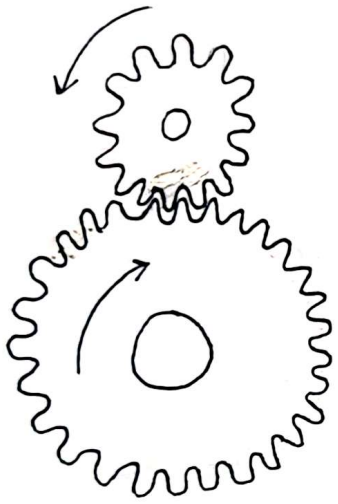
GEARS

ROLLING CONTACT IS A CONVENIENT WAY TO TRANSFER MOTION FROM ONE ROTATING PART TO ANOTHER. **GEAR SETS** ARE MACHINES THAT USE ROLLING CONTACT TO TRANSFER MOTION FROM ONE ROTATING PART TO ANOTHER.

- THE SMALLER OF TWO MATING GEARS IS CALLED THE **PINION**
- THE LARGER IS OFTEN CALLED THE **GEAR**.



SPUR GEARS

THERE ARE FOUR MAJOR GEAR TYPES:

- **SPUR GEARS** HAVE TEETH PARALLEL TO THE AXIS OF ROTATION AND ARE USED TO TRANSMIT MOTION BETWEEN PARALLEL SHAFTS.
- **HELICAL GEARS** HAVE TEETH INCLINED TO THE AXIS OF ROTATION AND CAN BE USED TO TRANSMIT MOTION BETWEEN PARALLEL AND NON PARALLEL SHAFTS.
- **BEVEL GEARS** HAVE TEETH FORMED ON CONICAL SURFACES AND ARE LARGELY USED TO TRANSMIT MOTION BETWEEN INTERSECTING SHAFTS
- **WORM GEARSETS** ARE COMPRISED OF A WORM, WHICH RESEMBLES A SCREW, AND A WORM GEAR. THEY ARE USED TO TRANSMIT MOTION BETWEEN NONPARALLEL AND NON INTERSECTING SHAFTS.

WHEN TWO GEARS ARE IN MESH, THEY ROLL ON ONE ANOTHER WITHOUT SLIPPING. IF WE DESIGNATE THE PITCH RADII OF THE INPUT AND OUTPUT GEARS AS r_{in} AND r_{out} RESPECTIVELY, THEN WE CAN DEFINE THE **ANGULAR VELOCITY RATIO** AS:

$$m_V = \pm \frac{r_{in}}{r_{out}} = \frac{\omega_{out}}{\omega_{in}}$$

THE TORQUE RATIO IS THE INVERSE OF THE ANGULAR VELOCITY RATIO:

$$m_T = \frac{1}{m_V} = \frac{\omega_{in}}{\omega_{out}} = \pm \frac{r_{out}}{r_{in}}$$

THE **GEAR RATIO** IS THE MAGNITUDE OF EITHER m_v OR m_T

- THE GEAR RATIO IS USUALLY POSITIVE
- THE GEAR RATIO IS USUALLY GREATER THAN 1.
- THE GEAR RATIO MAY BE EXPRESSED AS AN INTEGER OR AS A RATIO.

A GEAR SET IS **PRIME** WHEN THE NUMBER OF TEETH ON EACH MESHING GEAR HAVE NO COMMON FACTOR EXCEPT 1. THIS IS A DESIRABLE CONDITION AS ALL TEETH THEN TEND TO WEAR EVENLY.

SPUR GEAR TERMS

TERMINOLOGY FOR SPUR GEARS IS ILLUSTRATED IN FIGURE 13-5 IN SHIGLEY.

- THE **PITCH CIRCLE** IS A THEORETICAL CIRCLE USED FOR CALCULATIONS.
- THE **PITCH DIAMETER** (d) IS THE DIAMETER OF THE PITCH CIRCLE.
- THE **PITCH-LINE VELOCITY** (V) IS TANGENT TO THE PITCH CIRCLES AND HAS MAGNITUDE: $V = |\omega_{PINION} r_{PINION}| = |\omega_{GEAR} r_{GEAR}|$
- THE **CIRCULAR PITCH** (p) IS THE DISTANCE MEASURED ALONG THE PITCH CIRCLE FROM A POINT ON ONE TOOTH TO THE CORRESPONDING POINT ON THE ADJACENT TOOTH.
  - ↳ IT IS THE SUM OF THE **TOOTH THICKNESS** AND THE **WIDTH OF SPACE**.

$$p = \frac{\pi d}{N}$$

WHERE N IS THE NUMBER OF TEETH ON THE GEAR.

- THE **DIAMETRAL PITCH** (P) IS THE RATIO OF THE GEAR'S NUMBER OF TEETH TO THE PITCH DIAMETER. (ONLY USED IN THE U.S.)

$$P = \frac{N}{d} = \frac{\pi}{p} \quad [\text{TEETH PER INCH (TPI)}]$$

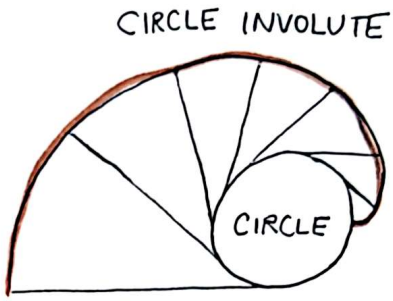
- THE **MODULE** (m) IS THE RECIPROCAL OF P, AND IS ONLY USED IN SI UNITS.

$$m = \frac{d}{N} = \frac{p}{\pi} \quad [\text{mm}]$$

GEAR TOOTH PROFILES

GEAR TOOTH PROFILES ARE ALMOST EXCLUSIVELY **INVOLUTES** OF A CIRCLE.

