Construction and function

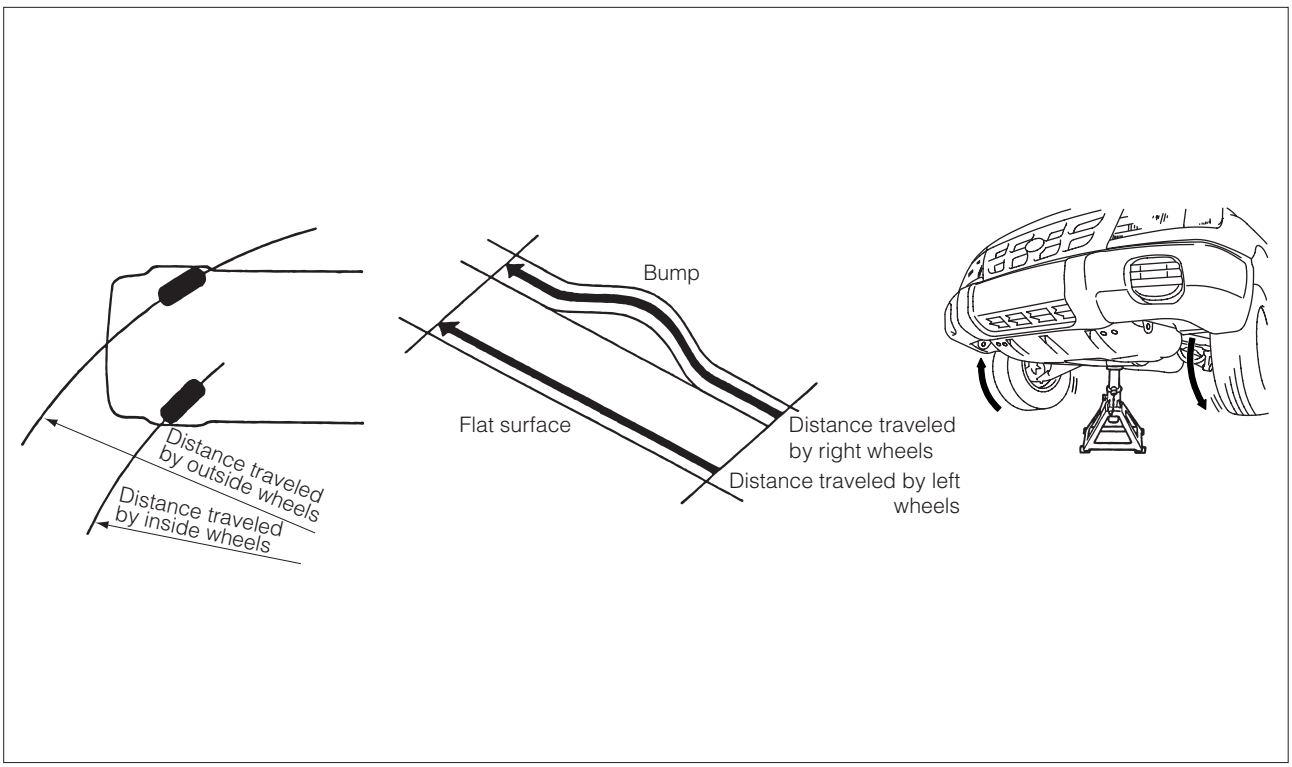
Overhaul

On board inspection

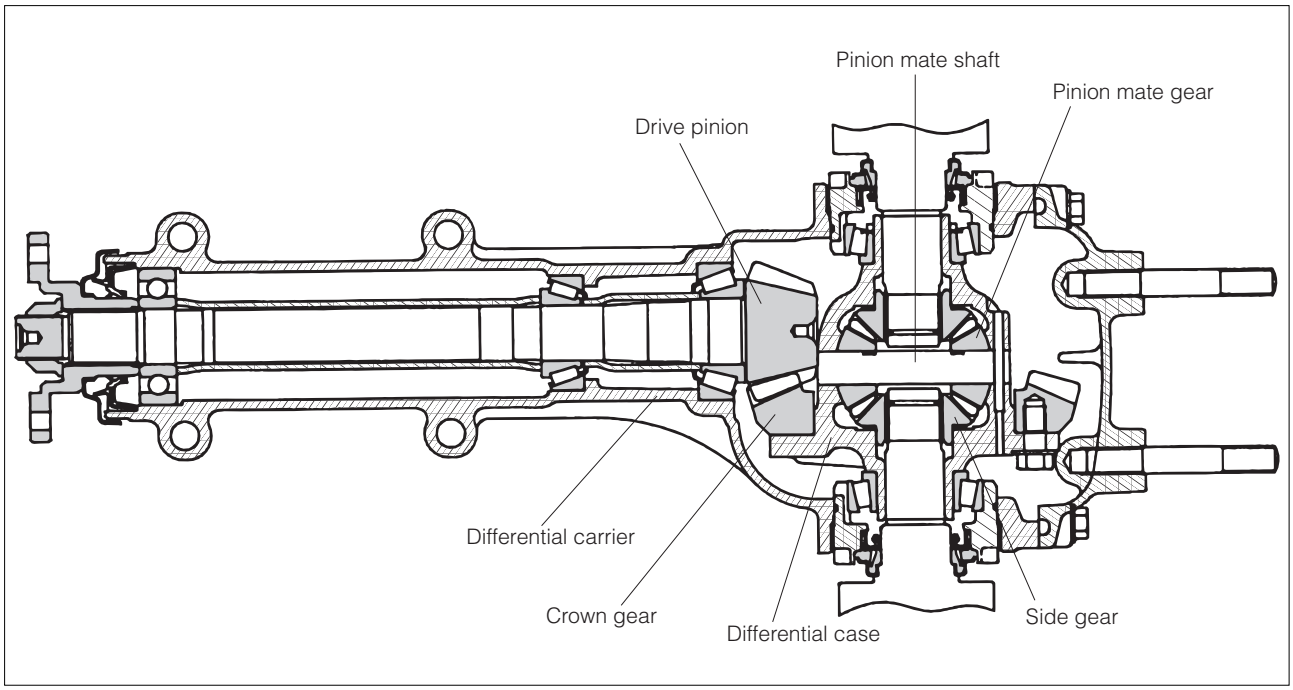
Overview

When a vehicle turns or drives over an uneven road surface, the distance traveled by each rotation of the left and right wheels is not uniform. If the vehicle is driven in this state, the drive wheels will wear unevenly or the driver may lose control of the vehicle. It is therefore necessary to change the rotating speed of the wheels. The differential is a device that uses a pair of pinion mate gears and side gears to vary the rotating speed of the left and right wheels while driving both wheels.

If the drive wheels are jacked up and the wheel on one side is turned by hand, the other wheel will turn at the same time in the opposite direction. That is due to the function of the differential.



Structural parts



Drive pinion and crown gear

