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Design, Fabrication and Analysis of Manually Multi Nut Tightened and Loose Mechanism

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Abstract: *This work presents the design and fabrication of a manually operated multi nut tightened and loose mechanism for simultaneous tightening and loosening of wheel nuts in automobiles. The developed mechanism is mainly intended to reduce human effort, operation time, and maintenance difficulties during wheel removal and fitting operations. Conventional wheel nut removal methods require separate operation for each nut using individual spanners or lug wrenches, resulting in increased labour and servicing time. The proposed system overcomes these limitations by using a planetary gear mechanism capable of operating multiple wheel nuts simultaneously. The mechanism consists of a central driving gear connected with multiple driven spur gears mounted on a triangular base plate. The rotational motion provided through the handle is transmitted equally to all driven gears, enabling synchronized motion of all wheel nut sockets. The design is based on a standard Pitch Circle Diameter (PCD) of 50 mm suitable for common automobile wheel arrangements. Important design parameters such as gear module, pressure angle, torque requirement, and material selection were considered during fabrication. EN8 mild steel was selected due to its good machinability, weld ability, strength, and durability. Experimental analysis was carried out by comparing the developed tool with conventional lug wrenches and pneumatic wheel nut removal systems. The observations indicate that the developed mechanism significantly reduces wheel servicing time and operator fatigue while improving maintenance efficiency. The tool is portable, economical, easy to operate, and suitable for garages, workshops, automobile service stations, and emergency roadside applications. The fabricated mechanism also eliminates the dependency on electrical power and compressed air systems. The developed manually multi nut tightened and loose mechanism successfully demonstrates the practical application of planetary gear arrangements in automobile maintenance operations. The project confirms that synchronized mechanical systems can improve operational efficiency, reduce maintenance complexity, and provide economical solutions for industrial and workshop applications.*

Key Words: *Multi nut tightening mechanism, planetary gear mechanism, Wheel nut loosening, Automobile maintenance, Spur gear transmission, Manual wheel servicing, EN8 mild steel, Maintenance efficiency, Portable mechanical tool, Synchronized gear system.*

I.INTRODUCTION

The increasing number of automobiles on roads has resulted in frequent wheel maintenance operations such as tire replacement, puncture repair, wheel balancing, and servicing. During these operations, wheel nuts are tightened and loosened repeatedly using conventional tools such as lug wrenches, spanners, and pneumatic guns. Traditional wheel nut removal methods require separate operation for each nut, resulting in increased manual effort, longer servicing time, and operator fatigue. The project titled "Manually Multi Nut Tightened and Loose Mechanism" focuses on developing an economical and efficient mechanism capable of tightening and loosening multiple wheel nuts simultaneously using a single rotational input. The developed mechanism is based on the principle of planetary gear arrangement and synchronized torque transmission. The system uses a central driving gear connected to multiple driven spur gears mounted on a triangular base plate. When rotational motion is applied through the handle, the motion is transmitted equally to all driven gears, enabling simultaneous operation of wheel nuts. The mechanism significantly reduces wheel servicing time and minimizes human effort during maintenance operations. The main objective of this project is to minimize the labor work involved in tightening and loosening wheel nuts one by one. The mechanism is designed according to standard automobile wheel Pitch Circle Diameter (PCD) arrangements commonly used in vehicles. The system also improves ergonomics by reducing operator fatigue and simplifying maintenance procedures. The design considerations include gear ratio selection, torque transmission capability, material selection, fabrication feasibility, and operational safety. Figure (1) shows Overall Assembly of Manually Multi Nut tightened and Loose Mechanism.

