Nat. Volatiles & Essent. Oils, 2021; 8(5): 3384 - 3393

Analysis On Bending Stress Of Helical Gear

[1]D Jeeva, [2]V Vijayakumar, [3]J Kabir Basha, [4]R Dinesh, [5]R Mohanraj

Department of Production Engineering, PSG College of Technology, Coimbatore-641004, India.
*Corresponding email address: rdh.prod@psgtech.ac.in

Abstract

Helical gears are used to transmit energy between parallel axes. They are made to transmit pressure evenly throughout the entire tooth. Helical gears operate smoother and quieter than other gears due to their tooth inclination and can transmit heavy loads efficiently. Helical gears are commonly employed in industry when power transmissions under heavy loads are required. This study used Finite Element Analysis (FEA) to determine how loads are distributed in helical gear. The helical gear, which is made of aluminum alloy and structural steel, was simulated for the process parameters derived from design considerations, and the bending stress distribution was calculated using ANSYS software. Solidworks, strong and current solid modeling software, is used to create three dimensional solid models for varying face widths, and ANSYS for a finite element analysis. In analytical research, the Lewis stress formula is employed. After that, the AGMA and FEA findings are compared.

Keywords: Helical gear, Finite element analysis, Bending stress, AGMA.

I. Introduction

Helical gears are cylindrical gears having teeth that are angled away from the gear wheel's axis of rotation. A set of helical gears has similar helix angle, however the helix hand would be in the opposite. A helical gear has teeth that are arranged at an angle. This allows the tooth to progressively mesh as the interaction progresses, starting with point contact and proceeding to line contact. The load on the mating teeth gradually increases. Helical gear has such a greater contact ratio, much gentler, have little disturbance and therefore can deliver a lot of power compared to spur gears. In helical gear, many teeth are very much in contact, leading in less strain on every tooth. Axial force causes helical gears to become misaligned. Thrust bearings and increased lubrication can help to alleviate this problem. Reverberations and wearing are reduced as forces are transferred more smoothly through one tooth towards the next tooth. In helical gear, bending stress for aluminium alloy and structural steel material are studied by modifying face width in this study..

II.Literature review

Naresh et al. [1] conducted an analysis by applying different loads to helical gear with different materials. The helical gear was developed in Solidworks software, and the analysis was carried out in ANSYS by applying various loads to various materials. Variable loads on various materials are used to investigate stress, strain, and displacement measurements. As a result of the findings, aluminum silicon carbide and grey cast iron are favored over chrome stainless steel, which showed breaking at a given load. Jadav et al. [2] performed an investigation on helical gear constructed of nylon 66 and stainless steel to estimate stress and pressure distribution. The two helical gears were developed with Pro/Engineer software, and the analysis was done with Altair Hyperwork Opti-Struct solver FEA software. According to the findings, in the first two load situations, the stress values on gear made up of nylon 66 are greater than the material's tensile strength. However, because Nylon 66 has low stress value against the yield limit in the third case, it can be used as a substitute for stainless steel in helical gear in high load scenario.

Gidado and Muhammad et al. [3] used ANSYS to analyse bending stress on helical gear. The main purpose of is to see how changing a helical gear's face width affects its bending stress. The helical gear was first modelled in Pro Engineer software, followed by analysis of stress in ANSYS. To determine how stress fluctuates with face width, bending stress is computed on a theory based and compared to the FEA result. Other characteristics like number of teeth, module, helix angle are kept constant to produce five alternative helical models. Vijayarangan and Ganesan [4] employed 3D finite element approaches to investigate displacements and stresses at different locations on helical gear teeth. The stress for gear made of C-45 steel material was used to verify the validity of their FEM results, and the results were compared to those obtained using a standard gear design equation. Also compared the performance of composite helical gears to the performance of six conventional carbon steel gears. According to the findings, composite materials can be utilised securely for power transmission, however face width must be correct. Abishek Kulkarni et al. [5] conducted a review on helical gear design and stress analysis. The root surface strength of the helical gear tooth and the surface toughness of a helical gear are studied in this study because they are a primary cause of gear pair failure. The high bending stress reduces as face width grows, and it is larger on gear with a smaller face width and a higher helix angle, according to a review of numerous research studies. Various influencing parameters such as gear ratio, helix angle and contact ratio are optimised to increase the performance and efficiency of the helical gear.

