.45 m/s

The corresponding value k_d=1.4 for HB > 350 **(PSG 8.16)**

Actual design torque $[M_t] = M_t x k x k_d = 136.4 \text{ x } 10^3 x1.05x1.4 = 200.5x10^3$ N-mm

STEP-9-CHECKING STRESSES

The induced compressive stress

$$\sigma_c = 0.74\left\{\frac{i+1}{a}\right\}\left[\frac{(i+1)}{i.b}E[M_t]\right]^{1/2}$$ **(PSG 8.16)**

$$= 0.74\left\{\frac{4+1}{220}\right\}\left[\frac{(4+1)}{4x66}2.15x10^5x200.5x10^5\right]^{1/2}$$ =480 N/mm²< 500 N/mm²

The induced bending stress

$$\sigma_b = \frac{(i+1)[M_t]}{a.m.b.y} = \frac{(4+1)x200.5x10^3}{220x4x66x0.402}$$ =43 N/mm²< $[\sigma_b]$=500 N/mm² **(PSG 8.13)**

y = Form factor corresponding to z_1=22

since the σ_c and $\sigma_b$are less than the allowable value, our design is safe.

STEP-10-OTHER PARAMETERS OF GEAR DRIVE

Addendum (h_a) = f_om = 1x4 = 4 mm **(PSG 8.22)**

Dedendum (h_f) = (f_o+c) m = (1+0.25)4 = 5 mm

Tip circle diameter of pinion d_{a1} = pitch circle diameter of pinion + z_1x addendum

d_{a1}= d_1+2xh_a =88+2x4 = 96 mm

Tip circle diameter of gear d_{a1} = pitch circle diameter of gear+ z_2x addendum

$$d_{a2} = d_2 + 2 x h_a = 352 + 2x4 = 360 \text{ mm}$$

Root circle diameter of pinion = pitch circle diameter of pinion – 2 x Dedendum

$$d_{f1} = d_1 - 2 x h_f = 88 - 2x5 = 78 \text{ mm}$$

Root circle diameter of gear = pitch circle diameter of gear – 2 x Dedendum

$$d_{f2} = d_2 - 2 x h_f = 352 - 2x5 = 342 \text{ mm}$$

Two mark questions

1. Mention a few gear materials.

Metallic gears – steel, cast iron

Non-Metallic gears – wood, compressed paper & synthetic resins

2. State an advantage and disadvantage of helical gear.

Advantage: Produce less noise than spur gears

Dis Advantage: Subjected to axial thrust loads

3. Why is tangential component of gear tooth force called useful component?

Because it transmits power.

4. Compare the contact between mating teeth of spur and helical gears.

i) In spur gears the line of contact is parallel to the axis of rotation. The total length of contact line is equal to the face width.

ii) In helical gears the line of contact is diagonal across the face of the tooth. The total length of contact line is greater than the face width. This lowers the unit loading & increases load carrying capacity.

5. What is backlash in gears?

It is the difference between the tooth space and the tooth thickness along the pitch circle.

6. What is the advantage of helical gear over spur gear?

i) Helical gears produce less noise than spur gears.

ii) Helical gears have a greater load capacity than equivalent spur gears.

7. Why is a gear tooth subjected to dynamic loading?

Inaccuracies of tooth spacing, Irregularities in tooth profiles, Misalignment between bearings.

8. State the law of gearing or conditions of correct gearing.

It states that for obtaining a constant velocity ratio, at any instant of teeth the common normal at each of contact should always pass through a pitch point, situated on the line joining the centres of rotation of the pair of mating parts.

9. What are the commonly used gear tooth profiles?

Involute &Cycloidal

10. State about herring bone gear.

The double helical gears connecting two parallel shafts are known as herringbone gears. They are used in heavy machinery and gear boxes.

11. State the law of gearing (Au may 06)

The law of gearing states that for obtaining a constant velocity ratio, at any instant of teeth the common normal at each of contact should always pass through a pitch point, situated on the line joining the centers of rotation of the pair of mating gears.