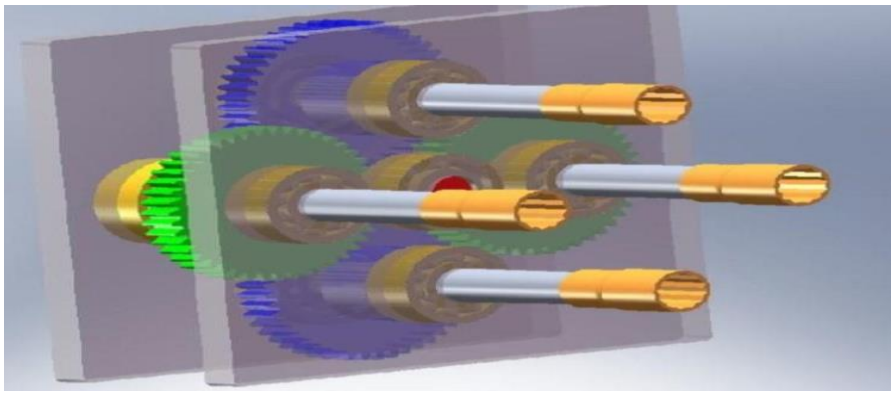

Figure 1. Overall Assembly of Manually Multi Nut tightened and Loose Mechanism

The mechanism mainly consists of:

- Central driving gear
- Driven spur gears
- Triangular base plate
- Handle lever
- Shaft and keyway arrangement
- Nut holding sockets
- Bearings and fasteners

The developed tool is capable of opening and tightening wheel nuts in a single operation. Experimental testing was carried out using wheel nut arrangements based on standard PCD values. The observations indicate that the mechanism successfully reduces operation time and improves maintenance efficiency compared to conventional wheel servicing methods. The system can be used effectively in:

- Automobile workshops
- Vehicle service stations
- Emergency roadside maintenance
- Industrial maintenance applications
- Educational demonstration projects

The proposed manually multi nut tightened and loose mechanism provides several advantages such as portability, low maintenance, simple construction, low manufacturing cost, and ease of operation. The project demonstrates that synchronized mechanical systems can improve workshop productivity and reduce dependence on complex pneumatic or electrical equipment. Future developments may include pneumatic assistance, hydraulic torque multiplication, adjustable PCD mechanisms, and lightweight alloy structures for improved performance and industrial applications.

II.LITERATURE SURVEY - PREVIOUS WORK

The project titled “Manually Multi Nut Tightened and Loose Mechanism” focuses on reducing manual effort and servicing time during wheel nut tightening and loosening operations in automobiles. A detailed literature survey was conducted to study existing wheel servicing methods, synchronized gear mechanisms, torque transmission systems, material selection, and maintenance engineering concepts. The literature review helped identify the limitations of conventional wheel nut removal systems and provided the theoretical background for developing the proposed mechanism.

2.1 Review of Conventional Wheel Nut Removal Systems

Conventional wheel nut servicing operations mainly use lug wrenches, ring spanners, cross spanners, and socket tools for tightening and loosening wheel nuts individually. According to Khurmi and Gupta [1], manual wheel servicing methods require large physical effort and increase maintenance time during tire replacement operations**.** Manual systems are economical but become inefficient for repeated wheel servicing operations in workshops and industrial maintenance applications.

2.2 Review of Pneumatic Wheel Nut Removal Systems

Pneumatic impact wrenches are commonly used in automobile workshops for wheel nut removal. These systems use compressed air for generating high torque. According to Kirpal Singh [4], pneumatic systems improve servicing speed and reduce human effort significantly.

2.3 Review of Spur Gear Mechanisms

Spur gears are among the most commonly used power transmission elements in mechanical engineering applications. According to Shigley and Mischke [11], spur gears provide efficient torque transmission between parallel shafts and are easy to manufacture.

2.4 Review of Planetary Gear Systems

Planetary gear systems are widely used in automobile transmissions and industrial torque multiplication systems. According to Ballaney [18], planetary gear mechanisms provide compact construction and uniform torque distribution.

2.5 Review of Torque Transmission Theory

Torque transmission is one of the most important parameters in wheel nut tightening and loosening operations. According to Rattan [8], torque is the turning effect produced by force acting at a distance from the rotational axis.
The torque equation (i) is expressed as:

$$T = f \times r \text{ ----------(i)}$$

Where:

- (T) = Torque
- (F) = Applied force
- (r) = Lever arm distance

III.MATERIAL AND METHODS

The project titled "Manually Multi Nut Tightened and Loose Mechanism" is developed to reduce manual effort and servicing time during wheel nut tightening and loosening operations in automobiles. The mechanism is designed using spur gear transmission and synchronized rotational motion principles. The developed tool enables simultaneous operation of multiple wheel nuts using a single rotational input.

