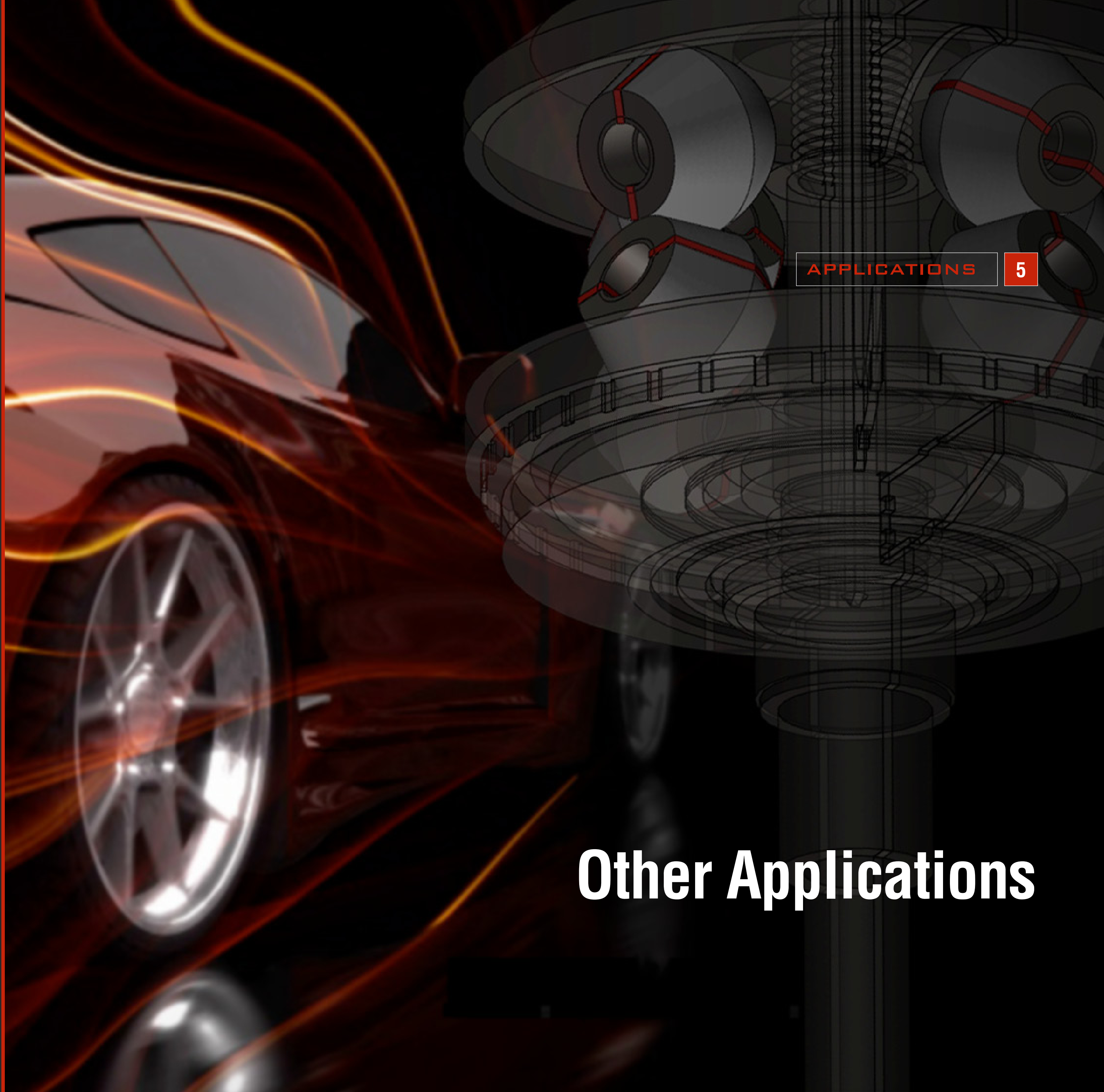
UTIMATE
TRANSMISSIONS



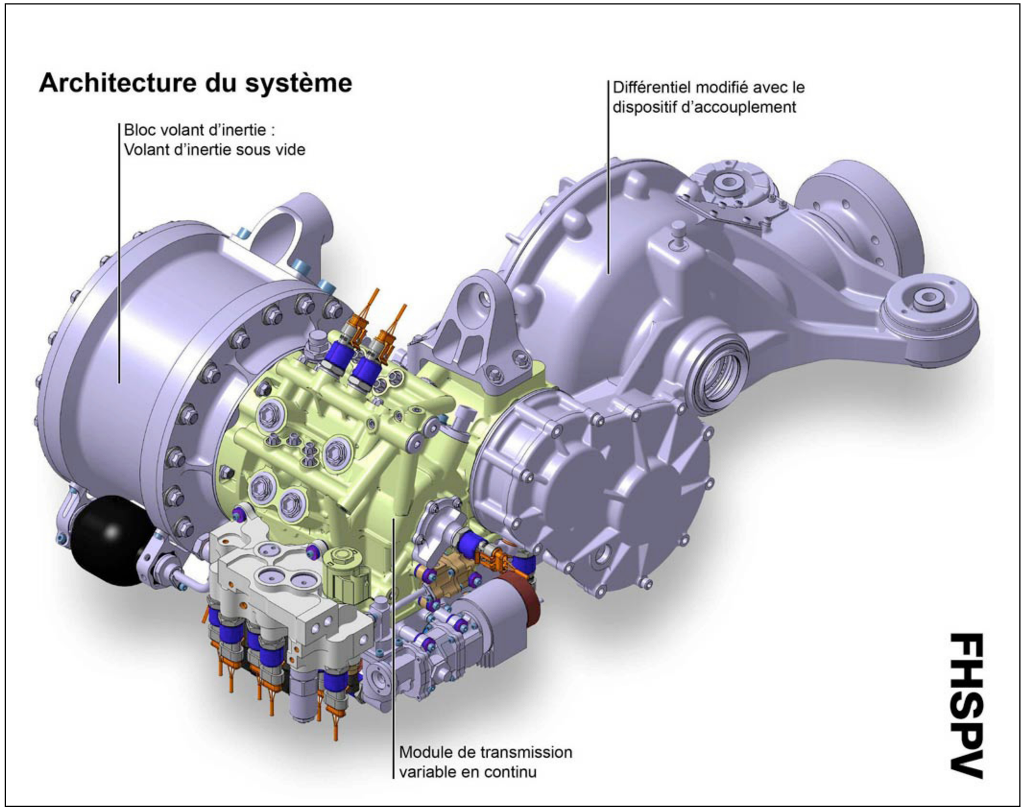


# Other Applications

# Contents

# Accessory Drives

Increasing interest is being generated in KERS or Kenetic Energy Recovery Systems. These have moved beyond a performance enhancing attachment used a few years ago in Formula One racing to full bodied Mechanical Hybrids.






Virtually the only way of coupling the flywheel to the wheels is via a CVT. Torotrak have successfully demonstrated this type of hybrid in a busses and in luxury cars using a SFTV.

For links to youtube showing interview with Torotrak on KERS Hybrid go to:

*http://www.youtube.com/watch?v=4PcIt0FPvWQ&feature=related*

