A Review on Design and Efficiency Improvement of Worm and Worm Wheel of a Gear Motor

Rahul Honkalas\textsuperscript{1*}, Bhagyesh Deshmukh\textsuperscript{2*}, Prabhakar Pawar\textsuperscript{3}

\textsuperscript{1,2}Walchand Institute of Technology, Solapur - 413003, M.H., India. 
\textsuperscript{3}LHP, Solapur - 413255, M.H., India.

Rahul Honkalas. Email: rahul.honkalas@gmail.com

Abstract. Geometry and operating standards determines that worm drives are critical components in and of applications within the power transmission industry. In one reduction point, it is used in large drive ratios with compact assembly dimensions. Worm and worm wheels are provided with a quiet operation owing to the movement of slipping between the worm and worm wheels tooth flanks. Its efficiency depends significantly on the thickness of the lubricating film, which in turn is dependent on various operating parameters. The different researchers have performed detailed research in the field of worm and worm wheel construction. Many researchers have developed and suggested methods for the prediction of worm and worm wheel gearbox performance with respect to different factors such as tribology, analytic and geometry. This paper includes a comprehensive literary analysis to obtain thorough knowledge of trends in the fields of worm and worm gears.

Keywords: Tooth Flank; Lubricating Film; Efficiency; Worm Profile; Gear Box; Worm and Worm Wheel Gears.

1. Introduction

Worm drives cannot be substituted components of the power transmission sector and its use because of the advantages resulting from geometry and operating theory. Many of times it used to achieve maximum ratios of transmission in a single reduction step with limited assembly dimensions. The prevailing slipping action between the tooth of the worm gear and the worm wheel characterises them with silent activity. Their efficiency, on the other hand, depends strongly on the thickness of the lubricating film affected by many operating parameters including lubricant, slipping rate, surface roughness, load, matches, worm profile, deflection of the shaft, meshing mistake and temperature. [1]

Worm gears are cylindrical gears with a spiral thread that drive worm gears to be fitted in applications with high-speed reduction. In general, these gears are in the proper angle. The worm and worm wheel are composed. Worm can spin the worm wheel, but it can't turn the worm. Single direction means worm gear drives. [2]

Worm shapes as defined in Fig.1 are used for power transmission in applications where the speed reduction ratio varies from 3:1 to 100:1 and in situations where precise rotary indexing is necessary. There can also be high gear ratios such as 200:1. Such basic gear construction parameters such as tooth strain bending tension, friction for the contact, fatigue power, acceptable
surface fatigue stress, tooth surface strength of gear and pinion, etc. should be studied closely in the assessment of worm and worm gear designs. [3] [4]

Figure 1. Worm and Worm Wheel with Motor. [4]

2. Literature Review

A systematic literature review is undertaken to learn more about the developments in the field of worm and worm gears.

The pitting kind of damage to worm wheels was double, according to Milan Opalić et al [1]. First of all, the verifiable link in between the area being pitted and the load cycles number dependent on the areas of the determination which damaged by digital images which were created. Secondly, it tried to expose harm dynamics using the same collection of visual images that were processed and novelly introduced. A relationship in between the pitted zone and the number of load cycles, which was then used to the comparison, was established using 6 teeth test results. Results revealed that there was definitely an effect on the scientific expression and hence estimation of the life of worm wheel between the dipped areas measured in the sample and throughout the study. An significant discovery also was the overlap of the affected areas on the teeth. Over 50% exist only on one or two tooth. Fig.2 indicates that the worm wheel has been damaged.