The drive pinion is turned by the engine driving force via the transmission. The crown gear is mounted on the differential case and is driven by the drive pinion. The drive pinion and crown gear assembly is referred to as the final gear, and the final drive ratio is generally 1:3 - 5.

Differential case

The differential case is fixed to the differential carrier and is comprised of a pinion mate gear, side gear, and other parts.

Pinion mate gear

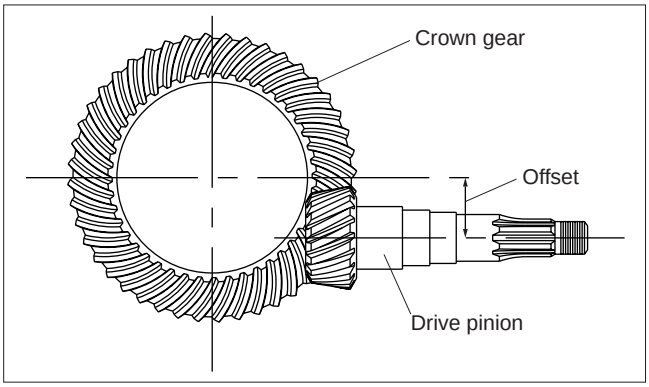
The pinion mate gear is installed on the differential case via the pinion mate shaft and it rotates together with the shaft and the differential case. At the same time, the pinion mate gear can turn freely around the pinion mate shaft; so when the left and right wheels revolve at different speeds, the pinion mate gear rotates around the axis of the pinion mate shaft (turns on its own axis).