# Accessory Drives

Most accessories such as air-conditioners, turbo chargers, power steering, braking systems etc are driven directly by the IC engine. The engine speeds typically vary from 1,000RPM to 6,000RPM meaning that at times the accessory is spinning too slowly and at times too fast. This wastes energy.

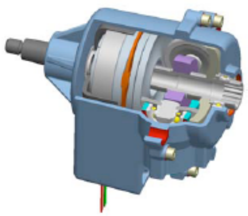
One of the most critical accessories is s turbo charger designed to allow downsizing of the engine. Turbo lag is a fact of life when the engine is starting up from a low speed and negatively affects the drivability of a motor vehicle.

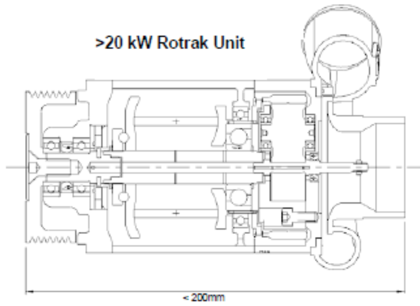
Again one of the only viable ways of overcoming this drawback is to connect the turbo fan via a CVT to the engine with a moderate ratio spread of around 4:1.

Torotrak have formed a joint venture with a leading turbo charger manufacturer to exploit this advantage.

