



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 3, March 2022

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 7.569

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com



Static Analysis of Spur Gear with Different Materials: A Conceptual Review

Adit Sen¹, Pushendra Kumar Mishra², Dilip Gehlot³

PG Research Scholar, Department of Mechanical Engineering, Malwa Institute of Technology, Indore (M.P.), India

Assistant Professor, Department of Mechanical Engineering, Malwa Institute of Technology, Indore (M.P.), India

Assistant Professor, Department of Mechanical Engineering, Malwa Institute of Technology, Indore (M.P.), India

ABSTRACT: Spur gears are considered as one of the prominent power transmission machined elements, and are used in vivid applications, all around the globe. Present research work is dedicated to the details of academic research contributions of different researchers in the field of analysis of spur gear. The paper presents different contributions and concludes with the investigated gaps in the research and objectives of the proposed research.

KEYWORDS: Spur gear, static analysis, research, literature.

I. INTRODUCTION

The spur gear is simplest type of gear manufactured and is generally used for transmission of rotary motion between parallel shafts. The spur gear is the first choice option for gears except when high speeds, loads, and ratios direct towards other options. Other gear types may also be preferred to provide more silent low-vibration operation. A single spur gear is generally selected to have a ratio range of between 1:1 and 1:6 with a pitch line velocity up to 25 m/s. The spur gear has an operating efficiency of 98-99%. The pinion is made from a harder material than the wheel. Spur gears are simple in construction, easy to manufacture and cost less. They have highest efficiency and excellent precision rating. They are used in high speed and high load application in all types of trains and a wide range of velocity ratios. Hence, they find wide applications right from clocks, household gadgets, motor cycles, automobiles, and railways to aircrafts. Present research is devoted to the academic contributions of different researchers in the field of spur gears.

II. RESEARCH CONTRIBUTIONS OF RESEARCHERS IN THE FIELD OF SPUR GEARS

Following points represent the survey of available literature in the field of spur gears.

Rajesh et al. (2022) [1]

High contact ratio gears are used to minimize the stresses generated on the tooth surface. This research article represents an idea to enrich the contact strength of gear drive using novel high contact ratio spur gear.

Zeng et al. (2022) [2]

Focusing on the centrifugal force in high-speed working condition, this paper developed an analytical-FEM framework to integrate the centrifugal field into the mesh stiffness and nonlinear dynamics. The additional potential caused by centrifugal force is condensed in the mesh stiffness calculation. The gear torsion dynamic model is further extended to embody the internal dynamic effect in centrifugal field. Solutions of gear statics and dynamics are compared with existing models and experiments, and results demonstrate the reasonable accuracy of the present model.

Zhao et al. (2021) [3]

In present research work, considering the influence of roughness on the normal contact stiffness of gears, a fractal contact model suited for gear pair contact has been established.

Yilmaz et al. (2021) [4]

In this study, the effect of rim thickness of hybrid gears on the root stress, joint stress, tooth stiffness, natural frequency, and dynamic behavior are examined numerically.



Zheng et al. (2021) [5]

This study focuses on the wear performance of the gear generated by modified cutter. Numerical results show that the wear resistance can be enhanced through proper cutter modification.

Demet & Ersoyoğlu (2021) [6]

In this study, the fatigue performances of symmetrical and asymmetrical spur gears were analyzed by performing single tooth bending fatigue tests. The gears tested were determined to be symmetrical spur gears with a $20^\circ/20^\circ$ pressure angle, asymmetrical spur gears with a $20^\circ/22^\circ$ pressure angle, and asymmetrical spur gears with a $20^\circ/25^\circ$ pressure angle. It was observed that the formation of tooth flank damage negatively affected the fatigue performance.

Lin et al. (2021) [7]

In the present research work, distributed cumulative wear and wear at various test stages are quantitatively evaluated. The method is experimentally validated and agrees with the previous simulation.

Zhang et al. (2020) [8]

The use of 3D printing to manufacture nylon polymer gears is evaluated in this paper. More specifically, Nylon spur gears were 3D printed using Nylon 618, Nylon 645, alloy 910 filaments, together with Onyx and Markforged nylon proprietary materials, with wear rate tests performed on a custom-built gear wear test rig. The results showed that Nylon 618 provided the best wear performance among the 5 different 3D printing materials tested.

