"Summarized Paper" for JSAE Spring Meeting in 2021 for your reference

▼ Methodology for calculating CO2 emissions from EVs

▼ Vibration Reduction Effect of Heron Balancer

***Self Introduction written in 2019**

I am a visiting professor at Hiroshima University, and also a motor journalist. I posted articles at the beginning of 2019 in Motor Fan Tech, an internet magazine, why the series hybrid and opposed piston 2 stroke engine is now in a broad perspective.   Following 7 articles are English translation from original manuscript.

1. My encounter with EVs, and my engine philosophy "Not having engine is better"

I've been a glider pilot since my school days and have been enjoying flying without engines using the power of nature for 50 years. I went to Australia, and flew more than 300 km over 5 hours without an engine. I also flew a motor glider with an engine, but I was relieved to stop the engine in the sky after take off. You can only hear the sound of the wind. Readers might find it hard to imagine, it feels much more like when a car is in idle stop. From here I came to think that "it is better not to have an engine". The engine generates a vibration noise, consumes fuel, emits exhaust gas, is heavy and takes up space ,,,. If the car can drive, you should not have an engine.

A student glider pilot who was majoring in robotics, Dr. Hatamura joined Toyo Kogyo (now Mazda) in 1975 and will be in charge of the development project of an autonomous car which has no engine called the new transportation system. I encountered the latest technology of the time ; light truck electric vehicle, with many lead batteries loaded tightly under the loading platform. At that time, when manual transmission was the nature, I was fascinated by the comfortable running of the EV. Although the absolute running is poor, the honest response when stepping on the accelerator, the quiet running without engine noise, the smooth acceleration without the need for gear shifting and the endless running, ..., the ideal car might there. However, battery performance at that time made it far from practical. And due to the oil crisis of the 1970s, the new transportation system project was dissolved after just three years, and I was moved to the engine design department.

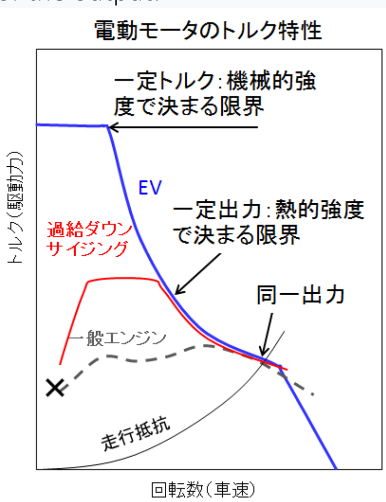
that "Not having engine is better", but I could not eliminate the engine. As a result of working on engine research and development for 40 years after being embedded in the turbocharged engine, in any case I have tried to make the engine smaller. Based on my engine philosophy, in 1993 I commercialized the world's first supercharged downsized gasoline engine miller-cycle engine. After that, we continued to advocate "turbocharged downsizing" and finally Japanese manufacturers also established turbocharged downsizing engines, but with the change of the exhaust gas measurement mode, light sizing / upsizing restores the overrun of downsizing. At the same time, in the context of the political protection policy automobile of each country, a trend has been born that the engine might be gone. So I began to insist that "the engine can not go away". What I think is important recently is the engine philosophy that "I can not lose the engine" but "I should not have the engine". The meaning of this will be explained below.

Mazda Company Guide in 1975

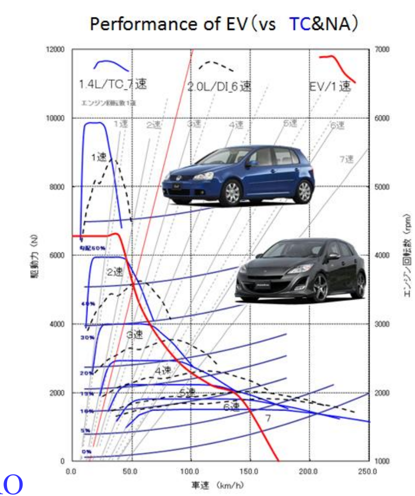
2. **Ideal for running a car and the limits of a rotating machine.**

Here, returning to origin I would like to think about the running of a car. The driving force of the car generates a large force from zero speed, and it is ideal to maintain the driving force to a high speed. The driving torque of the tire is a value obtained by multiplying the torque of the rotating machine (engine / motor) by the reduction ratio, but if the frictional force of the tire is sufficiently high, the maximum driving force is limited by achieved mechanical strength of the rotating machine inside or the reduction mechanism. The energy source of the rotating machine (fuel / power) multiplied by the energy efficiency can be taken as an output, but the remaining energy is released as heat.

When the heat causes the temperature of the rotating machine to rise to a temperature limit (eg, the temperature of the exhaust of the engine / the temperature of the winding of the motor), the output of the rotating machine becomes the limit. Maintaining the maximum driving force from low speed, and when the speed increases, the driving output (= driving force × speed) increases to the maximum output point, above the speed the torque decreases and maintain keep the output. It becomes the driving force curve of the output.



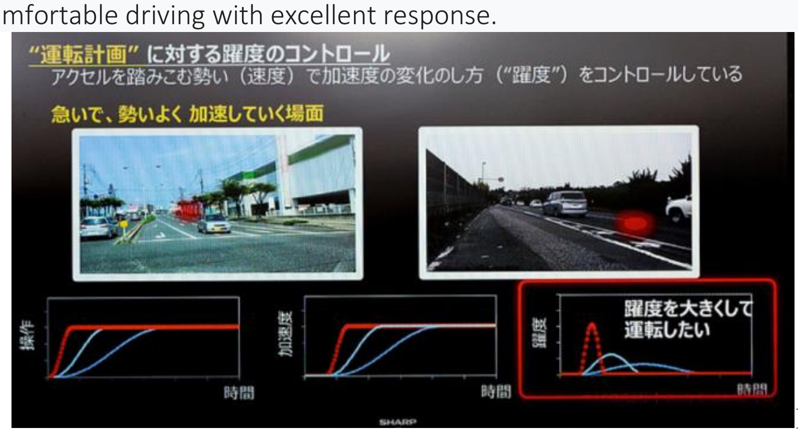
HERO



HERO

The electric motor drive has just such an ideal torque characteristic, but in the case of an engine, it can not be operated at zero rotation speed, and after 1000 rpm, a small torque is finally output, and the maximum torque is achieved at medium speed and at higher speed it will decline. Therefore, It is trying to force the ideal driving force curve by using a transmission, but since AT requires a shift, it can not avoid a response delay and shift shocks due to changes in engine speed. In the case of CVT, although it is a continuously variable transmission, the response delay accompanying engine speed change and the rubber band feel which is often described are unavoidable.

