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(54) Title: MOTOR-DRIVEN PUMP FOR HYDRAULIC CONTROL SYSTEM

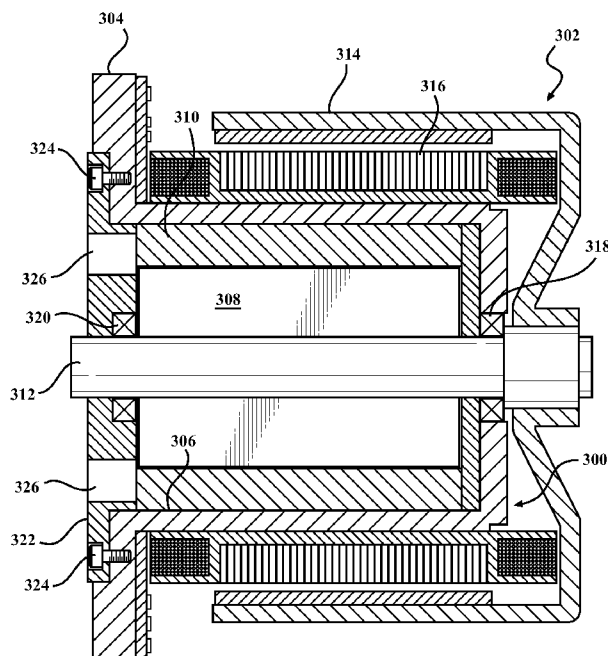


FIG. 2

(57) Abstract: A hydraulic control system for a vehicle transmission includes a housing defining a bore and a pump disposed within the bore and operable to supply a fluid to one or more components in the transmission. The system also includes an electric motor operable to selectively supply energy to the pump. The electric motor includes a stator disposed on the housing surrounding the bore and a rotor surrounding the stator.



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SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ,
GW, KM, ML, MR, NE, SN, TD, TG).

- *as to the applicant's entitlement to claim the priority of
the earlier application (Rule 4.17(iii))*
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- *as to applicant's entitlement to apply for and be granted
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MOTOR-DRIVEN PUMP FOR HYDRAULIC CONTROL SYSTEM

BACKGROUND

[0001] A vehicle transmission receives rotational input from an internal combustion engine or electric motor and increases torque by using gear-based reduction in rotational speed. The power from the transmission is output, for example, to a transfer case that distributes this driving power to the driven axles of the vehicle. Hydraulically-controlled transmissions use pressurized fluid to change gear ratios in a conventional manner using planetary gear sets. Pressure for the fluid is provided by a pump, the pump typically being a fixed-displacement pump having output linearly tied to engine or transmission speed. The fixed-displacement pump must be designed to provide sufficient hydraulic control of the transmission at low speeds and is thus oversized for other vehicle operating conditions. In some transmission designs, the fixed-displacement pump can be supplemented with an auxiliary pump that delivers fluid during vehicle operating conditions that are underserved by the fixed-displacement pump, such as when the engine is idle, but the need for two pumps adds cost and complexity to the hydraulic control system.

SUMMARY

[0002] One aspect of the disclosed embodiments is a hydraulic control system for a transmission. The system includes a housing defining a bore and a pump disposed within the bore and operable to supply a fluid to one or more components in the transmission. The system also includes an electric motor operable to selectively supply energy to the pump. The electric motor includes a stator disposed on the housing surrounding the bore and a rotor surrounding the stator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The description herein makes reference to the accompanying drawings, wherein like referenced numerals refer to like parts throughout several views.

[0004] FIG. 1 is a plan view illustration showing a drivetrain including a transmission.

[0005] FIG. 2 is a cross-sectional illustration showing a pump housed in an electric motor for use with the transmission of FIG. 1.

[0006] FIG. 3 is a cross-sectional illustration showing another pump housed in an electric motor and including a one-way clutch for use with the transmission of FIG. 1.

[0007] FIG. 4 is a cross-sectional illustration showing a planetary gear set in place of the one-way clutch in the pump of FIG. 3 for use with the transmission of FIG. 1.

[0008] FIG. 5 is a cross-sectional illustration showing another pump in series with another motor for use with the transmission of FIG. 1.

[0009] FIG. 6 is graph showing flow rate versus input shaft speed for the pumps of FIGS. 2-5 as compared to fixed displacement pumps under a variety of operating modes for the transmission of FIG. 1.

DETAILED DESCRIPTION

[0010] The disclosure herein is directed to pump and electric motor combinations for use with a hydraulic control system, for example, in a transmission within a motor vehicle drivetrain. In some embodiments, the electric motor can be designed to include a bore and an external rotor, allowing the pump to be nested within the bore to save packaging space. The pump can be designed to be driven by the engine of the vehicle, by the electric motor, or by a combination of the two depending on vehicle operating conditions. During some vehicle operating conditions, for example, at higher engine speeds, the pump can be designed to drive the electric motor, storing energy for use by other vehicle components.

[0011] FIG. 1 is a plan view illustration showing a drivetrain 100 for a four-wheel drive vehicle. The drivetrain 100 includes an engine 110 that is coupled to a transmission 112. The engine 110 is the prime mover of the drivetrain 100 and can be, for example, an internal combustion engine, an electric motor/generator, or a combination of the two. The engine 110 provides driving power (e.g. via a rotating output shaft, not shown) to the transmission 112,

wherein the transmission 112 includes components operable to convert the speed and torque of the driving power provided by the engine 110, such as by a gear train that provides multiple gear ratios. As examples, the transmission 112 can be a manual transmission, an automatic transmission, a hydraulically-controlled automatic transmission, a semi-automatic transmission, a continuously variable transmission, or a dual clutch transmission.

