Proposing a New Solution to Change the Vibration Force of Vibratory Rollers in Construction Operations.

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Abstract

A current construction machinery has been widely used for a long time, and its operating principles have remained essentially unchanged since their inception. Among these machines is the vibratory roller. The cause of vibration in this type of machine is based on the centrifugal force of the rollers. The purpose of this paper is to introduce a dynamic change driven by electrical command information. Knowledge related to machine configuration in this field has been relatively well demonstrated. Using mathematical learning methods and classical physics, the paper presents a new, supplementary alternative to previously available methods. During the research, the author found that this action is an effective method in designing machines with vibration-induced causes, such as vibratory rollers. If this method is widely applied, it will save costs and energy. Costs include: the machine design process, the machine manufacturing mode, and the personnel involved in this work. Construction tools involve many stages. Foundation reinforcement is one of the most important steps. The proposed solution reduces time and increases efficiency. However, like other theoretical studies, this paper still requires specific experiments in machine design and construction.

Keywords: construction machine, vibratory roller, force, increase, electromagnet.

1. Introduction

1.1 The operating principle of a hydraulic motor

A hydraulic motor is a device that converts the energy of a high-pressure fluid (usually hydraulic oil) into mechanical energy to produce rotational motion or traction. It is the "heart" of many industrial, construction, and lifting equipment systems

Basic Operating Principles

- Power Source: The hydraulic pump generates a high-pressure oil flow.
- Energy Transfer: The oil is directed into the working chamber of the hydraulic motor.
- Mechanical Action: The oil pressure acts on the internal components (impeller, piston, or gear).
- Energy Conversion: The force from the oil causes these components to rotate or move.
- Output: The rotational movement or thrust is transmitted to the motor shaft, thereby operating the machinery.

Table 1. Types of Hydraulic Motors

Motor Type	Main Principle	Applications
Gear Motor.	Pressurized oil rotates the gears	Construction machinery, compact systems
Axial Piston Motor	Pressurized oil drives pistons along the axis	Press machines, heavy industrial equipment
Radial Piston Motor	Pressurized oil drives pistons radially	Machinery requiring high torque
Vane Motor	Pressurized oil rotates the rotor with vanes	Systems requiring a stable rotational speed

Table 2. Advantages of hydraulic motors

Advantages	Description
High power density.	Generates high force in a compact size, suitable for high-performance equipment.
Easy speed and torque control.	Flexible adjustment via valve and oil flow.
Stable operation.	Low vibration and noise, suitable for environments requiring high precision.
High load capacity.	Suitable for heavy industrial machinery, lifting equipment, and presses.
Flexible design.	Can be installed in various locations and easily integrated into systems.

Table 3. Disadvantages of hydraulic motors

Disadvantages	Description
Requires a closed system.	Oil leaks can cause pressure loss, reduced efficiency, and contamination.
High maintenance costs.	Requires periodic inspections, oil changes, oil filters, and valve and pipeline checks
Requires auxiliary power source.	Requires a hydraulic pump and accompanying control system.
Difficult to achieve precise control at low speeds.	Some types of hydraulic motors exhibit lag when transitioning to low speeds.
Sensitive to temperature and oil cleanliness.	Dirty oil or excessively high temperatures can damage the system.

Advantages and disadvantages of electric motors that rotate eccentric weight in vibratory rollers.

The electric motor that rotates the eccentric wheel is the heart of the vibration system in a vibratory roller. It converts electrical energy into rotational motion, thereby creating an unbalanced centrifugal force to generate vibrations.

Advantages

• High compaction efficiency: Vibration helps to arrange soil, rock, and concrete particles more tightly, increasing foundation stability.
• Easy adjustment: The rotation speed or eccentric mass can be changed to control the vibration amplitude.
• Stable operation, low noise: Electric motors generally run quieter than internal combustion engines.
• Environmentally friendly: No direct emission of toxic gases.
• Easier maintenance: Fewer complex moving parts, long lifespan if properly maintained.

