

Introduction of the “RINCON TRX650FA” ATV

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ABSTRACT

The “RINCON TRX650FA” ATV, a new concept that provides an enjoyable and comfortable ride for use mainly in recreation, was developed as Honda’s flagship model of the utility oriented ATV (All Terrain Vehicle) series. An electronic controlled three speed automatic transmission with torque converter was employed in an ATV for the first time in the world. A powerful and comfortable running performance was realized by combining the transmission with a newly developed 648 cm³ single-cylinder engine of a flat torque type. Moreover, riding comfort and smoother handling were achieved by adopting a rear independent suspension, a first for Honda, and radial tires. Some weight reduction technologies, such as an aluminum alloy forged suspension arm, were effective for achieving higher maneuverability during running on rough roads. As a result, these advanced technologies along with an original new design using an SUV concept, realized an impressive running performance.

1. Introduction

The ATV market, centered predominately in North America, is expanding year by year. Along with this growth, there are a growing range of performance criteria and functional requirements. In 2000, Honda released the first automatic transmission equipped utility ATV, the RUBICON TRX500FA. In response to the intense market competition in the large class vehicle displacement and the expanding lineup of automatic models, Honda has developed its ATV flagship, the RINCON TRX650FA.

2. Development Aims

In addition to the power and high running stability required by conventional large displacement ATVs, a balanced higher level of riding comfort and ease of handling have been achieved to retain the successful riding

performance accomplished to date while providing an enjoyable and sporty ride. Figure 1 shows an external view of the vehicle and Table 1 lists the main specifications.

3. Engine

The engine size has been designed to take into account the rider’s comfort when sitting astride the vehicle and has adopted the same level of forward projection design as the TRX500FA while distributing the vehicle’s overall mass evenly. The engine design has successfully achieved a less than 60 kg format. Figure 2 shows the engine’s forward projection profile in comparison with that of the TRX500FA and Fig. 3 shows a sectional view of the entire engine. Parts used in the XR650R motorcycle were taken into consideration to achieve a 648 cm³ displacement with a bore × stroke setting of 100 mm × 82.6 mm. The maximum output is 27.3 kW/5,500 r/min and achieves a maximum torque of

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Fig. 1 External view of TRX650FA

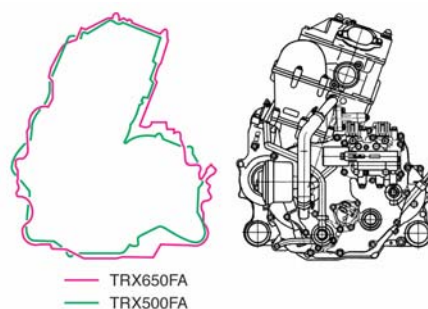


Fig. 2 Comparison of engine profiles

Table 1 Main specifications

Items		Specifications
Overall length	(mm)	2 113
Overall width	(mm)	1 189
Overall height	(mm)	1 207
Wheelbase	(mm)	1 289
Tread	Front	915
	Rear	945
Seat height	(mm)	875
Ground clearance	(mm)	234
Vehicle dry mass	(kg)	273
Engine type		Liquid cooled 4-stroke single cylinder
Displacement	(cm ³)	648
Bore × Stroke	(mm)	100 × 82.6
Compression ratio		9.2 : 1
Valve layout		OHV 4-valve
Max. Output	(kW/r/min)	27.3/5 500
Max. Torque	(Nm/r/min)	49.9/4 500
Torque converter		3-element, 2-phase
Creep control system		Direct hydraulic controlled system by linear-solenoid
Transmission type		Constant-mesh type 3-speed automatic
Fuel tank capacity	(L)	17
Tire size	Front	AT25 × 8R12
	Rear	AT25 × 10R12
Brake system	Front	Hydraulic drum
	Rear	Hydraulic disk
Suspension	Front	Double wishbone
	Rear	Double wishbone

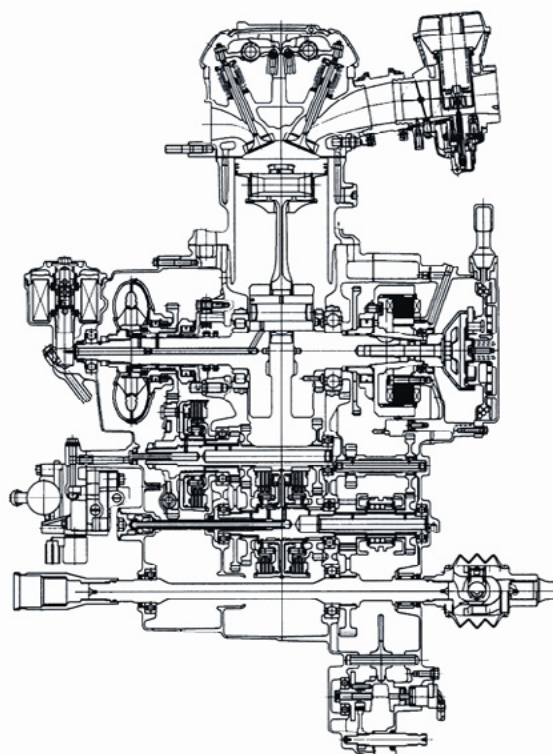


Fig. 3 Main section of engine

49.9 Nm/4,500 r/min to attach importance to the torque in the low speed range. To enable the 4-valve configuration for the vertical crankshaft placement, the same chain drive camshaft to cylinder configuration used in the TRX500FA has been adopted. A unique configuration has been implemented to drive the valves via the push rods and rocker arms. Figure 4 provides an illustration of the engine performance curve.