[0012] The transmission 112 provides driving power to a transfer case 120. The transfer case 120 is operable to distribute driving power to a rear driveshaft 130 and a front driveshaft 140. The rear driveshaft 130 provides driving power to a rear axle 150 via a rear differential 152. The rear axle 150 can be, for example, a solid axle or a pair of independent half axles. The rear axle 150 provides driving power to a pair of rear wheels 154 that are fitted with tires. The front driveshaft 140 provides driving power to a front axle 160 via a front differential 162. The front axle 160 can also be, for example, a solid axle or a pair of independent half axles. The front axle 160 provides driving power to a pair of front wheels 164 that are fitted with tires.

[0013] FIG. 2 is a cross-sectional illustration showing a pump 300 housed in an electric motor 302 for use with the transmission 112 of FIG. 1. A housing 304 extends between the pump 300 and the electric motor 302 and defines a bore 306 in which the pump 300 is substantially disposed. In other words, the pump 300 is nested inside the bore 306 of the housing 304, and both the pump 300 and the housing 304 are nested inside the electric motor 302.

[0014] The pump 300 includes a pump rotor 308 surrounded by a pump stator 310. The pump rotor 308 is driven by a shaft 312. The shaft 312 can be driven by the electric motor 302 based on the demand for hydraulic fluid and based on vehicle operating conditions. The pump 300 can be a gerotor pump, a vane pump, a crescent pump, or any other type of shaft-driven pump configured for packaging within the housing 304. In the example system of FIG. 2, the pump 300, the housing 304, and the electric motor 302 sequentially surround the shaft 312.

[0015] Unlike a conventional electric motor, the electric motor 302 of FIG. 2 includes a motor rotor 314 surrounding or encircling a motor stator 316. The motor stator 316 is disposed

on the housing 304, surrounds the bore 306, and can be installed, for example, by sliding the motor stator 316 around the cylindrical housing 304, though other shapes of the housing 304 are possible. The electric motor 302 can be connected to the shaft 312 through use of a spline, press joint, or any other type of drive joint in order to drive the shaft 312 and supply power to the pump 300. Thus, the electric motor 302 and the pump 300 share the common housing 304 and the common shaft 312, reducing the overall cost of the system.

[0016] The shaft 312 can be positioned in respect to the electric motor 302, the housing 304, and the pump 300 using a pair of bearings 318, 320. The first bearing 318 can be disposed in an opening at one end of the housing 304, and the second bearing 320 can be disposed in an opening in a pump end plate 322. The first and second bearings 318, 320 may be secured in place by any conventional means, such as snap rings, etc. (not shown). The pump end plate 322 can secure the pump 300 within the bore 306 by attachment to the housing 304, for example, using a pair of fasteners 324. Other methods of securing the pump 300 within the bore 306 are also possible.

[0017] The pump end plate 322 can define plate openings 326 that allow fluid to flow into and out of the pump 300. The fluid can be routed along fluid paths (not shown) within the pump 300, and the electric motor 302 can be cooled by the pump 300 when the fluid paths are disposed proximate to the motor stator 316 where, for example, coils can be located. By using an electric motor 302 with an external motor rotor 314, a large diameter of effective air gap is present, and the center space of the electric motor 302 is open, allowing packaging space for the housing 304 and the pump 300 inside the electric motor 302, while at the same time providing higher power and torque than a more conventional motor with an internal motor rotor of the same diameter and length.

[0018] In contrast to a fixed-displacement pump driven only by the engine 110 through the transmission 112, where output is dependent upon vehicle speed, the pump 300 can be electrically driven by the electric motor 302 to more efficiently match the flow rate of fluid to the demands of the vehicle. Housing the pump 300 within the electric motor 302 provides a

compact, low cost solution in comparison to a more traditional electric pump with an inner rotor motor (not shown).

[0019] FIG. 3 is a cross-sectional illustration showing the pump 300 of FIG. 2 housed in an electric motor 302 and including a one-way clutch 400 for use with the transmission 112 of FIG. 1. The one-way clutch 400 can include a hub or inner race 402 coupled to the shaft 312 and a cam or outer race 404 coupled to a sprocket 406. The sprocket 406 can connect to an engine crank (not shown) using a chain or a belt (not shown).

[0020] The one-way clutch 400 allows two modes of operation for the system: an electrical mode where the sprocket 406 is freewheeling and the electric motor 302 drives the shaft 312 to drive the pump 300 and a mechanical mode where the engine 110 and the transmission 112 drive the shaft 312 to drive the pump 300 and the motor rotor 314 is freewheeling. The speed of the electric motor 302 controls the one-way clutch 400 so that the one-way clutch 400 can switch between the electrical mode and the mechanical mode. For example, the electrical mode can be implemented during stop/start vehicle operation and at low speeds for the engine 110 and the transmission 112 and the mechanical mode can be implemented at higher speeds for the engine 100 and the transmission 112.

[0021] FIG. 4 is a cross-sectional illustration showing a planetary gear set 500 in place of the one-way clutch 400 in the pump 300 of FIG. 3 for use with the transmission 112 of FIG. 1. The planetary gear set 500 can include a sun gear 502 coupled to the electric motor 302, a ring gear 504 coupled to the pump 300 through the shaft 312, and a set of pinion gears 506 disposed between the sun gear 502 and the ring gear 504 in a gear carrier 508 coupled to the engine 110 through a chain 510. Optionally, a one-way clutch such as the one-way clutch 400 of FIG. 3 or a traditional brake (not shown) can be employed between the motor rotor 314 and the housing 304, for example, to ensure correct operation of the planetary gear set 500 and the pump 300.