Disadvantages:

• High energy consumption: Electric motors require a continuous power supply and high-power wiring.
• Strong vibration affects operators: Requires shock-absorbing seats and vibration-resistant cabin design.
• Bearing and eccentric wheel maintenance: Prone to wear due to continuous vibration, requiring regular inspection.
• Not suitable for all soil types: Very soft or very wet soil is easily damaged by vibration.

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Methods for adjusting vibration force:

• Changing the eccentric weight mass
→ By adding or removing weight (steel plates, semi-circular hammers) attached to the eccentric shaft.
• Changing the mounting angle of the eccentric weight
→ Adjusting the rotation angle between the eccentric weights to change the amplitude of the vibration force.
• Changing the rotational speed of the eccentric shaft
→ Adjusting the speed of the drive motor, thereby changing the frequency and vibration force.
• Combining changes in both mass and rotational speed
→ Allows for more flexible adjustment of vibration force, suitable for various soil types.

The Most Unfavorable Option
In practice, changing the eccentric structure is often considered the most unfavorable because:
• It requires mechanical disassembly and reassembly, which is time-consuming.
• It cannot be quickly adjusted during construction.
• It increases the risk of assembly errors, affecting machine durability.

Conversely, changing the rotational speed is often preferred due to its flexibility, despite the disadvantage of motor wear.

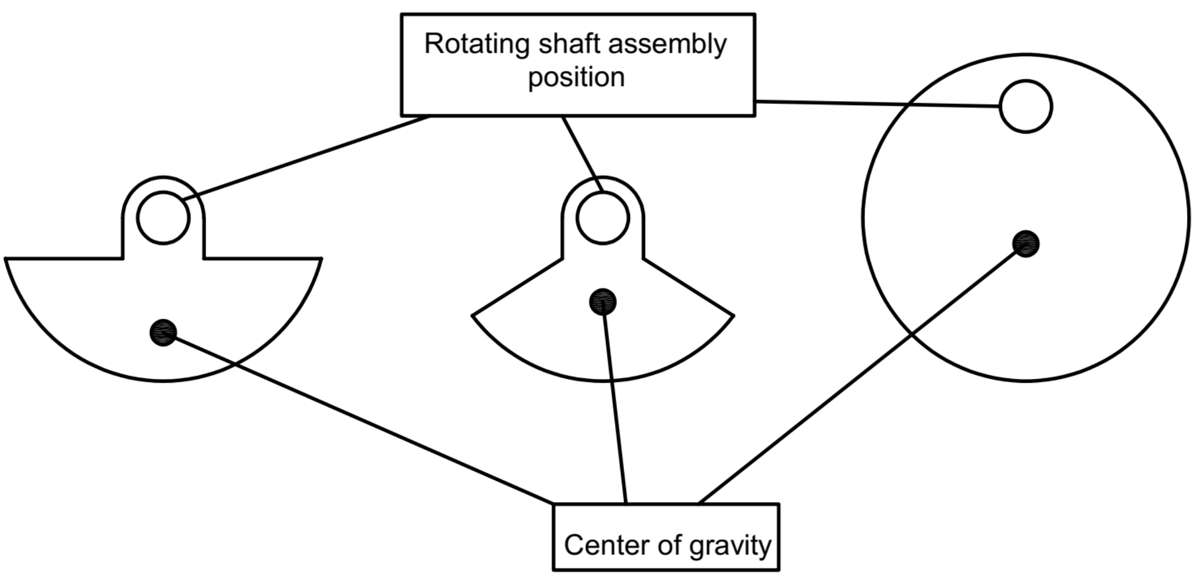

Figure 1. The drawing illustrates several types of eccentric weight.

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The principle of operation of a traditional vibratory roller is as follows:
A motor drives the shaft to rotate. Because the shaft is fitted with an eccentric weight, this eccentric mass rotates with it, thereby creating vibration.

In the context of the above problem, this paper proposes a new method for changing the vibration force. It uses electromagnetic force in combination with other traditional methods to change the vibration force and vibration efficiency.

2. Method

This research model is based on proven foundational knowledge. A hypothetical example is used to demonstrate the superiority of the solution presented in the paper.