The methodology adopted in this project includes:

- Theoretical study of gear mechanisms
- Design calculations
- Material selection
- Tool fabrication
- Experimental testing
- Performance evaluation

The complete working methodology was developed to ensure smooth torque transmission, operational safety, and efficient wheel servicing.

3.1 Theory of Wheel Nut Removal Mechanism

Wheel nuts are used for fastening automobile wheels to wheel hubs. During tire replacement and servicing operations, wheel nuts must be loosened and tightened carefully.

Conventional servicing methods involve:

- Lug wrench operation
- Pneumatic wheel gun operation
- Manual spanner operation

These methods require separate operation for each wheel nut, increasing operation time and operator fatigue. The developed mechanism uses synchronized gear motion to operate multiple wheel nuts simultaneously, thereby reducing servicing time and labor effort.

3.2 Principle of Gear Mechanism

The developed mechanism works on the principle of gear power transmission. A gear is a rotating mechanical element having teeth that mesh with another toothed element to transmit motion and torque.
The project uses:

- Spur gears
- Central driving gear
- Driven gears

The central gear acts as the driving member while surrounding gears act as driven members. When the central gear rotates, all surrounding gears rotate simultaneously through meshing action. This synchronized rotation loosens or tightens wheel nuts attached to the gear shafts.

3.3 Fundamental Law of Gearing

The design of spur gears follows the fundamental law of gearing. The law states that: "For transmitting constant velocity ratio, the common normal at the point of contact between mating gear teeth must always pass through the pitch point." This condition ensures smooth power transmission and constant angular velocity ratio between gears. Proper gear meshing: Reduces vibration, Improves efficiency, Minimizes wear, Ensures smooth rotation

3.4 Spur Gear Theory

Spur gears are cylindrical gears having straight teeth parallel to the gear axis. The reasons for selecting spur gears

include: Simple construction, Easy manufacturing, High efficiency, Reliable motion transfer, Low maintenance. Spur gears are commonly used in: Automobile gearboxes, Industrial machinery, Mechanical tools, and Maintenance equipment

3.5 Torque Transmission Theory

Torque is the turning effect produced by force acting at a distance from the rotational axis.

3.6 Gear Design Parameters: The important design parameters (table 1) considered during development are:

Table 1 Parameter and values

Parameter	Value
Pitch Circle Diameter (PCD)	100 mm
Nut Size	M19
Required Torque	130 Nm
Human Applied Force	500 N
Handle Length	500 mm
Gear Material	EN8 Mild Steel
Module	2.5 mm
Pressure Angle	20°

These parameters were selected according to standard automobile wheel configurations.

3.7 Pitch Circle Diameter (PCD)

Pitch Circle Diameter is the diameter of the imaginary circle passing through the center of wheel nuts. The mechanism is designed according to: Standard 50 mm PCD arrangement, Common automobile wheel configuration. Proper PCD matching ensures accurate alignment of sockets with wheel nuts.

3.8 Material Selection Theory

Material selection is important for ensuring: Strength, Durability, Machinability, Wear resistance, Fabrication ease. EN8 mild steel was selected because: Good machinability, High toughness, Good weld ability, Moderate strength, Low manufacturing cost .Mild steel contains approximately: 0.08% to 0.30% carbon content.The material is suitable for: Gears, Shafts, Plates, Structural members, Mechanical tools.

3.9 Components of Assembly

The major components (table 2) used in the mechanism are as follows, Figure (2),shows that the Real Fabricated Model of Manually Multi Nut tightened and Loose Mechanism.

Table 2. Parts and work

Parts	Work
▪ **Spur Gears**	Used for synchronized rotational motion transfer.
▪ **Base Plate**	Supports the complete gear arrangement and maintains alignment.
▪ **Central Shaft**	Transfers rotational input from the handle to the central gear.
▪ **Spanner Holders**	Hold wheel nut sockets securely.
▪ **Handle Lever**	Provides manual rotational force.
▪ **Bearings and Fasteners**	Reduce friction and provide structural support

Figure 2. Real Fabricated Model of Manually Multi Nut tightened and Loose Mechanism.