Pleguezuelos et al. (2020) [9]

This paper presents a study on the influence on the quasi-static transmission error of symmetric long profile modifications on high contact ratio spur gears.

Karpát et al. (2020) [10]

In this study, single tooth stiffness of involute spur gear was measured experimentally. A special test rig for this purpose was designed, and an experimental technique was proposed to investigate the effects of drive side pressure angle on the stiffness. The validation process of this study was performed using the finite element method. The experiments were repeated in ANSYS Workbench, and the elastic deformations were calculated. Experimental and numerical results were found to be generally consistent. Results showed that, the single tooth stiffness increase nearly 38% with the increase in drive side pressure angle from 20° to 35° . Single tooth stiffness of gear types manufactured by non-traditional methods, including additive manufacturing and forged bimetallic gears, can be investigated experimentally with this technique.

Chen et al. (2019) [11]

The complex gear foundation types and the crack propagation paths are considered in the proposed method, and the effects of various foundation types, crack propagation paths and crack lengths on the mesh stiffness are analyzed

Feng et al. (2019) [12]

Gear wear introduces geometric deviations in gear teeth and alters the load distribution across the tooth surface. Wear also increases the gear transmission error, generally resulting in increased vibration, noise and dynamic loads. This altered loading in turn promotes wear, forming a feedback loop between gear surface wear and vibration. Having the capability to monitor and predict the gear wear process would bring enormous benefits in cost and safety to a wide range of industries, but there are currently no reliable, effective and efficient tools to do so. This paper develops such tools using vibration-based methods.

Doğan & Karpát (2019) [13]

Gears are one of the most important power transmission elements in every area of the industry. Because of its importance, the gear design must be carefully performed. Unfortunately, due to the changing of the boundary conditions, gears are exposed to failures such as cracks, pitting, tooth missing etc. during the operation. Thus the gear diagnostic and monitoring become a very critical phenomenon for the gearboxes. A dynamic transmission error based numerical fault detection model is proposed.



Singh and Singh (2018) [14]

This study investigates the potential of three different thermoplastic materials viz. Acrylonitrile Butadiene Styrene (ABS), High Density Polyethylene and Polyoxymethylene to be used in plastic gearing applications.

Singh et al. (2018) [15]

This article presents a comprehensive review of the research on polymer spur gears operating under low (0–8 Nm) and moderate (>8 and ≤17 Nm) loading conditions. Different polymers and polymer composites used till date for the fabrication of such gears are included along with different operating conditions.

Diez-Ibarbia et al. (2018) [16]

In this proposal, the effect of the friction coefficient on the efficiency of spur gears with tip reliefs was analysed. For this purpose, the efficiency values using an average friction coefficient along the mesh cycle were compared with those obtained implementing an enhanced friction coefficient formulation, which is based on elastohydrodynamic lubrication fundamentals. In this manner, it can be established the differences between both formulations in the efficiency and friction coefficient values, as well as the advantages of using this enhanced friction coefficient with respect to formulations implemented in traditional approaches of efficiency calculation. In addition to studying the impact of the friction coefficient choice on efficiency, the profile modifications influence on the friction coefficient and efficiency was also assessed.

Simon et al. (2017) [17]

According to the researchers a very important feature of high quality gears is a low noise emission in all operating conditions. Micro-geometry of the gear is of relevance for the vibration excitation in the tooth contact and significantly affected by the manufacturing process, especially the finishing operations. Besides known process related effects, uncontrolled variations such as inaccuracies in the speed synchronization of different axes or vibrations influence the surface structure of the tooth flanks. In the research work a detailed simulation of the production process is presented, providing crucial information about characteristic process properties and enabling investigations on the impact of manufacturing process on gear mesh acoustics.

