



Worm Gear Reducer Design An Strength Analysis KissSoft-KissSys Program

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ABSTRACT

This manuscript presents a comprehensive engineering approach to the design and structural analysis of worm gear reducers. The gearbox system developed with the objectives of high reduction ratio, compact structure and reliable operation is evaluated in detail using numerical analysis methods and international design standards. Accordingly, basic design parameters such as gear geometry, material selection, assembly tolerances and lubrication conditions were systematically analyzed, and simulations were performed at component and system level with a focus on performance and reliability using KISSsoft and KISSsys software. As a result of the analyses, key performance parameters such as structural stresses, fatigue strength, deflections, contact geometries and overall efficiency were evaluated, and a critical point was identified, especially in the life of a shaft bearing, and areas for improvement were identified. The overall findings show that worm gear reducer systems can be effectively investigated and optimization potentials can be revealed with theoretical modeling and CAE tools.

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Introduction

In worm gear reducers used in applications requiring high torque transmission and compact design, a critical design problem arises between system efficiency and bearing life. The aim of this study is to investigate this problem through KISSsoft/KISSsys-based parametric analyses, to identify the reliability-limiting factors, and to discuss potential improvements.

Ulusoy (2024) conducted a study in which he performed a performance evaluation and backlash analysis of the worm gear mechanism. In this context, experiments were conducted with six different values for three different reducers, and the results were compared. The specially designed worm gear mechanism for this study demonstrated better performance compared to the traditional two-value worm gear mechanism. The results revealed that the designed mechanism provides lower backlash and higher accuracy [1]. Fang and Tsay highlighted the effects of mechanical factors such as contact pressures, friction, and wear in these gear sets through mathematical modeling. This study has made significant contributions to research in worm gear design and strength analyses and has provided insights into the design of more efficient gear systems [2]. Salman (2009) conducted a comprehensive study on the mathematical modeling of

worm gears and worm gear counterparts [3]. Kacalak and colleagues presented a study examining worm gear systems with improved kinematic accuracy. In this research, new design and machining techniques aimed at enhancing the kinematic accuracy of worm gear sets were discussed. The authors focused on minimizing tooth profile errors to improve the performance of the gear sets, and on methods that enhance the load-carrying capacity and efficiency of the gear systems [4].

Flexibility and accuracy provided by the CAD environment play a crucial role in optimizing the performance of gear sets. The study demonstrated that CAD-based modeling allows for a better understanding of gear systems from both kinematic and strength analysis perspectives, while also improving efficiency in the design process. This research serves as an important resource for future studies on worm gear design and strength analysis [5]. Strength analyses of the gear sets emphasized that double depth teeth enhance the durability of the gear systems, leading to longer lifespans. This study demonstrated how innovative structural modifications used in the design of worm gears provide significant advantages in terms of performance and durability, making important contributions to research in worm gear design and strength analysis [6]. Thesis demonstrated how computer-based methodologies could be effectively applied in the design of worm gear reducers and

underscored the importance of these approaches in engineering applications [7].

Recent studies emphasize the importance of coating technologies and thermal performance optimizations in reducing efficiency losses in worm gear systems [8-9].

Material Method

Worm gear reducers play an indispensable role in mechanical power transmission systems where high gear reduction ratios are required. These reducers are particularly favored in applications where low rotational speeds, high torque transmission, compact design, and quiet operation are essential. The software tools utilised, the design parameters determined according to application requirements, and the methodologies followed in selecting these parameters are systematically presented. In addition, structural analyses, material selection, and strength evaluations were conducted in accordance with international standards, including ISO/TR 14521 and DIN 3996, with the objective of assessing the mechanical performance of the reducer. In the present study, the KISSsys and KISSsoft software programmes were employed for the design and analysis of mechanical systems

Basic Data

In the “Basic Data” tab of KISSsoft, the basic geometry of the worm-worm wheel pair is initially defined by entering a modulus of 3 mm, a normal pressure angle of 20° , a center distance of 80 mm and a shaft angle of 90° . The number of teeth is then set to $z_1 = 2$ for the worm screw and $z_2 = 40$ for the worm wheel, resulting in a gear ratio of 20:1.