12. Why is pinion made harder than gear?

Because the teeth of pinion undergo more number of cycles than those of gear and hence quicker wear.

13. What are the main types of gear tooth failure?

a. Tooth breakage

b. Tooth wear: i. Abrasion ii. Pitting iii. Seizure

14. Why is a gear tooth subjected to dynamic loading?

In a gear tooth, dynamic loads are due to the following reasons:

a. Inaccuracies of tooth spacing

b. Elasticity of parts

c. Deflection of teeth under load

d. Dynamic unbalance of rotation masses.

15. What is virtual number of teeth in helical gears?may -07

The number of teeth on the virtual spur gear in the normal plane is known as virtual number of teeth.

16. What are the spiral gears? Why hands of helix are used?

A pair of crossed helical gears is known as spiral gears.

In most applications, the spiral gears have the same hand.

17. Differentiate double helical and herringbone gears.

When there is groove in between the gears, then the gears are specifically known as double helical gears.

When there is no groove in between the gears, then the gears is known as herringbone gears.

18. What are the advantages of helical gears over spur gears?

Less noisy, stronger than spur gears, can run at greater speeds than spur gears.

19. Why dedendum value is more than addendum value?

To provide necessary clearance between the gears while meshing. In other words, this is to provide necessary clearance between the gears while meshing.

20. Define module. [AU MAY-10]

It is the ratio of the pitch circle diameter to the number of teeth.

Ex.Design a spur gear drive to transmit 22 kW at 900 rpm.Speed reduction is 2.5 materials for pinion and wheel are C15 steel and cast iron grade 30 respectively. Take pressure angle of 20° and working life of the gears as 10,000 hours.

Ex.Design a spur gear pair to transmit 1.5kW at 1440 rpm from an electric motor to an air compressor running at 720 rpm. Take the working life as 10,000 Hrs. Materials to be used is cast iron grade 25 for both pinion and wheel. [Nov/Dec 2010]

Ex.Design a spur gear drive required to transmit 45 Kw at pinion speed of 800 rpm. The velocity ratio 3.5:1. The teeth are 20 full depths involute with 18 teeth on the pinion. Both the pinion gear are made of steel with a maximum safe static stress of 180N/mm^2

Ex.Design a straight spur gear drive to transmit 8 kW. The pinion speed is 720 rpm and the speed ratio is 2. Both the gears are made of the same surface hardened carbon steel with 55RC and core hardness less than 350 BHN. Ultimate strength is 720 N/mm^2 and yield strength is 360 N/ mm^2

PROBLEMS FROM ANNA UNIVERSITY EXAMS

Referring to fig spur gear A receives 3 kW at 600 rev/min through its shaft and rotates clockwise. Gear B is an idler and gear C is the driven gear. The teeth are 20^0 full depth.

Determine

(i) the torque each shaft must transmit
(ii) the tooth load for which each gear must be designed
(iii) the force applied to the idler shaft as a result of the gear tooth loads. [Nov/Dec 2010]

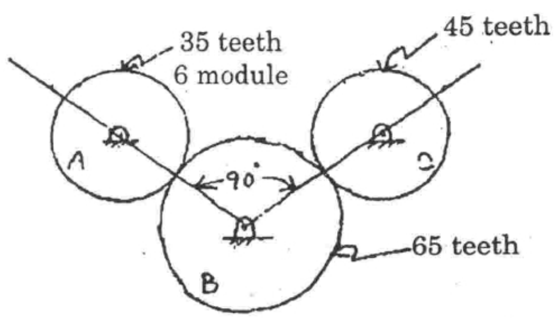


Fig. 1

An electric motor is to be connected to a reciprocating pump through a gear pair. The gears are overhanging in their shafts. Motor speed=1440 rpm. Speed reduction ratio =5.Motor power=36.8kW.The gears are to have 20^0 pressure angle. Design a spur gear drive.[April/may2010]

