

Review Paper on Design and Fabrication of Worm Shaft using

CNC Lathe Machine

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ABSTRACT

The performance and reliability of worm gear drives depend strongly on the accuracy and surface quality of the worm shaft, especially in applications requiring compact design and high reduction ratios. Conventional manufacturing methods rely on standard module hubs and manual machining operations, which limit flexibility and increase cost for customized worm shafts. This work presents the design and fabrication of a custom worm shaft using a CNC lathe machine, employing a grooving tool for custom thread cutting instead of specialized hobs. The methodology includes design calculations, 3D CAD modeling, CNC toolpath generation using CAM software, experimental machining on a CNC turning center, and inspection of dimensional accuracy and surface finish. Results indicate that the CNC-based approach can achieve dimensional tolerances of about ± 0.02 mm, surface roughness of approximately $Ra\ 1.6\ \mu m$, and a production time reduction of 25–30% compared with manual machining, while enabling flexible production of non-standard worm modules.

1. INTRODUCTION

Worm gear mechanisms are widely used in industrial power transmission where motion must be transferred between non-parallel, non-intersecting shafts arranged at right angles. They offer high reduction ratios in a compact layout, smooth operation, and self-locking capability in many cases. The worm shaft is the driving element of this pair and plays a crucial role in torque

transmission, efficiency, and noise characteristics of the gearbox.

Traditionally, worm shafts are manufactured using standard module hubs and multi-step manual operations on conventional lathes, including turning, threading, grinding, and finishing. These processes are labor-intensive, require high operator skill, and are optimized mainly for standard sizes and large batch production. When non-standard modules, special reduction ratios, or prototype gearboxes are required, reliance on standard hubs and specialized hobs becomes uneconomical and inflexible.

With the increasing trend toward customization and digital manufacturing, there is a need for a cost-effective method to fabricate custom worm shafts with high precision and repeatability. CNC lathe machines, in combination with CAD/CAM tools, provide the capability to generate arbitrary thread profiles and modules through programmable toolpaths, eliminating the need for dedicated hobs. This paper focuses on exploiting CNC technology to design and fabricate a worm shaft using a custom grooving tool, demonstrating a flexible, economical approach suitable for academic and small-scale industrial applications.

2. LITERATURE REVIEW

In conventional practice, worm shafts are produced on manual lathes using a sequence of operations—facing, rough turning, finish turning, thread cutting, and grinding or polishing. Thread profiles are created using taps, dies, or hobbing with specialized cutters that are designed for specific modules and pressure

angles. Manual control of feed and depth of cut introduces variability in thread depth and pitch, while multiple setups increase the likelihood of alignment and concentricity errors.

Existing methods are economical when large volumes of identical shafts are produced, since the cost of special hobs and dedicated fixtures can be distributed over many components. However, for small batches, customized modules, or frequent design changes, new tooling and setups become cost-prohibitive and time-consuming.

Advances in CNC technology have enabled precise control of spindle speed, feed, and tool motion, making it suitable for complex profiles such as threads and worms. When combined with CAM systems, CNC lathes can execute optimized toolpaths generated from CAD models, ensuring repeatable geometry and improved surface quality. The present work integrates these aspects into a unified workflow specifically tailored to custom worm shaft production.

3. OBJECTIVES

- i. To design a worm shaft for power transmission applications using standard machine design principles and strength criteria.
- ii. To determine shaft diameter and thread dimensions from torque and stress analysis, considering the properties of EN8 steel.
- iii. To model the worm shaft in 3D CAD software and generate CNC toolpaths via CAM for turning and threading operations.
- iv. To fabricate the worm shaft on a CNC lathe using a custom threading approach with a grooving tool instead of standard hobs.
- v. To evaluate dimensional accuracy, surface finish, production time, and cost-effectiveness of the CNC process compared with conventional methods.
- vi. To establish a low-cost, flexible workflow for small-batch and prototype worm shaft manufacturing suitable for academic and industrial environments.

4. SCOPE OF THE WORK

The scope of this work is limited to the design, CNC simulation, and fabrication of the worm shaft itself. It includes design calculations, CAD modeling, CAM toolpath generation, CNC turning and threading with carbide tools, and inspection of key dimensions and surface finish. Detailed design and fabrication of the mating worm wheel, full-load performance testing of

the gear pair, and long-term durability analysis are not covered and are proposed as future work.

The study is positioned to demonstrate the feasibility and advantages of a CNC-based approach in a laboratory or small-industry setting where access to CNC turning centers and CAD/CAM software is available.

5. METHODOLOGY.

- i. Problem Identification: Review of existing worm shaft manufacturing practices to identify limitations related to flexibility, cost, and accuracy in conventional systems.
- ii. Design and Analysis: Definition of power, speed, and reduction requirements followed by calculation of shaft diameter and thread parameters using machine design principles and EN8 material properties.
- iii. CAD and CAM Modeling: Creation of a 3D CAD model of the worm shaft and generation of turning and threading toolpaths in MasterCAM.
- iv. CNC Fabrication: Execution of facing, turning, grooving, and custom thread cutting operations on a CNC turning center using carbide tooling.
- v. Inspection and Evaluation: Dimensional and surface finish inspection of the fabricated shaft and comparison of CNC performance with conventional machining benchmarks.
- vi. Documentation: Systematic recording of design data, process parameters, measurements, and observations for analysis and future replication.

