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Designand Development of Lead measurement instrument for Worm gear Inspection

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***Abstract:** The accuracy of worm gear geometry plays a critical role in ensuring efficient power transmission in mechanical systems. Worm gears are widely used in various industrial applications because they provide high torque reduction, compact design, and smooth motion transmission. However, the performance and durability of these systems largely depend on the accuracy of important geometric parameters such as lead, pitch, and tooth profile. Any deviation in these parameters can result in improper meshing between the worm and worm wheel, leading to vibration, excessive wear, reduced efficiency, and shortened service life of the gear mechanism. Therefore, accurate inspection and measurement of worm lead is essential for maintaining the quality and reliability of gear transmission systems.*

The objective of this project is to design and develop a simple, economical, and reliable lead measurement instrument for worm gear inspection. Conventional lead measurement methods typically require advanced equipment such as coordinate measuring machines (CMM) or specialized gear inspection machines, which are expensive and not easily available in educational laboratories or small-scale industries. To overcome this limitation, this project proposes a cost-effective inspection system that can measure the lead and angular displacement of worm gears with acceptable accuracy while maintaining simplicity in design and operation.

***Keywords**: Metrology, Low cost design, Lead measurement, Worm gear inspection, Quality*

I. INTRODUCTION

Worm gear systems are widely used in mechanical engineering applications where high torque transmission, compact design, and smooth motion are required. These systems are commonly found in lifting mechanisms, conveyors, automotive components, and industrial machinery. The performance and efficiency of a worm gear system mainly depend on the accuracy of its geometrical parameters, among which the lead of the worm plays a critical role. The lead is defined as the axial distance advanced by the worm in one complete revolution, and any deviation in this parameter can directly affect the meshing condition between the worm and the worm wheel.

In industrial practice, maintaining accurate lead is essential to ensure proper power transmission, reduce vibration, and avoid excessive wear. However, measuring the lead of worm gears is not always straightforward, especially in cases where the components are manufactured using non-standard modules. In many industries, worm gears are treated as proprietary products, and their design details are not disclosed. As a result, when such components are brought for rework or inspection in a different facility, conventional gauges and standard measuring tools fail to provide accurate results.

Traditional methods of lead measurement often involve sophisticated and expensive equipment such as coordinate measuring machines (CMM) or dedicated gear inspection machines. While these methods provide high accuracy, they are not always accessible in academic institutions or small-scale industries due to their high cost and complexity. In addition, manual measurement techniques are time-consuming and depend heavily on operator skill, which may lead to inconsistencies in the results.

To address these challenges, this project focuses on the design and development of a simple, cost-effective lead measurement instrument specifically for worm inspection. The main idea is to create a system that can accurately measure the lead by synchronizing the rotational movement of the worm with the linear displacement of a measuring mechanism. By using a rotary encoder to track angular motion and a linear scale to measure axial movement, the system enables reliable and repeatable lead measurement.

The developed setup aims to bridge the gap between theoretical gear geometry and practical inspection requirements. It is designed to be easy to operate, economical to fabricate, and suitable for both educational and industrial applications. This approach not only improves measurement accessibility but also supports effective reworking and quality verification of worm components.

II. LITERATURE REVIEW

Lee surveys recent advancements in precision metrology techniques for worm gears, emphasizing tactile and optical methods for lead measurement. The paper highlights novel sensor technologies and improved calibration protocols that enhance measurement accuracy and repeatability. It discusses how these innovations tackle challenges like mechanical backlash and environmental variability in industrial inspection settings.

Stoddard providesanexhaustiveexaminationofmeasurementtechnologies in gear manufacturing, covering high-precision instruments used for thread lead evaluation. The author explores design principles for instrument rigidity, alignment accuracy, and sensor fusion, offering case studies on industrial applications and performance benchmarks.

Wright discusses theoretical and practical aspects of thread and gear measurement. It elucidates fundamental concepts behind lead measurement and presents standardized inspection protocols applicable to worm and helical gears. The Wrights emphasize the importance of measurement traceability and instrument calibration.

Smith focuses on design evolution of lead measurement instruments, highlightingchallengessuchasbacklash,synchronizationaccuracy,andenvironmentalfactors. The author reviews improvements in electronic control systems, servo mechanics, and data acquisition enhancing measurement precision.

Spera offers foundational knowledge on gear measurement technologies, addressing engineering principles to understand metrology challenges associated with worm gears and discusses material properties, deformation effects, and precision engineering strategies, etc.

Kroger delivers state-of-the-art gear inspection methods including non-contact measurement systems and automation integration and evaluates design configurations considering accuracy, speed, and industrial adaptability.

