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Determination of Lock Slippage in Gear tooth using Quasi-Static Analysis

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ABSTRACT : *Present automotive industry faces immense problems in Gear locking systems. At lock position, the locking should be perfect with gear teeth without slippage for the prescribed load conditions. In present paper, lock slippage is determined for one of the automotive application. Quasi-static analysis is performed in L S Dyna software to predict the load at which slippage takes place. The model is designed to reach the customer specification without slippage in mechanism.*
Keywords - *Lock Slippage, Quasi-Static Analysis, LS Dyna*

I. INTRODUCTION

Present Automotive Industry aims at designing, developing and performing analysis for the models by upgrading them until the required specification reaches. This includes the improvement of the performance and also the cost incurred to fabricate and assembling the mechanism reduces. Automotive seat structure has to provide comfort to passengers and plays an important role in car passive safety. Seat Structure comprises of Slider, Recliner, Height Adjuster, Back Frame and Cushion Frame. Adjustment mechanisms give comfort to the passengers.

The mechanisms mentioned above consist of Gear tooth, where they play major role. The paper concentrates on Gear teeth alone. In engineering and technology the term “gear” is defined as a machine element used to transmit motion and power between rotating shafts by means of progressive engagement of projection called teeth.

Figure 1. Gear Teeth

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk, and with the teeth projecting radially, and although they are not straight-sided in form, the edge of each tooth thus is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel axles. They find wide applications right from clocks, household gadgets, motorcycles, automobiles, and railways to aircrafts.

II. PROBLEM DEFINITION

The designed locking mechanism should reach the customer specification without slippage of gear teeth. The stress obtained after the slippage is to be more than the yield stress of the material considered. The analysis results are to match with the customer specification. In order to improve the material properties, proper heat treatment is followed.

III. THEORETICAL CALCULATION

The first criteria before slippage of gear is tooth breakage. For this the strength of the tooth is calculated and then the material is selected accordingly. Once the Gear tooth is meeting the strength specification, some how the slippage should take place. Our objective is to maintain slippage for the specification given by the customer.

3.1. Data Required for Calculations

Description	Value
Momentum designed (with 20% FOS)	1920 Nm
Pitch Circle Radius	27mm
Difference of PCR and Dedendum	0.22mm
Moment of Inertia	0.1mm^4
Coefficient of friction	0.1
Lower tooth angle	66.4degrees
Teeth Width	2.2mm

Table 1. Data Description

3.2. Gear tooth Strength Calculation

The stress at which breakage occurs is calculated using tooth bending stress equation

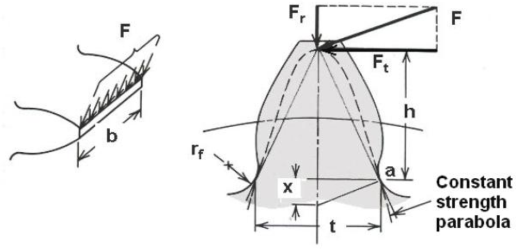

Figure 2. Gear Tooth

Moment on Single teeth

M = $F_t \times h$

Total Strength of single tooth

$$\sigma_y = \frac{M}{I} \times y$$

where F_t is tangential force on the tooth
I is moment of Inertia
Y is half of teeth thickness
h is difference between Pitch Circle Radius and dedendum.

3.3. Lock Slippage Calculation

Lock Slippage not to occur, the member, which in contact with pinion should resist the torque applied by the disengagement force on the Gear.

The total force on one teeth, $F_t = \frac{M}{N \times PCR}$

= 846.56 N

Normal Force, $F_N = F_t \cos\theta$

= 708.37 N

Frictional force, $F_f = \mu F_N$

= 0.1×708.37

= 70.837 N

Force in y direction, $F_y = F_t \sin\theta$

= 463.54 N

Total Disengagement Force

$$F_d = (F_f + F_y) \cos \theta$$

$$= 447.15 \text{ N}$$

The above disengagement force is for one teeth. According to number of teeth increases, the total disengagement force changes.

