A STUDY ON COMMON FAILURE OF GEARS

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ABSTRACT:- **: To objective of this paper to present the recent development in the field of gear failure analysis. By the help of this paper we can know about different types of failure detection and analyzing technique which is used to reduce these failure from gears. The basic reasons of gear failure misalignment of gear, spalling , pitting etc, follow the reason of gear failure. Gears generally fail when the working stress exceeds the maximum permissible stress. Advances in engineering technology in recent years have brought demands for gear teeth, which can operate at ever increasing load capacities and speeds. The gears generally fail when tooth stress exceed the safe limit. In this study the technology of gears is presented along with the various types of failure that gears have. The causes of these failures are studied. The type of stress related failure due to (fatigue failure) of gear tooth because of stress concentration is detailed in this paper**

Index Terms **- gear failure, misalignment, and spalling, stress, pitting, researcher.**

1. INTRODUCTION

Gears are the most common means of transmitting motion and power in the modern mechanical engineering world. A gear is a component within a transmission device that transmits rotational force to another gear or device. A gear is different from a pulley in that a gear is round wheel which has linkages “teeth” that mesh with other gear teeth, allowing force to be fully transferred without slippage. A gear is a machine element designed to transmit force and motion from on mechanical unit to another. The design and function of gears are usually closely associated; various types of gears have been developed to perform different function, the most common of these being spur gears, helical gears, straight and spiral bevel gears, and hypoid gears. The change the rate of rotation of machinery shaft and also the axis of rotation, for high speed machinery, such as an automobile transmission, they are the optimal medium for low energy loss and high accuracy. Their function is to convert input provided by prime mover into an output with lower speed and corresponding higher torque. Toothed gears are used to transmit the power with high velocity ratio. The characteristics of these various gear types are discussed in most mechanical design texts like all mechanical components, gears can and do fail in service for a variety of reasons. In most cases, except for an increase in noise level and vibration, total gear failure is often the first and only indication of a problem. Many modes of gear failure have been identified, for example fatigue, impact, wear or plastic deformation. Of these, one of the most common causes of gear failure is tooth bending fatigue. Fatigue is the most common failure in gearing. Tooth bending fatigue and surface contact fatigue are two of the most common modes of fatigue failure in gear. Several causes of fatigue failure have been identified. These include poor design of the gear set, incorrect assembly or misalignment of the gear, overloads, inadvertent stress raisers of subsurface defects in critical areas, and the use of incorrect materials and heat treatments [1]. A gear is a rotating machine part having cut teeth. Which is meshing the gear teeth to transmit the torque? A geared device can be change the speed, direction of power sources and magnitude [2]. The tooth meshing on another gear of non rotating parts is called rack. When it a rotation it provide transmission in analogous to the wheels in pulley. It is the cylindrical shaped its teeth are parallel in axis. its wide range of application most commonly used[3]. Gear failure can occur in various modes. In this chapter details of failure are given. If care is taken during the design stage it to prevent each of these failures a sound gear design can be evolved. The gear failure is explained by means of flow diagram in Fig1.

1. GEAR FAILURE

Gear failure can occur in various modes. In this paper details of failure are given. If care is taken during the design stage itself to prevent each of these failure a sound gear design can be evolved. The gear failure is explained by means of flow diagram in Fig1 there are many possibilities to describe,

