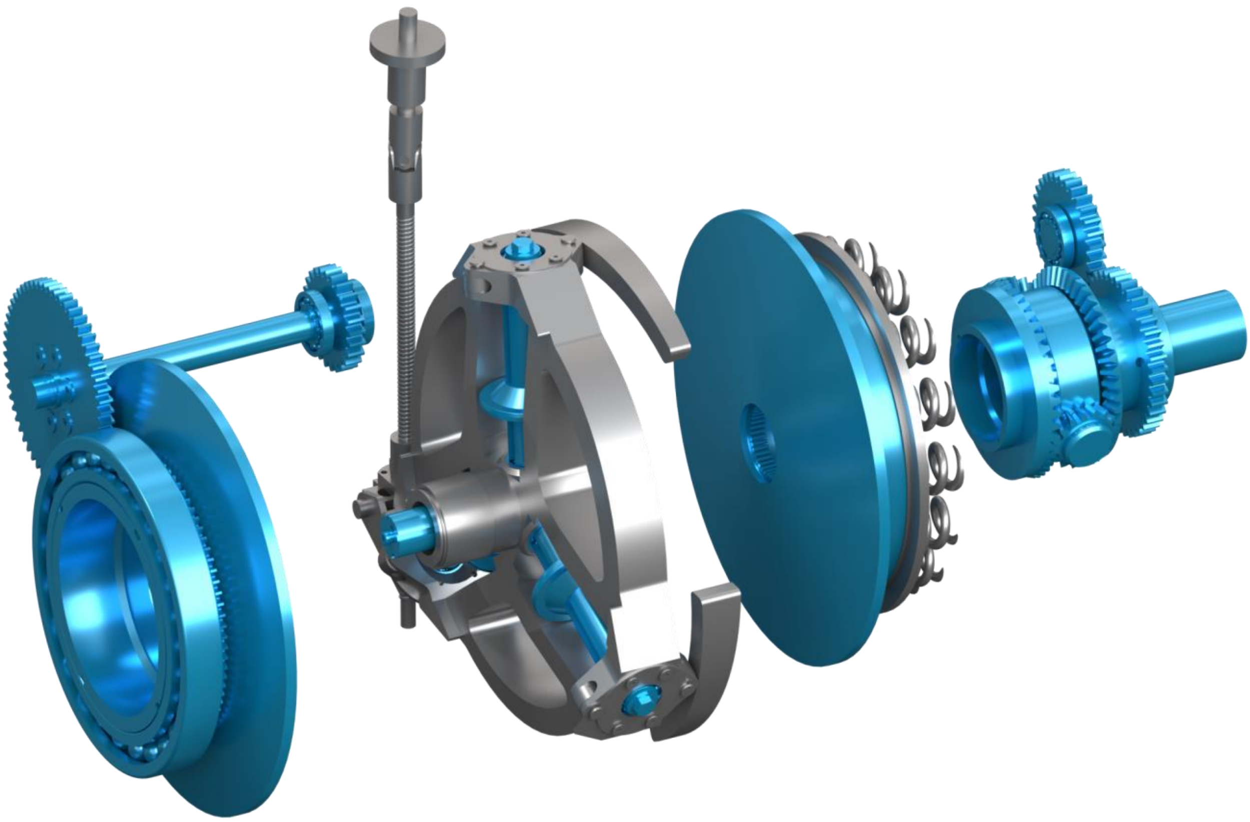
RADIALcvt, the CVT (Continuously Variable Transmission) of the future - NOW.



