

# Development of Electric Power Steering System for ATV

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## ABSTRACT

An electric power steering system (EPS) has been developed for an all-terrain vehicle (ATV), based on an automobile EPS system. The new EPS has been employed in the 2007 TRX500FPE FourTrax Foreman 4X4 ES. The EPS unit has been made compact to enable fitting without having to modify the vehicle configuration. Optimization of the size of the motor, the reduction ratio, and the spring rate of the torsion bar has enabled the prior ATV steering torque to be halved in both 2WD and 4WD operation, and has resulted in the achievement of a balance between reduced kickback and the maintenance of an appropriate level of feedback from the road surface. The use of a configuration that enables the EPS unit to avoid external loads (use of bearing holders, etc.) and a waterproof structure has helped ensure that the unit satisfies the requirements of ATV use.

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## 1. Introduction

Honda has a long history in the development of power steering systems for 4-wheel all-terrain vehicles (ATVs). After the company commenced marketing 4-wheel ATVs, the development of a hydraulic power steering system for use in the vehicles was started in 1986. Engine power loss is high in hydraulic power steering systems, and at that time, low-displacement vehicles with low steering torque represented the major market trend; these factors meant that market demand for the system was not high, and unfortunately it did not enter mass production. The increased displacement of today's ATVs, in addition to the use of 4WD operation, has increased steering torque and thus also increased the demand for power steering. Mass production of the world's first light vehicle fitted with electric power steering was commenced in 1988. The electric power steering system was efficient, displaying an extremely low level of engine power loss, compared to a hydraulic system, and its use became widespread. Honda judged electric power steering as possessing potential for application in ATVs, and commenced development in 2003. This paper provides an overview of an electric power steering system developed for use in ATVs, and discusses its specific features and effects.

## 2. Development Goals

An ATV is designed for off-road use, and will see service on rough and rocky ground, and be driven through

puddles and very shallow creeks and rivers. Consideration of this type of use environment, user-friendliness and ease of fitting in the vehicle led to the establishment of the following goals for the development of the electric power steering system:

- (1) System should require no alteration of existing ATV configuration.  
The EPS unit should make maximum use of components used in automobiles and should employ a compact configuration enabling multipurpose use.
- (2) Each component should be configured for ATV use conditions. (Consider waterproof property, etc in off-road driving.)
- (3) Reduction of steering torque by half (2WD and 4WD).
- (4) Feedback of reaction force from the surface the vehicle is traveling on; reduction of kick-back.
- (5) Equivalent level of steering stability to a conventional model, even if the EPS becomes non-functional.

## 3. System Layout

### 3.1. Overall Layout

Figure 1 shows an external view of the TRX500FPE FourTrax Foreman 4X4 ES, in which the developed EPS is fitted. Figure 2 shows the overall system layout. The developed EPS system was able to be fitted in the vehicle without altering the configuration of the base model, the previously-marketed TRX500FE. The EPS unit is positioned on the steering shaft. A dedicated EPS control unit is located close to the EPS unit. The sensors used in

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the base model have been used to monitor vehicle speed and engine speed in the new vehicle. In addition, an indicator lamp has been positioned inside the speedometer to warn the rider of system malfunctions.



