

Development of a New Wet Dual Clutch Transmission Transmission and Driveline

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ABSTRACT

To meet the requirements of low fuel consumption, good driving performance, vehicle packaging constraint, and manufacturing feasibility, a new wet dual clutch transmission family has been developed by SAIC Motor. This paper will provide a design overview of the transmission architecture, main characteristics, key subsystems and control strategies. The paper will also provide an overview of the development process, and the fuel economy benefit to the vehicle.

The transmission family adopts compact layout of gears and shafts, wet dual clutch, hydraulic system for actuation of clutch and forks, integrated parking system, integrated fork and synchronizer system, etc. To achieve compact package target, a coaxial dual clutch with integrated damper system, two countershafts system, and optimized layout of gear system are adopted. The technical features for low fuel consumption include waved clutch plates, targeted cooling of wet clutch, optimized gear ratios, optimized control strategies. The technical features for high driving performance include optimized control on clutch pre-filling and clutch swap, close loop control on gear engagement, optimized control on different driving mode.

The newly developed 6-speed dual clutch transmission was applied to the new ROEWE550 vehicle equipped with 1.8L turbo and 1.8L natural aspirated gasoline engines. The vehicle was launched to China market in the middle of 2013. The newly developed wet DCT improves not only vehicle dynamic performance, but also fuel economy, with above 5% acceleration improvement and above 8% fuel consumption reduction.

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INTRODUCTION

The growth rate of automatic transmissions in China is faster than it is globally as they become increasingly popular with consumers. As this trend continues, production of automatic transmissions in China is expected to grow rapidly over the next 5 to 10 years. Considering requirement on the reduction of fuel consumption which is shown as [Figure 1](#), performance and driving comfort, flexibility of available gear ratios and ratio spreads, capability of high torque application, compatibility of stop-start and hybrid function, and manufacturing basis, a significant portion of the locally produced automatic

transmission volume in China could be DCTs. From a global perspective, DCT has grown rapid especially in Europe and China market, DCT technologies have been described in the literature [[1](#), [2](#), [3](#), [4](#), [5](#)].

SAIC Motor started the development of the advanced 6-speed wet dual clutch transmission with an input torque range of 360Nm from 2007, which was in mass production in May of 2013. The first application of the DCT as shown in [Figure 2](#) is the new ROEWE550 passenger vehicle as shown in [Figure 3](#).

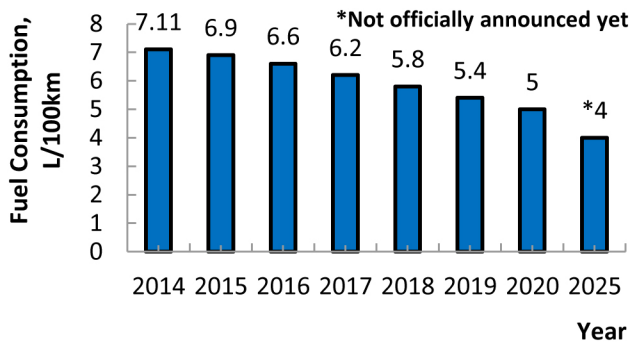


Figure 1. China's target of Corporate Average Fuel Consumption

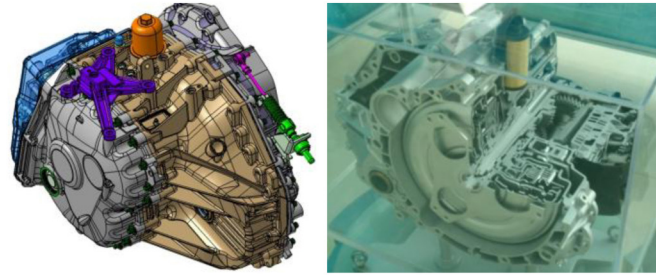


Figure 2. SAIC's new wet DCT



Figure 3. SAIC's new ROEWE550

The series of the wet DCTs will also be used for new large car platform and SUV platform. In addition to the strategic and market drivers, the wet DCT architecture is good solution to meet key program targets, as listed in the [Table 1](#).

Table 1. Program targets and design direction

Program Targets	Design Direction
Automatic transmission with high class shift comfort	Wet DCT for superior controllability over wide operating range
Improved fuel efficiency compared to Planetary AT	Dual clutch module with waved friction plates to minimize open-pack drag
Stop-start compatibility	DCT is compatible with stop-start without auxiliary electric pumps or charging devices
Competitive overall length for package capability	Innovative gearbox layout with maximum gear sharing Concentric dual-clutch module design
Multiple engine and vehicle applications	Layout design for maximum ratio flexibility Wet DCT for thermal robustness and low inertia
Minimum Weight	DCT has high specific torque capacity

The [Figure 4](#) below shows measured results of the first vehicle application, comparing both acceleration and fuel consumption.

