# ANALYSIS AND IMPROVEMENT IN DEVELOPMENT OF REVERSE GEAR SHIFTING IN THREE-WHEELER

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**Abstract: -** This Study investigates methods to improve and develop reverse gear shifting of constant mesh type three wheelers four stroke petrol engine by analysis through observation, field complaints and finding root cause of reverse gear shifting failure. The problem arises in gearbox due to failure of reverse gear shifting mechanism. While running vehicle, due to excessive play occurs between Reverse fork and Reverse gear, disturbing the alignment at gear shifting mechanism in gearbox of petrol engine. Deep enhancement aiming in describing the method for improvement to maintain fork position wrt. main housing gear box. Reverse shifting fork design modified & changed by adding extra oil seat sitting position with increase in diameter to maintain fork position wrt. Bore depth in gear shifting housing. While shifting on reverse with fork reverse gear references are shifted from idle location. The impact of development replicates on performances and smooth engine reverse gear shifting. This study is focuses on development & modification in failure parts with more working life of failure parts.

**Keywords: - Reverse fork, Reverse Gear, Idle gear, Gear Shifter Housing, Differential crown gear, Gear Box.**

## I. INTRODUCTION

ATUL AUTO LIMITED is leading automobile manufacturing industry in India. Vehicles manufactured & propelled new model of Gemini Premium in multi-fuel range i.e. Petrol, Diesel, CNG, LPG & Electric in both passenger and goods carry vehicles. Atul Auto Limited, launched new model name Atul Gemini Premium Passenger Vehicle running in gasoline/petrol fuel. After some testing on road, the problem of gear-shifting in in vehicle and gearbox failure is narrated. Factually number of vehicles are on road testing and number of problems reports also increased [1].

Gear box is a part of Petrol Engine which is mounted inside main frame on engine body. The cycle of power transmission in petrol engine takes place as follow:

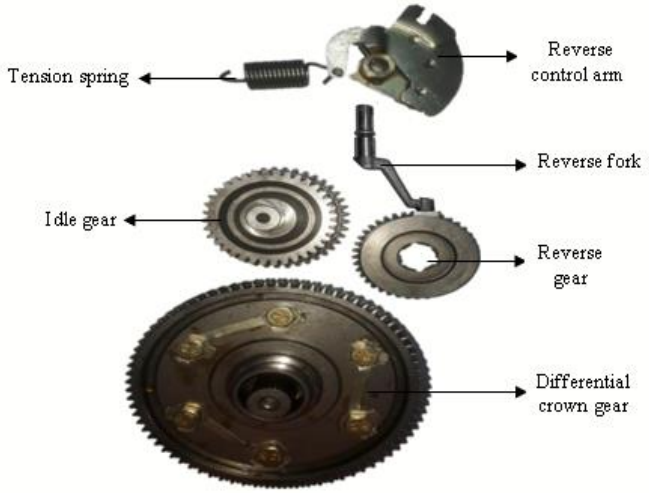


Fig 1. Exploded view of reverse gear shifting mechanism

**Case-1:- Normal position**

Piston - Crank Shaft – Primary Reduction Gear - Clutch - Cluster Gear - Speed Gear/Main shaft - Reverse Gear-Idler Gear - Differential crown gear - Rear Axle.

**Case-2:- Reverse position**

Piston - Crank Shaft – Primary Reduction Gear - Clutch - Cluster Gear - Speed Gear/Main shaft - Reverse Gear -Differential crown gear - Rear Axle.

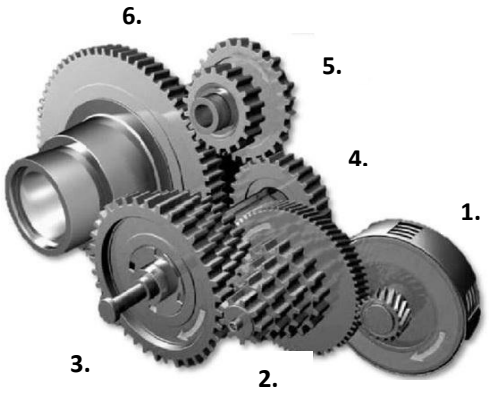


Fig 1.2 Normal position

| Sr. No. | Part Name |
|---|---|
| 1. | Clutch |
| 2. | Cluster gear |
| 3. | Speed gear/Main shaft |
| 4. | Reverse gear |
| 5. | Idle gear |
| 6. | Differential crown gear |

