CONCEPT 03

O'CUVOID

Hydrogen power generator package based on motorcycle technology to respond to diverse electricity needs and promote hydrogen adoption

O'CUVOID is a hydrogen power generator package designed to be used in a hydrogen society for a diverse range of applications from a power source for train cars, automobiles, and construction equipment, to power supply for various events and emergency situations.

This new invention is based on a motorcycle engine, which has been redesigned to use hydrogen as fuel and incorporate a turbocharger, aiming to innovate an electricity generation unit that is compact, high-output, cost-effective and capable of carbon neutrality.

As a power generator package that can be connected to others, like dry cell batteries, and by changing the number of units to be connected according to the power required, O'CUVOID can respond to diverse electricity needs. It is employed by ALICE SYSTEM, the future public transportation model proposed by Kawasaki, in which the number of units to be installed will be set for each mode of mobility to achieve the optimum power supply.

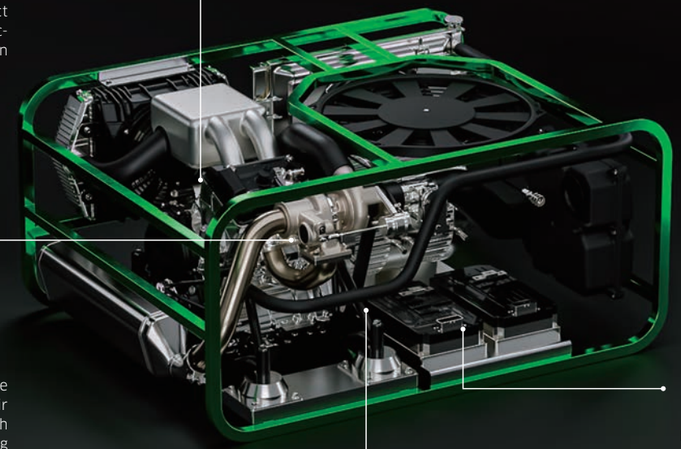
This multi-unit connection structure makes it possible to control the burden imposed on each unit independently to remain within the appropriate range for the unit to maintain efficient operations. It can also support downtime-free operations by allowing failure of some of the units to be compensated for by the remaining units.

The storage system containing hydrogen tanks is externalized to improve its flexibility in terms of layout and capacity selection.

O'CUVOID
HYDROGEN GENERATOR

Hydrogen engine

Heart of the unit. Based on a motorcycle engine redesigned to use hydrogen as fuel. Coming in a compact body, it achieves cost-effective, high-output, and carbon neutral performance.



Turbocharger

Driven by exhaust gases, the device supercharges extra air into the engine. Delivers high engine output while enabling clean combustion at the same time by increasing the excess air percentage to promote lean burn operation that can reduce NOx emissions.

Inverter

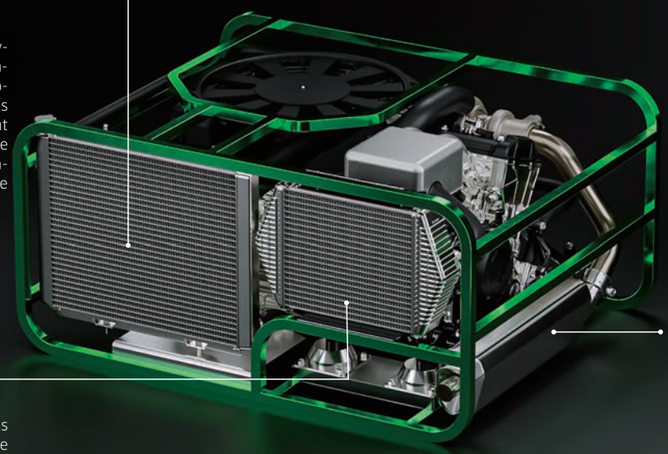
Regulates the generated electrical power to have the volt-ampere rating required by the equipment to be used. Its specifications can be changed to respond to various electricity needs.

Generator

Converts the engine's rotational kinetic energy into electrical power. A speed reduction mechanism is contained in the engine to achieve the optimal engine speed for power generation.

