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Original Article

Analysing Bevel Gears for Efficient Power Transmission: A Study on Design, Simulation and Performance Assessment

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ABSTRACT

Bevel gears find application in transmitting motion between unequally aligned shafts, typically forming a 90° angle relative to each other. Some of the several types that are available commercially are the straight bevel, the Zerol bevel, the spiral bevel, and the hypoid. Stainless steel, gray cast iron, titanium alloy and structural steel were used for the behavioural assessment. The design and modelling of the straight bevel gears were carried out using SolidWorks 2015, while ANSYS 18.2 was employed simulating to simulate the gears' stress and deformation. The 3D solid model generated using SolidWorks was imported into ANSYS, where the analysis was conducted using the finite element software, ANSYS Workbench. Stress distribution plot, deformation plot, and equivalent strain plot were generated. The highest stress, measuring 73.536 MPa, became evident as the load concentrated near the base of the gear teeth. The finite element analysis revealed a minimal likelihood of gear failure, and the least deformation was observed in the structural steel configuration, resulting in a deformation of 8.2354 x 10^-3 mm. Consequently, the gear pair can successfully transmit 6 kW of power without experiencing any failures with a good safety factor.

APA CITATION

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INTRODUCTION

Bevel gears feature teeth intricately shaped along the surface of a cone frustum, distinct from the cylindrical teeth seen in spur and helical gears. They must share a common apex to ensure smooth engagement between two such cone-frustum-shaped gears, without any slipping. This demands precise alignment when mounting bevel gears on their respective shafts. This alignment ensures that the gear teeth elements converge to form a singular apex point. This ensures that the pitch surfaces of the interlocked bevel gears maintain a consistent relationship with their distance from the shared apex, enabling smooth pure rolling motion. Because bevel gears have conical pitch surfaces, the dimensions of their teeth vary from the front end (toe) to the larger back end (heel) of the gear. Conventional practice in bevel gear technology entails meticulously defining the size and shape of the tooth profile at the gear's larger extremity, the back end.

The validation of bevel gear performance involved comparing the Algorithm's computations and the results produced by developed models (Oladejo & Bamiro, 2009; Akinnuli, et al., 2015; Abu, et al., 2016). Bevel CAD's effectiveness was confirmed, with slight variations attributed to approximation inaccuracies. Bevel CAD streamlines efficiency, reducing the tedium of extensive calculations, making it a recommended tool for both industrial and educational settings engaged in bevel gear design.

Bevel gears are typically found on shafts with a 90^{o} separation, but they can be customized for different angles (Rufus et al., 2016; Oladejo & Ogunsade, 2014). These gears have a conical pitch surface, and when two bevel gears mesh, it is known as bevel gearing. The pitch cone angles of the pinion and gear depend on the shafts' intersection angle. Bevel gears have widespread applications, including use in locomotives, marine vessels, automobiles, printing presses, cooling towers, power plants, steel plants, and railway track inspection machines.

The modelling application allows manipulation of a 3D gear model using predefined parameters based on geometric relationships and constraints (Ramana-Rao et al., 2013; Ligata & Zhang, 2011). Changing these parameter values alters the gear's shape, enabling rapid parameter-driven model creation for force and stress analysis. This modelling approach has potential applications in cone crushers, with software modification to calculate contact stress and acceleration variations in the driven wheel during meshing (Dong et al., 2011; Oladejo et al., 2018). Tooth modification significantly influences stress distribution, mitigating issues like load concentration, agglutination, and pitting.

Stress distribution at the tooth root of bevel gears is assessed under various load scenarios, including uniformly varying loads and concentrated loads at the pitch point (Mohan & Jayaraj, 2013; Oluwole et al., 2014). This study involves recalculating gear blanks while keeping flank geometry and tooth-cutting process unchanged (Karlis et al., 2014; Edward & Lucky, 2018; Raj & Jayaraj, 2013). Optimized tooth ends enhance tooth strength, streamline gear blank geometry, align with modern machining practices, and reduce outer gear diameter.

Bevel gears are vital in differential drives for transferring power to axles with varying speeds (Oladejo et al., 2021). They find use in cornering automobiles, hand drills, and redirecting shaft orientation. A comparison between the Lewis equation and ANSYS Workbench yielded similar results. Monte Carlo simulation's accuracy depends on sample quantity, with more samples enhancing precision but increasing computational costs. Varying fitness levels during optimization can mitigate this computational burden.

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Standards govern bevel gear design, analysis, and production (Ratnadeepsinh et al., 2013. Bending stress in bevel gear teeth is calculated using the Lewis bending stress equation applied to beams. Parametric design can be a foundation for finite element stress analysis or assembly procedures (Kurlapkar& Mirza, 2016). Macros successfully assembled a set of bevel gears, demonstrating precise gear meshing.

A study investigated the failure of a crown wheel and pinion set, attributing it to compromised raw material composition (Albert et al., 2006). Another approach aimed to harmonize bending stress distribution in both the pinion and gear (Zhou et al., 2017; Oladejo et al., 2017). An analytical examination of elastic-plastic stress distribution within a rotating orthotropic annular disc was conducted (Çallıoğlu et al., 2006). Dynamic models explored the interplay between surface wear on a gear and its dynamic behaviour (Ahmet & Ding, 2006; Oladejo, et al., 2018).

An asymmetric toothed gear was applied to enhance bending-related fillet strength (Kumar et al., 2008; Abu et al., 2016). Maximum fillet stress was examined to improve bending-related capacity, showing benefits, especially at higher-pressure angles.

A gear model derived from analytical simulation was compared with experimental tests using strain gauges (Al-Qrimli et al., 2016; Oladejo & Bamiro, 2009). Strain gauge measurements were conducted on a modified bevel gear. The primary focus of the present study involved the design and analysis of straight bevel gears, including 3D model creation and simulations to study bending stress, strain, and deformation across various materials.

MATERIALS AND METHODS

This study aims to design and analyse a straight bevel gear, create a 3D model using Solidworks, run stress simulations on the generated model and compare the simulation result to the numerical analysis result. The behaviour of different materials will be assessed under certain loading conditions. The materials that will be used for the behavioural assessment of the bevel gear (Figure 1) under certain loading conditions include: *(i) Gray cast iron, (ii) Stainless steel, (iii) Structural steel, and (iv) Titanium alloy,* and their properties are stated in *Table 1*.

