UTIMATE
TRANSMISSIONS

TRANSMISSIONS 4

The **Most Fuel Efficient Automated Transmission**

Contents

Overview

In order to understand the relative efficiencies of different forms of transmission a carefull study must be made of;

1. The efficency of the transmission itself
2. The overall efficiency of the complete powertrain including the IC engine, clutches and control support hardware.

It is also important to understand that the efficiency of both of these systems varies greatly dependant on the speed and load in the powertrain.

Government regulation now translates efficiency in the case of an automobile into allowable amounts of CO2 that can be released for each Kilowatthour of energy produced .

Torotrak has taken great pains to ensure that powertrain efficiencies and CO2 emmissions are being studied when any comparison is being made between a normal AT and a CVT. The stepless nature of IVT and CVT transmissions always give them a huge overall fuel efficiency advantage.

Torotrak CVT Efficiency

A paper written by Torotrak in 2003 concluded the following;

1. The current IVT using a SFTV CVT classed as a S111 was 84% efficient and that this was quite poor when compared to the efficiency of a 4 speed automatic.
2. The S111 could be “optimized” to deliver 88% efficiency

The combined effect of the optimisation work described above (including contact optimisation) resulted in a transmission efficiency increase of approx. 4 % from 84 % (existing Series III) to 88 % (optimised Series III) as shown in Figure 12. For comparison an automatic transmission with locked torque converter and a constant efficiency of 92 % was assumed [12].

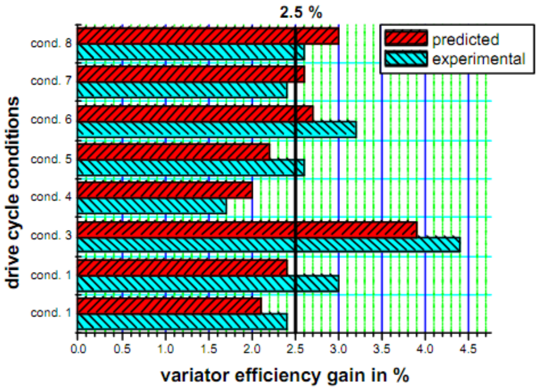


Figure 11: Variator efficiency gains due to variable endload system

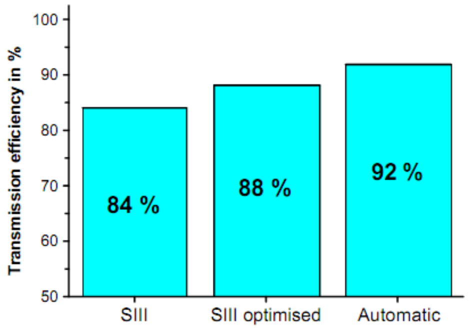
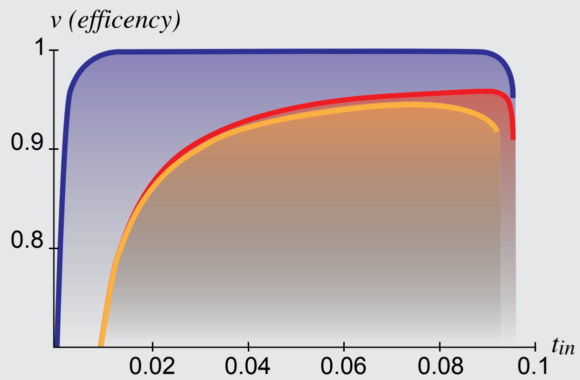


Figure 12: Typical transmission efficiencies (simulation @ 50 mph highway cruising)

Extract from SAE paper 2003-01-0971 “Powertrain Efficiency Optimization of the Torotrak Infinitely variable Transmission (IVT)” Matthew Burke, Graham Briffet, John Fuller, Hubert Heumann & Jonathan Newell.

Ultimate Transmission's DFTV – CVT Efficiency

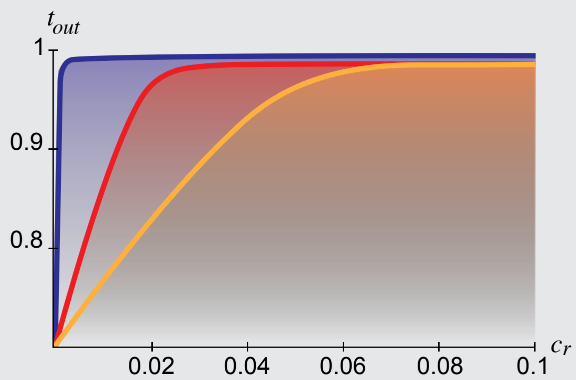
The DFTV exhibits a significant improvement in efficiency over the SFTV and SHTV and almost zero creep when in the 1:1 ratio position. This is despite the existance of three power contacts.