6. DESIGN AND EXPERIMENTAL SETUP

The worm shaft is manufactured from EN8 medium carbon steel, selected for its moderate hardness, good tensile strength, and favorable machinability for shaft applications. The raw stock is a cylindrical bar of approximately 150 mm in length and 16 mm in diameter, providing sufficient material for the final profile and chucking allowance.

The final geometry consists of a single-start worm thread with pitch determined by the required module and reduction ratio. The design includes undercut grooves, chamfers at edges, and appropriate fillet radii to reduce stress concentration and facilitate smooth meshing with the worm wheel. Thread form parameters are chosen based on standard worm gear data to ensure compatibility with typical worm wheel profiles, while maintaining adequate root strength.

The experimental setup utilizes a CNC turning center such as an LMW SmartTurn or Haas ST-10, equipped with a FANUC controller. Carbide inserts are used for roughing, finishing, and thread cutting operations, allowing higher cutting speeds and contributing to better surface finish and shorter cycle times. Process parameters such as spindle speed, feed, depth of cut, and coolant usage are selected based on material machinability data and tool manufacturer recommendations.

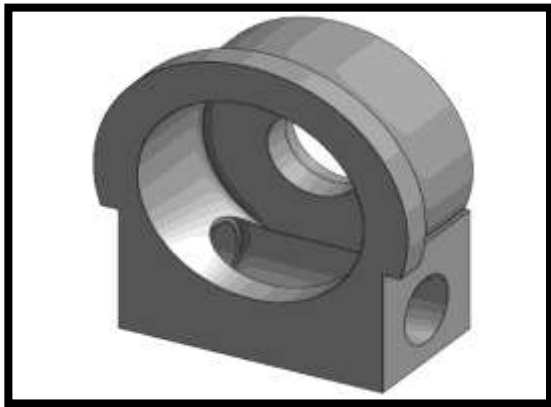


Fig.1 Design of Gear Box Body

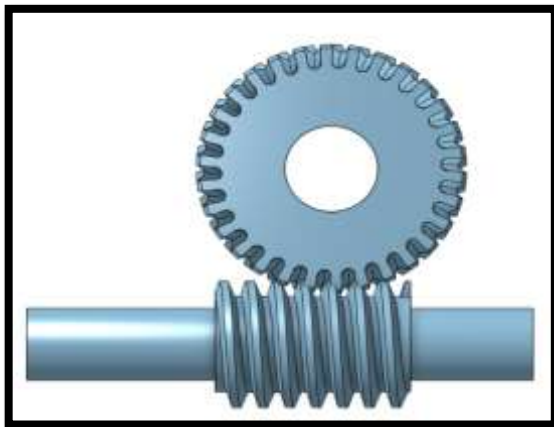


Fig.2 Design of worm wheel & shaft

7. RESULTS

Inspection of the fabricated worm shaft confirms that the CNC process can maintain key dimensions such as shaft diameter and thread pitch within approximately ± 0.02 mm of the design values. This level of precision is adequate for most worm gear applications and reduces the need for additional finishing or corrective machining.

Surface finish on the CNC-turned shaft is observed to be significantly better than that typically achieved with manual operations, with measured roughness values

close to $Ra 1.6 \mu\text{m}$ on functional surfaces. Improved surface quality contributes to smoother engagement with the worm wheel, reduced friction, and lower noise levels during operation.

From a productivity standpoint, the CNC-based process demonstrates an estimated reduction in production time of about 25–30% compared with equivalent operations on a conventional lathe. Although initial investment in CNC machinery is higher, this is offset in small-batch and prototype contexts by the elimination of special hobs and the ability to modify designs through program changes alone.

8. FUTURE SCOPE

- i Design and fabrication of the mating worm wheel followed by experimental evaluation of the complete worm gear set under various load and speed conditions.
- ii Measurement and analysis of efficiency, temperature rise, noise, and vibration to quantify functional improvements attributable to enhanced accuracy and surface finish.
- iii Systematic optimization of process parameters using design of experiments or response surface methodology to further improve productivity and tool life.
- iv Integration of real-time condition monitoring and adaptive control to adjust cutting parameters dynamically in response to tool wear and variations in material properties.
- v Development of parametric CAD/CAM templates that automatically generate toolpaths and CNC code for user-specified design inputs, enabling rapid customization of worm shafts and other threaded components.

9. ACKNOWLEDGEMENT

The authors wish to acknowledge the guidance of faculty members and laboratory staff for their support during the design, simulation, and machining phases of this work, as well as the institution for providing access to CNC turning centers and CAD/CAM software. The role of standard machine design and manufacturing texts and data books in providing essential design and process knowledge is also gratefully recognized.

10. CONCLUSION

This study demonstrates that custom worm shafts can be effectively designed and fabricated using CNC lathe technology with a grooving tool for custom threading, without the need for standard hubs or dedicated hobs. The integrated workflow—comprising design calculations, CAD modeling, CAM simulation, CNC machining, and inspection—achieves high dimensional accuracy, improved surface finish, and reduced production time relative to conventional manual methods.

The method offers key advantages including high precision and repeatability, superior surface finish, reduced dependence on operator skill, flexibility to produce different modules and profiles by modifying CNC programs, and lower per-component cost for custom and small-batch production when compared to tooling-intensive conventional methods. These benefits make the proposed CNC-based approach well-suited to academic laboratories, R&D centers, and small industries focusing on customized power transmission solutions.

11. REFERENCES

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