Figure 1: Bevel Gear Profile

Table 1: Material Properties for Behavioural Assessment

Parameter	Gray cast iron	Stainless steel	Structural steel	Titanium alloy	Unit
Young's Modulus	1.1×10^5	1.93×10^5	2×10^5	96000	MPa
Specific Heat	4.47×10^5	4.8×10^5	4.34×10^5	5.22×10^5	mJ/kg·°C
Ultimate Tensile Strength	240	586	460	1070	MPa
Density	7.2×10^{-6}	7.75×10^{-6}	7.85×10^{-6}	4.62×10^{-6}	Kg/mm^3

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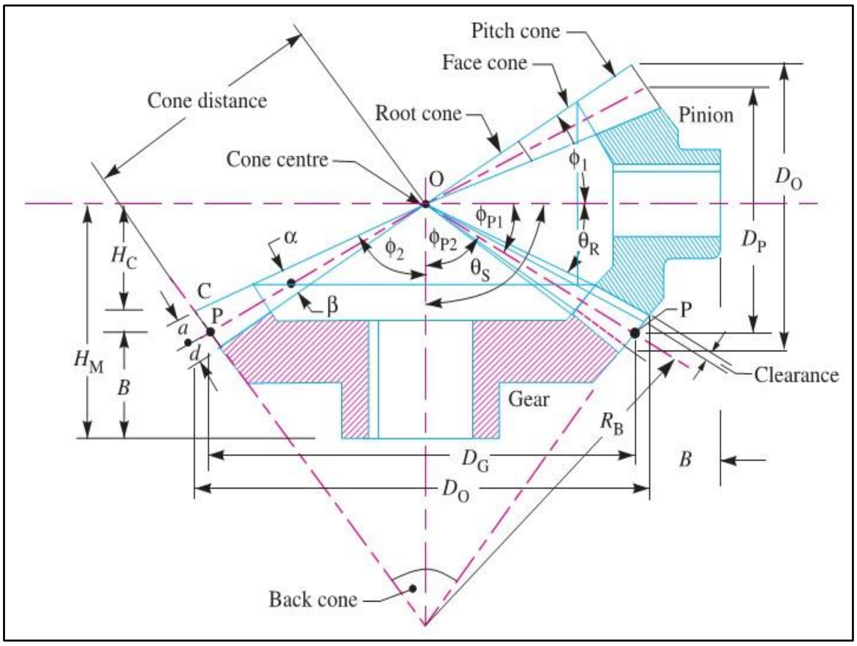
Design Equations

For the design of the bevel gear, a nomenclature is defined for the gear in *Figure 2* and the parameters and formulae for its design are stated in *Tables 2* and *3*.

Figure 2: Bevel Gear Nomenclature



Source: (Khurmi & Gupta, 2005)

Table 2: Bevel Gear Design Equations

Parameter	Formula
Velocity ratio or Gear ratio	V.R. = $\frac{D_g}{D_p} = \frac{T_g}{T_P} = \frac{N_P}{N_g}$
Pitch angle of pinion	$\theta_{P1} = \tan^{-1}\left(\frac{1}{V.R.}\right) = \tan^{-1}\left(\frac{D_P}{D_g}\right) = \tan^{-1}\left(\frac{T_P}{T_g}\right) = \tan^{-1}\left(\frac{N_g}{N_p}\right)$
Pitch angle of gear	$\theta_{P2} = \tan^{-1}(V.R.) = \tan^{-1}\left(\frac{D_g}{D_p}\right) = \tan^{-1}\left(\frac{T_g}{T_p}\right) = \tan^{-1}\left(\frac{N_p}{N_g}\right)$
Addendum Deddendum Clearance Clearance Working Depth Thickness of tooth Face width Mean Pitch Diameter	*a* = 1 m *d* = 1.2 m c = 0.2 m c = 0.2 m w = 2 m t = 1.5708 m b = 0.25 x OC $D_m = D - b\sin\theta_p$
Circumferential velocity on the Mean Pitch circle	$V_m = \frac{\pi D_m n}{6000}$
Nominal tangential load on the Mean	$F_t = \frac{p}{V_m}$ pitch circle
Bending Stress	$\sigma_b = \frac{F_m}{bmj} K_v K_o K_m$

Source: (Khurmi & Gupta, 2005)

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Table 3: Design Parameters

Parameters	Pinion	Gear	Unit
Power	6	6	kW
Number of teeth	20	30	-
Pitch circle diameter	100	150	mm
Module	5	5	mm
Pressure angle	20°	20°	Degree

Stress due to Bending in Bevel Gears

According to AGMA standard, Equation (1) is employed to determine the bending stress in bevel gears.

$$\sigma_b = \frac{2T}{d}\,\frac{Gr}{FmJ}\,\frac{K_a K_m K_s}{K_v K_x} \quad (1)$$

Where T = Torque; d = Diameter of gear; F = Face width; m = Module; Gr = Gear ratio; J = Geometry factor of gear; K_a = Application factor = 1; K_m = Load distribution factor 1.6; K_s = Size factor = 1; K_v = Dynamic factor = 1; K_x = Gear geometry factor = 1 for straight teeth bevel gear, = 1.15 for spiral bevel gear and zerol bevel gear

Load Calculation

The load calculation entails determining both the torque and tangential load exerted on the bevel gear. Consider a bevel gear with the following;

The speed of bevel gear (n) = 500 rpm and Power transmitted = 6 kW

Torque transmitted *(M_t)* is determined using Equation (2).

$$M_t = 9.5488 \times \frac{power(w)}{speed(rpm)} \quad (2)$$

$$M_t = 9.5488\frac{6\times 1000}{500}$$

M_t = 114.586 Nm = 114586 Nmm

Tangential component (*Pt*) is evaluated with Equation (3).

$$P_t = \frac{2\times M_t}{d} \quad (3)$$

$$P_t = \frac{2\times 114586}{100} = 2291.72\ N$$

Bending Stress

$$\sigma_b = \frac{P_t}{m\times b\times y\left(1-\dfrac{b}{A_o}\right)} \quad (4)$$

Where, y = Lewis form factor

$\left(1-\dfrac{b}{A_o}\right)$ = Bevel Factor

A_o =

$$A_o = \sqrt{\left(\frac{D_p}{2}\right)^2+\left(\frac{D_g}{2}\right)^2} = \sqrt{\left(\frac{100}{2}\right)^2+\left(\frac{150}{2}\right)^2} = 90.139\ mm$$

$$B = \frac{A_o}{3} = 30.05\ mm$$

$$\sigma_b = \frac{2291.72}{5\times 30.05\times 0.32\left(1-\dfrac{30.05}{90.139}\right)} = 71.50\ N/mm^2$$

MODEL DEVELOPMENT PROCESS USING SOLIDWORKS

A three-dimensional solid model of a bevel gear using SolidWorks was developed. The development involves the following steps.

Sketch the Gear Profile

Sketch the gear profile as shown in *Figure 3* and produce the solid model as shown in *Figure 4*. Utilize sketching tools to depict the tooth profile of the bevel gear, referencing Figure 5 for guidance. Generate a tooth structure resembling the one presented in *Figure 6*.