Dirk et al. (2017) [18]

Researchers tell that forming processes are generally characterized by a high degree of material utilization as well as short process times and, consequently, a decent economic efficiency. Considering their application in the manufacturing of large spur gears, forming processes offer a significantly attractive characteristic for the production of essential gearing components commonly used in wind turbines or marine engines. Furthermore, the hot forming process can be defined as an incremental forming process which enables the use of relatively low forming forces and results in a more compact design of the used machines. These conveniences are utilized in terms of roll forming with round tools to form gears and threads in a competitive way. Based on experiences gained over many years of researching rolling technologies, a cross-rolling process characterized by round tools with outer gearings was elaborated to realize a hot forming process for gear rolling of large spur gears at the Fraunhofer IWU Chemnitz. Based on the already researched forming of smaller dimensioned gears, rolling trials utilizing new hot-forming machinery - including defined inductive heating process before rolling - to realize large gears with outer diameters of up to 1000 millimeters were conducted. In terms of realizing this ambition, the derivation of the designated machine parameters for rolling large gears in real-life dimensions can be defined as a crucial factor. Consequently, the experimental research was followed by a mathematical analyzation of the forming forces, momentum as well as the necessary steps to determine the best possible scaling factors for the work pieces.

Wei et al. (2017) [19]

Researchers report that during cold precision forging of helical gears, the die experiences high forming pressure resulting in elastic deformation of the die, a main factor affecting dimensional accuracy of a formed gear. The divided flow method in material plastic deformation is an effective way to reduce the forming force and the die pressure during cold precision forging of helical gears. In this study, by utilizing the flow-relief-hole method, a billet design with different initial diameters of the relief-hole is developed to improve the dimensional accuracy of cold forging gears. During the research, three-dimensional Finite Element (FE) models are established to simulate the plastic deformation process of billet during cold precision forging of a helical gear and to determine the forming force acting on the die. Further models of die stress analysis are developed to examine the die elastic deformation and distribution of the displacement. Effects of the relief-hole diameters on die elastic deformation are studied. The results show that the



elastic deformation of the die is different in the addendum, dedendum, and involute parts of forging gear using different relief-hole diameters. The die elastic deformation increases firstly and then decreases when the relief-hole diameter increases. The tooth portions are of larger elastic deformation and the peak value locates in the addendum. It shows the importance of optimizing the relief-hole diameter to minimize the dimensional inaccuracy of forging gears caused by the die elastic deformation.

Wuhao *et al.* (2017) [20]

Researchers report that, cold orbital forging, as an advanced incremental forming process, has been widely researched and used to fabricate the spur bevel gear. However, the mechanism of cold orbital forging is quite different from that of traditional cold forging, which leads to the different forming laws and different properties of forged gear. In the research work, cold orbital forging and traditional cold forging of a spur bevel gear are simulated under the same conditions in the Deform-3D software platform. The filling process, geometric characteristics of forged gear, effective stress distribution, effective strain distribution, gear tooth accuracy are comprehensively clarified and compared. The results show that, comparing with traditional cold forging of a spur bevel gear, cold orbital forging can increase the degree and homogeneity of plastic deformation and improve the gear tooth accuracy.

Miryam *et al.* (2017) [21]

In the research work, the meshing stiffness of spur gear pairs, considering both global tooth deflections and local contact deflections, is evaluated at any point of the path of contact and approximated by an analytical, simple function. With this function, the load sharing ratio is calculated and compared with previous results obtained from the hypothesis of minimum elastic potential energy (MEPE model), considering the tooth deflections, but neglecting the hertzian deflections. Critical bending and contact stresses from both models are also compared both for standard and high contact ratio spur gears.

Suslin *et al.* (2017) [22]

According to the researchers, the main limiting factor in high-speed aviation gear systems is contact strength. There are two main ways for reducing contact stresses in gears with involute tooth profile: 1) by using a standard basic rack profile with increased pressure angle; 2) by using a non-standard basic rack profile i.e. increasing the overlap ratio. However, contact stresses can also be reduced by implementing point gearing; Novikov's gears in which the relative radius of curvature is much larger than it is in involute gears. On the basis of an involute and Novikov's gears, a point-involute gear was created which has a mixed engagement. An attempt was made to apply this design in the spur gear of the central gear box of gas turbine engines. But due to the point nature of the tooth profile, the limiting factor for the gear becomes its bending strength. Hence there was a necessity to conduct comparative tests with the usual spur gear of the central gas turbine engine gear box. A pulsator test bed was created for these tests and comparative tests were carried out.