Figure 2. Damages on worm wheels [1]

Mokara Bharati et al [3] developed a method of achieving the desired wormed gear design by modifying the best collection of worm gear design parameters that could be used to perform with SVM (Support Vector Machine). The key aim was to achieve high wear potential with module, strength, speed ratios and speed as design parameters. An evolutionary technology such as a Genetic algorithm (GA) was used along with that to improve the worm and worm wheel with multi objective goals. The disadvantages were taken into account, the middle gap and the power of the worm gear. Fig.3 displays the forward mapping projection for Support Vector Machine Model (SVM).
The MPS method suggested by Xingqiao Deng et al [6] for the determination of ration speed impact, depth of immersion, worm arrangement with lubricant viscosity with the loss of hydration and the distribution of pressure of oil in a roller enclosing turbo drive of gear has been stated. The use of the MPS System for meshing of gear and lubrication simulation overcomes the issue of gear meshing tooth surfaces, which retain complicated structural details. An experiment was undertaken to test the effects of simulation and confirm the calculative approaches used.

The paper thus provides a method for the numerical study of lubrication and friction between two curved areas and therefore it ideal to solve many transmission problems. The hybrid experimental and analytical method provided in this article. The speed reducer moving particle (MPS) models are seen in Fig. 4.

Qingxiang Meng et al [7] worked on the theory of point-to-point meshing for a conical surface which envelops the pair of tapered worms was well known. To decide momentary points of touch, contact equations are built with nine unknowns. The removal artifice was introduced to translate this into its equal form with three unknowns to overcome preceding equations in a timely manner. Another data point was calculated by the solution of a modified contact equation category in which the drive relation error in the worm pair was zero. The similarity of the angular orientation of the two motion frames at the point of touch was seen clearly and the relative main curvatures are properly accomplished. The envelopes of the conical worm and the discoid conical grinding wheel mentioned in Fig.5 and Fig.6 respectively.
Toroidal surface was formed with conical worm triggers which were rendered by a grinding wheel with a torus producing the worm by Chongfei Huai et al [8]. The theory of meshing of the given worm drive was extensively constructed, including the case for the non-orthogonal axial paths. The equation in the worm tooth profile and the method and formula for measurement of the angle of the tooth profile have been established with a technical reference to making and examining the worm and the corresponding conical plate.

On the basis of the hypothesis, simulatory experiments were performed routinely on the network efficiency of worm pair, and the comparative analysis with the enveloped surface conical worm drive was carried out. The value regularity of the parameters has been found by computational computation and this is very useful for iteratively evaluating the points of meshing of the worm gear. The analytical results shown consistency of proposed meshing of gear was greatly beneficial and asymmetry of meshing between both sides was poor in one tooth. Fig.7 demonstrated toroidal surface processing diagram surrounding with conical worm drive.

The newest designs of the worm gear drive were proposed by Wojciech Kacalak et al [9], allowing for revision or decrease of backlash. The revolutionary proposed designs of the worms and the worm wheels created this result. The drives proposed were designed to find use in structures for the correct location of measuring devices, accurate technological drives, and in micro-mechanisms. Fig.8 displays the worm wheel and the full circumferential rim assembly of the worm wheel.
Numerical method developed by Piotr Boral et al [10] was to allow for the determination of the surface of the worm wheel tooth without solving the condition of the envelope. Fig.9 defines the worm wheel tooth surface, while Fig.10 displays the worm wheel tooth profile.

Claudiu-Ioan Boanta et al [11], reported results from the thermal limits research carried out with the Nitrocarburization (cylindrical worm) and strengthened steel OLC 45 for the Speed Reducer fitted with updated geometry of hardenable steel 42MoCr11x (worm face wheel). This style of gear used was a worm façade version in order to simplify the geometry equipment and output technologies, where the worm side was executed with equivalent pressure angles. The resultant hard layer is shown as a speed reducing unit with the worm face geometry changed by the nitrocarburizing treatment worm. Fig.11.

The findings of an experiment on the location and touch patch scale of a double worm face gear was presented by Margareta Ciota et al [12]. The tested worm face gear was fitted with a one-piece double worm face roller with unique difficulties of adjustment. On a test stand, the effects of
touch pad control devices on both sides of a succession worm were performed using a training gear, recognising that the pressure angles are distinct. In both sides of the flanks the touch pad has different qualities, with the lower pressure angle providing optimal working conditions. The double worm face gear is shown in Fig. 12.