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Revolve the Tooth Profile

Use the "Revolve Boss/Base" feature. Select the sketch profile as the profile to revolve and specify the axis of rotation (centerline of the gear). Set the angle to 360 degrees to obtain the profile shown in Figure 7.

Create the Bevel Gear Teeth

The subtract tool in the “Combine” feature was used to create the teeth as shown in Figure 8.

Add the Second Bevel Gear (Pinion)

Similar steps were followed to create the second bevel gear (Figure 9) which is pinion.

Combine Gears in an Assembly

An assembly file was opened and the two gears were inserted into the assembly. The "Mate" tool was used to define the relationship and movement between the gears (Figure 10).

Save

The SolidWorks file is saved in “IGES” format for export to finite element analysis (FEA) software.

Figure 3: Sketch of the bevel gear

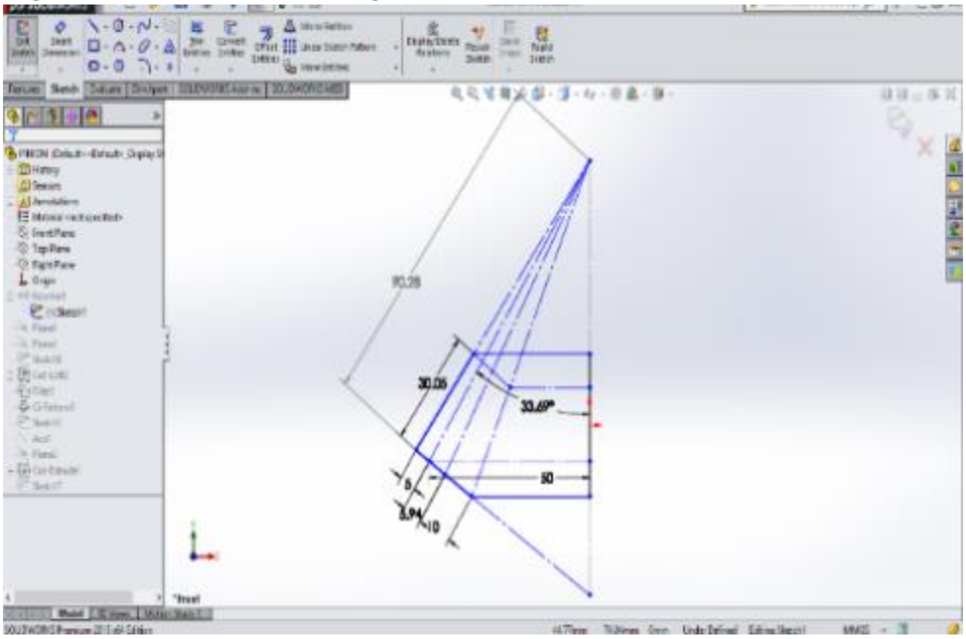

Figure 4: Solid model of the bevel gear

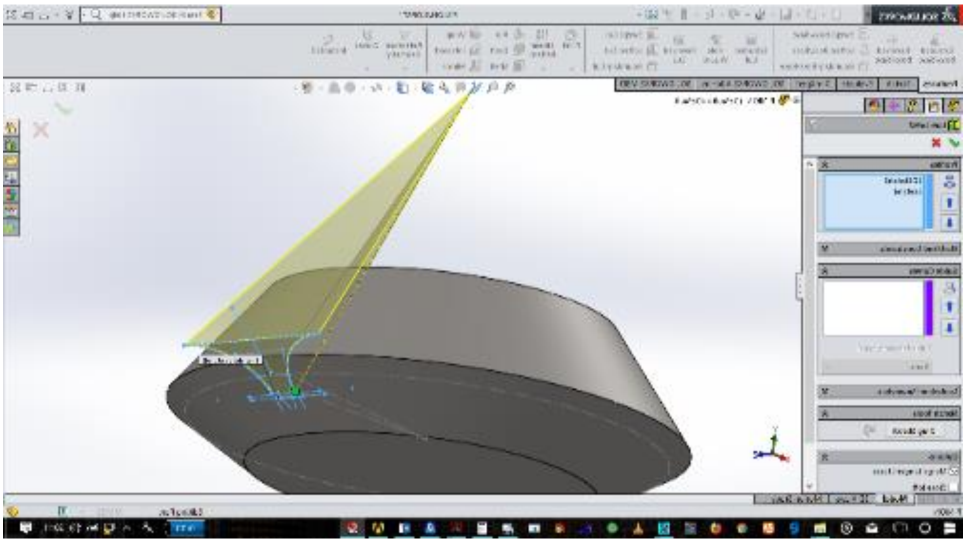

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Figure 5: Using sketch tools to draw the tooth profile

