Design & Analysis of Assembled Teeth Spur Gear

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Abstract. Gears are the most important components in modern mechanical engineering world. The use of gears has more common in all the industries. The advantages of spur gear are simplicity in design and can be manufactured easily, economically and less maintenance. At present scenario gears plays an important role in wide space of research especially in gear motors, gear pumps, electromechanical actuators and drive shafts for the car etc. Gears predominantly fail in contact fatigue mode (pitting/spalling) due to combined rolling and sliding motion. Pitting initiation has been experimentally investigated by many researchers under different loading and operating conditions. Contact and Bending stresses at pitch point happened due to a close agreement. The highest probability of pitting/bending failure initiation is observed in single tooth contact region due to full load sharing and the chance of contact fatigue failure is more in comparison to bending fatigue failure. But if the failure happened in teeth - entire gear is replacing. So, it is so expensive. Our Aim is to design and study the failures of assembled teeth spur gear. In this work, we are going to do conceptual design to detail design with CAD Model and proceed to check the failures using Analysis Tool. Aim to find out the contact stresses and deflection by using Solid works and Ansys software's.

1. Introduction

Gears are acting as most important components in mechanical transmission system in most of the industrial machines and aerospace components. In most of the industries, widely spur gear is most suitable and flexible components. Most of the researchers have concentrated to study the failure analysis of spur gear in different profile changes & different loading conditions. The stiffness of gear pair and profile will also influence the gear tooth errors so achieving this error as work, many researchers recommend changing the tooth profile and check by analytical stiffness model [1]. Some of the authors recommend changing the rack cutter design and geometric shape of gear which is designed and analyzed through the meshing process in the FEA [2]. Transmission error also influences the gear design. So, before and after profile changing the transmission error, we have to study it. Hence, will give clear decision for profile changing, so this modified profile plays a vital role in maintaining the film temperature and improving the tooth lubrication [3]. However, the stress analysis of gears is also important before fabricating the gears. The stress analysis is in different variation of contact stress with the lowest point of a single tooth the contact strength can study by using FEA [4]. Whenever analyzing the gear, the individual gears cannot give more information related to any stress analysis by using FEA. FEA can study the plastic effect and deflection [5-6]. Considering the spur gear design, bending and impact strength also influenced by gears at the root region, where it is having large stress at the affected area [7]. Vibration also one of the most important criteria to design the gear and it will help give clear idea about how the stress will generate.
because of the vibration in the gears [8]. Nowadays the composite gears also manufacturing because of weight reduction and stress distribution is playing main role in automobile sectors so when compare the other materials the composite material give very less stress valves [9]. The main aim of this work is to design the detachable teeth in spur gear and study the stress analysis by using FEA.

2. **Design of assembled spur gear**

2.1 **Design of Gear teeth**

The assembled and normal spur gear is designed by using design software like solid works. In General Gears are made of a single solid structure, but our assembled gear is consisting of below components the exploded view is shown in figure 1.

- Centre Plate
- End Plate
- Gear Teeth
- Pin

![Figure 1. Exploded view of assembled Gear Teeth.](image)

In order to check and compare, we have designed and modeled the spur gear with normal condition and then with the Assembled Gear tooth condition. With Respect to the ACMA Standard and below equation [10], we have calculated the gear geometrical data

Addendum (a): The distance from the pitch circle to the top of the gear tooth.

\[ a = \frac{1}{p} \quad \ldots (1) \]

Dedendum (b): The distance from the bottom of the tooth to the pitch circle.
Pitch circle diameter (dp) is also known as diameter of the pitch circle which is the relation between the number of teeth (N) and diametrical pitch.

\[ dp = \frac{N}{p} \quad \ldots \quad (3) \]

Base circle diameter (db) is the circle used to form the involute section of the gear tooth, Base circle Diameter (db) is calculated by below formula

\[ db = dp \cdot \cos \alpha_b \quad \ldots \quad (4) \]

Pressure angle (\( \alpha \)) is usually considered as \( \alpha = 20^\circ \). With the above procedure, we have calculated the below geometrical data of large gear and pinion gear and the geometrical data for large spur gear is shown in table 1.

