

Automotive Drive Concepts

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Transmission Types in Vehicles

Attempts to eliminate mechanical drive trains in automobiles and trucks have had limited success because of cost, weight, dynamic characteristic, and efficiency of the alternative components.

If the prime mover of an automobile is a combustion engine, the torque and rpm have to be adjusted continuously to the driving condition. Manual transmissions have a high overall efficiency of 94% to 97%, however, the shifting time as well as the fact that the average driver does not assure that the transmission is in the optimal gear reduces the resulting overall transmission efficiency one percent or more.

As a matter of fact, efficiency is not a single number but always a more dimensional characteristic. In the case of automotive transmissions it has become common to identify the efficiency versus input speed and torque. There are many more environmental influences such as temperature and vibrations of surrounding structures. Figure 1 shows the efficiency characteristic of a modern axle drive unit with a hypoid gear pair. The highest efficiency values are achieved in the example (Fig. 1) in the medium- to high-torque and speed range; this characteristic is typical for gear transmissions (Ref. 1).

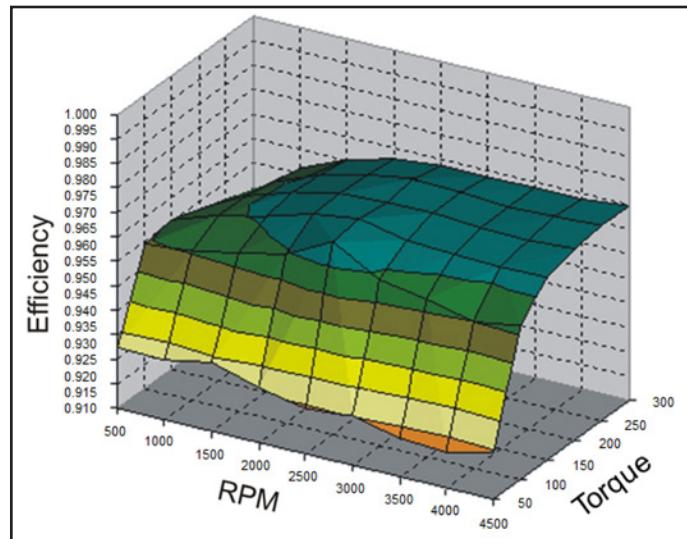


Figure 1 Hypoid efficiency versus input speed and torque.

The efficiency values mentioned in the following discussions apply always to the optimally achieved efficiency of the subject elements.

Another solution to transfer energy to two or four wheels applies individual electric motors in every wheel hub. One possible solution is the use of a combustion engine which is connected to an electrical generator. The electrical energy is transferred to the electric drives of two or four wheels with the possibility of sophisticated and fast reacting traction control.

The following sections discuss drive train and traction efficiency for different engine orientations and different driving

axles. The prime mover can be a gasoline or diesel combustion engine as well as a hydrogen engine. The different concepts are combined with electrical generators and electrical motors in order to establish the different basic categories of hybrid systems. The endless possibilities of two electric motors controlling dual clutch transmissions in order to optimize the efficiency between combustion engine and electrical generator or motor in every driving condition are not the subject of this chapter, however the conclusions in this chapter regarding engine orientation and traction concept will apply to all hybrid developments discussed here.

Comparison of different transmissions. The simplified diagrams in Figure 2—vehicle speed versus engine rpm for a medium drive acceleration from zero to 75 mph—compare mechanical or automatic shift transmissions with 4- and 6-transmission ratios with a constant variable transmission (CVT); the diagram shows engine rpm versus vehicle speed. The areas filled in green imply higher vehicle efficiency; the yellow areas imply lower efficiency. The upper two diagrams

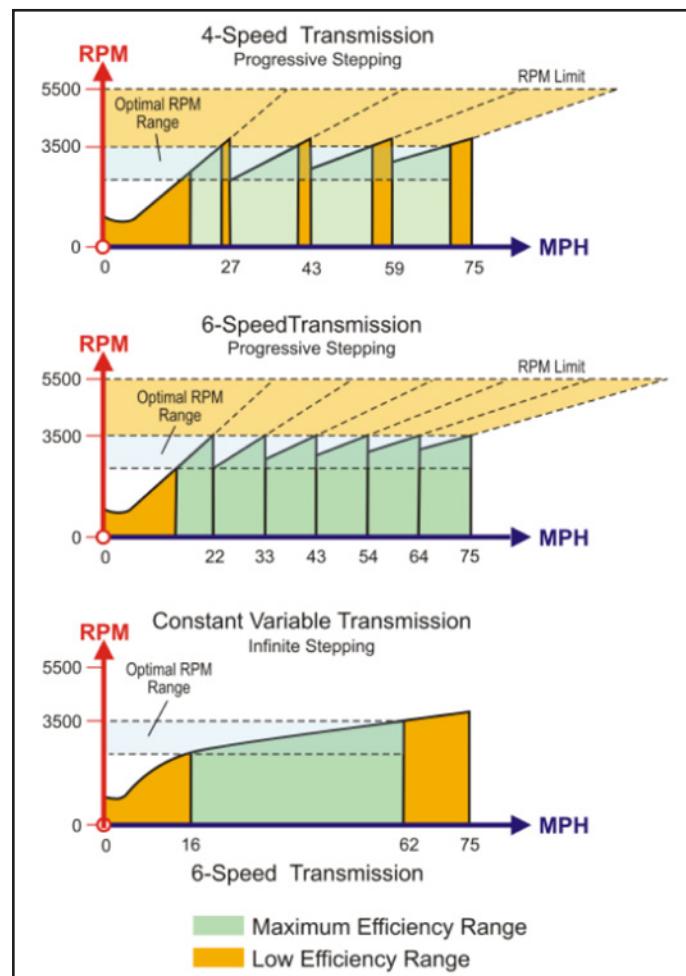


Figure 2 Efficiency ranges of different transmissions.

