

IHS Automotive

Sectoral Report

SupplierBusiness

The Automotive Transmissions Report

2014 edition

supplierbusiness.com



Contents

Introduction	6
Forces driving mainstream transmission changes	9
Transmission development drivers	11
Transmission efficiency gains	12
Greenhouse gas emissions and fuel efficiency	15
The European Union	15
The United States	17
Japan	18
China	18
Other countries	18
Testing regimes	19
The influence of engine development on transmission development	21
Product differentiation	22
Investment and installed capacity	23
Key influences on technology development	24
Packaging and weight	24
Safety regulations	26
Performance characteristics	26
Noise Vibration Harshness (NVH)	27
Ratio spread	28
Transmission costs	29
Transmissions technology	31
Manual Transmissions (MTs)	32
Automated manual transmissions (AMTs)	35
Dual clutch automated manual transmissions (DCT)	39
DCT Suppliers	39
DCT introduction	49
Commonality of componentry	52
Dry clutch or wet clutch?	53
Electro-hydraulic or electro-mechanical actuation?	54
Planetary automatic transmissions	56
Automatic transmissions gear set configurations	58
Torque converters	59
Six-speed automatic transmissions	61
Seven-speed automatic transmissions	63
Eight-speed transmissions	65
Nine-speed and ten-speed transmissions	67
Global AT production mix forecast by number of ratios	70
Manual override systems on ATs	71

IHS™ Automotive

SupplierBusiness

COPYRIGHT NOTICE AND LEGAL DISCLAIMER

© 2014 IHS. No portion of this report may be reproduced, reused, or otherwise distributed in any form without prior written consent, with the exception of any internal client distribution as may be permitted in the license agreement between client and IHS. Content reproduced or redistributed with IHS permission must display IHS legal notices and attributions of authorship. The information contained herein is from sources considered reliable but its accuracy and completeness are not warranted, nor are the opinions and analyses which are based upon it, and to the extent permitted by law, IHS shall not be liable for any errors or omissions or any loss, damage or expense incurred by reliance on information or any statement contained herein. For more information, please contact IHS at customercare@ihs.com, +1 800 IHS CARE (from North American locations), or +44 (0) 1344 328 300 (from outside North America). All products, company names or other marks appearing in this publication are the trademarks and property of IHS or their respective owners.



Continuously variable transmissions (CVT)	72
Market considerations	76
Next generation optimised CVT technology	79
Other transmission technologies	81
Infinitely variable transmissions (IVT) or toroidal transmissions	81
Transmissions and electrification	84
CVT hybrid transmissions	86
Planetary automatic hybrid transmissions	87
AMT hybrid transmissions	88
DCT hybrid transmissions	88
EV transmissions	89
Clutch development	94
Clutch friction materials	95
Clutch-by-wire	97
Market development	100
Global transmissions manufacturing	100
Design source	102
Supplier Profiles	104
Aichi Machine Industry	104
BorgWarner	106
Getrag	122
GKN	125
JATCO	147
Kongsberg	150
Oerlikon	154
Torotrak	171
Univance	174
Valeo	176

Figures

Figure 1: Sensor proliferation and driveline complexity	7
Figure 2: Changing industry drivers from an OEM perspective	9
Figure 3: Changes in transmission attributes CVT, DCT, AT	13
Figure 4: Market growth in AT types	13
Figure 5: Relative fuel consumption and loss sources	14
Figure 6: Global CO₂ (g/km) progress normalised to NEDC test cycle	15
Figure 7: The effect of alternative German proposals for CO₂ reduction regulation for Europe	16
Figure 8: CO₂ (g/km) performance and standards in the EU new cars 1994–2011	16
Figure 9: Additional costs entailed by tougher European CO₂ legislation for a vehicle with emissions of 161g per km	17
Figure 10: Comparison of different test regimes for EU, US and Japan	19
Figure 11: Launch response comparison of AT and DCT with turbocharging	21
Figure 12: Engine design trends 2011–2020	22
Figure 13: Changes in average engine displacement and power density 2011–2020	22
Figure 14: Regional and global vehicle segment trends 2011–2020	24
Figure 15: Regional and global vehicle cylinder count trends 2011–2020	24