Raghuwanshi & Parey (2017) [23]

Researchers report that time varying mesh stiffness is an important parameter in the study of gearbox vibration analysis. Mesh stiffness is affected by gear parameters (e.g. pressure angle, contact ratio, back-up ratio, module etc.) and due to presence of gear tooth faults (e.g. crack, pitting, spalling etc.). Back-side contact of gear tooth happens when tight meshing occurs or anti-backlash gears are used. So the effect of back-side contact becomes an important consideration for calculating mesh stiffness. In the research work, the effect of back-side contact on mesh stiffness of drive side of spur gear pair is analyzed. For this, a three dimensional model is investigated by finite element method (FEM). The results are discussed and it is found that the back-side contact affects the mesh stiffness significantly.

Khusainov *et al.* (2017) [24]

The research work examines the impact of the geometric and kinematic errors of gear shaping machines for the accuracy of processed wheels. There is a problem to establish a correlation between the errors of the technological system with the gear accuracy parameters defined by standards. In this article, the equation of the machined surface is proposed based on the coordinate transformation matrices and equations of involute surface of the tool in the form of a matrix equation. On the basis of this equation the machine output precision is given in the form of matrix equation. The impact of errors of the technological system elements is displayed by a matrix of variations, components of which are the projection of errors on the axis. Output errors are applied on the machined surface via the projection on the line of action. Next, the obtained values are translated into a standardized deviation of the gear accuracy. This enables forecasting the possibility of obtaining the products of certain accuracy on this machine, as well as to control the specific parameters of the technological system to ensure the accuracy and stability of the process.



Kalashnikov et al. (2017) [25]

The researchers considered the continuous cylindrical grinding wheel of the planetary transmission with the use of highly porous worm grinding wheels. The process of continuous grinding of teeth by the method of generating is characterized by high accurate of relative rotation of tool and work piece gears. The developed technological model of the interaction of radial, axial and tangential movements of the feed was allowed to produce the grinding with high accuracy and productivity. The application of highly porous circles makes it possible to reduce thermal stress of process and to improve the cutting conditions. The increase in the number of passes of the grinding wheel and the increase of cutting speed reduce the impact of the thermal processes occurring during grinding of teeth by reducing the contact time between the work piece and the tool. The treatment of the teeth of the satellites of the double grinding wheels improves performance of the process compared to the single pass on 26%. Statistical control of error radial run out of the teeth of the satellites indicates the high accuracy and stability of process of continuous grinding of teeth by the generating.

Dhamande and Choudhari (2016) [26]

Researchers report that gears and bearings are important components of almost every machines used in industrial environment. Hence detection of defect in any of these must be detected in advance to avoid catastrophic failure. The research work aims to address the effect of bearing defect on gear vibration signature and effect gear defect on bearing vibration signature. Also its purpose is to make vibration analysis of single stage spur gear box, when both gear and bearing are defective. A condition monitoring set up is designed for analyzing the defect in outer race of bearing and damaged tooth of gear. MATLAB is used for feature extraction and neural network is used for diagnosis. In the literature, many authors have analyzed defects in bearings and gears separately. But it is found that the real situation may be more complex. The work presents a laboratory investigation carried out through an experimental set-up for the study of combined gear –bearing fault. This paper proposes a novel approach of damage detection in which defects in multiple components are analyzed using vibration signal.

Sari et al. (2016) [27]

According to researchers, high performance gears require high geometrical qualities. For these aspects expensive grinding processes are indispensable as finishing processes. This paper deals with the investigation of wire EDM (WEDM) as a technological substitution to grinding from part functionality point of view. Geometrical gear quality, surface integrity and load carrying capacity for WEDM and ground gears were analyzed and compared. No difference regarding gear shape was found for both processes. Residual stress and hardening profiles did not show significant differences. The topography features the process typical characteristics. Following, load carrying capacity of the tooth flank surfaces was investigated. Researchers concluded that WEDM finished gears last three times longer than the ground gears due to a beneficial running-in topography formation with increased tribological characteristics.

Pawar and Utpal (2015) [28]

In this work metallic gears of steel alloy and Aluminium Silicon carbide composite have been manufactured. According to researchers, composites provide much improved mechanical properties such as better strength to weight ratio, more hardness, and hence less chances of failure. So this work is concerned with replacing metallic gear with composite material so as to improve performance of machine and to have longer working life.

