CEP Machine Design

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**GEARS**

**Chapter 1**

Gear reducers, in industries, reduce speed and increase torque. Found in electric motors, elevators and conveyor mills. Industrial gearbox is a machine, in which we need reliable life and factor of safety, and pitch line velocity limited to 25m/s.

Two types of gears are used, helical (spiral) and spur (straight). spur gears are easy to manufacture and inspect and can be rectified easily. Only disadvantage is tooth engagement is more in spur gears. Spur gears have pitch line velocity below 10m/s whereas helical have above 10 m/s. but spur gears are required to slide axially and helical gears are used where noise is to be kept minimum. Disadvantage of helical is that axial thrust is more when working.

Bevel gears are used when drives are 90 degrees, straight and spiral depending on applications.

**Torque selection:**

1. type, power and speed selection
2. overall ratio of gearbox
3. type of gears, spiral or straight.
4. Applications
5. Outside load requirements
6. Fatigue failure

The nominal torque at output is calculated using absorbed torque or from gear box ratio if absorbed torque is unknown. 3 points to remember

1. Brake should be positioned before gearbox, as unit is sized on brake torque for emergency braking.
2. Some machines take full torque load startup and frequent occurrences of stop/be start switching can be sized accordingly
3. Rigid type couplings can transmit shock easily to gear box than flexible gear couplings, and gears are designed such.

To select basic size, nominal torque is multiplied by service factor. As motors run at different speeds and power, the maximum torque is selected on equivalent life to suit duty cycles and maximum speed is selected on pitch line velocities.

**Materials:**

Gears must be strong to prevent tooth breakage. Ductile to resist shocks and fatigue and strong enough to resist stresses on shaft. Stepped forging is easy and economical. Cast steel should be of good quality.

**Through hardened:**

The material is heat treated before machining is carried out. This avoids heat treatment distortion, but since it has to be machined, there is a limit on hardness and strength.

**Flame/Induction Hardened:**

Gear teeth are cut into gear blank and then surface hardened. Depth hardening can make the whole tooth brittle, and slightly allowable bending stress is used for calculating the strength of tooth, around 80% to root is allowed. Hardened gears can be left unground but because of distortion a certain amount of hand dressing of the teeth can be required to mesh with its mate. Full contour hardening hardens flank and root of teeth. Avoids abrupt finish of residual stress.

**Nitride:**

Low temperature hardening process, hence distortion is kept low. Main disadvantage is time consuming around 80 hours, and case depth obtained is only 0.6mm. hence not suitable for heavily loaded teeth. But is very strong and can give best hardness i.e. 68 HRC.

But no machining is required except grinding. Everything should be done before holes, keyways etc. and then stress relieved after roughing out.

**Case carburized and hardened:**

Steel is low carbon alloy, subjected to high carbon after cutting. Carbon is allowed to soak into the skin and gear is hardened, quenched and tempered. Up to 60HRC is obtained and because of high temperature and long soak times, carburized gears suffer distortion unless controlled, and sections should be left heavy and symmetrical to minimize distortion. Teeth are then cut out leaving grinding allowance and then sent for carburizing and annealing and return the unwanted carbon from soft shaft is machined.

Alternative is to mask the areas using copper paint. Disadvantage is that small scratch can let carbon seep in and cause trouble at final machining. While threads aren’t carburized as they become brittled. They are then carburized and hardened in one go and component has to be ground over and then complete.

**Chapter 2**

**Gear mesh**

Single step ratio is calculated for overall ratio of gearbox. Higher ratio at high speed end.

Tooth pitch combinations:

The number of teeth for pinion depends on number of factors, including duty, speeds and hardness. Higher the speed or smaller the ratio, greater number of teeth in pinion.

Hunting tooth is when extra tooth is added or subtracted to avoid exact ratio for the purpose of same alignment and contacting exact pinion tooth revolution which is bad for even wear pattern. But disadvantage is if one pinion or gear has any error, it would magnify the error and can double fatigue at that point.

Contact ratio should be 1.2 and smooth with spiral angle of 35.

**Face width:**

Face width of pinion should be kept to a minimum to avoid bending and twisting. Wide enough to give sufficient overlap. Maximum ratio of face-width to pinion diameter should be around 1/1.3. pinions should be wider than wheels. For bevel gears, both pinion and gear should have same width up to max of 0.3 times than outer cone.

There is a difference between allowable powers based on strength and wear, and so pitch/tooth combination is changed. Increasing the numbers of teeth and making pitch smaller, lowers the strength but doesn’t increase wear.

**Details of gears:**

Positive correction is applied to gears,

1. To increase the bending strength of a tooth
2. To increase the diameter to enable bigger bearing
3. Fit a design center distance.
4. To benefit recess action of mating gears

Contact geometry is important. Backlash must be cut into industrial gears for 2 reasons, 1st to cater any errors and 2nd to allow for any dimensional changes due to temperature. For torque and rotation changing gears, backlash must be kept minimum while reverse for unidirectional gears. The bore must be kept below 70%, and increased due to machining and bearing tolerances, to keep eye from affecting root teeth stresses. If shrink drive is used then hoop stress should be taken into account and it is usual to allow bending stresses to 80%.

Double helical gears can be created by putting 2 single helical back to back., but only good for unidirectional gears otherwise thrust will be more.

Bevel gears should have minimum of 2 full tooth depths under teeth to give sufficient strength and support. And radial and axial surfaces must be machined before cutting for inspection.

Gears of 750mm diameter are manufactured from solid forging while above the size it is casted, welded or shrinked fit. Welding is carried out with low hydrogen welding rods and components are kept at 250C.

Alternative is buttering a low carbon weld metal to alloy rim and welding the center to weld at reduced temperature. But this requires machining and are removed.

Large gears are cast and statically balanced. If gears are ground after cutting then teeth are cut with perfect cutters. And grinding them blends 2 together without touching the root. But otherwise step will be developed. And so, grinding into the root is necessary making bending strength no better than core and create stress raiser.