Dr. J. J. Naude **16 November 2017**

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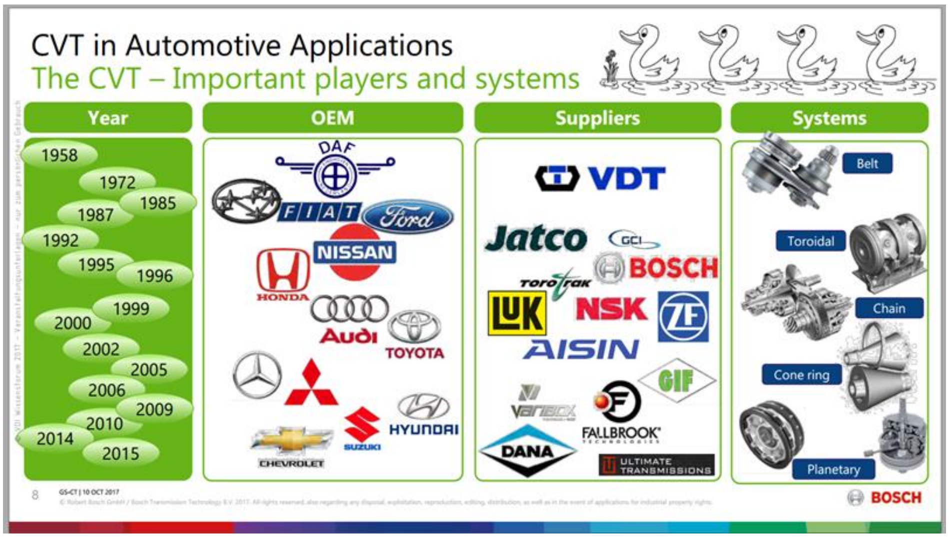
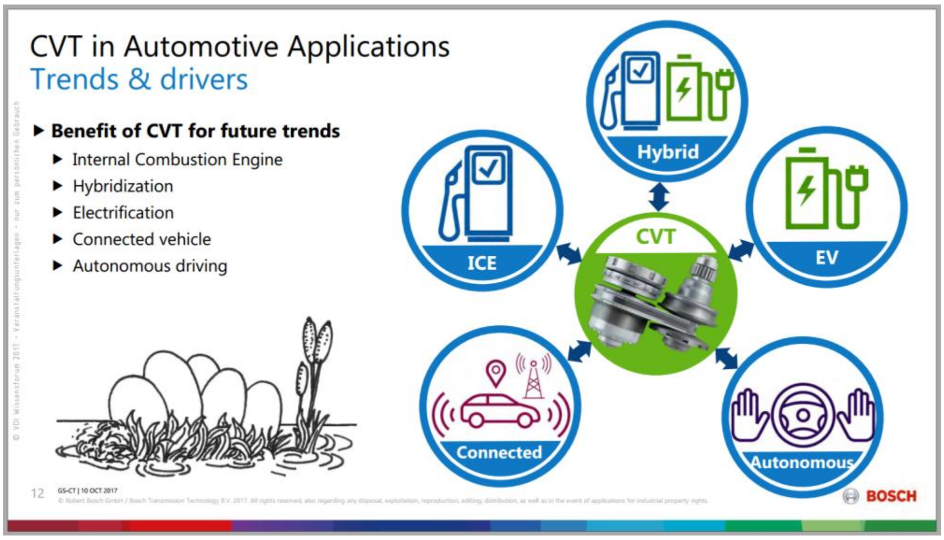
Background – Transmissions market

Competition in the current automatic transmission market is rife. There are many suppliers across the four automotive transmission categories vying for market share namely: Automated Manual Transmission (AMT), Dual Clutch Transmission (DCT), Automatic Transmission (AT) and Continuously Variable Transmission (CVT). Each of these transmission categories present products with their own strengths and weaknesses.



Important players in the CVT market as presented by BOSCH – Oct 2017

Continually variable transmissions (CVT) have emerged as the ideal drivetrain component to integrate and coordinate the energy related components (engine, batteries, electric motor/generator and vehicle kinetic energy) within Internal Combustion Engines vehicles(ICE), Hybrid vehicles (HV), Electric vehicles (EV) and Autonomous vehicles (AV). In these vehicles, CVT is the preferred gearing mechanism. The mechanical efficiency of current commercial CVT's however lack when compared to that of manual and stepped transmissions. The reason for this is that current commercial CVT's must include a hydraulic control system to facilitate the clamping and gear change, resulting in power losses.



Future CVT trends as presented by BOSCH – Oct 2017

Further losses are also created by the two, in series, dynamic friction drive interfaces that are present in all commercial CVT's making the units heavy and complex, leading to increased manufacturing costs.

In recent years, the growth of HV and EV have been driven aggressively by government emission policies all over the world. China, USA and European union, some of the largest emitting regions are actively pursuing energy efficiency improvements in various areas. A more structured shift away from carbon intensive activities (of which decreases in fossil fuel combustion in the automotive industry has become paramount) contributed considerably to the growth in HV and EV. The knock-on effect in the CVT market is that of increased demand and a search for components that will further support green initiatives.

The solution – RADIALcvt

To overcome the barriers mentioned above, Varibox CVT Technologies developed a product, the RADIALcvt, discussed herein.

