A General Overview on Common Causes of Breakdown in Planetary Gearbox

Parag Vyankatrao Thote
AS Engineering, Pune (MH), India.

Ashish Thorat
AS Engineering, Pune (MH), India.

Prashant Nimbalkar
AS Engineering, Pune (MH), India.

Abstract – Gearbox is heart of all the transmission based equipment. Planetary gearbox are able to provide higher speed reduction ratio and torque in a small package, have operating characteristics beyond those of fixed-axis gear trains. Whenever breakdown of any equipment happens, it is important to analyzing root cause analysis of problem. Until and unless the exact cause of failure can be define, development of new product in order to reduce existing problems is not possible. There are varieties of problem contributing for damages of planetary gearboxes. In this paper an attempt is made to elaborate knowledge of common causes for Planetary gearbox failure and their probable causes, also primary methods to avoid such problems are discussed.

Index Terms – Planetary Gearbox, types of gearbox failures, Service factor, Remedies

1. INTRODUCTION

Planetary gearing, with its inherent in-line shafting and cylindrical casing, is often recognized as the compact alternative to standard pinion and gear reducers. Being suited for a wide range of applications from electric screwdrivers to bulldozer power trains, these units are strong contenders when space and weight versus reduction and torque are chief concerns.

The planetary gear train is a core component of the automatic transmission system. The ability of the planetary gear train to deliver reliable gains in power, durability, higher torque-to-weight ratios, and configuration flexibility has enabled this gear set to become a key component of the automotive power train.

The most basic form of planetary gearing involves three sets of gears with different degrees of freedom. Planet gears rotate around axes that revolve around a sun gear, which spins in place. A ring gear binds the planets on the outside and is completely fixed. The concentricity of the planet grouping with the sun and ring gears means that the torque carries through a straight line. Many power trains are "comfortable" lined up straight, and the absence of offset shafts not only decreases space, it eliminates the need to redirect the power or relocate other components.

Planetary gear sets contain three major components or members. They are;

1. **The Ring Gear** or **Annulus** which has internal teeth and wraps around the entire assembly.
2. **The Sun Gear** is the smallest gear and sits in the center of the assembly. The planetary pinions orbit around the sun gear, hence the name of the gear set.
3. **The Planetary Carrier** which holds a set of Planetary Pinion Gears

- **The arrangement**

The Pinion Gears interact with the Ring Gear and the Sun Gear at the same time. The planetary gear set provides the necessary forward and reverse gear ratios. Some transmissions use more than one planetary gear set. The layout of planetary gears is similar to the solar system, with planet pinion gears orbiting around a sun gear. The ring gear surrounds the entire gear set.

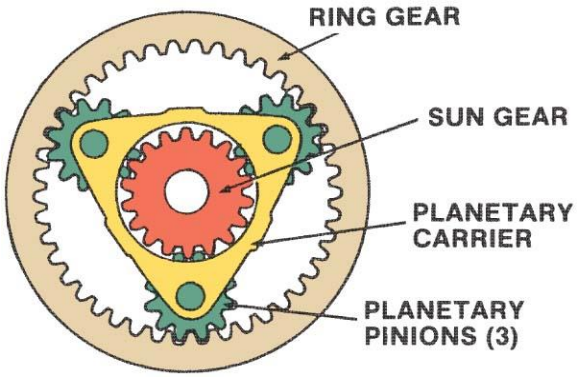

Fig. 01 Planetary gearbox arrangement

Each member of the planetary gear set can spin (revolve) or be held at rest. Any one of the three members can be used as the input or driving member. At the same time, another member may be held at rest or stationary. Depending on which member is the input, which is the output, and which is held, either a torque increase (under-drive) or a speed increase (overdrive) condition will be produced. A reverse direction can also be produced if the planetary carrier is held stationary.

In a simple planetary setup, input power turns the sun gear at high speed. The planets, spaced around the central axis of rotation, mesh with the sun as well as the fixed ring gear, so they are forced to orbit as they roll. All the planets are mounted to a single rotating member, called a cage, arm, or carrier. As the planet carrier turns, it delivers low-speed, high-torque output.