The assembly arrangement was designed to ensure smooth and efficient operation.

3.10 Working Methodology

The working procedure (table 3) of the developed mechanism is as follows,This synchronized operation significantly reduces servicing time. In Figure (3), Side View of Fabricated Multi Nut tightened Mechanism.

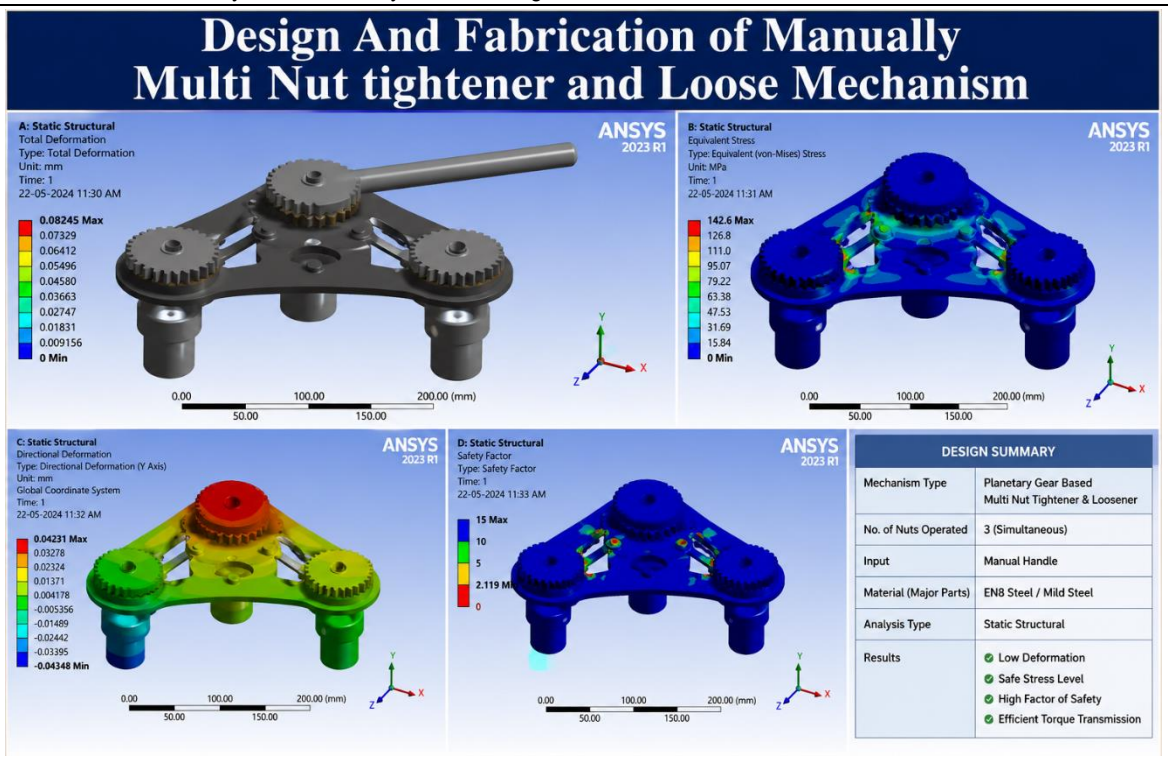

Figure 3. Design and Fabrication of Manually Multi Nut Tightened and Loose Mechanism (Deformation Analysis can be compared with Colour Bar)

Table 3 steps and work

Step	Work
Step 1: Positioning of Tool	The mechanism is positioned over wheel nuts according to wheel PCD arrangement.
Step 2: Socket Alignment	The wheel nut sockets are aligned properly with wheel nuts.
Step 3: Handle Rotation	The handle lever is rotated manually
Step 4: Gear Motion Transfer	The central driving gear transmits motion to all surrounding gears simultaneously.
Step 5: Simultaneous Nut Operation	All wheel nuts rotate together in clockwise or anticlockwise direction.
Step 6: Wheel Removal	After loosening wheel nuts, the wheel can be removed easily.