Haefner et al. (2015) [29]

Researchers report that, nowadays, micro motors are used in combination with micro transmissions in manifold industrial applications such as dental drills or the equipment for minimally invasive surgery in the medical industry, hexapodmicro positioning systems for wafer processing in the field of industrial automation or adjustable automotive components such as fixings of LCD monitors. Micro transmissions consist of micro gears, which are critical to their functionality. Micro gears are typically defined as gears with a module which is lower than 200 μm . To ensure proper operation of the micro gears for their expected purpose, a reliable prediction of their lifetime is crucial. Lifetime evaluation is particularly important for micro gears, as the influence of their geometric shape deviations on their load rating is significantly higher in comparison to gears with larger modules. This is a consequence of the larger shape deviations of micro gears in relation to their part size due to their manufacturing processes. The lifetime of micro gears can be evaluated by an experimental approach. Within this a pair of micro gears is systematically worn under realistic, clearly defined conditions, until a defect of one of the micro gears can be detected. This can be conducted by means of a highly precise experimental setup. In this article, a methodology to calculate the characteristic loads at the tooth flanks of the pair of micro gears during the experiments based on finite element analysis is introduced. For this purpose, CAD models of the real gear geometry of the specimen are deducted by means of high precision 3D measurements and



spline interpolation. On the basis of these data, the lifetime of the micro gears dependent on their shape deviations can be predicted by means of a model based on reliability statistics.

Kazumasa *et al.* (2015) [30]

In the research work, a method for remanufacturing pinion member of large-sized skew bevel gears using a CNC machining center and respecting an existing gear member is proposed. For this study, first the tooth surface forms of skew bevel gears are modeled mathematically. Next, the real tooth surfaces of the existing gear member are measured using a coordinate measuring machine and the deviations between the real and theoretical tooth surface forms are formalized using polynomial expression. Moreover, the tooth contact pattern and transmission errors reflecting the deviations of the tooth surface forms of the gear member are analyzed, and the tooth surface form of the pinion member that has good performance mating with the existing gear member is designed. The pinion member was remanufactured by swarf cutting using a CNC machining center. The gear member is also remanufactured using this method in order to apply to the case where pinion member exists in reverse or both gear and pinion members do not exist. The tooth surface form deviations were detected, and the experimental tooth contact pattern of the pinion and gear members was compared with analytical one. According to the researchers, the results showed good agreement.

Zhang *et al.* (2015) [31]

According to researchers, gears as the key transmission parts of machineries are widely used in mechanical and aeronautical fields. GeoSpelling, a framework standardized as ISO 17450-2005 supported tolerancing process by a set of concepts and mathematical algorithms, is a coherent and complete model to manage the shape variations of geometrical parts. Considering current gear specification standards incline to inspection convenient ignoring tolerance quality control, so it is a realistic necessary to develop a coherent gear specification model based on GeoSpelling language. This model should not only consider integrating functional requirements involved in design stage but also be able to correspond to manufacturing and inspection procedures. In this paper a new approach based on discrete geometry is introduced to design gear specification model. It also focuses on a perspective discussion on how SSA (Statistical Shape Analysis) method could be a solution to analyze the gear integrated errors into different individual errors, such as tangential composite error, tooth-to-tooth tangential composite error, pitch accumulated deviation, tooth-to-tooth pitch accumulated deviation and geometric eccentricity. According to them, the fundamentals mentioned above provide a reliable methodology for analyzing gear manufacturing errors. As a result it is able to enhance the computational processing capability and metrological traceability for gear quality control.

Bruzhas and Lopatin (2015) [32]

The research work describes the preparation methods for solid models of gears of different geometries using emulation cutting tooth profile generating circuit rack and further processing in Autodesk Inventor. The parameters of the rack contour can be set at a designer's request.

Marimuthu and Muthuveerappan (2014) [33]

In the present research work, using direct design method, gear pair is selected from area of existence diagram. This area of existence diagram gives N number of possible gear pairs. From this possible gear pairs it is important to optimize the fillet strength of pinion and gear with respect to the optimum profile shift. Optimum design of gear drive means the maximum fillet stresses developed at the pinion and gear are to be equal. Present work attempts for a reasonably accurate estimation of optimum profile shifts based on pinion and gear tooth fillet strength for a load at critical loading point considering the load sharing between the gear pair on asymmetric normal and high contact ratio asymmetric spur gear through direct design.