This vehicle is the world's first ATV to have successfully employed a three-speed automatic transmission configuration that makes use of a torque converter to achieve a powerful

and comfortable ride to match the SUV concept. The creep phenomenon commonly associated with torque converters has been eliminated through the implementation of a newly developed creep control system to achieve a take off similar to that achieved by a conventional automatic wet type centrifugal clutch.

3.1. Built-in Oil Tank

The crankcase has a built-in oil tank which improves the vehicle's handling by providing for a lighter configuration and concentrating the mass centrally. Figure 5 provides a structural view of the crankcase oil tank location.

To stabilize the hydraulic supply to the hydraulic mechanical CVT (HFT) transmission in the TRX500FA, a separate oil tank has been positioned in the forward part of the engine. By utilizing a three-speed automatic transmission, the TRX650FA is able to allocate the lower central portion of

the crankcase, which accommodates the mechanical shift fitted to conventional ATVs, for the oil tank. This has achieved approximately a 2 kg weight reduction over a separate oil tank.

3.2. Multi Scavenger Oil Pump

The crankcase is divided into three separate chambers and consists of the centrally positioned oil tank, the laterally positioned crankshaft, and the transmission chamber. The oil

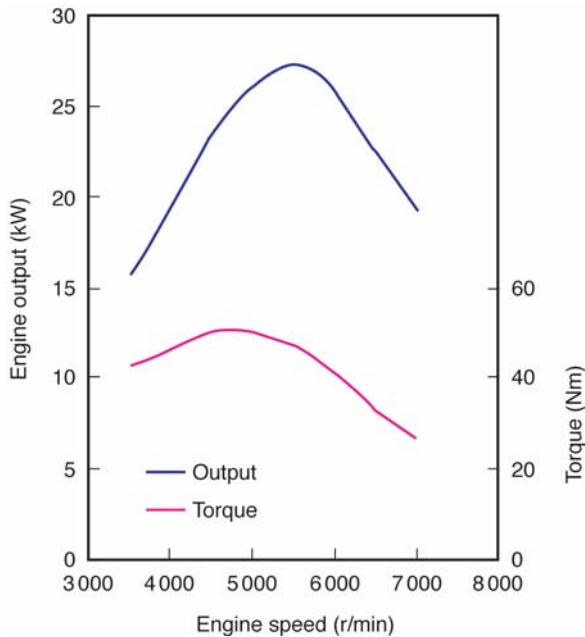


Fig. 4 Engine performance curve

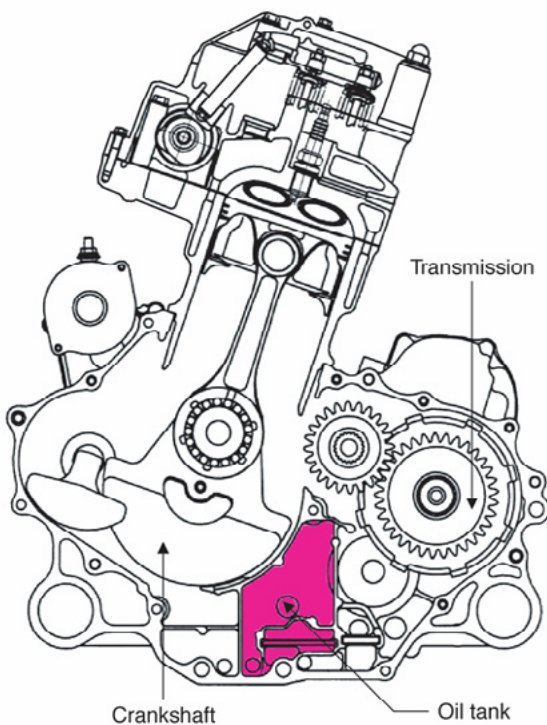


Fig. 5 Location of oil tank

pump draws the oil from these three chambers independently. Figure 6 shows the structure of the oil pump.

The oil pump is fitted with three trochoid rotors and a built-in relief valve. The oil drawn from the crankshaft and transmission chambers is cooled as it passes through the forward positioned oil cooler and is then returned to the oil tank. The oil from the oil tank is supplied to the engine and transmission system. The TRX650FA adopts a three-speed automatic transmission, which embodies a torque converter and three hydraulic clutch units. To preserve the same degree of maintenance commonly associated with conventional ATVs, one type of engine oil is used to lubricate all of the hydraulic driven parts.

3.3. Torque Converter

Instead of the automatic centrifugal clutch used in conventional ATVs, a torque converter is positioned on the crankshaft. The primary gear is welded into a single unit providing a configuration unique to ATVs and not typically found in an automobile. Figure 7 provides an external view of the torque converter.