In this study, a worm gear system was developed for use in an automatic garage door. An AC motor with an input speed of 600 rpm and an output torque of approximately 12–14 Nm was selected to drive the mechanism. A gear ratio of 20:1 was selected to reduce the motor speed of 600 rpm to approximately 30 rpm at the output shaft, ensuring controlled movement of the garage door. This ratio also allows sufficient torque amplification to meet the lifting requirements of an average garage door, while maintaining compactness and efficiency of the gear system. Additionally, this ratio is commonly used in similar commercial applications, which supports its practicality.

A module value of 3 mm was selected to provide sufficient strength and durability for the worm and worm gear teeth, ensuring safe transmission of torque without excessive wear. This value also maintains a balance between gear size and load capacity, and corresponds to a standard metric gear size that facilitates manufacturing and component sourcing. The number of teeth was chosen as $Z_1 = 2$ for the worm and $Z_2 = 40$ for the worm gear to achieve the desired reduction ratio of 20:1. A two-thread worm ($Z_1 = 2$) was selected to improve transmission efficiency and reduce sliding wear, while maintaining compatibility with the target speed reduction. The 40-tooth worm gear allows for a compact design and ensures sufficient output torque. The center distance was selected as 80 mm to provide sufficient spacing between the worm and worm gear while maintaining a compact design. This value also accommodates the selected module ($m = 3$ mm) and tooth

numbers ($Z_1 = 2$, $Z_2 = 40$), ensuring proper meshing and tooth contact. A slightly extended center distance compared to the theoretical minimum (63 mm) helps reduce surface pressure and improves the durability and thermal stability of the gear set. A module value of 3 mm was selected to ensure sufficient tooth thickness and load carrying capacity for the worm gear system. This fig.1 value represents a practical balance between mechanical strength and component compactness, while also being a commonly available standard in gear manufacturing.

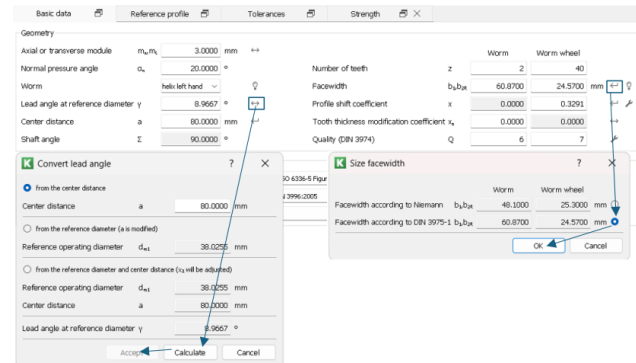


Figure 1. Convert lead angle and size facewidth tabs in 'Basic data' tab of KISSsoft software

Material Selection

Material selection in worm gear mechanisms plays a critical role in terms of efficiency, durability and long life of the system. In such mechanisms, hardenable steel (e.g. 20MnCr5) for the worm element and bronze with high tin content (e.g. CuSn12-C-GZ) for the gear wheel are generally preferred.

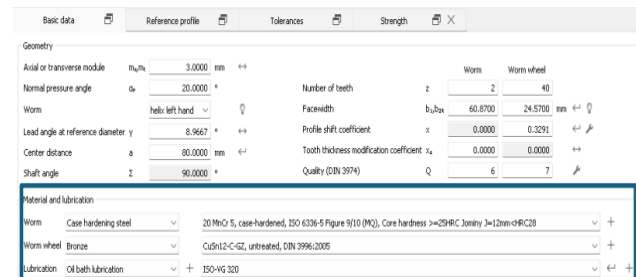


Figure 2. Material selection tab of KISSsoft software

Tolerances

The Tolerances tab in KISSsoft facilitates the precise definition of manufacturing eviations and clearance parameters for both the worm and the worm wheel.