Eisenstein investigates optimization strategies for worm gear lead measurement, combining experimental setups and computational models, proposes enhancements to mechanical synchronization and error correction methods.

Johnson reviews the development and implementation of automated lead measurement instruments focused on worm and helical gears. The article describes system architecturesintegratingPLCs,HMIs,andservomotorstoachievesynchronizedrotationaland linear measurement. It reviews the effectiveness of error compensation algorithms and feedback systems in improving inspection throughput and consistency.

The reviewed literature shows that gear lead measurement has evolved from manual methods to precise automated systems. Key challenges include minimizing errors due to backlash, misalignment, and environmental factors. Modern techniques focus on integrating sensors, servo systems, and control units for improved accuracy and efficiency. Both contact and non-contactmethodsofferadvantagesdependingonapplicationneeds.Thisprojectaimstodevelop a cost-effective and accurate measurement system addressing these challenges.

III. METHODS AND MATERIALS

The development of the worm lead measurement system was carried out through a structured approach involving design, component selection, fabrication, and testing. The primary objective was to create a stable and reliable setup capable of measuring both angular and linear displacement with sufficient accuracy.The mechanical structure of the system was designed to ensure rigidity and proper alignment during measurement. A mild steel base plate was used as the foundation of the setup, providing stability and minimizing vibration. The worm shaft was mounted securely between two dead centers to maintain proper alignment and prevent deflection during rotation. A semi-circular guideway system was incorporated to guide the movement of the measuring mechanism along a defined path.To measure angular displacement, a rotary encoder was integrated into the system. The encoder converts the rotational motion of the worm shaft into electrical pulses, allowing precise tracking of the angular position.

In this setup, the encoder provides a fixed number of pulses per revolution, enabling accurate measurement of rotational movement. Along with this, a linear scale (Digital Readout system) was used to measure the axial displacement of the measuring carriage. The combination of these two measurements forms the basis for calculating the lead of the worm.A linear bush and shaft arrangement was used to ensure smooth and low-friction movement of the measuring mechanism. This helps in maintaining consistent contact between the probe and the worm thread during measurement. The entire system was assembled carefully, with particular attention given to alignment between the worm shaft, encoder, and linear measuring unit.The fabrication process involved machining operations such as milling, drilling, and surface grinding to achieve the required dimensional accuracy.

Components like the base plate, guideways, and mounting blocks were manufactured using standard workshop machines including Vertical Machining Centre (VMC), radial drilling machine, and surface grinder.

Wire cut EDM was used for producing precise semi-circular guideway profiles.After assembly, the system was tested under controlled conditions. The worm shaft was rotated manually, and corresponding linear displacement readings were recorded. Multiple trials were conducted to ensure repeatability and consistency of the measurements. The collected data was then used to calculate the lead of the worm, and the results were compared with theoretical values for validation.The selected materials and methods ensured that the system remained economical while still providing reliable measurement performance. The combination of mechanical stability and simple instrumentation makes the setup suitable for practical inspection applications.

IV. EXPERIMENTAL SETUP

The experimental setup was developed to accurately measure the lead and pitchof a worm gear using a synchronized measurement system that combines rotational and linear motion tracking. The primary objective of the setup is to provide a simple, economical, and reliable alternative to conventional inspection machines such as coordinate measuring machines (CMM).The system is built on a rigid mild steel base plate that serves as the foundation for all components. The base ensures structural strength, stability, and minimal vibration during operation. Proper surface finishing and machining of the base plate were carried out to achieve flatness and accurate mounting of components.A tailstock arrangement is provided at both ends to support the worm shaft securely. This arrangement maintains proper alignment of the shaft and prevents deflection during rotation. The tailstock can be adjusted along the base plate to accommodate worm shafts of different lengths, making the setup flexible for various applications.To measure angular displacement, a rotary encoder is mounted on the worm shaft. The encoder used in this system provides 360 pulses per revolution, allowing the rotation of the shaft to be divided into small increments. As the shaft rotates, the encoder generates electrical pulse signals corresponding to the angular position. These signals are used to determine the exact rotational movement of the worm gear.