Side gear

The side gear is incorporated in the differential case and is fixed to the left and right axle shafts via a spline, it therefore turns together with the wheels.

Pinion mate shaft

The shaft is used to mount the pinion mate gear to the differential case.

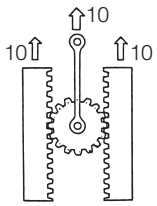


Hypoid gear

A hypoid gear is generally used for the final gear. Since the hypoid gear is constructed with the centers of the drive pinion and crown gear offset, its teeth can be made longer for increased strength. Because of this offset, moreover, the differential carrier can be raised above the drive shaft, securing the minimum ground clearance. Since it has a large number of simultaneously meshing teeth, the hypoid gear can rotate quietly. Its drawback, however, is that it can easily seize, so specified hypoid gear oil must always be used.

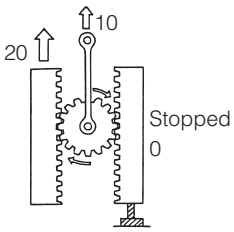
Differential working principle

When left and right racks move at the same speed



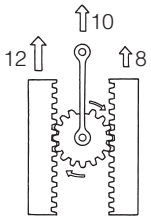
The pinion and 2 racks move at the same speed and the pinion does not turn. This is situation when the vehicle is traveling straight ahead on a flat road surface.

When rack on one side are stopped



The pinion moves and rotates at the same time and make the rack on one side moves twice as fast as the pinion shaft. This is situation when the wheels on one side drive through mud or other obstructions, the influenced wheels spin twice as fast as the crown gear, while the other wheelx stops rotating.

When rack on one side moves slower

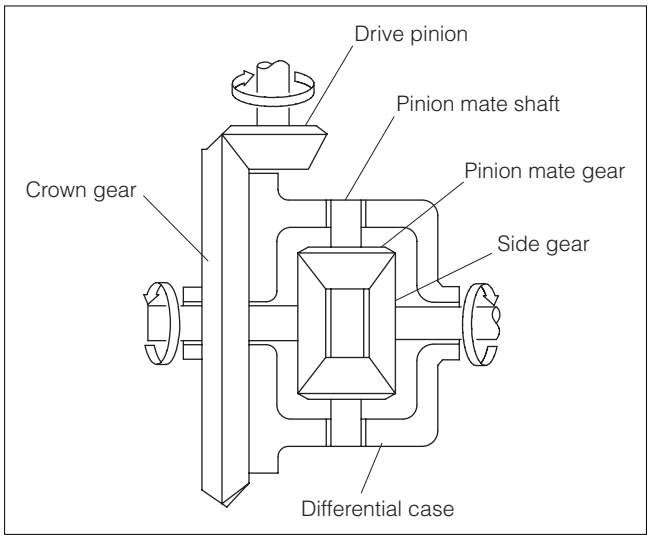


When the rack on one side moves slower, there is a corresponding rotation of the pinion, which increases the rack moving speed on the other side (but the total speed of the 2 racks does not change). This is situation when a vehicle is turning and the rotating speed of the inside wheels decreases while that of the outside wheels increases.