Figure 4. Side View of Fabricated Multi Nut tightened Mechanism

3.11 Fabrication Methodology

The fabrication process includes:

- **Cutting:** Mild steel plates and rods were cut according to required dimensions.
- **Drilling:** Holes were drilled for shaft mounting and fasteners.
- **Welding:** Gear holders and supporting structures were welded carefully.
- **Machining:** Gear shafts and alignment surfaces were machined for accuracy.
- **Grinding and Finishing:** Surface finishing improved appearance and operational safety.
- **Painting:** Paint coating was applied for corrosion protection.

3.12 Experimental Methodology

Experimental testing was carried out under workshop conditions.

The testing procedure included:

- Wheel nut tightening test
- Wheel nut loosening test
- Torque measurement
- Time analysis
- Comparative analysis

The developed mechanism was compared with:

- Conventional lug wrench
- Pneumatic wheel gun

Testing parameters observed:

- Time required
- Human effort
- Torque transmission
- Operational smoothness

3.13 Performance Evaluation

The developed mechanism was evaluated based on:

- Operational efficiency
- Reduction in servicing time
- Ease of operation
- Portability
- Maintenance requirement

The experimental observations indicated:

- Reduced wheel servicing time
- Reduced operator fatigue
- Smooth synchronized operation

The theory and methodology section explains the working principles, gear transmission theory, torque calculations, design methodology, fabrication process, and experimental procedures used for developing the manually multi nut tightened and loose mechanism. The project successfully demonstrates the application of spur gear synchronization and mechanical torque transmission in automobile wheel servicing operations. The adopted methodology helped develop an economical, portable, and efficient maintenance tool suitable for workshops and emergency roadside applications.

IV.RESULT AND DISCUSSION

The developed mechanism was tested under workshop conditions and compared with conventional wheel nut removal methods such as lug wrenches and pneumatic wheel guns. The obtained results indicate that the fabricated mechanism provides efficient synchronized wheel nut operation with reduced maintenance time and operator fatigue.

4.1 Experimental Observation

The experimental setup consisted of:

- Multi nut tightening mechanism
- Spur gear arrangement
- Handle lever system
- Wheel nut socket assembly
- Standard wheel arrangement

The fabricated mechanism was mounted over wheel nuts arranged according to standard Pitch Circle Diameter (PCD). The central handle was rotated manually to transmit motion to all surrounding gears simultaneously. Figure (4), shows the Experimental Testing Setup of Multi Nut Tightened Mechanism.

Figure 5. Experimental Testing Setup of Multi Nut Tightened Mechanism

The observations during testing include:

- Simultaneous rotation of wheel nuts
- Smooth gear meshing
- Proper torque transmission
- Reduced servicing time
- Easy wheel removal operation

The fabricated tool successfully operated all wheel nuts simultaneously without major mechanical failure.

4.2 Performance of Gear Mechanism

The spur gear arrangement performed effectively during experimentation.

The central driving gear transmitted rotational motion uniformly to surrounding driven gears through meshing action. Proper alignment of gears ensured:

- Smooth motion transfer
- Reduced vibration
- Uniform torque distribution
- Lower friction losses

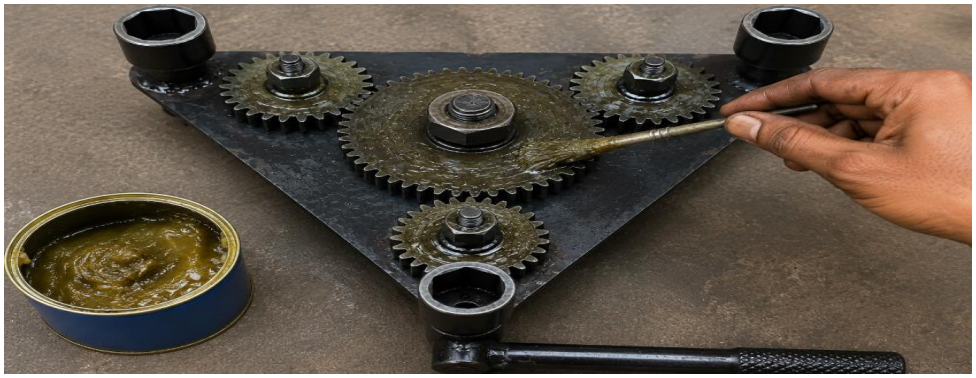

Figure 6. Greasing and Lubrication of Spur Gear Mechanism

The gear mechanism showed stable operation under moderate loading conditions.