were developed using a progressive stepping with a decreasing stepping factor between the different gear ratios (as is typical for automotive applications). The four-speed transmission is required to run the engine above the optimal rpm range at the end of each ratio in order to cover the given speed range and minimize the less-efficient yellow areas.

The lower diagram in Figure 2 shows rpm versus vehicle speed for a CVT. The graph has a constant slope beginning at 22 mph. This slope assures that the engine rpm increases during vehicle acceleration, which in turn keeps the constantly required ratio change small. Constantly high ratio changes would result in reduced efficiency due to slippage. A higher-sloped graph would reduce the operating area (green) in the high-efficiency range of the engine; a lower slope increases the required ratio change and reduces the efficiency between 0 and 22 mph.

The diagrams in Figure 2 neglect the energy waste during shifting and clutch actuation, and also assume the driver will always shift at the optimal engine rpm. The strength of modern automatic transmissions is that the optimal shifting point is derived from engine rpm, vehicle speed, load and speed change. Even the shifting execution time and characteristic is constantly optimized, depending on driving conditions. However, the torque converter and the hydraulically or electrically actuated clutches absorb additional energy, which has to be compared to the energy loss due to the shifting and clutch actuation pattern of average drivers in cities, on country roads and on highways.

The result of comparisons show that—regarding efficiency—automatic transmissions with mechanically lockable torque converter, 6 or more speed ratios and sophisticated electronic control unit, will out-perform a mechanical 4-to-6-speed transmission operated by an average driver on highways and country roads.

CVT transmissions should solve the problem of adjusting the engine rpm optimally to the vehicle speed and torque requirement in every driving condition. The control units of CVT-equipped vehicles are programmed to optimize engine rpm and engine torque to the driving speed and driving condition. Besides those advantages, CVT-equipped vehicles present a good basis for the connection of a combustion engine with an electric motor and an electric generator. The input rpm of a CVT is in every driving condition closer to the rpm for engine efficiency and, therefore, also more constant. Lesser rpm variations will result in higher efficiency of electric power units in motor or generator mode.

The argument for more driving fun in case of an engine sound that is synchronized to the gear shifting periods is subjective and relative. An airplane jet engine is considered smooth, powerful and impressive in its sound, yet it goes through similar sound pattern like the engine of a CVT-equipped vehicle.

Most constant variable transmissions today are still based on the principle of two tapered pairs of

disks. The pair on the input shaft increases its distance while the pair on the output shaft reduces the distance (or vice versa) in order to keep the length of the transmission element (special-designed chain belt) constantly tight while the ratio changes (Fig. 3), left image (Ref. 2). The high-contact pressure and constant periodic material deformation of disks and belt chain, as well as the angular movements of the chain elements under high tension, lead to additional energy loss and material fatigue.

The right image in Figure 3 is a planetary transmission which can be utilized as a power collector from a combustion engine and an electric motor, while the electric motor also changes the ratio between input and output. In the case of a high ratio between electric motor and carrier, it is possible to utilize the electric motor between negative and positive rpms only in order to change the ratio between input and output shaft.

Figure 4 shows a principle based on two slim cones which are oriented against each other with respect to their taper. The cones have a constant clearance gap between them that is used to connect the cones locally with a transmission ring. A very small force, applied slightly off-center and opposite to the contact zone between driving cone, ring, and driven cone, will actuate a longitudinal movement of the ring which causes a step-less change of the transmission ratio. All surfaces are hardened and

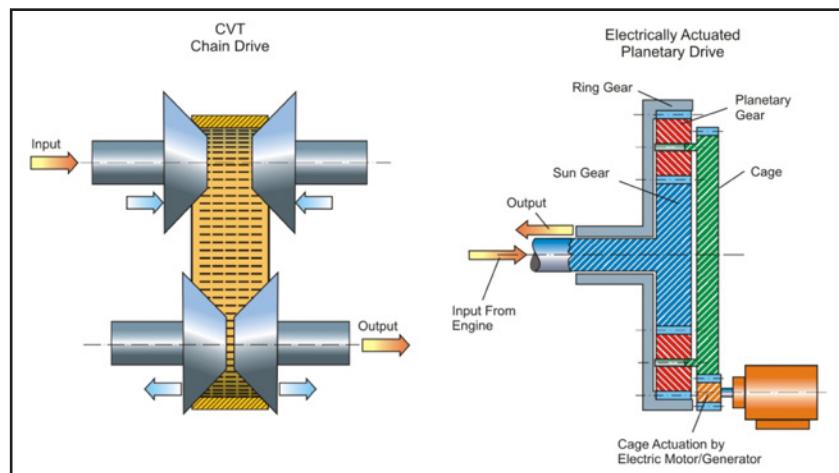


Figure 3 CVT chain drive and planetary split-torque CVT.