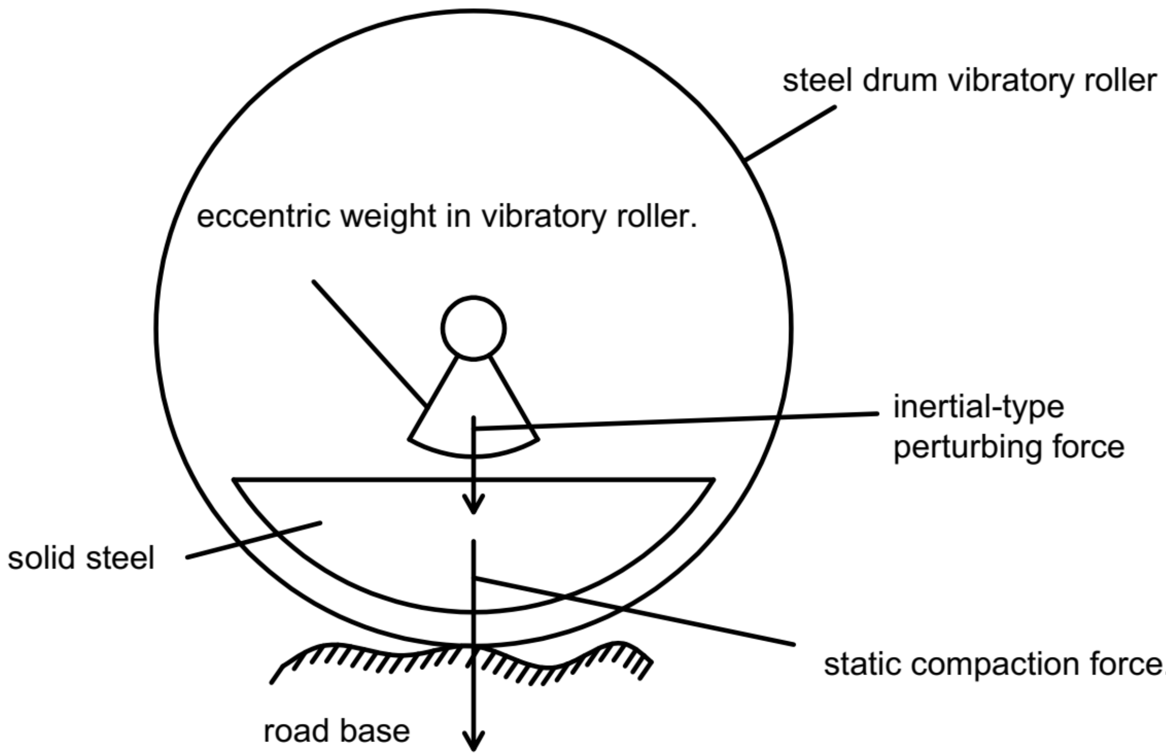

Figure 2. This diagram illustrates the operating principle of a traditional vibratory roller.
The eccentric wheel rotates in combination with static forces to create vibrations. These vibrations then compact the soil.