- THE INVOLUTE OF A CIRCLE IS THE SPIRALING CURVE TRACED BY THE END OF AN IMAGINARY TAUT STRING UNWINDING ITSELF FROM THE BASE CIRCLE.

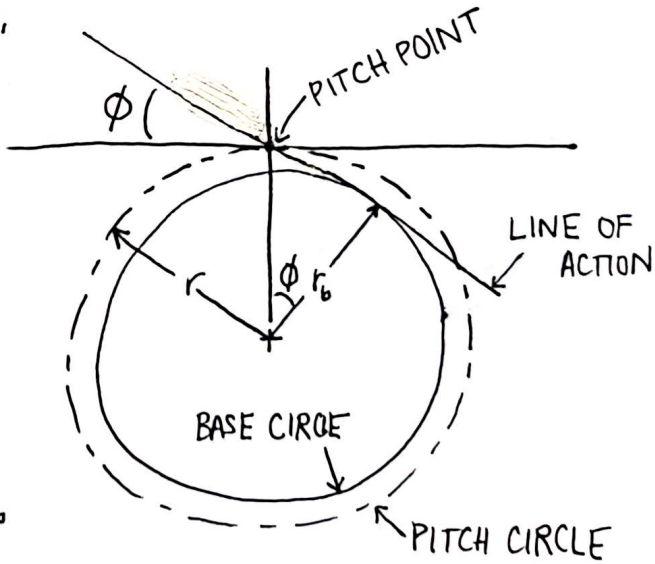


AS A GEARSET ROTATES, THE CURVED SURFACE OF A PINION TOOTH PRESSES AGAINST THE CURVED SURFACE OF A GEAR TOOTH.

- THE POINT OF CONTACT IS WHERE THE TWO SURFACES ARE TANGENT TO EACH OTHER.
- THE CONTACT FORCE IS TANGENT TO BOTH TOOTH SURFACES.

THE CONTACT FORCE ACTS ALONG THE **LINE OF ACTION**.

- FOR INVOLUTE GEAR TOOTH GEOMETRY, THE LINE OF ACTION IS ALSO TANGENT TO THE BASE CIRCLES OF THE PINION AND OF THE GEAR
- THE **PRESSURE ANGLE** (ϕ) IS THE ANGLE BETWEEN THE LINE OF ACTION AND THE DIRECTION OF THE PITCH-LINE VELOCITY.
  - STANDARD VALUES ARE $\phi = 20°$ AND $\phi = 25°$
  - THE OLD STANDARD WAS $\phi = 14.5°$



$$r_{bi} = r_i \cos\phi \qquad i = 1, 2$$

WHERE r_{bi} IS THE BASE RADIUS OF GEAR i, AND
r_i IS THE PITCH RADIUS OF GEAR i

MESH CONSIDERATIONS

THE RELATIVE MOTION BETWEEN TWO GEARS IN MESH IS:

- PURE ROLLING WHEN THE CONTACT POINT IS THE PITCH POINT
- A COMBINATION OF ROLLING AND SLIDING WHEN THE CONTACT POINT IS NOT THE PITCH POINT.

THE CONTACT RATIO (m_c) IS THE AVERAGE NUMBER OF PAIRS OF TEETH IN CONTACT.

- CONTINUOUS MOTION TRANSFER REQUIRES TWO PAIRS OF TEETH IN CONTACT AS THE MESH MOVES FROM ONE PAIR OF TEETH TO THE NEXT.
- GEARS SHOULD NOT TYPICALLY BE DESIGNED WITH $m_c < 1.2$
- THE CONTACT RATIO IS CALCULATED FROM THE LENGTH OF THE LINE OF ACTION BETWEEN THE ADDENDA CIRCLES OF THE PINION AND GEAR (L_{ab}):

$$m_c = \frac{L_{ab}}{p\cos\phi}$$

BACKLASH IS THE DIFFERENCE BETWEEN THE TOOTH THICKNESS AND THE WIDTH OF SPACE.

- A SMALL AMOUNT OF BACKLASH IS REQUIRED TO PREVENT GEARS BINDING.
- TOO MUCH BACKLASH CAN BE PROBLEMATIC, PARTICULARLY IF THE PINION ROTATION REVERSES.

INTERFERENCE OCCURS WHEN THE TOOTH PROFILES OF MESHING GEARS ARE NOT CONJUGATES.

- CONTACT OCCURS IN THE NONINVOLUTE PORTION OF THE GEAR TOOTH.

INTERFERENCE CAN BE CORRECTED BY UNDERCUTTING THE GEAR TEETH.

- A CUTTING TOOL CAN REMOVE INTERFERING PORTIONS OF THE TEETH.
- THIS WEAKENS THE TEETH.