On the other hand, there is a word "YAKUDO (KAKASOKUDO)" that Mazda has recently started to claim. It is not a Mazda coined word but in the dictionary. It is called "Jerk" in English and is a word often used to evaluate the ride comfort of vehicles. The driver adjusts the acceleration with the amount of depression of the accelerator and adjusts the degree of jerk with the depression speed, so the idea is that a comfortable running can be realized by matching the movement of the car to the driver's expected value. Mazda is pursuing this ideal with the powertrain control of the car’s engine, and aims to provide comfortable driving with excellent response.



Mazda test ride（2017 December）

Even with conventional car’s engine, the expected acceleration can be obtained according to the degree of accelerator pedal depression , but it is impossible to achieve the target Jerk. In addition to the fact that a four-cycle engine response requires tow revolutions(one cycle) of dead time, when a large acceleration is required, the expected driving force can’t be obtained until the engine speed is increased by shifting with the transmission. As a result, a time lag is unavoidable after pressing in accelerator. Since the driver is used to it, it does not feel non-conforming, and in fact, there is a big divergence between the accelerator pedal speed and the Jerk. To achieve an ideal run, only an electric motor drive which can be controlled instantly as aimed can be considered. As more and more people get into the attractive driving EVs coming out one after another, there will be an increasing number of users who are not satisfied with the driving comfort without using an electric motor. In addition, even if automatic driving becomes widespread and AI controls the accelerator, the superiority of the electric motor drive does not change in terms of comfort and safety. Cars that drive tires directly with engines may one day become called 20th century relics.

3. CO2 emissions from Well to Wheel of various powertrains

Next-generation vehicles aim to reduce CO2 emissions are,

1) electric vehicles (EV),

2) fuel cell vehicles (FCV),

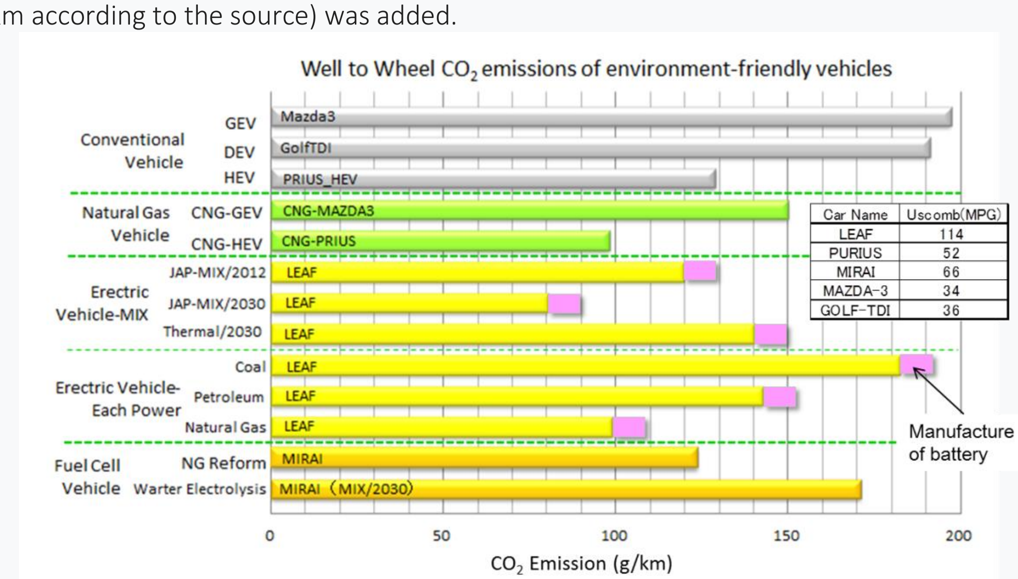
3) high efficiency engine + hybrid (HEV),

4) natural gas vehicles (NGV) etc.

However, in order to correctly estimate the CO2 emission reduction effect, it is necessary to calculate CO2 emissions without leakage at the well to wheel including the manufacturing process of each energy source (electric power and fuel).

The figure shows the author's calculation of CO2 emissions from Well to Wheel of various powertrains. The fuel efficiency of each powertrain is not JC08, which is pointed out that there is a discrepancy with the practical fuel efficiency, but using the fuel efficiency label value of the EPA of vehicles sold in the United States with various corrections to approximate practical fuel efficiency. Since EV and FCV differ greatly in CO2 emissions depending on the method of producing electricity and hydrogen, The EV is calculated using the average value of CO2 emission of 2012 when the nuclear power plant hardly worked and 2030 power supply configuration plan is realized. The FCV is shown for the case of natural gas reforming with the lowest emissions and for the case of electrolytic hydrogen in a 2030 power supply configuration.

The effect of renewable energy 23%, nuclear power 21% is large, CO2 emissions of EV of the power average of 2030 become the smallest. On the other hand, in the case of coal-fired thermal power, it is equivalent to the CO2 emissions of conventional engine vehicles. Furthermore, in the case of EV, since a large amount of energy is used in the battery manufacturing process, the value of its CO2 emissions (10 to 30 g / km according to the source) was added.



For the 2030 assessment aiming to reduce CO2 by about 30%, it is possible to use such calculations based on current fuel and power, but the COP21 (2015 21st Framework Convention on Climate Change) adopted at The Paris Agreement adopted by the signing country conference calls for an 80% reduction in CO2 emissions in developed countries by 2050. It is at a level that can not be achieved by conventional methods for improving fuel efficiency, and it is essential to use carbon neutral (practical zero CO2 emission) energy produced from renewable energy by innovating the production process of electricity and fuel. Renewable energy includes hydrocarbons (gas, liquid, solid) produced from bioenergy and electricity produced from hydro, geothermal, wind, solar and marine energy. Part of the power can be converted to hydrogen energy by water electrolysis. The reaction of hydrogen and the recovered CO2 can produce a gas (methane) or liquid synthetic fuel.

http://www.pride-trendaffiliate.com/archives/1708.html

Power is expected to be promising in the simplistic thinking because it does not emit exhaust gas directly from the car, but in the medium term, the spread of EVs has no effect on CO2 reduction unless a drastic review of power supply configuration is implemented. It is thought that some energy will be mixed until it goes to the final form after 2050 via 2030. In the long-term, the power supply configuration has been greatly reconsidered, and the thermal power plant that emits CO2 has been abolished, and the electric power derived from renewable energy has become the main power source, as described above. As with FCV, HEV and NGV, fuel derived from renewable energy is used, and carbon neutral travel will be achieved.