A motor shaft rotating at 1500 rpm has to transmit 15 kW to a low speed shaft with a speed reduction of 3:1.Assume starting torque to be 25% higher than the running torque.The teeth are 20^0. Involute with 25 teeth on the pinion. Both the pinion and gear are made of C45 Steel.Design a spur gear drive to suit the above conditions and check for compressive and bending stresses and plastic deformation. Also sketch the spur gear drive. [April/may2008]

In a spur gear drive for a rock crusher, the gears are made of case hardened alloy steel.The pinion is transmitting 18 kW at 1200 rpm with a gear ratio of 3.5.The gear is to work 8 hours/day for 3 years. Design the drive's major dimensions, check for compressive and bending stresses and sketch arrangement [April/may2009]

Design a spur gear drive to transmit 15 kW at 900 rpm of forged steel pinion 120 mm diameter to a cast steel gear to run at 300 rpm.Take pressure angle of 20^0 and working life of gears as 10000hrs. [April/may2012]

A motor shaft running at 1440 rpm has to transmit 15 kW to a low speed shaft rotatinng at 500 rpm.The teeth are 20^0 involute with 25 teeth on the pinion.Both the pinion and gear are made of cast iron with a maximum safe stress of 56 Mpa.A safe stress of 35 Mpa may be taken for the shaft on which the gear is mounted.Design and sketch the spur gear drive to suit the above condidtions.The strating torque may be assumed as 1.25 times the running torque. [April/may2009]

A 27.5 kW power is transmitted at 450 rpm to a shaft running at approximately 112 rpm through a spur gear drive.The load is steady and continuous. Design the gear drive and check the design.Assume the following materials:Pinion-heat treated cast steel;gear-high grade cast iron. [April/may2010]

Design a spur gear drive to transmit 10 kW at 1440 rpm, speed reduction is 3.Take pressure angle as 20^0 and working life of gears as 15,000 hrs. Assume the materials for pinion and wheel as heat treated steel and high grade cast iron respectively. [Nov/Dec2012]

Design and draw spur gear drive transmitting 30 kW at 400 rpm to another shaft running approximately at 1000 rpm. The load is steady and continuous. The materials for the pinion is cast steel and for gear is cast iron. Take module as 10 mm. also check the design for dynamic load and wear. [May/june2014]

Design a straight spur gear drive. Transmitted power 8 kW. Pinion speed 764 rpm. Speed ratio is 2.The gears are to be made of C45 Steel. Life is to be 10,000 hours. [AU, M/J 2013]

Design a pair of straight gears to transmit 12 kW at 1500 rpm. Speed reduction required is 4. Check for compressive and bending stresses. Also check for plastic deformation of teeth. Make a schematic diagram and show the results neatly. [AU, N/D 2012]

Design a spur gear drive for a heavy machine tool with moderate shocks. The pinion is transmitting 18 kW at 1200 rpm with a gear ratio of 3.5. Design the drive and check for elastic stresses and plastic deformation. Make a sketch and label important dimensions carried. [AU, M/J 2012]

In a spur gear drive for a stone crusher, the gears are made of C40 steel. The pinion is transmitting20 kW at 1200 rpm. The gear ratio is 3. Gear is to work 8 hours per day, six hours a week and for 3years. Design the drive. [AU, M/J 2011]

A motor shaft rotating at 1500 rpm has to transmit 15 kW to a low speed shaft with a speedreduction of 3:1. The teeth are 20° involute with 25 teeth on the pinion. Both the pinion and gear aremade of steel with a maximum safe stress of 200 N/mm^2. A safe stress of 40 N/mm^2 may be taken forthe shaft on which the gear is mounted and also for the key. Design a spur gear drive to suit the aboveconditions. Assume starting torque to be 25% higher than the running torque. [AU, N/D 2011]