## Cost–effective Variable Supercharger

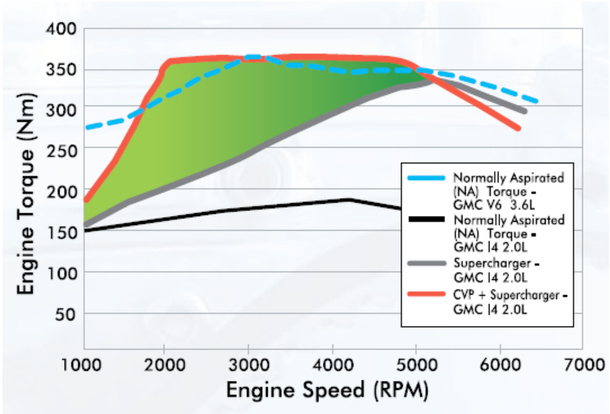
- **Combination of two unique technologies:**
  - Torotrak: compact, variable, toroidal traction drive drive
  - Rotrex: high-speed traction drive centrifugal supercharger
- **Positioned to address downsizing of engines for $CO_2$**
- **Single-stage system**
- **Concept studies show ability to outperform conventional sophisticated pressure-charging solutions**






# Accessory Drives

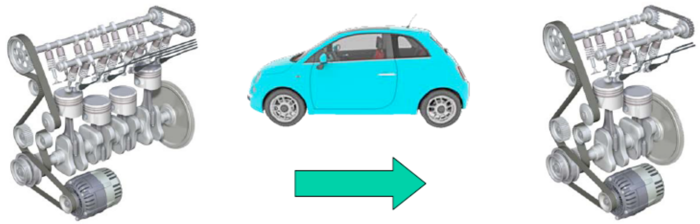
Fallbrook technologies, have proposed this as an application for the NuVinci variator, which also has limitations in overall ratio spread. They claim that using this technique the torque of a 2 litre engine can match and then exceed that of a 3.6 litre engine by the time it has reached 1,600RPM (figure 2).




In a similar analysis Rotrex claim that a 2 cylinder engine can reduce CO2 emissions by 50% without compromising the performance of a normally aspirated 4 cylinder engine.

## Engine Downsizing via Pressure Charging

- Works equally well for small engines



| | 4 cylinder naturally aspirated | | 2 cylinder turbo |
|---|---|---|---|
| Engine | 1.2 L | 1.4 L | 0.875 L |
| Power / Torque | 68ps / 102Nm | 100ps / 131Nm | 85ps / 145Nm |
| 0-60mph | 12.9 s | 10.5 s | 11.0 s |
| Top speed | 99 mph | 112 mph | 107mph |
| $CO_2$ | 119 gm/km | 149 gm/km | 95 gm/km |

ROTRAK supercharging innovation

Source: FIAT

# Electricity Generation Using an IC Power Plant

Placing a CVT between the Diesel engine and the generator on a conventional site generator it is possible to reduce overall energy consumption.

CVTCorp specializes in this type of genset using a SFTV CVT.


CVT CORP

**CVT VariGen-50 kW (Iveco Engine)**

*Client:* Petrobank

*Location:* Estevan, Saskatchewan

*Description:* Rental Replacement

**FUEL SAVINGS**
**64% ( $ 250 / day)**

Client was using a **125 KW** Diesel genset. The load requirement was varying between 22 and 41 amps on 480 V power. The motor size was 30HP. The measure fuel consumption for this unit was 5.5 GPH average. The VariGen-50 was installed and the fuel meter was connected to. The fuel **consumption on the Varigen-50 was 2.0 GPH average** resulting in a **64% drop in fuel consumption**. Using current fuel pricing the savings is **$250/day**.

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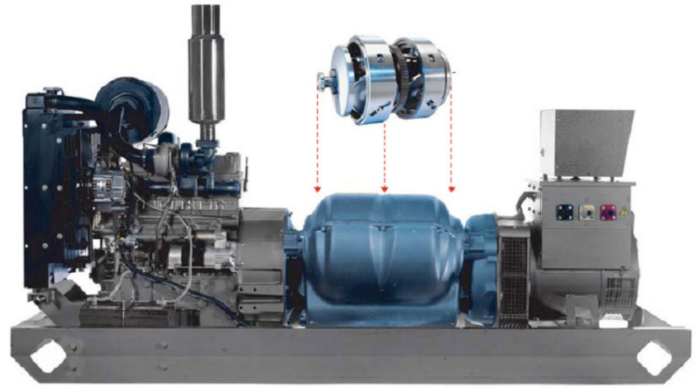
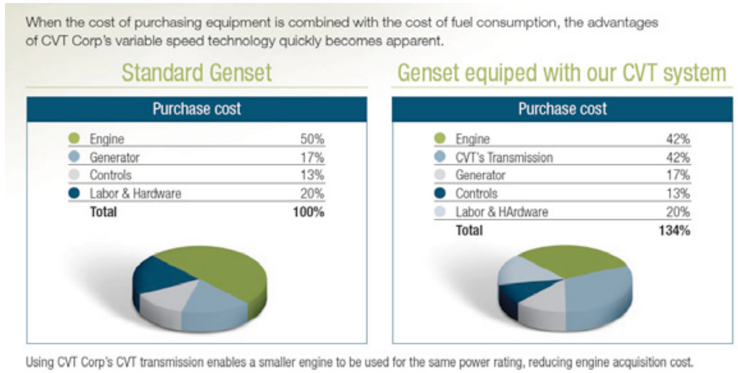
COMGEN POWER SOLUTIONS LTD.
*See our dealer*
www.comgenpower.ca
info@comgenpower.ca