In this way, the spread of EVs is not always an effective means to reduce CO2 in the medium to long term. In addition, in order to drive vehicles using renewable energy, it is necessary to consider the cost per unit of CO2 reduction associated with vehicle production, fuel production, and infrastructure maintenance. In some cases, EVs are not wise in terms of the cost of CO2 reduction due to the high cost of not only charging infrastructure investment but also the mass production of cars. In order to achieve significant reductions in CO2 emissions from automobiles, the total social cost required to achieve the target is evaluated, and then the powertrain is considered in consideration of the performance and convenience of the car, which is a condition for widespread use. It is important to choose.

4. **Fuel for Carbon Neutral Driving**

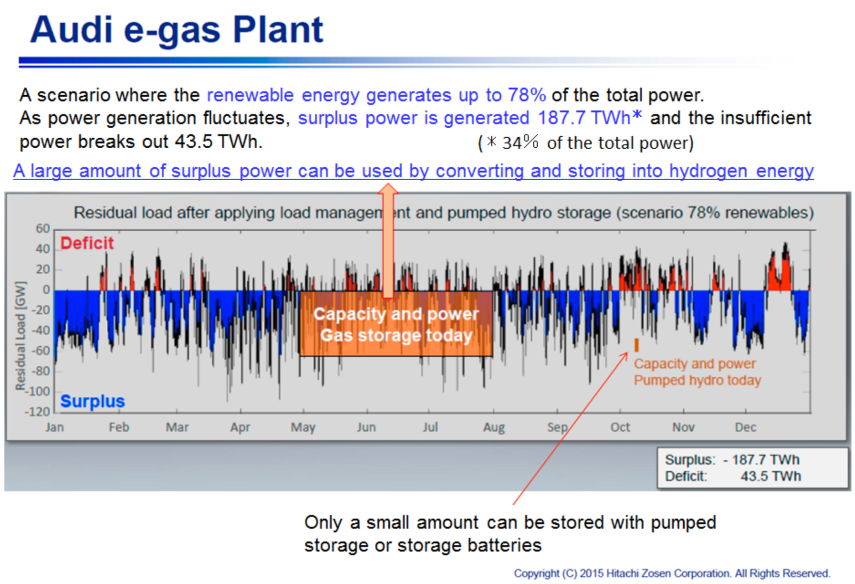
Attention is being focused on EV that use electric power generated by renewable energy generation and FCV that use hydrogen produced by decomposing water as cars that achieve carbon neutral running. Consider the form of renewable power supply required for a large number of cars.

If the thermal power plant is operating in the power system that charges the EVs, stopping charging the EVs and stopping the thermal power plant equivalent to that amount of power is effective in reducing CO2 emissions. If you stop the coal-fired plant by running gasoline with HEV instead of charging with EV, CO2 emissions will be reduced to about 2/3 overall. In other words, the conditions for EVs to run in carbon neutral mode are limited to cases where there is no thermal power plant that emits CO2, and if there is no demand for EV charging, renewable power will be surplus.

Lack of power is often a topic, but when unstable renewable energy power generation spreads in earnest, there is the problem of excess power. This situation will frequently occur at a national level in the future, just as in Kyushu October 2018, the surplus of electricity would prevent renewable energy generation.

There is a document like the figure below which predicted the power situation of 2050 in Germany. Renewable energy generation accounts for 78%, and it has been shown that there is a shortage or surplus of power depending on the weather. The surplus power lasts about one month, and the amount of power is about 200 TWH per year (the amount of power in Garmany is about 500 TWH / year), which is too great an amount to store in batteries or pumped power generation.

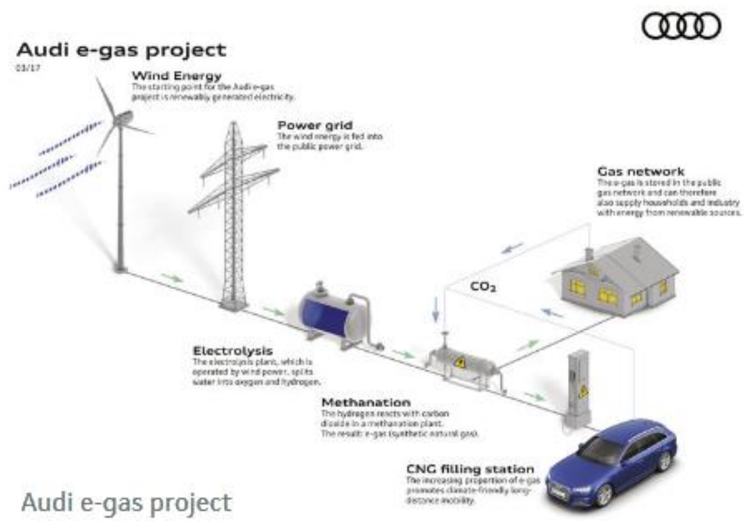
At present, the only way to store this amount of power is to convert it into hydrogen. This is the reason for aiming to build a hydrogen society. Surplus power is truly renewable energy, and if it is converted to hydrogen energy, it can be stored, taken out when needed, and returned to power by hydrogen power generation. That power can charge the EV, or FCV can use hydrogen directly. It will be decided finally by the superiority of the overall efficiency, “hydrogen power generation → power transmission → EV charging → electric drive driving” and “hydrogen filling → fuel cell → electric drive driving”. It can also be reacted with the recovered CO2 to produce hydrocarbon fuels that can be used in engines. This is largely due to technological innovation in the future.