The creep phenomenon, commonly associated with

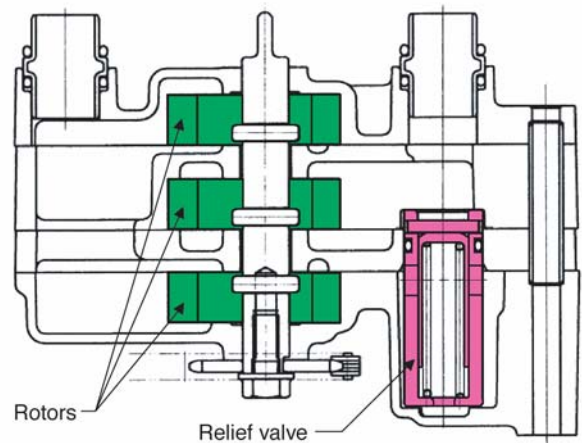


Fig. 6 Structure of oil pump



Fig. 7 External view of torque converter

torque converters, has been controlled by the oil pressure of the hydraulic clutch to maintain a similar degree of drivability as with conventional ATVs. The hydraulic controller, which uses a linear solenoid valve, enables the clutch to engage continuously to deliver the correct oil pressure as required by the vehicle speed, throttle opening, engine speed and oil temperature.

3.4. Transmission

The transmission utilizes three parallel shaft units. The main primary shaft unit accommodates the low clutch and the counter shaft unit accommodates the 2nd and 3rd clutch. The rear end of the counter shaft is fitted with a drive and reverse range switching mechanism. The drive force is transmitted to the front and rear propeller shaft from the final drive shaft unit via the final reduction gear.

To attain the same degree of vehicular drive rolling load as conventional ATVs, the selection of the neutral gear is mechanically effected and is set on the drive and reverse switching mechanism close to the propeller shaft.

Operating oil for the hydraulic clutch is supplied from the main shaft and counter shaft units via a typical feed pipe. All high pressure passage circuits, including the hydraulic controller, are concentrated under the engine front cover. Under the front cover an oil filter cartridge and the hydraulic controller valve body has been pre-assembled inside a clean room to prevent contaminants from entering the hydraulic circuit. Also, since processing along the assembly line has been simplified, the unit can be assembled on the same assembly line as that used for conventional ATVs.

Additionally, hydraulic clutches have been incorporated into the main and counter shaft units, respectively. The longer feed pipes for the counter shaft unit have been designed to enable the removal of an individual pipe from the outer engine surface. Figure 8 illustrates the structure of the transmission unit.

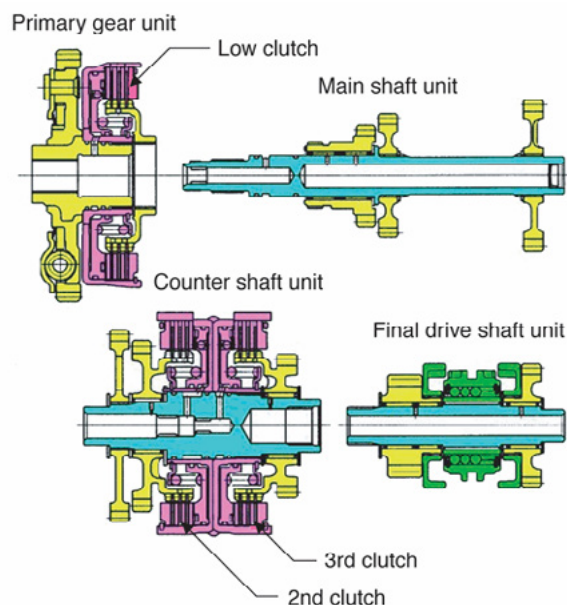


Fig. 8 Structure of transmission unit

the operator controls. The instrument panel has been allotted high priority to provide visibility for off road running and incorporate a new styling that matches the exterior character, all packaged in a highly usable and balanced configuration. All of the switches to be operated while the vehicle is running have been positioned and designed to provide ease of operation without requiring the driver's hands to be removed from the handle bars. The lever for operating the vehicle forward or reverse adopts a column style controller to provide the same feeling as an automotive driving experience.

4. Vehicle Body

The body design of the RINCON TRX650FA was developed along the lines of the SUV concept. SUVs are an extremely popular category in the North America automobile market. The RINCON TRX650FA has incorporated a balance of utility and recreational characteristics typically associated with SUVs to establish this as a new vehicle category in the ATV market. As Honda's flagship ATV, the TRX650FA incorporates a large range of original technology features to make it a benchmark vehicle design for future Honda ATVs offering a solid and sporty riding experience with a sense of quality and sophistication.

4.1. Exterior

Honda's characteristic ATV body carries a hybrid bumper design, which has eliminated the previously incorporated round piping. The new design employs steel piping set in blow molded plastic. By combining specially designed large integrated headlights, Honda has successfully captured the design concept of a SUV while creating a revolutionary new sporty look. A particular feature of this vehicle is the rear mounted independent suspension, offered for the first time on a Honda ATV. In addition to a superior quality aluminum alloy forged suspension arm, the vehicle adopts a uniquely configured dual tail lamp design. Figure 9 shows the front and rear view of the TRX650FA. Figure 10 show a view of

4.2. Fender Molding

Weight reduction has been emphasized in the development of this vehicle. To achieve a lighter exterior, all of the exterior parts have been constructed in a completely new format. In conventional approaches to development, it can take an inordinate amount of time to achieve the desired specifications for reducing weight.