When the cost of purchasing equipment is combined with the cost of fuel consumption, the advantages of CVT Corp's variable speed technology quickly becomes apparent.

**Standard Genset**

| Purchase cost | |
|---|---|
| Engine | 50% |
| Generator | 17% |
| Controls | 13% |
| Labor & Hardware | 20% |
| **Total** | **100%** |

**Genset equiped with our CVT system**

| Purchase cost | |
|---|---|
| Engine | 42% |
| CVT's Transmission | 42% |
| Generator | 17% |
| Controls | 13% |
| Labor & HArdware | 20% |
| **Total** | **134%** |

Using CVT Corp's CVT transmission enables a smaller engine to be used for the same power rating, reducing engine acquisition cost.

# Electricity Generation Using an IC Power Plant

A similar approach is needed in a jet engine powered airplane where the turbines spin at a very high speeds.

Tokyo, November 14, 2006 — Kawasaki Heavy Industries, Ltd. announced today that Kawasaki and Shinko Electric Co., Ltd. have jointly developed the T-IDG, the world's first traction drive integrated drive generator (IDG) employing a TD-CVT*1 for application in large -size aircraft.

An IDG is the main power supply unit used in aircraft jet engine. It consists of an AC power generator combined with a constant-speed drive unit to drive the generator at a constant revolution speed. This constant-speed drive unit makes it possible to maintain a stable and constant frequency power supply for an aircraft regardless of engine revolutions.

The newly developed T-IDG is the world's first IDG for aircraft applications employing a high-speed TD-CVT, instead of the conventional hydraulic CVT, as the constant-speed drive unit. It delivers significantly enhanced efficiency and durability compared with other existing models while ensuring superior power supply quality due to its high controllability as well as increased aircraft fuel economy and reliability. In developing the T-IDG, Kawasaki worked on the overall integration of the TD-CVT and IDG while Shinko Electric was responsible for the generator and its control unit.

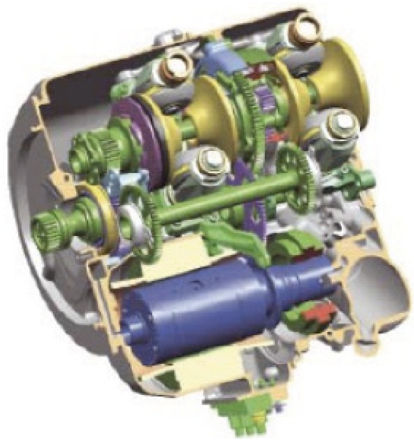



図11　トラクションドライブ式IDG（T-IDG）MkII試作
Fig.11　Traction drive IDG（T-IDG）prototype Mk II

# Electricity Generation using an IC Power Plant

The T-IDG uses a half-toroidal TD-CVT that allows for an infinite variability in the speed ratio by changing the angle of the rollers located between the two half-toroidal-shaped discs that face each other. The technological breakthroughs Kawasaki achieved in developing its TD-CVT for practical aerospace applications include:

**1) Reduced weight**

Kawasaki achieved a lighter weight TD-CVT by employing a lower-loss surface profile and a ceramic shaft bearing while establishing a technology for controlling traction drive speed (15,000 rpm, double the speed of an automotive traction drive) for high-speed low-torque operation.

**2) Higher efficiency and reliability**

A power split mechanism that distributes the engine's drive power to both the traction drive and the gear in addition to the sensor-free control that allows for virtual control of traction drive have been employed to significantly increase overall power transmission efficiency and reliability.