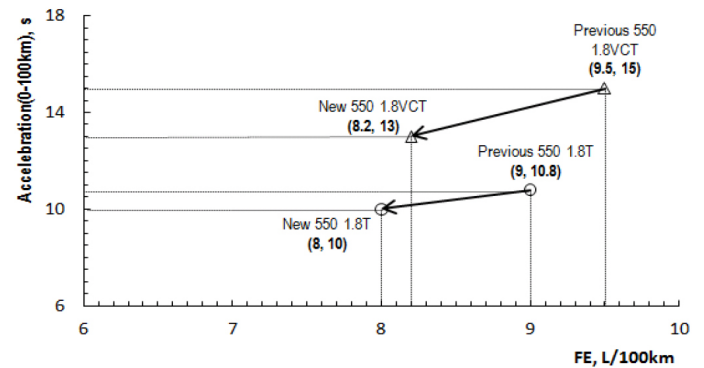


Figure 4. The comparison of vehicle performance

Regarding fuel consumption, the results include Start-Stop function contribution which is around 3% and DCT contribution which is above 8%. These results show the program targets of increased performance, while also delivering significant gains fuel economy, have been achieved.

TRANSMISSION KEY FEATURES

The first SAIC wet DCT is a 6-speed transverse dual-clutch transmission for front-wheel-drive passenger vehicle applications with key parameters as [table 2](#).

Table 2. Key parameters

Overall Length (mm)	353
Total Mass (kg)	88 (including TVD & oil)
Maximum Torque (Nm)	360
Forward Speeds	6
Shafts	3+R idler
Center Distance (mm)	197
Maximum input speed (rpm)	6800
Maximum efficiency	94%

3-shaft layout with concentric inputs and multiple gear sharing, off-axis gear driven pump, and multiple cone synchronizers are adopted as [Figure 5](#) and [Figure 6](#).

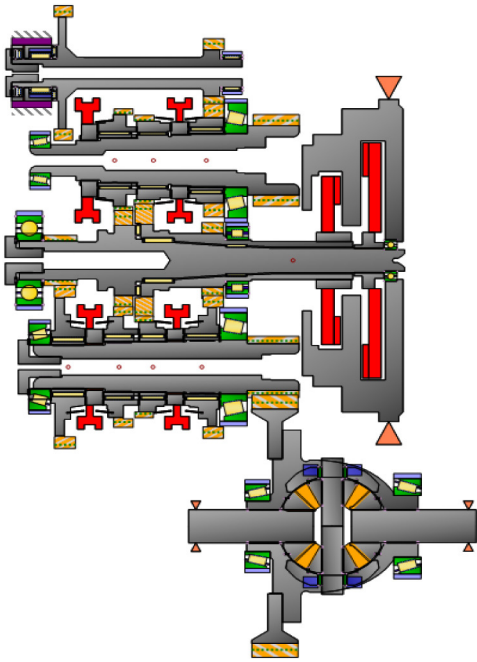


Figure 5. Overall layout

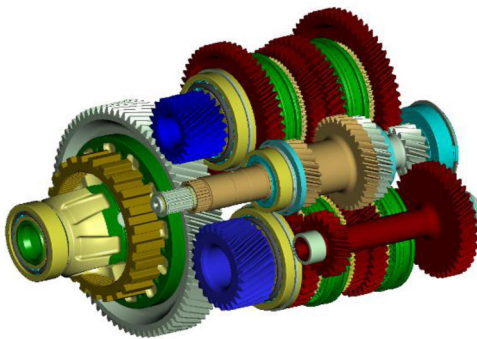


Figure 6. Structure of gear and shaft system

The overall structures including gear system, housing system, clutch system, hydraulic system, electrical system, parking system, filter system, shift system and differential system are shown by the exploded view as [Figure 7](#).