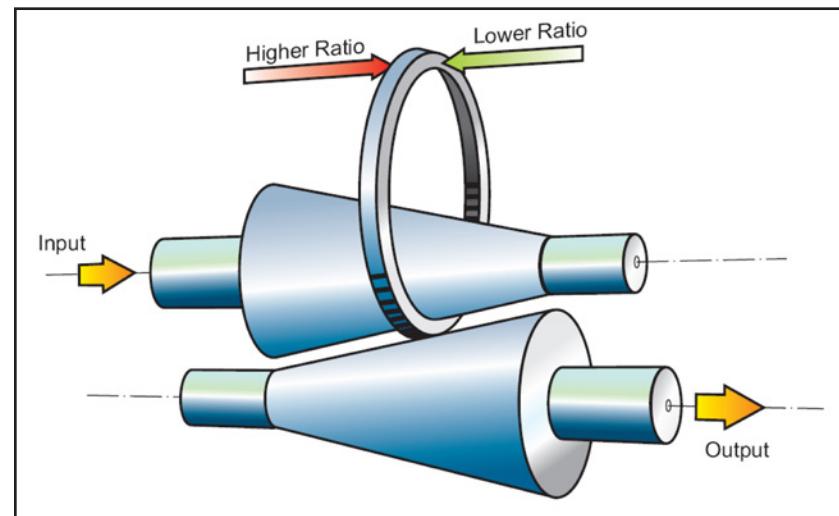


Figure 4 CVT with friction cones.

have a defined surface micro structure. The center distance of the two cones in connection with the radial wall thickness of the transmission ring provides the friction for the required torque transmission.

All friction-based CVT developments work at every constant driving speed on a lower efficiency level than shift or automatic transmissions using involute gear tooth contact as transmission elements. The advantages of CVTs can off-set the efficiency loss due to friction (versus involute gear transmission) in certain driving conditions. However, particularly hybrid vehicle concepts which benefit from the CVT transmission ratio change, depend on the highest possible efficiency of all transmission elements, which is not optimally given for transmissions with a friction-based ratio adjustment.

Electrical wheel hub motors. A combustion engine is connected by a clutch with an electrical generator; Figure 5 shows a principal sketch of such a concept. A second, smaller electrical generator/motor is permanently connected with the engine and functions as a starter motor, as well as a generator in engine operating conditions which turned out to reduce the performance of the large main generator. Four pancake-shaped wheel hub units act as electric motors to supply torque and speed directly to the wheels (Ref. 3). The same units can act as generators in coast and brake conditions in order to regenerate electrical energy from the kinetic energy of the vehicle in order to recharge the battery. In spite of the simplified sketch in Figure 4, the wheel hub units are integrated into the inside of the rim which brings the obstacle of elevated temperatures of up to 300°F being transferred into the rims and tires. This system still cannot completely eliminate a friction brake for critical deceleration maneuvers.

The result is a reduction of available space in the center of the wheels and a high, un-sprung mass. High masses rigidly connected to the wheels reduce the quality of the vehicle dynamics and lower the safety of a vehicle similar to beam style rear axles. They also constantly require additional energy to "bounce" this weight up and down in order to connect the vehicle with the road and compensate for imperfections in the pavement. High un-sprung masses require considerable amounts of energy for the up and down acceleration, which is converted into heat in the tires, the springs and the shock absorbers.

However, not only is the complexity of such a system very high which results in high manufacturing costs of those

vehicles, but the overall efficiency is rather low. The total system efficiency is calculated as the product of single efficiencies of units connected in line:

- Combustion engine (38%)
- Electrical generator (82%)
- Electronic power control units (85%)
- Wheel hub drive units (82%)
- Storage, transmission and transformation of electrical power (92%)
- Un-sprung mass (98%)
- Traction factor, wheel-road (96%)
- Efficiency improvement due to hybrid function (X)

$$\eta_{total} = 0.38 \cdot 0.82 \cdot 0.85 \cdot 0.82 \cdot 0.92 \cdot 0.98 \cdot 0.96 \cdot X = 0.188X$$

The efficiency numbers above and in the following sections are of course only rough approximations. However, in the comparison of the different drive concepts, the same numbers are used consistently, which makes the result of the comparison relatively objective. The total reflects only the energy loss between engine and tires — including the traction efficiency. Air resistance, gravity, inertia and centrifugal force influences which depend on the vehicle's body design and weight are not considered in the main body of this chapter and only mentioned briefly in the conclusion in order to allow a comprehensive recommendation for a future-oriented vehicle design. Lost energy due to braking and coasting is also not part of the total efficiency calculation, but is considered to some extent in the hybrid factor X, which is above 1.0 and reflects the regeneration of some, otherwise lost energy.

The system in Figure 5 includes all elements of a hybrid system. The overall efficiency of a hybrid system according to Figure 5 will not have an improved total efficiency, although regenerative energy from the wheel hub generators (motors) can be recycled through the battery. The constant conversion between mechanical energy and electrical energy, the storage of electrical energy, and the low efficiency of the individual wheel hub motor/generator units, take away some of the big advantages a hybrid vehicle concept has. The function that makes hybrid vehicles attractive regarding fuel consumption is the regeneration, storage and re-use of energy which is converted from kinetic energy into heat during brake action and coast driving conditions in conventional vehicles. Successful regeneration, storage and re-use of energy require a high efficiency in all components, as well as a high efficiency in the overall concept.