III. Methodology

a. Modeling the helical gear as per requirements using Solidworks.
b. Importing the developed design on ANSYS for numerical analysis.
c. Analysis on the developed design, meshing was done on the created model.
d. Using ANSYS, most appropriate and proper material selection for the generated gear design was performed.
e. Analysis of bending stress on the helical gear model.
f. Comparison of bending stress of helical gear made up of aluminum alloy and structural steel with the theoretical formula.

IV. Design of gears

A) Design principles in broad sense

The projected transferred power, the speed of the driving gear, the speed of the driven gear, and the centre distance all factor are considered for gear design for power transmission. The bending stress equation of helical gear tooth is provided as, and the helical appropriate bending strength criterion was designed in this study [3],

$$\sigma_b = \frac{F_t}{bmj} K_v K_o (0.93 K_m) \qquad (1)$$

Helical gears have a significantly lower sensitivity to mounting circumstances; hence a constant of 0.93 was added to the mounting element. The AGMA recommended equation.1 is used in all calculations. The diameter of a pinion gear's pitch circle was determined using the equation.2 below,

$$D \geq \frac{2T}{bmj\,[\sigma_b]} K_v K_0 (0.93 K_m) \quad (2)$$

Where,

Force transmitted (F_t) = 1326.26N

Normal module (m) = 10 mm

Face width (b) = 100 mm

Velocity Factor (Kv) = 1.34

Geometry factor (J) = 0.56

Overload factor (K_0) = 1.25

Load distribution factor (Km) = 1.3

B) Tangential force

The succeeding requirements were anticipated when manufacturing the gear as per the bending strength criterion [3],

Power (P) = 25 kW

Speed (N) = 1200 R.P.M

Torque (T_P) = $\frac{60\times P}{2\pi N}$=198.94Nm

Tangential force (Ft) $= \frac{2000\times T_p}{300} = 1326.26\text{N}$

C) Bending Stress

For five distinct face widths (b = 100 mm, 95 mm, 90 mm, 85 mm, 80 mm) are considered, the following is how the AGMA bending stress calculation is done [3],

$$\sigma_{b_{AGMA1}} = \frac{1326.26}{100 \times 10 \times 0.56} \times 1.34 \times 1.25(0.93 \times 1.3) = 4.7960 \text{ MPa}$$

$$\sigma_{b_{AGMA2}} = \frac{1326.26}{95 \times 10 \times 0.56} \times 1.34 \times 1.25(0.93 \times 1.3) = 5.0497 \text{ MPa}$$

$$\sigma_{b_{AGMA3}} = \frac{1326.26}{90 \times 10 \times 0.56} \times 1.34 \times 1.25(0.93 \times 1.3) = 5.3289 \text{ MPa}$$

$$\sigma_{b_{AGMA4}} = \frac{1326.26}{85 \times 10 \times 0.56} \times 1.34 \times 1.25(0.93 \times 1.3) = 5.6423 \text{ MPa}$$

$$\sigma_{b_{AGMA5}} = \frac{1326.26}{80 \times 10 \times 0.56} \times 1.34 \times 1.25(0.9 \times 1.3) = 5.9950 \text{ MPa}$$

V. Modeling of helical gear

Solidworks is a 3D solid modelling computer aided design tool. It includes comprehensive three-dimensional software tools for creating, simulating, publishing, and handling information. Helical gear was developed in Solidworks in this study. Five helical gear models were designed by altering the face width of the helical gear**.** Fig.1 shows the helical gear design and Fig.2 shows the helical gear pair in working condition. Table. I shows the gear design parameters.

Table. I Gear parameters [3]

S.No.	Title	Value	Units
1.	No of Teeth (Z)	30	-
2.	Module (M)	10	mm
3.	Pitch diameter(D)	300	mm
4.	Pressure angle(α)	20	degree
5.	Helix angle (β)	15	degree
6.	Face width (F)	100	mm
7.	Addendum (A)	10	mm
8.	Dedendum (B)	1.25×A	mm
9.	Power (P)	25	kW
10.	Speed (N)	1200	Rev/min