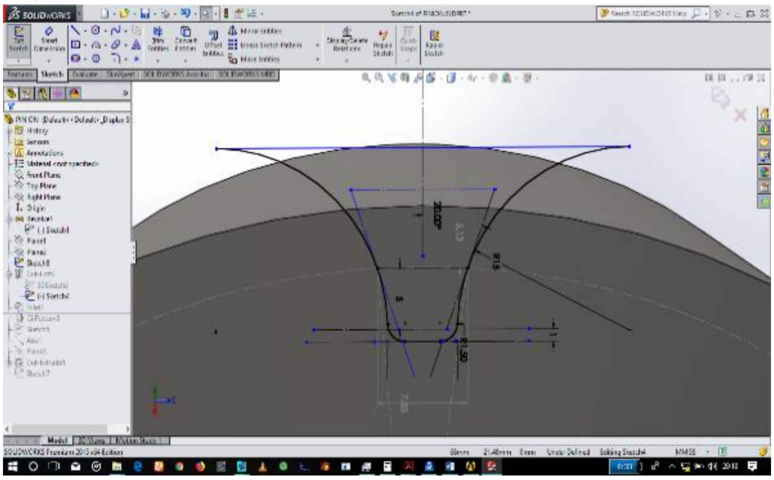

Figure 6: Development of a tooth profile

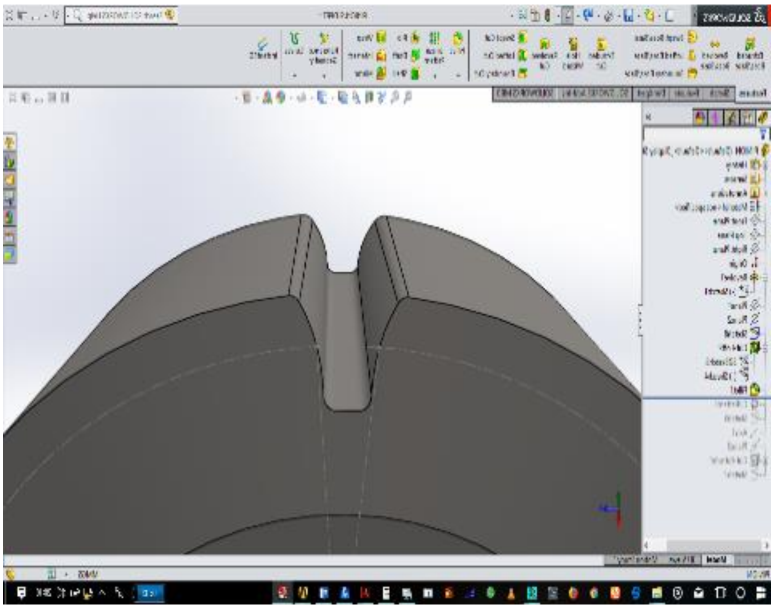

Figure 7: Revolving the tooth profile

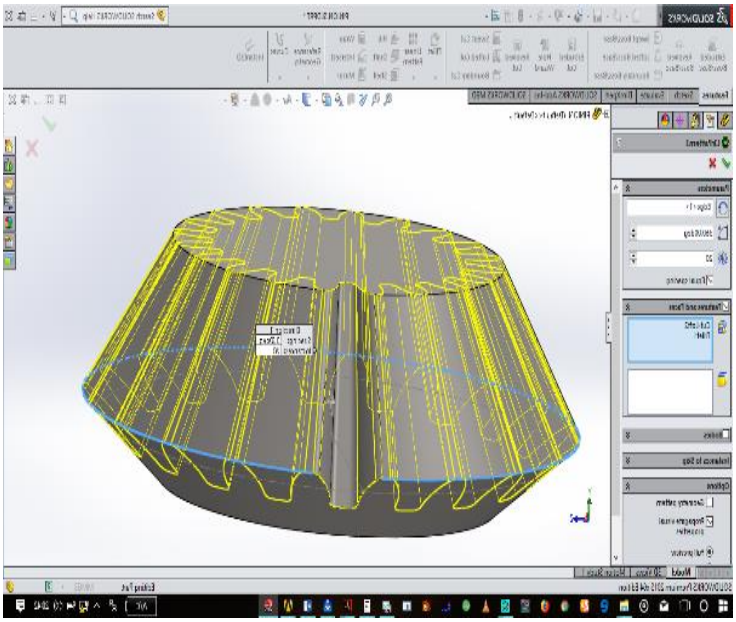

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Figure 8: The developed 3D model of the gear

