JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Effect of contact stress on the varying helix angle of helical gears

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Abstract: Symmetric helical gear has been using in a distinct part of the gearbox. The surface contact between helical gear drives plays a vital role in developing contact stress. The study deals with better results regarding the reduction in contact stress of the gear drives. An accurate involute profile of helical gear has been modelled as per ISO with the help of KISSsoft software and simulation was carried out for the application of tangential load on varying helix profile on gear drives. This analysis indicates the contact characteristics to get equivalent outcomes using ANSYS and compared with the results of AGMA stress. The contribution of the surface contact lines changes significantly depending on the helix angle, which describes the results with a reduction in contact stress values.

Keywords: Helical gear, AGMA Stress, ANSYS, KISSsoft, Solidworks, Pressure angle, Face width.

1. INTRODUCTION:

Gear is used to change the speed, magnitude, and direction of the power source. Gear sets are one of the fundamental components of rotating mechanical elements, which are widely applicable in numerous engineering applications due to their compactness and high torque-to-weight ratios. The gear tooth profile is typically determined by the generating cutting tool (gear hob or sharper cut) on the tooth tip trajectory. The design and manufacture of precision gears are made from high-strength materials. The gear teeth should have sufficient tensile strength so that they will not fail under static and dynamic loading during normal running conditions.

The helical gears should be strong; corrosion resistant, light-weight and durable for a long time. The design of a helical gear pair is a complex process. Helical gear can fail due to excessive bending stress at the root of the gear tooth or surface contact stress. These can change by minimizing bending and contact stress or by modifying the geometry or parameters of the gear tooth.

Gidado A.Y [1] worked on different face widths are increasing, there is a corresponding decrease in the value of the tooth bending stress of a helical gear calculated from AGMA as well as that obtained from ANSYS analysis. Gambhir et al. [2] found that as the drive side pressure angle increases, the contact stress on teeth reduces as compared to symmetric involute helical gear. D. Deepak [3] investigated the characteristics of a helical gear system mainly focused on bending and contact stress using analytical and FEA. Bozca M [4] identified the helix angle influence on the helical gear load carrying capacity, including the bending and contact relation, which has been determined for constant pressure angle. Sarkar G.T et al. [5] used FEA software to simulate a 3D model of a gear to determine the bending stress and compare it to the AGMA stress. Simon V. [6] developed results for the estimation of load and stress distribution in helical gear. The load distribution variables are affected by the number of teeth and the width of the face. Sonali A. et al. [7] carried out the design of gear as per AGMA equation and carried out the analysis on the material which is best suited for helical gear based on results. Patil J. [8] studied the effect of pressure angle and helix angle at the root of helical gear tooth under dynamic state to reduce the total bulk of the gearbox. Miryam B. [9] obtained critical value of stress with critical load condition utilized in a complete analysis of the tooth bending strength has carried out for bending load capacity of the helical gear. Jabbour T. [10] presented a method to calculate the distribution of the stress at the tooth root and of the Bending stress is maximum on each line of a pair helical gear.

2. DESIGN OF GEAR

These gears transmit more power and can utilize at high speeds and noiseless operations. The increase in fatigue life and the reduction of bending stress, root fillet is introduced in the design of helical gear. KISSsoft software has proposed a helical gear with specifying all the parameter used to generate the tooth profile. Fig. 1 shows the KISSsoft parameters to input the specific values in the software, which has consider to be Addendum (h_{aP}), Dedendum (h_{fP}), Protuberance height (h_{prP}), Protuberance Angel (α_{prP}), Ramp Angle (α_{KP}), Root fillet radius (ρ_{fP}).

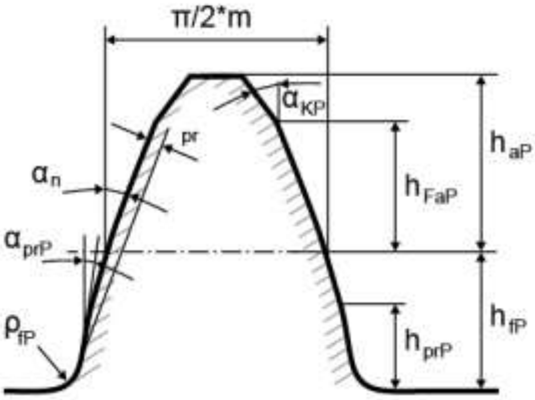

Fig. 1. Tooth Profile

To Proceed the calculation of the helical gear parameters, the Design text book G Maitra has considered [12]. The calibrated values of the helical gear have tabulated in **Table 1**. The material properties of the gear are tabulated in the below **Table 2**.