**3) Environment resistance**

In order to meet strict environmental conditions required for aircraft, Kawasaki developed a negative-G capable oil system, traction oil with high mobility at low temperatures and a sealing technique for resisting pressure difference.

**4) High response**

A highly-responsive electro-hydraulic servo system is used to control traction drive speed, ensuring superior power supply quality while allowing for uninterruptible switching of power supplies.

The new T-IDG is capable of controlling the variable engine speed (approximately 5,000 to 10,000 rpm)with the TD-CVT to maintain a constant traction drive speed and ensure a stable supply of AC power to an aircraft at a constant frequency of 400 Hz. The T-IDG can supply up to 90 kVA of power and will be upgraded to 250 kVA in the future.

Kawasaki plans to develop a line of products that will expand aerospace applications of the T-IDG on a global basis.

**1.TD-CVT: traction drive continuously variable transmission. A traction drive is a power transmission mechanism that utilizes the viscous resistance of oil film and can transmit power between two objects with a smooth surface. Tilting the roller placed between two half-troidal-shaped discs can adjust the input/output speed ratio with no discrete steps or shifts. This type of CVT is called a half-troidal CVT.*

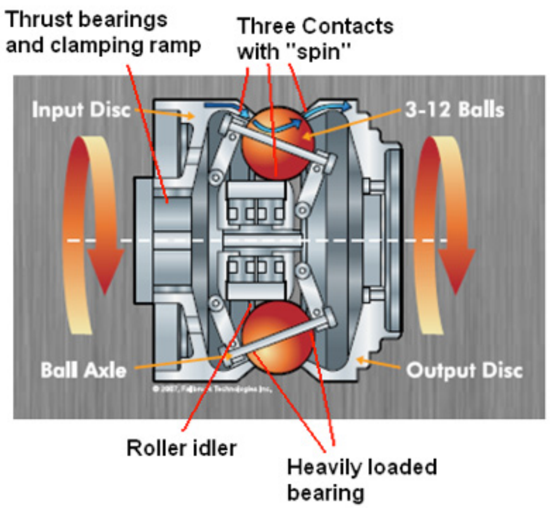
# Push Bikes

## Fallbrook Industries brought out such a transmission applied to bikes in 2005. Its introduction appears to have been very successful.

Fallbrook Industries brought out such a transmission applied to bikes in 2005. Its introduction appears to have been very successful.

Fallbrook relies on a traction drive invention called Nuvinci. Its particular design appears ideal for incorporation into the hub of the rear wheel of a push bike.

Fallbrook intend to promote the use of this variator to the same target markets identified by UT.




**Diagrammatic section through a NuVinvi (CVP) or Planetary Variator.**
The variator is characterized by its unique arrangement of spherical balls, input and output discs, and an idling roller that supports the balls against the inward thrust created by the pressure on the discs. The contact forces are small when compared to those in a toroidal Variator but are combined with large lever arms giving the variator a quite high torque density, similar to a Torotrak SFTV and around 30% of that of a DFTV.

Ultimate Transmissions have created mathematical models of this variator and find that its torque density is limited by the pressure that the balls exert on the idler roller; the limit of which is reached before the differential velocities on the ball to disc contacts become excessive.

This arrangement can be built inside the rear-wheel hub of a standard push bike and will provide adequate torque transfer for normal street riding provided the ratio of front to rear sprocket is kept greater than 1.8:1.

The arrangement is typically larger and heavier than a similar wheel hub gear-system such as Shimano although the ratio range may be slightly higher and of course the riding experience very smooth.

NuVinci do not specify the maximum input torque to the variator by the rear sprocket. UT’s study places it at around 60Nm. (this limits the traction coefficient to 0.09 and the maximum hertzian stress to 4.2 GPa).

A DFTV equivalent can deliver this torque at half the size and weight of a NuVinci.

# Push Bikes

This arrangement can be built inside the rear wheel hub of a standard pushbike and will provide adequate torque transfer for normal street riding provided the ratio of front to back sprockets is kept greater than 1.8:1.

The hub is typically larger and heavier than a similar wheel hub gear –system such as a Shimano, although the ratio spread may be slightly higher, and of course the riding experience much smoother.

