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(54) Title: A HYDROELECTRIC DRIVE AXLE FOR A VEHICLE

(57) Abstract: The present disclosure relates to a hydroelectric drive axle (100) for a vehicle (200) with integrated hydrostatic transmission with crawl and pawl assembly (35). The hydroelectric axle comprises a differential assembly having a differential casing and a gear arrangement disposed within the differential casing to distribute power from an input shaft to wheel axles. Further, a drive assembly having an electric drive module is mechanically supported on the electric motor. The drive assembly comprises a hydrostatic transmission assembly (20) coupled to the input shaft. An electric motor (30) is coupled to the hydrostatic transmission assembly with integrated crawl and pawl assembly. Furthermore, at least one energy storage module is provided to store and supply electrical energy to the electric motor. The drive assembly is integrated within an enclosure and positioned on the electric motor.

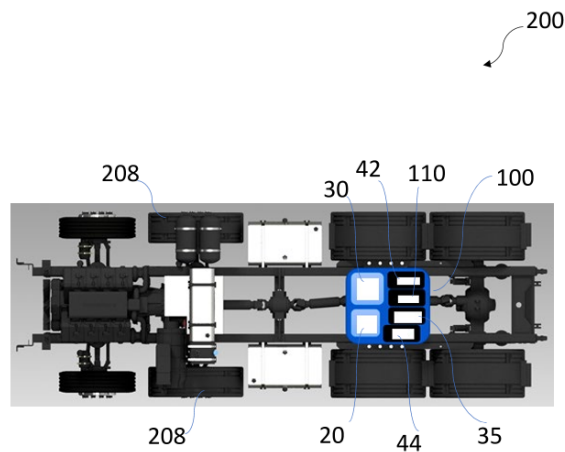


Fig. 1

FORM 2

THE PATENTS ACT 1970
(39 OF 1970)

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The Patent Rules, 2003

Complete Specification

(See Section 10 and Rule 13)

1. TITLE OF THE INVENTION

A HYDROELECTRIC DRIVE AXLE FOR A VEHICLE

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3. PREAMBLE TO THE DESCRIPTION

COMPLETE

The following specification describes the invention and the manner in which it is to be performed

DESCRIPTION

TECHNICAL FIELD

5 [0001] The present disclosure generally relates to a field of drive systems for vehicles. Particularly but not exclusively the present disclosure relates to an electrical axle arrangement for a vehicle.

BACKGROUND OF THE INVENTION

10 [0002] Typically, hybrid electric vehicles (HEVs) are powered by an internal combustion engine in combination with one or more electric motors that use energy stored in batteries. In few types of hybrid electric vehicles, the electric motor and the internal combustion engine work independently or in combination to generate and deliver power to the wheels. Usually, various types of electric and hybrid powertrain arrangements are applied to HEVs. Purely electric drives have an electric motor and a transverse differential, by means of which the electric drive power is distributed to the two drive wheels. Therefore, conventional Electric vehicles and HEV have electric motors differential systems, transmission unit and power
15 electronics which are separately placed.

[0003] Generally, heavy duty electric vehicles or hybrid vehicles such as trucks and buses face a challenge of insufficient torque to pull heavy loads for a long distance. This is due to limited capacity of electric motors and battery. So, heavy duty electric vehicles need to compromise internal spatial capacity to accommodate additional battery to achieve improved torque and
20 performance of the vehicle.

[0004] To address these above challenges electric axle systems are proposed which can combine an electric motor, power electronics and a transmission into a compact unit that can be integrated to any axle of the vehicle. Moreover, these electric-axle systems do not have integrated crawl and pawl systems to position and drive the vehicle as per requirement. Thus,
25 there is a need to further compact existing electric axle systems.

[0005] The present disclosure is directed to overcome one or more limitations stated above or any other limitations associated with the prior art.

SUMMARY OF THE INVENTION

[0006] One or more shortcomings of existing electric axles for vehicles have been overcome, and additional advantages are provided through the structure as claimed in the present disclosure. Additional features and advantages are realized through the techniques of the present disclosure. Other embodiments and aspects of the disclosure are described in detail herein and are considered a part of the claimed disclosure.

[0007] A primary aim of the present disclosure is to provide an electric drive axle for a vehicle to provide required torque and power for heavy duty performance.

[0008] Another aim of the present disclosure is to provide an electric drive axle that is enclosed in a compact unit with integrated hydrostatic transmission with crawl and pawl assembly.

[0009] Further aim of the present disclosure is to provide an electric drive axle for heavy capacity vehicles without compromising internal spatial capacity for accommodating additional battery packs.

[0010] The limitations of the prior arts are addressed to a great extent by an electric drive axle for a vehicle, as disclosed in the present disclosure.

[0011] The electric drive axle for a vehicle is disclosed. The electric axle drive assembly includes a differential assembly having a differential casing and a gear arrangement that is disposed within the differential casing. The gear arrangement is structured to distribute power from an input shaft to wheel axles. Further, a drive assembly includes a hydrostatic transmission assembly that is coupled to the input shaft. Further, an electric motor is coupled to the hydrostatic transmission assembly such that the electric motor includes an integrated crawl and pawl assembly. The drive assembly includes an electric drive module which is supported on mechanically supported on the electric motor. Furthermore, at least one energy storage module is provided that stores and supplies an electrical energy to the electric motor. The drive assembly is integrated within an enclosure and positioned on the electric motor. In an embodiment, the hydrostatic transmission assembly includes an input shaft and an output shaft.