Table 1. Niemann tolerances to DIN 3967

Proposal acc. to Niemann (tolerances acc. to DIN 3967, module > 0.5 mm)	
Casted rims	a29, a30
Rims (normal backlash)	a28
Rims (tight backlash)	bc26
Turbo gears (high temperatures)	ab25
Polymer machines	c25, cd25
Locomotive gear trains	cd 25
Standard mechanical engineering, heavy machinery, not reversing	b26
Standard mechanical engineering, heavy machinery, reversing	c25, c24, cd25, cd24, d25, d24, e25, e24
Automobiles	d26
Agricultural vehicles	e27, e28
Machine tools	f24, f25
Printing machines	f24, g24
Measuring gearboxes	g22

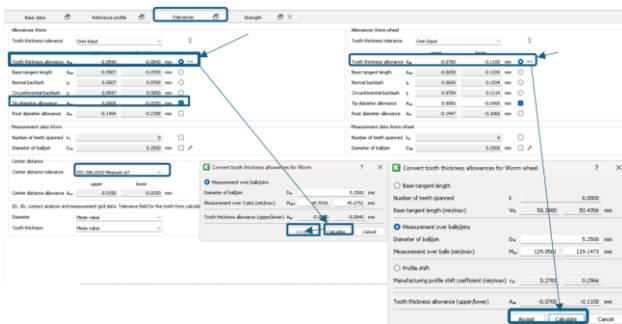


Figure 3. 'Tolerances' tab of KISSsoft software

To make this calculation, click on the double-sided arrow icon to the right of the Tooth thickness allowance option, then click Calculate and accept in the window that opens and the calculation is made. Click on the tick next to Tip diameter allowance. Tooth thickness tolerances, which directly affect the precision of the gear geometry, were determined based on “ball over pins” as the measurement method. These tolerances, defined in the range of $-0.0540 / -0.0840$ mm and $-0.0700 / -0.1100$ mm for worm and worm wheel, respectively, ensure post-production measurement and assembly precision and contribute to the efficient operation of the system by reducing backlash. End diameter tolerances, on the other hand, are not directly in the contact zone, but are important in terms of assembly fit. For this reason, $0 / -0.0250$ mm for worm and $0 / -0.0400$ mm for worm wheel. In addition, the center distance tolerance in the system is defined in the js7 tolerance class in accordance with the ISO 286-1 standard and is left in the range of ± 0.015 mm. This choice ensures that the gear contact line is protected, creating a quiet and smooth working condition. All these tolerances have been set to optimize both the manufacturability and the longterm performance of the system.

Strength

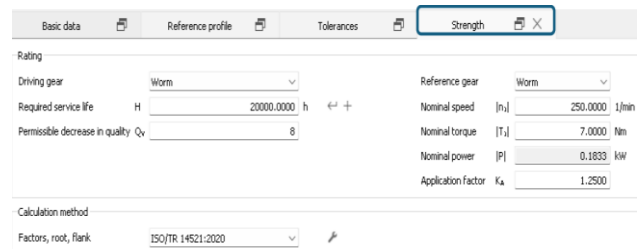


Figure 1 'Strength' tab of KISSsoft software

The Strength section in KISSsoft is utilized for the calculation of the root and flank strength of gear systems. In this section, key operating parameters such as torque, speed, power, and service life are defined, and strength analysis is carried out according to international standards.