DFTV
SHTV
SFTV

The efficiency vs. the input traction, for the three toroid geometrics.

Calculations are done at a ratio S_{rID}=1 and clamping force F_D = 22kN



DFTV
SHTV
SFTV

The output creep vs. the overall creep for for the three toroid geometrics.

Calculations are done at a ratio S_{rID}=1 and clamping force F_D = 22kN

These graphs depict the DFTV in its most efficient state which occurs over almost 60% of its ratio range. The DFTV exhibits an efficiency improvement over the SFTV of between 6% and 4.5% at all times.

Preliminary results of an indpendant academic study, being undertaken at a leading tribology research centre.

The details of this study can be made available by request.

Torotrak's Fuel Efficiency Estimates

Torotrak identified that even without the "optimization" of the S111 the IVT transmission already delivered greater fuel economy than a 4 speed automatic.

Table 1: Measured fuel economy benefits of Series III IVT compared to 4 AT

Drive cycles	Series III
Metro-Highway (combined cycle)	20 % improvement
EPA FTP75 (city cycle)	23 % improvement
HWFET (highway cycle)	16 % improvement

Further simulation studies have shown that, compared to 5 and 6 speed automatic transmissions, similar absolute and higher relative fuel economy gains can be achieved through system optimisation.

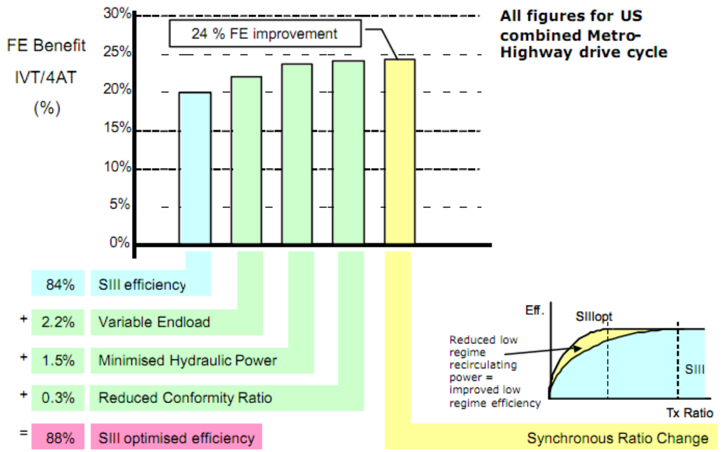


Figure 16: Effect of efficiency improvement on fuel economy (Series III IVT/4AT)

In these papers Torotrak do not state if the Automatic transmissions (5 & 6 speed) compared in these fuel consumption studies included a lock up clutch.

It is believed that they did not and that the results (of fuel savings) for the 5 and 6 speed automatics would not look as good if they included a lock up clutch.

Table 1. Extracts above from SAE paper 2003-01-0971 "Powertrain Efficiency Optimization of the Torotrak Infinitely variable Transmission (IVT)" Matthew Burke, Graham Briffet, John Fuller, Hubert Heumann & Jonathan Newell.

Figure 16. Extracts above from SAE paper 2003-01-0971 "Powertrain Efficiency Optimization of the Torotrak Infinitely variable Transmission (IVT)" Matthew Burke, Graham Briffet, John Fuller, Hubert Heumann & Jonathan Newell.

SFTV & SHTV Efficiency Comparison

Professor Carbone has studied the relative efficiencies of the SHTV and the SFTV and reached this conclusion.

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6. Conclusions

The paper deals with the mechanical efficiency of full and half toroidal traction drives and has the aim of comparing the performances of these two CVT typologies. A fully flooded isothermal model of the contact between discs and rollers, based on the results of EHL theory, has been implemented to evaluate the slip and spin losses. The analysis has shown that by optimizing the roller geometry of the full toroidal variator, it is possible to reduce its spin momentum below the value of the half-toroidal variator. But, since the energy dissipation due to the spin losses is the product of the spin momentum and the spin velocity, the full-toroidal variator always results to have a smaller efficiency because of its much bigger spin velocity. Moreover the full-toroidal traction drive needs higher values of global creep (smaller speed efficiency) to transmit the same torque of the HT traction drive. This causes an additional heating of the lubricant and a further reduction of its traction capability and also of the mechanical efficiency. Moreover, the mechanical efficiency of the half-toroidal CVT, in comparison to that of the full-toroidal variator, is less affected by the value of the normal contact forces and often over the threshold of 90% on the most part of the torque range. The full-toroidal CVT, instead, shows a different behavior, its efficiency varies within a bigger range of values, and it is more affected by the normal load at the contact between the rollers and discs.

