Gearbox Design Ratings

Gearbox design ratings
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When a single screw extruder gearbox reduces motor speed to screw speed, it experiences generated gear forces as well as screw end pressure thrusting, and possible twisting and bending screw forces on the driveshaft. The reducer is designed and sized accordingly using industry standards.

A twin screw gearbox, in addition to the above, distributes torque to both shafts in proportion to the relative rotational resistance of each screw. Also, unlike a single screw gearbox, the close spacing of the two shafts restricts the amount of allowable torque that can be transmitted to the screws. Numerous gear train design schemes are used to compensate for this limitation.

The extrusion process emphasis is on power requirements, but it is the torque, or resistance to rotation, that determines the design and limitations of the gearboxes and other drive components.

Transmitting torque by meshing of the gearteeth generates forces that act on the rotating shafts and then through the supporting bearings into the housing. The bearings, while resisting these forces, maintain the shafts in close alignment within the gearbox.

Alignment of the extruder screw within the barrel begins at the gearbox when the barrel assembly is centered on the gearbox housing and the screw is centered on the driveshaft. If the screws are rigidly coupled to the drive shafts, the gearbox bearings on the output shaft provide a cantilevered sup port for the screw. Any bending or twisting caused by forces acting between the barrel and screws is transmitted back into the shafts and bearings.

Although the gear forces themselves are constant in magnitude and direction, as long as the torque is constant, the surfaces on which they act are constantly changing be cause of shaft rotation. At any given point the loads are therefore cyclic and can impose fatigue type failures on critical components in the gearbox such as the gears, bearings and shafts. It is prevention of these failures that is used to design and establish a load rating.

Meshing gears generate equal and opposite forces at the point of contact. These include a tangential force, a radial separating force which acts toward the center of each gear and, if a helical gear, axial forces that may add to or subtract from the screw end pressure thrust on the output shafts.

There are four fatigue failure criteria to be evaluated:

l) Contact stress on the gear tooth surface. This is called gear durability and is expressed in horsepower.
2) Bending stress on the root of the geartooth. This is called the gear strength rating and is expressed in horsepower.
3) Contact stress on the bearing raceway and roller surfaces. This is expressed by L-10 life in hours.
4) Bending stress on the shaft. It is usually a maximum at a bearing shoulder and should be less than the endurance stress established for the shaft material.

Although expressed in different terms, gear durability and bearing fatigue life are the same type of stress failure mechanism in which cracks develop at subsurface defects and propagate below the surface at the point of maximum shear stress. The intersection of several cracks can result in loss of surface material known as pitting or spalling.

Besides being subject to bending fatigue stress, a drive shaft must withstand torsional shear stresses which act in combination with the bending stress to increase the total stress, which is a maximum on an outside surface. Abrupt changes in geometry greatly in crease its magnitude. The shear stress is a constant and should be less than half the yield strength of the shaft material.

The gear industry (AGMA) has established gear durability and strength rating formulas to calculate allowable horsepower at given operating speed. These formulas include stress levels for the material and heat treat, pitch diameter, face width, tooth profile geometry, finish, misalignment and dynamic load factors, life cycle derating, and service factors. The designer is given a degree of flexibility in establishing the ratings since it is recognized that a gear made from certified material and heat treat, and inspected thoroughly after manufacture, should have a higher rating than one that is not.

Likewise, the bearing fatigue life rating in hours is not very precise and can have a considerable amount of interpretation. The L-10 rating indicates a 10 percent probability of fatigue failure after a given number of hours of operation at a specified load and speed.

The preceding design ratings all assume that the gearbox is adequately lubricated with the right oil, the temperature is controlled, no contaminants are present and it has been assembled correctly. If these conditions do not exist, the gearbox cannot be expected to have the durability intended despite what the ratings indicate. On the other hand, a box that is well maintained should be expected to perform reliably for many years and may exceed the ratings established for it.

— Tom Crouch

See also:

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- Gearcase maintenance
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