Scientific Bulletin of the Petru Maior University of Tirgu Mures
Vol. 6 (XXIII), 2009
ISSN 1841-9267

TOOTH'S TENSIONS ANALYSIS OF FACE WORM GEARS WITH CYLINDRICAL PINION DEVELOPMENT OF FEA

Gavrilă Ion
ion_gavrila@yahoo.com

Abstract

Tooth's tension in lapping process for worm face gear is proposed. The stress analysis of the gear drive is performed using a three-dimensional finite element analysis. The developed simulation is illustrated with numerical examples. This complex and intuitive simulation was created with CAD-CAM, MATH-CAD and FEM support. This simulation contain data collected from EU standards

1. Introduction

The subject of this research project is extensive analysis of tension, stress and strains of face worm gear tooth, with special attention given to the influence of surface roughness. Gear teeth working surfaces are subjected to repeated rolling and sliding contacts. For operating conditions common for power transmission applications, the loads are sufficient to cause eventual fatigue of the surface. The surface roughness of a gear is one of the most influential factors that defines the quality of surface how determine indirectly fatigue capability of gear, and so this subject is of particular interest and importance to the field of gear design. This research project sought to provide analytical tools to further the understanding of the causal relationship of gear surface roughness to surface fatigue.

We present in this paper step by step a simulation of tooth analysis of worm face gears. Worm face gear are a particular kind of worm gears**.** Procedures describe in this paper can be applied for any particular application. Method requited CAD-CAM, MATH-CAD and FEM supports. We want to demonstrate it is possible to create a virtual simulation of any particular gear without any dedicate programs. The paper discusses peculiarities of face worm gear design.

2. Tooth's tension analysis development of FEA.

Loaded tooth contact analysis provides a realistic picture of tooth contact behavior under given loads (applied torques) and axle deflections.

He advanced development of analysis is based upon following ideas and considerations:
Tooth surface geometry is exactly defined and executed. The analysis results provide bench contact pattern and the motion graph from which instant contact positions, and the number of adjacent meshing tooth pairs, can be identified if it considers usefully. The FEA meshing models with multiple teeth are generated, using the exact tooth surface generating model for the worm gear wheel.

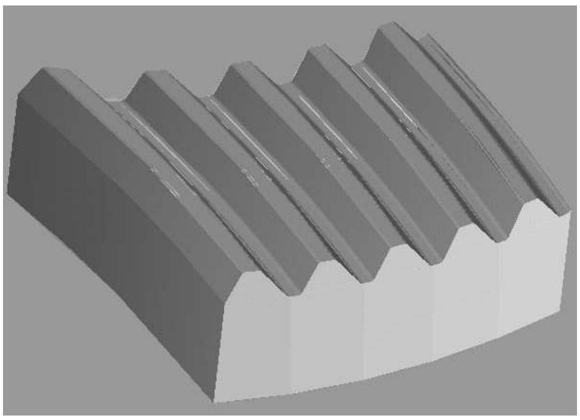


Fig. 1. Surface for FEA analysis

The total number of elements in the models can be chosen by the by selecting the element numbers in tooth thickness, profile, and

Keywords: *worm gears, tensions analysis, fea analysis*

lengthwise directions. Consider this particular type of gears where we know from previous tests 10-12 % from total number teeth are in contact with pinion in the same time so we create a test surface form by 5 teeth (see figure 1).

Solving the governing equations needs an iteration process in which the kinematical approach can be assumed, and eventually determined together with the load distribution and gap vectors. As an analysis result, the loaded displacement and contact pattern at each contact position can be determined.

Two values of torque need to be specified in tooth contact analysis. The first value of torque is the full-load torque applied to the gear or pinion, corresponding to the torque used in evaluating the strength performance of the gear design. The second value of torque corresponds to the torque used in the deflection tests that were conducted to determine limit stress on overcharge conditions. In general, the two values of torque may not be the same. The torque can be gradually applied as the percentage of the full torque.

This study will be develop distinctly. Simulation mean in our point of views identification of lapping process parameters such as: roughness, contact stress and friction factor.

3. Build geometry

Probably the most important feature of this simulation is to determine a exact geometry tooth profile. For this task we use only valid geometrical description we have: we use ITW (Illinois Tool Works) geometry formulas[1].

Some important parameters of worm plain wheel chosen for this numerical example are listed in table bellow.