Pawar and Utpal (2014) [34]

In this work a composite is developed by adding silicon carbide in Aluminum metal by mass ratio 2.5%, 5%, 7.5% and 10%. The composite is prepared by stir casting technique. Mechanical tests such as hardness test, microstructure test are conducted. It is proposed to use this material for power transmitting elements such as gears which are subjected to continuous loading. In case of increased silicon carbide content, the hardness, and material toughness are enhanced. From the results it is concluded that transmission gears. composite material such as aluminium silicon carbide is one of the option as a material for power .

Naik and Dolas (2014) [35]

The main objective of this paper is to analyze the bending stresses occur on the gear tooth profile of gear used in gear box of special purpose machine also effect on bending stress by variation of the gear parameters.



Mishra et al. (2013) [36]

Researchers report that Electrochemical honing (ECH) is emerging as a potential gear finishing technique in which achieved surface finish and material removal are significantly influenced by the processing time. The research work comprises the findings of experimental investigation to explore the influence of processing time on process performance parameters: surface quality of gear teeth profile, tribological performance of the teeth surface and process capability and thus, to estimate the optimum processing time by graphical analysis. The emphatic characteristics of developed machine setup and guidelines for future research have also been discussed to stimulate the research community to carry out further research in this field to mature the process.

Vilmos (2013) [37]

The aim of this research work is to define optimal tooth modifications, introduced by appropriately chosen head-cutter geometry and machine tool setting, to simultaneously minimize tooth contact pressure and angular displacement error of the driven gear (transmission error) of face-hobbed spiral bevel gears. As a result of these modifications, the gear pair becomes mismatched, and a point contact replaces the theoretical line contact. In the applied loaded tooth contact analysis it is assumed that the point contact under load is spreading over a surface along the whole or part of the *potential* contact line. A computer program was developed to implement the formulation provided above. By using this program the influence of tooth modifications introduced by the variation in machine tool settings and in head cutter data on load and pressure distributions, transmission errors, and fillet stresses is investigated and discussed. The correlation between the ease-off obtained by pinion tooth modifications and the corresponding tooth contact pressure distribution is investigated and the obtained results are presented.

Baragettiet al. (2011) [38]

The research work studies the rolling contact fatigue (RCF) behavior of case-hardened transmission gears for racing motorcycles both numerically and experimentally and both as-produced and PVD-WC/C coated conditions are analyzed. During the Finite element models of the gears were developed and a calculation procedure was applied to predict their RCF life. During the research work, Ti-6Al-4 V alloy was also considered to investigate the mass decrease of the components. RCF tests were carried out in both dry and lubricated conditions. The experimental results were compared with the numerical ones to check the reliability of the predictive method proposed.

III. GAPS IN THE RESEARCH AND OBJECTIVES OF THE RESEARCH

During survey of available literature, following gaps are being observed.

- a) There is very limited research which uses different materials for modeling a gear; and
- b) There is very limited research which tells about ranking of different materials used for making gears.

On the basis of these gaps, objectives of the proposed research work are formulated.

Following are the objectives of present research work:

- a) To determine different mechanical properties of the gears made up of different materials; and
- b) To rank different gear materials in accordance with the properties shown by them.

IV. CONCLUSION

Present research work tells about the details of research contributions of the researchers, gaps in the research and the objectives of a new research, which shall be able to initiate the research for a customized application.

REFERENCES

- [1] Kalashnikov, A.S., Morgunov, "Y.A. and Kalashnikov, P.A. Continuous grinding of teeth by generating cylindrical planetary transmission gears", *Procedia Engineering*, 206, pp.1167-1172, 2017.
- [2] Suslin, A. and Pilla, C.. "Study of loading in point-involute gears", *Procedia Engineering*, 176, pp.12-18, 2017.
- [3] Haefner, B., Quiring, M., Gullasch, J., Glaser, G., Dmytruk, T. and Lanza, G. "Finite element simulation for quality dependent lifetime analysis of micro gears", *Procedia CIRP*, 31, pp.41-46, 2015.
- [4] Chen, K., Huangfu, Y., Ma, H., Xu, Z., Li, X. and Wen, B. "Calculation of mesh stiffness of spur gears considering complex foundation types and crack propagation paths", *Mechanical Systems and Signal Processing*, Vol.130, pp.273-292, 2019.