In the design of this vehicle, computer graphics (hereafter, referred to as CG) were employed where basic design sketching would have traditionally been used to develop a clay model representation. CG was used in the development of the exterior design of the vehicle and to design the exterior mounted parts. This was instrumental in improving the



Fig. 9 External view of TRX650FA's front and rear



Fig. 10 External view of operator controls

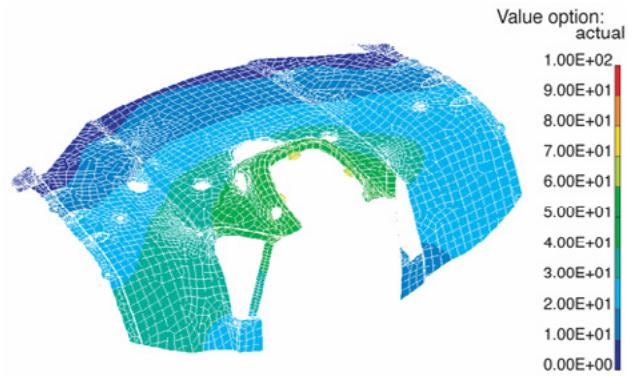


Fig. 12 Calculation results of flow analysis

accuracy of the specifications at the initial development stage. Figure 11 shows an external view of the vehicle under development with CG.

Using the external view data, a numerical flow analysis was conducted to estimate the plastic molding configuration and the appropriate thickness of each part. This approach finally enabled a thickness of only 2.8 mm, which was virtually inconceivable up to this point. This has resulted in a 20% weight reduction in fender weight compared to previous designs. Figure 12 shows the calculation results of the numeric flow analysis.

4.3. Transverse Muffler

Usually, the muffler is located on the left or right rear side of the vehicle and is mounted longitudinally. However, if a rear independent suspension was to be adopted, it would impinge on the operating range of the shock absorbers and impair the lightweight suspension unit's design. To address this issue, priority was given to the suspension's freedom of movement while achieving an overall weight reduction to the vehicle by extending the exhaust pipe to the rear of the vehicle and positioning the muffler transversely. Adopting this configuration has provided greater freedom in the selection of exhaust pipe length while achieving the desired level of engine performance. Also, centralizing the muffler

positioning has made it easier to balance the weight along the lateral direction and has enhanced the layout flexibility of the overall vehicle. Figure 13 shows the location of the muffler.

5. Chassis

Conventional Honda ATVs have typically employed full time 4WD and a swing arm type rigid axle rear suspension. To provide Honda's flagship TRX650FA with the ideal underbody specifications, it has been designed with an independent rear suspension and a selectable 2WD/4WD system.

In addition to these specifications, the vehicle employs a range of weight reduction technologies, never used before in ATVs, to achieve a vehicular weight of 273 kg. This has limited the weight increase of the underbody to 1.2 kg in comparison to the full time 4WD and swing arm mechanism. In addition to reducing the vehicle weight, it provides for an easy to handle, comfortable ride, both of which have been key development concepts.



Fig. 11 External view by "CG"

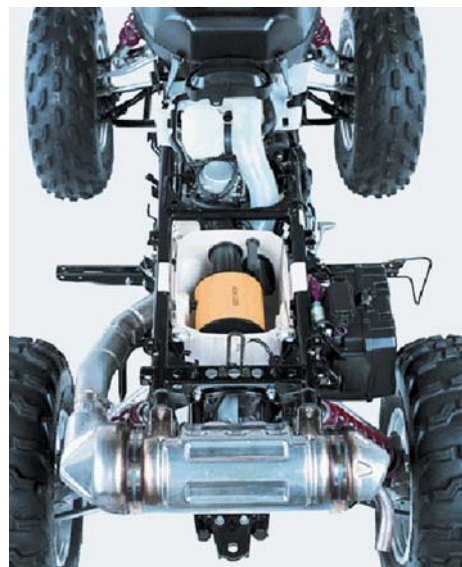


Fig. 13 Location of muffler

5.1. Independent Rear Suspension

The rear suspension employs a double wishbone type independent suspension, another first for Honda ATVs. A conventional swing arm type rigid axle utilizes a riding style where the rear of the vehicle slides while turning. Such a method is, however, limited in its capacity to enhance comfort when travelling over severe bumpy and rough road surface conditions. While the independent suspension system enhances driver comfort, it has contributed to an overall weight increase, and the increased horizontal rolling pitch tends to reduce the turning performance.

By taking a radical new approach to the entire body construction, the TRX650FA has incorporated an innovative suspension placement design and achieved a balanced set of specification settings for each component. Figure 14 shows a view of the rear suspension.