![Figure 12. Double worm face gear [12]](image)

**Mautner et al. Eva-Maria et al [13]**, In this research project, experimental research was carried out on large worms with centre distance at 315 mm (a pairing of steel worms with a bronze worm wheel). The key objective was to obtain confirmed information on the capability and efficiency of carrying loads for given worm gear sizes. The paper described the experiments performed in detail and showed basic test results. Overall performance of the worm gearbox of up to 96% has been calculated during these trials. A FZG worm gear test collection has been recorded for larger worm gears with a distance of centre a = 315 mm. Fig.13 is the FZG worm gear assembly test rig.

![Figure 13. FZG worm gear test rig [13]](image)

The method for maximising worm gears output was clarified by **Ehsan Soury et al [14]** by considering the correct location of the touch patterns. The touch pattern has been optimised and the lubricant temperature has been decreased in line with the necessary axial change in worm wheel axis. This technique improves the effectiveness and productivity of the gears. Fig. 14 shows the right-hand teething and the reciprocating pump shows Fig. 15.
Claudiu-Ioan Boanta et al [15] proposed a model for film and numerical simultaneous generation of worm-facing geometry-friendly gear and considered that, in the field of kinematics, the worm-facing gear can be replaced by a gear made up of rack and worm wheel. In order to construct the model, matrix-vector approach was used, the calculations results carried out by MATHCAD in INVENTOR 2012 were reflected. Fig.16 shows various Worm profiles, including a) spiroid reference profile b) spiroid simplified profile c) usual cylindrical profile.

The mechanical property tests for glass reinforced plastic worm wheels were analysed by Gun-Hee Kim et al [16] and analytical and evaluation methods were conducted according to the fibre contents. The orientation and contents of glass fibre will affect the mechanical properties in the case of glass fiber-reinforced resin. Computer Assisted Engineering (CAE) computational methods, such as structural and injection moulding experiments, of polyamide resin reinforcing glass fibres have been carried out for the plastic worm wheels characteristic prediction. Fig.17 illustrates the injection moulding plastic worm wheel.
The key goal of Y K Mogal et al [17] was to decrease the volume of a worm wheel and the remaining goals as restrictions such as width of middle, lowering of worm and the power of the worm gear were taken as limits. Researchers have employed a genetic algorithm evolutionary strategy (GA).

The probability of monitoring seed defects on acoustic weapons was investigated by Elfjorjani et al [18], and comparisons were made to study vibrations. Contrary to other kinds of gearboxes, it is not commonly known to track worm gearboxes. Acoustic emissions have been found to be safer for diagnostic than vibration tests. The fault forms of test gear are normally seen in Fig. 18, which are small and huge.

Takao Koide et al [19] defined power transfer efficiency, generation of heat, plastic and worm wheel life, meshed together with worm especially steel. A measuring machine was designed to calculate the transmission performance of plastic worm gears, which have a varying central distance and shaft angles. Experiments were carried out without lubrication with plastic helical and worm wheels and steel worms. The test instruments and illustrated test gears Fig.19 and Fig.20 respectively.
The mathematical definitions of the surface of the globoidal worm tooth flank and worm wheel of straight axial teeth hourglass worm hob were given by Piotr Polowniak et al [20]. The kinematic method of the globoidal worm gear was illustrated. In order to establish the worm tooth surface, the globoid helix and tooth axial profile of the worm have been explained. The contact lines are obtained on the basis of the meshing equation. Centered on contact line and by extreme edge of the worm hob, a numerical description of the globoidal worm wheel tooth flank was carried out. For example, to examine the gear's touch pattern, the provided mathematical model with a TA worm and worm wheel tooth flank. Fig.21 shows a straight axial profile of the globoidal worm surfaces.