The latter half of the 21st century is expected to become a society that uses this hydrogen energy. Hydrogen is stored and transported in high-pressure tanks and liquid hydrogen, but the energy density per volume is low, so an ultra-high pressure of 350 atmospheres is required, and an ultra-low temperature of -253 ° C is required to make it liquid. Storage and transport of hydrogen involves significant energy consumption. Therefore, it combines with toluene to form a liquid organic hydride, combines with nitrogen to form an ammonia that is easy to liquefy, and reacts with CO_2 to t transform it to a main component of natural gas, methane. Methods are researched and developed.

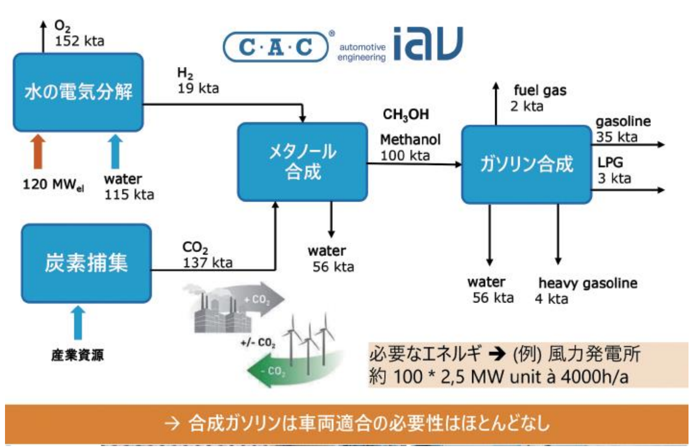
On the other hand, carbon-neutral fuels used for automobile engines are known to use biomass that uses algae, or to burn methane gas produced by fermenting plants or waste, but little is known about gas and liquid fuels that are synthesized using hydrogen derived from renewable energy and recovered CO_2.. The former is said to have a problem in securing an amount sufficient to meet the massive demand for automobiles, so let's think about the latter here.

With regard to carbon neutral fuel, a plant in which Audi has been reaching reacts electrolytic hydrogen and CO_2 from the biogas plant to generate a methane called e-gas since 2013 , can operate 1,500 NGVs per year for 15,000 km. Since methane is the main component of natural gas, it can be used by flowing into existing pipelines, or it can be used as it is in NGV.



AUDI Media Center

Fuels synthesized from hydrogen and CO2 are called e-fuel, and Audi is keen on this development, and in addition to methane (e-gas), is promoting development to produce gasoline (e-gasoline) and diesel (e-diesel) fuel. The e-diesel has a pilot plant already in operation, and the e-gasoline has a demo plant in operation. Apart from this, Iceland not only produces hydrogen by geothermal power generation, but also produces liquid fuel by reacting it with CO2 that comes out secondarily. The plant, which began operation in 2012, produces 100,000 tons of methanol annually and mixes it with gasoline. The process of producing gasoline from hydrogen and CO2 is shown in the figure below.



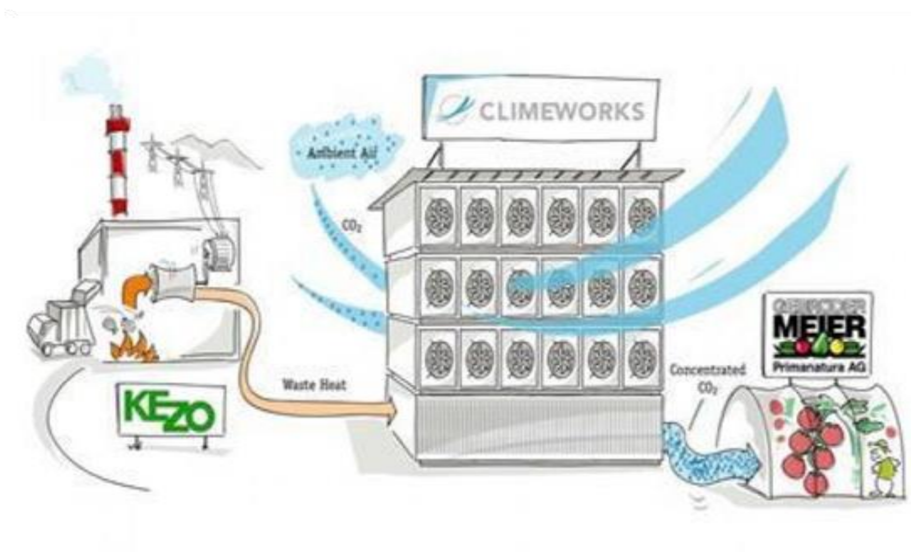
MOTOR FAN ILLUSTRATED/Vol.142P85

However, it should be noted here that although using renewable power to produce hydrogen is the same as in the case of EV, thermal power generation that emits CO2 in the same power system is running. It is a fact that CO2 reduction is more effective if you run HEVs that use gasoline to stop thermal power generation, rather than using that power for hydrogen production. It is meaningless if you do not produce hydrogen with surplus power, but unlike EV charging, hydrogen production it is possible to choose the time zone when surplus power is generated. Since the cost of electricity is reduced during the time when surplus power is generated, it is reasonable to produce hydrogen during that time, economically.

Currently, it cannot be said that producing hydrogen uses fully surplus power, but we can tell from the e-gas data from Audi that the situation is similar to using surplus energy. It will be about 100% renewable energy methane in the future.

Even if methane is not 100% renewable energy, when methane-based natural gas is used, methane (CH 4) molecules contain less carbon, so the CO 2 emissions of natural gas are reduced by about 25% relative to gasoline. Starting with a 25% reduction and finally being able to make a continuous transition to a 100% reduction, methane can be realized using established technology, so I think it should be more focused on as a fuel for the future.

On the other hand, since the production of e-fuel requires CO2 and emits CO2 at the time of combustion, there is still the problem that it can not be used if there are no power plants or plants that emit CO2 in the future. The news that swiss venture company Climeworks has commercialized the technology to recover CO2 in the atmosphere and that a commercial plant that supplies CO2 (which activates photosynthesis) to the greenhouse of farmers has started operation has been noteworthy recently. The atmosphere is sucked with a fan and passed through a special filter to absorb CO 2 at a concentration of 0.03% to the filter, and when the filter is full, the temperature is raised to 90 ° C. The absorbed CO 2 is released. It is a dreamlike technology that you can collect CO2. A temperature of 90 ° C uses the waste heat of the power plant and no additional energy is required. The only energy needed is the power to drive the fan. Audi uses this CO2 to operate an experimental plant that produces diesel fuel by reacting with hydrogen like e-fuel.



igure : CLIMEWORKS

SankeiBiz 2016.3.9

In this way, it is not only renewable energy power that realizes carbon neutral travel, but also hydrogen, which is energy converted from that power, and fuels of gas and liquid prodeuced using the hydrogen, and these fuels are mounted on the vechicle and burned in the engine to drive the vechicle.