[0012] In an embodiment, the output shaft of the hydrostatic transmission assembly is coupled to the input shaft of the gear arrangement.

[0013] In one non-limiting embodiment of the present disclosure, the crawl and pawl assembly is interposed between an output shaft of the electric motor and the input shaft of the hydrostatic transmission assembly.

5 [0014] In one non-limiting embodiment of the present disclosure, the crawl and pawl assembly is positioned within a casing of the electric motor in a space defined between a rotor and the output shaft of the electric motor.

[0015] In one non-limiting embodiment of the present disclosure, the crawl assembly assists in controlling an acceleration and braking of the vehicle at required gradient. Also, the pawl assembly is operatively engaged to a vehicle's park gear to maintain the vehicle in a required
10 position.

[0016] In an embodiment, at least one energy storage module includes a primary battery module that is integrated to the wheel axle of the vehicle. Further, energy storage module includes a secondary battery module that is disposed within the enclosure of the electric drive module.

15 [0017] In one non-limiting embodiment of the present disclosure, at least one energy storage module is rechargeable battery.

[0018] In one non-limiting embodiment of the present disclosure, the electric drive module comprises a controller module configured to operate the electrical drive module.

[0019] It is to be understood that the aspects and embodiments of the disclosure described
20 above may be used in any combination with each other. Several of the aspects and embodiments may be combined together to form a further embodiment of the disclosure.

[0020] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects and features described above, further aspects and features will become apparent by reference to the drawings and the following detailed description.

25 **BRIEF DESCRIPTION OF ACCOMPANYING DRAWINGS**

[0021] The novel features and characteristic of the disclosure are set forth in the appended claims. The disclosure itself, however, as well as a mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description

of an embodiment when read in conjunction with reference to the accompanying drawings wherein like reference numerals represent like elements and in which:

[0022] FIG.1 illustrates a schematic view of a vehicle comprising a hydroelectric drive axle (hydroelectric axle), in accordance with the embodiment of the present disclosure;

5 [0023] FIG. 2 illustrates a perspective view of the hydroelectric axle having energy storage module of Fig. 1;

[0024] FIG. 3 illustrates a perspective view of hydroelectric axle of FIG. 1;

[0025] FIG. 4 illustrates a bottom view of the hydroelectric axle of Fig. 1;

[0026] FIG. 5 illustrates a top view of the hydroelectric axle of FIG. 1;

10 [0027] FIG. 6 illustrates a perspective view of the hydroelectric axle with hydrostatic transmission assembly of FIG. 1; and

[0028] FIG. 7 illustrates a perspective view of the electric motor of hydroelectric axle of FIG. 1.

15 [0029] The figures depict embodiments of the disclosure for purposes of illustration only. One skilled in the art will readily recognize from the following description that alternative embodiments of the structures and methods illustrated herein may be employed without departing from the objective of the disclosure described herein.

DESCRIPTION

20 [0030] While the embodiments in the disclosure are subject to various modifications and alternative forms, specific embodiments thereof have been shown by way of example in the figures and will be described below. It should be understood, however, that it is not intended to limit the disclosure to the particular forms disclosed, but on the contrary, the disclosure is to cover all modifications, equivalents, and alternative falling within the scope of the disclosure.

25 [0031] It is to be noted that a person skilled in the art would be motivated from the present disclosure and modify construction of an electric drive axle for a vehicle. However, such modifications should be construed within the scope of the disclosure. Accordingly, the drawings show only those specific details that are pertinent to understand the embodiments of

the present disclosure, so as not to obscure the disclosure with details that will be readily apparent to those of ordinary skill in the art having benefit of the description herein.

5 [0032] The terms “comprises”, “comprising”, or any other variations thereof used in the disclosure, are intended to cover a non-exclusive inclusion, such that a system and method that comprises a list of components does not include only those components but may include other components not expressly listed or inherent to such system, method, or assembly, or device. In other words, one or more elements in a system or device preceded by “comprises... a” does not, without more constraints, preclude the existence of other elements or additional elements in the system or device.

10 [0033] The present disclosure relates to a hydroelectric drive axle for a vehicle that is compact and having integrated hydrostatic transmission with crawl and pawl assembly. Typically, commercial vehicles such as trucks and buses which are powered by electric motor as powertrain or hybrid configuration face a challenge of insufficient torque to pull heavy loads for a long distance. This is due to limited capacity of electric motors and battery. Also, existing
15 electric axles are constrained to single axles of the vehicle. Accordingly, the present disclosure discloses a hydroelectric drive axle. The hydroelectric drive axle comprises a drive assembly with hydrostatic transmission assembly, electric motor with integrated pawl and crawl assembly and with energy storage module. The hydroelectric drive axle is structured to reside within an enclosure to form a compact unit for providing required torque and power for heavy
20 duty performance.

[0034] The following paragraphs describe the present disclosure with reference to FIGs.1 to 7. In the figures, the same element or elements which have similar functions are indicated by the same reference signs.

25 [0035] Referring to Figure 1 to Figure 7 which are exemplary embodiments of the present disclosure illustrating a hydroelectric drive axle (100) [also referred as “hydroelectric axle”] for a vehicle (200) which is compact with integrated pawl and crawl assembly.

[0036] The hydroelectric axle (100) comprises a differential assembly having a differential casing. Further, a gear arrangement is disposed within the differential casing. The gear arrangement is structured to distribute power from an input shaft to wheel axles (206). The
30 differential assembly allows the wheels (208) of the vehicle (200) to rotate at different speeds

due to the gear arrangement. The differential assembly is at least one of open, locking, limited-slip and torque-vectoring differentials to drive the wheel axles (206).