Radiator

Essential component of a hydrogen engine for temperature control to prevent abnormal combustion. Controls the temperature of coolant circulating within the engine to maintain its proper temperature in order to ensure stable continuous running.



Exhaust System

Exhaust catalysts are installed as a measure to achieve clean exhaust gas emissions. Equipped with a silencer to reduce the exhaust sound of the engine, thus ensuring low-noise electricity generation.

Intercooler

Cools hot intake air that has been compressed by the turbocharger. Prevents abnormal combustion, a major issue with hydrogen engines, and ensures high-output engine running.

Introduction

O'CUVOID is a next-generation carbon-neutral power unit featuring new-concept unit connectivity. This section gives an introduction to the basic concept and elemental technologies of this invention as well as its future application potential.

O'CUVOID: Basic concept and advantage

(1) Reasons for adopting a hydrogen engine

O'CUVOID has adopted a hydrogen engine, a choice suited to taking advantage of the Kawasaki Group's expertise to promote practicality, cost effectiveness, and simplified system configuration in this technology field, compared with the fuel cell, the main power generator using hydrogen.

Compared with a hydrogen engine, a fuel cell excels in power generation efficiency on an individual basis, but its load following output capability is low, particularly for rapid load changes. One solution for improved response to load change is by mounting large-capacity batteries as a buffer. A larger buffer battery means a larger-scale system and a lower cost effectiveness. In comparison, a hydrogen engine, a type of internal combustion engine, has good following and responding capabilities against output fluctuations, allowing for significantly downsized buffer batteries. This allows for lightweight and affordable systems, which can provide optimal power units in response to diverse electricity needs in consideration of performance, cost and efficiency in a balanced way.

Featuring a simple system configuration, O'CUVOID can offer a solution to issues faced by conventional fuel cell vehicles employed by public transportation systems, which require many components to be mounted, resulting in increased weight and lower maintainability.

(2) Unit design in consideration of connectivity

In addition to single-unit operation, O'CUVOID is also capable of multi-unit connection to increase system output and ensure high-efficiency operation. According to the principle of the internal combustion engine, fuel efficiency changes within the range of engine speed and load, and the maximum domain varies according to the type of engine. Specifically, fuel efficiency tends to decline during high-speed high-load operation in small engines, and during idling or low-load operation in large engines.

In the O'CUVOID system capable of multi-unit configuration, the number of units can be optimized according to the output requirement in order to maximize per unit fuel efficiency. Take the example of the case of O'CUVOID applied to the operation of train cars, which is characterized by a high maximum system output requirement and an extremely low load during constant-velocity running. O'CUVOID can produce high output by connecting multiple units. For low-load operation, it can achieve high-efficiency performance of the overall system by limiting the number of units to be engaged in service within a high-efficiency domain, rather than engaging the entire connected structure in service at a single average rate.

(3) Packaging design for high versatility

Looking to accommodate diverse application uses, O'CUVOID is designed to house all the necessary accessories in a single unit coming in a compact body.

In addition, owing to its connectivity designed to ensure flexible response to system output requirements, O'CUVOID has a wide range of applications from a portable compact power source for emergency situations and various outdoor events, to public transportation systems, construction equipment, and personal mobility vehicles, which demonstrates its high versatility. This property will be exhibited to introduce hydrogen power generation capabilities to various fields. For example, a construction equipment manufacturer, even if lacking hydrogen engine technology, can produce hydrogen-powered models by adopting O'CUVOID as a power unit.

As just described, O'CUVOID aims to be a power unit with high versatility to provide an electricity supply source to all types of equipment used in society.

(4) Flexible system configuration with hydrogen tanks separated

The O'CUVOID system is configured to externalize the storage system containing hydrogen tanks, pressure governors, and other components. This is a measure to respond to a wide variety of requirements for the storage system as an outcome of the power unit's requirements for output and continuous run time changing depending on needs. In this context, a configuration with an internal storage system containing hydrogen tanks would pose difficulties with achieving an optimal design to satisfy specific needs. For example, in the case of a request for satisfying a low output requirement and a high continuous run time requirement at once, excessive units would have to be connected in order to increase the storage capacity, constituting a failure in optimal design. As a way to avoid such problems, O'CUVOID is designed to have a separate storage system to ensure flexibility for choosing the type and volume of tank best suited to the users' needs related to continuous run time and availability of hydrogen infrastructure. Also, by externalizing the storage system, this configuration has increased flexibility in designing the layout of the power unit to be mounted in various types of equipment, which is often constrained by physical restrictions associated with the storage system.