Figure 16: Engine and AMT package in Volkswagen's compact up! model	25
Figure 17: Influence of engine trends on transmission driveline NHV	28
Figure 18: Consumer add-on transmissions prices	29
Figure 19: Willingness to pay extra for AMTs, CVTs and DCTs	30
Figure 20: Global MT production by number of forward speeds, 2012–2017	31
Figure 21: European transmission installations.....	32
Figure 22: North American transmission installation market	33
Figure 23: Chinese transmission installations	33
Figure 24: Japan/ Korea transmission installations	34
Figure 25: Global MT production proportions 2012–2017	35
Figure 26: Oerlikon Graziano's innovative 7-speed AMT	37
Figure 27: Global AMT production, 2012–2017	38
Figure 28: A 3 dimensional model of FEV's 7-xDCT gearset.....	40
Figure 29: FEV's 10-xDCT overview	40
Figure 30: The FTP C635 transmissions family in MT and DCT form.....	41
Figure 31: Fiat Powertrain Technologies transmissions portfolio 2014.....	42
Figure 32: Getrag's FWD DCT product roadmap.....	43
Figure 33: Getrag's product development strategy.....	44
Figure 34: Getrag's 6DCT250 DCT with dry clutch.....	45
Figure 35: Getrag's FWD DCT family based on 7DCT300	45
Figure 36: LuK dry and wet double clutch assemblies for DCTs	46
Figure 37: ZF's 7DT multi-plate wet clutch DCT.....	48
Figure 38: ZF's Traxon modular heavy duty transmission.....	49
Figure 39: Global DCT production, 2012–2017	50
Figure 40: DCT hardware comparison conventional vs one-way clutch design.....	52
Figure 41: BorgWarner FWD Power Split transmission architecture	52
Figure 42: Electromechanical gear actuation Getrag's 7DCT300	54
Figure 43: AT and DCT ratio production trend, 2012–2020.....	56
Figure 44: Relative CO2 output improvements for AT together with powertrain electrification	58
Figure 45: Hydrodynamically cooled clutch	60
Figure 46: Bosch Mechatronic Control Module.....	61
Figure 47: GM's 6T70 6-speed AT developed in collaboration with Ford.....	62
Figure 48: Average percentage fuel economy improvement for 7G-Tronic Plus (NEDC).....	64
Figure 49: Mercedes-Benz 7G-Tronic Plus automatic transmission.....	64
Figure 50: ZF's 8HP AT	65
Figure 51: A schematic of ZF's hydraulic impulse storage system	66
Figure 52: ZF 9HP.....	67
Figure 53: GM Ford collaboration 9-speed AT	68
Figure 54: Mercedes-Benz 9G-Tronic AT	69
Figure 55: 7G-Tronic gear set	69
Figure 56: Ratio proportions 2012–2017.....	70
Figure 57: Tiptronic shifter on a 2003 Porsche 911.....	71
Figure 58: Audi-LuK MultiTronic link-plate chain	72
Figure 59: Jatco's next-generation CVT, the first to apply an auxiliary gearbox.....	73
Figure 60: A Fixed Pitch Continuously Variable Transmission (FPCVT) assembly with two FPCVT units connected in series.....	74
Figure 61: Honda's CR-Z CVT	75
Figure 62: CVT production, 2012–2017	77
Figure 63: Jatco's CVT7	77
Figure 64: CVT production by region 2012–2017.....	78
Figure 65: Key technologies in improving CVT performance.....	79
Figure 66: Partial (left) and full (right) toroidal spaces within an IVT	81
Figure 67: Torotrak IVT variator	81
Figure 68: Torotrak's Flybrid flywheel and IVT system	82