[0037] The hydroelectric axle (100) of the present disclosure discloses a drive assembly which is supported on the electric motor (30). The drive assembly include a electric drive module (100) that may be mechanically integrated and supported on top of an electric motor (30). The electric drive module (110) functions as an electric powertrain for any hybrid and/or electric vehicles. Further, the electric motor (30) is coupled to a hydrostatic transmission assembly (20). The electric motor (30) is coupled to at least one energy storage module (40) such that the energy storage module (40) stores and supplies an electrical energy to the electric motor (30). The hydroelectric axle also works as a DC link unit for electric drive module. The electrical energy flows from energy module (40) to electric motor (30). The electric motor (30) provides torque that is transmitted from output shaft (31) of the electric motor (30). The electric motor (30) is defined with a stator (32) and a rotor (33). The stator (32) is static, while the rotor (33) rotates. In the electric motor (30), the stator (32) uses electric energy supplied via the energy module (40) to create a magnetic field to turn the rotor (33). Further, this spinning of rotor (33) generates a mechanical energy needed to turn drive the hydrostatic transmission assembly (20).

[0038] Further, the hydrostatic transmission assembly (20) of the present disclosure includes a variable displacement hydraulic pump [not shown in figures] connected in a closed hydraulic circuit with a fixed or variable displacement hydraulic motor [not shown in figures] for driving the differential assembly (202) with increased torque. The pump is driven by a prime mover in this case the electrical motor (30) at a certain speed in a certain direction.

[0039] The closed hydraulic circuit includes at least one conduit connecting an outlet of the pump with a hydraulic motor inlet and another conduit connecting the hydraulic motor outlet with an inlet of the pump. Changing the displacement of the main pump will change its output flow rate, which controls the speed of the hydraulic motor.

[0040] The hydrostatic transmission assembly (20) includes an input shaft (20a) to drive hydraulic pump, and an output shaft (20b) extending from the hydraulic motor. This output shaft (20b) of the hydrostatic transmission assembly (20) is coupled to the input shaft (204) of the gear arrangement i.e., the differential assembly (202). On the other hand, the input shaft (20a) of the hydrostatic transmission assembly (20) is driven by the output shaft (31) of the

electric motor (30) such that the output shaft (20b) of the hydrostatic transmission assembly (20) runs the differential assembly (202) with improved torque and high power.

5 [0041] The electric motor (30) of the present disclosure comprises an integrated crawl and pawl assembly. Further, the crawl and pawl assembly (35) is interposed between the output shaft (31) of the electric motor (30) and the input shaft (20a) of the hydrostatic transmission assembly (20).

10 [0042] In an embodiment, the crawl and pawl assembly (35) are positioned within a casing of the electric motor (30) in a space defined between a rotor (33) and the output shaft (31) of the electric motor (30). The pawl and crawl assembly (35) within the casing may comprise electromagnetic clutch, at least one position sensor, a planetary gearset assembly and a rotor pivot bearing. The pawl assembly (also referred as parking pawl assembly) operatively engage with a vehicle's park gear, to maintain the vehicle (200) in a "parked" position or at a required state. The pawl assembly provides a relatively quiet and smooth release of torque when the vehicle (200) is shifted out of the "parked" position. The pawl assembly include a rotatable member or a "parking pawl," which is selectively engages with a park rod [not shown in figures] of the vehicle (200) when the transmission of the vehicle (200) is shifted into the "parked" position. When the park rod engages the parking pawl, the parking pawl pivots or rotates into a position to prevent the park gear and the output shaft from further rotating. Further, a return spring [not shown in figures] is provided to connect with the parking pawl causing the parking pawl to disengage from the park gear when the park rod is retracted (i.e., when the vehicle (200) is shifted out of the "parked" position). Further, the crawl assembly assists in controlling acceleration and braking to drive the vehicle (200) at required gradient. Crawl assembly includes a plurality of sensors to determine driving conditions to adjust the vehicle's operation.

25 [0043] Further, the at least one energy storage module (40) includes a primary battery module (42) and a secondary battery module (44). The primary battery module is integrated to the wheel axle (206) of the vehicle (200). Further, the primary battery module may be disposed in a space formed between a point of wheel hub to a rim outer boundary. This configuration of the primary battery module aids in utilizing the available space within the vehicle (200). More specifically, this arrangement of primary battery module (42) reduces some weight from the vehicle (200) chassis thereby reducing centre of gravity of the vehicle (200) to prevent toppling of the vehicle (200) at higher speeds. The secondary battery module (44) is disposed within the

enclosure of the electric drive module (110). The secondary battery module (44) supplies stored electric energy to the electric motor (30). Also, the battery module receives and stores electric energy from the electric motor when operated as a generator. When the electric motor (30) is driven at relatively high voltage, high frequency, and with low maximum current. Energy stored in batteries is transformed into AC drive pulses of appropriate frequency to provide adequate torque at low RPM. Further, when necessary for acceleration or terrain climbing of the vehicle (200), the electric motor (30) is operated to add torque to that provided by the internal combustion engine. Under braking or coasting conditions, the electric motor (30) may be operated as a generator to charge the batteries. The at least one energy storage module (40) is a rechargeable battery.

[0044] The electric drive module (110) comprises a controller module which receives inputs such as acceleration, reverse, and deceleration or braking commands, and receives data from sensors monitoring various elements of the system, including data responsive at least to engine speed, electric motor speed, battery voltage, battery charging status and other input data may be provided as required. The controller module [not shown] is configured to control the operations of the electric drive module (110) based on various inputs.