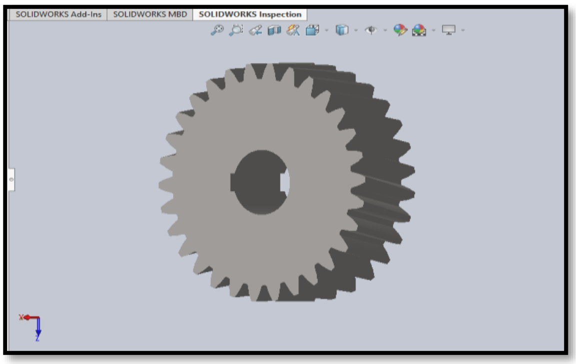

Fig.1 Design of helical gear

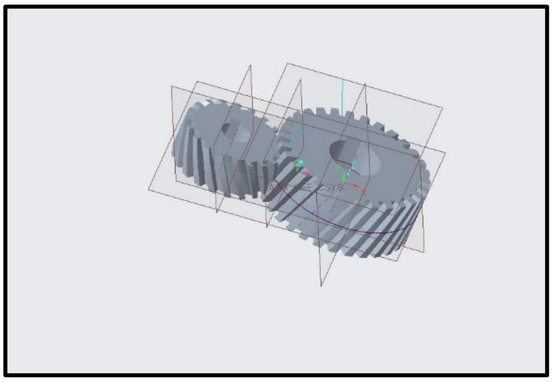

Fig.2 Helical gear pair in working condition

VI.Finite Element Analysis

The ANSYS platform is one of the basis software for the complete variety of advanced engineering simulation. By providing CAD connections, powerful strong mesh [4-5], an operation update mechanism, widespread parameter management, and incorporated optimization techniques, it enables detailed numerical study. Analysis was completed using ANSYS software. This paper used

ANSYS modal and static structural analysis. Finite element analysis (FEA) is the method of simulating a part's or assembly's response within limited circumstances. Theoretical and experimental studies are modelled using FEA, which reduces the need for real life prototyping while also enabling part improvement as part of the construction design [6-10], which is then loaded into ANSYS software. Helical gear bending stress was computed with the help of static structural analysis. Fig.3 shows the meshing of helical gear. Fig. 4 shows helical gear bending stress for aluminium alloy material which is commonly used [11-12] (Face width=80 mm). Fig.5 shows helical gear bending stress for aluminium alloy material (Face width=85 mm). Fig.6 shows helical gear bending stress for structural steel material (Face width =80 mm). Fig.7 shows helical gear bending stress for structural steel material (Face width= 85 mm).

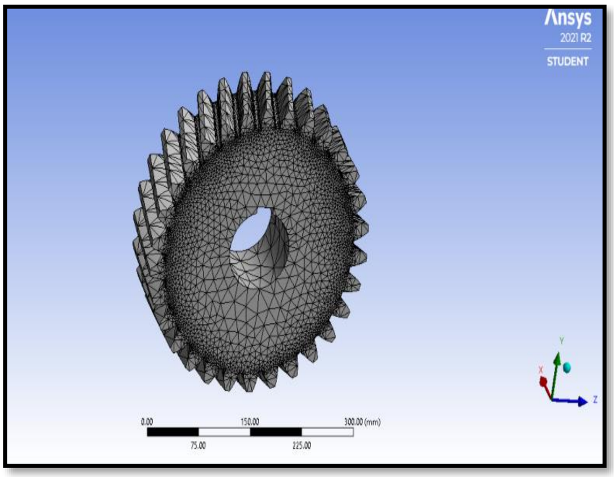

Fig.3 Mesh of helical gear

A) Boundary conditions for Aluminium alloy

Model type: Static structural
Support type: Fixed support
Mesh type: Tetrahedron
Force applied: 1326.26 N
Poison's ratio: 0.220
Modulus of elasticity for aluminium alloy: 69 GPa

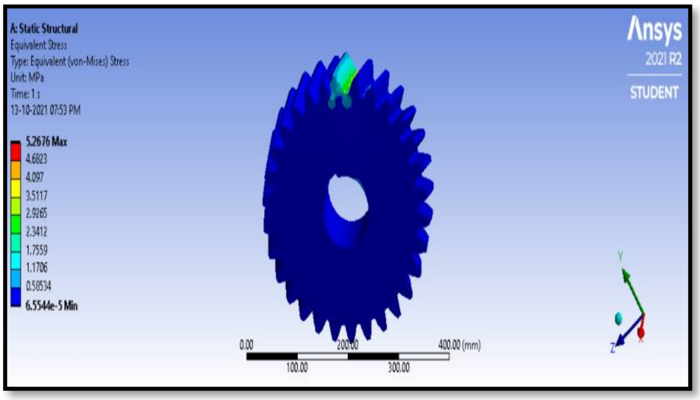

Fig.4 Helical gear bending stress for aluminium alloy material (Face width=80 mm)