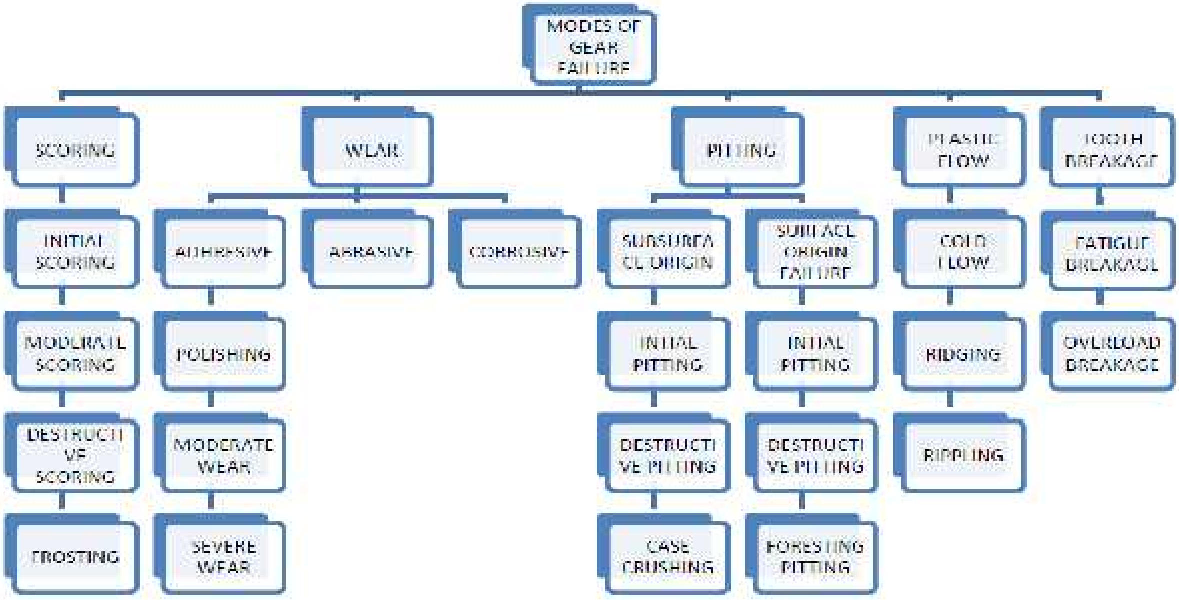


Fig.1 Different modes of failure

Classify and evaluate gear failure. Several authors have studied gear failure and defined different ways to classify them:

- An accepted way to describe gear failure is associated with the definition: "A gear has failed when it can no longer do efficiently the job for which it defined" [4].
- Gear failure can be separated into lubricated-related failure, like overload bending and fatigue and non lubricated-related failure, like Hertzian fatigue (pitting wear and scuffing). These classifications are described in Erricho [5].
- Gear failure can be divided into gear tooth flank failure like pitting, scuffing and wear or failure modes on gear root fillets, like bending, and impact.[6].
- In 1973 Shipley divided gear failure in their frequency of occurrence. [7] He is divided it into:
    - Fatigue : Tooth bending, surface contact (pitting or spalling), rolling contact, thermal fatigue
    - Impact: Tooth bending, tooth shear, tooth chipping, case crushing, torsion shear.
    - Wear: Abrasive, adhesive.
    - Stress rupture: Internal, external.

2.1. SCORING

Scoring is due to combination of two distinct activities: First, lubrication failure in the contact region and second, establishment of metal to metal to metal contact. Later on, welding and tearing action resulting from metallic contact removes the metal rapidly and continuously so far the load, speed and oil temperature remain at the same level. The scoring is classified into initial, moderate and destructive.

2.1.1 INITIAL SCORING

Initial scoring occurs at the high spots left by previous machining. Lubrication failure at these spots leads to initial scoring or scuffing as shown in Fig 3.1 Once these high spots are removed, the stress comes down as the load is distributed over a larger area. The scoring will then stop if the load, speed and temperature of oil remain unchanged of reduced. Initial scoring is non-progressive and has corrective action associated with it.

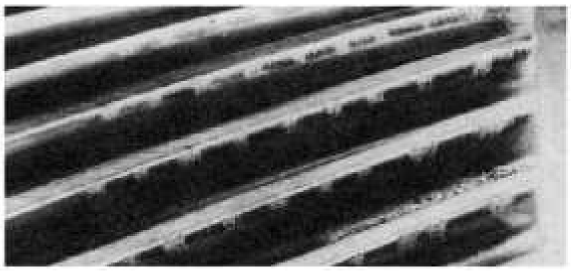


Fig.2 Initial scoring

2.1.2 MODERATE SCORING

After initial scoring if the load, speed or oil temperature increases, the scoring will spread over to a larger area. The scoring progresses at tolerable rate. This is called moderate scoring as shown in Fig.3.2