- [5] Sari, D., Welling, D., Löpenhaus, C., Klocke, F., & Klink, A. "Adjusting surface integrity of gears using wire EDM to increase the flank load carrying capacity", *Procedia CIRP*, 45, 295-298, 2016.
- [6] Demet, S.M. and Ersoyoğlu, A.S. "An analysis of the effect of pressure angle change on bending fatigue performance in asymmetrical spur gears", *Proceedings of the Institution of Mechanical Engineers, Part L: Journal of Materials: Design and Applications*, 235(9), pp.2142-2150, 2021.
- [7] Diez-Ibarbia, A., Fernandez-del-Rincon, A., De-Juan, A., Iglesias, M., Garcia, P. and Viadero, F. "Frictional power losses on spur gears with tip reliefs. The friction coefficient role", *Mechanism and Machine Theory*, Vol.121, pp.15-27, 2018.
- [8] Landgrebe, D., Sterzing, A., Lahl, M., Milbrandt, M. and Taubert, A.M. "Hot forming of large spur gears", *Procedia engineering*, 207, pp.615-620, 2017.
- [9] Doğan, O. and Karpat, F. "Crack detection for spur gears with asymmetric teeth based on the dynamic transmission error", *Mechanism and Machine Theory*, 133, pp.417-431, 2019.
- [10] Feng, K., Borghesani, P., Smith, W.A., Randall, R.B., Chin, Z.Y., Ren, J. and Peng, Z. "Vibration-based updating of wear prediction for spur gears", *Wear*, 426, pp.1410-1415, 2019.
- [11] Misra, J.P., Jain, P.K., Dwivedi, D.K. and Mehta, N.K. "Study of time dependent behaviour of ECH of bevel gears", *Procedia Engineering*, 64, pp.1259-1266, 2013.
- [12] Karpat, F., Yuce, C. and Doğan, O. "Experimental measurement and numerical validation of single tooth stiffness for involute spur gears", *Measurement*, 150, p.107043, 2020.
- [13] Kawasaki, K., Tsuji, I., Gunbara, H. and Houjoh, H. "Method for remanufacturing large-sized skew bevel gears using CNC machining center", *Mechanism and Machine Theory*, 92, pp.213-229, 2015.
- [14] Keerthi, M., Sandya, K. and Srinivas, K. "Static & dynamic analysis of spur gear using different materials", *International Research Journal of Engineering and Technology (IRJET)*, 3(01), pp.2395-0056, 2016.
- [15] Dhamande, L.S. and Chaudhari, M.B. "Detection of combined gear-bearing fault in single stage spur gear box using artificial neural network", *Procedia Engineering*, 144, pp.759-766, 2016.
- [16] Lin, J., Teng, C., Bergstedt, E., Li, H., Shi, Z. and Olofsson, U. "A quantitatively distributed wear-measurement method for spur gears during micro-pitting and pitting tests", *Tribology International*, 157, p.106839, 2021.
- [17] Zhang, M., Shi, Z., Mathieu, L., Nabil, A. and Yang, J. "Geometric product specification of gears: The geospelling perspective", *Procedia Cirp*, 27, pp.90-96, 2015.
- [18] Sánchez, M.B., Pleguezuelos, M. and Pedrero, J.I. "Approximate equations for the meshing stiffness and the load sharing ratio of spur gears including hertzian effects", *Mechanism and Machine Theory*, 109, pp.231-249, 2017.
- [19] Naik, K. N., & Dolas, D. R. "Static Analysis of Bending Stresses on Gear Tooth Profile by using Finite Element Analysis", *International Journal of Engineering Research & Technology*, 2014, Volume 3 (6),.
- [20] Raghuvanshi, N.K. and Parey, A. "Effect of back-side contact on mesh stiffness of spur gear pair by finite element method", *Procedia engineering*, 173, pp.1538-1543, 2017.
- [21] Marimuthu, P. and Muthuveerappan, G. "Optimum profile shift estimation on direct design asymmetric normal and high contact ratio spur gears based on load sharing", *Procedia Engineering*, 86, pp.709-717, 2014.
- [22] Pawar, P.B. and Utpat, A.A. "Analysis of composite material spur gear under static loading condition", *Materials Today: Proceedings*, 2(4-5), pp.2968-2974, 2015.
- [23] Pawar, P.B. and Utpat, A.A. "Development of aluminium based silicon carbide particulate metal matrix composite for spur gear", *Procedia materials science*, 6, pp.1150-1156, 2014.
- [24] Pleguezuelos, M., Sánchez, M.B. and Pedrero, J.I. "Control of transmission error of high contact ratio spur gears with symmetric profile modifications", *Mechanism and Machine Theory*, 149, p.103839, 2020.
- [25] Khusainov, R.M. and Khaziev, R.R. "Mathematical model for assessing the accuracy of processed gears on gear shaping machines", *Procedia Engineering*, 206, pp.1087-1092, 2017.
- [26] Rajesh, S., Marimuthu, P. and Dinesh Babu, P. "Optimization of contact stress for the high contact ratio spur gears achieved through novel hob cutter", *Forschung im Ingenieurwesen*, pp.1-9, 2022.
- [27] S SRatan. *Theory of Machines*, TATA McGRAW Hills, 2005.
- [28] Baragetti, S., Cavalleri, S. and Tordini, F. "A numerical method to predict the RCF behaviour of PVD-coated transmission gears and experimental results", *Procedia Engineering*, 10, pp.1485-1490, 2011.
- [29] Kimme, S., Bauer, R., Drossel, W.G. and Putz, M. "Simulation of error-prone continuous generating production processes of helical gears and the influence on the vibration excitation in gear mesh", *Procedia CIRP*, 62, pp.256-261, 2017.
- [30] Singh, A.K., Siddhartha and Singh, P.K. "Polymer spur gears behaviors under different loading conditions: A review", *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology*, 232(2), pp.210-228, 2018.