[0045] In an embodiment, the design of the structure and capacity of the components of the hydroelectric axle (100) is highly modular that can be suitable to multiple suspension mounts and can also be stacked according to single axle or multi-axle configuration based on the requirements/application.

[0046] In an embodiment, the hydroelectric axle (100) of the present disclosure may be used for different types of hybrid or electric vehicles applicable for heavy duty purposes such as trucks, buses etc.

[0047] In an embodiment, the hydroelectric axle (100) of the present disclosure may provide 18 to 20 Times more torque with respect to conventional motor and transmission.

[0048] In an embodiment, the hydroelectric axle (100) of the present disclosure can be used to power additional hydraulic modules for auxiliary support such as power take-off unit (PTO) for the vehicle (200).

[0049] In an embodiment, the hydroelectric axle (100) of the present disclosure promotes dual motor architecture incorporating electric and kinetics from the electric motor and the hydrostatic transmission.

5 [0050] It is to be understood that a person of ordinary skill in the art may develop a structure of similar configuration without deviating from the scope of the present disclosure. Such modifications and variations may be made without departing from the scope of the present invention. Therefore, it is intended that the present disclosure covers such modifications and variations provided they come within the ambit of the appended claims and their equivalents.

ADVANTAGES OF THE INVENTION

10 [0051] A hydroelectric axle (100) for a vehicle in accordance with the present disclosure is compact and easy to operate.

[0052] A hydroelectric axle (100) in accordance with the present disclosure is configured with multiple energy storing modules without comprising the internal spatial capacity of the vehicle.

15 [0053] A hydroelectric axle (100) in accordance with the present disclosure comprises of components that are easily removable/ replaceable to be accommodated in different types of vehicles.

[0054] A hydroelectric axle (100) in accordance with the present disclosure comprises electric motor with integrated crawl and pawl assembly structured within an enclosure.

Equivalents:

20 [0055] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

25 [0056] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (e.g., bodies of the appended claims) are generally intended as “open” terms (e.g., the term “including” should be interpreted as “including but not limited to,” the term “having” should be interpreted as “having at least,” the term “includes” should be interpreted as “includes but is not limited to,” etc.). It will be further understood by those within

the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases “at least one” and “one or more” to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles “a” or “an” limits any particular claim containing such introduced claim recitation to inventions containing only one such recitation, even when the same claim includes the introductory phrases “one or more” or “at least one” and indefinite articles such as “a” or “an” (e.g., “a” and/or “an” should typically be interpreted to mean “at least one” or “one or more”); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean at least the recited number (e.g., the bare recitation of “two recitations,” without other modifiers, typically means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to “at least one of A, B, and C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, and C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances, where a convention analogous to “at least one of A, B, or C, etc.” is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., “a system having at least one of A, B, or C” would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase “A or B” will be understood to include the possibilities of “A” or “B” or “A and B.” While various aspects and embodiments have been disclosed herein, other aspects and embodiments will be apparent to those skilled in the art. The various aspects and embodiments disclosed herein are for purposes of illustration and are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

WE CLAIM:

1. A hydroelectric drive axle (100) for a vehicle (200), the hydroelectric drive axle (100) comprising:
 - a differential assembly (202) comprising:
 - a differential casing (202a); and
 - a gear arrangement disposed within the differential casing (202a), the gear arrangement is structured to distribute power from an input shaft (204) to wheel axles (206); and
 - a drive assembly comprising:
 - a hydrostatic transmission assembly (20) coupled to the input shaft (204);
 - an electric motor (30) coupled to the hydrostatic transmission assembly (20), wherein the electric motor (30) comprises an integrated crawl and pawl assembly (35);
 - an electric drive module (110), supported on the electric motor (30);
 - at least one energy storage module (40) to store and supply electrical energy to the electric motor (30);wherein the drive assembly is integrated within an enclosure and supported on the electric motor (30).
2. The hydroelectric drive axle (100) as claimed in claim 1, wherein the hydrostatic transmission assembly (20) comprises an input shaft (20a) and an output shaft (20b).
3. The hydroelectric drive axle (100) as claimed in claim 2, wherein the output shaft (20b) of the hydrostatic transmission assembly (20) is coupled to the input shaft (204) of the gear arrangement.
4. The hydroelectric drive axle (100) as claimed in claim 1 to 2, wherein the crawl and pawl assembly (35) is interposed between an output shaft (31) of the electric motor (30) and the input shaft (20a) of the hydrostatic transmission assembly (20).
5. The hydroelectric drive axle (100) as claimed in the claim 1, wherein the crawl and pawl assembly (35) are positioned within a casing of the electric motor (30) in a space defined between a rotor (37) and the output shaft (31) of the electric motor (30).

6. The hydroelectric drive axle (100) as claimed in claim 1, wherein the crawl assembly assists controlling acceleration and braking to drive the vehicle (200) at required gradient.
7. The hydroelectric drive axle (100) as claimed in claim 1, wherein the pawl assembly is operatively engaged to a vehicle's park gear to maintain the vehicle (200) in a required position.
8. The hydroelectric drive axle (100) as claimed in claim 1, wherein the at least one energy storage module (40) comprises:
 - a primary battery module (42) integrated to the wheel axle (206) of the vehicle (200); and
 - a secondary battery module (44) disposed within the enclosure of the electric drive module (40).
9. The hydroelectric drive axle (100) as claimed in claim 1, wherein at least one energy storage module (40) is a rechargeable battery.
10. The hydroelectric drive axle (100) as claimed in claim 1, wherein the electric drive module (110) comprises a controller module configured to operate the electrical drive module (110).