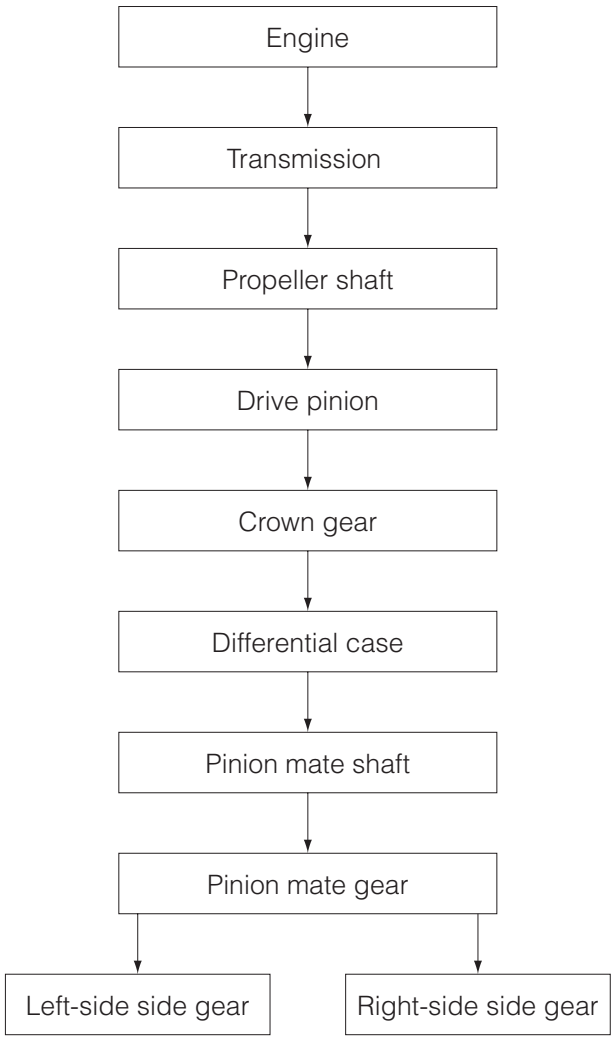
These figures explain the working principle of the differential in terms of 2 racks (equivalent to side gears) and a pinion. Three cases are described: when the 2 racks move at the same speed; when one rack is stopped; and when one rack moves at a reduced speed of 8, with the pinion moving speed (equivalent to crown gear rotating speed) assumed to be 10.

Operation

When left and right wheels rotate at the same speed

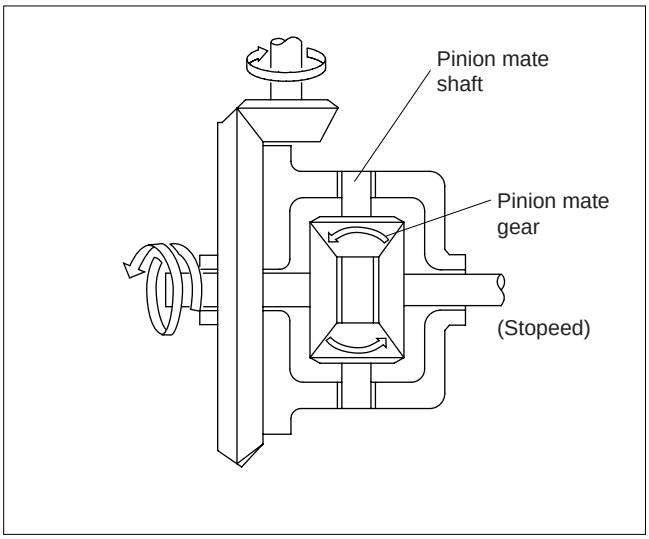


The rotation of the drive pinion is transmitted to the crown gear, which is geared to the drive pinion, and it is then transmitted from the differential case to the pinion mate shaft, thereby turning the side gears via the pinion mate gear. Since there is no difference in the rotating speed of the left and right wheels, the pinion mate gear revolves with its shaft but does not turn around the axis of the shaft, and the left and right side driving force ratio is 50:50.