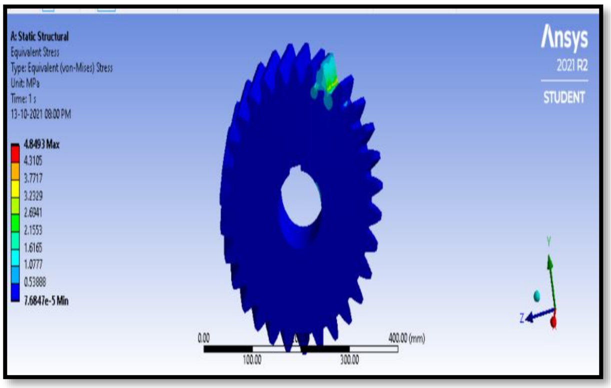

Fig.5 Helical gear bending stress for aluminium alloy material (Face width=85 mm).

B) Boundary conditions for Structural Steel

Model type: Static structural
Support type: Fixed support
Mesh type: Tetrahedron
Force applied: 1326.26 N
Poisson's ratio: 0.3
Modulus of elasticity for structural steel: 210 GPa

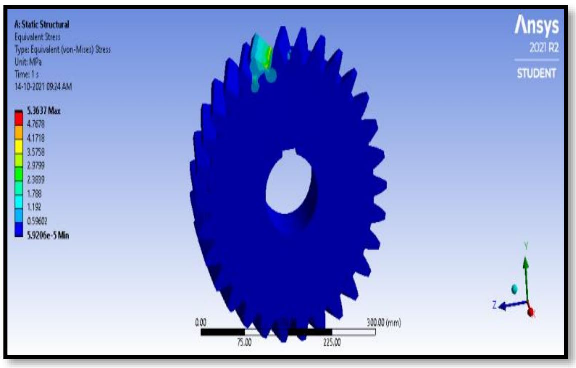

Fig.6 Helical gear bending stress for structural steel material (Face width =80 mm)

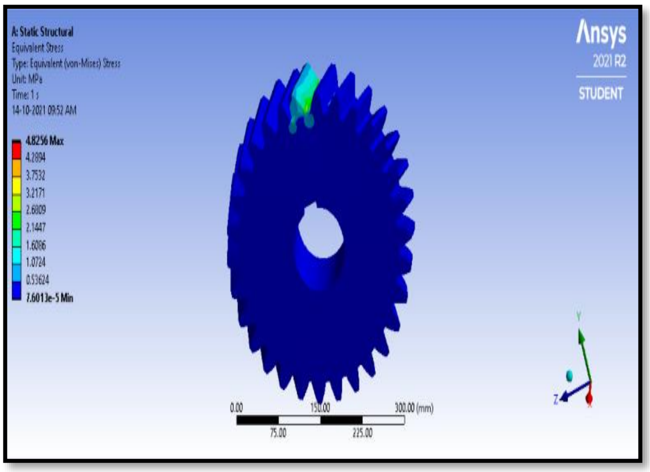

Fig.7 Helical gear bending stress for structural steel material (Face width= 85 mm)

VII. Results and discussion

Geometrical components like face width as well as helix angle are critical in defining the stress phase during gear design [13-17]. As a consequence, the purpose of this study is to conduct a computational analysis to examine how changing the face width impacts the bending stress of helical gear constructed of various materials [18-21]. To measure the stresses fluctuation with five distinct helical gear types with varying face width, various parameters like as helix angle, module, pressure angle, diameter of the pitch and so on were held constant. The findings of bending stress as a function of helical gear tooth face width are provided. Table II and III shows the bending stress comparison of theoretical and FEA results for aluminium alloy and structural steel material.