[0022] The use of the planetary gear set 500 allows the pump 300 to operate in several modes to address a variety of vehicle operating conditions. For example, in a mechanical mode, the pump 300 can be driven only by the engine 110 through the shaft 312. In an electrical

mode, the pump 300 can be driven only by the electric motor 302 through the planetary gear set 500 and the shaft 312. In a hybrid mode, the planetary gear set 500 can operate as a speed-change device for the pump 300, allowing both the engine 110 and the electric motor 302 to drive the pump 300 to increase fluid flow only when necessary. In an alternative hybrid mode and for use at higher engine speeds, rotational input from the engine 110 can drive both the pump 300 and the electric motor 302. In this example, the electric motor 302 can work as a generator to store excess energy for use by other vehicle components that would have been wasted in driving the pump 300 beyond a speed necessary to meet hydraulic control needs.

[0023] FIG. 5 is a cross-sectional illustration showing the pump 300 in series with another motor 600 for use with the transmission 112 of FIG. 1. The components of the pump 300 are as described in FIG. 2, though the electric motor 600 differs from the electric motor 302 described in FIGS. 2-4, as the electric motor 600 is disposed in series with the pump 300. The electric motor 600 in FIG. 5 includes a motor housing 602 and a motor stator 604 disposed within the motor housing 602. The electric motor 600 also includes a motor rotor 606 disposed within the motor stator 604 and extending from a motor shaft 608. The motor shaft 608 also extends from the motor housing 602 to a sun gear 610 while the shaft 312 in the pump 300 extends from the housing 304 to a ring gear 612 coupled to the sun gear 610 by a set of pinion gears 614 disposed between the sun gear 610 and the ring gear 612 in a gear carrier 616 coupled to the engine 110 through a chain 618. In addition, a one-way clutch 620 surrounds the motor shaft 608. In FIGS. 4 and 5, proper bearing support (not shown) can be implemented to ensure good pilot and support for the planetary gears 502, 504, 506, 610, 612, 614.

[0024] The pump 300 and the electric motor 600 combination shown in FIG. 5 operates in a similar manner to the pump 300 and the electric motor 302 combination shown in FIG. 4, that is, the sun gear 610, the ring gear 612, and the pinion gears 614 operate in the same manner as the sun gear 502, the ring gear 504, and the pinion gears 506. In a mechanical mode of the system in FIG. 5, the pump 300 can be driven only by the engine 110 through the shaft 312. In an electrical mode, the pump 300 can be driven only by the electric motor 600 through both

the shaft 312 and the motor shaft 608. In a hybrid mode, the pinion gears 614 can operate as a speed-change device for the pump 300, allowing both the engine 110 and the electric motor 600 to drive the pump 300 to increase fluid flow. The one-way clutch 620 can lock the electric motor 600 in the mechanical mode.

[0025] FIG. 6 is graph showing flow rate versus input shaft speed for the pump 300 of FIGS. 2-5 as compared to traditional fixed displacement pumps under a variety of operating modes for the transmission 112 of FIG. 1. An example of flow rate required according to vehicle operating mode is shown by flow demand 700. The flow demand 700 represents the flow rate requirement to provide sufficient line pressure in the hydraulic control system over a variety of vehicle operating modes. An example of flow rate versus input shaft speed for a traditional fixed displacement pump is shown by flow curve 702. An example of flow rate versus input shaft speed for a down-sized fixed displacement pump is shown by flow curve 704. Finally, an example of flow rate versus input shaft speed for an electric motor-supplemented, down-sized mechanical pump, such as the pump 300 of FIGS. 2-5, is shown by flow curve 706.

[0026] In a first vehicle operating mode, namely, a vehicle stop/start mode represented by mode region 708, the flow demand 700 is at a minimum level required to maintain sufficient line pressure in the hydraulic control system to allow the transmission 112 to shift upon a restart of the engine 112. The flow curve 702 indicates that the traditional fixed displacement pump is unable to meet the flow demand 700 in this vehicle stop/start mode since the traditional fixed displacement pump does not operate when the vehicle is stopped. The flow curve 704 indicates that the down-sized, fixed-displacement, mechanical pump is similarly unable to provide sufficient flow rate to meet the flow demand 700 since the down-sized fixed displacement pump does not operate when the vehicle is stopped. Operating the pump 300 of FIGS. 2-5 in the previously described electrical mode within the mode region 708 results in the flow curve 706, providing a sufficient flow rate to meet the flow demand 700. The pump 300 can be a down-sized mechanical pump.

[0027] In a second vehicle operating mode, namely, an overdrive mode represented by mode region 710, the flow demand 700 reaches a peak and levels off, remaining constant. The flow curve 702 indicates the traditional fixed displacement pump supplies excess flow rate well above the flow demand 700 for much of the mode region 710, while the flow curve 704 indicates that the down-sized fixed displacement pump is not able to provide sufficient flow rate to meet the flow demand 700. The flow curve 706, representative of the pump 300 operating in a hybrid mode and being driven both by the electric motor 302, 600 and by the engine 110, indicates that the flow demand 700 is being exactly met in mode region 710.

[0028] In a third vehicle operating mode, namely, a drive mode represented by mode region 712, the flow demand 700 remains at a constant level. The flow curves 702, 704 indicate that both the traditional fixed displacement pump and the down-sized fixed displacement pump supply sufficient flow rate to meet the flow demand 700 over the entire mode region 712. The flow curve 706, representative of the pump 300 operating in a mechanical mode and being driven only by the engine 110, indicates the pump 300 is now supplying a slight excess flow above the flow demand 700 in the mode region 712. The excess flow generated by the pump 300 can be exploited in the final vehicle operating mode as described below.

[0029] In a fourth vehicle operating mode, namely, an underdrive mode represented by mode region 714, the flow demand 700 again remains at a constant level. The flow curves 702, 704 indicate that both the traditional fixed displacement pump and the down-sized fixed displacement pump supply flow in excess of the flow demand 700 over the entire mode region 714. The flow curve 706, representative of the pump 300 operating in a hybrid mode and being driven by the engine 110 while the electric motor 302 operates as a generator, indicates that the pump 300 can be used both to provide a fluid flow, and at the same time, convert energy for storage. Generating energy with the electric motor 302 is possible when the pump 300 is mechanically driven at high engine speeds to provide a flow rate in excess of the flow demand 700 and in absence of, for example, a one-way clutch 400, 620.