Table 1. Plain worm wheel Input data

Number of teeth	47
Module, mm	2,5
Diametric pitch, mm	7.85049
Circular pitch, mm	7.85049
Whole depth, mm	9.14915
Addendum, mm	4.57457
Chordal tooth thickness reference, mm	42.955
Tooth width, mm	43.94497
Pressure angle, deg.	25
Outside diameter, mm	196
Root fillet, mm	0.45025
Backlash reference, mm	0.6

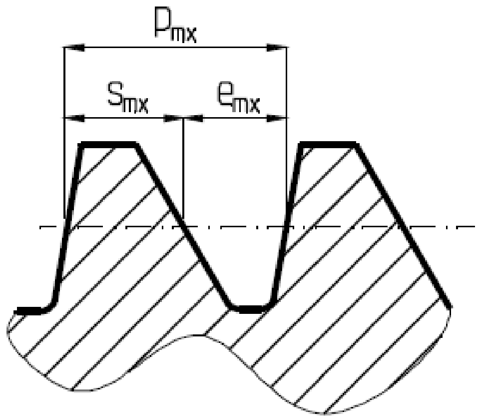


Figure 2. Normal section in teeth

The analysis of tooth load face-gear drives is presented in this section.

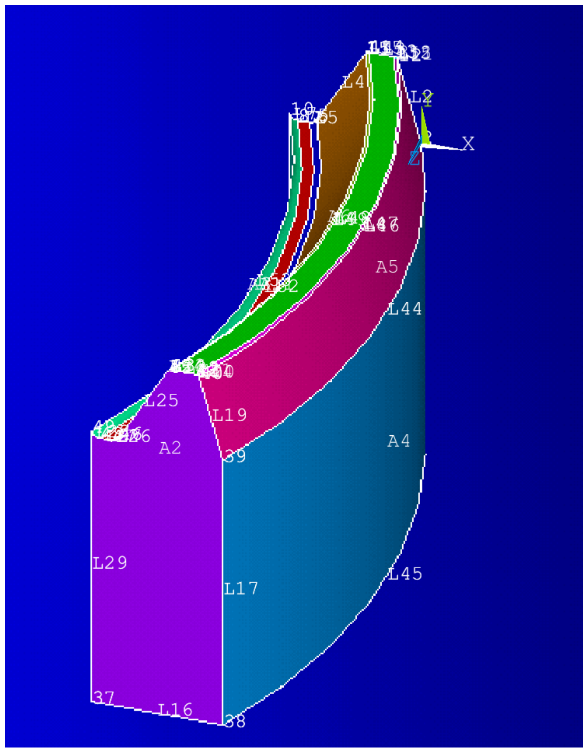


Figure. 3. 3-D view of teeth

The lubricant used for testing was from a single batch of synthetic oil density 1,048 kg/dm^3.

4. Define material

To define material properties for this analysis, with given values for Young's modulus of elasticity and Poisson's ratio.

Table 2. Nominal chemical composition of 40 Cr10 material (STAS 791-80) – ASTM 5140

Element	Weight %
Carbon	0,36
Nickel	-
Chromium	0,035
Molybdenum	-
Manganese	0.50
Silicon	0,17
Sulfur	0,035 max
Phosphorous	0,035 max
Hardened	R_{p02}=790 (N/mm^2)
E modulus (Young's modulus)	181000
Poisson's ratio	0,31

The analysis will be limited to the case of face-gear drives with intersecting axes of rotation.

5. Generate mesh

Multiphysics simulation software from ANSYS allows users to create virtual prototypes of their designs operating under real-world multiphysics conditions. This industry leading software enables engineers and scientists to simulate the interaction between structural mechanics, heat transfer, fluid flow and electromagnetics all within a single, unified engineering simulation environment.

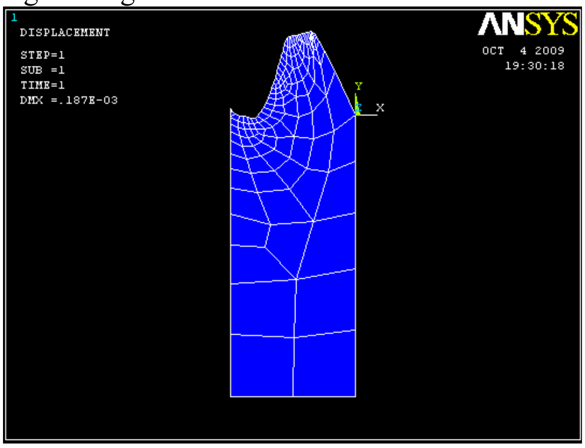


Figure 4. Meshing in normal section

For this analysis, you will use only one element type, PLANE82, which is a 2-D, quadratic, structural, higher-order element. The choice of a higher-order element here allows you to have a coarser mesh than with lower-order elements while still maintaining solution accuracy. Also, ANSYS will generate some triangle shaped elements in the mesh that would otherwise be inaccurate if you used lower-order elements (PLANE42). You will need to specify plane stress with thickness as an option for PLANE82. (You will define the thickness as a real constant in the next step.)[7]

It provides more accurate results for mixed (quadrilateral-triangular) automatic meshes and can tolerate irregular shapes without as much loss of accuracy. The 8-node elements have compatible displacement shapes and are well suited to model curved boundaries.

The 8-node element is defined by eight nodes having two degrees of freedom at each node: translations in the nodal x and y directions. The element may be used as a plane element or as an axisymmetric element. The element has plasticity, creep, swelling, stress stiffening, large deflection, and large strain capabilities.