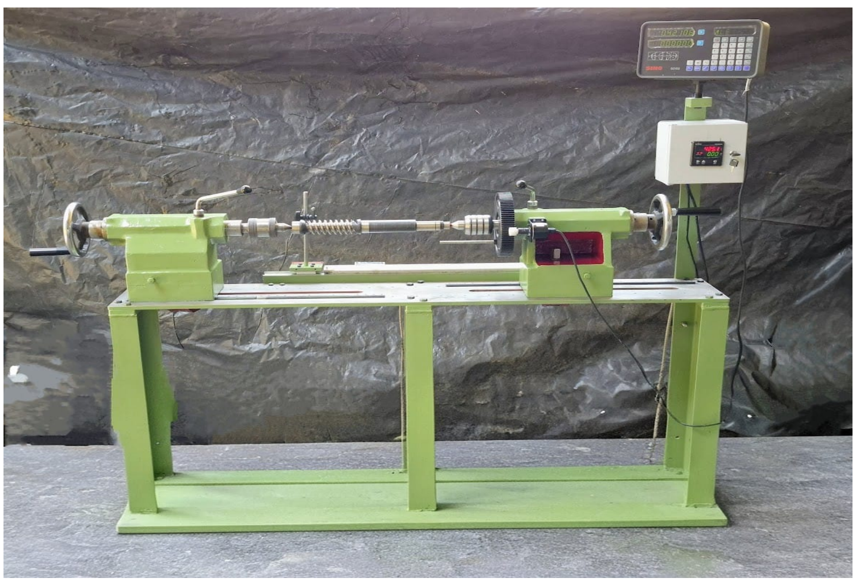

Fig. 1 Experimental setup - Lead measurement of Worm gear inspection

For measuring linear displacement, a linear scale (SINO KA series encoder) is integrated into the setup. The linear scale consists of a fixed grating scale and a movable reading head. As the measuring mechanism moves along the axis of the worm shaft, the reading head detects displacement and converts it into electrical signals. These signals are processed to determine the precise axial movement.A Digital Readout (DRO) system is connected to the linear scale to display displacement values in real time. The DRO converts pulse signals into numerical values, enabling easy observation and recording of measurements. It also provides functions such as unit conversion and zero setting, which improve usability during experiments.The smooth motion of the measuring mechanism is achieved using semi-circular guideways and a linear bush arrangement. These components reduce friction, maintain alignment, and ensure controlled linear movement along the shaft. Proper lubrication and fitting were ensured to avoid backlash and wear.

During operation, the worm shaft is rotated manually, and both angular and linear displacements are recorded simultaneously. The lead of the worm is determined by correlating the axial movement with one complete revolution of the shaft. Measurements are carried out under no-load conditions to eliminate external disturbances and improve accuracy.

Overall, the experimental setup provides a stable, accurate, and cost-effective solution for worm gear inspection. It is suitable for use in educational laboratories, research environments, and small-scale industries where high-cost inspection equipment is not feasible.

V. RESULTS AND DISCUSSIONS

The developed lead measurement system was tested to evaluate its accuracy, repeatability, and overall performance in measuring worm gear parameters. The experimental results were obtained by rotating the worm shaft under controlled, no-load conditions while simultaneously recording angular displacement using the rotary encoder and axial displacement using the linear scale.During testing, the system exhibited smooth and consistent operation. The worm shaft rotated freely without noticeable vibration, indicating proper alignment and rigidity of the setup. The tailstock arrangement effectively supported the shaft and prevented deflection, ensuring stable measurement conditions.The rotary encoder produced uniform pulse signals corresponding to angular displacement, confirming its reliability in tracking rotational movement. Similarly, the linear scale provided precise and continuous feedback of axial displacement. The Digital Readout (DRO) system displayed real-time values, allowing easy monitoring and recording of measurements.

From the experimental observations, the axial pitch of the worm gear was measured as approximately 6.60 mm, and the lead value was calculated as 13.20 mm for a two-start worm. These values closely matched the theoretical design calculations, indicating good accuracy of the developed system. The small deviation observed in some readings can be attributed to minor alignment errors and manual operation.Repeatability tests were conducted by performing multiple trials under the same conditions. The results showed consistent measurements with negligible variation, demonstrating the reliability of the setup. The use of linear bush and guideways ensured smooth linear motion and minimized frictional errors.The system also proved to be efficient in terms of simplicity and cost. Compared to conventional inspection equipment such as CMM machines, the developed setup is significantly more economical while still providing acceptable accuracy for educational and small-scale industrial applications.However, certain limitations were identified during testing. Since the system is manually operated, measurement accuracy may depend on the operator’s handling. Minor backlash and alignment errors may also affect precision. These limitations can be reduced in future by incorporating automation, servo control, and digital data acquisition systems.Overall, the results confirm that the developed lead measurement instrument can provide accurate, repeatable, and reliable measurements. The system successfully meets the project objectives and serves as a practical alternative for worm gear inspection.