- [31] Singh, P.K. and Singh, A.K. “An investigation on the thermal and wear behavior of polymer based spur gears”, Tribology International, 118, pp.264-272, 2018.
- [32] Bruzhas, V.V. and Lopatin, B.A. “Development of solid-state models for the gears of different geometry”, Procedia engineering, 129, pp.369-373,2015.
- [33] Simon, V., “Design of face-hobbed spiral bevel gears with reduced maximum tooth contact pressure and transmission errors”, Chinese Journal of Aeronautics, 26(3), pp.777-790, 2013.
- [34] Feng, W., Lv, J., Hua, L., Long, H. and Wang, F. “Effect of relief-hole diameter on die elastic deformation during cold precision forging of helical gears”, Procedia engineering, 207, pp.627-632, 2017.
- [35] Yılmaz, T.G., Doğan, O. and Karpat. F., “A numerical investigation on the hybrid spur gears: Stress and dynamic analysis”, Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 236(1), pp.354-369, 2022.
- [36] Zhang, Y., Purssell, C., Mao, K. and Leigh, S. “A physical investigation of wear and thermal characteristics of 3D printed nylon spur gears”, Tribology International, 141, p.105953, 2020.
- [37] Zhao, Z., Han, H., Wang, P., Ma, H., Zhang, S. and Yang, Y., “An improved model for meshing characteristics analysis of spur gears considering fractal surface contact and friction”, Mechanism and Machine Theory, 158, p.104219, 2021.
- [38] Zheng, F., Zhang, J., Yao, L. and Tan, R. “Investigation on the wear of spur gears generated by modified cutter”, Friction, 9(2), pp.288-300, 2021.

BIOGRAPHY



Mr. Adit Sen is a M. Tech research scholar in CAD/ CAM at Malwa Institute of Technology, Indore (M.P.), India.



Mr. Pushendra Kumar Mishra, (M.E. in Machine Design) is working as an Asst. Prof in the Department of Mechanical Engineering Malwa Institute of technology Indore (M.P.), India.



Mr. Dilip Gehlot, is working as an Asst. Prof in the Department of Mechanical Engineering Malwa Institute of technology Indore (M.P.), India.



**Impact Factor:
7.569**



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details