The geometrical worm gear feature, the operational principle and the basis of theoretical efficiency calculation have been described by Pavel Melnikov et al [21]. Several research studies have examined both manufacture and the use of worm gears, aimed at developing new advanced techniques. One was selected and experimentally confirmed on the basis of the analysed
techniques. Recommendation to improvement in the efficiency of worm gear 2H-63 type have been developed based on the carried-out research and experiments. Displays Fig.22. The single stage worm gear contains a worm 1 which is leading and a worm 2 which is guided in a shielding box 3.

Figure 22. Single stage worm gear [21]

The efficiency and output power were taken as the key features of the worm gear reducer by Slavica Miladinović et al [22] and their optimization was performed. The influencing variables have taken into account the lubricant viscosity, revolutions number input and the control unit current intensity. The L27 Taguchi orthogonal matrix was used for experimental experiments. The Grey approach has been introduced leading to numerous performance problems. The optimum combination of variables was A3B2C3 based on the Grey link grade using ANOVA analysis. The highest relational grade was the lubricant viscosity 460 mm$^2$/s and present pressure of 0.2 A for the revolutions 2000 min$^{-1}$. In comparison, the existing intensity in the control unit with 72.1 percent has the most effect on Grey relational grade. Fig.23 and Fig.24 shows test set up device AT 200 and control unit respectively.

Figure 23. Test set up device AT 200 [22]  Figure 24. Control unit [22]

The physical method of measuring the effectiveness of worm gear drives has been stated by B Magyar et al [23]. This estimate was based on the tribological simulation MEGT, which could calculate the coefficients of local tooth friction. Their interpretation allows for the measurement of
other energy losses such as coils, oil churns and seals. The next move was then to approximate the performance of the gearbox. Their confirmation with steps and a quick study of power loss sources have been seen after the definition of this complex analysis. Fig. 25 indicates different losses of power and flow of power in a worm gear unit.

**Figure 25.** Losses of power and flow of power in a worm gear unit [23]

The declining performance of James Banks [24] has been explained by several factors, including form of gear, number of gear-stage breaks, type of fluid, viscosity, bearings and dyes. The article concentrated on the reliability study with respect to the type of gear used and the number of gear measures. The performance relation of the right-angle gear drives is defined in Fig. 26.

**Figure 26.** Efficiency comparison of right-angle gear drives [24]

Seong Han Kim et al [25] have suggested a way of estimating the performance of a plastic worm wheel worm gear. Friction coefficient experiments and quantitative calculations obtained theoretical efficiency. The friction of nylon6 on steel at different natural pressures was measured using a tribometer. In order to measure the point of contact position and curvature at the contact point, geometry of the geometry was used and Hertz Law was used to calculate the contact field.
The theoretical efficiency was very reliable with all the variables in mind; it demonstrated the same efficiency pattern, with an improved torque and no variation between the values. They reached their optimum values at the same output torque. This methodology of performance forecasting can be extended to different types of plastic gears. Fig.27 shows the productivity device for the worm gear and Fig. 28 shows the graph of the efficiency measured.

Figure 27. Worm gear efficiency apparatus [25]

Figure 28. Calculated efficiency [25]

The simulation programme WTplus has been applied for the auto-analysis of the performance and heat balance of different worm gear designs by Constantin Paschold et al [26]. New methods have been developed and applied for estimating load-dependent and no-load losses, new nodaling and node connection algorithms. Moreover, critical formulas have been customised that define thermal resistance. Measurements from the testing and industry demonstrated a very similar alignment to different operation points and gear designs confirmed the simulation findings. The control losses and causes of their frequency were analysed by Z Radosavljević et al [27], in a worm gear reducer. This includes losses in the coupling of worm teeth and worm gear, losses in bearings, seals and losses in transmitting force due to churning oil. For the individual versions of worm gear reducer, power losses were calculated on the advanced tester AT200 at Kragujevac Faculty of Engineering, Serbia. The tester was the base of measuring power transfer. Complete losses were calculated according to the previously specified experimental plan with various values of the number of input revolutions, the output torque and differing oil forms. The paper was directed at an experimental evidence of theoretical hypotheses that the losses in the worm reducer have been caused by different causes.