The parts attached to the lower side of the shock absorbers and the upper arm fulcrum are set along the same axis. This transfers the reaction force from the trail surface directly to the shock absorbers. The upper arm and lower arms have been designed to bypass any flexural load exerted by the trail's reaction force and have achieved reduced weight to the entire system. To maintain a sufficient axle stroke, a twin chamber type single tube damper has been adapted. The built-in twin chamber enables a high degree of packaging flexibility and increases the angle for the damper. To enhance this angle setting, the upper part of the damper is positioned close to the main frame. By repositioning the damper in this way, smaller sized brackets can be used to attach the damper. This has achieved a lighter rear suspension system that offers highly efficient operability while preserving an axle stroke of 203 mm. When addressing the issue of rolling as the vehicle turns, comfort and vehicular balance need to be taken into account. An independent suspension system is more effective than a rigid axle for ground contact of the inner wheel as the vehicle turns. To reduce the degree of rolling, it would be better to increase the stabilizer load, yet conversely, that would not contribute favorably to riding comfort.

This has been resolved in this new vehicle by setting a certain degree of tow out to the rear tire. Also, radial tires have been adopted, another first for a utility ATV. An

improved balanced load setting to the stabilizer has provided greatly enhanced riding comfort and sporty handling performance compared with conventional rigid axle systems. Along with the changes made to the suspension system, the increase in weight has been addressed by applying aluminum alloy forgings on the upper and lower arms and knuckle to achieve targeted weight reduction. Figure 15 shows an external view of these parts.

5.2. Separate Rear Frame Construction

The independent rear suspension system uses a greater number of components than conventional rigid axle systems. The same production line used for the conventional rigid axle system is used for the new suspension system. The assembly of such a large number of parts has contributed to a reduced level of efficiency along the production line. To resolve this issue, the rear frame has been designed in a modular construction so that all the components on the rear suspension and rear final drive are assembled on an independent production line in a sub frame unit. This has greatly reduced the number of assembly processes on the main production line and increased efficiency in the combined manufacturing of other machines on the main production line. Figure 16 shows the sub frame unit.

5.3. Rear Final Drive System

A Birfield type constant velocity joint has been employed in the rear power train, which transfers the drive from the rear final shaft to the wheel. The ratio of the axle stroke to the tread is large in ATVs compared with usual passenger vehicles. This increases the angle of the constant velocity joint, which in turn leads to the generation of heat thereby contributing to endurance related issue. To resolve this issue, it required that the length of the left and right drive shafts were made equal and that the angle to the constant velocity joint be reduced to a minimum. To achieve this, the rear final gear needed to be positioned closer to the center of the vehicle. This however would cause a misalignment of the propeller shaft, which connects the engine and the final gear case. This is normally resolved by using a pair of yoke joints. In the TRX650FA, because the engine is positioned close to



Fig. 14 External view of rear suspension



Fig. 15 Rear upper and lower arm & knuckle



Fig. 16 Rear sub frame unit

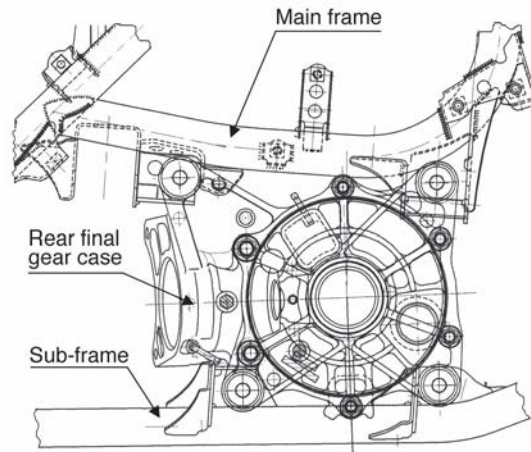


Fig. 18 Rear final gear case and rear frame

the rear final gear case, if a pair of yoke joints were to be used, it would increase the angle setting which would decrease the efficiency of power transfer and would generate heat. The engine output shaft has been set in a direct line from the front final gearbox to avoid using a yoke joint on the front propeller shaft. The change in the positioning of the engine output shaft however makes it difficult to reduce the velocity joint angle. By setting the cross angle on the rear final bevel gear to 77° , the propeller shaft is positioned in an angle to the vehicle body to enable the use of a simple drive system which uses only the yoke joint coupled to the engine side. Figure 17 shows the structure of the final drive system. Additionally, the rear final gear case, described in Section 5.2, is used to strengthen the connection between the main frame and sub frame units. By fixing the rear brake system directly to the gear case, the entire weight of the overall vehicle has been reduced. Figure 18 shows the integrated sub frame unit.

5.4. Rear Brake

The rear brake is fitted with a brake disk 170 mm in outer diameter on the propeller shaft and the caliper is clamped on to the rear final gear case. This enhances the operation efficiency of the cushion by greatly reducing the weight of the movable parts on the rear suspension. It also enhances the maneuverability as the vehicle travels over rough road conditions. Since the input torque load exerted to the brakes is reduced according to the reduction ratio of the rear final gear, the diameter of the brake disk has been decreased and the weight of the entire vehicle reduced.