Front-wheel drive, conventional & hybrid. The comparison of the efficiency of front-wheel-driven versus rear-wheel-drive vehicles delivers an unexpected result for many vehicle owners. Front-wheel drive vehicles with so called "East-West"-oriented engines use a helical gear set behind the shift or automatic transmission as final drive reduction with a speed reduction of about three.

The two output shafts of front-wheel-drive transmissions are connected to a first constant velocity joint (CV-joint), a drive shaft and a second CV-joint. The first CV-joints are specified to compensate the up and down movements of the front end of the vehicle. The second CV-joints are specified to allow for steering action of the front

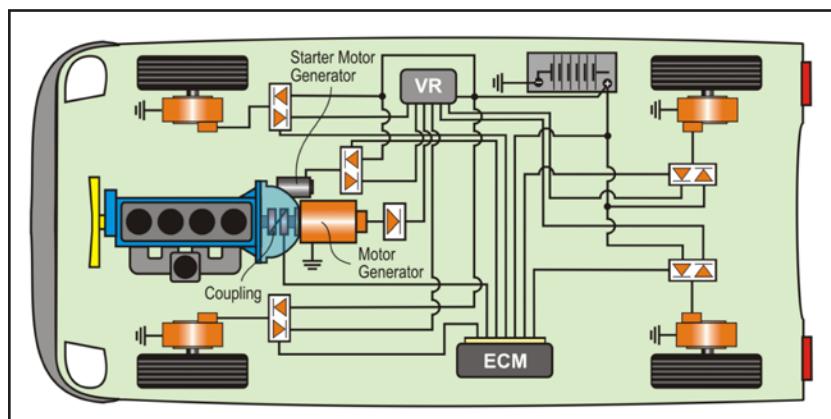


Figure 5 Individual 4-wheel-hub electrical drives,

wheels and in addition also to compensate the up and down movements of the front end (Fig. 6).

One disadvantage of such a system is the concentration of the entire drive train together with the prime mover in a tight space. The second disadvantage is an unfavorable center of gravity of front-wheel-drive vehicles, which have a driving dynamic that is not optimal and gives the driver less control over the vehicle in dangerous situations, compared to rear-wheel-drive or all-wheel-drive vehicles.

Beyond all this, there is a considerable energy loss in the second CV-joints due to the steering action. Even driving around slight highway bends reduces the efficiency below the level of rear wheel drive vehicles.

There is only one condition where front wheel drive has a concrete advantage over rear wheel drive. It is the instance to get a vehicle to move after a full stop on snow or ice. Even sophisticated traction control systems cannot eliminate this shortcoming of rear wheel drive vehicles which has its cause in the low weight above the rear axle. However, an additional weight of 35 to 50kg (77 to 110lbs) in the trunk of a rear wheel drive car will eliminate the traction deficit which occurs in particular in the winter time.

The overall efficiency of a front wheel drive vehicle consists of the following single efficiency of engine and drive train components:

- Combustion engine (38%)
- Transmission (94%)
- Final front drive (98%)
- Inner CV joints (99%)
- Outer CV joints (steering, 95%)
- Traction factor, wheel-road (93%)
- Efficiency improvement due to hybrid function (X)

$$\eta_{total} = 0.38 \cdot 0.94 \cdot 0.98 \cdot 0.99 \cdot 0.95 \cdot 0.93 \cdot X = 0.306X$$

One possible version of a front wheel drive hybrid, shown in Figure 6 uses a central electric motor/generator which is connected to a transmission and a combustion engine. The combustion engine and electric motor share the required power to drive the vehicle in cases of acceleration. In driving conditions of deceleration or downhill driving, the electrical unit acts as a generator and charges the battery. The transmission in most of today's front wheel drive hybrids works with constant variable ratio (CVT). This concept definitely accomplishes higher efficiency than conventional front wheel driven cars, however, the weight concentration on the front axle is even higher and the energy loss in the outer CV joints caused by the higher steering forces does not present the optimal solution regarding efficiency, traction, handling and safety.

A solution of a four-wheel-driven vehicle is shown (Fig. 7). The concept is based on the front-wheel-drive hybrid concept shown in Figure 6. It uses one central electric motor in the rear, which uses a cylindrical gear or chain reduction in order to

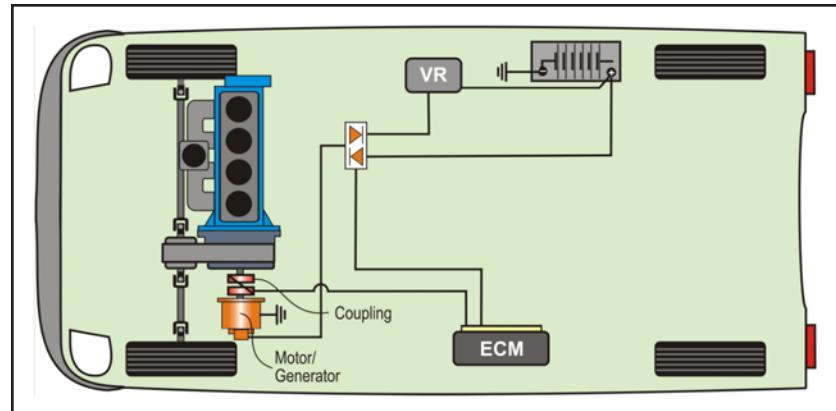


Figure 6 Front-wheel-drive hybrid vehicle scheme.