The variant of the worm gear drive with better bearing contact, decreased degree errors of transmission and reduced alignment sensitivity was described by Faydor L Litvin et al [28]. The surfaces of the hob and worm tooth are not matched with the current method (in addition to the oversize of the hob). Increased interaction was supported by a localised longitudinal bearing contact with a negative (but non-positive) feature of the transmission fault. TCA (Tooth Interaction Analysis), which applied to unloaded and loaded gear drives, verified the positive characteristics of the proposed system. Finite factor with the whole worm gear and a quarter of the worm shown in Fig.29.
A worm gear was developed to estimate the overall performance of equipment used in plug valve applications by Abhijeet P Shah et al [29]. Finite element models have been studied in detail for the interaction between two cylinders. The theoretical and ANSYS programme evaluated the deformation and contact stress and the introduction of the contact part. This research has documented stress and deformation in gear pairs. It was noted that in the software review, deformation and stress were considered minimal than theoretical value; this seen encouraging for the design of worm gears.

Simulated Annealing (SA) was used by Paridhi Rai et al [30] to mitigate the loss of power of worm gear pipelines under the architecture restrictions. Linear friction, bending strength and worm deflection were some design constraints included in the issue of design optimisation. The geometry variables considered include number of gear tooth, friction coefficient and helix angle. The obtained findings in earlier research work in the referred literature have been compared and checked. It reveals that SA achieves optimum architecture worm gear drives value to minimise losses in power. Power loss and iterations for SA explain Fig.30.

Octrue Michel [31], In the first part of the paper, the analytical design approach for assessing the ability of worm gears was defined. The second section outlined a brief description of the experimental programme and research tools used at CETIM to validate the basic assumptions and the surface resistance limits for worm gears on the gear and test wheels. The end of the paper compared the conclusions of the process and test outcomes explicitly.

F L Litvin et al [32] recommended methods of tracing connections and transmission error reduction accomplished in respect of a hob, the instrument producing the worm gear, by double-crowning the drive worm. A computer software for meshing and touch simulation has been
created. Two types of hob surface thread were regarded as numerical examples dependent on implementation.

**Parth B. Shah et al [33]**, the causes of worm wheel failure have been remedied and therefore the life improved. Lead Angle, Backlash and Bearing loss were considered in the study. The study of job and worm gear revealed that there was a failure in the bearing of deep groove ball bearings, and also that there was a failure of gear tooth due to heavy loads. With algorithms used to refine the lead angle of parameter and bearing form, which increased the performance of the gearbox and the operation of the tapered roller and thrust bearing rather than a deep groove ball roller bearing, the bearing failure was reduced and the reliability of the bearing and gearbox improved.

Detailed design protocol for a plug valve application in the worm gear and worm gear was developed **by Yuvraj B. Jadhav et al [34]**. To calculate the surface stress of the tooth gear, a mathematical worm gear model was proposed in the implementation of the plug valve. The term was accomplished with the maximum stress distribution to realise the maximum stress value. The findings were important in predicting worm gear pairs static and dynamic performance.

**Seong Han Kim [35]** proposed a worm gear model for the efficiency of the electric power steering system considering misalignment. In Electric Power Steering (C-EPS) systems and Anti Rattle Spring (ARS), C-EPS systems were used to prevent rattling when the car is going on the humpback road. A worm gear was applied in C-EPS systems. Misalignment and geometric and tribological analysis were performed in the worm gear efficiency model. For geometrical analysis, normal gear-to-teeth load was calculated by means of the output torque, worm wheel diameter pitch, lead angle and regular pressure angle. By mathematically analysing geometry, contact points between the worm and worm wheel tooth flanks were obtained and Hertz's theory was used to calculate the contact point.

**Massimiliano Turci et al [36]**, The worm gear box efficiency with central distances of 28 mm to 150 mm that was individually reduced from 5 to 100:1 was compared with the efficiency. The effectiveness of a number of standards or methods has been calculated.

