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DESIGN OF A DEVICE FOR CONVERTING RECIPROCATING MOTION INTO ROTARY MOTION WITH SHAFT TRANSMISSION

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Abstract: The efficient conversion of reciprocating motion into rotary motion remains an important challenge in modern mechanical engineering. Such mechanisms are widely used in transportation systems, industrial machinery, power generation equipment, and energy recovery applications. Conventional ratchet and one-way clutch mechanisms often suffer from excessive wear, limited-service life, and structural complexity due to repeated contact between metallic components. This study presents the design and operational analysis of a novel device for converting reciprocating motion into rotary motion with transmission to a rotating shaft.

Keywords: reciprocating motion, rotary motion, one-way clutch, flywheel, shaft transmission, energy harvesting, mechanical design, road infrastructure.

INTRODUCTION

The conversion of reciprocating motion into rotary motion is one of the fundamental tasks in mechanical engineering. Such motion conversion mechanisms are employed in numerous engineering systems, including internal combustion engines, pumps, compressors, transportation equipment, and industrial machinery [1]. The efficiency and durability of these systems largely depend on the reliability of the motion conversion mechanism.

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With the increasing demand for sustainable energy solutions, researchers have shown growing interest in technologies capable of recovering unused mechanical energy from transportation systems. Road traffic represents a significant source of mechanical energy due to the repeated loading caused by moving vehicles. The conversion of this energy into useful mechanical or electrical power has become an attractive research direction in recent years [2].

Various mechanisms have been developed to transform reciprocating motion into rotary motion. These include ratchet mechanisms, roller clutches, crank-slider systems, and cam-based transmissions [3]. Although these systems are widely used, many of them suffer from mechanical complexity, high maintenance costs, and limited durability.

Ratchet mechanisms are among the most common solutions for one-directional rotary motion generation. However, continuous metal-to-metal contact between the ratchet wheel and pawl causes severe wear of tooth surfaces. Repeated cyclic loading leads to plastic deformation, profile distortion, increased friction losses, and eventually mechanical failure [4].

Roller-type one-way clutches provide an alternative solution by transmitting torque through wedging action rather than tooth engagement. Such systems can reduce impact loading and distribute contact stresses more uniformly. Nevertheless, many existing clutch designs contain a large number of precision components and require complex manufacturing processes [5].

The analysis of existing technologies demonstrates the need for a simpler and more reliable device capable of converting reciprocating motion into rotary motion while reducing wear and maintenance requirements. Therefore, this study proposes a new mechanical design that combines a road-mounted drive unit, cable transmission mechanism, roller-type one-way clutch, shaft, and flywheel.

The objective of this research is to develop a durable and efficient mechanism for converting vehicle-induced reciprocating motion into rotary shaft motion through a roller-type one-way clutch system.

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MATERIALS AND METHODS

The proposed device was designed to convert reciprocating motion generated by vehicle loads into rotary motion transmitted to a rotating shaft. The system consists of two main functional units: a drive mechanism and a one-way clutch mechanism. The drive mechanism is installed beneath the road surface and acts as the primary energy collection unit. It includes a housing, a movable drive cover, a return spring, cable rollers, a stabiliser rod, and fastening elements. When a vehicle passes over the road surface, the wheel load causes the drive cover to move downward. This vertical displacement generates a reciprocating motion that is transferred through a steel cable connected to the clutch mechanism.

The one-way clutch mechanism consists of a shaft, sleeve, key connection, rollers, springs, lever, housing, and flywheel. The sleeve is rigidly connected to the shaft by means of a keyed joint, ensuring reliable torque transmission. Roller elements are positioned between the sleeve and the housing and are supported by springs that provide automatic engagement and disengagement during operation. The flywheel is mounted on the shaft to accumulate kinetic energy and maintain a stable rotational speed.

The working principle of the device is based on the conversion of linear motion into rotary motion. When a vehicle wheel applies a load to the drive cover, the cover moves downward and tensions the steel cable. The cable pulls the clutch lever, causing the rollers to wedge between the sleeve and the housing. As a result, the clutch engages and transmits rotary motion to the shaft. The shaft then rotates the flywheel, which stores part of the generated mechanical energy. During the return stroke, the cover is restored to its initial position by the return spring. At this stage, the rollers are released, and the clutch automatically disengages, preventing reverse rotation of the shaft. Consequently, rotational motion is transmitted only in one direction. The displacement height of the drive cover can be adjusted within the range of 20–50 mm depending on the operational conditions and the required level of energy conversion.

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The proposed design offers several engineering advantages compared with conventional ratchet-based mechanisms. The use of a roller-type one-way clutch reduces contact stresses between moving components and minimizes wear of working surfaces. The absence of direct tooth-to-tooth interaction decreases friction losses and improves operational reliability. The cable transmission system simplifies the mechanical structure and reduces the number of moving joints, resulting in easier manufacturing and maintenance. Furthermore, the stabiliser rod ensures uniform vertical movement of the drive cover and minimises misalignment during operation. These features contribute to increased service life, smoother torque transmission, improved durability, and reduced maintenance requirements, making the proposed device suitable for road energy harvesting and other mechanical energy conversion applications.

RESULTS AND DISCUSSION

The structural analysis of the proposed mechanism indicates significant improvements compared to conventional ratchet-based systems.

Unlike ratchet mechanisms, where localised tooth contact produces high stress concentrations, the roller clutch distributes mechanical loads over larger contact areas. This reduces surface fatigue and minimises wear of the working components [6].

The cable transmission system further simplifies the mechanical arrangement by reducing the number of moving joints and eliminating complex linkage systems. As a result, assembly and maintenance procedures become easier and more economical.

The flywheel plays a critical role in improving system performance. During operation, the flywheel stores kinetic energy generated by intermittent vehicle loading. This stored energy helps maintain more stable shaft rotation even under irregular traffic conditions.

The stabiliser rod contributes to operational reliability by preventing uneven displacement of the drive cover. This feature reduces mechanical vibration and ensures consistent force transmission to the clutch mechanism.

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A qualitative comparison between the proposed device and conventional ratchet systems is presented below:

Parameter	Ratchet Mechanism	Proposed Device
Wear Rate	High	Low
Structural Complexity	High	Moderate
Maintenance Frequency	High	Low
Impact Loading	Significant	Minimal
Service Life	Limited	Extended
Motion Smoothness	Moderate	High

The proposed design demonstrates particular potential for road infrastructure applications where repeated vehicle loading is available as a renewable source of mechanical energy.

CONCLUSION

A novel device for converting reciprocating motion into rotary motion with shaft transmission has been developed and analysed.

The proposed mechanism utilises vehicle-induced displacement of a road-mounted drive cover, cable transmission, roller-type one-way clutch, shaft, and flywheel to generate unidirectional rotary motion.

The design eliminates many disadvantages associated with traditional ratchet mechanisms by reducing wear, lowering contact stresses, and simplifying construction. The inclusion of a flywheel improves rotational stability, while the cable transmission system provides efficient force transfer.

The proposed device offers increased reliability, longer service life, and reduced maintenance requirements. It can be applied in road energy harvesting systems, transportation infrastructure, and various mechanical power transmission applications.

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