[0030] While the disclosure has been made in connection with what is presently considered to be the most practical and preferred embodiment, it should be understood that the disclosure is intended to cover various modifications and equivalent arrangements.

CLAIMS**What is claimed is:**

1. A lubrication system for a transfer case (120), comprising:
a pump (300) operable to supply lubricant to one or more components in the transfer case (120),
wherein the pump (300) is driven by a shaft (312), and
wherein the shaft (312) is selectively driven by a vehicle engine (110); and
a motor (302) operable to supply energy to the pump (300),
wherein the motor (302) surrounds the pump (300), and
wherein the motor (302) is operable to selectively drive the shaft (312).
2. The lubrication system of claim 1, further comprising:
a housing (304) extending between the pump (300) and the motor (302), wherein the housing (304) defines a bore (306).
3. The lubrication system of claim 2, wherein the pump (300) is disposed substantially within the bore (306), and wherein the motor (302) substantially surrounds the bore (306).
4. The lubrication system of claim 1, wherein the motor (302) is selectively driven by the shaft (312) to store energy.
5. The lubrication system of claim 1, wherein the motor (302) comprises:
a rotor (314) encircling and radially spaced from the shaft (312); and

a stator (316) disposed radially within the rotor (314) and encircling the shaft (312).

6. The lubrication system of claim 1, further comprising:
a clutch (400, 500) coupling the shaft (312), the pump (300), and the motor (302); and
wherein application of the clutch (400, 500) determines whether the shaft (312) is driven by the pump (300) or driven by the motor (302).
7. The lubrication system of claim 1, wherein the pump (300) is one of a gerotor pump, a vane pump, and a crescent pump.
8. A lubrication system for a transfer case (120), comprising:
a housing (304) defining a bore (306);
a pump (300) disposed within the bore (306) and operable to supply a lubricant to one or more components in the transfer case (120); and
a motor (302) operable to selectively supply energy to the pump (300), the motor (302) comprising:
a stator (316) disposed on the housing (304) surrounding the bore (306); and
a rotor (314) surrounding the stator (316).
9. The lubrication system of claim 8, wherein the pump (300) extends along and is driven by a shaft (312), and wherein the shaft (312) is selectively driven by a vehicle engine (110).
10. The lubrication system of claim 9, wherein the pump (300), the housing (304), and the motor (302) sequentially surround the shaft (312).
11. The lubrication system of claim 9, wherein the motor (302) selectively drives the shaft (312) to supply energy to the pump (300).

12. The lubrication system of claim 11, further comprising:
a clutch (400, 500) coupling the shaft (312), the pump (300), and the motor (302);
wherein application of the clutch (400, 500) determines whether the shaft (312) is driven by the pump (300) or driven by the pump (300) and the motor (302).
13. The lubrication system of claim 9, wherein the motor (302) is selectively driven by the shaft (312) to store energy.
14. The lubrication system of claim 8, wherein the pump (300) is one of a gerotor pump, a vane pump, and a crescent pump.
15. A lubrication system for a transfer case (120), comprising:
a pump (300) operable to supply lubricant to one or more components in the transfer case (120),
wherein the pump (300) is driven by a shaft (312), and
wherein the shaft (312) is selectively driven by a vehicle engine (110);
a motor (302, 600) operable to supply energy to the pump (300),
wherein the motor (302, 600) comprises a rotor (314, 606) encircling and radially spaced from the shaft (312, 608) and a stator (316, 604) disposed radially within the rotor (314, 606) and encircling the shaft (312, 608),
wherein the motor (302, 600) is operable to selectively drive the shaft (312), and
wherein the motor (302, 600) is selectively driven by the shaft (312, 608) to store energy; and
a housing (304) defining a bore (306),
wherein the pump (300) is disposed substantially within the bore (306), and
a clutch (400, 500, 620) coupling the shaft (312, 608), the pump (300), and the

motor (302, 600);

wherein application of the clutch (400, 500, 620) determines whether the shaft (312) is driven by the pump (300) or driven by the pump (300) and the motor (302, 600).