However, the propeller shaft to which the brake disk is mounted is less exposed to air flow as the vehicle is being driven in comparison to a wheel mounted brake. A continued application may cause insufficient heat radiation. By insulating the brake pads and using a floating type of brake disk, the rear brake system is able to overcome these issues. Figure 19 shows an external view of the rear brake system. The rear brake on the ATV utility vehicle has two

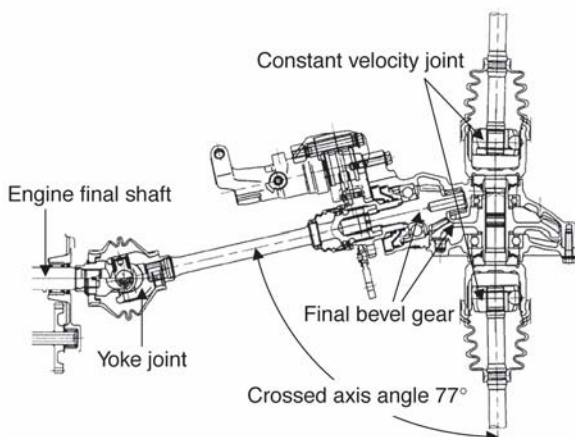


Fig. 17 Structure of rear power train



Fig. 19 Rear brake system

independent operating input positions: one on the right foot pedal and the other on the left handle bar. The handle bar is fitted with a parking brake function for securing the vehicle position. A rear brake on conventional vehicles typically uses a mechanical drum brake. In the dual brake system described above, two input cables are connected to a single brake arm to operate the brake. In conventional vehicles, a brake adjustment screw fitted to the cable ends had to be manually adjusted to modify any play in the brake. The TRX650FA employs a collet type caliper that is fitted with a mechanical piston to enable automatic brake adjustment. Figure 20 shows the structure of the rear brake caliper. The caliper piston is operated by input from the foot pedal, which is converted by hydraulic pressure in the master cylinder via the brake hose. Brake control input from the handle bar uses the cable to operate the mechanical piston. Enabling the rear brake input conditions to be set independently has brought greater control to the braking function and enabled automatic brake adjustment on both braking systems.

5.5. Front Suspension

The front suspension employs the same basic structural design and wishbone configuration with an axle stroke of 175 mm as that used in the TRX500FA. However, to provide ease of handling for both 2WD/4WD operating conditions, the alignment of the main kingpin angle has been redesigned. This new design employs an aluminum alloy forged upper arm, a first for ATVs, to achieve the targeted weight reduction. Figure 21 shows an external view of the aluminum forged front upper arm.

5.6. Front Final Drive System

The front final gear assembly comprises an electromagnetic controlled mechanical clutch unit⁽¹⁾ (hereafter referred to as MCU) for 2WD/4WD switching

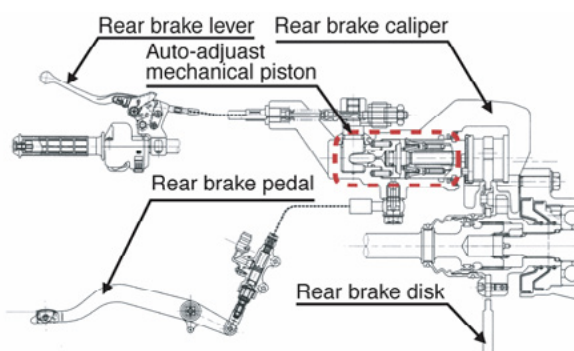


Fig. 20 Structure of rear brake caliper



Fig. 21 Aluminum forged front upper arm

control; a torque sensitive cam differential; and a near net forged straight bevel gear. Figure 22 shows the structure of the front final gear assembly. The electromagnetic MCU has an electromagnet and a two-directional roller clutch assembly and was adapted to the TRX450FE ATV utility vehicle in 2001. The MCU operates by intermittently controlling the electromagnet current to provide easy and instantaneous roller clutch switching to the drive and idling running modes. When the roller clutch is engaged, 4WD is operational and when disengaged, 2WD is operational. Figure 23 shows the structure of MCU. When no current is flowing to the electromagnet, a switch spring load causes the retainer to hold the roller position in the center of the cam ring. Since a clearance is maintained between the outer ring and roller in the center of the cam ring, the transfer of the drive force from the propeller shaft is cancelled which switches the vehicle to 2WD. In 4WD, the electromagnet attracts the armature. The electromagnet is connected to the propeller shaft and the armature rotates at the same speed as the retainer. When the electromagnet and armature come in contact, the retainer tends to slip from the center of the cam ring. This creates a rotational difference between the retainer and cam ring and creates a torque to override the force of the switch spring. The retainer moves the roller from the center of the cam ring to a locked position thereby transferring the drive force. Figure 24 illustrates the MCU torque force transfer.