Can occur. In particular, if gasoline and diesel fuel can be synthesized using renewable energy, it has the attractive feature that existing infrastructure and vehicles can be used as they are. In order to achieve significant reductions in CO2 emissions, with a view to technological changes and changes in the social environment, we should consider the use of energy and the continuity of infrastructure in each age, and calmly plan the widespread use of next-generation vehicles. It must be remembered that EV is not the only way to do it. "The engine won't go away".

5. **Powertrain that balances running and environmental performance**

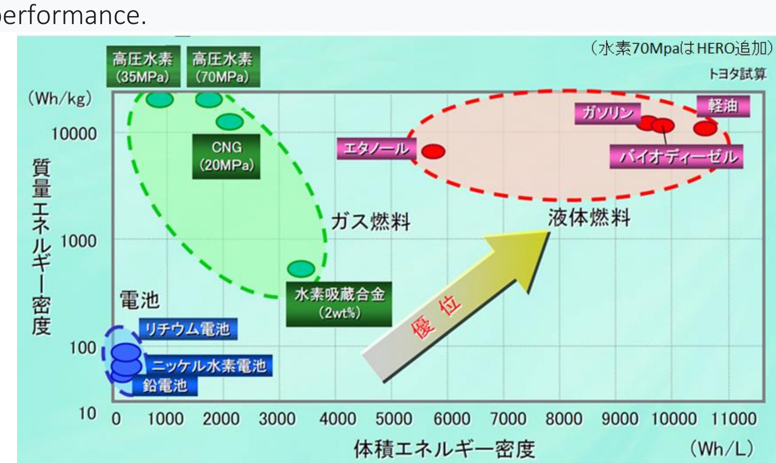
Section 2 describes the ideal of running a car, Section 3 explains the environmental performance of various powertrains, and Section 4 transforms the manufacturing process of energy (electric power and fuel) to achieve significant future CO2 reductions. We have introduced the need and the movement. The following two conclusions can be drawn from there.

1) Nothing other than the electric motor drive can be considered to realize the ideal of the running of the car.

2)In the medium term, there is no effect of CO2 reduction in the spread of EVs that charge while driving. In the long run, not only EVs but also FCVs and HEVs that run on renewable fuels will be carbon neutral.

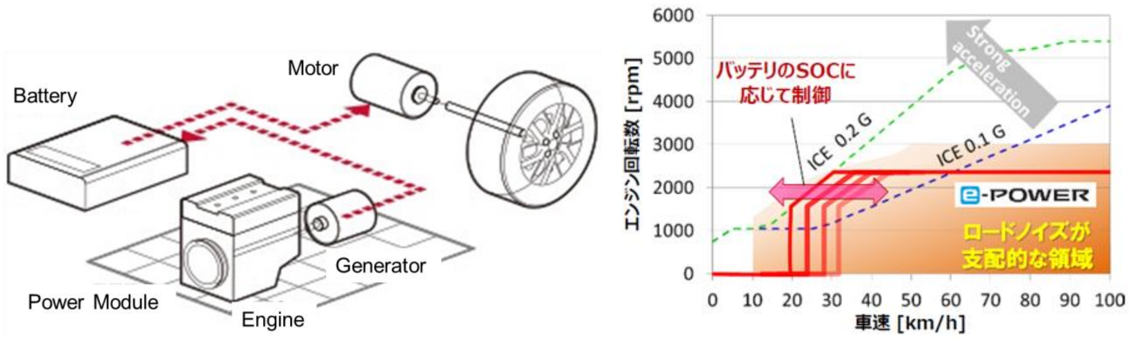
From this, a car that achieves both driving and environmental performance is a hybrid that is driven by electric motors and runs with fuel, not charging. That is, it is a series hybrid represented by e-POWER. In terms of running, EVs also pass, but in the medium term it is necessary to curb the spread according to the extent of the spread of renewable energy (the abolition of thermal power plants).

Considering that a car is a moving body, the energy density of the mounted energy source (electric power or fuel) is an important factor. The energy density of various energy sources is shown in the figure below. The energy density of the cell is two orders of magnitude smaller than that of liquid fuel. Gas fuel is in between. Even if battery technology advances, it will not reach the high energy density of liquid fuel. Considering that the mass of the car has a great effect on running and fuel efficiency, even if carbon neutral running is realized, EV can not move from a disadvantageous position in terms of both running and environmental performance.



Diversification of fuel and energy and initiatives for biomass_2006TOYOTA

For the above reasons, we will pursue the possibilities of series hybrids here. In July last year, I drove 1100km in Hokkaido with a Note e-POWER to explore the potential of the series hybrid. The e-POWER is a series hybrid configuration, with no mechanical connection between the engine and the tire, and the engine employs a 1.2L 4-cylinder miller-cycle dedicated to power generation. The relatively small engine is not operated at low speeds with low road noise, and the engine starts only after the vehicle speed has increased to about 30 km / h. The engine noise is hidden by the road noise, or even if it is heard, the rotational speed is increased with the vechicle speed, so there is no sense of discomfort. The control is strictly "to have no engine".



Nissan public relations materials

Last summer in Hokkaido was extremely hot and so needed air-conditioning, but the value of the fuel meter showed an average of 26 km / L, and the worrying fuel consumption of the expressway was also equal to the suburban fuel consumption. It was not a hybrid that thoroughly pursues fuel consumption, but a journey that was highly satisfying with the series hybrid, which pursues driving comfort (Not having engine is better). Returning to Hiroshima and driving our research vehicle Demio Diesel, I was anxious about the stop / start of the engine, noise at low speed acceleration, shift time lag, etc. I could not help feeling that direct engine drive impaires the driving comfort.