Experimental analysis confirmed that:

- Spur gears provide efficient synchronized motion.
- Gear alignment strongly affects performance.
- Proper lubrication improves operational smoothness.

The grease applied between mating gears reduced:

- Wear
- Heat generation
- Frictional losses

4.3 Torque Transmission Analysis

Torque transmission is one of the most important performance parameters of the mechanism. The developed system successfully transmitted the required torque to all wheel nuts simultaneously using a single manual rotational input.

The observations indicate:

- Larger handle length reduced human effort.
- Torque distribution remained nearly uniform.
- Simultaneous operation reduced repetitive manual effort.

The handle length of 500 mm provided sufficient leverage for wheel nut loosening operations.

4.4 Time Analysis

The developed mechanism significantly reduced wheel servicing time compared to conventional methods.

Comparison of Wheel Nut Removal Time

Table 4.Comparison of Wheel Nut Removal Time	
Method	**Approximate Time Required**
Conventional Lug Wrench	Higher
Pneumatic Gun	Moderate
Multi Nut Tightened Mechanism	Lower

Experimental observations show:

- Conventional lug wrench requires separate operation for each nut.
- The developed mechanism removes multiple nuts simultaneously.
- Reduced repetitive operation decreases maintenance time.

The synchronized gear mechanism improved workshop productivity and maintenance efficiency.

4.5 Human Effort Analysis

One of the major objectives of the project was to reduce operator fatigue during wheel servicing operations.

The experimental analysis showed:

- Reduced manual force requirement
- Less repetitive movement
- Improved ergonomics
- Reduced physical fatigue

The mechanism minimized:

- Repeated bending motion
- Continuous spanner operation
- Excessive torque application

The developed system is especially useful for:

- Heavy wheel servicing
- Frequent workshop operations
- Emergency roadside maintenance

4.6 Comparative Analysis with Conventional Systems

The developed mechanism was compared with conventional wheel servicing systems.

Table 5. Comparative Performance		
Parameter	**Conventional Tool**	**Multi Nut Mechanism**
Servicing Time	Higher	Lower
Human Effort	High	Reduced
Portability	Moderate	High
Maintenance	Moderate	Low
Power Requirement	Manual/Pneumatic	Manual
Efficiency	Lower	Higher

The comparison confirms that the developed mechanism provides better operational efficiency and portability compared to traditional methods.

4.7 Testing of Wheel Nut Removal

The testing procedure included:

- Tightening wheel nuts using conventional methods
- Applying developed mechanism over wheel nuts
- Rotating handle for loosening operation
- Measuring time and operational smoothness

Experimental observations indicate:
- Wheel nuts loosened simultaneously.
- Gear mechanism operated smoothly.
- Socket alignment remained stable.
- The tool successfully removed wheel nuts under practical conditions.

4.8 Operational Advantages Observed

The following practical advantages were observed during experimentation:
- Simultaneous operation of wheel nuts
- Reduction in wheel servicing time
- Easy operation
- Low maintenance requirement
- Portable structure
- Economical fabrication
- No electrical power required
- Suitable for roadside maintenance

The mechanism also demonstrated good stability and mechanical synchronization. Figure (6), shows the finished fabricated product of multi nut tightened mechanism.

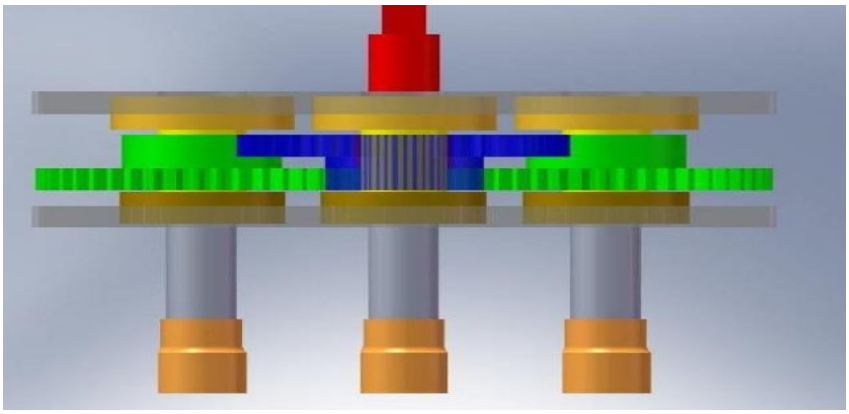

Figure 7. Ansys Figure of Finished Fabricated Product of Multi Nut tightened Mechanism