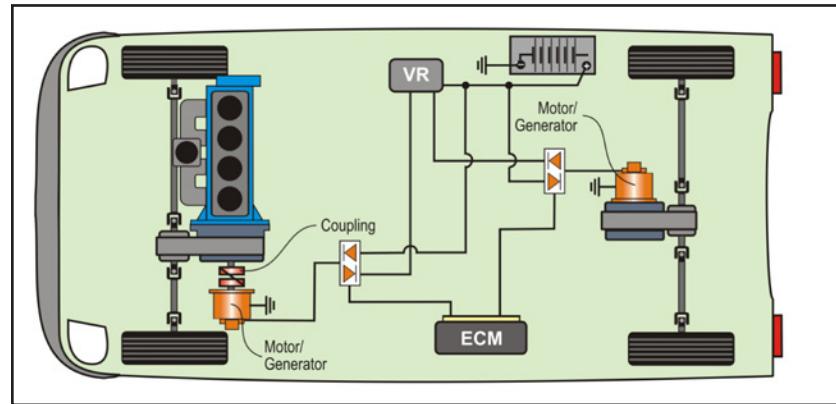


Figure 7 Four-wheel-drive hybrid vehicle, derived from front wheel drive.

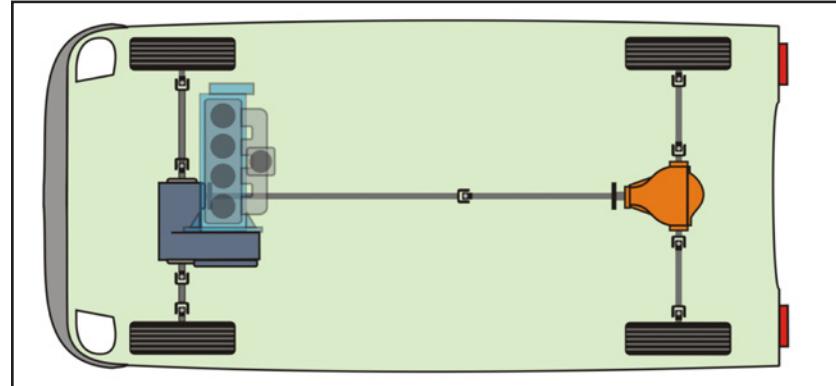


Figure 8 Four-wheel-drive, derived from front wheel drive.

rotate the drive shafts. The rear axle motor can also act as generator in cases of vehicle deceleration. The engine connected generator charges a battery to provide enough electrical energy to feed the rear axle motor. The transmission allows for a disconnection of the engine and the front axle, while the electric motor is still mechanically connected with the front axle and can act as a generator in cases of deceleration.

A common concept today is a four-wheel-drive vehicle with an "east-west" engine and a power take off unit (PTU) that drives a propeller shaft and a rear axle. Figure 8 shows the basic drive train arrangement of such a four-wheel-drive vehicle, derived from the most common front-wheel-drive concept. The power split between front and rear axle is commonly 60% (front) and 40% (rear). A power take off unit is mounted (mostly as an add-on) to the side with the longer drive shaft. All the power

passes through the transmission — including the final drive gears — before a part is split off by the PTU and redirected by 90°.

The PTU is also a speed increaser, where the ring gear drives the pinion. This is commonly done in order to keep the torque in the propeller shaft lower than required on the drive shafts. The rear axle reduces the speed by the same factor that the PTU had used for increasing the speed. This is done in order to achieve the correct torque and rpm for the rear drive shafts. The procedure of speed increase in gear trains is less efficient than speed reduction. The following efficiency calculation considers this fact, but it only applies this to 40% of the vehicle's energy consumption.

The approximate efficiency of such a system is:

- Combustion engine (38%)
- Transmission (94%)
- Final front and PTU drive, (98%)
- Front and rear, Inner CV joints (99%)
- Front outer CV joints (steering, 95%)
- Rear, outer CV joints (40% power, 99.6%)

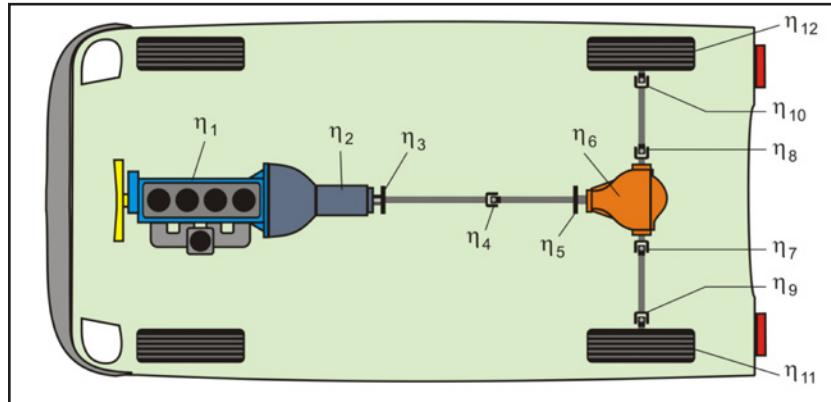


Figure 9 Modern rear-wheel-drive concept.