- **Service Factor**

Selection of service factor of planetary gearbox is depends upon working duty cycle of equipment and type of load acted on gearbox. Proper load calculation and duty cycle avoids break down of planetary gearbox.

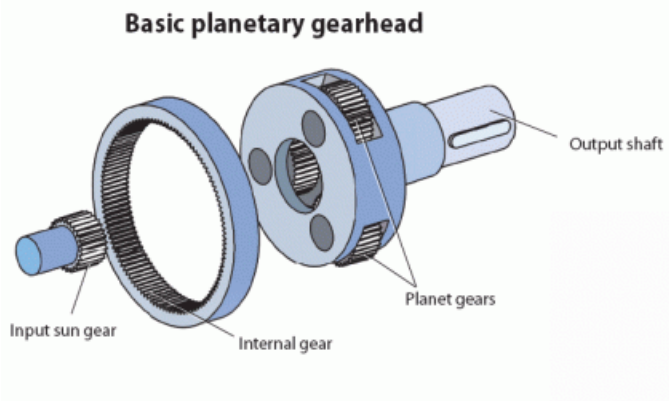

Fig. 02 Exploded view of Planetary gearbox

2. RELATED WORK

As we all know, life of every gearbox is mentioned in the form of number of rotation or number of working hours called rated life. Planetary gearbox are exposed to high speed reduction mostly because of their capability and compact size. Faulty design is not only the reason for gearbox failure, manufacturing and material handling can be one.

While examining failure in Planetary gearbox it is observed that; Improper installation or installation misalignment, overloading, over speeding, improper lubrication or use of wrong grade lubricant, wrong bearing selections can cause failure of gearbox before rated life. Some of the common failures observed in Planetary gearbox failure are mentioned below;

a) Abnormal noise and vibrations in planetary gearbox

In planetary gearbox, noise is usually no worse, and often better than standard gear-and-pinion reducers. Having smaller gears means a lower pitch line velocity than a comparably rated pinion and gear set. However, having a lot of identical planet teeth engaging at the same frequency with each input shaft revolution contributes to noise, especially at very high speeds. And the fact that these meshes occur in a circular orbit can make the situation more complex. Obviously, using spur gears of reasonably high quality couldn't hurt. But helical gears, with their gradual rather than instantaneous tooth engagement, might be better for some operations.

Another noise reduction strategy that has been used involves designing the system so the planets mesh out of phase from one another and thereby provide a canceling effect. Damping the system can also help, as it discourages resonance.

i. Lubrication- Gears and bearing need to properly lubricate for noiseless working.

ii. Overload- Need to lower the load which reduces the noise. If this not working then lager sized gearbox model will be installed.

iii. Improper Installation- Misalignment between prime mover and gearbox creates noise. Other one is improper installation of gearbox which results loose bolts of mounting. Proper alignment and tightening loose bolts reduces noise.

iv. Damaged bearings- Damaged bearings makes abnormal sound. Damaged Bearings may need to replace.

v. Backlash- This is clearance between two matching faces of gear. This clearance contributes abnormal sound, for minimizing need to replace gears.

vi. High input speed- Need to lower the speed of prime mover.

b) Gear Teeth Worn out

As far as lifetime and wear are concerned, in-line planetary systems distribute the load remarkably well among major components, and the economic size is evidence of this. If all the components were of similar quality, yet a potential weak spot had to be singled out, it might be the bearings that support the individual planet gears.

Here space is often very limited, so planet bearings can be small compared to some ordinary gear-and-pinion reducers where there is a lot of leeway for larger bearings. And don't forget, the canceling effect of multiple planets on radial loads

applies only along the central shafting; it is in fact the radial loading on individual planet bearings that drives the carrier around.