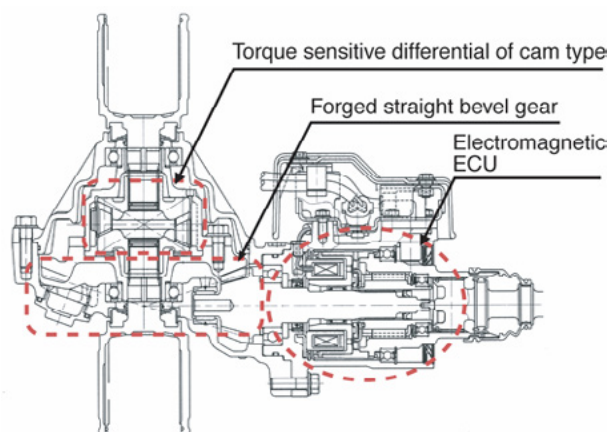


Fig. 22 Structure of front final gear assembly

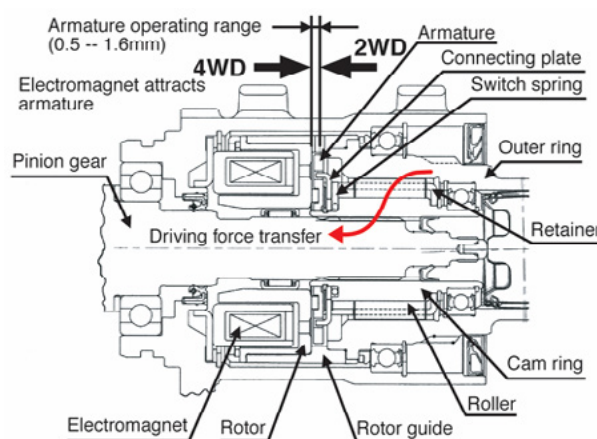


Fig. 23 Structure of MCU

The TRX650FA has a cam type torque sensitive differential built onto the front drive system as shown in Fig. 25. Unlike typical limited slip type differentials, which use friction disks, multiple cams are constructed so that when the power force is transferred, friction control is also applied. The integration of these functions has enabled weight

reduction and reduction of the horizontal width. It also incorporates advantageous system features for narrow treaded ATV vehicles. The TRX650FA is configured with a maximum torque displacement of 1:3.9 to the left and right wheels to free the vehicle from muddy road conditions. Also, by employing a different ratio to the front and rear final gear,