The RADIAcvt provides an alternative CVT design, with a number of very significant and fundamental advantages. This uniquely configured CVT uses existing traction fluid technology that has been in existence since the 1980's, eliminating the barrier to entry that exists with other, alternative CVT inventions.

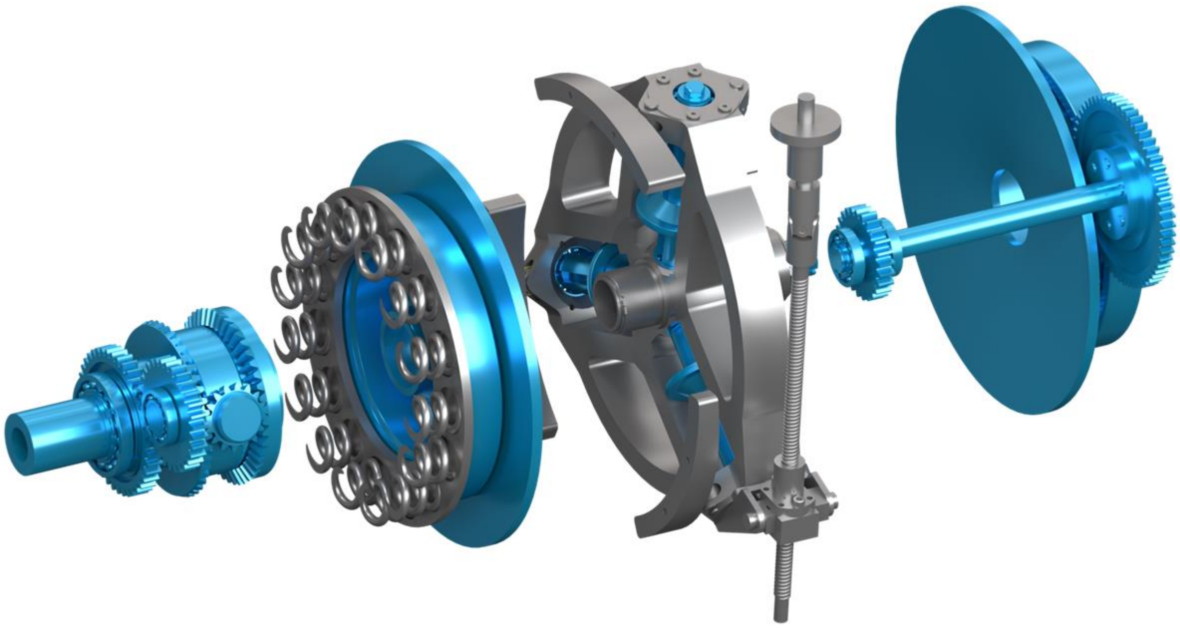
The uniqueness of the RADIALcvt lies in the mechanical configuration that was patented in February 2017, after which marketing efforts began to commercialise the invention.

Varibox presented the first test results for the RADIALcvt prototype during an exhibition at the CVT conference in Eindhoven in the Netherlands from 10-11 October 2017, showcasing the simplicity and efficiencies of the invention as proven via a tested prototype.

RADIALcvt Explained

RADIALcvt features a single friction drive interface in series, and at least 6 power split friction drive parallel paths to result in an effective power dense CVT. A constant input radius on the friction drive input make it possible to use a constant clamping force which is provided by springs. Therefore, the RADIALcvt concept has no hydraulic control system, directly increasing mechanical efficiency and reducing cost and weight.

The RADIALcvt also has a very large radius variation on the friction drive output which provides the ratio variation. Due to the fact that the radial drivers are clamped between two opposite rotating disks, the force on the radial drivers are largely cancelled out. The RADIALcvt's first ratio is hard geared to eliminate the "kerb test" issue common with push belt CVT's.



RadialCVT by Varibox is a simplified CVT transmission with proven high mechanical efficiency

Fundamental design differences of RADIALcvt

One friction interface: There is only one friction drive interface, in series, in a parallel power path. All other CVT's, both in development stage as well as commercial units have two friction drive interfaces, in series, thus resulting in a compound friction loss. If one assumes that the friction contacts have the same efficiency then the RADIALcvt will have 50% of the friction drive losses compared to that of other CVT's.