O'CUVOID: Elemental technologies

(1) Hydrogen engine

The engine, the heart of the unit, has been developed employing a 650 cc two-cylinder motorcycle engine as its base, redesigning it to use hydrogen as fuel, and incorporating a turbocharger. By combining a motorcycle engine, characterized by its compact structure and high output capacity, and a turbocharger, the development has achieved a broad operating range with a high load following capability.

While a hydrogen engine can be designed to achieve a high combustion efficiency and implement a broad range of operating conditions by taking advantage of the major characteristics of hydrogen, specifically a high burning rate and low minimum ignition energy requirement, it also carries the risk of abnormal combustion, such as spontaneous ignition, due to the very same characteristics. This issue can be addressed by leveraging the expertise on hydrogen combustion cultivated by the Kawasaki Group while developing technologies for hydrogen gas turbines and hydrogen motorcycle engines. Also, by adopting a mass production engine as the base, the initial investment can be kept to the minimum while achieving high productivity by using the same line as producing motorcycles in a highly cost-effective manner.

(2) Generator

The generator is a non-integrated structure to be connected by a shaft to the engine, a configuration to provide high flexibility in choosing an appropriate model to combine according to the power generation requirements. Also, the transmission mechanism mounted in a motorcycle engine can be utilized as a decelerator as a measure to optimize the engine speed to ensure efficient performance of the generator.

(3) Inverter

The inverter, a device to regulate electrical power to have the volt-ampere rating required by the equipment to be connected, is configured separately from the generator to allow for the choice of model suitable for the equipment.

(4) Turbocharger

In order to achieve a high output rating at 50 kW and good efficiency, O'CUVOID contains a supercharging system based on a turbocharger, a mechanism powered by energy recovered from engine exhaust gases, thus enabling high supercharging efficiency. This supercharging system plays a key role in combustion control. While hydrogen engines virtually emit no carbon dioxide (CO_2) while running, thus being capable of carbon neutral operation, they can generate nitrogen oxides (NOx) when burned around the theoretical air fuel ratio (stoichiometric combustion) due to a rise in the burning temperature. One major solution to this issue is provided by introducing a gas purification catalyst into the exhaust ducts. Among others, one suited to operation with a low per unit load requirement is by supercharging air to create a lean-burn engine, a measure to decrease the burning temperature, which is conducive to controlling NOx emissions from hydrogen burning around the theoretical air fuel ratio. Lean-burn operation involves lower output relative to stoichiometric combustion, but this issue can be addressed by adopting a supercharger to minimize output reduction. As described above, by choosing the better of the two methods — environmentally friendly lean-burn engine or high-output stoichiometric combustion — according to the situation and the specification of the unit, O'CUVOID can respond to needs for high environmental performance and various types of load requirements alike.

(5) Cooling system

Anticipating the possibility of accommodating many different application needs, O'CUVOID houses within the package a cooling system containing a radiator and an intercooler. The cooling system has achieved a compact layout while installing an individual cooling fan in the radiator and the intercooler as well as one for the whole unit on the ceiling. This enables the unit to be included in the layout for various use settings, such as underfloor spaces of train cars, and the engine room of small mobility vehicles and construction equipment.

O'CUVOID: Application deployment

Due to its unit configuration and related technologies, O'CUVOID allows for its innovative implementation in terms of efficiency and maintainability.

(1) Concept of downtime-less operation enabled by unit replacement

O'CUVOID's unit configuration can bring about a significant change to maintenance processes to minimize system downtime, thus implementing the concept of "downtime-less" operation. One possible use case is for a single-engine train service, which carries a sizable risk of a failed engine causing an immediate operation shutdown and entire system failure. This poses a serious problem especially to freight train services operating in undeveloped regions overseas.

