UTIMATE
TRANSMISSIONS

The Most Durable Automated Transmission

Contents

Overview

Because the DFTV based IVT can be so compact and light weight when durability is important the transmission size can be increased so that durability is increased.

The durability of the various transmission components in any form of transmission are very dependent on the quality of the fluid used in the transmission and the ability to keep the fluid clean and the ability to keep the fluids cool.

The Traction fluids used in CVT's are some of the best available and the inherent efficiency ensures the fluid is not thermally stressed. The filter system and oil circulation in a CVT ensures the fluid is kept exceptionally clean. Typical CVT's require oil changes at around more than 200,000 kms.

The friction clutches in a non IVT transmission are subject to high contact speeds as the transmission steps through the required ratios. High speeds create wear within the clutch plates and are a source of pollution of the lubricants.

In an IVT transmission the contact speeds of the clutch plates is always low as there are no steps and no launching process requiring plates to slip over each other at high speed.

The durability of the CVT components is critical to the overall durability of a transmission using a CVT.

Nissan Experience

The Nissan NSK transmissions that were introduced into the first cars in 2000 have proven their durability performance in real automobile applications. Ultimate Transmissions research has revealed very few transmission failures in under 200,000 kms. The failures that did occur were almost always associated with the use of the wrong traction fluid. Of the rest, it was common for the thrust bearings not the discs and rollers to fail.

The design life of an NSK CVT was 400,000 kms. The calculations made to ensure this design life were based on conventional bearing life calculations taking into account the fact that exceptionally pure steel as being used, and typical passenger vehicle duty cycles.

Torotrak Experience

Torotrak state* that they base the CVT life on 380 million cycles at 2.1 GPa for calculating design life. This equates to a maximum contact stress of 3.15GPa. When a Torotrak variator is operating in low gear at maximum input torque the maximum design stress under the (inner) contact point is 4.2GPa.

Nissan/NSK limit their maximum stress to 3.95 GPa or a Mean stress of 2.63GPa.

A more recent Torotrak paper expresses the following view of roller and disc durability.

The most recent development is the results from extended testing at lower contact stresses in the area of ~ 2.0GPa mean Hertzian contact stress. Here, a number of test results have been produced with fatigue life extending well beyond the 12th power prediction. This leads to the potential for extended (if not potentially infinite) life of the variator below a contact stress threshold – see figure 14.

The impact is extended durability and, in conjunction with powersplit transmission architectures, further downsizing of the variator and hence transmission.

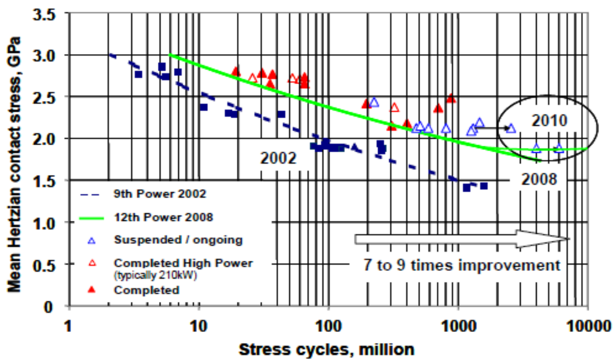


Fig. 14. S-N curves from fatigue tests

It can be seen from this diagram that most of the duty is associated with very low wheel torque and low speed. In this condition Ultimate Transmission estimates the Mean contact stresses as being less than 1GPa. In this condition a life exceeding 3,800 million cycles is expected. At 40 kms/hr. this equates to over 1,500,000 kms.

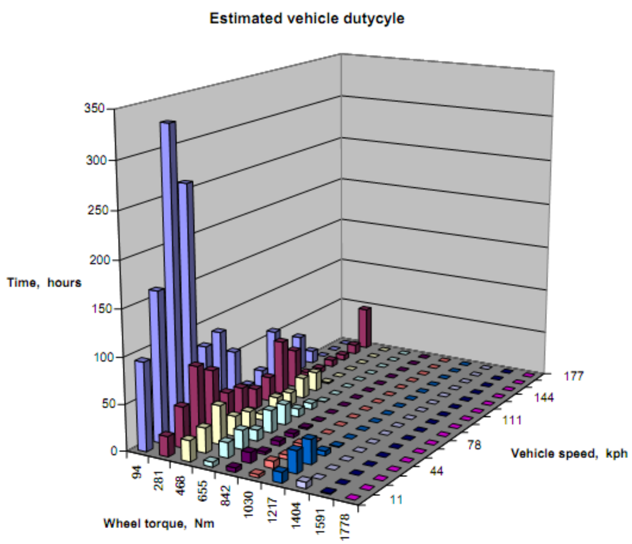


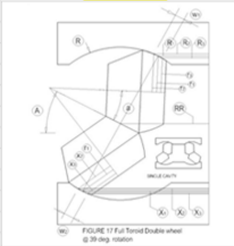
Figure 9 – Small front Wheel Drive Car Duty Cycle 160,000 kms.