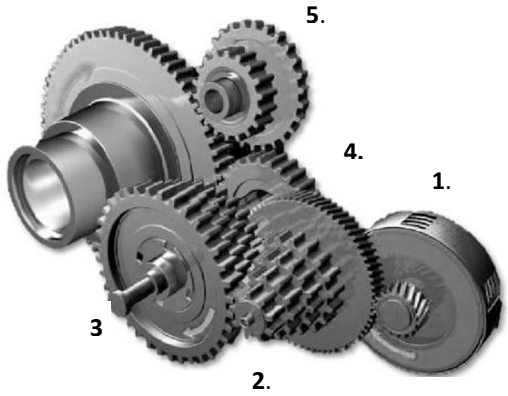


Fig 1.3 Reverse position

The suitable analysis and appropriate process improvements is to be done to increase the gearbox lifespan and vehicle sustainability in competitive market. In this paper, a practical approach has been made to design, improvement and development of a conventional reverse fork and reverse gear, which will give advantages of using conventional design with modern science. Conventional design will give easiness and cost effectiveness. To increase Reverse gear and Reverse fork by proper engaging and disengaging reverse gear and decrease gearbox failure rate.

Table 1.1 Parts of Reverse gear shifting mechanism and its function.

| Part No. | Part Name | Function |
|---|---|---|
| 1. | Tension Spring | Provides the stiffness to return the reverse control arm |
| 2. | Reverse Control Arm | It's one end is associated with spring and in another end, the Reverse fork is associated by means of pin so as to shift the Reverse gear and brings itself in original position for bring reverse fork in normal position. |
| 3. | Reverse Fork | To slide the Reverse gear from rear to front side |
| 4. | Idle Gear | Power transmit in forward direction by receiving power from reverse gear and transmit to differential crown gear |
| 5. | Reverse Gear | Power transmit in reverse direction by transmitting power directly to differential crown gear |
| 6. | Differential Crown Gear | To point the engine power at the wheels. |

Amid power transmission, control and delivered in third stroke Power stroke. Transmitting power exchanged to primary reduction gear through interfacing crankshaft, control is stream main shaft. Main shaft is the principle transmission gear assembly of speed gearbox. The power transmitted to Reverse gear shaft which is mounted on LH Gear box main body. This power further switched from Reverse shaft to the reverse gears, which is assembled by stem. Switch over the power from Idle Gear transmitted to differential Crown Gear center point and finally to Rear Axle.

The appropriate analysis with process improvements is vital to increase the gear shifting transmission in gearbox lifespan and sustainability in modern competitive market. The followings field complaints that are noted while on road testing of vehicle.

1) Reverse gear fork broken in 2-piece failure.
2) Reverse gear shifting key bore oval/damage.
3) Main housing of gearbox damage/crack by reverse gear.
4) Differential Cover crack/damage due to excess vibration.
5) Oil leakage from crack and gear shifting hard.

## 2. OBSERVATION

Above all problems arises due to reverse gear fork & key failure. On road vehicle running with multispeed gear, play occurs between key and reverse gear along with reverse gear fork head. Due to which idle gear & reverse gear teeth damages during meshing/shifting. As a negative impact of damaged teeth disturb alignment of reverse gear for key with reverse gear which in results meshes and damages other parts as a big failure. Moving component Reverse gear with play and vibration disappoints structure, results to Rolling Contact Fatigue which occur because of the after-effect the gear cyclic force on teeth created amid task and parts that include in system disappointment of sliding component [1]. Static force analysis, oil pressure, shifting gear working, wear pattern of gear, key structure, reverse gear fork overhanging, stuck over load on key etc. were the probabilities to find the failure of gear shifting in gearbox and prevent from damages [2]. During observation, following things had been identified,

- Huge Vibration in Engine gear box at speed more than 30km/h.
- Main differential case damage/crack from inside.
- Reverse fork damage
- Reverse & Idle gear teeth damage.
- Differential gear teeth damage.
- Main shaft worn out.

## 3. ROOT CAUSE

Due to uneven forces, sudden load and stress developed at key, reverse gear and certain connecting cycles, deep scratches are generated and fork along with key worn out. Due to these crack & deep scratches worn out in parts, key and damaged fork freely moves in gearbox between rotating gears[5]. Resulting to this the more failure and part damage happens and last gearbox cover broke apart. The failure of fork and key jams the idle gear along with differential housing in the gear box body. At high torque and rpm, the reverse gear will become free and unstable which digs more teeth & other parts of gear box.