Line contact: The friction drive contact in the RADIALcvt friction drive can be a line contact. Line contact reduces the maximum contact stress and increases power transfer capability.

Constant input radius: The RADIALcvt has a constant friction drive input radius. All other CVT's have a variable input radius which results in high surface rolling speeds and a lower coefficient of friction which require higher clamping forces. The maximum surface rolling speed in the current RADIALcvt concept design is less than 15m/s.

Six parallel power paths: The RADIALcvt has at least 6 parallel power paths. Such a large number of parallel paths results in high power density and a compact design.

Large output friction disk: The output friction drive disk of the RADIALcvt can be positioned concentrically and close to the engine flywheel and can approximate the flywheel size. The diameter of this output friction drive can therefore be much larger than any other CVT's output friction drive components. Due to this fact, the RADIALcvt provides its highest efficiency in low ratios associated with city driving. Fuel consumption is minimised as a result.

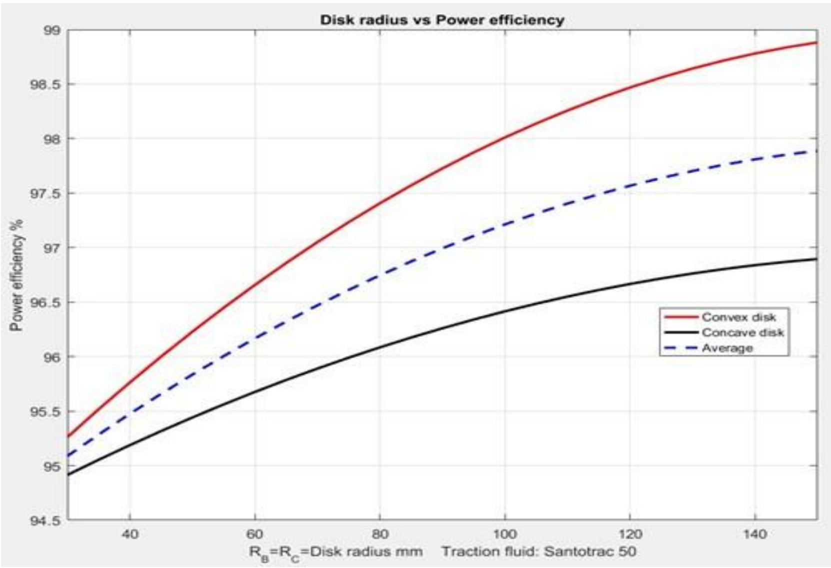
No hydraulic control: The RADIALcvt is realised without any hydraulic control. All current developmental and commercial CVT require a hydraulic control system.

Clamping force utilization: In the RADIALcvt configuration, a unit of clamping force supports two parallel friction drive interfaces, while in all other developmental and commercial CVT's, only one friction drive interface is supported. Losses due to clamping forces should thus be 50% lower in the RADIALcvt.

Clamping force location: In the RADIALcvt, clamping force bearing losses are associated with the unit output alone, while the input from the radial drivers are in equilibrium. Bearing losses are therefore only associated with RADIALcvt output speed. This produces loss advantages in low output speed ratios which stands in contrast to all other CVT's where the clamping force bearing losses are associated with both the input and output speeds.

Proven advantages of RADIALcvt

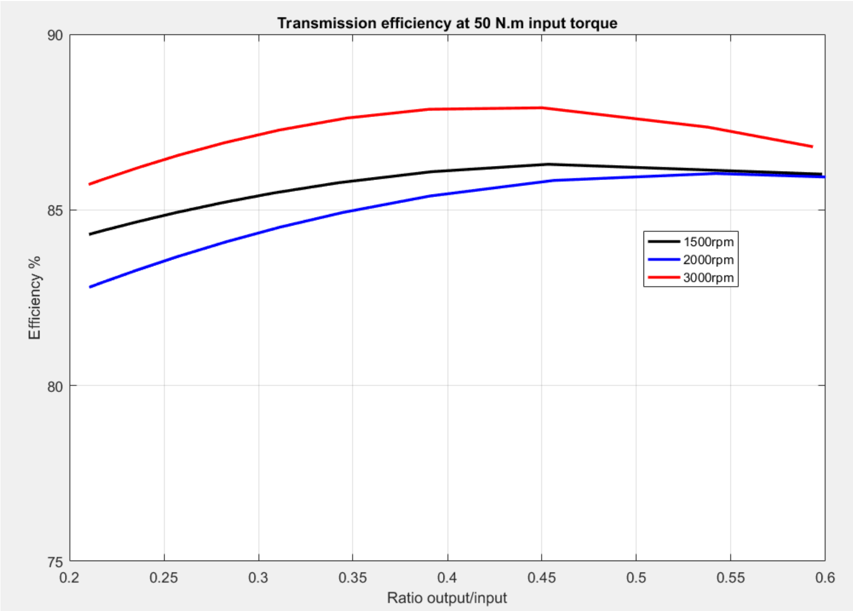
High power efficiency: Simulations, as presented below, of the unique design of the RADIALcvt results in a friction drive contact power efficiency of 98% in low ratio up to 95% in high ratio in a 4.7 ratio range variator as intended for small passenger vehicles. With the use of an integrated two speed AMT (automated manual transmission) or E^2 configuration, the ratio range is increased to 10 and beyond.