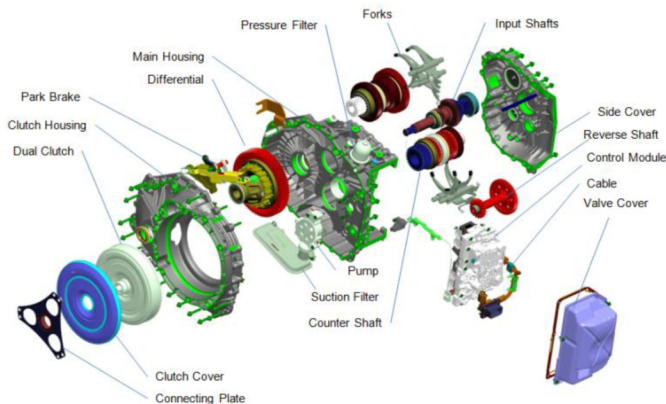


Figure 7. Overall exploded view

Wet dual clutch module is a concentric design with an integrated torsional vibration damper. This configuration represents best-in-class torque density and package efficiency. Hydraulic control module is a compact, self-contained control body with integrated gear actuation, proportional actuation control, proportional clutch control, lube flow control, line pressure control, and cooler pressure protection. See as [Figure 8](#) and [Figure 9](#).

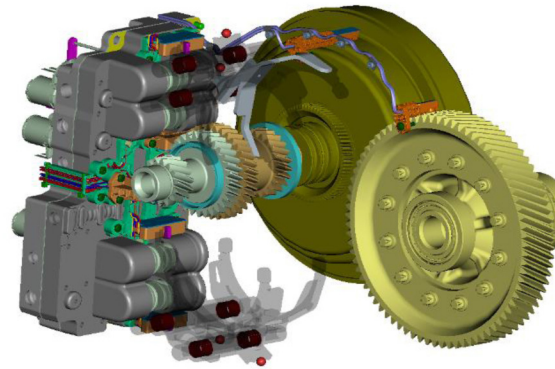


Figure 8. System layout of wet clutch and control module

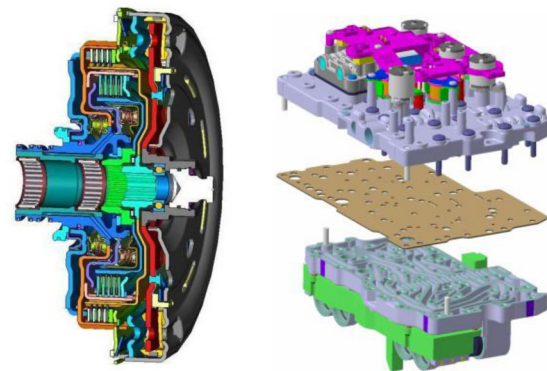


Figure 9. Structure of wet dual clutch and hydraulic control module

There is a plate connecting the flywheel and the damper which is integrated together with the dual clutch. [Figure 10](#) shows the power flow when outer clutch is engaged. Outer clutch controls the inner shaft and inner clutch controls the outer shaft. To achieve lower drag torque, the waved clutch plates have been used.

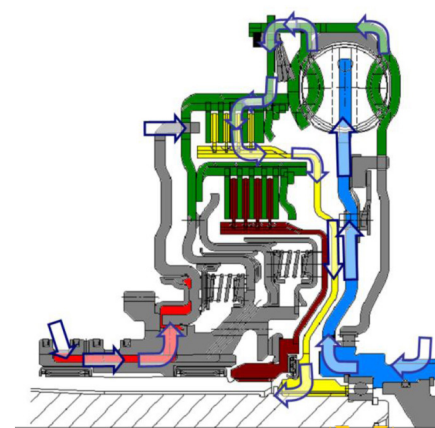


Figure 10. Schematic diagram of the clutch/damper power flow

There are 2 level of filtering before the oil entering inside to control clutch and fork which makes the system has better capability to avoid contamination issues. See as [Figure 11](#).

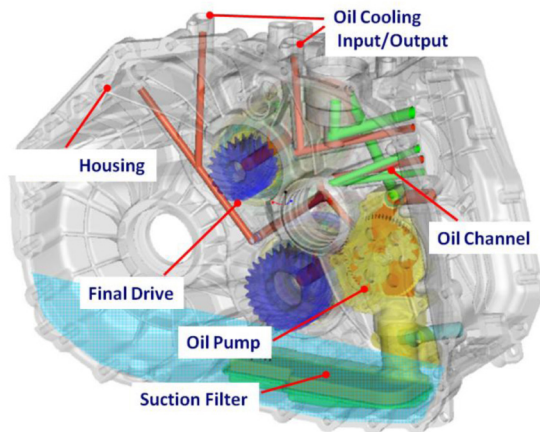


Figure 11. Oil filtering and oil cooling

The schematic diagram of electrical system is shown as [Figure 12](#). The stand alone TCU has been adopted for low cost and high reliability. TCU monitors sensors including 4 rotational speed sensors, 2 pressure sensors, 3 temperature sensors, and 4 fork position sensors and controls 2 On-off Solenoids, 4 Variable Bleeding Solenoids and 2 Variable Force Solenoids. The overall system ensures the effectively real-time control with high accuracy.