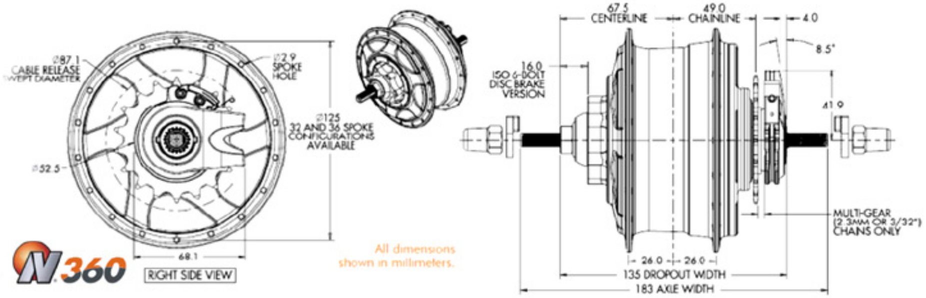
NuVinci do not specify the maximum input torque that can be applied to the rear sprocket. UT's study places it at around 60Nm (this limits the traction coefficient to 0.09 and the maximum Hertzian stress to 4.2GPa).

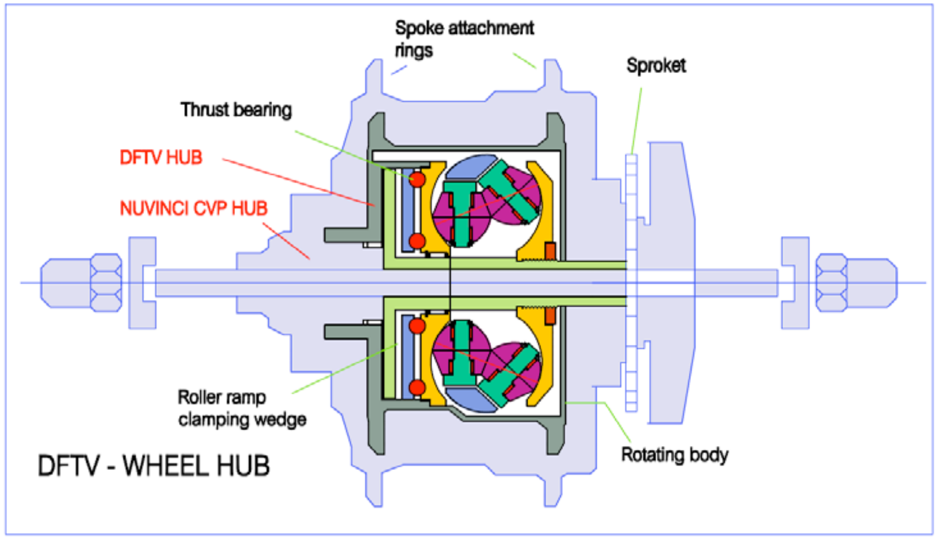
A DFTV equivalent can deliver this torque at less than half the size and weight of a NuVinci.

The diagram (b) shows the outline of a NuVinci hub with an equivalent DFTV placed inside.

The difference in size is immediately apparent. Both Variators require a thrust bearing and a clamping system. The NuVinci clamping forces are only 17% of the size of the DFTV clamping forces but the overhangs are much less.

UT estimates the weight of the DFTV hub as1.2kg. The NuVinci is 2.45kg.




(b)

# Light Electric Vehicles

There is a position for simple CVT's in association with Light Electric Vehicles.LEV. Although electric motors have a very broad operating rev range they have peak performance in only a part of this range just like IC engines.

NuVinci carried out a study on such a vehicle which revealed an operational performance of the vehicle fitted with a NuVinci transmission markedly better than the standard vehicle using the same motor and batteries.

Table 1. Benchmark Test Results*

| | | 2008 Stock Currie IZIP | 2008 *NuVinci* IZIP | *Percent Improvement* |
|---|---|---|---|---|
| ***ACCELERATION*** | | | | |
| 0-16 kph | (sec) | 3.4 | 2.1 | 38% |
| 0-19 kph | (sec) | 4.7 | 2.9 | 38% |
| 0.2 km time | (sec) | 30.0 | 23.4 | 22% |
| ***MAXIMUM SPEED*** | | | | |
| Sustained Speed | (kph) | 28.4 | 41.8 | 47% |
| ***HILL CLIMB, 0.46 km*** | | | | |
| Time | (sec) | 141.0 | 113.4 | 20% |
| Average Speed | (kph) | 18.9 | 23.5 | 24% |
| ***MAX LOAD UP GIVEN GRADE*** | | | | |
| Max Load @ 20% Grade | (kg) | 77.6 | 120.7 | 56% |
| ***RANGE*** | | | | |
| Highway Range | (km) | 19.0 | 18.9 | -0.7% |
| City Range | (km) | 11.3 | 13.5 | 20% |
| Hill Range | (km) | 9.3 | 10.0 | 7% |

* Beta Prototype (FLB03) Data per March 2008

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Because an electric motor is capable of very sensitive control and is happy to start stop and reverse when called for the CVT needed to be coupled with a an electric motor can be very simple and cheap.