VI. CONCLUSIONS

The project on the measurement of worm lead was successfully completed through systematic design, drafting, fabrication, and experimentation phases. A specialized setup was designed and developed to measure the lead of the worm by converting rotational motion into linear displacement. All components were designed using precise engineering drawings and assembled carefully to ensure proper alignment and functionality of the system.The developed experimental setup provided accurate and repeatable results during the measurement process. The arrangement of the shaft and linear bush ensured smooth motion with minimal friction, enabling reliable lead measurement. The values obtained from the experimental setup closely matched the theoretical calculations. The developed system is simple, reliable, and suitable for use in academic laboratories as well as small-scale industries for basic inspection purposes.

During testing, certain minor limitations were observed in the system. Small alignment errors and manual handling could introduce slight variations in readings. Additionally, the absence of full automation means that measurement consistency may depend on operator handling. However, these limitations are not significant and can be minimized through careful operation and proper calibration. Future improvements such as automation and digital data acquisition can further enhance the accuracy and efficiency of the system.

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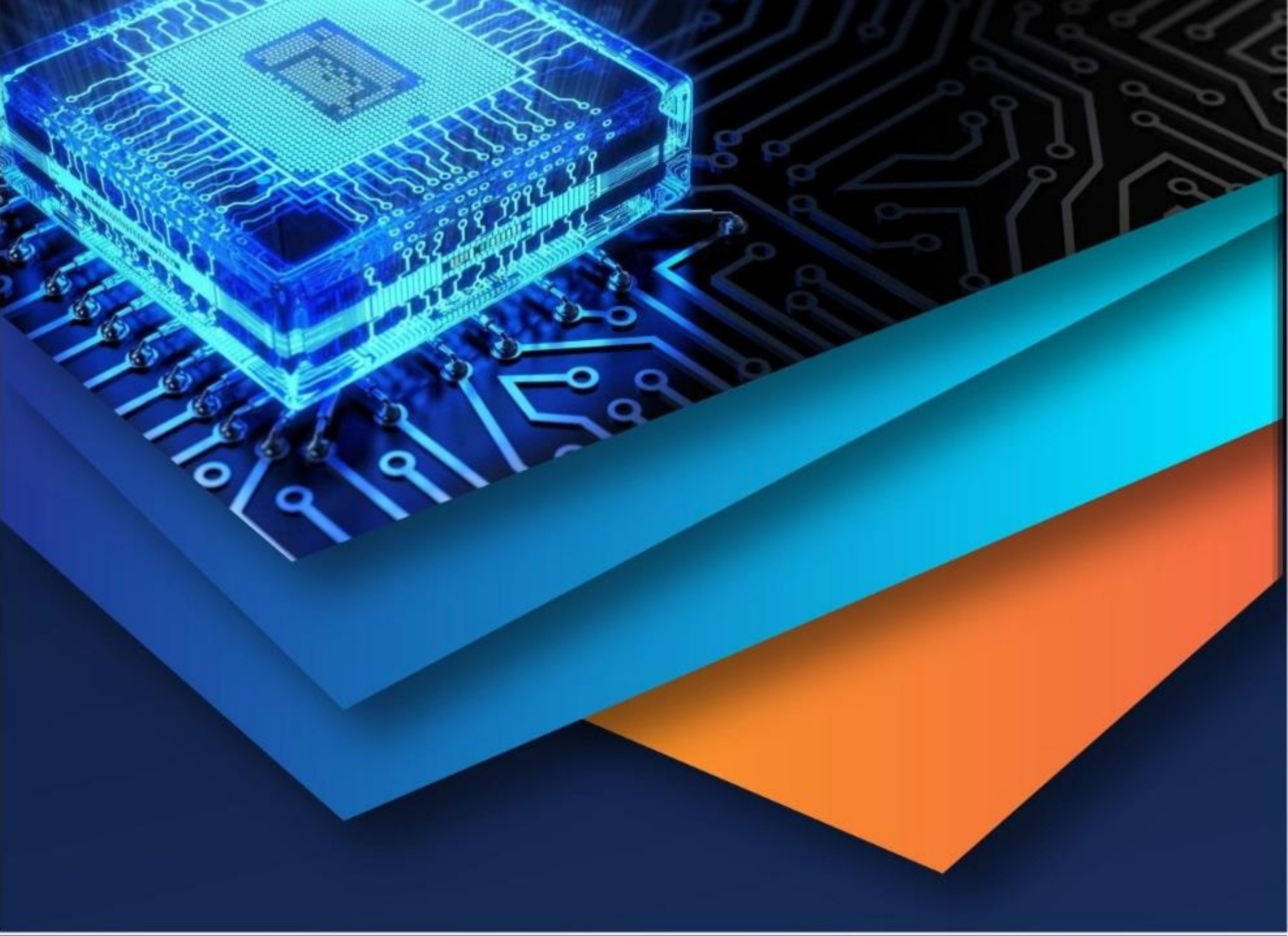

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