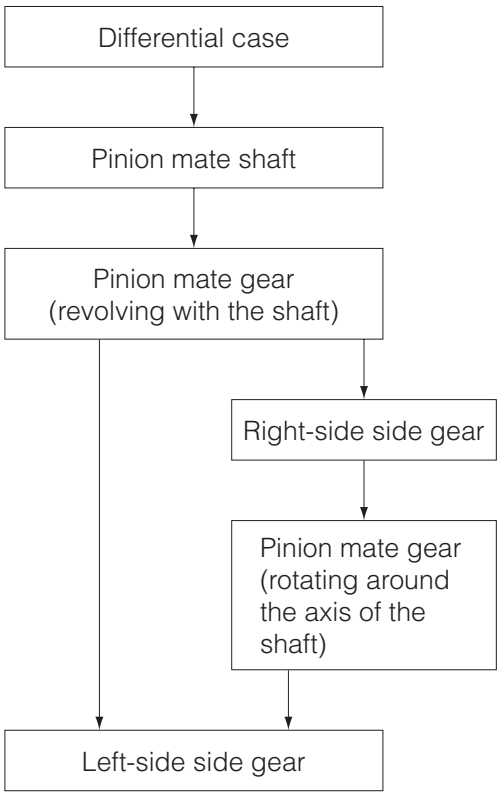


Driving force ratio: 50:50.

When wheels on one side are stopped



When the wheel on the right side stop turning, the pinion mate gear rotate around the axis of the pinion mate shaft, even as it revolves together with the shaft. This causes the driving force distributed to the right side to turn the pinion mate gear. Since the pinion mate gear turns the side gear on the left side, the driving speed on the left side is doubled to the driving speed of pinion mate shaft.