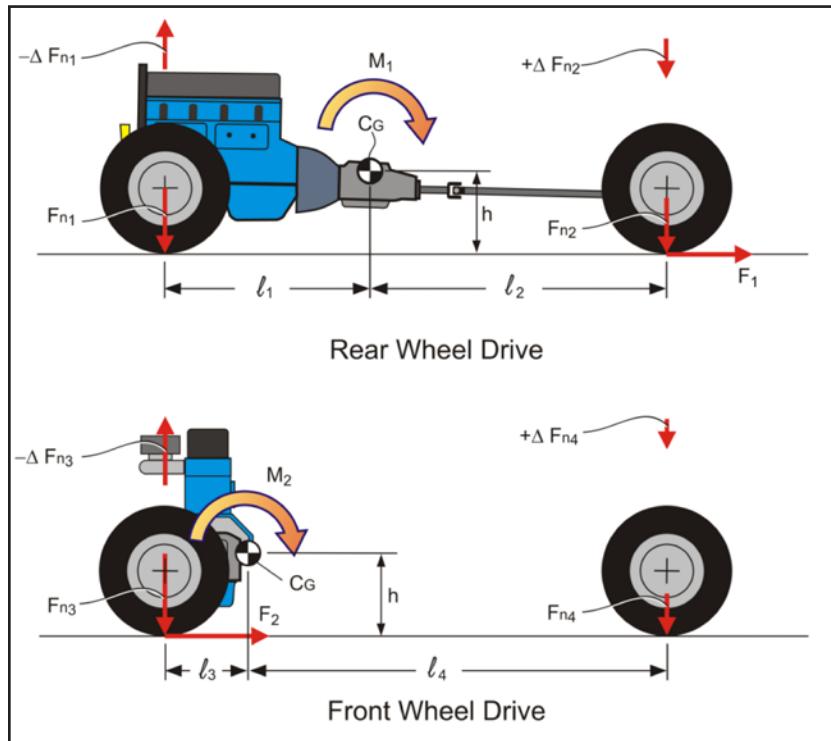


Figure 10 Center of gravity and force diagram for longitudinal and "east-west" engine orientation.

- PTU (gear drives pinion, 40% energy, 96.5%)

- Hardy disks (40% power, 99.4%)

- Universal joint (40% power, 99.6%)

- Rear axle, 40% power (98%)

- Traction factor, wheel-road (96%)

- Efficiency improvement due to hybrid function (X)

$$\eta_{total} = 0.38 \cdot 0.94 \cdot 0.98 \cdot 0.99 \cdot 0.95 \cdot 0.996 \cdot 0.965 \cdot 0.994 \cdot 0.996 \cdot 0.98 \cdot 0.96$$

$$\eta_{total} = 0.295$$

Rear-wheel-drive—conventional and hybrid. Modern rear-wheel-drive technology is becoming more popular. Premium class compact cars, sedans, and luxury vehicles benefit from rear-wheel-drive because of the optimal weight distribution with a center of gravity behind the front axle. This allows those vehicles safe maneuvering in critical driving conditions. The advantage of excellent control and high safety are combined with high fuel economy of rear-wheel-drive vehicles.

The overall efficiency of the system shown (Fig. 9), besides the factor X, which is not applicable, is the highest of all the different solutions discussed:

- Combustion engine (38%) Transmission (94.5%)

- Hardy disks (98.8%)

- Universal joint (99%)

- Rear axle (97.5%)

- Inner CV joints (99%)

- Outer CV joints (99%)

- Traction factor, wheel-road (95%)

$$\eta_{total} = 0.38 \cdot 0.945 \cdot 0.988 \cdot 0.99 \cdot 0.975 \cdot 0.99 \cdot 0.99 \cdot 0.95 = 0.319$$

The vehicle manufacturing cost, related to the drive train components, is comparable to front-wheel-drive vehicles. Serviceability of the system (Fig. 9) is better and the service and repair statistics show that the drive train from the transmission to the rear wheels causes little or no issues during the life of a vehicle. This is quite different in front-wheel-drive vehicles.

Fuel economy is based not only on engine and drive train efficiency, but also on traction and slippage of the wheels that transmit the driving force to the road. The driving force F (Fig. 10) is always present, except in the case of coasting without any engine brake action. F multiplied with the height of the center of gravity causes a moment, clockwise about the center of gravity G , which in turn gives an additional normal force to the rear axle and takes away normal force from the front axle. This means, in the presence of a driving force, the traction will be enhanced in the case of rear-wheel-drive and reduced in the case of a front-wheel-drive.