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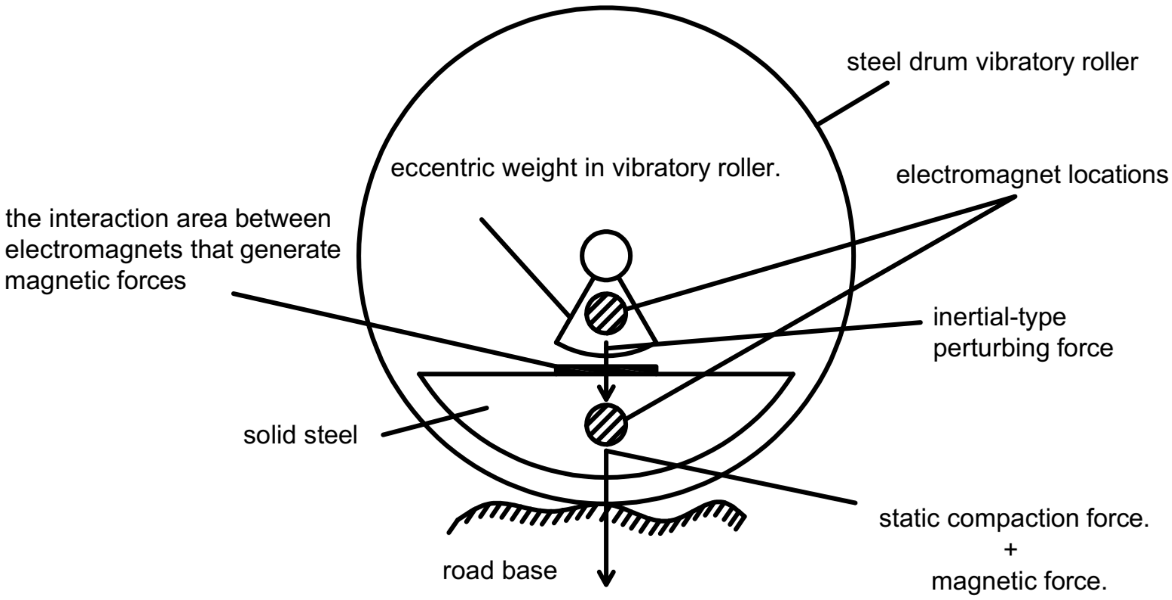

Figure 3. The diagram illustrating the operating principle of the proposed vibratory roller is shown.

The vibrating force consists of three components: static force, force due to eccentricity, and force generated by the electromagnet.
The difference between the two operating principles lies in the fact that, in addition to the centrifugal and static forces of the vibratory roller, there is also an electromagnetic force generated by the electromagnet.

The following is an example of calculation and comparison of a typical structure
Key technical specifications of a vibratory roller available on the market.

Machine Specifications.

- **Engine:** 4-cylinder Turbo model
- **Operating Weight:** Approximately 13.8 tons
- **Centrifugal Force (High/Low):** 300 kN / 146 kN
- **Vibration Frequency (High/Low):** 33 Hz / 33 Hz
- **Vibration Amplitude (High/Low):** 1.7 mm / 0.8 mm
- **Static Linear Load:** 38 kg/cm
- **Drum Width:** ~2130 mm
- **Advantages:** High maneuverability, fuel efficiency, smooth and compact construction surface

Design of Electromagnet with 2-Ton Attractive Force at 33 Hz

Requirements

- Attractive force: $F \approx 20{,}000$ N
- Frequency: 33 Hz (AC power)
- Assume good magnetic steel core, saturated at $B \approx 1.5$ T.

Calculate Contact Area

$$F = \frac{B^2.A}{2\mu_0} \quad (1)$$

Role in the force equation

- (F): attractive force (N)
- (B): magnetic flux density (Tesla)
- (A): contact area (m^2)
- μ: the absolute magnetic permeability of a material (such as steel or iron).
- (μ_0): permeability of free space

Here, **A** directly scales the force. If you double the contact area while keeping (B) constant, the attractive force also doubles.

$$A = \frac{(2\mu_0 \cdot F)}{B^2} \quad (2)$$

Substitute values:

$$A \approx \frac{(2 \times 4\pi \times 10^{-7} \times 20000)}{(1.5)^2} \approx 0.011\, m^2 \quad (3)$$

→ Contact area ≈ 110 cm^2 (example: 10 cm × 11 cm surface).

Core Dimensions

Assume cylindrical core, contact face diameter $d \approx 12$ cm.

- Circular face area: $A = \pi(d/2)^2 \approx 113\ cm^2$ → suitable.
- Core length: $l \approx 10$ cm.
- Core volume: $V \approx A \cdot l \approx 0.0011\ m^3$.

Steel core mass (density ≈ 7800 kg/m^3):

$m \approx 0.0011 \cdot 7800 \approx 8.6$ kg

Coil

To generate magnetic field

$$B = \frac{\mu \cdot (N \cdot I)}{l.} \quad (4)$$

In the electromagnet formulas, the symbol **N** represents the number of turns (or windings) of the coil around the core.