| Table 1 | Geometrical data of geometrical data of spur gear – large. |
|---------|----------------------------------------------------------|
| Gear Parameter | Notations | Gear |
| Pitch Circle Dia | PD | 148.9456*2 | 297.89mm |
| No. of teeth | N | 30 |
| Pressure Angle | PA | 20° |
| Tip Radius | TipR | 1.27 |
| Root Radius | RootR | 0.508 |
| Diametrical Pitch | DP | "N" / "PD" | 129.95 |
| Angle A | AngleA | 360 / ("N" * 2) | 6° |
| Angle B | AngleB | "AngleA" / 2 | 3° |
| Angle C | AngleC | D2@SketchICL | 2.14604° |
| Outside Diameter | OD | "PD" + ( 2 * "a" ) | 158.875 |
| Dedendum Radius | DR | ( "PD" / 2 ) - "b" | 68.267 |
| Addendum | a | 25.4 / "DP" | 0.195467 |
| Dedendum | b | 31.755 / "DP" | 0.244333 |

| Table 2 | Geometrical data of geometrical data of spur gear – small. |
|---------|----------------------------------------------------------|
| Gear Parameter | Notations | Gear |
| Pitch Circle Dia | PD | 74.473*2 | 148.95mm |
| No. of teeth | N | 15 |
| Pressure Angle | PA | 20° |
| Tip Radius | TipR | 1.27 |
| Root Radius | RootR | 0.508 |
| Diametrical Pitch | DP | "N" / "PD" | 129.95 |
| Angle A | AngleA | 360 / ("N" * 2) | 12° |
| Angle B | AngleB | "AngleA" / 2 | 6° |
| Angle C | AngleC | D2@SketchICL | 5.14604° |
| Outside Diameter | OD | "PD" + ( 2 * "a" ) | 84.402422 |
| Dedendum Radius | DR | ( "PD" / 2 ) - "b" | 31.030418 |
| Addendum | a | 25.4 / "DP" | 0.195467 |
| Dedendum | b | 31.755 / "DP" | 0.244333 |
2.2 Modeling of Spur Gear in Solid works Software

With the equation tool in Solid Works software module, spur gear with diametral pitch \( P = 299 \), pressure angle of \( 20^\circ \) according to AGMA Standard, and number of teeth \( N = 30 \) all parameters are input as per shown in figure 2.

![Figure 2. Base circle sketch, dedendum circle, and pitch circle in equation form.](image)

Finally check all geometric relations are defined to ensure a solid sketch. The extrude cut with the sketch is shown in figure 3.

![Figure 3. Extrusion of the root tooth and two flanks of spur gear.](image)

![Figure 4. Geometric modeling of spur gear with number of teeth.](image)

By the using the circular pattern command numbers of instances are related with the global variable \( N \) teeth generated shown in figure 4.
2.3 Analysis of Gear teeth using Ansys:
Analysis is done using the Ansys software by below procedure:

Step 1: Drawing of gear tooth is done by using solidworks and import IGS file in Ansys workbench.

Step 2: Select Static Structural in ansys selection.

Step 3: In Engineering Data, Select Alloy Steel as material.

Step 4: Geometry → Select Import Geometry and select IGS file.

Step 5: Model → Connections → Select Contact Region → Select Contacting Surface & make it as fully defined.

Step 6: Mesh → Select Coarse → then select update to complete meshing.

Step 7: Select Center and provide as frictionless support.

Step 8: Insert Moment on the pinion wheel as 200 N-mm.

Step 9: Pressure on the Touching Face on Large Gear as 2.2Mpa.

Step 10: Solution → Insert → Von Misses Stress, Von Misses Strain & Deformation.

Step 11: Click Solve to get results.

The design spur gear sample models are shown in figure 5.

Large Spur Gear.   Pinion- Small Spur Gear.
3. Results & Discussion

To check and study the Assembled Gear Teeth Design, first we need to study for the original Gear with pinion mating and compare with the Assembled gear teeth mating with pinion. From the Above Analysis, we got the below data from Ansys.