Figure 69: Progressive drivetrain electrification	84
Figure 70: Additional functionality requires higher voltages – 48 volts	85
Figure 71: Toyota's Synergy hybrid Drive (SHD)	86
Figure 72: ZF's 8HP hybrid transmission	87
Figure 73: IAV's 7H-DCT280 hybrid transmission	89
Figure 74: Representation of a full sequence of a shift event using Oerlikon Graziano's eDCT	90
Figure 75: BorgWarner's 31-03 eGearDrive single speed transmission	91
Figure 76: Getrag's 2eDCT600 EV transmission	91
Figure 77: Wrightspeed GTD	92
Figure 78: Xtrac transmission for the Rolls-Royce 102EX	93
Figure 79: Comparison of baseline and forced dry-clutch cooling on traffic jam driving	94
Figure 80: Controlled cooling simulation during full-throttle launch	95
Figure 81: ZF's hydrodynamically cooled clutch	96
Figure 82: LuK's dry double clutch unit	98
Figure 83: Global transmissions production by region, 2012–2017	100
Figure 84: Global transmissions design source by region, 2014	101
Figure 85: Global transmissions design source by region, 2021	101

Tables

Table 1: Relating sector drivers to technical requirements	7
Table 2: Range of fuel consumption reduction potential, 2015–2020, for powertrain technologies	11
Table 3: Comparison of fuel economy regulations	11
Table 4: Transmission value contribution by technology	29
Table 5: Dry versus wet DCT performance	53
Table 6: Getrag's FWD DCT family showing hybridisation options	88
Table 7: Top 20 transmissions manufacturers 2012 and 2020	102

The General Motors Easytronic system was developed in collaboration with LuK and, in an attempt to improve shift quality the clutch release travel was set so that the clutch was engaged only sufficiently to transmit the amount of torque being delivered at the time in order to reduce the interruption time. Mitsubishi, on the other hand, used a drum-operated shifting system on the Allshift similar to that used in motorcycle transmissions, so that the synchromesh of the next gear is engaged as that of the other gear is being disengaged.

The optimisation of shift strategies can increasingly make up for the torque interrupt shortfalls of the AMT and reduce this to a minimum through intelligent gear change actuation. Sensors, as illustrated in Error! Reference source not found., can be used to relay a complex matrix of information to the control system, and using relevant algorithms the system calculates optimum shift points and controls the clutch and shift points automatically. Today this technology can also be used to enhance safety by briefly interrupting torque in order to counter the risk of skidding.

However, despite the technological progress made and the potential for both fuel and cost efficiency, AMTs have continued to suffer from poor or inconsistent shift quality under all driving conditions compared with ATs and DCTs. While there have been several technological attempts to rectify this, some of which have been mentioned above, the single-clutch AMT has never really been accepted by consumers apart from in low-cost A and B segment cars in which shift quality has been less of an issue.

There has been a wide range of exercises designed to benchmark AMTs against both MTs and DCTs because, despite shortcomings the overall concept is highly attractive:

Theoretically AMTs have advantages over MTs, DCTs and ATs:

- Optimising shift strategies minimises fuel consumption more successfully than MTs;
- Similarly the optimisation of shift management can minimise emissions compared to MTs;
- AMTs are favourably priced in comparison to both ATs and DCTs, and in fact can be very competitive against MTs where suitable modularisation and scale economies can be used together with existing installed capacity for MTs;
- AMTs generally enjoy packaging advantages over ATs and DCTs;
- On-vehicle weight is usually round 20% lower for AMTs over DCTs, which usually amounts to some 40Kg;
- The AMT can be around 4% more fuel-efficient than a wet clutch DCT.

This means that there is considerable motivation for AMTs to be developed that can boast a higher shift quality, the single real impediment to their widespread use.

To this end electrification has begun to provide the solution, using an electric machine to infill torque during the gearshift. In addition, this development solution lends itself well to progressive hybridisation solutions.