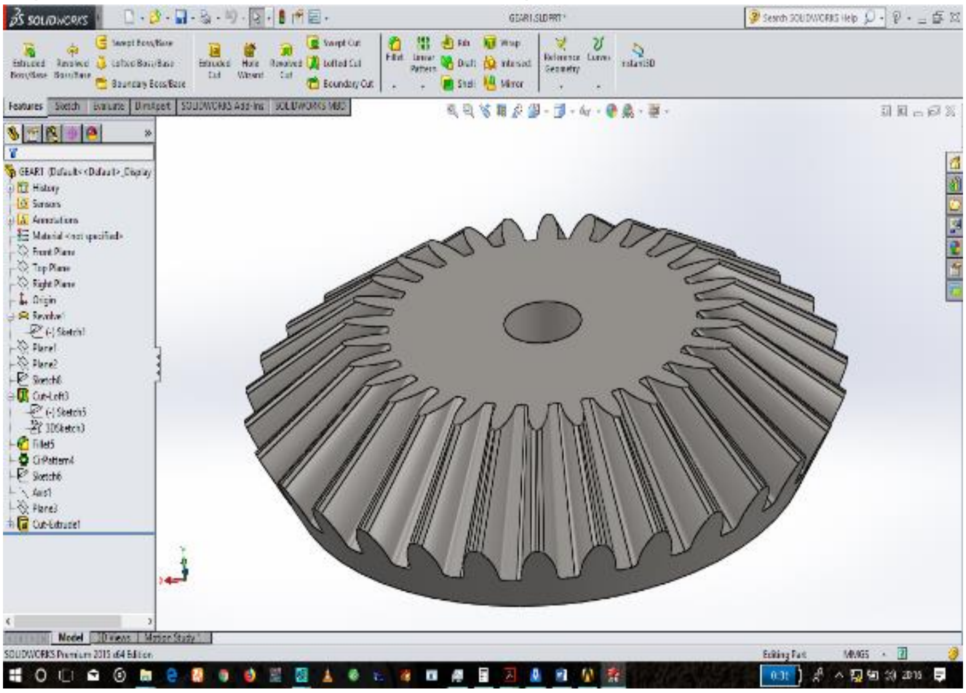

Figure 9: The developed 3D model of the gear

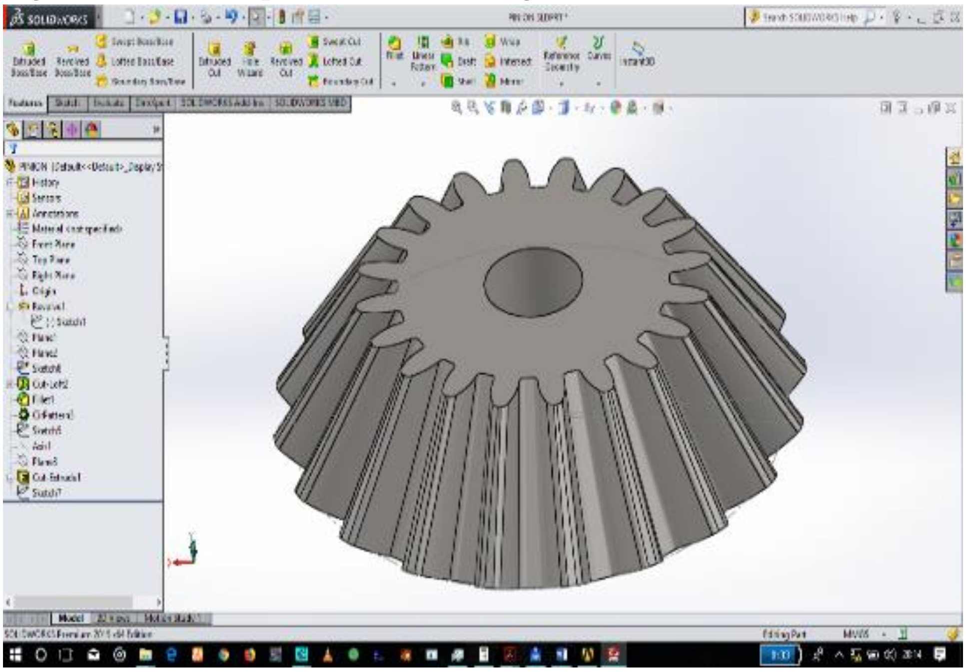

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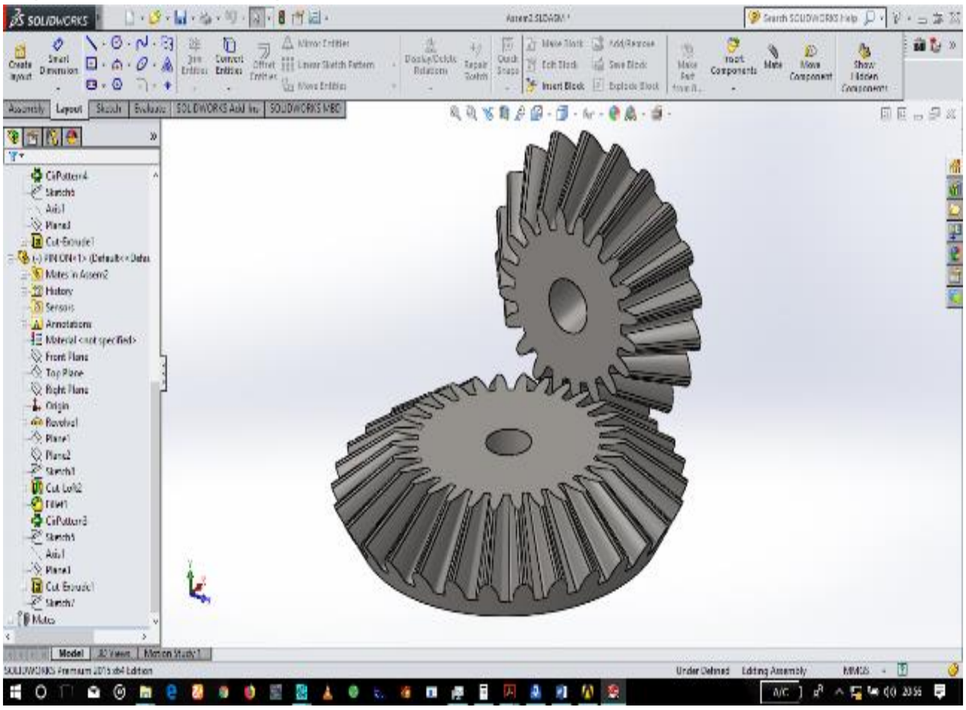
Figure 10: Assembling of Pinion and Gear

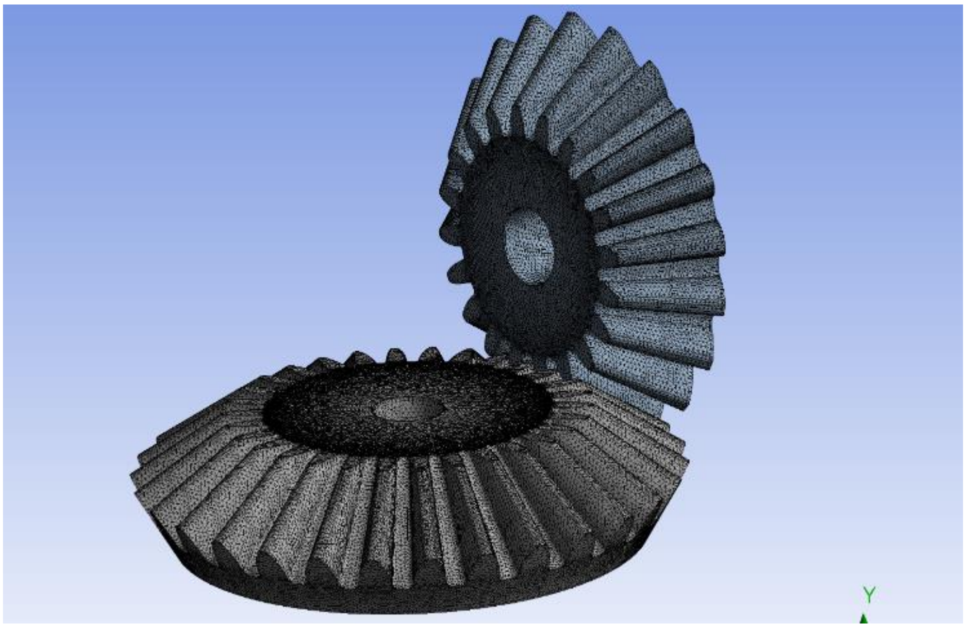


ANALYSIS OF 3D MODEL OF THE BEVEL GEARS

Finite Element Model

The SolidWorks software generated a comprehensive three-dimensional solid model, which was subsequently imported into ANSYS. The subsequent analysis involved the application of the finite element (FE) program, ANSYS Workbench 19.1. The initial 3D solid model constitutes an assembly comprising two interlocking gears, as depicted in Figure 11. This assembly consisted of a total of 598,289 elements. The subsequent step encompassed a stress analysis of the solid model, with the primary objective being the determination of both normal and shear stresses.

Figure 11: Meshing of Gear Pair



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Loading and Boundary Conditions

The load is exerted as a moment, with a magnitude of 114586 Nmm, acting upon both faces of the pinion. The pinion's bore is supported without friction, while the gear is affixed with fixed support. The frictionless support on the bore enforces a normal constraint across the entire surface. This arrangement permits translational movement in all directions except perpendicular to the supported plane.

RESULTS AND DISCUSSION

The results of a mechanical analysis conducted on bevel gears using the ANSYS Workbench software were obtained to evaluate the bending stress, strain, and deformation of the gears made from different materials (structural steel, stainless steel, gray cast iron and titanium alloy). *Figure 11* presents a visual representation of the equivalent stress distribution across the bevel gears. This implies that the greatest stress is concentrated near the base of the teeth, with an approximate maximum stress value of 73.536 MPa recorded for Titanium Alloy.

Table 4 displays the numerical outcomes of the material analysis individually. The bending stress values resulting from the applied loads span a range of approximately 73.05 MPa to 73.54 MPa across various materials (depicted in Figures 12 to 15), with structural steel exhibiting the lowest stress level. Regarding strain values, they vary from around 4.2453 x 10^{-4} to 8.795 x 10^{-4} mm/mm among the different materials, with structural steel again demonstrating the least strain. The deformation measurements encompass a range of approximately 8.2354 x 10^{-3} to 1.7466 x 10^{-2} mm across diverse materials, with structural steel registering the lowest deformation.