Fig. 03 Teeth Worn out

Thermal and cyclic fatigue may be promoted in these bearings by the limited load distribution and the fact that planet gears can spin pretty fast on their axes. What's more, with high speeds and heavy planet gears, centrifugal forces can add significantly to the burden. That is not to say that planet bearings don't often outlast other components clearly, high-grade precision bearings used with low-grade, high-tolerance gears isn't an "all things equal" arrangement.

i. Speed of prime mover- Higher Input speed worn out the teeth. Need to minimize input speed.

ii. Alignment and installation- Non linear alignment of gearbox and prime mover causes teeth wear and tear and also loose installment at mounting of gearbox causes wear and tear.

iii. Load- higher load on gearbox causes tension in gears and this causes wear and tear of gear. For larger load, use large size gearbox.

c) Temperature at gearbox

A planetary gear train running at very high speeds and continuous duty is apt to generate enough heat to justify cooling. With ordinary gear-and-pinion systems, the load often requires quite a large chunk of gearing and surface area, which amounts to an appreciable heat sink. The compactness of planetary units can limit the rate of heat dissipation, and therefore additional measures are sometimes taken; the lubricant may be circulated through a heat exchanger, or a cooling fan is employed. If the operation is continuous, the system has less opportunity to cool than if it runs intermittently, and without sufficient cooling, the speed allowance might need to be lowered. Or, as mentioned, other kinds of speed reducers can be attached ahead of the planetary reducer, although this is an added encumbrance.

The range of speeds for planetary gearing varies widely depending on the application. Often, the size of the gear drive largely affects the speed rating, since a higher pitch line velocity can mean a heat increase far beyond any cooling effect from the larger geometry. Indeed, there are small planetary drives that run at tens of thousands of rpm.

i. Ambient Temperature- If ambient temperature is high it reduces efficiency of gearbox, for minimizing install cooling system for gearbox.

ii. Bearing Mounting- Improper bearing mounting creates temperature, need to reassembly of bearing.

iii. Lubrication- Improper lubrication to gear causes temperature. Advised proper lubrication.

iv. Loads- Higher loads on gearbox create temperature. Lower the load, automatically temperature decreases.

v. Alignment- Improper alignment of prime mover and input shaft of gearbox creates temperature.

d) Breakdown of output shaft

Fig. 04 Output Shaft brake down

i. Sudden machinery crash- Sudden machinery stops but Prime mover still driven gearbox, and at this time due to action and reaction force shaft breakdown is happen.

ii. Improper Installation- This results misalignment of prime mover and gearbox and improper installment of gearbox at mounting. Need to proper align and install gearbox for prevent break down of shaft.

iii. Overloading- If axial and radial loads are too heavy, this causes damage to output shaft. For minimize this load need to minimize.

iv. Perpendicularity- This causes torsional force at bore and cut face of output shaft broken. For minimize this need confirm perpendicularity first and after mount the planetary gearbox.

e) Locking of Gearbox shafts

When the term lockout of gearbox shaft comes into picture, the first part to inspect is bearing. As bearing plays very important role in rotational member supporting system. The shaft is fixed in casing with the help of bearings. Bearing effectiveness will reduce rotational vibrations, noise & thrust. But due to industrial applications of Planetary gearbox there are chances of dust or suspended particles saturation in bearing inner race. This saturation will reduce bearing life and affect transmission capabilities of bearing. Some of the reasons for lockout of gearbox shaft along with possible remedies are given below

i. Gear teeth- worn gear not allow to rotate, need to replace worn gear.

ii. Locked Gear- If any outer material is locked in gear it not allows the shaft to rotate. This foreign material needs to remove for proper rotation of shafts.

iii. Alignment- Alignment of gear should be linear.

iv. Bearing- Damaged and locked bearings not allow shaft to rotate.

v. Lubrication- Proper lubrication rotates the gears and shaft smoothly

Fig. 05 Failure of Bearing (lockout of gearbox shaft)

3. CONCLUSION

The design of planetary gearbox is complicated. When common causes of failure are studied it is observed that, the failure causing factors are generalized i.e. improper lubrication, misalignment of gears or improper loading arrangement, over loading, improper installation, rated lubricating oil, improper selection of bearing. We can avoid failure of gearbox by considering simple working conditions.

Simple remedies are also suggested so life of gearbox can be improved. While dealing with industrial gearbox, failure will result in huge loss in terms of money. Fault detection is one of the most important criteria for reducing loss due to failure. Accurate fault detection will help to reduce repair timing ultimately reduction in loss. This paper will help developers to know about common causes of failure so they can design new product based on this failure terms.

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