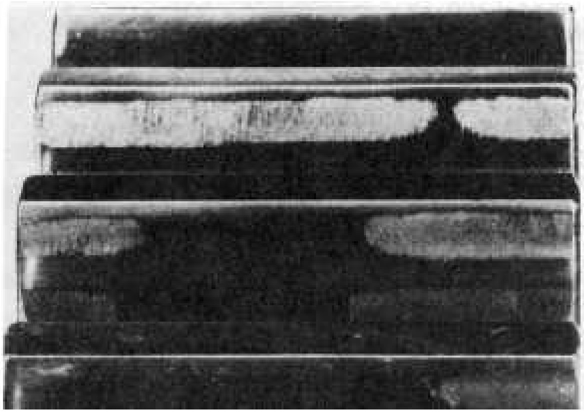


Fig.3 Moderate scoring

2.1.3. DESTRUCTIVE SCORING

After the initial scoring, if the load, speed or oil temperature increases appreciably, then severe scoring sets in with heavy metal torn regions spreading quickly throughout as shown in Fig.3.3 Scoring is normally predominant over the pitch line region since elasto-hydrodynamic lubrication is the least at that region. In dry running surfaces may seisze.

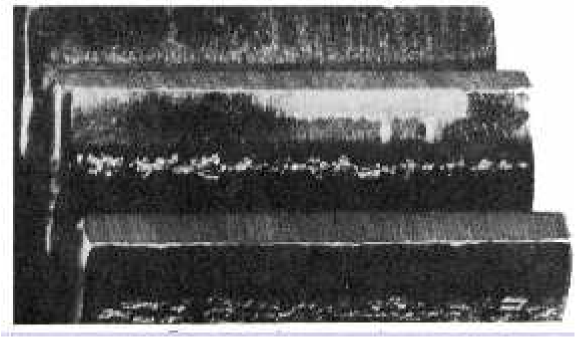


Fig4. Destructive scoring

2.2. WEAR

A surface phenomenon in which layers of metal are removed, or "worn away," more or less uniformly from the contacting surfaces of the gear teeth. Wear describes a loss or removal of material of gear flanks. In terms of gear failure, it is more a deterioration of a gear profile, for instance, a damage of a tooth layer. Adhesive and abrasive wear are important modes of wear. Abrasive wear occurs when a surface is cut away by abrasive particles.

2.2.1. ABRASIVE WEAR

Abrasive wear has taken place, contacting surface show sings of a lapped finish, radial scratch marks or grooves, some other unmistakable indication that contact has taken place .

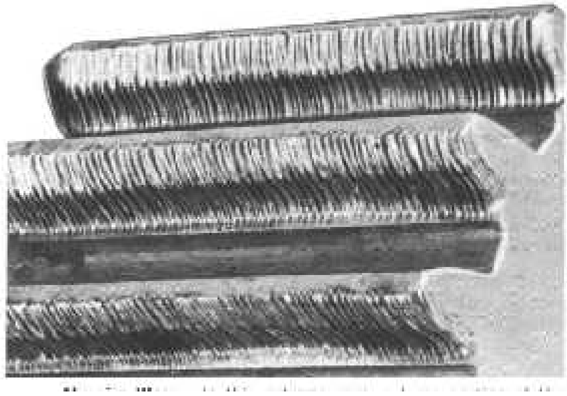


Fig.5 Abrasive wear

2.2.2. ADHESIVE WEAR

Result from high attractive forces of the atoms composing each of two contacting, sliding surfaces. Teeth contact at random asperities and a strong bond is formed. The junction area grows until a particle is transferred across the contact interface.

Fig.6 Adhesive wear

2.2.3. EXCESSIVE WEAR

This is simply normal wear which has progressed to the point where a considerable amount of material has been removed from the surfaces. The pitch line is very prominent and may show signs of pitting.

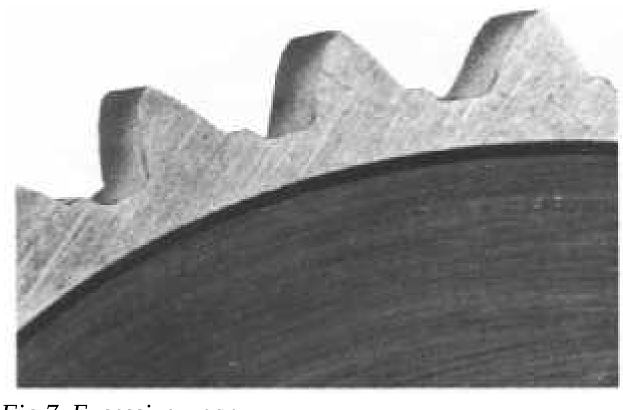


Fig.7 Excessive wear

2.2.4. CORROSIVE WEAR

This is a deterioration of the surface due to chemical action. It is often caused by active ingredients in the lubricating oil, such as acid, moisture, and extreme-pressure additives.