Figure 12: Bending Stress analysis of Bevel Gears in ANSYS Workbench

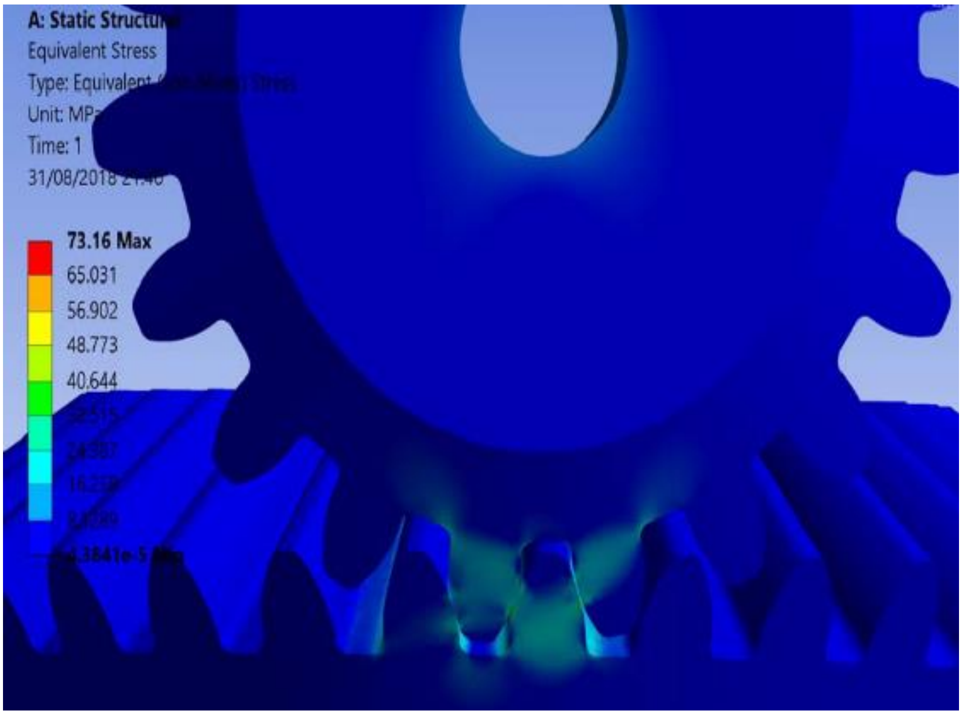

Table 4: Bending Stress, Strain and Total Deformation of Bevel Gears in ANSYS

Materials	Bending Stress (MPa)	Strain (mm/mm)	Deformation (mm)
Structural Steel	73.16	4.2453 x 10^{-4}	8.2354 x 10^{-3}
Stainless Steel	73.216	4.3954 x 10^{-4}	8.5613 x 10^{-3}
Gray Cast Iron	73.055	7.732 x 10^{-4}	1.4875 x 10^{-2}
Titanium Alloy	73.536	8.795 x 10^{-4}	1.7466 x 10^{-2}

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Figure 13: Deformation of Bevel Gears in ANSYS Workbench (Structural Steel)

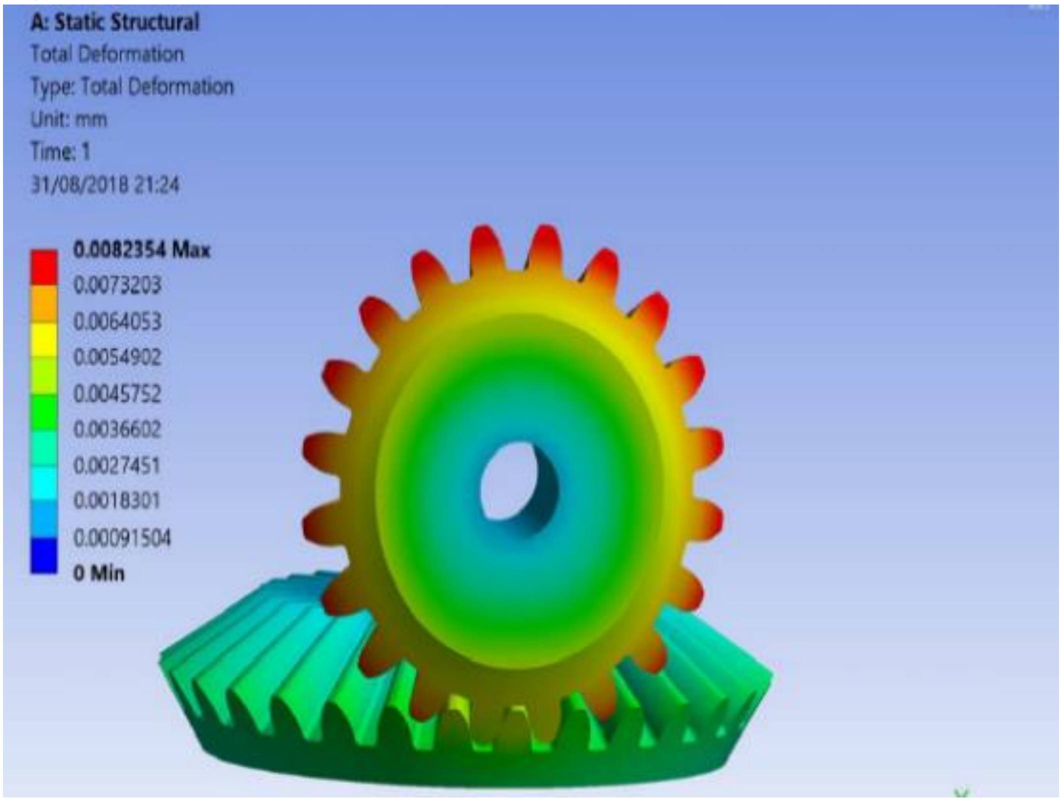

Figure 14: Deformation of Bevel Gears in ANSYS Workbench (Stainless Steel)

