

Development of Dual Clutch Transmission for Large Motorcycles

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ABSTRACT

Large motorcycles have a strong recreational aspect. Therefore, in addition to the sportiness that comes from the direct torque feel and the comfort that comes from the ease of operations, users demand improvements to fuel economy from the perspective of the environment and riding economics. In order to satisfy these needs, we have developed the world's first dual clutch transmission (hereinafter referred to as DCT) for motorcycles. In order to make the DCT more compact, we adopted a dual shaft construction for the main shaft, two hydraulic clutches arranged in-line, the basic structure of the gear shift mechanism carried over from a manual transmission (hereinafter referred to as MT) vehicle, a hydraulic circuit consolidated into the engine side cover, and shared use of engine oil for clutch actuation. Through these innovations, it became possible to carry over the die of the crankcase used on the MT vehicle as well as being able to load it onto the same frame as the MT vehicle. In order to achieve the smooth starts and gear shifts demanded of motorcycles, independent linear solenoid valves were positioned on each of the two clutches; this configuration makes it possible to control the clutch hydraulic pressure directly. At a standstill, no creep torque is applied. Then, by controlling the clutch hydraulic pressure rise characteristics immediately after starting launch controls, it is possible to start smoothly. Gear shifting by the two linear solenoid valves directly controlling hydraulic pressure makes it possible to control the clutch capacity of the driving side and the non-driving side with precision to realize smooth gear shifting with no drops in torque. A 5% improvement in fuel economy compared to the MT vehicle in WMTC mode was realized by optimizing the shift schedule.

INTRODUCTION

The most common type of automatic transmission (hereinafter referred to as AT) for motorcycles is the belt converter type equipped on scooters. With smooth starts and gear shift, it is loved by a wide range of users. At the same time, there are many users that prefer stepped transmissions with gear shift speeds that allow the user to enjoy sport driving and feel the torque being transmitted directly. Thus, we have fully automated a stepped transmission with a DCT system and built it onto a V4 engine (Fig. 1).



Fig. 1. External view of V4 engine with newly developed Dual Clutch Transmission

Table 1. Comparison of specifications of Manual Transmission and Dual Clutch Transmission

		Manual Transmission	Dual Clutch Transmission
Engine	Type	4-cylinder V-type	4-cylinder V-type
	Bore (mm)	81	81
	Stroke (mm)	60	60
	Displacement (cm ³)	1237	1237
Clutch	Type	Mechanical	Hydraulic
	Number	1	2
Transmission	Type	6-speed Manual	6-speed Manual + Automatic
	Ratio	Low	2.600
		2nd	1.736
		3rd	1.363
		4th	1.160
		5th	1.032
		6th	0.939
	Mainshaft no.	1	2
	Countershaft no.	1	1
Hydraulic	Axis length (mm)	75	75
	Oil capacity (L)	4	4.9
	Clutch control pressure (kPa)	—	900

DEVELOPMENT GOALS

A DCT is a technology that is already on the market in automobiles and ATVs (All-Terrain Vehicles) [1]. It is characterized as having the same direct torque feel and equivalent torque transmission efficiency as a MT, as it has the same elements to transmit torque, and it is widely known to have no drops in torque due to the controls that switch between the clutches at gear shifts. On the other hand, there are issues with these systems when performing starts with a hydraulic clutch. It is difficult to build a smooth start control system, and they require a more complicated construction than a MT. The aims of the development were thereby established as described below:

1. To make an AT that has sport performance and fuel economy performance equivalent to a MT vehicle.
2. To have smooth starts and gear shift characteristics suitable for motorcycles.
3. To be able to load the system onto the same frame as a MT vehicle and carry over the die of crankcase without making any changes to the basic positioning of the clutch, transmission shaft and gear shift mechanisms of a MT vehicle.

SYSTEM OVERVIEW

A comparison of the specifications of the MT and the DCT is shown in [Table 1](#) [2]. A cross-sectional drawing is shown in [Fig. 2](#). The engine torque is transmitted through the primary gear into the two clutches, then through the transmission and into the engine final shaft. The two clutches are connected to the main shaft individually with the gear trains of the #1

clutch connected to the odd-numbered gears (1st, 3rd and 5th) and the #2 clutch connected to the even-numbered gears (2nd, 4th and 6th). Gear shift methodology starts with the shift mechanism actuation to pre-shift the gear on the non-driven side clutch to a target gear position beforehand. The clutch hydraulic pressure is then switched over from the driven side to the non-driven side to change gears, then, the gear now on the non-driven side goes into the neutral position to complete the gear shift action. A time chart for shifts during starts and gear shifts is shown in [Fig. 3](#). Switching between clutches is done by two linear solenoid valves that control the clutch hydraulic pressure individually. Switching between shift positions is done with a configuration that is automated by motor power using a shift mechanism that is the same as that of the MT vehicle. Gear shift modes are implemented to include an AT Mode that performs fully automatic shifting and a MT Mode that allows manual shifting of gears as commanded by the user through a shift UP/DOWN button located on the left grip. Starting is controlled automatically in both modes. In addition, there are two types of AT Mode: “D” designed for fuel-efficient riding, and “S” designed for sport riding.