From Paper "Use of a Continuously Variable Transmission to optimize Performance and Efficiency of two – Wheeled Light Electric Vehicles (LEV)" by Jeremy Carter, Loren McDaniel, Christopher Vasiliotis – EET-2007 European Ele-Drive Conference Brussels, Belgium, May 30 – Jun 01 2007

# Motor Bikes and Sports Vehicles

The simplicity and operator friendliness of the CVT and its related IVT make it ideally suited for these vehicles.

Normally they are not fitted with reverse gear and often fitted with centrifugal clutches making the drive chain architecture very simple either as a simple CVT or a single range IVT without geared neutral.

Belt drive (rubber) CVT's have been used in snowmobiles for many years.

# Marine Applications

There are applications in the marine industry as fixed pitch propellers in light motor craft are rarely operating at their most efficient speeds as the speed of the craft varies a great deal.

# Renewable Energy

## It is well understood that most forms of mechanically derived renewable energy arrives in a very eratic manner.

Wind generators are a particular example of this where the wind speed varies greatly and the available power moves up and down. Because power must be delivered to the grid at a fixed frequency variations in wind speed mean variations in the speed of rotation of the turbines.

There are many devices that can deal with this problem including variable pitch propellers and solid state conversion of the output current. They all involve cost and efficiency losses.

An opportunity exists for a very durable and efficient CVT to convert varying rotor output speeds to a constant grid compliant frequency.