Fig. 1 TRX500FPE FourTrax Foreman 4x4 ES

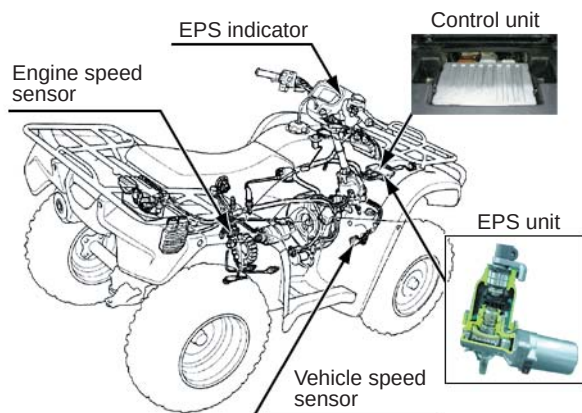


Fig. 2 EPS system layout

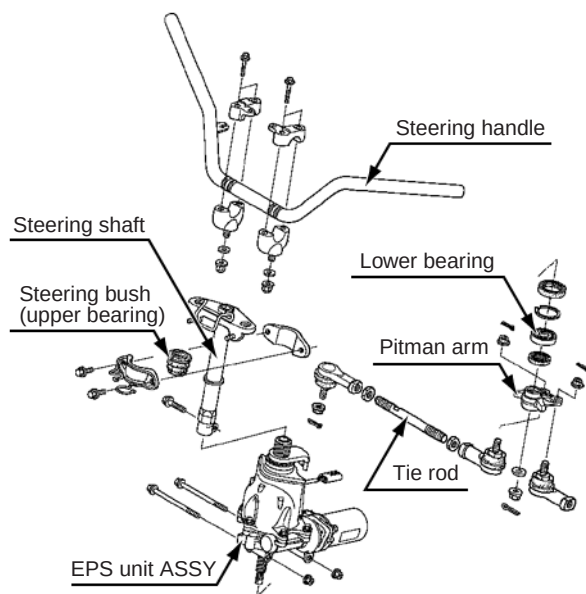


Fig. 3 Configuration of steering system

### 3.2. Steering System

The steering system of the ATV features a steering handle attached to the steering shaft (column), which is in turn connected to a steering arm (Pitman arm). When the EPS system was fitted, the lower half of the steering shaft was replaced with a column-type EPS unit, with no change to the overall configuration of the vehicle. As Fig. 3 shows, the EPS unit connected to the steering shaft is supported by upper and lower sets of spherical sliding bearings, a configuration that does away with the requirement for adjustment when the system is assembled, regardless of the precision of the vehicle framework, and prevents an increase in friction.

### 3.3. EPS Unit Configuration

Figure 4 shows the configuration of the ATV EPS unit. Figure 5 shows a cross-section of the unit.

A bearing holder is positioned above the EPS unit;