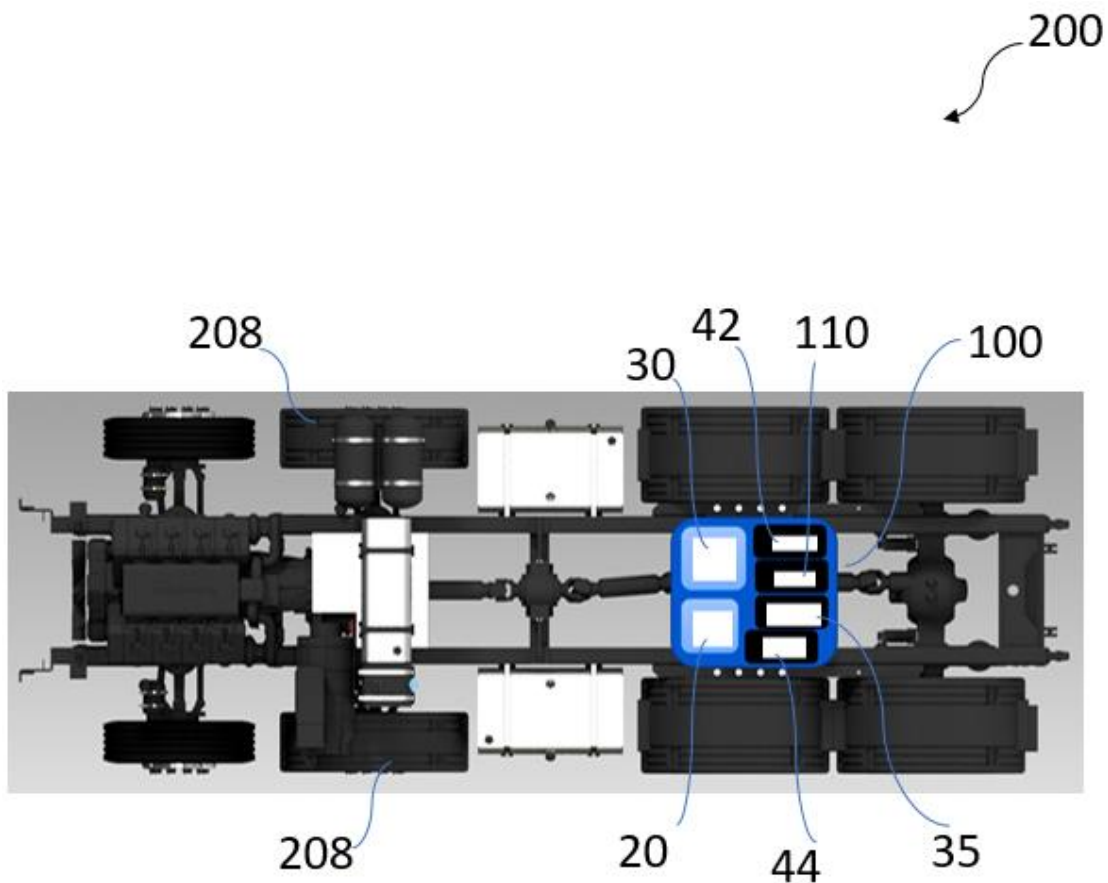
Dated this 22nd day of August 2022

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ABSTRACT

A HYDROELECTRIC DRIVE AXLE FOR A VEHICLE

The present disclosure relates to a hydroelectric drive axle (100) for a vehicle (200) with integrated hydrostatic transmission with crawl and pawl assembly (35). The hydroelectric axle comprises a differential assembly having a differential casing and a gear arrangement disposed within the differential casing to distribute power from an input shaft to wheel axles. Further, a drive assembly having an electric drive module is mechanically supported on the electric motor. The drive assembly comprises a hydrostatic transmission assembly (20) coupled to the input shaft. An electric motor (30) is coupled to the hydrostatic transmission assembly with integrated crawl and pawl assembly. Furthermore, at least one energy storage module is provided to store and supply electrical energy to the electric motor. The drive assembly is integrated within an enclosure and positioned on the electric motor.