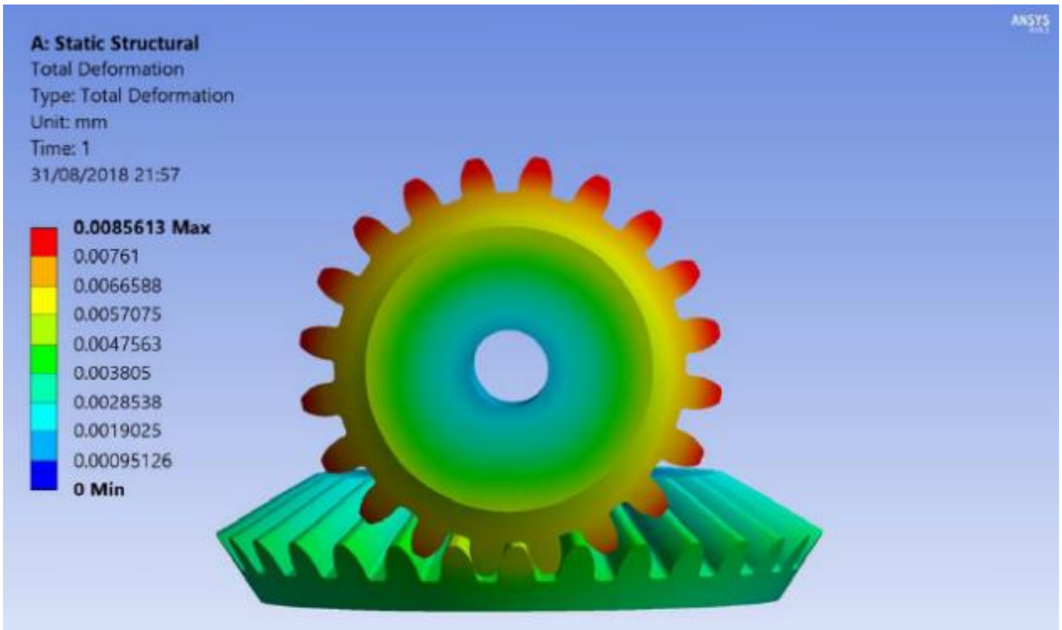

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Figure 15: Deformation of Bevel Gears in ANSYS Workbench (Gray Cast Iron)

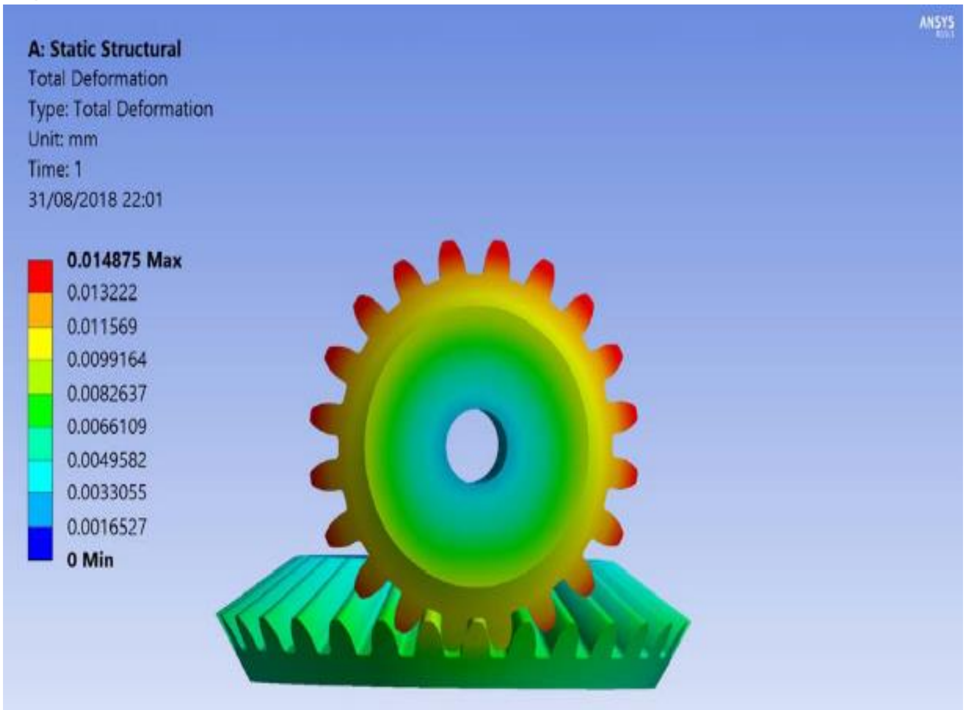
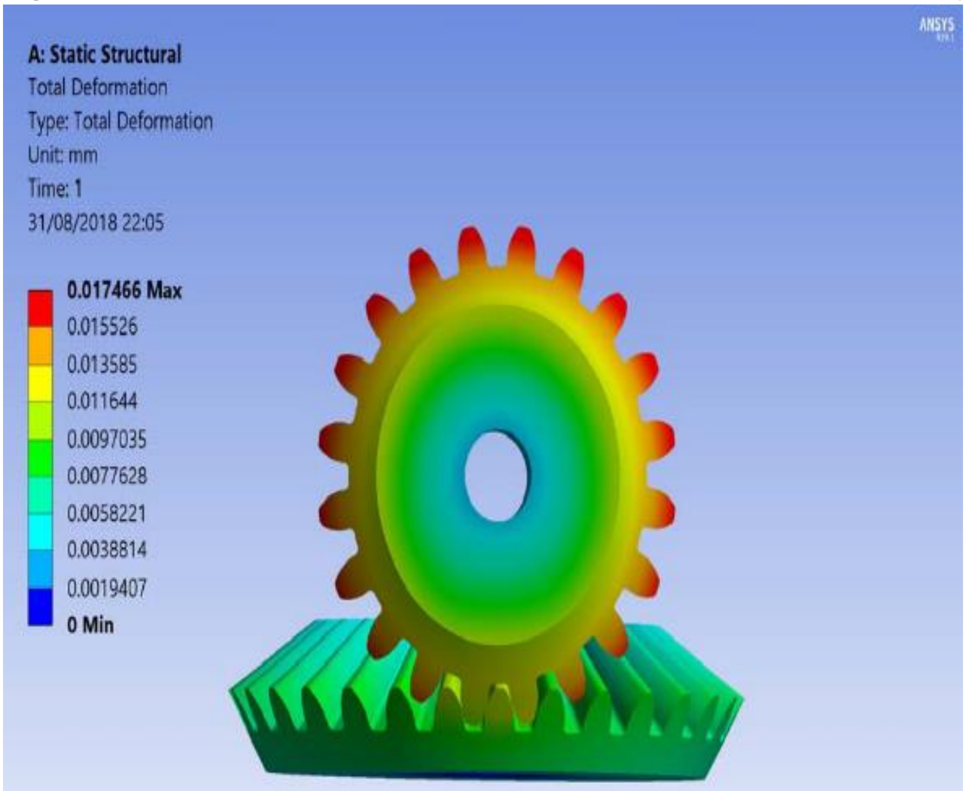


Figure 16: Deformation of Bevel Gears in ANSYS Workbench (Titanim Alloy)



CONCLUSION

A straight bevel gear was designed, analysed, and simulated using a combination of SolidWorks and finite element analysis (ANSYS Workbench). The behaviour of the gear was assessed under different loading conditions, considering various materials such as gray cast iron, stainless steel, structural steel, and titanium alloy. The results showed that structural steel exhibited the lowest deformation (8.2354×10^{-3} mm) among the materials tested. The gear pair made of structural steel can be used

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to transmit the 6kW power without the gear failing. This study offers significant insights into the design and analysis of bevel gears, underscoring the crucial role of material selection and modelling in enhancing gear performance and reliability across a range of mechanical applications.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abu, R., Ajao, O.J., & Oladejo, K.A. (2016). Development of computer-based model for gear design and analysis. Proceedings of the 3rd International Conference of Mechanical Engineering, Energy Technology and Management (IMEETMCon), University of Ibadan. 7-9 September 2016. 92-113pp.