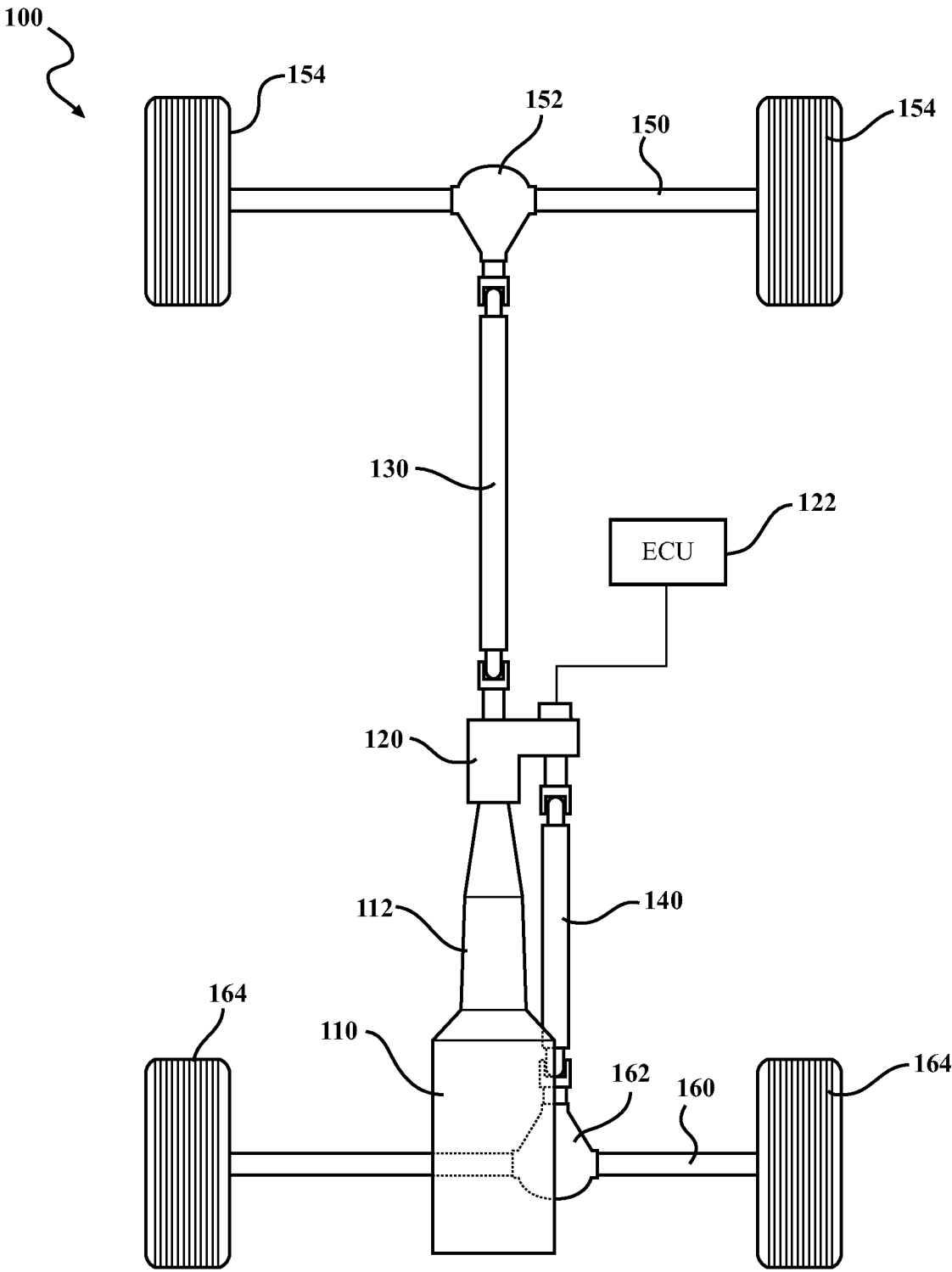


FIG. 1

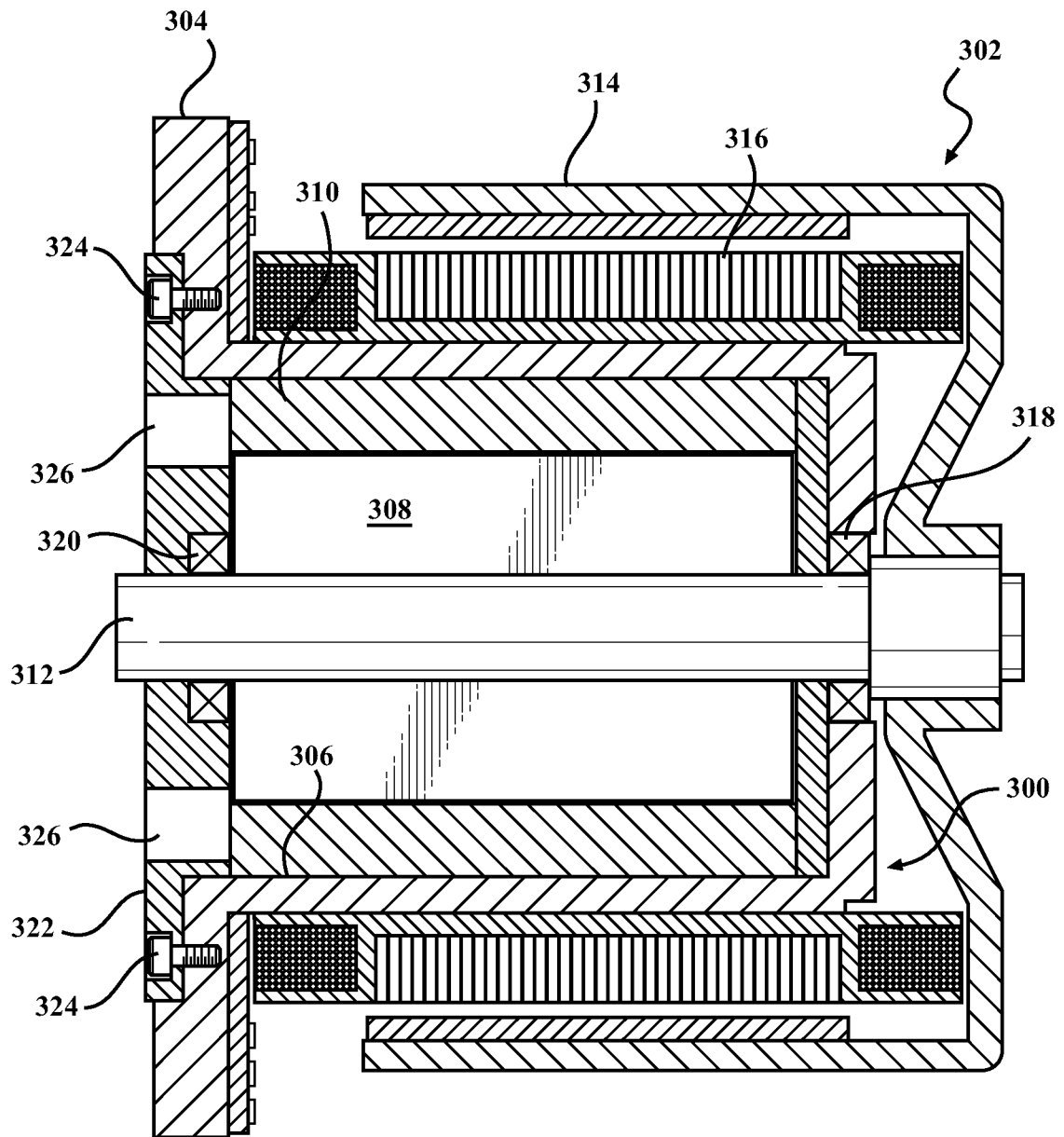


FIG. 2

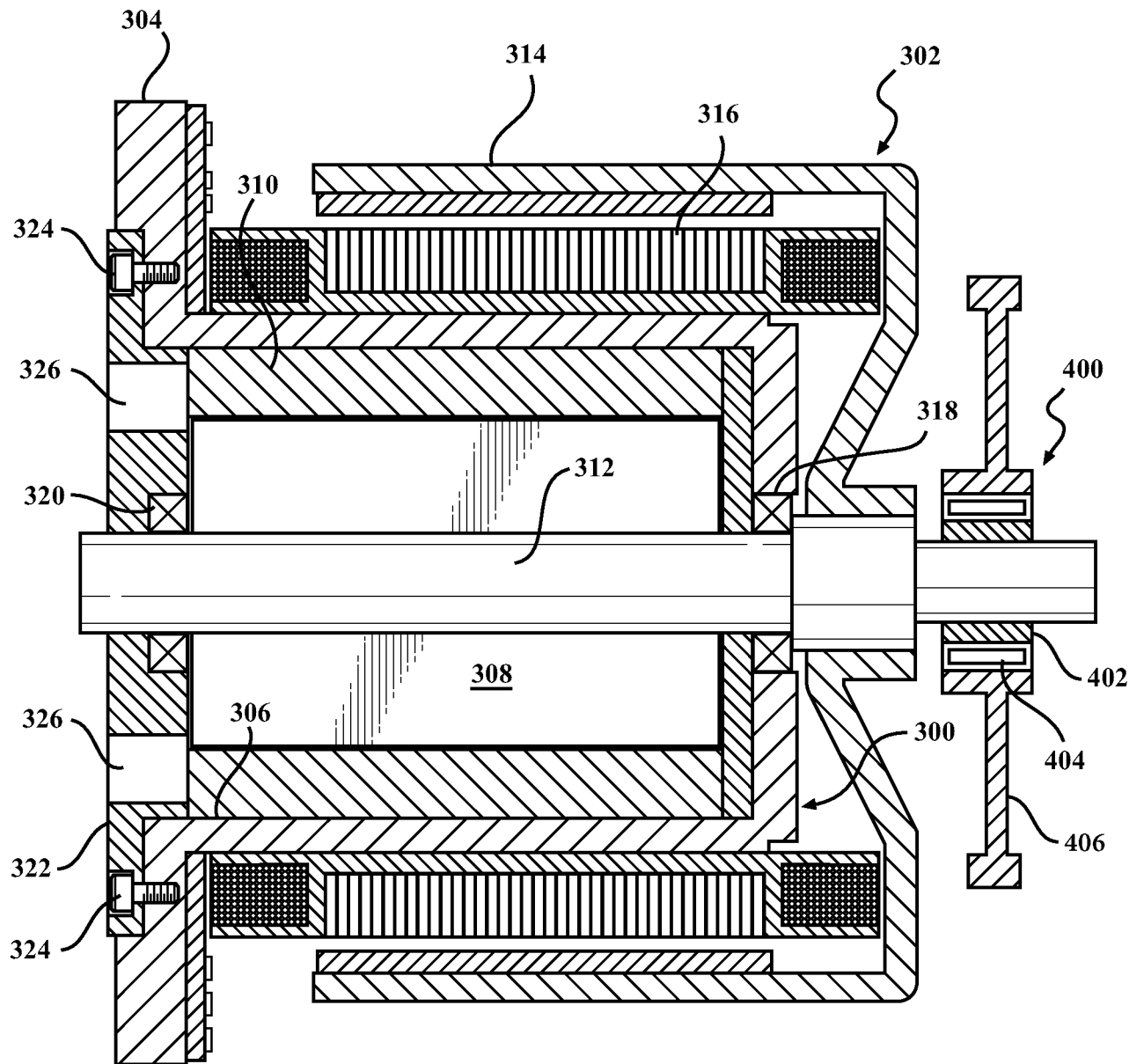


FIG. 3

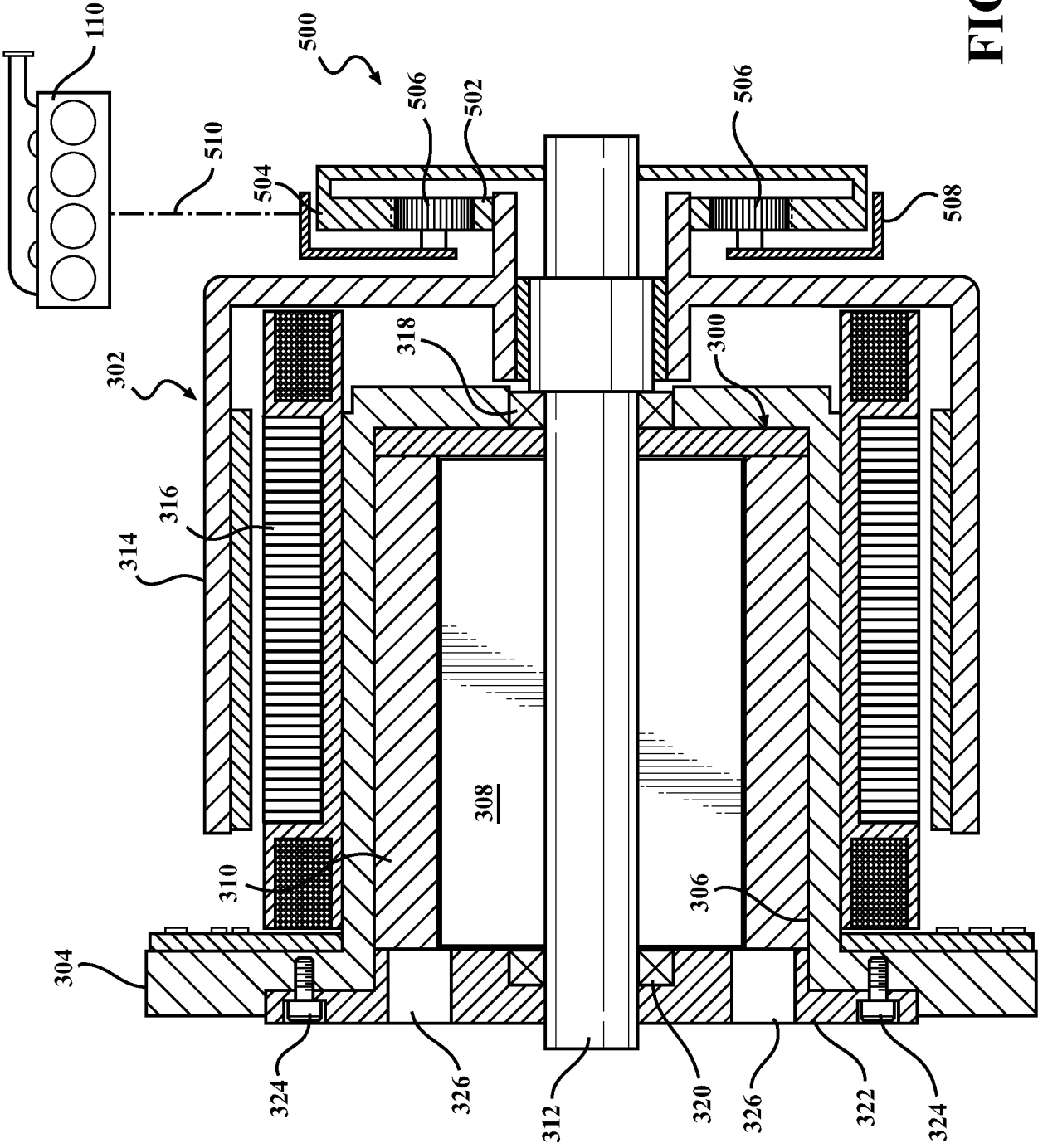


FIG. 4

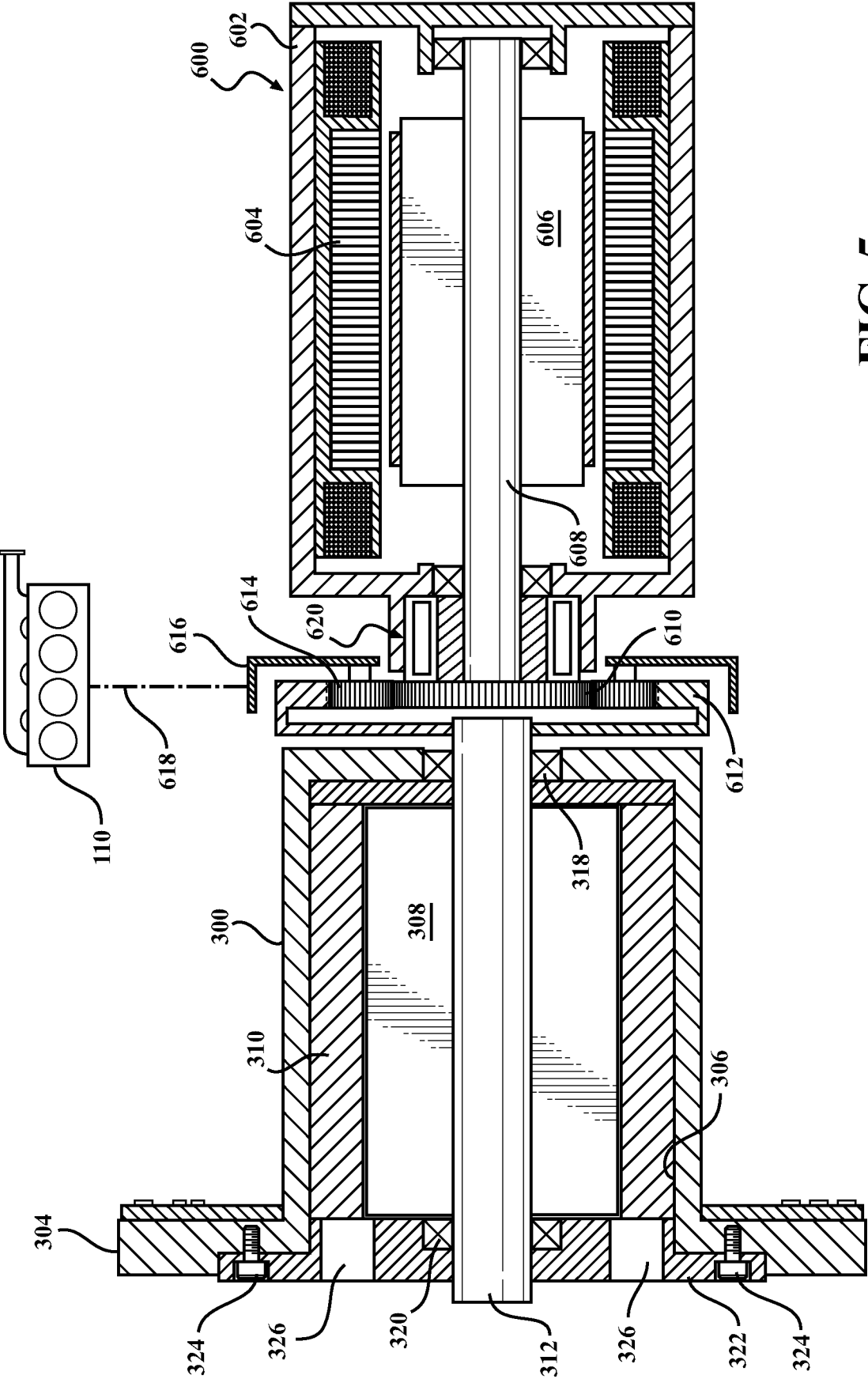


FIG. 5

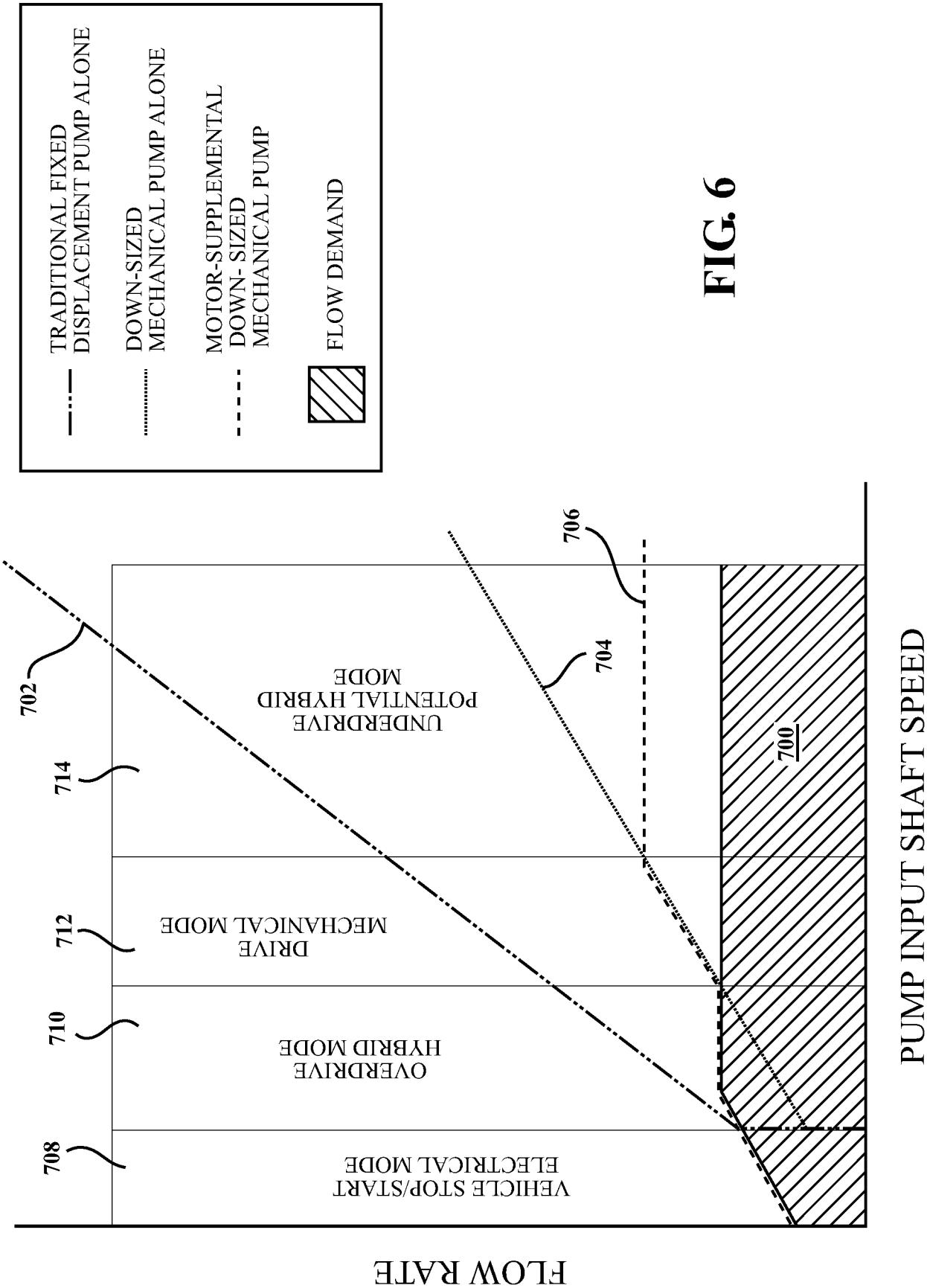


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/018621**A. CLASSIFICATION OF SUBJECT MATTER****F16H 61/00(2006.01)i, F16H 57/04(2010.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16H 61/00; F04B 17/00; F04B 35/00; F16H 37/06; F04C 14/08; F04B 41/06; F04C 15/00; F16H 57/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: hydraulic pump, motor, transfer case, shaft, engine, clutch, pump housing, stator, rotor

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0150199 A1 (ZF FRIEDRICHSHAFEN AG) 13 June 2013 See paragraphs [0032]-[0038], [0043] and figure.	1-15
Y	US 2014-0255210 A1 (HYUNDAI MOTOR COMPANY) 11 September 2014 See paragraphs [0026]-[0028], [0037]-[0041], claims 1, 4, 5, and figures 1, 6A-6D.	1-15
Y	US 2012-0141297 A1 (JEONG et al.) 07 June 2012 See paragraph [0013], claim 1, and figure 1.	4, 13, 15
A	US 2005-0265858 A1 (KLAUS et al.) 01 December 2005 See paragraphs [0023]-[0031] and figure 1.	1-15
A	US 2005-0169773 A1 (SCHWARZ et al.) 04 August 2005 See paragraphs [0021]-[0026] and figure 1b.	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

21 April 2017 (21.04.2017)

Date of mailing of the international search report

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Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

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