NSK have also published a great deal of research on the performance characteristics of the SHTV (Single Roller Half Toroidal Variator).

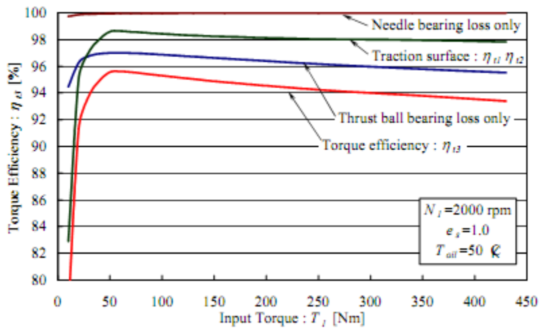


Fig.6 Calculated torque-transmission efficiency of the variator, and portion of torque losses of thrust ball-bearings, needle bearings and spin loss on the traction contact at $e_s = 1$, $N_i = 2000$rpm and $T_{oil} = 50$°C

6 Conclusions ... Extract from a paper "A Comparison of performances of Full and half toroidal traction drives" published in Mechanism and machine theory 39 (2004) 921-942 (Elsevier) Professor G. Carbone, L. Mangialardi, & G. Mantriota - Dipartimento di Ingegneria Meccanica e Gestionale, Politecnico di Bari Italy.

Figure 6. Extract from Paper "Development of a 6 Power – Roller Half – Toroidal CVT – Mechanism and Efficiency – " Hirohisa Tanaka & Nozomi Yoyoda Yokohama National University & Hisashi Machida, & Takashi Imanishi NSK Ltd.

SFTV & SHTV Efficiency Comparison

The SHTV remains more efficient than the SFTV because it matches the surface velocities of the contact points much better. However it must also include the losses of the thrust bearings that support the reaction loads off the rollers. The DFTV also matches the surface velocities but does not require any thrust bearings. As can be seen in this graph the (torque) losses of the thrust bearing are double the losses associated with "spin". There are additional losses associated with creep (predominately the result of "spin") that will amount to an additional 1%.

Further research by NSK identified the significant improvement of the SHTV over the SFTV. It also identified the way in which the efficiency of the SFTV could be manipulated using the crown radius conformity but at the expense of mechanical volume.

The graph below depicts both of these factors and agrees substantially with Carbone's results.