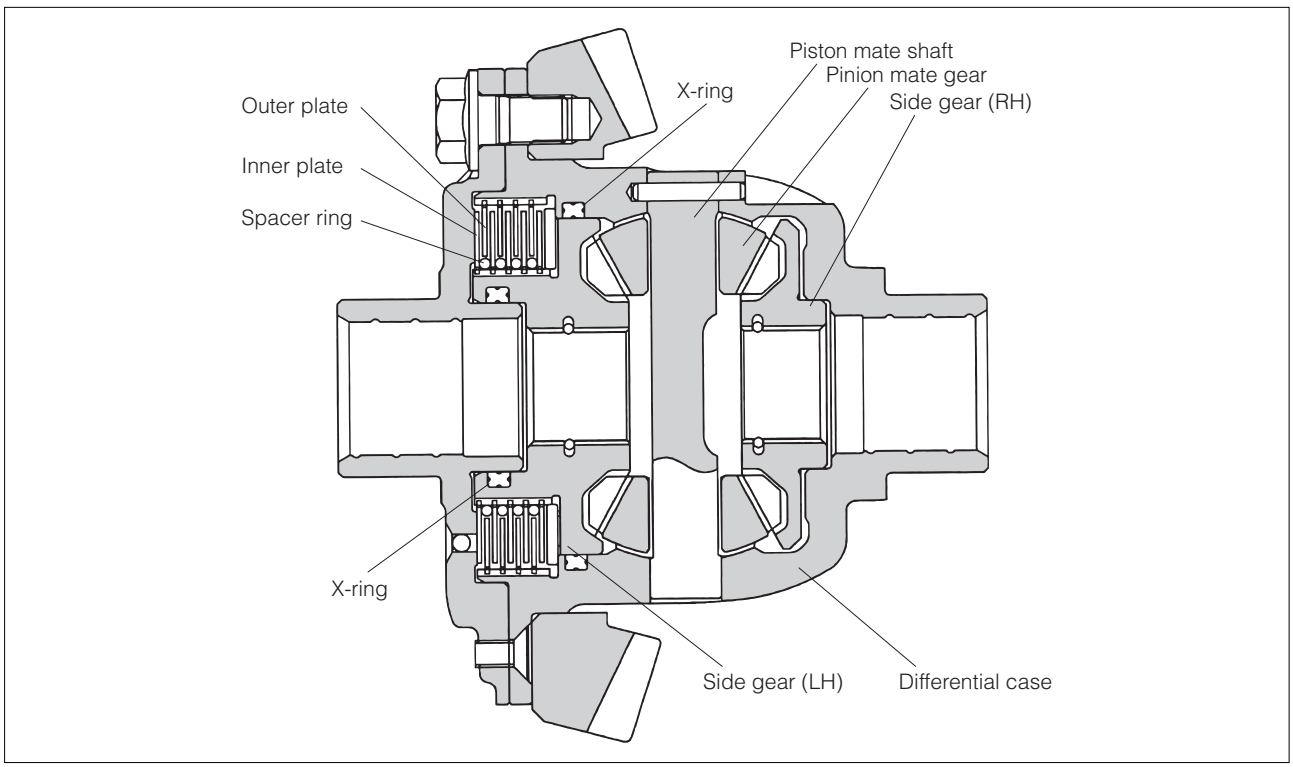
Driving speed ratio: 100:0

Limited Slip Differential (LSD)

Overview

When the vehicle is equipped only with a normal differential, then when the wheels slipped on an icy or muddy road or dropped into a rut, only the wheels not in contact with the road surface would slip, while the wheels on the other side would stop turning. Also, to improve course stability under normal driving conditions and to distribute a portion of the driving force on the side of the slipping wheels to the wheels in contact with the road, a limited slip differential (LSD) is equipped. Here, a viscous-coupling type LSD is described.