A solution to this problem can be provided by O'CUVOID taking advantage of its standard design for multi-unit connectivity, which can enable a possible failure to be compensated for by the remaining working units to continue operation without interruption. The capacity for avoiding a complete system shutdown and continue operation to reach the nearest base represents the principle of redundancy, the primary pillar of the downtime-less operation concept.

The secondary pillar is related to a swift restoration of normal operation by replacing units. Due to its package configuration including the necessary accessories, O'CUVOID is capable of a quick on-the-spot selective replacement of failed units to restore the system to a normal state easily. In the case of train cars, conventionally, an engine failure means a failed large engine to be replaced and repaired by specialized engineers in a dedicated factory. In this situation, O'CUVOID, which is capable of package replacement, can reduce the need for special facilities and workers. Furthermore, appropriate service manuals can be prepared based on those for motorcycle engines and distributed to service garages and dealerships to allow them to respond to maintenance and repair requests. This can avoid the need for large maintenance facilities, conducive to the expanded scope of applying hydrogen power units.

(2) Assumed use case of hydrogen train cars for regional railway service

The above-described redundancy and maintainability are eminently suitable particularly for public transportation systems. To provide hydrogen-powered train cars for regional railway services, for example, multiple units will be put together and mounted in each car (development of the "hydrogen-ready" car to allow for easy replacement of a diesel-engine car is underway at Kawasaki Railcar Manufacturing), which can enable a failure of one component unit to be compensated for by the remaining units to continue operation and avoid a service suspension. The failed unit can be replaced by a backup unit in stock at terminal stations or shuttle operation bases. Additionally, stockpiled units can serve as an emergency power source.

GreenHICE Car, hydrogen-ready train car to replace a diesel engine car

This plan for hydrogen train cars aims to provide regional railway service with capabilities for autonomous operations on non-electrified sections where the power-feeding system is not available, with the capacity for running at around 60-80 km/h assumed.

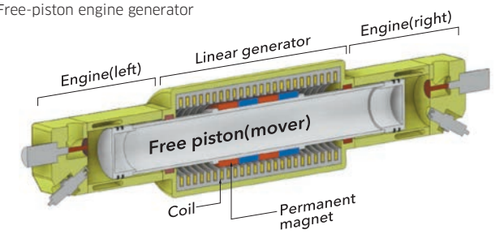
The number of units to be operated is controlled according to the output required by the integrated control unit mounted on the train car sending a command to the ECU of each unit of O'CUVOID.

Owing to the compact package configuration including necessary accessories, multiple units of O'CUVOID can be installed together in train cars using underfloor spaces. This is also effective in lowering the center of gravity, offering a sense of stability to passengers.

O'CUVOID: Application development

One possible plan for O'CUVOID's application development is related to a monitoring function aimed at the sophistication of downtime-less operation. Efficiency of the operation can be improved by building an advanced management system for performing real-time monitoring of the operating time and status and parts replacement history of each unit to determine an optimal timing of unit replacement to maximize efficiency, Among other possible plans is one to adopt a free-piston hydrogen engine generator in order to further reduce the size and weight and increase operation efficiency of the unit while promoting effective use of its connectivity. The free-piston engine generator is an electricity generation system that uses a linear generator to convert the linear motion of the piston directly into electric energy. One of the main advantages of this system comes from the absence of a crank mechanism, which brings about decreased mechanical friction and ensures flexibility for optimizing the compression ratio according to the amount of power generation, thus enabling high-efficiency operation. Also, fewer components can facilitate a further reduction in size and weight.

Free-piston engine generator



Conclusion

O'CUVOID has been developed by adopting as its core the well-established mass-produced motorcycle engine model, and designed while pursuing versatility, cost-effectiveness and scalability and based on the package design concept. Especially, equipped with unit connectivity, providing flexibility for responding to various application needs, and a unit replacement system supporting ease of maintenance, this technology holds the latent potential to bring about a substantial reduction in cost and need for specialized skills, a major hurdle to the adoption of hydrogen energy at present. In the context of the Kawasaki Group promoting its initiative to create a hydrogen society by building a supply chain that covers the entire range of processes from production, transportation and storage to utilization, O'CUVOID, a hydrogen-based function to respond to diverse electricity needs in society, represents the first step to offer a real solution in the utilization phase.

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