Table.II Helical gear bending stress is compared using theoretical and FEA results (Aluminium Alloy)

No	Face width in mm	Theoretical [MPa]	FEA [MPa]
1	80	5.9950	5.2676
2	85	5.6423	4.8943
3	90	5.3289	4.3708
4	95	5.0497	4.0249
5	100	4.7960	3.8744

Table.III Helical gear bending stress is compared using theoretical and FEA results (Structural steel)

No	Face width in mm	Theoretical [MPa]	FEA [MPa]
1	80	5.9950	5.3637
2	85	5.6423	4.8256
3	90	5.3289	4.4071
4	95	5.0497	4.2294
5	100	4.7960	3.9035

The value of the helical gear bending stress computed using the AGMA including that derived using the ANSYS analysis diminishes as the face width rises. As a result of the findings, we may conclude that the gear with a larger face width is appropriate for any constant force and speed**.** The helical gear bending stress is compared using AGMA and ANSYS for aluminium alloy as shown in Fig. 7, the helical gear bending stress is compared using AGMA and ANSYS for structural steel is shown in Fig. 8.

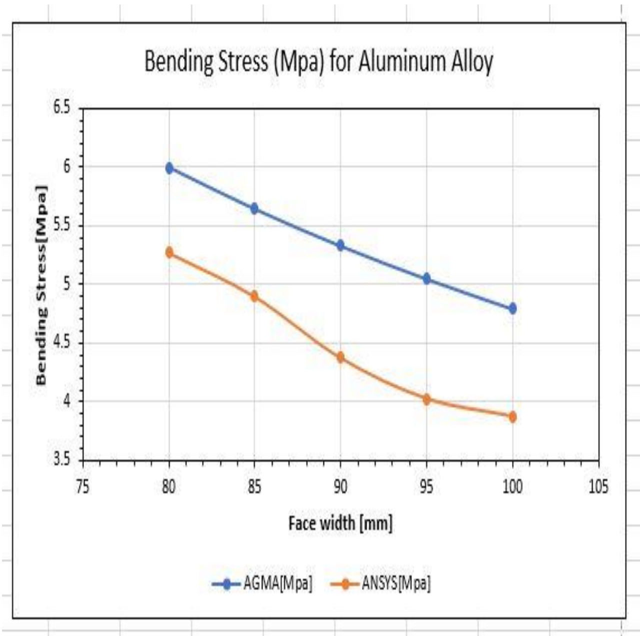

Fig.7 Graph shows the helical gear bending stress for theoretical and FEA results (Aluminium Alloy)

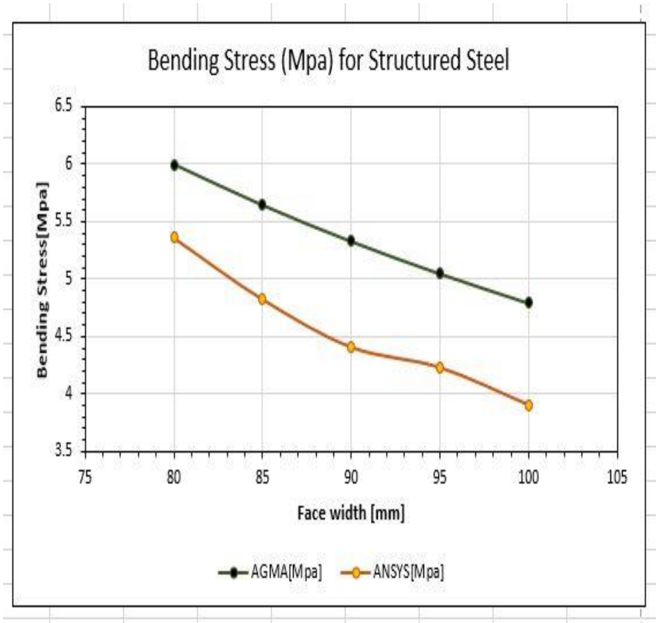

Fig.8 Graph shows the helical gear bending stress for theoretical and FEA results (Structural steel)

VIII.Conclusions

Bending stress was used to evaluate for helical gear manufactured of aluminium alloy and structural steel with varied face widths. After that, the ANSYS and AGMA results were compared, and they were found to be within a reasonable range. From the findings that the gear with a larger face width is suitable for any steady speed and load. FEA can also forecast bending stress values at any required face width, which is useful to address the complicated design challenges.