In differential case, case is provided for instalment of the reverse gear fork. While shifting and running many cycles, wear and tear occurs between fork and case because of which the case getting enlarge and results in play between case and fork head. Due to improper fitment, fork produces vibration and under this condition, when the reverse gear shifts, its teeth get damaged with damaging idle and differential crown gear. Reverse gear is always done when the vehicle is stationary. While shifting, reverse gear shifts from idle gear to differential crown gear through reverse fork, bringing it in normal condition fork again pushes back in its original condition. In reverse fork assembly, shifter key is there which is attached in reverse gear slot and while running so many cycles the vehicle; the shifter key got damaged and due to vibration key jump out from the fork. Causing the vibration occurs in fork and during shifting process, it also damaged the Reverse and idle gear.

1) More clearance between reverse gear fork & housing, dimension not maintained in ES cover.
2) In most failure key face rubbing with reverse gear slot & tear apart from key & get enter in running system results system failure.
3) Key already displaced at assembly line.
4) Fitment not proper
5) Manufacturing defect at housing plant.
6) Due to vibration and axial play in fork and key, while shifting front gear to reverse gear from reverse gear fork to reverse gear.

## 4. DIMENSION

The face width, circular pitch, working depth, and the tooth thickness are same for reverse gear, idle gear and differential crown gear. Below given table shows the dimensions of fork and different gears.

Table 4.1 Dimensions of failure parts

| | Reverse gear | Idle gear | | Differential crown gear | Reverse fork | | Reverse fork Key | |
|---|---|---|---|---|---|---|---|---|
| | | Small end | Big end | | | | | |
| **No. of Teeth** | 40 | 36 | 41 | 77 | Height | 88.41 mm | Height | 10.5 mm |
| **Tooth Thickness** | 3.25mm | 3.25mm | 3.25mm | 3.25mm | | | | |
| **Circular pitch** | 4.5mm | 4.5mm | 4.5mm | 4.5mm | | | | |
| **Face width** | 15mm | 15mm | 15mm | 15mm | Width | 51.5 mm | Width | 9 mm |
| **Pitch circle diameter** | 68mm | 62mm | 72mm | 134mm | | | | |
| **Working depth** | 4mm | 4mm | 4mm | 4mm | | | Length | 16.78 mm |
| **Normal pressure angle** | 14.5 ˚ | 14.5 ˚ | 14.5 ˚ | 14.5 ˚ | | | | |

By strategies to improve thorough and measured examination while concerning with the base design materials with process media along surface morphologies, little scale uneven area pieces and under organization circumstances development of primary drivers to settle failure, almost instruments were discussed, and measured countermeasures are proposed [2].

## 5. ACTION TAKEN

All problems arise due to vibration of reverse fork and improper reverse gear meshing with idle and differential crown gear. After some cycles due to excessive play occurs between system & this will disturb alignment transmission power to differential gear. Vibration occurs in fork due to play generated resulting wear and tear between reverse fork, key, idle gear, differential gear system, main housing and differential cover. The clearance between reverse gear fork and housing is needed to adjust so that the vibration between fork and gear decreases. The increase in vibration increase sudden load in parts and wear and tear with number of failure increases.

1) Two slots given for O-rings in Reverse fork preventing oil leakage.
2) O-rings dimensions changed from 0.5 mm to 1 mm.
3) Cut mark provided in differential cover for proper fitment.
4) More slope given in fork to decrease vibration and load.
5) Chamfers provided two sides of Reverse fork key for proper installment.
6) CMM program modified to cover up all critical dimensions to GB assy.
7) Gear tooth trochoidal root fillet changed to circular root fillet.
8) Chamfer provided for ease of functional operation of Reverse gear in vehicle.
9) Cut off no.: **KGD70RMC9B1350223, GB No.: P 1059 B 38.**

## 6. MODIFIED PARTS

1) TWO SLOTS FOR O-RINGS: - Reverse gear fork, 1st 'O ring' located at 28.50 mm from head with 10 mm diameter with 1 mm 'O ring' sitting slot & 2nd 'O ring' located at 31.50 mm from head with 10 mm diameter with 1 mm 'O ring' sitting slot Before modifying oil leak chances and resting clearance on MS Housing of gear box. Reverse gear shifting plate and fork

position will be having measurable clearance, after modifying reverse gear fork position always stable and maintain wrt. to shifting plate.