Fig.8 corrosive wear

2.3. FATIGUE/ PITTING OF GEARS

Fatigue occurs under repeated stresses which are lower than ultimate tensile strength and higher than “fatigue limit”, pitting is the most common mode of fatigue and particular form of spalling.

Pitting is a surface fatigue failure of the gear tooth. It occurs due to repeated loading of tooth surface and the contact stress exceeding the surface fatigue strength of the material. Material in the fatigue region gets removed and a pit is formed. The pit itself will cause stress concentration and soon the pitting spreads to adjacent region till the whole surface is covered. Subsequently, higher impact load resulting from pitting may cause fracture of already weakened tooth. However, the failure process takes place over millions of cycles of running. There are two types of pitting, initial and progressive.

2.3.1 INITIAL/INCIPIENT PITTING

Initial pitting occur during running- in period where in oversized peaks on the surface get dislodged and small pits of 25 to 50 μm deep are formed just below pitch line region. Later on, the load gets distributed over a larger surface area and the stress comes down which may stop the progress of pitting.

Fig9 Initial pitting

In the helical gear shown in Fig.9 pitting started as a local overload due to slight misalignment and progressed across the tooth in the dedendum portion to mid face. Here, the pitting stopped and the pitted surfaces began to polish up and burnish over. This phenomenon is common with medium hard gears. On gears of materials that run in well, pitting may cease after running in, and it has practically no effect on the performance of the drive since the pits that are formed gradually become smoothed over from the rolling action. The initial pitting is non-progressive.

2.3.2. PROGRESSIVE OR DESTRUCTIVE PITTING

During initial pitting, if the loads are high and the corrective action of initial pitting is unable to suppress the pitting progress, then destructive pitting sets in. Pitting spreads all over the tooth length. Pitting leads to higher pressure on the unpitted surface, squeezing the lubricant into the pits and finally to seizing of surfaces. Pitting begins on the tooth flanks near the line along the tooth passing through the pitch point where there are high friction forces due to the low sliding velocity. Then it spreads to the whole surface of the flank.

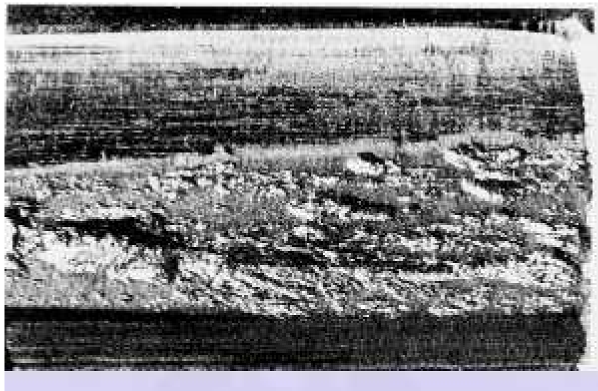


Fig.10 Tooth surface destroyed by extensive pitting

Tooth faces are subjected to pitting only in rare cases fig11 shows how in destructive pitting, pitting has spread over the whole tooth and weakened tooth has fractured at the tip leading to total failure.

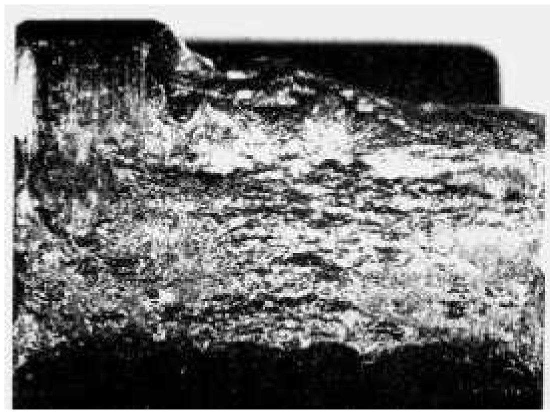
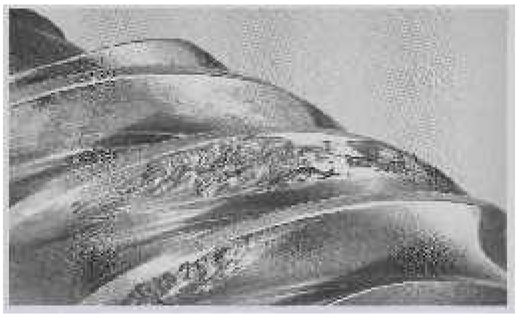