# Renewable Energy

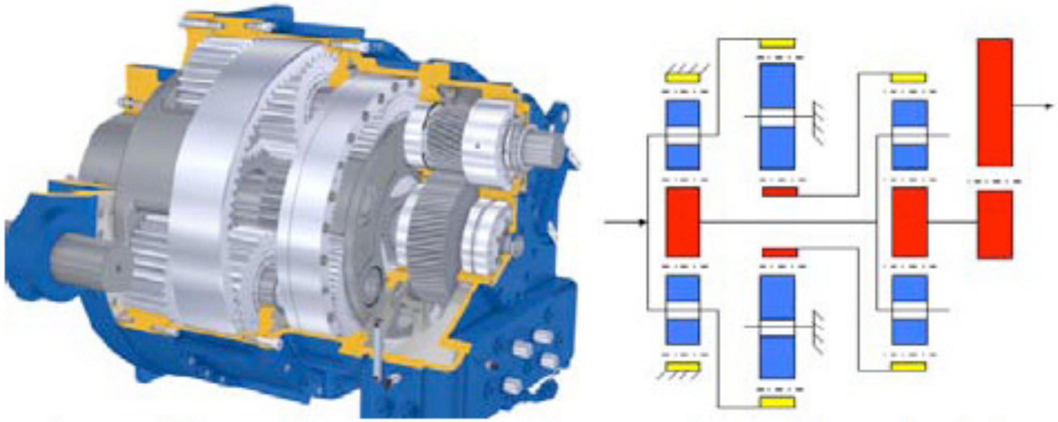


Fig. 4 Differential gearbox, Bosch Rexroth, working principle

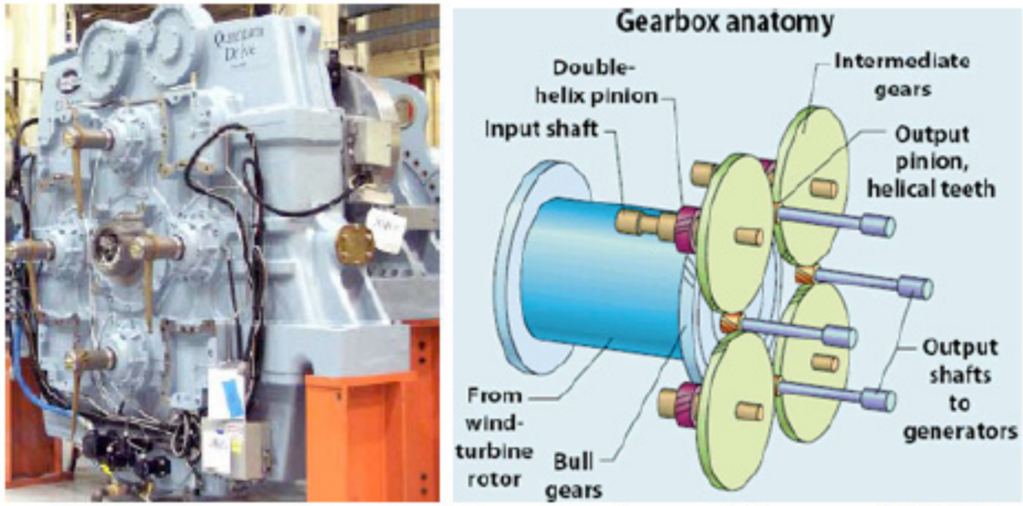
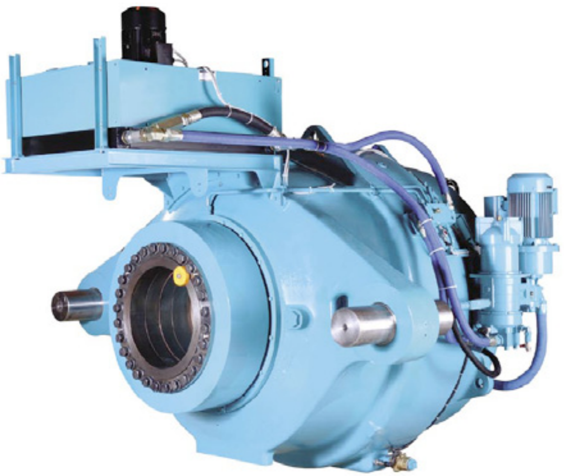



Fig. 5 Clipper Quantum Drive, gearbox architecture [8], [9]

# Renewable Energy

Fig. 3 Worlds largest operational wind gearboxes. Left: Winergy 5MW gearbox. Right: Renk 5MW gearbox (during assembly).



# Renewable Energy

Hydrostatic CVTs are already in use.

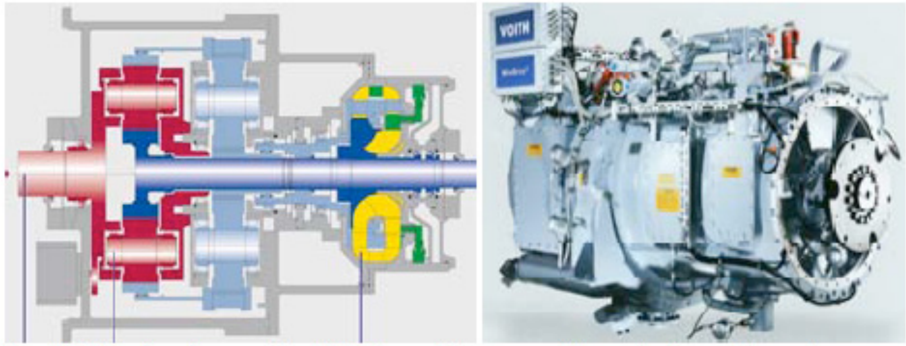



Fig. 12 Hydrodynamic CVT gearbox used in wind turbines between main gearbox and generator [5]

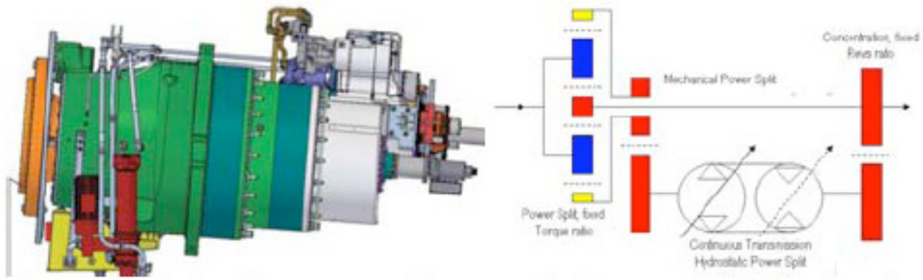



Fig. 13 Hydrostatic CVT gearbox attached on output side of main gearbox, working principle [6]

Research is being carried out into the feasibility of using Chain Type Variators to handle very high powers. As Pulley and belt CVT become larger although the pull chains can handle the tension the deflections in the pulleys become difficult to control

A large size DFTV will have the ability to convert variable speed outputs into constant shaft speeds even when the power throughput is well over 2,000KW. The improved efficiency durability and cost of the DFTV will produce an opportunity for application of a CVT to large Wind Power generators.