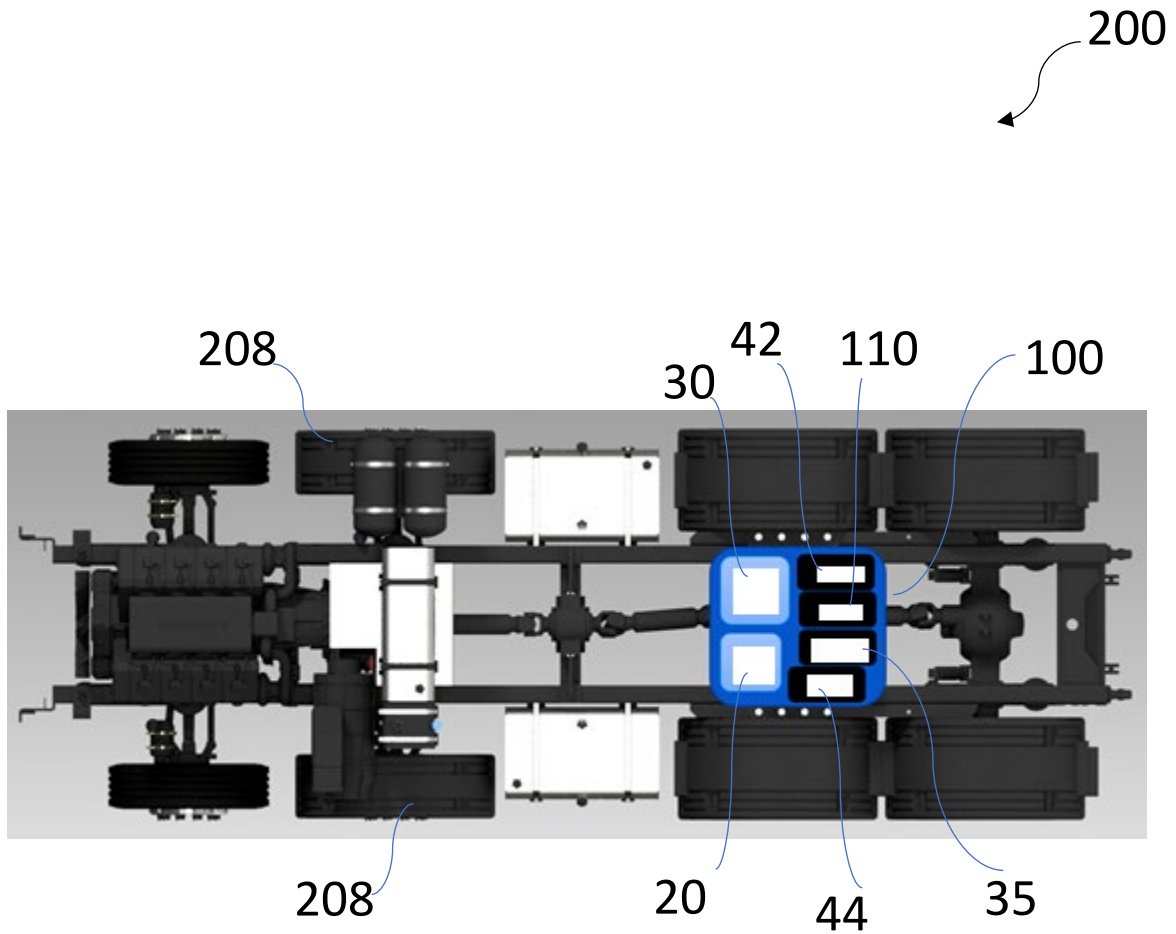


Fig. 1

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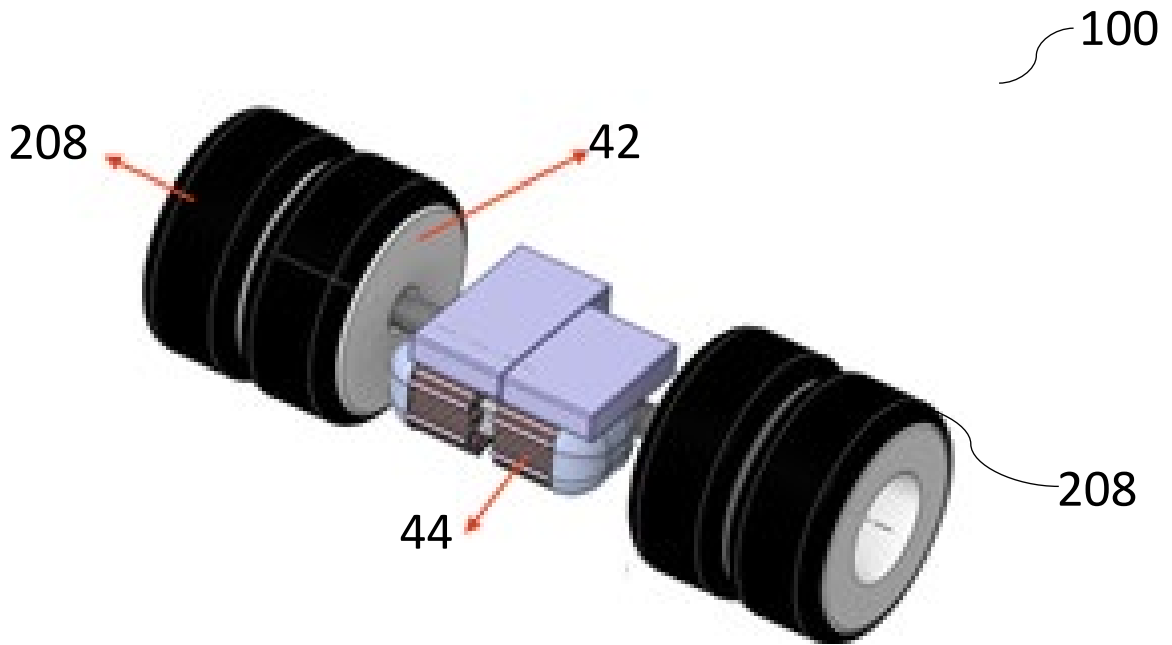