Contact traction drive power efficiency from the simulated RADIALcvt prototype

Low bearing losses: Disk bearing (clamping force) losses, which are a well-known source of traction drive CVT losses, are very low and varies between 1.5% and 2.5% of transmitted power.

Prototype test results: Varibox tested the first transmission efficiencies of the RADIALcvt, proving the mechanical efficiency of the prototype. The results are presented below.



RADIALcvt first prototype, first efficiency test results

The results of the mechanical efficiency tests as depicted above, superimposed on published transmission efficiencies of a developmental as well as commercial CVT are displayed in the image below. The RADIALcvt results are the 3 lines for 1500, 2000 and 3000rpm respectively extending from a Transmission Speed Ratio of 0.2 to 0.5. Note that these results are drawn from initial tests performed on the first RADIALcvt prototype in comparison to CVT's that have been in development and production for a number of years. The RADIALcvt transmission efficiency proved to be consistent with current production CVT's. In future development prototypes, further large mechanical efficiency improvements are expected.

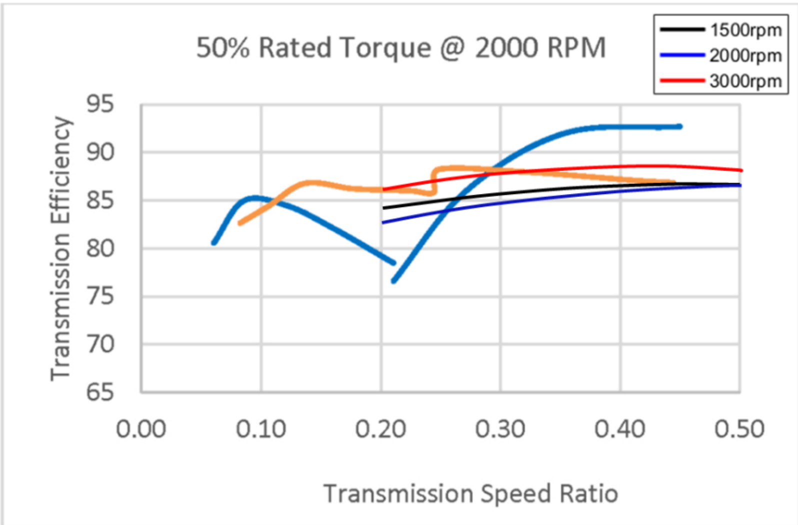
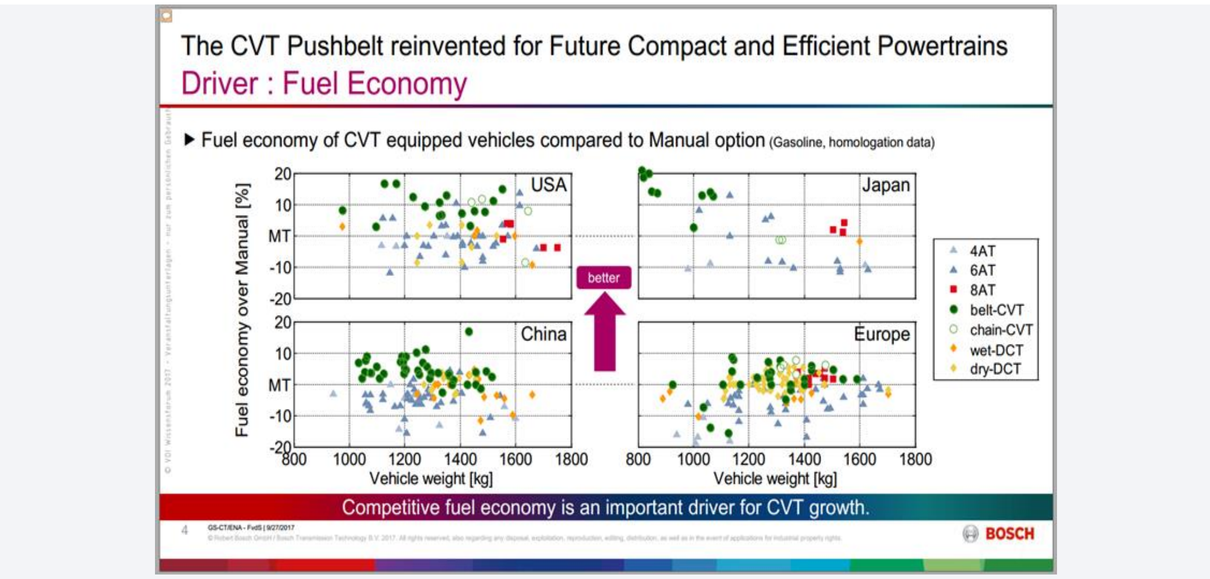