HERO

At the end of last year, the author, who was fascinated by the e-POWER run in summer, gave up the familiar Demio for four years and bought the e-POWER Note as a research vehicle. It enjoys a round trip to Hiroshima University and a comfortable run, but unlike summer, the frequency of engine operation has increased significantly. It's quite loud when the engine runs at low speed. The cause seems to be that the engine is being operated to keep the water temperature high as it heats up in winter. Even in the case of Demio, the idle stop often did not work when it was cold, and in the same way operating the engine for heating is not good from either a noise nor an efficiency aspect. I look forward to future improvements.


HERO

From the below figure that shows the operating range of the e-POWER engine, it can be seen that it is operating at a pinpoint of 70 Nm@2400 rpm in practical driving. When accelerating on a freeway or uphill, it increases the number of revolutions with the same torque and generates the required output. In other words, there is room to further improve fuel efficiency by developing a dedicated engine that is largely different from the conventional one by using an e-POWER-like series hybrid that can use an engine specialized for only a specific operating point.

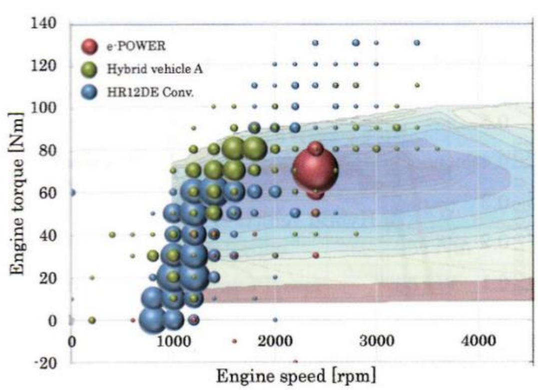


図-7　実用燃費モードでのエンジン動作点頻度
Fig. 7　Operating point for real-world fuel economy
(Nissan's definition)

NISSAN Technical Review/2017No.80

6. **Toward Realization of High Efficiency Engine Dedicated to Series Hybrid**

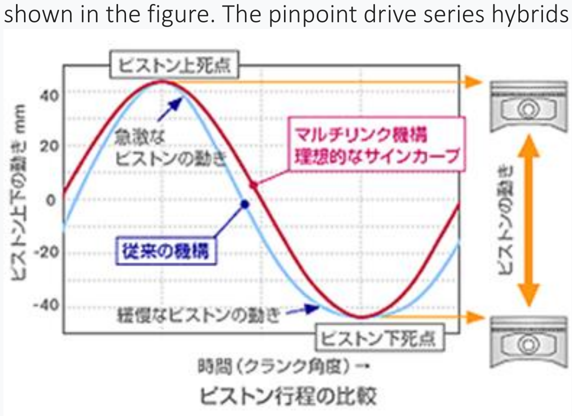
Technologies that improve engine thermal efficiency in response to increasingly stringent fuel efficiency regulations are being commercialized or developed in automotive companies around the world. Among them, SKYACTIV-X, which is scheduled to debut this year, is attracting particular attention. It has become the world's first HCCI engine.

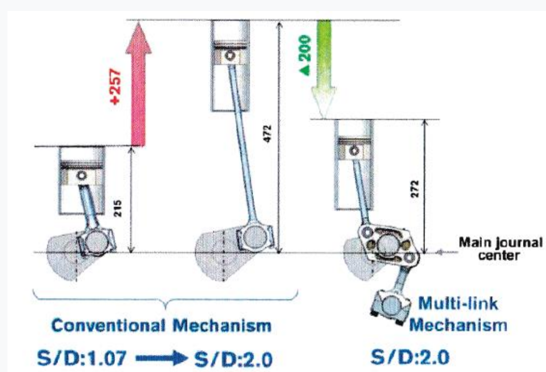
The author also conducted research and development of the HCCI engine jointly with Chiba University and

Company H for six years. Although the goal was finally achieved, it did not advance to commercialization development. At the beginning of the research, we aimed to improve the partial load fuel efficiency by assuming mild hybrids, but at the end of research and development after six years, company H started mass production of strong hybrids, and the highest thermal efficiency point is emphasized from partial load fuel efficiency. One of the reasons is that since HCCI can not operate at high load, the thermal efficiency of the highest efficiency point remains at the same level as the Miller(Atkinson)-cycle, and the thermal efficiency of part load can not be utilized for a strong hybrid. Of course, even if used in series hybrids, no effect can be expected for the hard work.

Along with the adoption of the exhaust gas control WLTC and RDE, it is required to improve the exhaust gas and fuel efficiency of high load rather than the conventional low load. Therefore, in the gasoline engine, the increase in “volume ratio” (I use the word instead of geometrical compression ratio) started by SKYACTIV-G becomes important. Volume ratio increase is a battle against knocking, and adoption of the Miller cycle is increasing. Audi VW has introduced light sizing (upsizing to correct oversized downs) to compensate for the shortcomings of Miller cycle torque drop. The Miller cycle is ideal for series hybrid engines that do not require large full open torque.

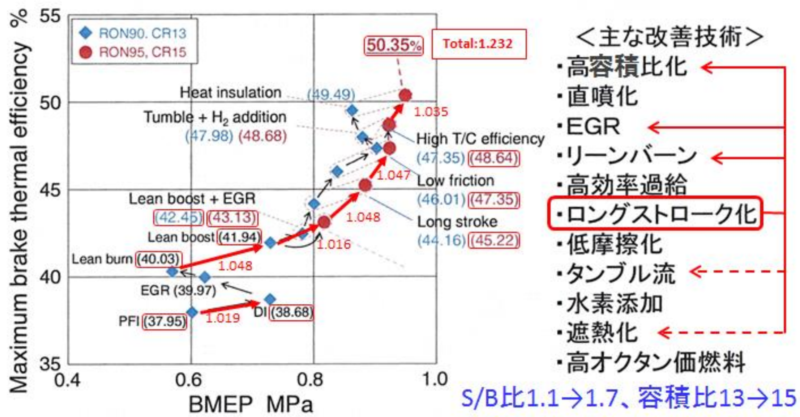
On the other hand, Nissan succeeded in commercializing the world's first variable displacement ratio engine and introduced it in the US. Compared to the method of making the length of connecting rods variable by the European research institutes (AVL, FEV), it uses a complicated crank mechanism, but it is superior in that the movement of the piston becomes a sine curve. It eliminates the need for a balance shaft and slows the movement of the piston at top dead center, which is advantageous for high volume ratio combustion. The inclination of the connecting rod is small and the friction loss of the piston is also reduced. Also, using this mechanism, a very long stroke can be realized as shown in the figure. The pinpoint drive series hybrids do not need volume ratio to be changed.