Fig.2

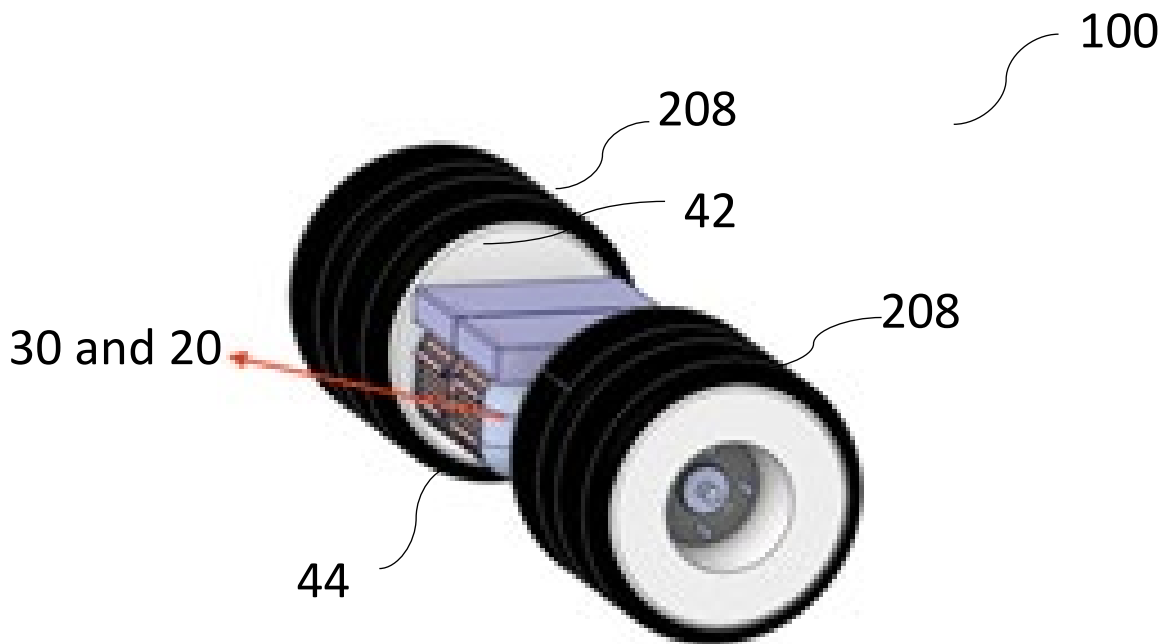


Fig.3

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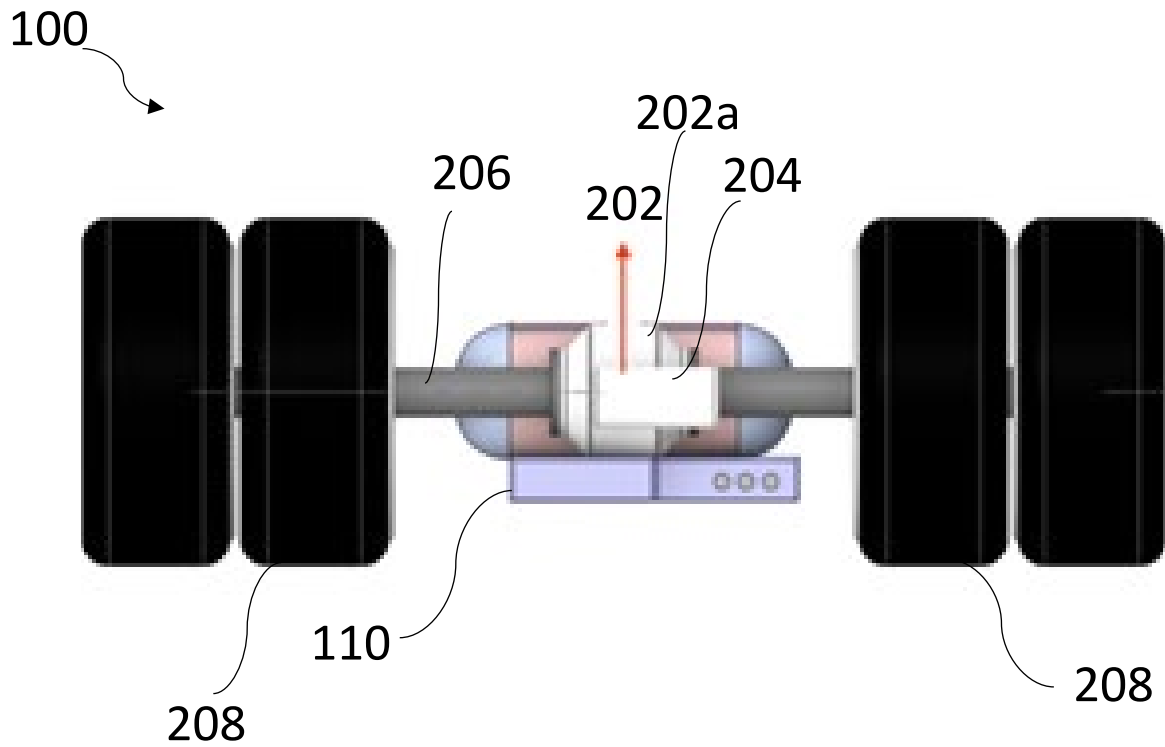