Viscous-coupling type LSD



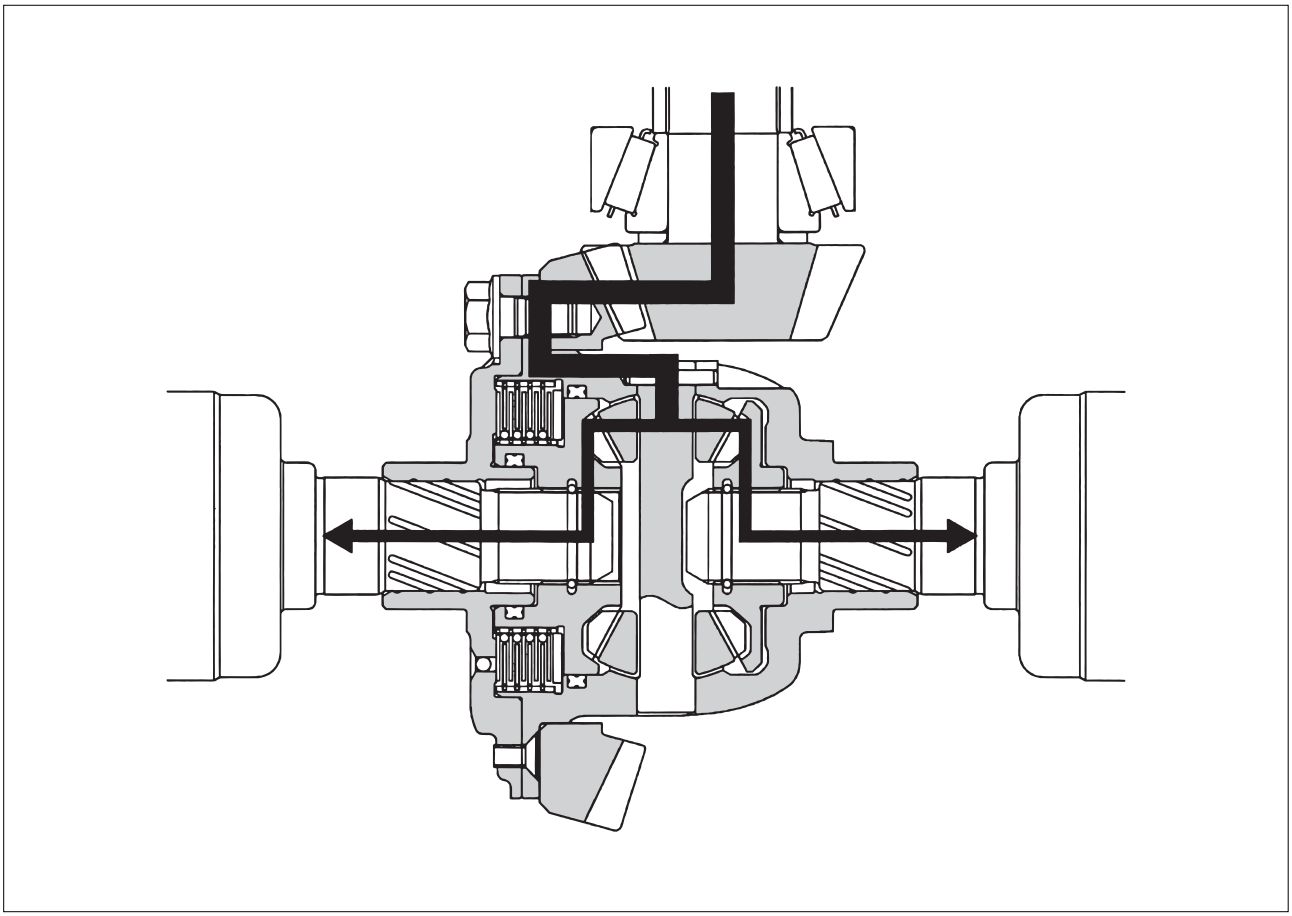
In addition to a normal differential construction, the viscous-coupling type LSD has a viscous coupling. Inside the coupling there are outer plates fixed to a differential case and inner plates fixed to a side gear hub. The area between the two plates is packed with high-density of silicone oil. Due to its high viscosity, this silicone oil generates a large resistance when there is a large difference in rotating speed between the left and right wheels.