Figure 11. Comparison of Over All Transmission Efficiency.

RADIALcvt efficiency results superimposed on published commercial CVT results

Fuel consumption benefits: The below image represents the current fuel consumption of a variety of transmissions, compared to that of manual transmissions. It is clear that CVT's offer superior fuel economy. Therefore, the fundamental design differences of the RADIALcvt will improve fuel consumption even further.

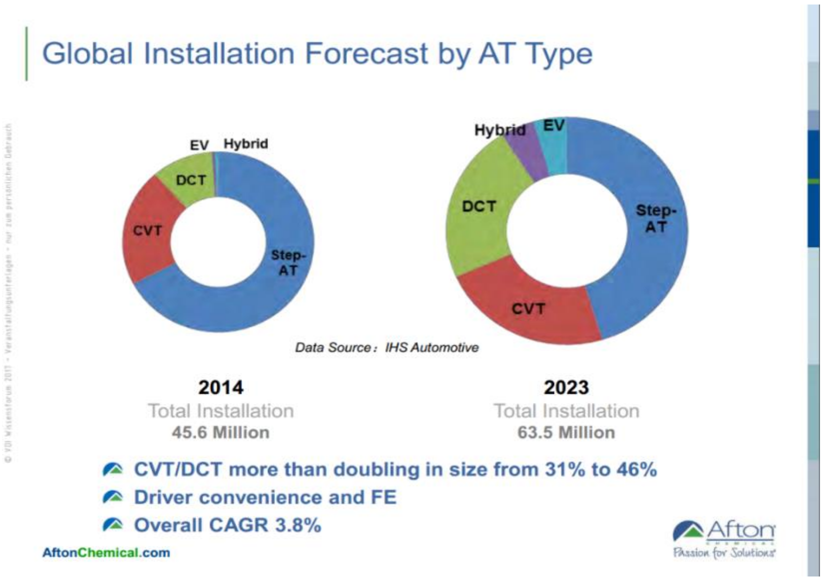


Fuel economy comparison as presented by BOSCH – Oct 2017

Reduced emissions/environmental impact: Increased mechanical efficiency directly results in lower fuel consumption and emissions.