Table 1 Helical Gear Parameters

S/N	Variable Name	Description Value (mm) (KW)	Pinion	Gear
1	Z	No. of Teeth	18	36
2	M_n	Normal Module	4	
3	D	Pitch Diameter	74.20	148.40
4	θ_p	Pressure Angle	20	
5	β	Helix Angle	14^0(RH)	14^0(LH)
6	F	Face Width	40	
7	a	Addendum	4	4
8	b	Dedendum	5	5
10	D_t	Tip Circle Diameter	82.20	156.40
11	D_r	Root Circle Diameter	64.20	138.40
12	C	Clearance	0.3	0.3

Table 2 Material Properties of Gear

S no	Description	Unit
1	Material Type	ALLOY STEEL-15Ni5Cr4Mo1
2	Working temperature	850-1150
3	Tensile strength	1350 MPa
4	Yield strength	720 MPa
5	Density	7850 kg/m3
6	Young's modulus	210 GPa
7	Poisson ratio	0.3

AGMA (American Gear Manufacturing Association) stress theory is a standardized calculation methodology of gear tooth design for the tooth Contact stress, which has considered for the study for evaluation of contact stress. This study depends upon on the tangential force acting between the surface tooth of the pinion and gear. For the calculation of tangential force, we need to execute the force analysis which is depends on the parameters like normal module, helix angle, gear teeth, speed of the gear and power acting on the pinion shaft. There are two type of contact ratio found in helical gears such as face contact ratio **Eq. (1)** and transverse contact ratio **Eq. (2)**. The total contact ratio **Eq. (3)** is calculated to be the summation of both **Eq. (1)** and **Eq. (2).**

- Face Contact Ratio (CR_{FA}):

$$CR_{FA} = \frac{F\sin\beta}{aM_n} \tag{1}$$

- Transverse Contact Ratio (CR_{TR}):

$$(CR_{TR}) = \frac{\sqrt{{r_{a1}}^2 - {r_{b1}}^2} + \sqrt{{r_{a2}}^2 - {r_{b2}}^2} - a\sin\alpha}{P_b} \tag{2}$$

- Total Contact Ratio (CR_t):

$$CR_T = CR_{FA} + CR_{TR} \tag{3}$$

- AGMA Contact Stress Formulae:

$$\sigma_c = C_p \sqrt{\left(\frac{F_t}{FDI}\right)\left(\frac{\cos\beta}{0.95 \times CR_T}\right) K_v K_o (0.93 K_m)} \tag{4}$$

For the theoretical value of contact stress (σ_c) **Eq. (3)** has considered to calculate the accurate value of contact stress in **Eq. (4)**. All the necessary factor has considered from [11-15] with considering all type of graphs with various limitation such as overload factor (K_o) is defined for uniform driven machinery with light shock source of power, velocity factor (K_v) is considered after calculating the tangential velocity from the velocity factor graph, Load distribution factor (K_m).

Fig. 2. CAD model of helical gears

The parameters and the materials properties used for gear modelling as mentioned above. In order to do Contact stress analysis on the helical gear drive, a helical gear model is developed as shown in **Fig. 2** and imported to ANSYS workbench in static structural module in the format of STEP. The material of helical gear is added as mentioned in the **Table 2**.

3. STATIC STRUCTURAL ANALYSIS

The helical gear model is meshed with very fine quality of Tetrahedron method, in which the number of nodes and elements are shown in Table 3. **Fig.3** Shows the fine meshed elements of the 14^0 helix angle of helical gear in the similar way other five helical gears has been meshed and detail is mentioned in the **Table 3**.