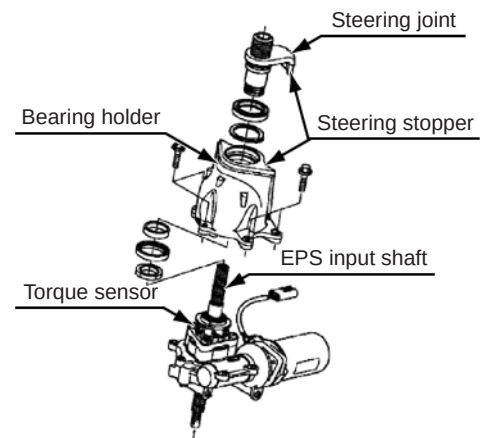


Fig. 4 Configuration of EPS unit

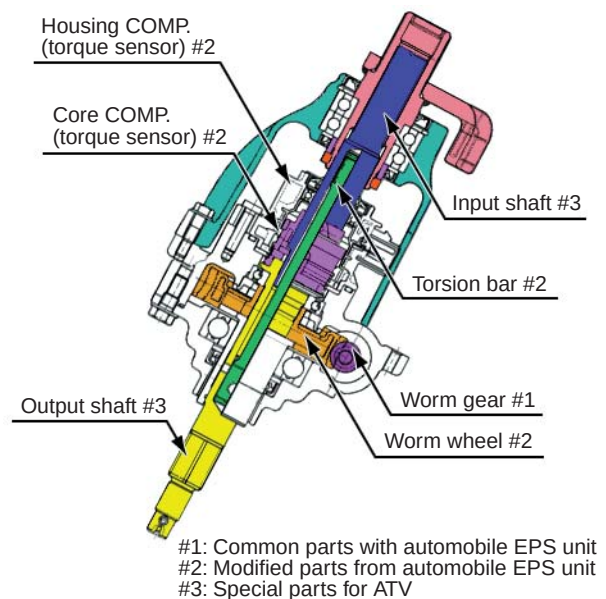


Fig. 5 Cross-section of EPS unit

above this, a steering joint is connected to the steering shaft and the steering handle. This configuration ensures that the load in the direction of inclination of the shaft is received by the bearing holder, and is not inputted to the torque sensor. The steering joint and the input shaft of the EPS unit are fitted by a spline, rather than a clamp. When a load is input from the handle in the axial direction, this spline slides to dissipate the load. In addition to the steering stopper installed on the Pitman arm, stoppers have also been fitted onto the bearing holder and the steering joint in the upper section of the EPS unit, providing a configuration that receives impact loads from the steering handle if the vehicle rolls or slides. The bearing holder also functions to help protect the torque sensor from foreign objects, such as flying stones or branches.

The basic structure of the interior that is used in an automobile EPS has been used in the ATV EPS unit. The motor used in light vehicles has been employed, and a worm gear has been used as the reduction mechanism, as in automobiles, making the unit more compact. The unit is also completely sealed, in consideration of waterproof property that is needed in the ATV use environment.

### 3.4. Torque Sensor

As discussed in section 3.3, the steering system of the ATV is a Pitman arm with a steering handle. Because wheel movement is directly transmitted to the handle, the transmission torque is relatively high, compared to that of an automobile. In addition, the spring rate of the torsion bar has a significant effect on the assist function and steering stiffness. Given this, it is necessary to increase the spring rate by approximately 7 times against that of an automobile. In order to do so, the external diameter of the torsion bar was increased, as shown in Fig. 5. Despite this, only a modification of the size of the internal bearings was required to enable the torque sensor housing comp from an automobile to be used.

### 3.5. Motor

An ATV has a higher steering torque than an

automobile, and thus also requires high assist torque. The unit employs an automobile motor, but the maximum motor current was increased by approximately 7% in order to increase the maximum assist torque and satisfy this requirement. ATVs are frequently used on winding mountain roads and rough roads, and the frequency with which maximum current is transmitted to the motor is therefore correspondingly high. Because of this, the brush in the motor generates more heat than is the case in an automobile. A material that controlled this heat generation was therefore used for the brush.

### 3.6. Control Unit

As in the case of the EPS unit, waterproof property in the ATV use environment was considered for the control unit; waterproof connectors were used, and the interior was filled with potting material. Because of this, the configuration of the case, heat sink, circuit board, etc., was designed specifically for ATV use. The basic circuit configuration that is used in the control unit of an automobile has been used in the ATV control unit, but a circuit enabling detection of the signal from the 2WD/4WD switching mechanism has been added for ATV use.

## 4. EPS Control

As described below, the basic control that is used in an automobile EPS has been used in the ATV. Figure 6 shows a block diagram of the control system. The values of the controlled currents in (1)-(3) can each be varied on the basis of vehicle speed. The control elements in (4) and (5) have been modified and added for ATV use.

- (1) Base current control  
Sends current to the motor in response to torque sensor signal, and controls basic assist torque.
- (2) Damper control  
Estimates revolution speed of motor, and reduces motor current based on estimated speed, to produce a damping effect.
- (3) Inertia control