Bearing Selection In KISSsys

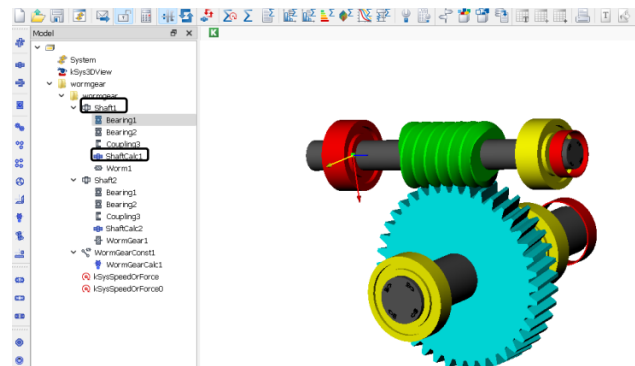


Figure 4. Bearing selection tab of KISSsys software

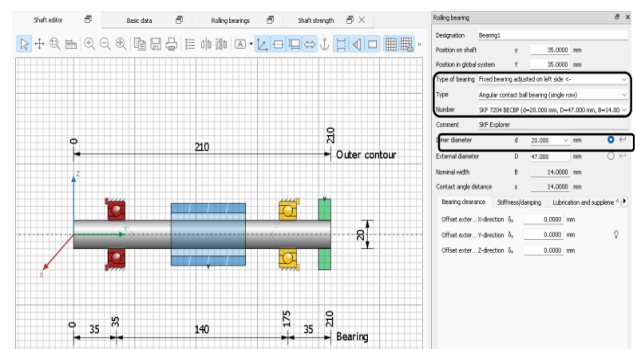


Figure 5. Worm 2D bearing selection screen in KISSsys

For this specific design, the SKF 7204 BECBP model single-row angular contact ball bearing was selected for the worm shaft. This bearing, with standard dimensions of a 20 mm inner diameter, a 47 mm outer diameter, and a 14 mm width, features the "BECBP" designation, which indicates an approximate 40° contact angle, a robust steel cage, and universal matching capability.

When our design is finished, we must define the input speed and torque to the system. For this, some elements are added into Shaft 1 in the models section. To add this shaft element, select the element box from the Insert tab and select the 2nd element (kissSyscoupling) from the left in the shaft element and add it into Shaft1.

Figure 6. Speed-Torque calculation in KISSsys

In this fig.6, we can define speed and torque for the couplings that we previously added to Shaft1 and Shaft2. In our system, since the input will be from the worm, we select the element we added to shaft1. then we must make the Speed constrained and torque constrained option yes so that we can give values. then we enter the speed =600.00rpm (1/min) and torque = 10.00Nm values we have determined, click ok and confirm.

Strength

The structural behavior of the worm shaft (Shaft1) under working loads was investigated in detail by means of deflection analysis performed by means of KISSsoft software. The shaft deformation graph presented in Figure 7 visualizes the displacement in millimeters as a result of bending and other forces to which the shaft is subjected along the axial Y direction.

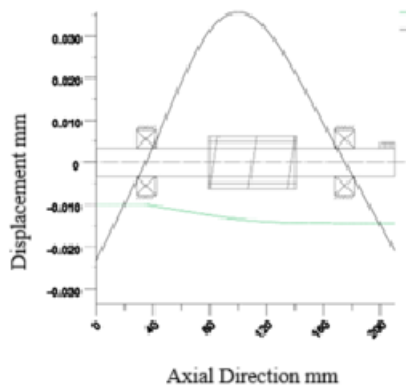
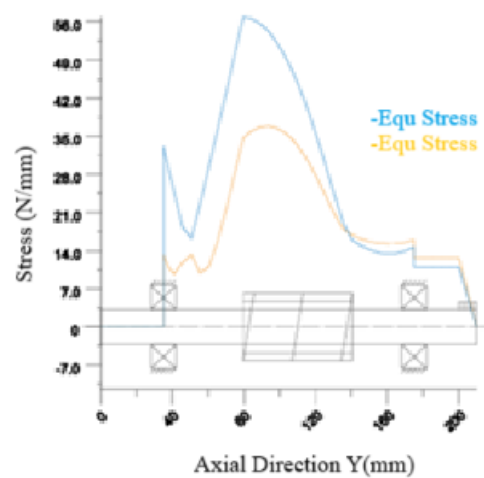


Figure 7 Deformation analysis results of worm shaft (Shaft1) under load

According to this graph and the accompanying numerical data, the maximum deflection on the shaft was calculated to be 35.636 μm (micrometers) and it was determined that this maximum deformation occurred at a location of approximately 98.294 mm on the shaft between the bearing points. It was also found that the shaft was subjected to a total axial load of -3333.333 N during operation and exhibited a torsion angle of 0.044 degrees under the influence of the applied torque.