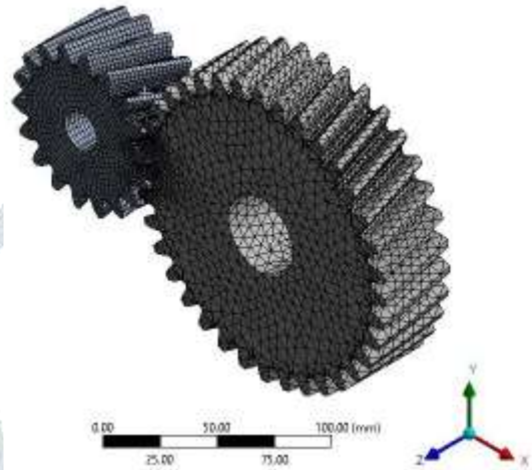

Fig. 3. Helical gear drive with 14^0 helix angle.

Table 3 Number of Nodes and Element of different helix angle of helical gear drives.

HELIX ANGLE	14^0	16^0	18^0	20^0	22^0
NO. OF NODES	256232	785962	263268	256324	273754
NO. OF ELEMENTS	145872	428634	162540	145752	173526

4. RESULTS AND DISCUSSION

The Finite Element stress analysis has been carried out by using ANSYS software, the Von-Mises equivalent stress distribution for a helical gear. In the present case of torque of 150.06 Nm and 4044.96 N load is applied on the teeth of the helical gear drive. The finite element analysis shows that the maximum von-mises stress 359.91 N/mm^2 is developed on the helical gear tooth as shown in **Fig. 4.**

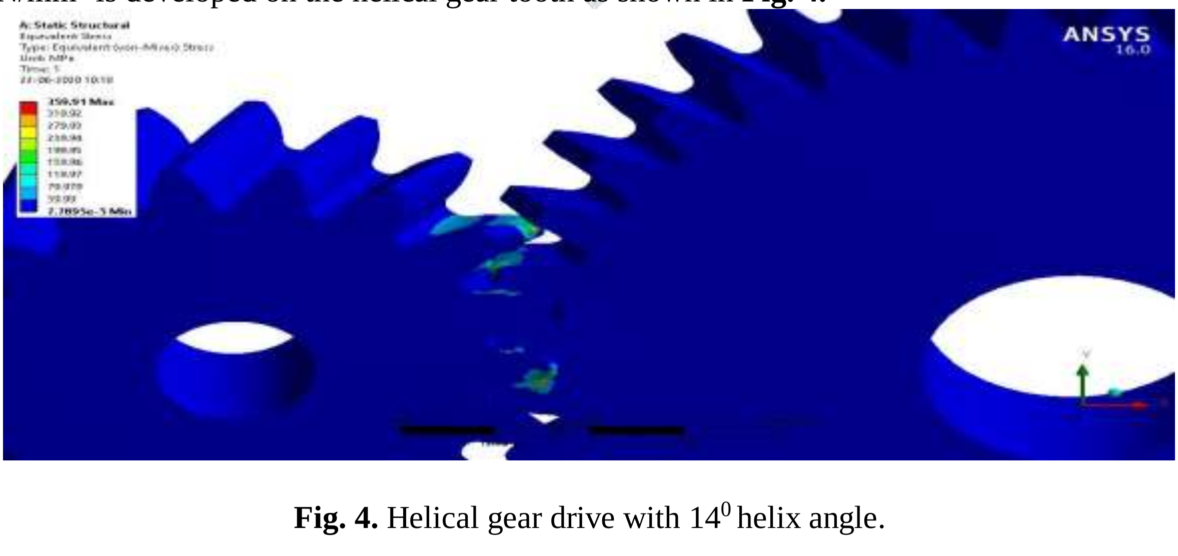

Fig. 4. Helical gear drive with 14^0 helix angle.

Consequently, by varying the Helix angel and keeping the other parameters, factors constant with various models of the helical gear are analysed and four of the models created by varying Helix angle are shown in **Fig. 5, Fig. 6, Fig. 7** and **Fig. 8.**