Nissan_VCR_details NIKKEI Automotive2017/8 MOTOR FAN ILLUSTRATED/Vol.129

It is SIP's innovative combustion technology activity that aims to achieve the pinpoint maximum thermal efficiency of 50%. Although the figure shows a way to improve from 38% to 50% of the base PFI engine, the adoption of various technologies as well as high volume ratio is being considered. As a combustion technology among them, research on super lean burn which carries out premixed uniform spark ignition combustion with A / F 30 (does not generate NOx) is energetically advanced. A final five-year report on SIP research will be held at the end of January, and will be introduced on another occasion.

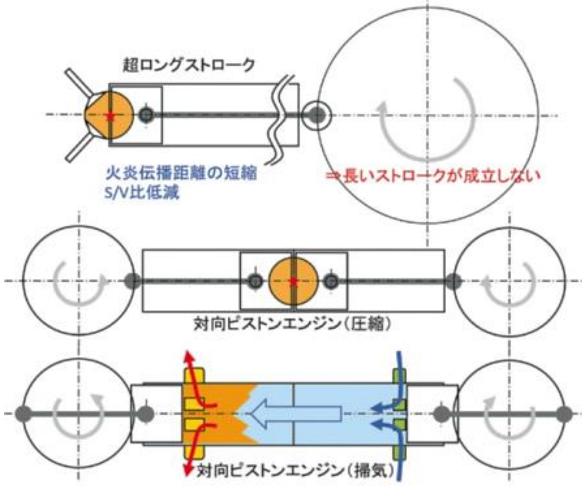


"Possibility and destination of high efficiency engine system" Yasuhiro Daisho、

Among them, long strokes are of particular interest to me. Generally, adopting a high volume ratio not only causes a problem of knocking but also increases the cooling loss because of the flat combustion chamber. If the stroke is long, since the bore is small, the burning speed can be increased to suppress knocking. In addition, the surface area of the combustion chamber can be reduced to prevent an increase in cooling loss. As the piston speed is increased, the combustion instability of lean combustion can also be improved. There exist many good things. A long time ago, S / B ratio 1.0 was generally used, but 1.2 has been mass-produced to 1.2 as a standard. In this study, it is considered to be 1.7 further. The S / B ratio of a large marine two-stroke diesel engine, which exhibits the world's highest thermal efficiency over 50%, is generally 3 and recently around 4 has appeared. I would like to adopt this kind of super long stroke in a car, but the large-sized marine diesel has a special crank mechanism called crosshead and the engine becomes too high in shape and too complex for the car and it can not be used. The focus is on the opposed piston engine, which has a double stroke.

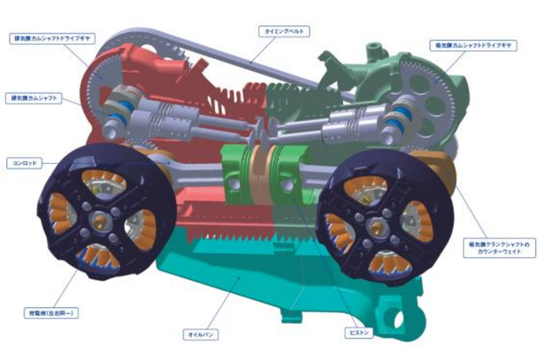
7. Possibilities of a two-stroke opposed-piston gasoline engine

An opposed-piston engine without a cylinder head with two crankshafts is known for being mounted on the German Junkers bombers during World War II. In Japan, a 2.7 L2 cylinder opposed piston engine was used during wartime mounted on a UD truck. Recently, a US venture company (Achates Power) is promoting development, and mass production is said to be imminent. Because opposed piston engines without a cylinder head can not set normal intake and exhaust valves, these diesel engines are two-stroke engines with an intake and exhaust port that opens and closes with a piston. Further, in order to smoothly exhaust, the phase of the exhaust side crank is advanced relative to the phase of the intake side crank so that the exhaust port opens earlier.



MOTOR FAN ILLUSTRATED /Vol.129P65

The characteristic of the opposed piston engine is that in addition to the super long stroke, if the phases of the two crankshafts are made the same, it is possible to realize a non-vibration engine by eliminating unbalance vibration. A four-cycle SI (spark ignition) engine for cogeneration that can be used on a wall is developed by a venture company in Gunma Prefecture (Ishikawa Energy Research) using this vibration-free characteristic. Last year, a prototype engine was mounted on a drone in a test flight. Instead of the problematic two cycles, four intake and exhaust valves are set in the combustion chamber that has been added to the side in order to make the general four cycles.



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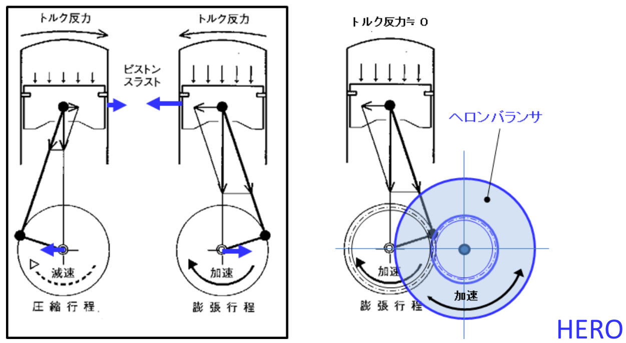
There are two major sources of engine vibration. It is often discussed that there is a disproportionate reciprocation force, and the rotary engine and the in-line six-cylinder engine do not have this imbalance, so they can be operated very smoothly to high speeds. The other is reaction force moment of torque fluctuation, which becomes a big problem at low rotational speed and high load with a small number of cylinders (1, 2, 3 cylinders). This is the reason why cars with two or fewer cylinders are rarely used. In the compression stroke and the combustion stroke, the generated torque in the engine is reversed to generate a large torque fluctuation. As a result of the torque fluctuation accelerating and decelerating the flywheel, the reaction force moment causes the cylinder to vibrate in the rotational direction. If a large reverse rotation flywheel is mounted, reaction force moments in reverse directions can be generated to balance the reaction force moments, and this reverse rotation flywheel is called a heron balancer. It is often found in patents, but it is unclear whether there are practical examples.