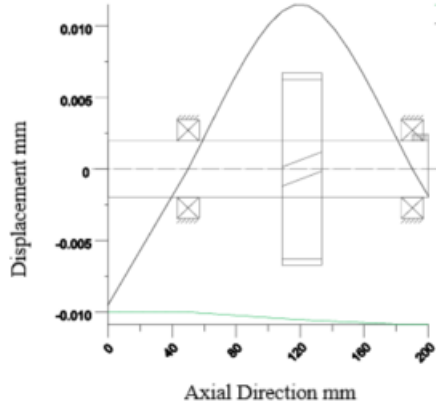
The deflection and torsion values obtained from this analysis provide important information about the geometric stability and stiffness of the worm shaft during operation. In particular, the maximum deflection of 35.636 μm is a critical parameter for maintaining the correct contact between the gears and the performance of the bearings. It is concluded that this deflection is within acceptable limits (as confirmed by the high deflection safety coefficient calculated as $S_d=19.958$ in the relevant section of the KISSsoft report), considering its effects on the overall operating accuracy and life of the system. Therefore, it is considered that the worm shaft has sufficient structural strength under the designed loads and the required stiffness to exhibit the expected functional performance. This is a positive indication for long life and reliable operation of the gearbox.



Graphic 8 Equivalent stress distribution along the axial direction of the worm shaft (Shaft1) calculated according to von Mises (GEH) and Tresca (SSH) criteria

In order to determine the structural adequacy of the worm shaft (Shaft1) under service loads, the distribution of equivalent stresses along the shaft was analyzed using KISSsoft software. The stress distribution graph presented in Figure 9 shows in detail the equivalent stress levels (in N/mm^2) along the axial Y-direction of the shaft calculated according to both von Mises (blue curve denoted as GEH) and Tresca (orange curve denoted as SSH) criteria. By examining the graph, it is clear that the highest stress concentration occurs close to the central regions of the shaft, especially around the region where the worm gear is located (between about 80 mm and 100 mm). In this critical region, the von Mises equivalent stress reaches a peak value of just over 56 N/mm^2 , while the Tresca equivalent stress reaches a maximum value of around 38 N/mm^2 . The maximum equivalent stress values obtained from this analysis are compared with the mechanical properties of the C45 steel from which the shaft is manufactured, such as yield and fatigue strength, to provide a basis for concluding on the safety of the shaft. The observed maximum von Mises stress of approximately 56 N/mm^2 is well below the typical yield strength of C45 steel. This indicates that the

shaft has a low risk of permanent deformation under static loads and will maintain its structural integrity under operating conditions. Therefore, the stress distribution and peak values obtained indicate that the design of the worm shaft has sufficient strength for the applied loads and can operate safely.



Graphic 9 Deformation analysis results of worm wheel shaft (shaft2) under load

Conclusion

When the KISSsoft analysis make on the performance of the worm gear reducer system designed within the scope of your thesis study is evaluated in general, it is seen that the design is successful in many aspects, but there is potential for improvement in some critical points. The worm gear set analysis results show that the main power transmission elements of the gearbox meet the targeted criteria in terms of strength and life. The calculated wear safety coefficient ($SW=1.264$), pitting safety coefficient ($SH=1.347$) and tooth bottom fracture safety coefficient ($SF=3.794$) for the gear wheel are above the minimum requirements specified in the relevant standards. The calculated system service life of 119,613 hours for the gear set significantly exceeds the targeted service life of 20,000 hours. The deflection safety of the worm shaft ($S_d=19.958$) and the thermal safety of the system ($ST=2.050$) with a calculated oil temperature of 43.9°C are also satisfactory. The calculated total efficiency of the gearbox was determined as 70.993%. When the structural analyses of the shafts are examined, the maximum deflections ($35.636\ \mu\text{m}$ and $11.505\ \mu\text{m}$, respectively) and the maximum equivalent von Mises stresses ($\sim 56\ \text{N/mm}^2$ for shaft1 and $\sim 54\ \text{N/mm}^2$ for shaft2) occurring in both the worm shaft (shaft1) and the worm wheel shaft (shaft2) under operating loads are within acceptable limits considering the mechanical properties of the C45 shaft material used. This confirms that the shafts show sufficient stiffness and strength under load. The evaluation of bearing performances points to an area where the results require more careful scrutiny. Both of the SKF 7007 ACD/P4A bearings (Bearing1 and Bearing2) used in the worm wheel shaft (Shaft2), with their calculated L10h life (199,523 hours and 347,193 hours respectively), more than meet the targeted service life of 20,000 hours. However, of the SKF 7204 BECBP bearings used in the