- (B): magnetic flux density (Tesla)

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- (μ): magnetic permeability of the core material
- (N): number of turns of the coil
- (I): current through the coil (Ampere)
- (l): length of the magnetic path (meter)

Here, **N multiplies with the current I** to give the total magnetomotive force (MMF).
- For steel, $\mu \approx 1000\mu_0$.
- Assume I = 2 A, l = 0.1 m.

$$N \approx \frac{B \cdot l}{\mu \cdot I} \approx \frac{1.5 \times 0.1}{1000 \times 4\pi \times 10^{-7} \times 2} \approx 60 \ turns \quad (5)$$

→ Coil requires several dozen to a few hundred turns, depending on wire cross-section. Copper wire mass adds about 2–5 kg.

Total Mass
- Steel core: ~8–9 kg
- Copper wire: ~3–5 kg
- Housing and structure: ~2–3 kg

Total electromagnet mass: about 13–17 kg.

Thus, the vibration force will increase by 2 tons, but the structural mass remains almost unchanged. This is because a quantity of steel on the eccentric wheel, as well as the steel block that creates the static rolling force, has been removed and replaced with electromagnets. Therefore, the energy consumption due to mechanical movement remains almost constant. It should be clarified that the electromagnets only activate to generate additional vibration force when the eccentric wheel is at its lowest position; at other positions, the electromagnets are inactive and do not affect other processes of the vibratory roller.

3. Results

The use of magnets to regulate vibration force in vibratory rollers yields significant results. By varying the magnetic field intensity, the oscillation amplitude of the vibration system can be controlled more flexibly than with traditional mechanical methods. Specifically:

• Vibration level: The vibration amplitude increases or decreases correspondingly with changes in magnetic force, allowing for adjustment to suit different soil types.
• Energy saving: Compared to traditional vibration mechanisms, adjustment using magnets reduces energy consumption by limiting mechanical losses.
• Controllability: Changing the vibration force by adjusting the current to the electromagnet allows for instantaneous control, enhancing operational flexibility.

Overall, the research results demonstrate that the application of magnets in the vibration mechanism of vibratory rollers not only improves soil compaction efficiency but also opens up new avenues for the development of modern construction equipment, with the ability to control and save energy precisely.

4. Discussion

Along with economic development, infrastructure construction is progressing rapidly. Ground consolidation using vibratory rollers is a crucial activity. Improved vibratory rollers are more efficient and therefore contribute significantly to design and construction. Previous studies have generated vibration force by varying the frequency of the electric current, the rotational speed, and the mass of the eccentric wheel. Additionally, for hydraulically driven motors, the hydraulic oil pressure or flow rate can be varied.

By utilizing electromagnetic force with a nearly unchanged roller wheel structure, a greater compaction force can be generated and easily controlled by a computer. This leads to higher compaction efficiency. This efficiency includes reduced time, fuel consumption costs, the number of compaction passes, and the scope of application of vibratory rollers, as well as rollers with different principles and structures.

This paper only proposes the principle and does not include specific calculations regarding the shape. The placement of the magnets has not been designed. The control of electromagnets using electronic computers to generate vibration force at the precise moment has not yet been considered. Furthermore, due to the increased vibration force, the durability of related components, such as bearings, bushings, and shafts, needs to be reviewed during the design process.

The supplementary vibration force generation system using magnets can be easily integrated with automatic controllers, soil compaction sensors, or even artificial intelligence to optimize the compaction process.

In short, changing the vibration force using magnets in a vibratory roller opens the door to widespread application in modern knowledge. This is a promising research direction that requires further large-scale testing across diverse geological conditions to confirm its practical value.

Conclusion`

This study presents a novel method of adjusting vibratory force in road rollers using electromagnets. The approach enhances compaction efficiency, reduces energy consumption, and provides unprecedented flexibility in vibration control. While technical and economic challenges persist, the results highlight strong potential for practical application in modern construction. Future research should focus on prototype development, durability testing, and large-scale field trials to fully establish the viability of this technology.

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