Front-wheel-drive vehicles have very high front tire wear because the main brake load, steering forces and driving force act on the same two wheels. The driving force applied to the rear wheels will distribute the different forces better between the four wheels and, as explained before,

enhance the traction which is expressed as efficiency factor between tires and road. In this chapter, the traction efficiency factors used in connection to the different concepts are:

- Front-wheel-drive: $\eta_{traction} = 93\%$
- Rear-wheel-drive: $\eta_{traction} = 95\%$
- Four-wheel-drive: $\eta_{traction} = 96\%$

The concept in Figure 11 uses a longitudinally oriented engine which is connected via transmission and clutch with an electric generator. The generator is connected with the propeller shaft and charges electrical energy to the battery. In cases of downhill driving or deceleration the generator receives mechanical energy through the propeller shaft from the rear axle. The generator acts as an electrical motor in cases of acceleration and shares the required power to drive the vehicle with the combustion engine.

The overall efficiency of the rear-wheel-driven hybrid vehicle consists of the following single efficiency of engine and drive train components:

- Combustion engine (38%)
- Transmission (94.5%)
- Hardy disks (98.8%)
- Universal joint (99%)
- Rear axle (97.5%)
- Inner CV joints (99%)
- Outer CV joints (99%)
- Traction factor, wheel-road (95%)
- Efficiency improvement due to hybrid function (X)

$$\eta_{total} = 0.38 \cdot 0.945 \cdot 0.988 \cdot 0.99 \cdot 0.975 \cdot 0.99 \cdot 0.99 \cdot 0.95 \cdot X = 0.319X$$

The four-wheel-drive concept (Fig. 12) has, in addition to the rear-wheel-drive concept in Figure 11, a transfer case with a propeller shaft which is connected to a front axle unit. The common split of power is 40% to the front and 60% to the rear. The hybrid function is identical to the rear-wheel-drive version.

The overall efficiency of the four-wheel-driven hybrid vehicle consists of the following single efficiency of engine and drive train components:

- Combustion engine (38%)
- Transmission (94.5%)
- Rear&front, inner CV joints (99%)
- Front, outer CV joints, 40% energy split (steering, 97.5%)
- Rear propeller shaft hardy disks, 60% rear energy split (99.1%)
- Rear propeller shaft universal joint, 60% rear energy split (99.4%)
- Two front propeller shaft universal joints, 40% energy split (99.2%)
- Rear&front axle (96%)
- Rear, outer CV joints, 60% rear energy split (99.4%)
- Traction factor, wheel-road (96%)
- Efficiency improvement due to hybrid function (X)

$$\eta_{total} = 0.38 \cdot 0.945 \cdot 0.99 \cdot 0.975 \cdot 0.991 \cdot 0.994 \cdot 0.992 \cdot 0.96 \cdot 0.994 \cdot 0.96 \cdot X$$

$$\eta_{total} = 0.310X$$

Modern four-wheel-drive systems with torque vectoring achieve improved efficiency due to the reduction of mechanical energy loss, but also deliver breathtaking traction and cornering abilities (Ref. 4).

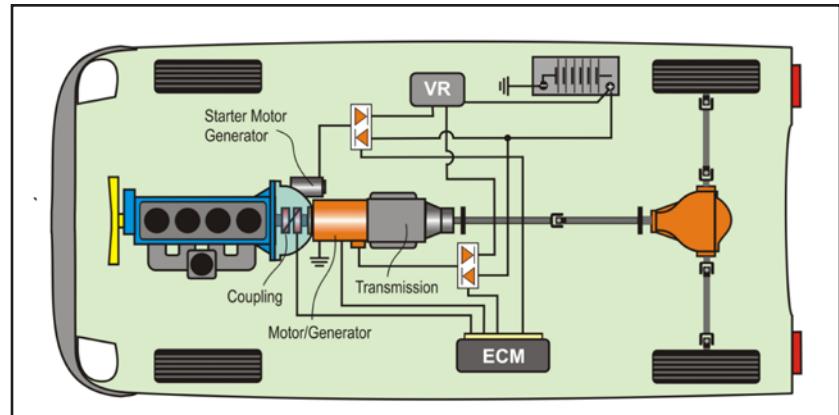


Figure 11 Rear-wheel-drive hybrid concept.

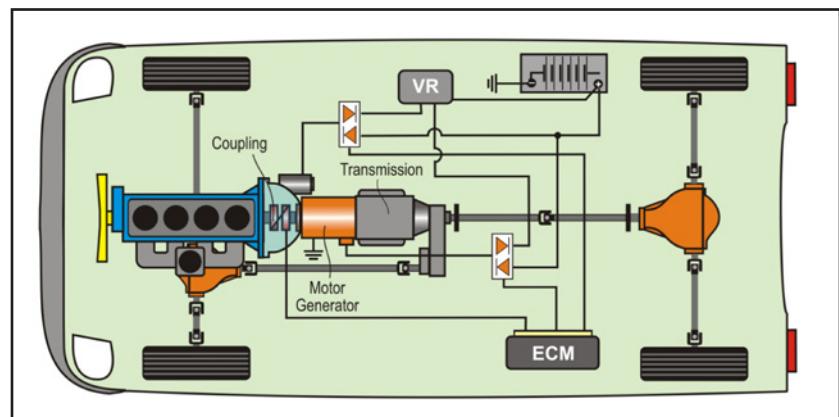


Figure 12 Four-wheel-drive hybrid concept, derived from rear wheel drive.