worm shaft (Shaft1), the calculated L10h life of the primary bearing (Bearing1) located closer to the power input is approximately 5498 hours. This is well below the targeted service life of 20,000 hours, indicating a damage rate of 363.78%. This finding suggests that the design requires a critical refinement or more detailed investigation at this particular point. It should be noted that the bearing life calculations assume an ISO-VG 220 viscosity oil at an operating temperature of 70°C for the shaft bearings and an ISO-VG 320 viscosity oil for the gear set, with an oil bath temperature of 43.9°C . If a single common oil bath is used in the system, updating the bearing life analysis to the actual operating conditions of the gear set with oil (ISO-VG 320) and a lower temperature (approximately 44°C) may provide a more realistic assessment of the life of this critical bearing. Otherwise, the choice of a different bearing or a modification of the bearing arrangement may be unavoidable. The obtained efficiency value of 70.99% is reasonable when compared to the 72–75% range reported in the study of Zhao et al. (2021). However, the bearing life results (approximately 5,498 hours) are considerably lower than the lifetimes reported in the literature for similar capacities (over 20,000 hours). This indicates that the input-side bearings, in particular, represent a critical limitation for system reliability. In conclusion, it is concluded that the analyzed worm gear reducer design is generally successful and safe in terms of the gear set and shafts, but the life of the primary bearing on the worm shaft is the most important limiting factor in terms of the overall reliability and targeted service life of the system, and this issue should be further investigated or the design should be revised.

Acknowledgement

This study was carried out practically in a special gearbox enterprise and the results were manufactured correctly.

References

- [1] Ulusoy, E., Diş Boşluğu Ayarlanabilen Sonsuz Dişli Mekanizmasının Tasarımı, Karabük Üniv. Müh.Fak. Mak.Müh. Fen.Bil.Enst., (Yüksek Lisans Tezi), Türkiye, 2024.
- [2] Fang, H. S. ve Tsay, C. B., "Büyük boy ocak kesiciler tarafından kesilen ZN tipi sonsuz dişli setinin matematiksel modeli ve yatak kontakları. Mekanizma ve Makine Teorisi", 35(12), 1689-1708, 2000.
- [3] Selman, B. (2009). Sonsuz vidalar ve sonsuz vida karşılık dişlisi helisel dişli matematik modellemesi, İTÜ Fen Bil.Enst. Mak.Müh., (Yüksek Lisans Tezi).
- [4] Kacalak, W., Majewski, M., Budniak, Z. ve Ponomarenkow, J., "Geliştirilmiş kinematik hassasiyete sahip sonsuz dişli tahrikleri", Malzemeler, 14(24), 7825, 2021.
- [5] Połowniak, P., Sobolak, M. ve Marciniak, A., "CAD ortamı kullanılarak çift zarflı sonsuz dişli modellemesi", Polonya Bilimler Akademisi Teknik Bilimler Bülteni, e136736-e136736, 2021.
- [6] Chen, W. L., Tsay, C. B. 2011. "Mathematical Model and Tooth Surfaces of Recess Action Wormgears with Doubledepth Teeth," Mechanism and Machine Theory, vol. 46 (12), p. 1840-1853.
- [7] Pak, M. (1998). Sonsuz vidalı redüktörlerin bilgisayar yardımıyla parametrik tasarımı, Sakarya Üniversitesi, Fen Bil.Enst. Mak.Müh., (Yüksek Lisans tezi).
- [8] Li, X., et al. (2022). "Tribological performance of worm gears with advanced coatings." *Wear*, 494–495, 204285.
- [9] Zhao, Y., et al. (2021). "Optimization of worm gear design considering efficiency and thermal performance." *Mechanism and Machine Theory*, 162, 104379 .