The physically based technique for tribological study of worm gears was introduced by **Manuel Oehler et al [37]**. The calculation effort was significantly reduced by average values instead of local parameters for the tribological considerations. The comparison of the coefficients of tooth friction calculated with a more intricate, local simulation was well agreed with easily handled method.

The stable OKAS gear model was proposed by **Oladejo K. Adesola et al [38]** for the design and study of worm-typing gear mechanisms. The model has been proposed to help the analyst easily imagine the system's reaction to a wide variety of speeds and torque inputs. The model has been evaluated and validated by means of a number illustration on the basis of geometry, bent load and wear load. Total percent errors were 0.97 percent, respectively 3.27% and 1.77% of errors from geometry characteristics, bent loads and wear loads. Software that measures geometric parameters, flexes, wears, and selects suitable materials with good precision for worm mechanisms was developed.

**Steve Dereyne et al [39]** spoke of an Automotive Gearbox Calculation Campaign. The details on the performance of the gearboxes were illustrated and the test ban and flow map of the gearbox were quickly clarified. There has been detailed research on thirteen industrial gearboxes. The findings and the performance effect gearbox parameters have been evaluated. Performance was seen to rely mainly on torque. The difference in performance was less when the gearbox power range increased or the ratio decreased.

Experiments of **Adil Muminović et al [40]** have shown that synthetic oils are more powerful than mineral. In contrast with synthetic oils in the same working condition, mineral oils were higher friction coefficient: oil temperature, sliding speed and gear load capabilities. The overall performance findings also indicate that the temperature load of the machinery lubricated with mineral oil and synthetic oil was distinct. In terms of temperature limit, synthetic oil has a much
greater load power. Synthetic oils were much more adherent than mineral oils, which worked somewhat better.

The Kuan-Yu Chen et al [41] reported ZN-type hourglass worm created by straight blades, and an hourglass-type wheel developed by hourglass-type worm. The ZN-type hourglass worm gear model was derived on the basis of the mechanism of generation and theory of gear. The machine graphs of the ZN-type hourglass worm and wheel were presented according to the established mathematical model of the gear pack. The tooth surface, the border line and the touch lines of the ZN Hourglass worm gear were examined and compared with the ZA-type hourglass worm gear set form under multiple lead angles, pressure angles and modules.

The new approach to estimate load share and distribution of worm gear packs and the calculation of instantaneous meshing stiffness was developed by H Elkholy et al [42]. The worm gear drive was designed as a series of spur gear slices and the well-established formulas for loading spur gear and stresses have been used to analyse every single slice. The entire worm gear set loadings and stresses were obtained by combining the results achieved for all slices.

The complex modelling material was chosen by Marina Franulovii et al [43]. Low-cycle fatigue material behaviour was described by the material model combining isotropic and cinematic hardening with material damage mechanics in order to simulate elastic-plastic material response as well as nucleation and accumulation of damage. In accordance with crack initiation period the material models chosen were implemented into Finite Element Code for numerical modelling of the response material in the gear tooth root and life forecast. Due to the material softening tendency and residual stresses affects gears root, the life expectancy curves show potential growth in the loading capacity of the gear. The numerical modelling of fatigue damage can provide good estimated fatigue life for the gears tooth root and can be improved at an early stage by focusing on the crack start time and the gear design.

The method for studying worm gears with Archimedes and involved worms, based on contact pressures, wear on wheel teeth and gear life, as well as the sliding speed of the joint, was evaluated by M V Chernets [44]. Regularities of the correction influence on the specified gear parameters have been indicated. When the coefficient of correction for wheel teeth was positive, the maximum contact pressure and the linear wear of wheel teeth decreased compared to the non-corrected gear, and the correction coefficient increased.