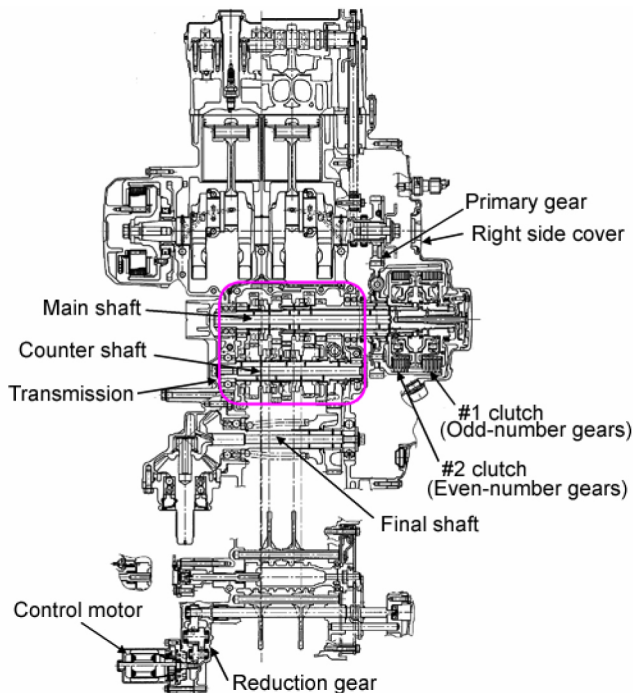


Fig. 2. Cross-sectional drawing of engine with Dual Clutch Transmission

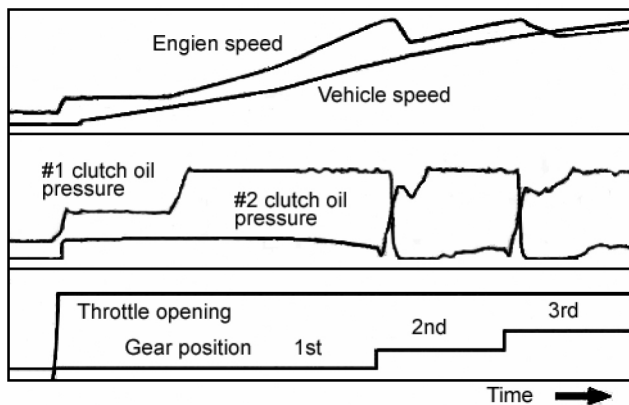


Fig. 3. Time chart for shifts during starts and gear shifts

CONSTRUCTION

LAYOUT

The die of the crankcase could be carried over by keeping a layout common to the MT vehicle for the basic positioning of the “clutch and gear shaft” and the “engine and transmission shaft”, as well as the distance between the shafts. On the right side of the engine, the clutch and oil paths are positioned and consolidated with a side cover; on the left side is an electrically powered motor for automating the gear shift mechanism. With such a layout, it is possible to keep the same lateral center of gravity as the MT vehicle.

CLUTCH

A hydraulic piston system that uses the engine oil as its actuation oil was adopted for the clutch and a canceller chamber was set to cancel the centrifugal hydraulic pressure generated in the piston chamber. Hydraulic pressure is supplied to the clutch from a feed pipe on the right side cover of the engine, and goes through the inner main shaft. The main parts of the system are made of die cast aluminum, which reduces weight and improves the heat dissipation characteristics and actuation responsiveness. An in-line arrangement was adopted in order to retain commonality to the base MT vehicle for the two clutches and to equalize the inertia moment of the two clutches (Fig. 4). The system does not have a clutch exclusively for starting; the #1 clutch with odd-numbered gears is used as a starting clutch. Since the #1 clutch used for starting has more heat generated than the #2 clutch, the clutch plate thickness is thicker to raise its heating capacity.

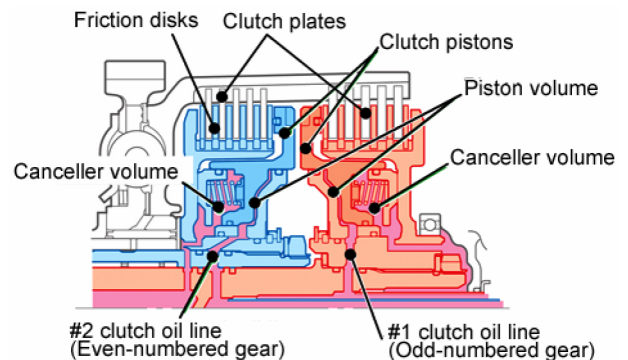


Fig. 4. Structure of Dual Clutch

TRANSMISSION AND GEAR SHIFT MECHANISM

A structural drawing of the transmission and gear shift mechanism is shown in Fig. 5. The transmission for the MT vehicle is set with close ratios on the 1st to 3rd gears to reduce gear shift noise from dog engagement during shifts. The basic construction of the gear shift mechanism for the MT vehicle was carried over to this system but in order to automate the gear shift motion performed by the rider's foot in the MT vehicle, the shift pedal was eliminated and an electrically powered motor and gear train were added. The dog transmission construction that actuates the drivable gear when moving the shift fork left/right by turning the shift drums is the same as the MT vehicle except that an angle sensor to detect drum phase was added. The shift drum has 12 positions (Table 2) and the non-driven side is put in standby during driving to improve fuel economy and reduce the differences in UP/DOWN shift speeds.