3.1 Analysis of Main gear (Original Gear) with Pinion: Mating Condition:

In this Analysis result, the load is provided on the pinion mating area of Large spur gear and get the below results

Load on mating face – 2.2 Mpa
Moment on Pinion Wheel - 200 N-mm

To get failure details, the main parameters are deformation, stress and strain

Analysis of Main Gear (Original Gear) with Pinion: Mating Condition – Deformation

From the below Figure 6, deformation analysis with Gear (Original Gear) with Pinion - Mating Condition and we got the deformation as per below.

Minimum [mm] - 3.8711e-005
Maximum [mm] - 2.7132e-004
Average [mm] - 2.1278e-004
Analysis of Main Gear (Original Gear) with Pinion: Mating Condition - Von Misses Stress
As per below Figure 7, stress analysis with Gear (Original Gear) with Pinion - Mating Condition, we got below stress values.
- Minimum [MPa] - 9.6062e-007
- Maximum [MPa] - 1.8441
- Average [MPa] - 3.3689e-002

![Figure 7. Von Misses Stress Analysis.](image)

Analysis of Main Gear (Original Gear) with Pinion: Mating Condition - Von Misses Strain
The figure 8 shows the strain analysis with Gear (Original Gear) with Pinion – Mating Condition, we got below strain values
- Minimum [mm/mm] - 1.6162e-011
- Maximum [mm/mm] - 9.1369e-006
- Average [mm/mm] - 1.754e-007

![Figure 8. Von Misses Strain Analysis.](image)

Analysis of Assembled Gear Teeth with Pinion: Mating Condition: the analysis with normal Gear (original Gear) with pinion mating condition, will proceed to study our analysis with assembled gear teeth condition with same loads and moment
Analysis of Assembled Gear Teeth with Pinion: Mating Condition – Deformation
From the below Figure 9, deformation analysis for Assembled Gear Teeth with Pinion - Mating Condition and we got the deformation as per below
- Minimum [mm] - 0
- Maximum [mm] - 0.7376
Figure 9. Deformation.

Analysis of Assembled Gear Teeth with Pinion: Mating Condition - Von Misses Stress
As per below Figure 10, stress analysis for Assembled Gear Teeth with Pinion - Mating Condition, we got below stress values

Minimum [MPa] - 0
Maximum [MPa] - 149.52

Figure 10. Von Misses Stress Analysis.

Analysis of Assembled Gear Teeth with Pinion: Mating Condition - Von Misses Strain
As per below Figure 11, strain analysis for Assembled Gear Teeth with Pinion - Mating Condition, we got below strain values

Minimum [mm/mm] - 0
Maximum [mm/mm] - 7.1616e-004
Average [mm/mm] - 1.5624e-006
Figure 11. Von Misses Strain Analysis.

From the above Analysis results, we got the values of Deformation, stress and strain for original gear with pinion gear and assembled gear teeth with pinion gear. From the Results, we have tabulated all the results in below table 3.

Table 3. Analysis results table.

| S.No / Loads at 2.2 N/mm² | Normal Gear | Assembled Teeth Spur Gear |
|--------------------------|-------------|---------------------------|
| Von Misses Stress (Mpa)  | 1.8441      | 149.52                    |
| Von Misses Strain (mm)   | 9.1369x10^-6| 0.00071616                |
| Deformation (mm)         | 0.00027132  | 0.7376                    |

4. Conclusions
- From the analysis results concluded with respect to the Normal Load of 2.2 N/mm², the Stress, Strain & Deformation is found more due to the difference in Assembled Teeth Spur Gear when compared to Normal spur gear.
- Assembled Teeth Spur Gear is Approx 80% stress more than Normal Spur Gear. In terms of Deformation, it is far more. So, Failure will be at faster rate than normal gear, so we can suggest this concept of gear can be used for low torque applications.
- To check for further results, below trials can be done as a below alternate proposal
  - By Changing the Material
  - By Changing the Gear Design

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