3. Findings of Literature
   a. Different researchers have conducted extensive research on worm and worm wheel design.
   b. Many of these researchers have reported studies on worm and worm wheel such as efficiency assessment, design optimisation, thermal analysis and lubricant behaviour.
   c. When two shaft speed ratios are higher, a worm and worm wheel gear set is generally utilised. Worm and wheel gear sets can reduce the speed and load when non-parallel, non-interacting shafts are employed.
   d. Iterative considerations should be taken while design of the worm gear set to have a minimum number of components in the composite arrangement.
   e. Researchers have established and proposed methods on the basis of various aspects, including tribology, analysis and geometry to predict the efficiency of the worm and worm gear box.
   f. Worm and worm wheel efficiency may be enhanced by making a special nozzle with low friction coefficient material.
   g. Efficient use of high-quality sealing devices to improve worm and worm wheels.
   h. In the production of worm and worm wheels, use of toughest and wear resistant material can improve the efficiency of worm and worm wheels.
   i. Increasing the worm and worm wheel crown diameter will improve worm and worm wheel performance.
   j. Performance of worm and worm wheel can be increased by supplying additional material substrate for the worm wheel's teeth or by covering with a high friction coefficient material.
k. For typical applications like the soot motor no researcher published on the configuration of the worm and worm wheel with a 45:1 gear reduction ratio with higher efficiency.

4. Future Work and Proposed Methodology

In tune with the identified problem and industrial requirement, work will be undertaken on

i) Analysis of existing design of worm and worm wheel of a gear motor for a typical application with torque requirement at around 500 Nm and center distance of 67 mm to satisfy the industrial need.

ii) Improving the design of worm and worm wheel on the basis of suitable aspect like tribological, analytical, geometrical, design of experiments etc.

iii) Propose a mathematical model to estimate life of worm and worm wheel.

iv) Validate the results by using suitable methods.

5. Merits and Demerits

Based on the literature reviewed and the findings, the proposed system will have merits and some limitations as discussed below

Merits

- The system will be useful to predict the life of worm and worm wheel and ultimately the life of gear box.
- Improve the existing design of worm and worm wheel.

Demerits (Scope of the Study)

- The Proposed work is limited to study of worm and wheel and may not be generalized for all type of gear systems.

6. Conclusion

This study aimed to analyse detailed literature on the design of worm and worm wheel in recent years. Research has shown that several researchers developed and proposed methods for predicting the effectiveness and improved design of worm gearboxes in a number of aspects, such as tribology, analysis and geometry. In addition, it can also be easily seen that the fields of worm and worm wheel studies are based on the assumption that the enhanced configuration and performance of worm and worm wheel for a gear motor has still not been identified for standard applications, for example. There will then be a great deal of space for future work in the area of worm and worm wheel to satisfy the industrial need.

Acknowledgement: Authors are thankful to the authorities of Walchand Institute of Technology, Solapur to support this work.

Funding Statement: The authors received no specific funding for this study.

Conflicts of Interest: There is no conflicts of interest to the authors in publishing this paper.

References

[1] Milan O, Dragan Z, Krešimir V 2015 Wear 332-333 1145–50.
[2] Wanarase U B, Patil U S, Patil N B 2017, Thomson Ruters IJESRT 6
[3] Mokara B, Poornima V D, Jyothrimai S 2015 International Journal of Scientific and Research Publications 5 Issue 2.
[4] Mailapalli R, Hidayatulla S K 2017 IJMETMR 4.
[5] http://www.lhp.co.in, Laxmi Hydraulics Pvt. Ltd, Chincholi, MIDC, Solapur.
[6] Xingqiao D, Shisong W, Youssef H, Linmao Q, Yucheng L 2020 Tribology International 146
106261.

[7] Qingxiang M, Yaping Z, and Zaiyou Y 2019 Proc I Mech E Part C: J Mechanical Engineering Science 0(0) 1–11.

[8] Chongfei H, Yaping Z 2019 Mechanism and Machine Theory 134 476–98.

[9] Wojciech K, Maciej M, Zbigniew B 2018 archives of civil and mechanical engineering 18 983 – 99.