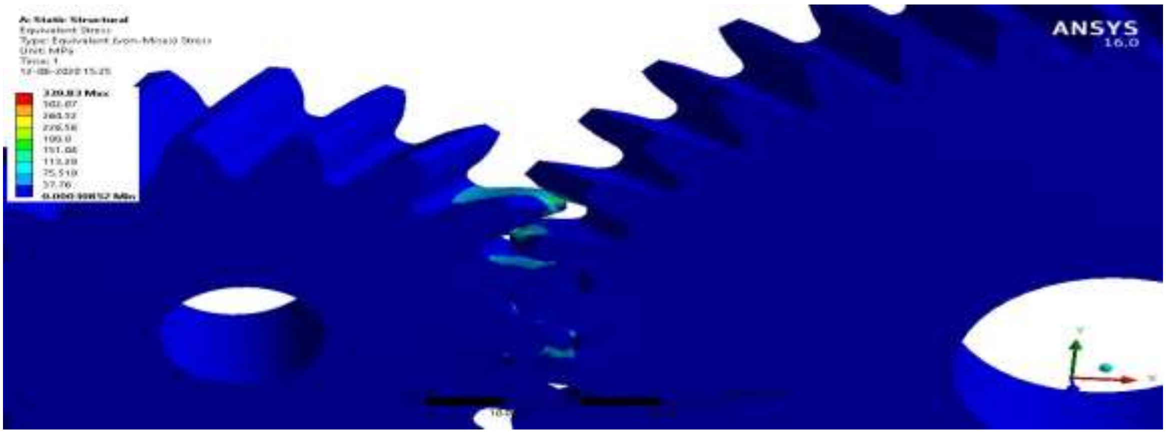

Fig. 5. Helical gear drive with 16^0 helix angle.

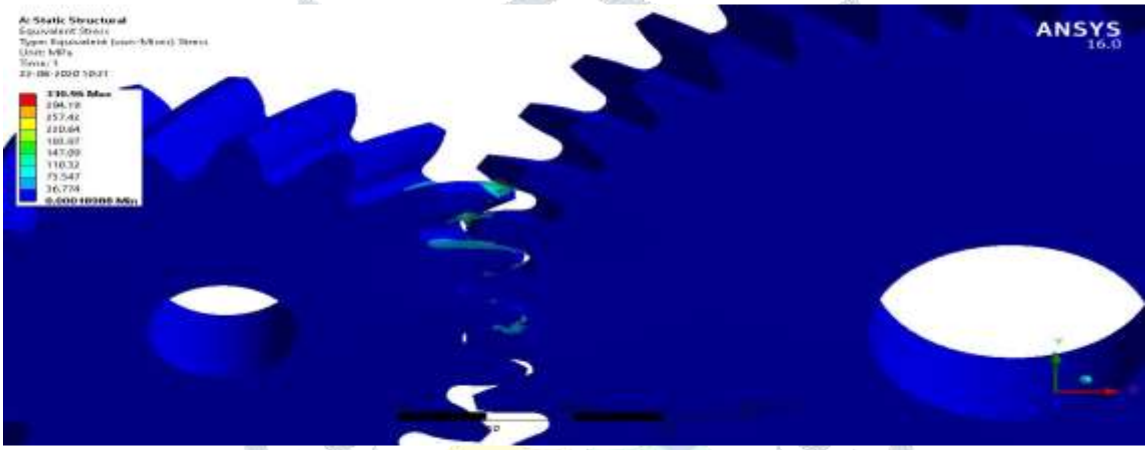

Fig. 6. Helical gear drive with 18^0 helix angle.

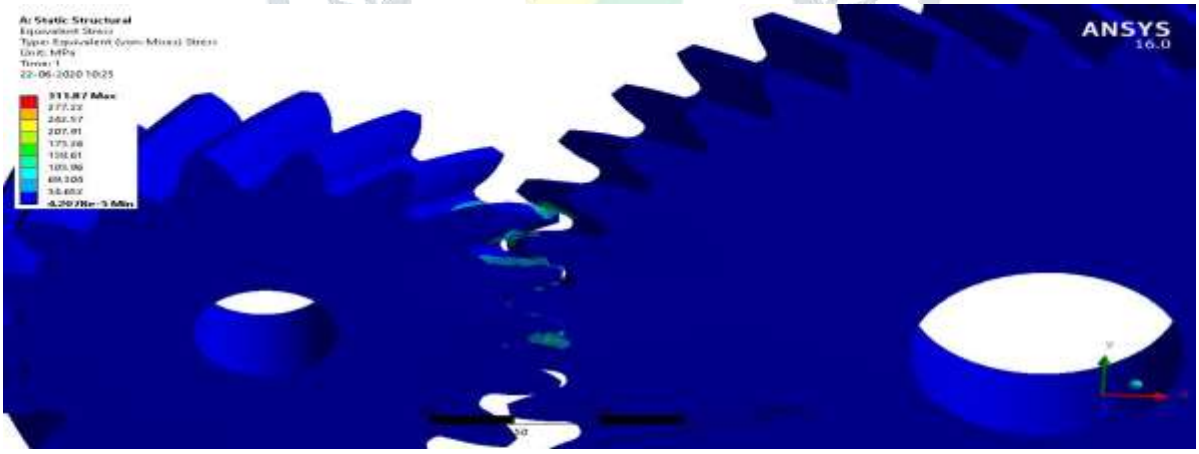

Fig. 7. Helical gear drive with 20^0 helix angle.