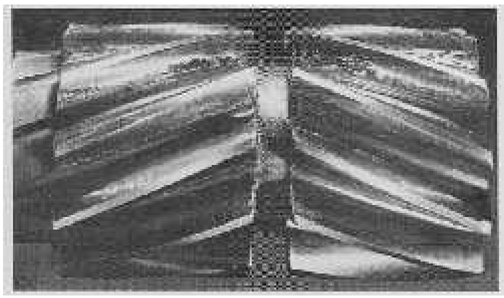
Fig.11 Whole tooth is destroyed by extensive pitting

2.3.3. **FLAKING/SPALLING**

In surface-hardened gears, the variable stresses in the underlying layer may lead to surface fatigue and result in flaking (spalling) of material from the surface as shown in Fig.12



(a) Flaking



(b) Spalling

Fig.12 Flaking/Spalling

2.3.4. PITTING – SUBSURFACE ORIGIN FAILURE

Fig.13 shows the subsurface origin failure.

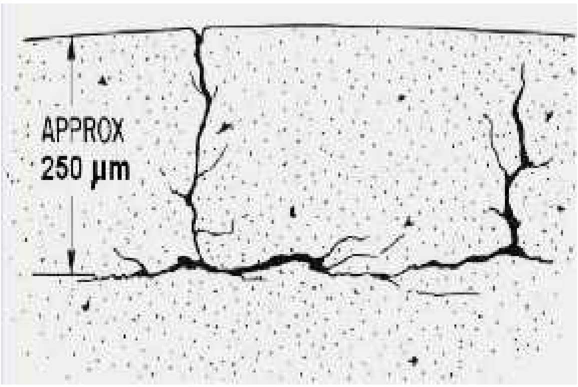


Fig.13 Subsurface origin failure

2.3.5. PITTIN – SURFACE ORIGIN FAILURE

Failure modes in gear namely the surface origin failure is shown in Fig.14

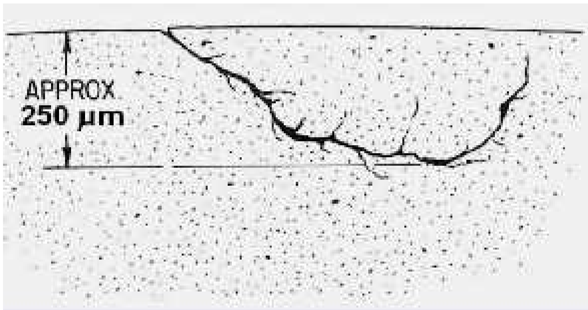


Fig.14 Surface origin failure

2.3.7. PITTING- FROSTING

Frosting usually occurs in dedendum portion of the driving gear first aatd later on the addendum as shown in Fig15. The wear pattern doesn't have normal metal polish but has etched-like finish. Under magnification, surface reveals very fine micro-pits of 2.5µm deep. These patterns follow the higher ridges caused by cutter marks. Frosting results from very thin oil film and some asperity contact.

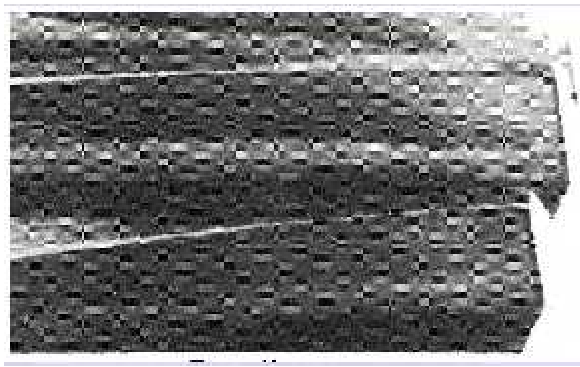


Fig.15 Frosting

2.4 **CRACKING**

Cracking starts with small stress raisers quite in the root of a gear. This causes unsuspected overloads with a high sliding speed which raises the temperature of the hardened case. Cold lubrication and hot gears leads to thermal fatigue cracks or hardening cracks associated with heat treated gears. Grinding cracks are also a result of localized overheating but it occurs on the tooth surface after the tooth finished grinding on the gear tooth pair. Process Related failure can be of following types:

- Quench Cracks, Grinding cracks
- Grinding cracks
- Nicks, scratches
- Electric arcing
- Grinding "Burns"
- Improper Edge Breaks

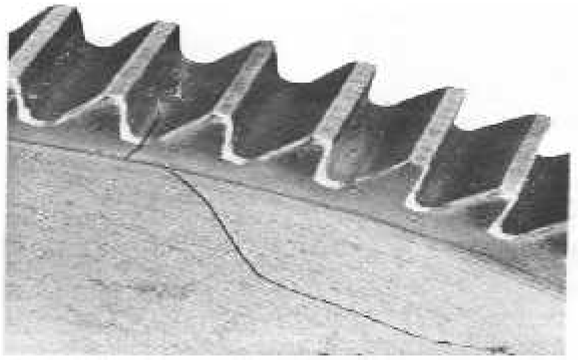


Fig16 failure by cracking

2.5 FRACTURE

Fracture is also called tooth breakage or rupture. It is one of most dangerous gear failure because the gear could be damaged or it might destroy other component like shafts or bearings. Brittle fracture is a rapid crack with less deformation while ductile fracture has a deformation before a part of a gear breaks. A combination of brittle and ductile fracture is called mixed mode fracture. Shear fracture is caused by an overload of a single tooth. It starts with a weak point within a gear which builds up higher stresses than the strength of material allows. Therefore a small crack can grow and a tooth might break off. Depending on the way in which the fracture occurs, it can be of following types:

- Overload
- Random Fracture
- Root/Rim/Web
- Resonance

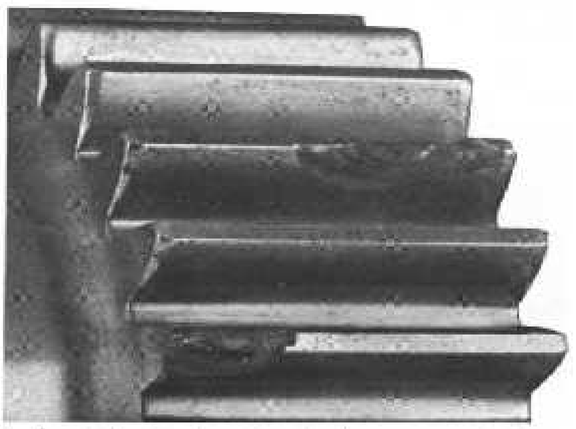


Fig.17 Gear teeth fracture

CONCLUSION

In this paper presented a brief review of gear failure analysis different conventional and recent techniques were discussed for particularly helical and spiral bevel gear through fatigue failure in gear while operation at various region. It was observed that the stresses induced the gear tooth were higher than the permissible/safe limit. Failure types in the most of the gear are high stress, low cycle fatigue fracture, abrasion wear and plastic deformation. The heat generated at the contact under these conditions is much larger to enhance the likelihood of scuffing significantly. The stresses induced on the gear tooth can be reduced considerably by making hole at the root of the gear tooth. And after the review of this paper following points were calculated.

I. The failure zones were examined with help of scanning electron Microscope equipped with EDX facility. For further investigation an analysis through SEM was carried out close to the crack initiation. It was found that the damage in the bevel gear were by fatigue fracture mode.
II. The misalignment in gear teeth while meshing is the one of main causes of gear teeth fatigue failure. Due to this crack is also initiated in the vicinity of gear teeth. A alignment in gear wheel and pinion is necessary to reduce this failure.
III. A fatigue analysis has been performed following the FITNET FFS procedure it has concluded that no fatigue problem should have occurred in failure section and also that this section should not have been the most stressed one the hypothesis.
IV. The conclusion inspired to further research to reduce the fatigue failure in gears to incorporate other parameters and symptoms with fatigue features develop more robust expert systems for fatigue failure in gears.

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