[10] Piotr B 2017 Procedia Engineering 177 57 – 63.

[11] Claudiu I B, Vasile B 2016 Procedia Technology 22 68 – 73.

[12] Magareta C, Vasile B 2016 Procedia Technology 22 55 – 59.

[13] Eva M M, Werner S, Johann P S and Karsten S 2015 Proc I Mech E Part C J Mechanical Engineering Science 0(0) 1–5.

[14] Ehsan S, Houshmand A, Nezamabadi A 2014 Indian J.Sci.Res./I 2 525-27.

[15] Claudiu I B, Vasile B 2014 Procedia Technology 12 442 – 47.

[16] Gun H K, Jeong W L, and Tae I S 2013 Materials 6 1873-90 doi:10.3390/ma6051873.

[17] Mogal Y K and Wakchaure V D 2013 Bonfring International Journal of Man Machine Interface 3 No.1.

[18] Elforjani M, Mba D, Muhammad A, Sire A 2012 Applied Acoustics 73 859–63.

[19] Takao K, Mikio T, Hideo T, Koutis M 2011 Proceedings of the ASME 2011 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference 2011.

[20] Piotr P and Mariusz S 2017 Open Eng 407–15.

[21] Pavel M and Svetlana S 2019 MATEC Web of Conferences 298.

[22] Slavica M, Saša R, Sandra V, Raed A, Aleksandar S, Veljko Š 2017 Applied Engineering Letters 2 No.2 69-75.

[23] Magyar B, Sauer B 2014 ResearchGate Chapter.

[24] James B STOBER Drives Inc. (Maysville) 800-711-3588.

[25] Seong H K, Min C S, Jung W B, Kwang H and Chong N C 2012 International Journal of Precision Engineering and Manufacturing 13, No. 2 pp. 167-174.

[26] Constantin P, Martin S, Thomas L, Karsten S 2020 Forsch Ingenieurwes 84 15–125.

[27] Radosavljević S Z, Stojanović B Z and Skulić A D 2018 IOP Conf. Series: Materials Science and Engineering 393 012050.

[28] Faydor L L, Ignacio G P, Kenji Y, Alfonso F, Kenichi H 2007 Mechanism and Machine Theory 42 940–59.

[29] Shah A P, Jadhav Y 2020 Researchsquare.

[30] Paridhi R., Barman A G 2019 IOP Conf. Series: Materials Science and Engineering 635.

[31] Octue M A C.E.T.I.M. Senlis France.

[32] Litvin F L, Argentieri G, De Donno M, Hawkins M 2000 Computer Methods in Applied Mechanics and Engineering. 189 785-801.

[33] Shah P B, Motka C, Shah K A 2015 International Journal of Advance Engineering and Research Development 2 Issue 5.

[34] Jadhava Y B, Shah A P 2017 International Journal of Scientific & Engineering Research 8 Issue 4.

[35] Seong H K 2018 Mech. Sci. 9 201–10.

[36] Massimiliano T 2016 Technology.

[37] Manuel O, Balázs M and Bernd S, 2018 Power Transmission Engineering.

[38] Oladejo K A, Abu R, Kolawole T O , Dare A A and Olufemi A B 2018 European Journal of Engineering Research and Science 3 No. 12.

[39] Steve D, Pieter D, Elewijn A, Stijn D, Kurt S Ghent University Campus Kortrijk Department of Industrial System and Product Design Belgium.

[40] Adil M N R D Z 2013 Transactions of Famena, xxxvii-4.

[41] Chen K Y, Chung B T 2009 Mechanism and Machine Theory 44 1701–12.
[42] Elkholy A H, Falah A H 2015 World Academy of Science Engineering and Technology
International Journal of Mechanical and Mechatronics Engineering 9 No.9.

[43] Marina F, Robert B, Robert K, Ivan P 2011 Procedia Engineering 10 562–67.

[44] Chernets M V 2019 Journal of Friction and Wear 40 No. 4.