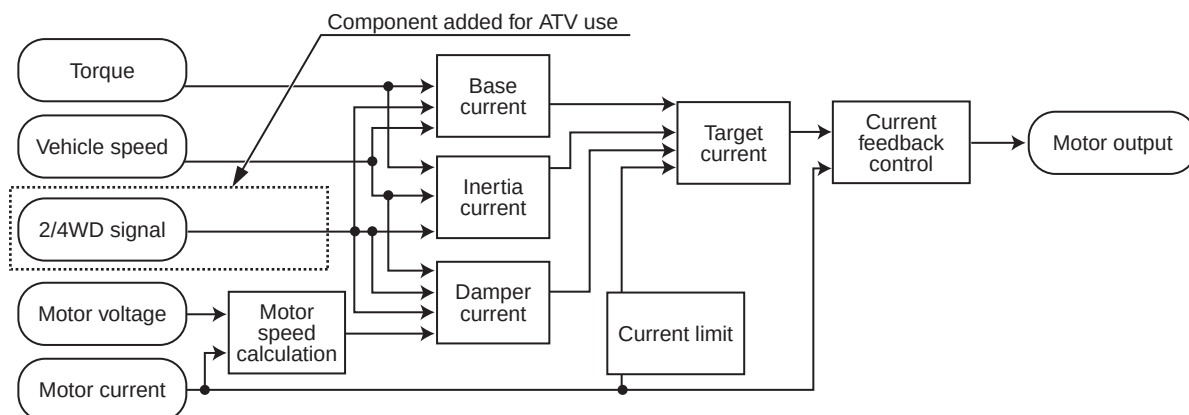


Fig. 6 Control system block diagram

Increases the motor current on the basis of the time-rate-of-change of the torque sensor signal and achieves greater assist torque responsiveness, thus enabling correction of torque for motor inertia.

(4) Targeted current limit

To help prevent the motor and control unit from overheating, if a high current continues to be provided, the unit features a mechanism for heat control, as in an automobile. The level of generated heat is estimated on the basis of the motor current, which is detected by a current sensor positioned inside the control unit. If the heat exceeds a preset figure, the upper limit for motor current is reduced. The method of estimating the level of heat generation has been modified to increase accuracy, to enable control of the increased amount of heat generated by an ATV.

(5) 2WD/4WD assist torque switching control

Steering torque is generally higher in 4WD operation than that in 2WD operation in an ATV that does not employ EPS. The new ATV has been provided with a mechanism for switching control of assist torque in response to the signal for switching between 2WD and 4WD operation, as detected by the detection circuit discussed in section 3.6, in order to enable the achievement of similar steering torque during 2WD and 4WD operation.

## 5. Performance

### 5.1. Assist / Steering Characteristic

Figure 7 shows a graph of the assist torque characteristic of the EPS against vehicle speed. As vehicle speed increases, the level of assist torque is reduced. The level of assist torque is not reduced to 0 even at high speeds (40 mph and above); the use of the damper and inertia control discussed in section 4 helps prevent phase delay caused by twisting of the torsion bar, as shown in Fig. 8, and produces a direct and responsive steering characteristic without instability.

As the graph of steering torque characteristics in Fig. 9 shows, a conventional ATV that does not employ EPS displays the following characteristics:

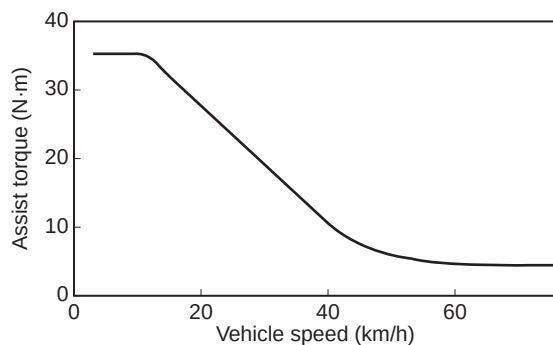


Fig. 7 Assist characteristic against on vehicle speed

2WD operation: The degree of increase of counter torque against steering angle is linear and stable, but steering becomes slightly heavy.

4WD operation: The steady state steering counter torque when the vehicle is proceeding straight or turning is stronger; the counter torque against steering angle declines in linearity, but the counter torque when the handle is turned is weaker.

Changing the assist characteristic between 2WD and 4WD operation has reduced steering torque by half while maintaining the above characteristics.