Fig. 4

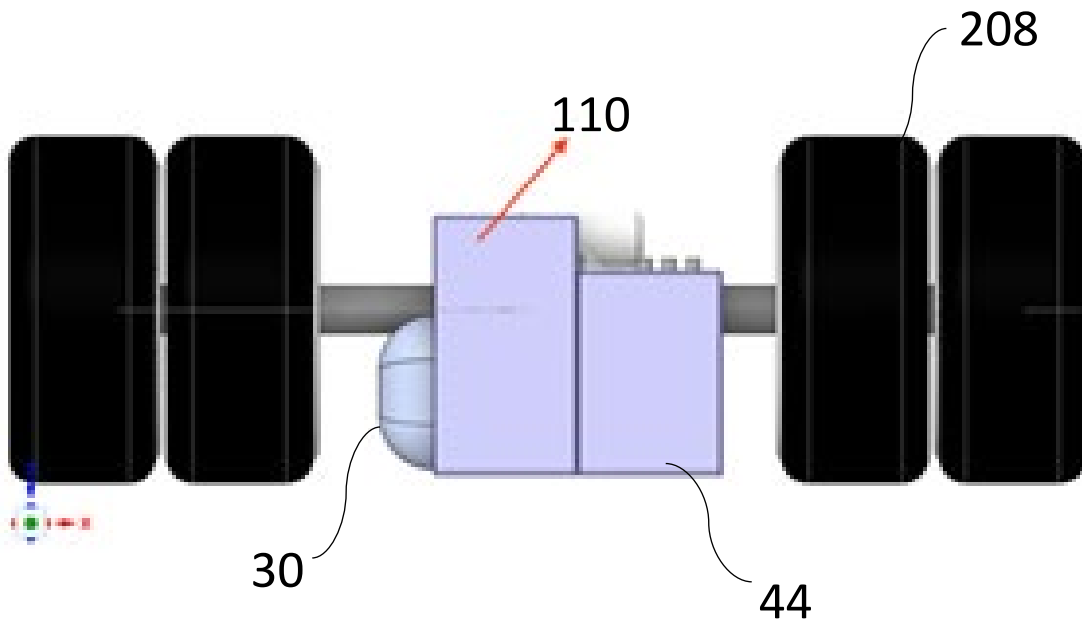


Fig. 5

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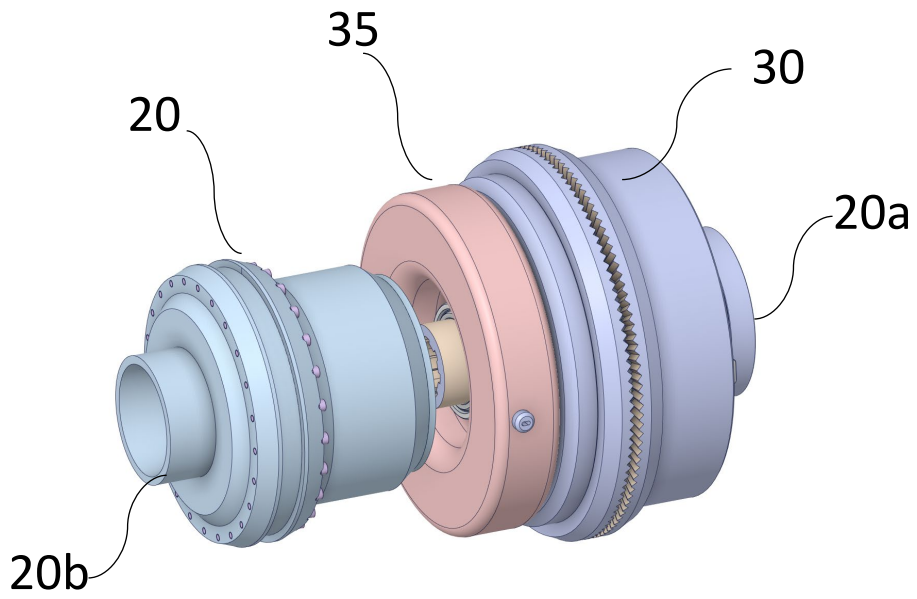


Fig.6

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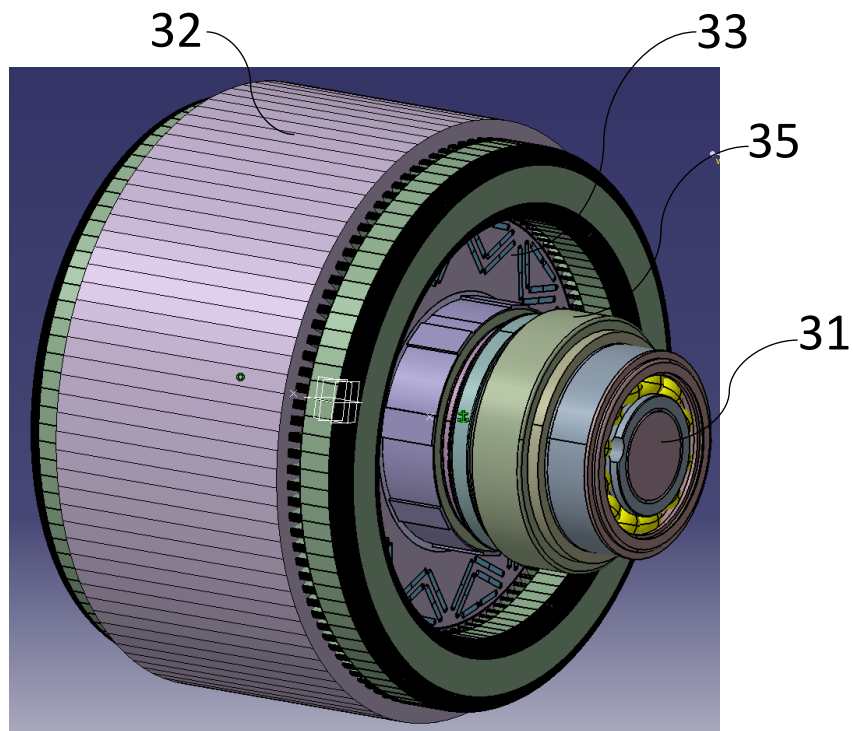


Fig. 7

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