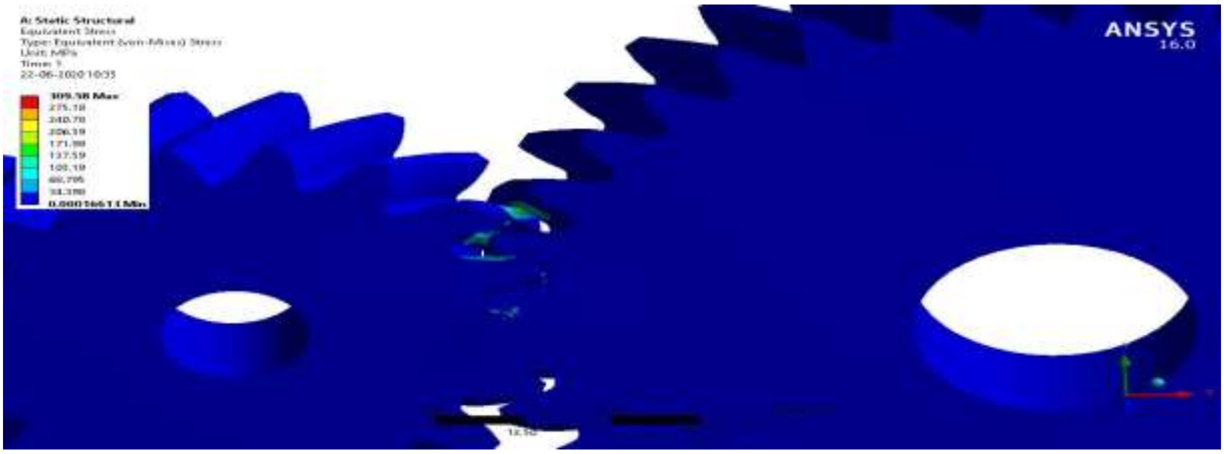

Fig. 8. Helical gear drive with 22^0 helix angle.

The surface of tooth contact in gear drives is visible in **Fig. 2.** The maximum stress has generated at the contact point and contact stress propagated along diagonally. The increased helix angle causes the increase in total contact ratio as [15]. The sum of face contact ratio and overlap contact ratio has drawn as the contact area between the teeth of the helical gear.

The comparison of results both numerically and analytically obtained from the design of helical gear presented in **Table 4.**

Table 4 Contact Stress value for existing design

S/N	Helix angle [Degree]	AGMA [Mpa]	ANSYS [Mpa]	Differences [%]
1	14	365.10	359.91	3.7
2	16	350	339.90	2.9
3	18	336.10	330.10	1.8
4	20	322.80	311.90	3.4
5	22	311.40	309.58	0.58

The above table shows that as the Helix angle increasing there is decreasing in contact stress of the helical gear calculated from AGMA as well as obtain from ANSYS analysis. **Fig. 9**. shows the graph of contact stress against the helix angle.