References

1. K. Naresh, C. Chandrudhu, Design and Analysis of Helical Gear, International Journal of Professional Engineering Studies, 6 (2016) 194-203.
2. P. Jadhav Prafulla, V. Bhaskar Santhosh, Design & Analysis of Helical Gear made of Stainless Steel & Nylon under Different Loading Conditions, International Journal of Engineering Research and Technology, 5 (2016) 546-552.
3. A.Y. Gidado, I. Muhammad, A. A. Umar, Design, Modeling and Analysis of Helical Gear According Bending Strength using AGMA and ANSYS, International Journal of Engineering Trends and Technology, 8 (2014) 1-5.
4. S.Vijayarangan, N. Ganesan, A Static Analysis of Composite Helical Gears using a Three-dimensional Finite Element Method, 49 (1993) 253-268.
5. Abhishek Kulkarni, Shubham Lonkar, Prafull Pachare, S. J. Gulhane, Review Paper on Design and Stress Analysis of Helical Gear and Manufacturing Through Rapid Prototyping Method, International Research Journal of Engineering and Technology, 5 (2018) 478-482.
6. Mohanraj R, Elangovan S, Arunkarthik B, Pratheesh Kumar, Maaz Baig N, Shriram Al, Muneeskumar M (2021), Effect of process parameters on tensile strength and surface quality of PLA-ABS part produced by fused deposition modelling. Indian Journal of Engineering & Materials Sciences, 28, 300-310.
7. S.Pratheesh Kumar, S.Elangovan, R.Mohanraj, S. Boopathi (2021), Real-time applications and novel manufacturing strategies of incremental forming: An industrial perspective. Materials Today: Proceedings, 46, 8153-8164.
8. S.Pratheesh Kumar, S.Elangovan, R.Mohanraj, B.Srihari (2021), Critical review of off-axial nozzle and coaxial nozzle for powder metal deposition. Materials Today: Proceedings, 46, 8066-8079.
9. S.Pratheesh Kumar, S.Elangovan, R.Mohanraj, V.Sathya Narayanan (2021), Significance of continuous wave and pulsed wave laser in direct metal deposition. Materials Today: Proceedings, 46, 8086-8096.
10. R.Mohanraj, S.Elangovan, V.Kesava Chandran, M.F.Mohamed Sulaiman, R.Harsha Pradhaa, S.Poojasri, J.R.Ramakrishna (2021), Numerical analysis on bending and contact stress of single and double start worm drive. Materials Today: Proceedings, 46, 8038- 8044.
11. S.Pratheesh Kumar, S.Elangovan, R.Mohanraj, S.Boopathi (2021), A comprehensive review in incremental forming on approaches of deformation analysis and surface morphologies. Materials Today: Proceedings, 43, 3129-3139.
12. Mohanraj, R., Elangovan, S., Shanmathy, A.R. (2021), Experimental Investigation on Electrically Assisted Incremental Sheet Metal Forming of Ti-6Al-4V Alloy. In: Mohan, Santhakumar, Shankar, S., Rajeshkumar, G. (Eds.) Materials, Design, and Manufacturing for Sustainable Environment. Lecture Notes in Mechanical Engineering. Springer, Singapore.
13. U.B. Wanarase, U.S. Patil, N.B. Patil, Review paper on worm gear analysis, Int. J. Eng. Sci. Res. Technol. 6 (2017) 277–281.
14. Design Data Book, PSG College of Technology, M/s. DPV Printers, Coimbatore, 2012.
15. R.G. Budynas, J.K. Nisbett, Shingley’s Mechanical Engineering Design, Mc Graw Hill, New York, 2015.
16. S.S. Maheedhara, F. Pourboghrat, Finite element analysis of composite worm gears, J. Thermoplast. Compos. Mater. 20 (2007) 27–51.
17. M. Ranjith, M. Hidayatulla Sharief, design and assembly analysis of a worm assembly in a gear box, Int. J. Magaz. Eng. Technol. Manage. Res. 4 (2017) 86–90.

18. F. Yang, D. Su, and C. R. Gentle, 2001, Finite Element Modelling and Load Share Analysis for Involute Worm Gears with Localized Tooth Contact, Proceedings of the Institution of Mechanical Engineers, Part C: Journal Of Mechanical Engineering Science, 215 805–816.
19. A. P. Shah and Y. Jadhav, 2020 Design, Analysis and Experimental Study of Worm and Worm Gear Pair for Plug Valve Application.
20. Wojciech Kacalak, Maciej Majewski and Zbigniew Budniak, Worm Gear Drives With Adjustable Backlash, Journal of Mechanisms and Robotics, 8 (2015), 14504-14511.
21. I.H. Seol, F.L. Litvin, Computerized design, generation and simulation of meshing and contact of modified involute, klingelnberg and flender type worm-gear drives, J. Mech. Des. 118 (1996) 551–555.