IV. ANALYSIS PART OF SLIPPAGE

4.1. Modelling of Gears

Gear and Pinion modelled in Catia Software. In assembly module, both were made contact by giving proper alignment to axis and surfaces.

Steps followed in modelling

1) *2 Dimensional Sketching*
2) *Extruding the Sketcher Parts*
3) *Assembly using proper alignment*

4.2. Meshing

Meshing part is done in Hypermesh for better-refined mesh so that the results obtained will be precise. First 2d mesh is done taking all the surfaces. The element used for meshing in 2 dimensional is Quadrilateral element type. Once 2 dimensional meshing is completed, 3d module is selected and then the complete surfaces are converted into solid object. The element type considered for 3 dimensional is Tetrahedron element type.

The element size considered is to be very small and the quality parameters are checked frequently so that no elements were failed.

The quality parameters checked were

1) Warpage
2) Minimum element size
3) Maximum element size
4) Skewness
5) Angles minimum and maximum

4.3. Pre-processing Work

This module is done in LS Dyna software. The contacts between the parts were given using Automatic Single Surface contact. Once the parts come in contact, the given type of contact is activated. The static coefficient friction considered is 0.1 and the dynamic coefficient of friction in 0.05.

Element used for elasto-plastic solid type for better results. The type of loading is quasi-static loading, which implies, the load is acting gradually with respect to time by considering short time frames.

Termination time is given for the mechanism to stop once the specified load reaches. The maximum time specified in load curve and the termination time is to be given same.

V. SIMULATION RESULTS

Solver used to determine slippage is LS Dyna where the analysis is explicit analysis. Since the analysis is time dependent, the analysis is called explicit analysis. Certain cards were given to extract output results. Once the analysis is solved, the von-mises stress results were extracted using Hyperview.

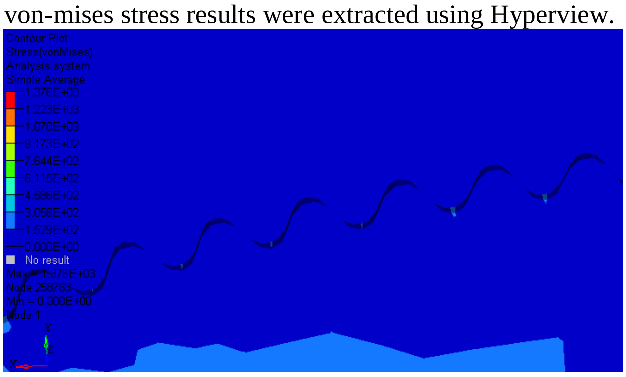

Figure 3. First stage of slippage

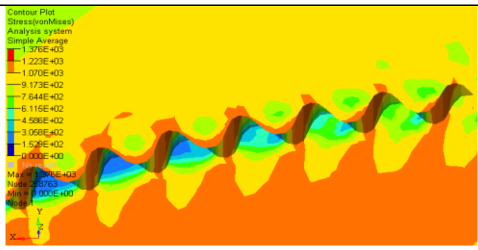

Figure 4. Second stage of slippage

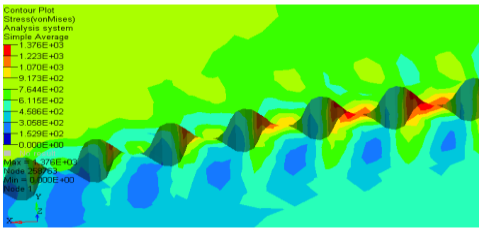

Figure 5. Final slippage

Fig 3, Fig 4 and Fig 5 shows the stages of slippage taking place as the load is gradually increasing from 0 to 4500 N. The force at which the slippage occurs can be calculated from the time frame.

VI. CONCLUSION

Load at which slippage takes place is calculated and the stress is calculated. The stress obtained from the analysis is 1376 MPa and the yield stress of the material considered is 1187 MPa. Since the main objective in the paper is to find the slippage, the stress obtained crosses the yield stress.

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