6. Apply loads

Here the factor is determined through exact measurement, extensive mathematical analysis of the transfer system or existing operational experiences. Because of this, all gear and loading data shall be known. The mean hertzian stress is a parameter of essential importance to the flank loading. (ISO 145212-2006).

Table 3. Selective values of loads apply to test tooth's surfaces regard STAS 13024-91- Strength calculation – Cylindrical worm gear.

Limit value for the contact stress between teethes MPa	29,28314
Friction factor μ	0,07
Bending stress, MPa	27,6
Limit value for the contact stress at overcharge MPa	346.0195
Bending stress for working condition MPa	13.462
Bending stress for overcharge condition MPa	201.86

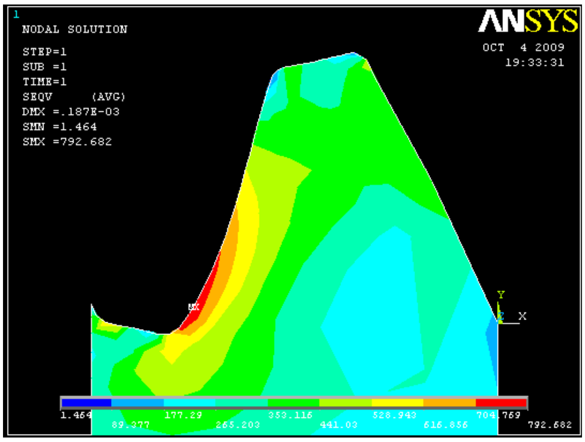
Table 4. Selective values of loads apply to test tooth's surfaces regard (ISO 145212-2006). Calculation of load capacity for plain worm wheel.

Mean contact stress σ_{Hm} MPa	62,064
Base coefficient of friction μ_{0T}, of the standard reference gear.	0,038
Mean coefficient of friction μ_{zm}, of tooth	0.017
Roughness of tooth's face	0,5
Mean tooth coefficient of friction	0,017
Limit value for the contact stress, MPa	354.22
Limiting value of shear stress tooth root, MPa	70
Limiting value of deflection δ_{lim}	0,0632
Tooth force components	
Worm axial forces N	3880,597
Wheel axial forces N	604,65

The calculation methods are partly based on investigations of test gears (see, standard reference gear, 5.2)[3], and partly on application experience. Investigations on test gears are mainly ascertained through varied test conditions and verified through practical experience. They are not however physically justified.

7.Obtain solution

During lapping process, body of pinion exercise through grinding bond elements put under tension lapping grains. This tension can be discomposed in normal section N and in tangential section F which it is consider a working force. Lapping force varies [2], between 0,015 N/mm^2 at superfinnish process of soft material and 0,55 N/mm^2 for hardened steel materials .



Specifically condition of lapping and tensions induce by process are then included in simulation's loads. Such example we consider friction factor of grinding given by simplifying hypothesis in consideration of a singular form of lapping abrasive grains. For this simulation we consider spheroid lapping grain only [4]

For more contrast of material's deployment we execute a Von misses factor creep simulation, how test the simulation area until material it is fracture under tension pressure.

8. Conclusion

This paper presents the developments in tooth analysis of face worm gear. The mathematical model is directly associated to both face milling and face hobbing processes with both non-generated and generated methods. A specifically tooth analytical algorithm is proposed. The geometric models are created with consideration of various tooth surface modifications.

This advance simulation use extensive information from standards: Gear calculation of load capacity of worm gears (ISO/DIS 14521.2-2006), cylindrical wormed gears–strength calculation STAS 13024-91 and ITW (Illinois Tool Works) geometry formulas to create a realistic FEA simulation.

These theoretical determinations will further validate and corrected by experimental determination.

8. References

[1] Boloş V. *Angrenare melcate spiroide, Danturarea roţilor plane*, Editura Universităţii „Petru Maior", Târgu Mureş -1999

[2] Dumitraş C., Opran C.; *Prelucrarea materialelor compozite, ceramice şi minerale*; Editura Tehnică, Bucureşti, 1994;

[3]Fan, Qi.; Wilcox Lowell, Dr.. (2007). *New developments in Tooth contact analysis (TCA) and Loaded TCA for spiral Bevel and Hypoid Gear Drives*, Publisher, Gear Technology May 2007

[4] Goddard J., Wilman H.; *A theory of friction and wear during the abrasion of metals*; Wear, nr. 5 / 1962; Sin H., Saka N., Suh N.P.; Abrasive wear mechanisms and the grit size effect; Wear, nr. 55 / 1979;

[5] STAS 13024-91 *Cylindrical wormed gears–strength calculation*

[6]INTERNATIONAL STANDARD ISO/DIS 14521.2 *Gear — Calculation of load capacity of worm gears* ISO 14521 was prepared by technical Committee ISO/TC 60, *Gears*, Subcommittee SC 1, *Nomenclature and worm gearing*

[7] Ansys Multiphysics, Release 10, Tutorials