* Extract from paper presented by Torotrak (Development) Ltd. Jtekt Corp & Shell Global Solutions to the JSME International Conference on Motion and Power Transmissions May 13-14, 2009 Matsushima Resort Japan entitled " FULLOTOROIDAL TRACTION DRIVE HIGH TEMPERATURE DURABILITY" By Dr Adrian Lee, Dr Andrew Hillsden, Yoshihiro Ono and Dr Stephen Evans.

Figure 9. Extract from Paper by Torotrak (Development) Ltd."Full Toroidal Traction Drives for Front Wheel Drive Applications" by Chris Brockbank & Dave Burtt 2006

DFTV Durability

Ultimate Transmission's designs for the DFTV variator limit the maximum Hertzian stresses to 3.95GPa (Mean 2,63GPa) which is more in line with the NSK limits.



CALCULATION OF SPIN LOSSES MAXIMUM INPUT TORQUE AND MECHANICAL VOLUME FOR TORQUE CONTROLLED VARIATOR DOUBLE ROLLER																		
The following model can be used to calculate 1) the maximum spin losses, 2) The maximum ratio, 3) Mechanical Volume 4) Maximum input torque. 5) Estimated weight																		
Primrary inputs are shown as						*Secondary inputs from Hertzian contact calculator are shown as*									*Calculated Outputs*			
INPUTS																		
Radius of centre of Toroid						RR	67.07	mm.		INPUT RPM					6000	RPM		
Transverse radius of Toroid						R	50.92	mm.	Width of contact point on input					W1	9.85	mm.		
Wheel inclination						a	21.70	deg	Width of contact point on output					W2	9.36	mm.		
Radius of roller						r1	24.80	mm.		**OUTPUT RPM**					**2,561**	RPM	*0.42675328*	
Primrary rotation angle						A	31.95	deg		**ROLLER RPM**					**9,707**	RPM	25.20	m/sec
Radius of crown of roller							38.70	mm.		**TOTAL RATIO CHANGE**					**5.49**			
Conformity of wheel to cavity							76.00	%	Area of inner contact point						**19.21**	sq.mm		
Length of input contact point						L1	2.48	mm.	Maximum Hertzian Stress						**3.85**	Gpa	check in	check out
Number of wheels							4	rollers	Maximum stress on inner point from Hertzian table						**49,514**	N	49,314	49,695
Number of cavities							1	cavity	Traction coefficient						**0.055**			
Length of output contact point						L2	3.2016		maximum reaction force on roller bearings						5,447	N		
	R1	R2	R3	r1	r2	r3		Sin A	Cos A	Sin a	Cos a	Size factor	Total clamping force		198,058	N		
	40.1211469	44.3014173	35.9408765	24.7986	26.6202	22.9770		0.529179	0.84851021	0.36974676	0.92913257	1.38			stress under output contact			3.17
	X1	X2	X3	r1	x2	x3		Sin A	Cos A	Sin a	Cos a		Overall radius of transmission without actuator					107.07
	94.0148531	97.9843536	90.0453526	24.7986	26.5283	23.0689		0.529179	0.84851021	0.36974676	0.92913257		Overall length of transmission without hydraulics					165.60
													Overall length between outside of discs					122.21
							Speed dif	% loss		Spin for this position			MAXIMUM INPUT TORQUE				spin	
Speed at	R1	1,511,765		r1	1,511,765 mm/minute		0						**437.05**			Nm		
Speed at	R2	1,669,277		r2	1,622,812		46,465	3.07%		**5.83%**								
Speed at	R3	1,354,252		r3	1,400,717		-46,465	3.07%		ESTIMATED MASS			ESTIMATED VOLUME					
										35.05		kg	**7.15**			litres		
Speed at	X1	1,511,765		r1	1,511,765		0			% of SFTV				4.40	Discs and rollers only	litres	torque density	99.340317
Speed at	X2	1,575,595		x2	1,617,213		-41,619	2.75%		**63.82%**			KW					
Speed at	X3	1,447,935		x3	1,406,316		41,619	2.75%					**274.58**					
										SPIN LOSSES								
CALCULATION OF APPARENT RADIUS OF CONTACTING POINTS										Spin loss in "L" position				5.83%		ENERGY LOST TO SPIN		
Angle of inclination of circle of contact of toroidal disc						A	31.95	deg		Spin loss in "LM" position				3.58%		2.23%	factor	0.675
Angle of inclination of circle of contact of roller						a	21.70	deg		Spin loss in "C" position				0.00%		ENERGY LOST TO BEARING		
Radius of input circle of contact on toroidal disc							75.82	mm.		Spin loss in "HM" position				3.19%		0.00%		
Radius of output circle of contact of toroidal disc							-177.66	mm.		Spin loss in "H" position				7.17%		TOTAL LOSS		
Radius of contact of (toroidal) roller surface							26.69	mm.		Average spin loss				**3.30%**		2.23%		
										VOLUME OF OPERATIONAL CAVITIES				4.45	litres			

Extract from Ultimate Transmissions
Excel based Traction performance calculator.

The extended life available from properly designed rolling contacts combined with the limited use of gears and clutches and associated lower parts count all go to verifying the superior life expectations of a DFTV - IVT.

The DFTV - IVT can remain smaller and more efficient than other transmission designs while maintaining greater life expectancy.

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