Oerlikon Graziano and Vocis Driveline Controls, its part owned UK partner, have developed an innovative 7-speed automated manual transmission (AMT) that combines the dual-clutch principle of a DCT with the lightweight and compactness that is possible with an AMT when no manual option is required.

Designed for application in the new Lamborghini Aventador, the 79kg gearbox is substantially lighter than its predecessor yet provides an extra ratio, handles more torque and maximises cabin space by packaging into an exceptionally narrow transmission tunnel.

The new, 6.5 litre Lamborghini engine delivers 700 bhp (515 kW) at 8,250 rpm and 509 lb ft (690 Nm) at 5,500 rpm, which would normally require a substantial transmission. A conventional AMT, with external control systems, would not fit the available space; neither would a DCT, which would require bulky wet clutches to meet the power handling requirements.

An AMT uses the established “H” pattern gearshift of a manual gearbox, in which the various gears are selected by sliding

Dual clutch automated manual transmissions (DCT)

The DCT is now making serious inroads into the transmissions market, particularly in Europe and IHS forecasts that they will make up around 8% of global production by 2017 or 7.5 million units, up from 5% in 2013 (4 million units).

The underlying advantages of DCT as a transmission technology have proved compelling in recent years, particularly as wet-clutch DCTs have proved to have shift quality as good as that of a planetary AT. They are also as easy to drive while providing a more responsive drive for sporting applications. DCTs are more economical than a six-speed MT and hence can make a useful contribution to CO2 reduction across the full range of vehicle segments, with feature content adjustable through electronic control mechanisms, particularly the capacity to ensure that the engine is kept within its most efficient operating range.

Historically the DCT was developed to deal with the torque interruption and shift quality issues associated with automating manual transmissions with a single clutch set. This was achieved using two clutches configured so that one is always engaged. However, due to the design challenges encountered when developing DCTs, the underlying relationship between MT and DCT design and production was quickly diluted and negated as an underlying development driver.

DCTs can be considered as two AMTs in parallel (one with first, third, fifth, seventh where fitted and reverse gears, the other with second, fourth and sixth gears) with the next gear pre-selected and ready to be engaged in the inactive part of the gearbox before the torque is moved from one clutch to the other without torque interruption. The electronic control system can also be used to fill the 'torque hole' during the shift by increasing engine torque output momentarily, a feature that Ford promotes on its Getrag-developed 'PowerShift' DCT. The driver can only just feel this torque handover and the shift characteristic is similar to a traditional AT.

A DCT can be operated in fully automatic mode, typically with the options of 'drive' automatic or 'sport' automatic settings, or in 'manual' via a shift lever or steering wheel-mounted paddles that enable sequential shifting. In the 'drive' automatic mode, the engine is kept in its more fuel-efficient operating range while in 'sport' mode the shift points are at higher engine speeds. The technology is also easily suited to stop-start technology, since the transmission is typically designed to shift to neutral when the vehicle is stationary in order to be ready for launch in first gear and to minimise oil churning losses.

Both dry and multi-plate wet clutch systems have been employed, typically in a concentric arrangement, although BorgWarner's low-cost DT170 unit has two separate clutches mounted on the two separate gear shafts and linked by a chain.

DCT Suppliers

BorgWarner

BorgWarner, and is the leading global supplier of wet dual clutch and electro-hydraulic control modules. The company has been producing for the Volkswagen Group since 2003 (re-branded Direct Shift Gearbox (DSG) transmissions) and they are a major supplier of DCT components to a number of other European OEMs.

In 2009 the company established a joint-venture with the China Automobile Development United Investment Co. (CDUI), which is owned by 12 Chinese OEMs. This joint-venture is known as the BorgWarner United Transmission Systems Co., Ltd., and is located in Dalian, China. The company has produced various dual-clutch transmission modules beginning in 2011. The JV will manufacture and develop core modules for the DCT assembly including dual clutch modules, torsional vibration dampers and control modules.