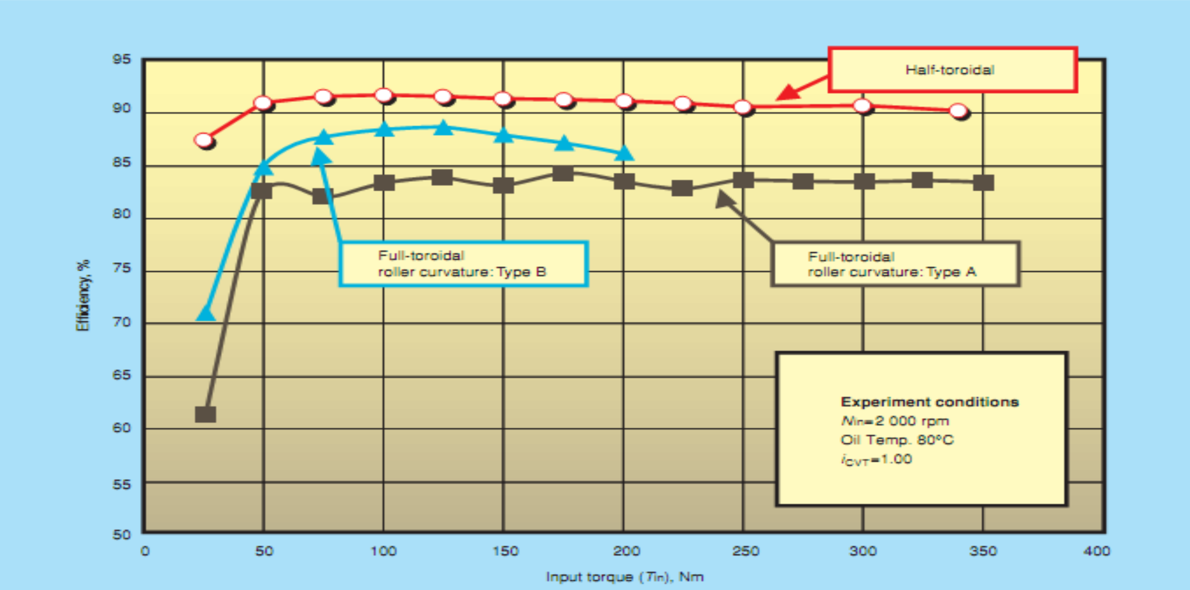
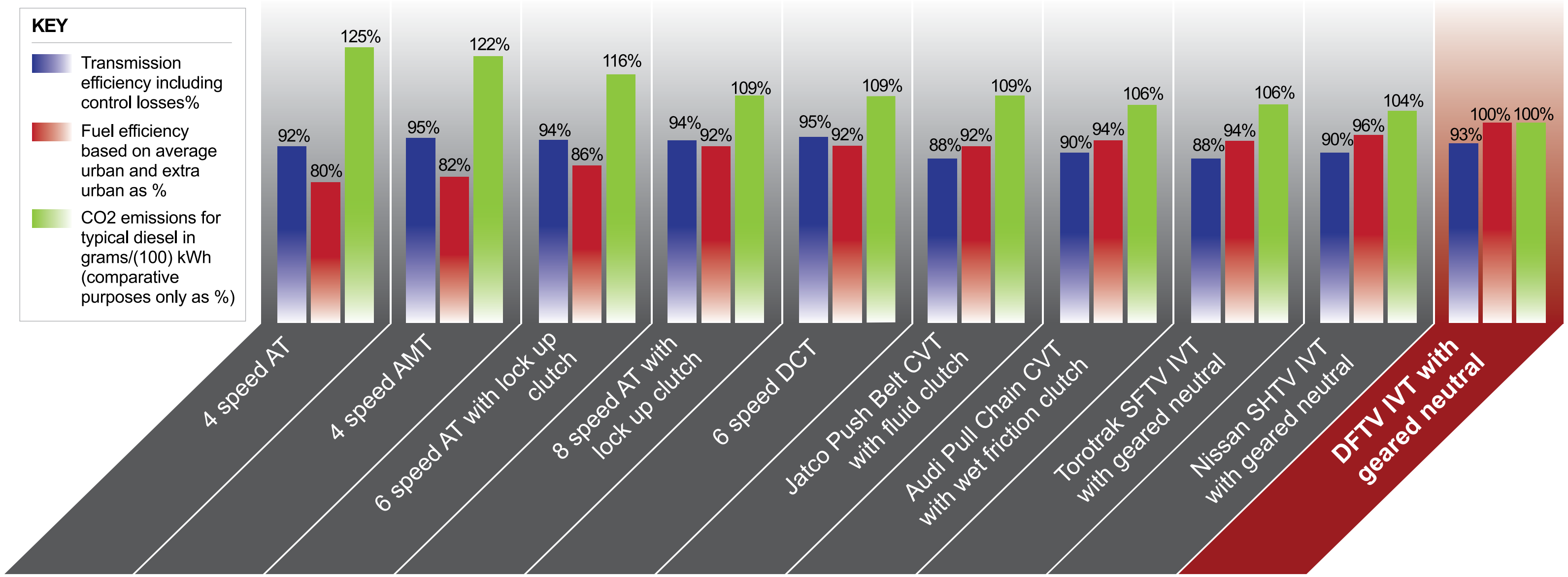


Fig. 9 Efficiency of half-toroidal and full-toroidal CVT

Extract from paper "Development of POWERTOROS Unit Half toroidal CVT – Comparison between Half-Toroidal and Full-Toroidal CVT's" Takashi Imanishi & Hishashi Machida Research and development Centre NSK.

Conclusion

The DFTV based IVT will offer fuel savings exceeding those predicted by Torotrak for its upgraded S111. This will make it much more efficient than all the other forms of transmission including MT AMT and any of the other CVT types of automated transmissions.



The chart above was created from research by Ultimate Transmissions and sets out the relative transmission efficiencies and the expected fuel consumptions and CO2 emissions expectations of the DFTV-IVT compared to other automatic transmission types.

Although the overall Transmission Efficiency of the DFTV based IVT may not be the highest of the group a vehicle fitted with this transmission type will deliver a higher mileage and emit less CO2 because of the advantage imbedded in the step-less ratio changes and direct coupling to the IC engine.

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