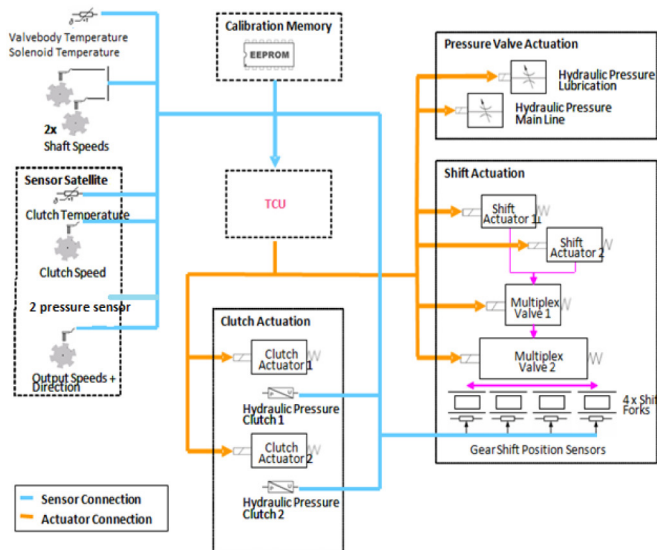


Figure 12. Schematic diagram of electrical system

The locations of some sensors are shown as [Figure 13](#). The integrated satellite sensor includes 1 clutch speed, 1 output speed and 1 clutch temperature sensor. The integrated sensor plate includes 2 shaft speed sensors, 4 position sensors and 1 valve body oil temperature sensor. The electromagnetic compatibility has been detailed considered during design phase and has been fully verified.

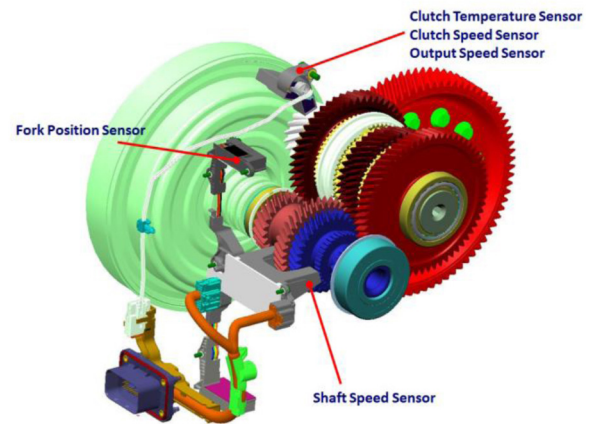


Figure 13. Installation location of sensors

Passenger compartment mounted TCU as [Figure 14](#) is installed with high future 32 bit CPU, high accuracy current control drivers, independent power supplier to ensure transmission high safety level functions, and SubRom interface to enable transmission parameters storage.

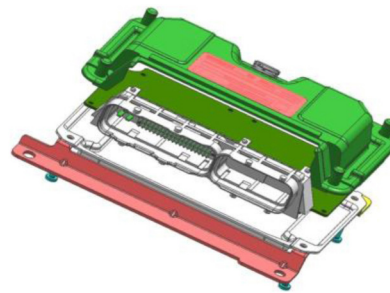


Figure 14. Transmission control unit

DEVELOPMENT PROCESS

To ensure the success of the program, SAIC global power-train development process was used which include eight gateways for program checking. A comprehensive development program was planned using the latest processes and tools, which was grouped into four main categories: requirements development, mechanical system design, electrical controls development, and design verification and validation. The [table 3](#) as below lists some of the key processes employed by the team in the development process.

Regarding hardware development, the process is followed up as [Figure 15](#), which includes design, virtual validation, bench validation and vehicle validation, in several phases.

Regarding software development, mature process was adopted as [Figure 16](#). At the phase of modeling, according to the external and internal requirement, the model is built and function is developed. Secondly, function prototyping is established and prototyping-calibration is done. After that, TCU code is implemented. And then TCU is tested. Finally, on-board calibration with tested TCU is done. Also, sometimes after the phase of prototyping calibration, on-board calibration is done.