The scalability of RADIALcvt

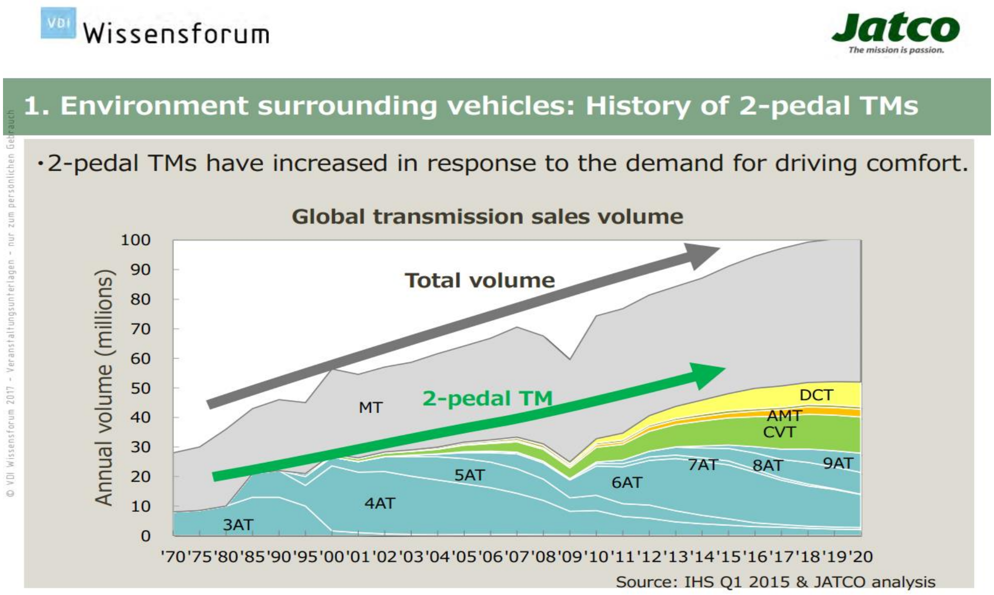
The RADIALcvt can be scaled to a wide variety of applications and power ranges.



Global installation forecast by AT Type as presented by Afton – Oct 2017

Market scale figures

Above are the forecasted installation figures by AT type, as well as global sales volume figures. CVT growth is anticipated to be higher than the total transmission increase and thus the CVT will rapidly gain market share.



Global transmission sales volume as presented by Jatco – Oct 2017

Electric Vehicles (EV) – The next growth area

With the current drive towards the advance of EV, the optimization of all components that contribute to the overall energy efficiency of the EV is becoming more important. The development of energy dense batteries and other energy storing devices that make EVs more efficient, have highlighted the need to eliminate inefficient components that could have a negative effect on the advances made in the development process. The pure EV is expected to grow in market share and we will see an increase in its stepped ratios to 2, 3 and 4. Development in this area will also continue as reported by ZF and Bosch.

RADIALcvt's mechanical efficiency is at most within an estimate of about 3% less than stepped transmissions while it is much more compact than the stepped transmission with a clutch or dual clutch. Although CVT simulations have proved the advantages of a CVT transmission in pure EVs, the low overall efficiencies of current commercial CVT's have eroded the advantages away. RADIALcvt, on the other hand, provide an excellent solution for pure EV's because of its simplicity and fundamental design differenced that produce high mechanical efficiency without the need for a hydraulic control system.

Commercialisation

Varibox is an intellectual property company that specialises in the development of alternative high efficiency CVT concepts. Our business model revolves around the licensing of our patent protected concepts in order for to the licensee to commercialise the product. However, Varibox is committed to provide the licensee with the required services for the successful roll-out of the product.

There is a three-level progression in term of the licensing agreement with Varibox. The first is to provide a license for the evaluation and development of each licensed concept. This is in addition to the Varibox prototype tests that have been conducted. After successful completion, a second level license is awarded for development of a production prototype, thereafter a long-term manufacturing licence is issued.

The licensee is guaranteed exclusive use or exclusive use with others of the technology, enjoying all the benefits of the technology which include superior mechanical efficiency, manufacturing cost saving, fuel efficiency and environmental benefit.

As there are currently only two companies globally (LUK and Bosch) selling the critical belt and chain components employed in current commercial CVT's, the RADIALcvt will serve as a piece of disruptive technology to challenge the status quo with its superior configuration and performance.

Recent Varibox achievements include an honourable mention in the US based 2017 Tech Briefs, Create the Future Design Contest. Varibox was in the top 4 in the Automotive/Transportation category. See https://contest.techbriefs.com/2017/winners

Varibox also received a finalist award for sustainability in the 2017 Da Vinci TT100 awards. See http:/www.davinci.ac.za

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Downloads

The full RADIALcvt, design, simulation and testing document can be downloaded from:

http://www.varibox.com/media/1195/radialcvtdesignver110-004.pdf

The document highlighting the RADIALcvt as the ideal electric vehicle (EV) transmission can be downloaded from:

http://www.varibox.com/media/1189/radialcvtelectricver15-updated.pdf

A full RADIALcvt presentation in the form of a mp4 video with animations and voice over can be downloaded from:

http://www.varibox.com/media/1201/radialcvtfullpresentation.mp4