The housing is completely sealed with X rings and there is no oil leakage into the final drive chamber even when the oil pressure rises due to a large difference in rotating speed between the left and right wheels.

Since it is a sealed assembly, the LSD cannot be disassembled; if damaged, therefore it must be replaced.

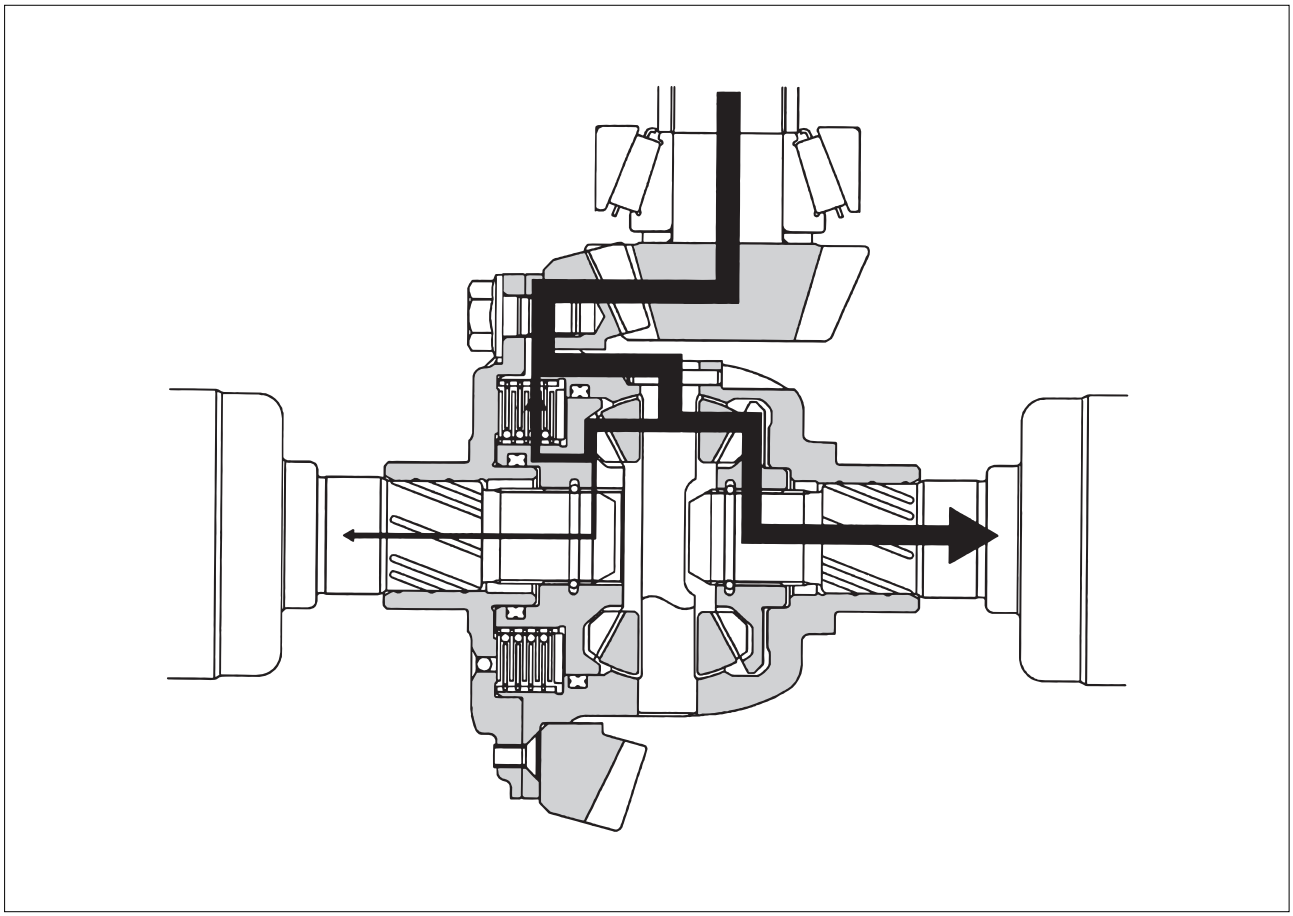
LSD operation

Under normal driving conditions (when left and right wheels turn at the same speed)



Under normal driving conditions, when the left and right wheels are turning at the same speed, the side gear rotates together with the differential case and the driving force is evenly distributed to the left and right sides, as with a normal differential.

When the left and right wheels turn at different speeds



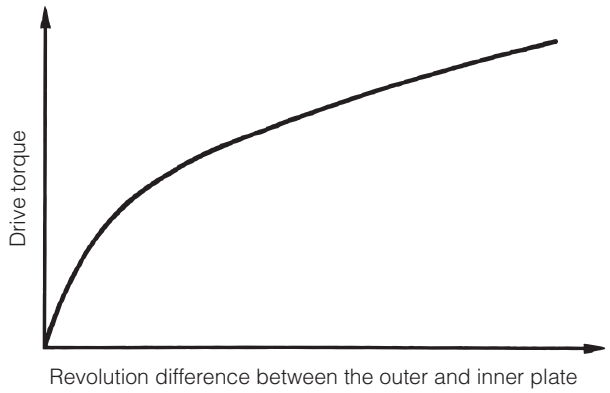
* When the left wheels slip

When the left wheels are driven through mud or drop into a rut and they start to slip, the differential functions to decrease the rotating speed of the right wheels so that the right wheels turn slower than the left wheels. At this time, as the difference in rotating speed of the left and right wheels is large, the high viscosity of the silicone oil packed inside the LSD turns into resistance, distributing a portion of the inner plate (left wheels) to outer plate driving force (differential case) . This enables the right wheels to generate driving force, even though the left wheels are slipping, and the vehicle can be driven out of the mud or rut.

Characteristic of viscous coupling

When a difference in rotating speed between the outer and inner plate occurs, a viscous shearing force is generated in the silicone oil placed between the outer and inner plates.
The torque is then transmitted by the silicone oil between the outer and inner plate.

The greater the difference in rotating speed between the outer and inner plate, the greater the shearing force of the silicone oil. The relationship between the torque transmission and rotation speed difference is shown in the figure. As can be seen from the figure, the smaller the rotating speed difference, the lesser the torque transmission and the differential-action.



Therefore when the car is turning at the corner, viscous coupling does not produce so much torque due to small speed difference between right wheel and left wheel and when one wheel is slipping, large torque is produced due to large speed difference.