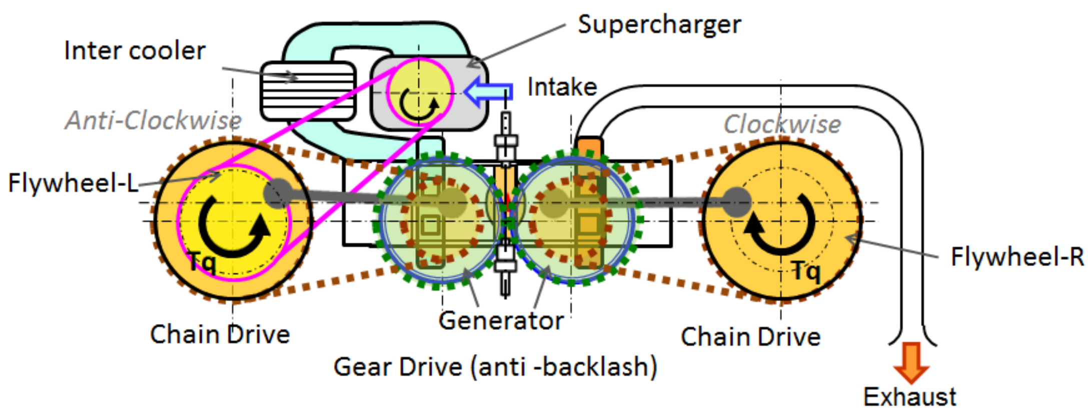


The opposing piston engines have perfect balance of reciprocation inertia as seen from the piston movement on the left and right, and since the cranks and flywheels on the left and right are reversely rotated, reaction force moments are also perfectly balanced, and a vibration free engine can be realized. In the previous drone engine, a generator with a large moment of inertia is connected and balanced to the left and right reverse cranks. The editorial staff who visited Ishikawa Enage Research for coverage of the special feature of Motor Fan Illustrated Vol. 129 was astonished that "There was really no vibration."

In the four-stroke cycle with intake and exhaust valves, the features of the compact combustion chamber of the opposed piston engine are lost. However, two-stroke engines inherently have problems with high load reliability and low load operation instability, and it is difficult to comply with HC and CO regulations in response to the tightening of exhaust gas regulations. They disappeared from car engine in time late 80s. Here, when considered as a series hybrid dedicated engine, the two-cycle opposed piston engine has the following features leading to the solution of these problems. 1 High load operation is not required to operate at the highest thermal efficiency point. An equivalent torque can be obtained with a half load (BMEP) of 4 cycles. (2) The problem of HC derived from oil is greatly alleviated by the fact that low load operation with unstable combustion is not necessary and the mixing of oil into the combustion chamber is greatly reduced because the scavenging gas does not use a crank chamber.

Although oil consumption from the exhaust port can not be avoided because the intake and exhaust ports are opened and closed by pistons, it can be expected that a solution can be found since the rotary engine is put into practical use. On the other hand, considering that four cycles of injection fuel are divided and injected twice, a lean burn operation with the same torque as that of the four cycles can be performed by operating with A / F ≒ 30 which is twice the four cycles. The addition of no vibration to these characteristics opens the way for the adoption of large displacement single-cylinder engines. I'm worried about a large single cylider causes intake and exhaust noise, but it is possible to take measures because it is pinpoint operation.

Based on the above ideas, I have been researching a high efficiency series hybrid engine dedicated to the concept shown in the figure. It is a 1.2L (B = 86, S = 103 x 2) two-stroke single-cylinder opposed-piston direct-injection lean-burn gasoline engine designed for use in B-class passenger cars. Computer simulation is performed to calculate the optimum values of volume ratio, S / C size, intake / exhaust port size, phase difference between IN and EX cranks, intake / exhaust pipe length and other parameters to obtain the maximum thermal efficiency. As a result, in order to maximize the thermal efficiency, the EX crank was slightly delayed contrary to the conventional case, and a 1 m long exhaust pipe was set. The exhaust start timing and the compression start timing are delayed due to the delaied the EX crank, and the compression start pressure is lowered by the negative pressure wave of the long exhaust pipe. As some readers understand, this is a miller-cycle where expansion ratio> compression ratio.



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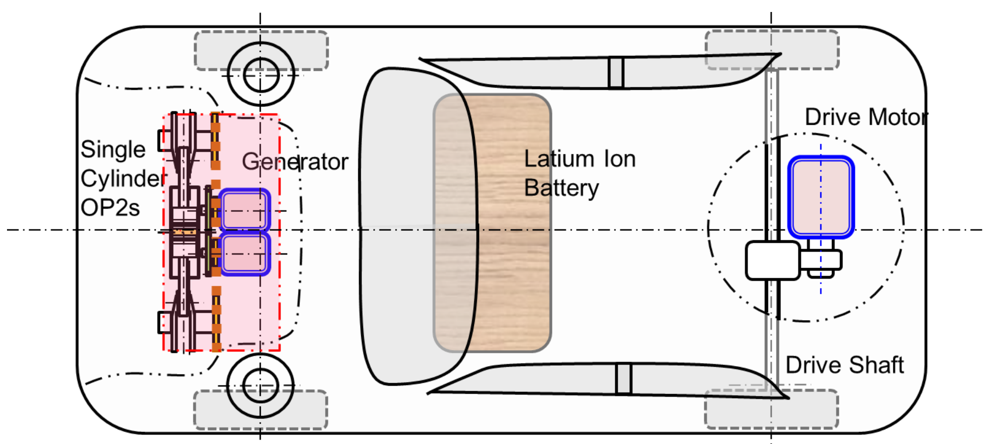
Although not completely vibration-free, the effect of super long strokes should reduce the cooling loss to about 2/3, and adding the effect of high volume ratio using Miller cycle should be close to 50% thermal efficiency. If this power generation engine set is mounted on the front as shown in the figure and a drive motor is mounted on the rear, it runs with comfortable steering stability of the front engine rear drive combined with the low center of gravity of the lithium ion battery under the floor. Also it realizes comfortable drive of EV. An attractive car will be born that is compatible with environmental performance.

Currently, we are preparing to conduct full-scale research jointly with Hiroshima University and others. From now on, engine research and development will became interesting.



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