Conclusion

The comparison of all basic drive concepts and approximate total efficiencies lead to the following efficiency ranking:

1. Rear-wheel-drive: $\eta_{total} = 31.9\% (+4.2\%)$
2. Four-wheel-drive with longitudinal engine: $\eta_{total} = 31.0\% (+1.3\%)$
3. Front-wheel-drive with "east-west" engine: $\eta_{total} = 30.6\%$ (reference 100%)
4. Four-wheel-drive with "east-west" engine: $\eta_{total} = 29.5\% (-3.6\%)$
5. Four-wheel-drive with electrical wheel hub motors: $\eta_{total} = 18.8\% (-38.6\%)$

The comparison shows that if No. 3 (the common concept for today's compact cars) is used as a reference basis (equalized to 100%), then a rear-wheel-drive vehicle with the same body style and weight will achieve 4.2% higher efficiency. Beyond this, the rear-wheel-drive vehicle will require lesser maintenance in the drive train and has a lower tire wear. An interesting aspect of the comparison is also the fact that the most economical four-wheel-drive has a longitudinal engine and even out performs a front-wheel-drive only vehicle with similar body style and same weight.

Rear-wheel-drive vehicles are perfectly suitable as compact and small cars. The classic compact vehicle shown (Fig. 13) is vintage 1966, and is still on the road today. It still has a rather low average fuel consumption of 6.76 liter/100 km (35miles/gallon), while it was mostly used for country side driving. The vehicle in Figure 13 has a curb weight of 780kg (1,700lbs) and is driven by a beam style rear axle. A similar vehicle with today's technology (efficiency improved combustion engine, modern 5- or 6-speed transmission and a modern, independent rear axle with traction control) would most likely achieve 6.0 to 5.3 liter/100km (40 to 45miles/gallon), even without hybrid technology.



Figure 13 Opel Kadett B, RWD, built in 1966.

A rear-wheel-drive passenger car has a good weight balance and shows better control in steering action and dynamic driving situations than comparable front-wheel-driven cars. Inefficient beam rear-axle technology and the easy assembly package of front-wheel-propelled cars led automobile manufacturers to pick the front-wheel-drive as their concept of choice for sedans of all sizes. This trend started in the 1980s and continues today. However, for about 5 years we have seen a trend to rear-wheel-driven mid-size sedans with longitudinally oriented engines and the four-wheel-drive derivatives thereof.

Some manufacturers picked the rear-wheel-drive concept — even for their latest compact editions — and demonstrated that the “driving pleasure” and the feeling of safety in their small cars are outstanding. Figure 14 shows a compact and a midsize vehicle with rear-wheel-drive and a dominating sporty image. However, BMW demonstrated with their introduction of a 1-Series makeover in spring 2007 that the rear-wheel-drive concept is a very good basis for not only sporty, but also for very economical small vehicles. This vehicle has been called “mild hybrid” in www.hybridcars.com (Ref. 6). The report highlights features such as variable valve timing; electric power steering; lightweight materials; low- resistance tires; gearshift change indicator; and, most notably, an auto stop function with regenerative braking. The vehicle promises outstanding handling and excellent fuel economy between 6.0 and 5.0 liter/100 km (40 to 33miles/gallon) during highway and country side driving. At the same time, the fact that the 1-Series requires neither an additional electric motor nor a considerable capacity of batteries is an advantage to both the “total cost of ownership” and also the environment. ☀

For more information.

Questions or comments regarding this paper?
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Figure 14 Modern RWD vehicles, BMW 1-series (top) and Dodge Charger (bottom).

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Dr. Hermann J. Stadtfeld is the Vice President of Bevel Gear Technology and R&D at the Gleason Corporation and Professor of the Technical University of Ilmenau, Germany. As one of the world's most respected experts in bevel gear technology, he has published more than 300 technical papers and 10 books in this field. Likewise, he has filed international patent applications for more than 60 inventions based upon new gearing systems and gear manufacturing methods, as well as cutting tools and gear manufacturing machines.

Under his leadership the world of bevel gear cutting has converted to environmentally friendly, dry machining of gears with significantly increased power density due to non-linear machine motions and new processes. Those developments also lower noise emission level and reduce energy consumption.

For 35 years, Dr. Stadtfeld has had a remarkable career within the field of bevel gear technology. Having received his Ph.D. with summa cum laude in 1987 at the Technical University in Aachen, Germany, he became the Head of Development&Engineering at Oerlikon-Bührle in Switzerland. He held a professor position at the Rochester Institute of Technology in Rochester, New York From 1992 to 1994. In 2000 as Vice President R&D he received in the name of The Gleason Works two Automotive Pace Awards—one for his high-speed dry cutting development and one for the successful development and implementation of the Universal Motion Concept (UMC). The UMC brought the conventional bevel gear geometry and its physical properties to a new level. In 2015, the Rochester Intellectual property Law Association elected Dr. Stadtfeld the "Distinguished Inventor of the Year." Between 2015–2016 CNN featured him as "Tech Hero" on a Website dedicated to technical innovators for his accomplishments regarding environmentally friendly gear manufacturing and technical advancements in gear efficiency.

Stadtfeld continues, along with his senior management position at Gleason Corporation, to mentor and advise graduate level Gleason employees, and he supervises Gleason-sponsored Master Thesis programs as professor of the Technical University of Ilmenau—thus helping to shape and ensure the future of gear technology.