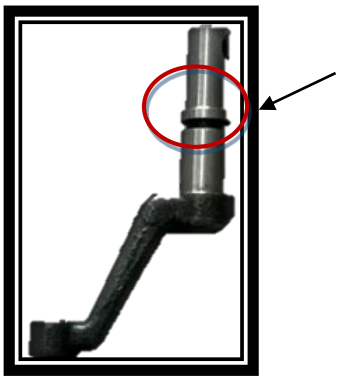

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Fig 1.2 Before modifying Reverse fork

Fig 1.3 After modifying Reverse fork

2) REVERSE GEAR MODIFIED: Chamfer provided in Reverse gear at edge of slot while assembly on reverse gear shaft. As a result functional operation of gear shifting sliding take place under comfortable affluence. In existing reverse gear, no privileged circumstances like chamfering is provided as in modified on. While functioning on reverse gear, smooth transmission of power with less friction.

No Chamfering

Chamfering is provided

Fig 1.4 Reverse Gear without chamfer

Fig. 1.5 Reverse Gear with chamfer

3) REVERSE FORK KEY MODIFIED: Reverse gear key stuck and during power transmission reverse gear shifting due to vibration, cut & chips are formed also key gets deformed. In modified reverse fork key chamfer is provided on both side. Modified key dimensions of total length 16.78 mm, total width 10.5 mm, total height and center hole diameter of 7.5 mm with clearance of -0.015 to +0.020 mm.

Key without chamfer

Key with chamfers at both sides

Fig 1.6 Reverse Gear fork key without chamfer

Fig. 1.7 Reverse Gear fork key with chamfer

4) TWO SLOTS FOR O-RINGS: - Reverse gear fork slope is given in modified part for ease in shifting and not to interact with main housing or cover part, before modify chances to touch housing and stuck, gear shifting hard problems were noted. More clearance provided on fork & MS Housing of gear box.

Slope not given

Slope given

Fig 1.8 Before modifying Reverse fork

Fig 1.9 After modifying Reverse fork

5) CUT MARK AT MAIN HOUSING: On engine main housing LH side a cut mark is done to increase clearance between reverse gear fork & Main Housing of gear box.in non modified part fork stuck and creates vibrations when sudden gear shifting takes place.


Fig 1.10 After modifying Main housing Engine differential side

## 7. EFFECT OF MODIFICATION

Modification carried out on reverse fork and reverse gear in order to prevent failure of gearbox.

1) Modified Reverse gear fork with two slots given for O-rings, during working, Oil leakage stopped and life cycle of fork with contact to main housing increased. The play occurring is decreased and also increase in lifespan of both part with less vibration occurrence. Also, efficiency with performance of power transmission increased.
2) The chamfering at sliding part of reverse gear provided increases in ease in functional operation, smooth gear shifting as well with smooth power transmission.
3) Slope or clearance given in reverse fork gives smooth and obstruct free reverse gear shifting. Earlier problem of hard shifting and unwanted noise was cleared with smooth power transmission.
4) Chamfering in reverse fork key provides ease in movement of slot and smooth shifting in reverse gear slot. This provides less obstruct and fork shift with minimum vibration transmission to main housing and differential cover.
5) Appreciable reduction in bending stress value for circular root fillet design in comparison of bending stress value in trochoidal root fillet design.

## 8. CONCLUSION

The current work establishes technically feasibility in modified part. Modification which carried out on reverse gear fork, reverse gear fork key and reverse gear in order to counteract failure of gearbox. This continual development & improvement is done to improve engine power transmission parts durability. New revisions ae given of modified parts. Part interchangeability process is currently in process for new modified vehicles. Process improvement along with improvement circulars are on process and modified gearbox are introduced in new lot of premium vehicles.

For future investigations of gearbox, reverse fork and reverse gear analysis, it is recommended to simulate all other functioning parts with different boundary conditions in order to fulfill more features available in software. For futuristic instance, other analysis like applied torque on different rotating parts, fatigue analysis can be carried out for better results. At comparison, analysis results and reports related to parts design to their accuracy, simulation may simple structures is recommendable. Ensuring ease and clear shown, arranged controlled calculation with evocative conclusions, further used absolute values will be comparing the simulation outcomes

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