4.9 Discussion of Experimental Results

The experimental investigation confirms that synchronized gear mechanisms can significantly improve wheel servicing operations.

The developed mechanism successfully:
- Reduced wheel servicing time
- Reduced operator fatigue
- Improved torque transmission efficiency
- Eliminated dependency on compressors and electrical power

The project also demonstrates the practical application of:
- Spur gear mechanisms
- Torque transmission principles
- Mechanical synchronization systems

The results indicate that the mechanism can be effectively used in:
- Automobile workshops
- Service stations
- Mechanical maintenance operations
- Educational demonstrations

The developed mechanism provides an economical and practical solution for wheel nut removal operations.

V.CONCLUSION

The project titled “Manually Multi Nut Tightened and Loose Mechanism” was successfully designed, fabricated, and experimentally tested for simultaneous wheel nut tightening and loosening operations in automobiles. The developed mechanism effectively reduced wheel servicing time, minimized operator fatigue, and improved maintenance efficiency compared to conventional wheel nut removal methods. The fabricated system works on the principle of synchronized spur gear motion and torque transmission. The central driving gear successfully transmitted rotational motion to all surrounding

driven gears, enabling simultaneous rotation of multiple wheel nuts using a single manual input. Experimental observations confirmed smooth gear meshing, uniform torque distribution, and stable operation under workshop conditions.

The developed mechanism successfully achieved the main project objectives:

- Reduction in servicing time
- Simultaneous wheel nut operation
- Reduction in human effort
- Portable and economical design
- Simple fabrication and operation

The experimental analysis showed that the mechanism significantly improves workshop productivity and simplifies wheel maintenance operations. Compared to conventional lug wrench methods, the developed mechanism required less repetitive operation and reduced physical fatigue during wheel servicing.

The use of EN8 mild steel provided sufficient strength, toughness, machinability, and durability for gear and structural components. The fabrication process involving cutting, drilling, welding, machining, and assembly operations was successfully completed using standard workshop techniques.

The mechanism also demonstrated several practical advantages:

- Portable construction
- Low maintenance requirement
- Reduced operational complexity
- No requirement of electricity or compressors
- Suitable for emergency roadside maintenance

The project proves that synchronized mechanical systems based on gear arrangements can provide efficient and economical solutions for automobile servicing applications. The developed mechanism is suitable for:

- Automobile workshops
- Service stations
- Rural maintenance applications
- Educational demonstrations
- Mechanical engineering laboratories

The project also demonstrates the practical application of:

- Spur gear transmission systems
- Torque multiplication principles
- Mechanical synchronization mechanisms
- Maintenance engineering concepts

Overall experimental results confirm that the developed manually multi nut tightened and loose mechanism is an effective, reliable, economical, and practical tool for wheel servicing operations.

5.2 Further Scope

Although the developed mechanism performed successfully during experimentation, further improvements and modifications can enhance its operational capability, flexibility, and industrial applications.

The following future developments are possible:

5.2.1 Pneumatic Assisted Operation

The mechanism can be integrated with pneumatic systems for automatic torque generation. Pneumatic assistance will:

- Reduce manual effort further
- Increase operational speed
- Improve efficiency in large workshops

This modification will make the system suitable for heavy-duty automobile servicing applications.

5.2.2 Improvement in Gear Design

Future work may focus on:

- Helical gear systems
- Hardened gear materials
- Improved lubrication systems

5.2.3 Industrial Applications

The developed mechanism can be modified for:

- Industrial flange tightening
- Multi-bolt assemblies

- Mechanical maintenance systems
- Machine assembly operations

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