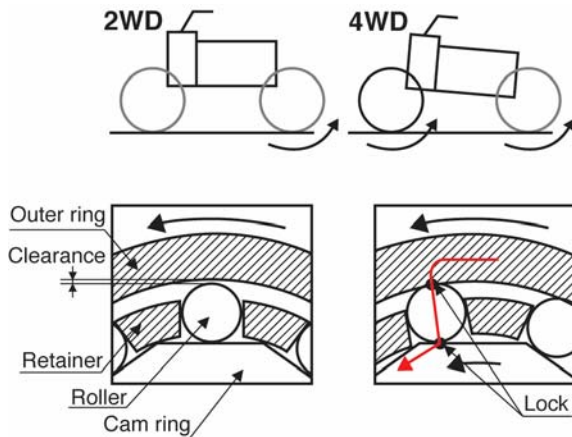


Fig. 24 Structure of MCU

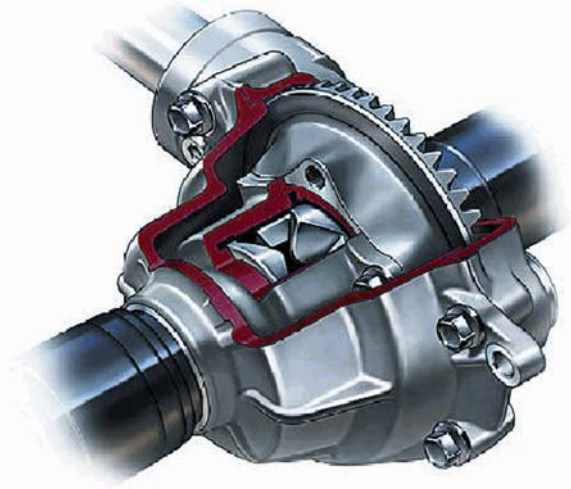


Fig. 25 Cam type torque sensitive differential

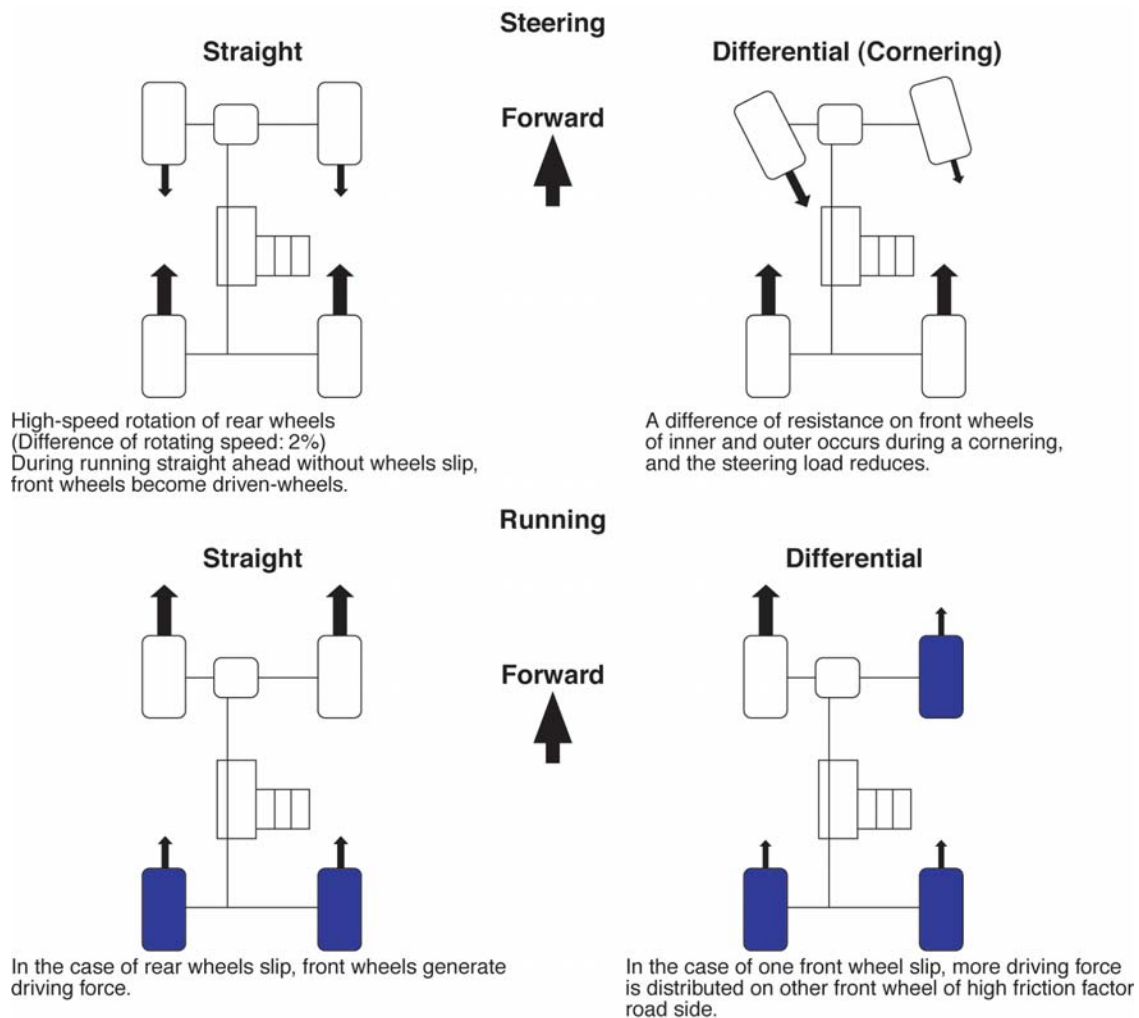


Fig. 26 Characteristics of vehicle

the front wheels rotate 2% faster than the rear wheels. Figure 26 shows the drive power distribution in different driving conditions. The front wheels become driven-wheels in normal straight drive conditions and are subject to resistance. When the handle bar is turned in such conditions, the front inner wheel with a lower rotation speed takes on a greater amount of resistance than the outer wheels because of the differential's torque distribution ratio. This results in a significantly improved turning performance. Furthermore, on low resistant road conditions, such as muddy roads and severe rough road surface conditions, the torque distribution ratio contributes to making the course more drivable. The combined front torque sensitive type differential and the front/rear wheel rotation differential provide comfortable handling and a smooth riding course. Even in the 2WD drive mode, the differential influences vehicle handling and the inner electromagnetic MCU friction is set to the optimal integrated handling specifications.

The ATV final gear has conventionally employed a straight bevel gear made of a near net forging and has achieved a lower degree of cost compared with a machined spiral. To further this technology, an optimal sized gear has been adopted to contribute to weight reduction. This has resulted in a 0.4 kg reduction in weight in the front final assembly compared to the TRX450FE, which employed the same system. Figure 27 shows the gear set used in the assembly.

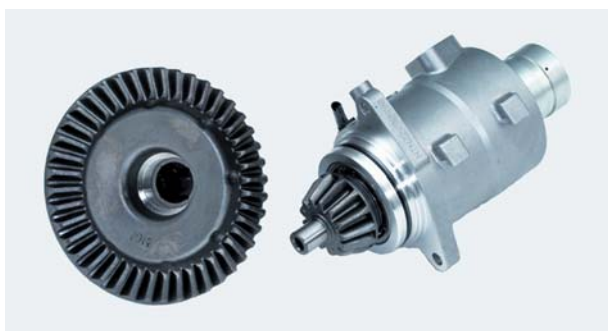


Fig. 27 Forged straight bevel gear

6. Summary

The TRX650FA is an ATV based on new SUV concepts and incorporates a new vehicular design and numerous new configurations that are summarized below.

- (1) Employs an engine with a maximum output power of 27.3 kW/5,500 rpm and a maximum torque of 49.9 Nm/4,500 rpm in addition to achieving an overall vehicular weight of 273 kg, which have contributed to a balanced running performance, ease of handling, and a high level of maneuverability.
- (2) Constructed with an original design that incorporates a solid and sporty riding experience with a sense of quality and timeless sophistication.
- (3) Incorporated operational stability and comfort into a balanced easy to handle and comfortable riding experience.

Acknowledgements

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electromagnetic MCU and FCC Ltd. for their cooperation in the development of the cam type torque sensitive differential.

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