Ahmet, K., & Ding, H. (2010). A methodology to predict surface wear of planetary gears under dynamic conditions. *Mechanics Based Design of Structures and Machines*, 38(4), 493-515. DOI: 10.1080/15397734.2010.501312

Akinnuli, B. O., Agboola, O. O., & Ikubanni, P. P. (2015). Parameters determination for the design of bevel gears using computer aided design. *British Journal of Mathematics and Computer Science*, 9(6), 537-558. http://sciencedomain.org/review-history/9852

Albert, B, Jayakumar, S.S., Dhasan, M.L., Govindan, N., & Rajadurai, A. (2006). *Failure investigation of crown wheel and pinion. Engineering Failure Analysis*, 13(8), 1285-1292. DOI: 10.1016/j.engfailanal.2005.10.002

Al-Qrimli, H.F., Khalid, K.S., Abdelrhman A.M., A. Mohammed R.K., & Hadi, H.M. (2016). A review on a straight bevel gear made from composite. *Journal of Materials Science Research*, 5(3), 73-82. DOI: 10.5539/jmsr.v5n3p73

Dong, Y., Huanyong, C., Xijie, T., Qingping, Z., & Pengfei, Xu, (2011). Research on Tooth Modification of Spur Bevel Gear, *The Open Mechanical Engineering Journal*, 5, 68-77.

Çallıoğlu, H., Topcu, M., & Tarakcılar, A. R. (2006). Elastic–plastic stress analysis of an orthotropic rotating disc. *International Journal of Mechanical Sciences*, 48(9), 985–990. doi:10.1016/j.ijmecsci.2006.03.008

Edward, E. O., & Lucky, A. (2018). Design of straight bevel gear for pitting resistance. *FME Transactions*, 46, 194-204. doi:10.5937/fmet1802194O

Karlis, P, Arturs, I., & Toms, T. (2014), Spiral bevel gears with optimised tooth-end geometry. *Procedia Engineering*, 69, 383 – 392. doi: 10.1016/j.proeng.2014.03.003

Khurmi, R.S., & Gupta, J.K. (2005). Machine design. Ram Nagar, New Delhi: Eurasia Publishing House (PVT.) LTD.

Kumar, V.S., Muni, D.V., & Muthuveerappan, G. (2008). Optimization of asymmetric spur gear drives to improve the bending load capacity. *Mechanism and Machine Theory*, 43(7), 829-858. DOI: 10.1016/j.mechmachtheory.2007.06.006

Kurlapkar, R.R., and Mirza, M. (2016). Design and static structural analysis of bevel gear. *International Journal of Engineering Trends and Technology*, 35(7), 309-313. DOI: 10.14445/22315381/IJETT-V35P264

Ligata, H., & Zhang, H. H., (2011). Geometry definition and contact analysis of spherical involute straight bevel gears. Proceedings of the IAJC-ASEE, International Conference, 163, ENG 107, ISBN 978-1-60643-379-9.

Article DOI: https://doi.org/10.37284/eaje.7.1.1735

Mohan, R. N., & Jayaraj, M. (2013). Design of contact stress analysis in straight bevel gear. *International Journal of Computational Engineering Research*, 3(4), 145 – 148.

Oladejo K. A, Oriolowo K. T, Abu R. & Ibitoye O, (2021). Analysis for Involute Spur Gears, the Bendings and Pittings Stress on Gears. *Applied Engineering*, 5(2): 51-59. doi: 10.11648/j.ae.20210502.13

Oladejo, K. A., Abu, R., Oriolowo, K. T., Adetan D. A., & Bamiro, O. A., (2018). Development of computer-based model for design and analyses of worm gearing mechanism. *EJERS, European Journal of Engineering Research and Science*, 3(12), 84-90. DOI: http://dx.doi.org/10.24018/ejers.2018.3.12.1040

Oladejo, K. A, Adetan, D. A., Ajayi, S. A., & Aderinola, O. O, (2017). Finite element simulation of bending stress on involute spur gear tooth profile. *International Journal of Engineering Research in Africa*, 30, 1-10, Revised: 2017-03-18. doi:10.4028/www.scientific.net/JERA.30.1

Oladejo, K. A., & Bamiro, O. A, (2009). Technical survey of gear-drives design and manufacturing practices in some selected states in Nigeria. Proceedings of the 1st Faculty of Technology Conference, OAU, Nigeria, Vision 20: 2020, (RETAV), 69 – 73 pp.

Oladejo, K. A., & Ogunsade, A. A. (2014). Drafting of involute spur-gears in autocad-vba customized environment. *Advancement in Science and Technology Research, (ASTR)*, 1 (2), 18-26.

Oluwole, O., Oladejo, K. A., & Abu, R. (2014). Literacy across scientific curriculum–case for regular across board curriculum enhancement by standardization boards using stakeholders. *International Journal of Scientific and Engineering Research, (IJSER)*, 5(3), 380-388.

Raj, N. M., & Jayaraj, M. (2013). Design of contact stress analysis in straight bevel gear. *International Journal of Computational Engineering Research*, 3(4), 145-148.

Ramana-Rao, A.V., Bhanu-Prakash, C. H., & Sivaram, K.M. (2013). Parametric modelling of straight bevel gearing system and analyze the forces and stresses by analytical approach. *International Journal of Engineering Trends and Technology, (IJETT), (*4)9, 3837.

Rufus, O. C., Samuel, I.U., Abdulrahim, A.T., & Benjamin, I.C. (2016). Design, modeling, application, and analysis of bevel gears. *International Journal of Engineering Research and Applications*, 6(4) (Part - 3), 44-52.

Ratnadeepsinh, M.J., Dipeshkumar M.C., & Jignesh, D.L, (2013), Bending Stress Analysis of Bevel Gears. *International Journal of Innovative Research in Science, Engineering and Technology*, 2(7), 3041-3046.

Zhou, C., Li, Z., Hu, B., Zhan, H., & Han, X. (2017). Analytical solution to bending and contact strength of spiral bevel gears in consideration of friction. *International Journal of Mechanical Sciences*, 128-129, 475– 485. https://doi.org/10.1016/j.ijmecsci. 2017.05.010.