### 5.2. Steering Damper Performance

The reduction ratio employed and motor size were decided with consideration of the achievement of a balance with assist torque, resulting in a reduction in kickback, while feedback of the reaction force from the road surface has been maintained at an appropriate level.

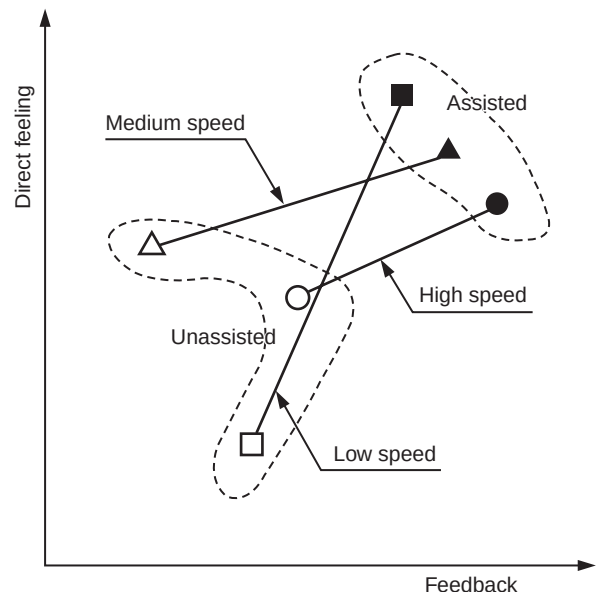


Fig. 8 Characteristic of steering feeling

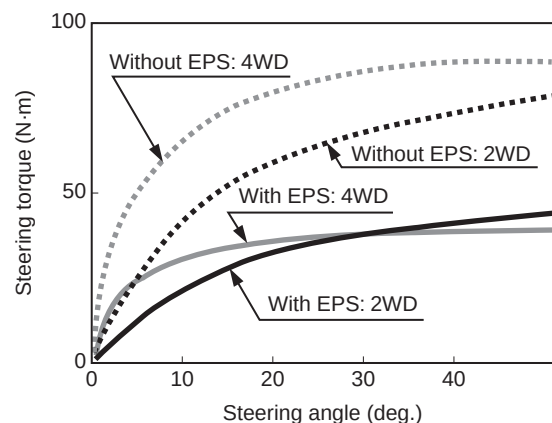


Fig. 9 Characteristic of steering torque

### 5.3. Steering Characteristic during Malfunction

(1) Failsafe control

The control unit conducts diagnosis in all electrical system components. If a malfunction is detected, the indicator lamp flashes, and assist is stopped.

(2) Steering characteristic during malfunction

To reduce the inertial mass of the gears and motor employed in the EPS unit, and reduce friction and increase the efficiency of the worm wheel/gear, the worm wheel teeth have been made of plastic, and the level of backlash in the worm wheel/gear has been increased above the standard level for an automobile. This has resulted in the achievement of a steering characteristic similar to that of a non-power-steering vehicle when assist is stopped during a malfunction, as discussed above.

## 6. Conclusion

A new electric power steering system for ATVs has been developed to increase user comfort. The salient points of this development can be summarized as follows:

- (1) The EPS unit has been made more compact, and is able to be fitted without having to modify vehicle configuration.
- (2) Configuration of the EPS unit to avoid external loads (use of bearing holders, etc.) and other measures including the use of a waterproof structure have helped ensure that the unit satisfies ATV use requirements.
- (3) The use of 2WD/4WD assist torque switching control has enabled steering torque to be halved in both 2WD and 4WD operation.
- (4) A focus on the motor, reduction ratio, and EPS control has reduced kickback while maintaining an appropriate level of reaction force feedback from the road surface.
- (5) Reduction of the inertial mass of the motor and other components and reduction of gear friction has enabled the achievement of a steering characteristic equivalent to that of a conventional vehicle, even if the system malfunctions.

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