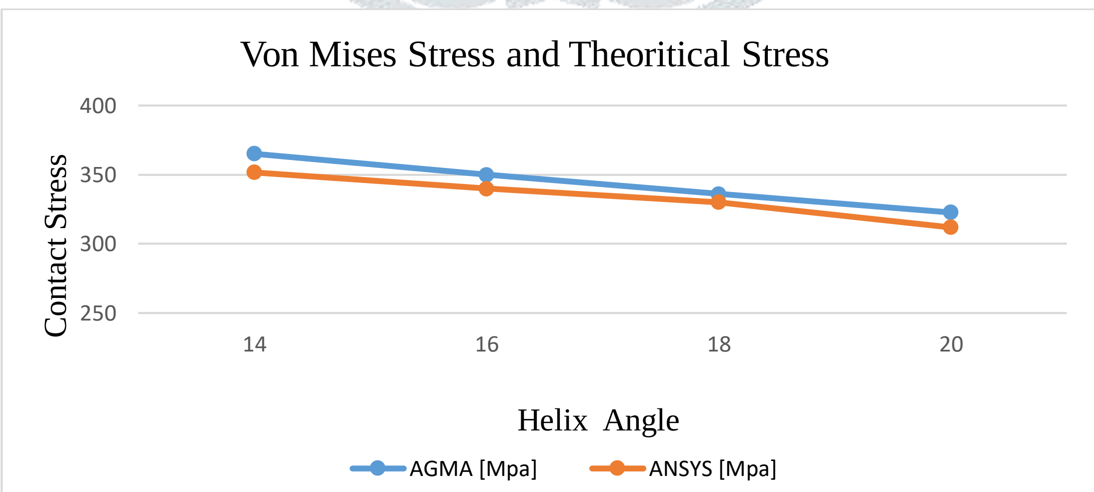

Fig. 9. Relation between Contact stress and helix angle at 5975N of tangential load with increase in helix angle

Fig.9. describes an accuracy of the analytical value and theoretical value of the contact stress, analysis of varying helix angle with reduction of error from 3.4% to 0.58%. The amount of increase in contact ratio could increase the possibility of decrease in contact stress by analysing the simulation results, which satisfies

the increasing value of the helix angle could be the result of the reduction in contact stress in the helical gear mates. Above graph represents the number of increases in helix angle can lead to a decrease in Contact stress.

5. CONCLUSION

The results of performed in research allow the following conclusions to be defined:

- The critical contact stress obtained at the point of contact between the gear mates, so a reduction in Contact stress in symmetric helical gear drive occurs with an increase in Helix angle of the helical gear.
- The maximum decrease in Contact stress occurs in Gear with Helix angle of 22^0 with 12 % of reduction in Contact stress.
- The noise generation can be observed, due to the increase in the area of contact in Helical Gear.

REFERENCES

[1] Gidado, A. Y., I. Muhammad, and A. A. Umar. "Design, Modeling and Analysis of Helical Gear According Bending Strength Using AGMA and ANSYS." International Journal of Engineering Trends and Technology (IJETT), ISSN (2014): 2231-5381.

[2] Gambhir, Jairaj, et al. "Effect of Drive Side Pressure Angle on Load Carrying Capacity of Asymmetric Involute Helical Gear." IJAPIE-SI-IDCM 612 (2018) 57–61.

[3] D. Deepak. "Load Sharing Based Analysis of Helical Gear using Finite Element Analysis Method."

[4] Bozca, Mehmet. "Helix Angle Effect on the Helical Gear Load Carrying Capacity." World Journal of Engineering and Technology 6.04 (2018): 825.

[5] Sarkar, G. T., Yenarkar, Y. L., & Bhope, D. V. (2013). Stress analysis of helical gear by finite element method. International Journal of Mechanical Engineering and Robotics Research, 2(4), 1-8.

[6] Simon, V. "Load and stress distributions in spur and helical gears." (1988): 197-202.

[7] Sonali A. et al. "Design and FEM Analysis of Helical Gear." International Journal of Engineering Research and Advanced Technology (IJERAT), Volume.4, Issue 4 April -2018.

[8] Patil, Prashant Jaysing, Maharudra Patil, and Krishnakumar Joshi. "Investigating the effect of helix angle and pressure angle on bending stress in helical gear under dynamic state." World Journal of Engineering (2018).

[9] Sanchez, Miryam B., José I. Pedrero, and Miguel Pleguezuelos. "Critical stress and load conditions for bending calculations of involute spur and helical gears." International Journal of Fatigue 48 (2013): 28-39.

[10] Jabbour, T., & Asmar, G. (2015). Tooth stress calculation of metal spur and helical gears. Mechanism and Machine Theory, 92, 375-390.

[11] Bhandari V B (2012), Design of Machine Elements, 2nd Edition, Tata Mc-Graw Hill Publishing Company Limited.

[12] Gitin M Maitra, "Handbook of Gear Design", 2nd Edition

[13] ISO gear standards, http://www.iso.org/.

[14] AGMA standards, http://wwwagama.org/.

[15] Shigley, Joseph Edward. Shigley's mechanical engineering design. Tata McGraw-Hill Education, 2011.