(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 900 973 B1

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
23.06.2010 Bulletin 2010/25

(51) Int Cl.:
E21B 43/16 *(2006.01)*

(21) Application number: **06291449.4**

(22) Date of filing: **13.09.2006**

(54) **Method of performing hydraulic fracturing and fracturing pump system**

Hydraulisches Frakturierungsverfahren und Frakturierungspumpenvorrichtung

Procédé de fracturation hydraulique et système de pompe de fracturation

(84) Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

(43) Date of publication of application:
19.03.2008 Bulletin 2008/12

(73) Proprietors:
- **Services Pétroliers Schlumberger**
  75007 Paris (FR)
  Designated Contracting States:
  FR
- **Schlumberger Technology B.V.**
  2514 JG The Hague (NL)
  Designated Contracting States:
  BG CZ DE DK GR HU IE IT LT PL RO SI SK TR
- **Schlumberger Holdings Limited**
  Road Town, Tortola (VG)
  Designated Contracting States:
  GB NL
- **PRAD Research and Development N.V.**
  Willemstad, Curacao (AN)
  Designated Contracting States:
  AT BE CH CY EE ES FI IS LI LU LV MC PT SE

(72) Inventors:
- **Salvaire, André**
  78180 Montigny le Bretonneux (FR)
- **Metson, James**
  Sugar Land, TX 77479 (US)

(74) Representative: **Hyden, Martin Douglas et al**
Rouse Patents
1st Floor
228-240 Banbury Road
Oxford
Oxfordshire OX2 7BY (GB)

(56) References cited:
EP-A- 0 485 094
EP-A2- 0 059 055
DE-A1- 3 812 412
FR-A1- 2 482 692
JP-A- 58 046 246
JP-A- 2002 202 083
JP-A- 2002 202 084
JP-A- 2005 016 476
US-A- 4 066 123
US-A- 4 311 066
US-A- 5 092 824

- **DATABASE COMPENDEX [Online] ENGINEERING INFORMATION, INC., NEW YORK, NY, US; WADMAN B W: "2000 HP gas turbine fracturing rig" XP008074468 Database accession no. EIX19670030505 & DIESEL GAS TURBINE PROGRESS; DIESEL AND GAS TURBINE PROGRESS AUG 1966 MILWAUKEE, WI, UNITED STATES, vol. 32, no. 8, August 1966 (1966-08), pages 36-37,**
- **DATABASE COMPENDEX [Online] ENGINEERING INFORMATION, INC., NEW YORK, NY, US; EAGER V ET AL: "DEVELOPMENT OF A QUINTUPLEX MOBILE SERVICE PUMP" XP008074437 Database accession no. EIX70060062593 & ASME-PAPER 69-PET-24 1969, 1969,**

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).

EP 1 900 973 B1

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 1

Description

Technical field

[0001] The present invention relates to transmission systems for taking drive from a prime mover to an operating unit. In particular, the invention related to such a transmission for use in driving pump, especially pumps of the type used in the oil and gas exploration and production industries for fracturing and cementing operations.

Background art

[0002] During hydraulic fracturing pumping operations on oil or gas wells it is often necessary to pump fluids downhole from the surface at high pressures and flow rates. Depending on the well and the particular operation being performed, it may be necessary to provide in excess of 12000 HP to overcome the downhole pressure at the desired volumetric rate.

[0003] In a typical fracturing pump setup, several pumps are used, each typically being fitted with a diesel engine as primary driver for a high pressure triplex or quintuplex positive displacement pump, coupled through a five to seven speed transmission. Each pump typically delivers between 1500 to 2000 HP depending on the type and size of the engine fitted. Large fracturing operations can require more than 16 pumping units to be available at the well site to meet the pumping power requirements and provide backup in case of failure of individual units.

[0004] Due to the nature of the wells it is often necessary to start the pumping operation against an existing well pressure. This is known to put a high stress on the pump transmission and occasionally cause failure.

[0005] In the event that an active pump fails during the operation, a stand-by unit is required to take its place. In this case the stand-by pump will need to start against a high pressure from standstill. In order to do this, operators must put the engine at speed and engage the desired gear. The transmissions typically used are fitted with a torque converter that allows a limited amount of slip between engine speed and pump speed. However the unit will only tolerate running with such internal slippage for a very limited amount of time.

[0006] An increase is sometimes required to the overall pumping volumetric rate. In most cases this can only be done by changing gears on the transmission of some of the pumps, or starting other pumps.

[0007] All of the above operations place a great strain on the transmission systems, pumps and engines which can lead to unreliability and reduced operational life.

[0008] Conventional cementing or fracturing pump units are typically provided with a five-gear automatic transmission to allow either the full pump flow capacity or the full pump input torque. The weakness of this system is that for pumping under pressure, the engine must be at peak torque speed when the transmission is shifting up or down damaging the transmission disks.

[0009] An alternative to this type of transmission is a conventional hydrostatic transmission (HST) comprising a variable volume pump drive by the engine and a hydraulic motor drive by this pump. Such systems provide a gearless drive mechanism that translates engine power to hydraulic power continuously. Such systems are widely applied in construction machinery, because of their superior speed changeability. However HST does have certain problems that make is unsuitable for pumping systems, e.g. limited low speed / torque range and narrow shift range.

[0010] HST is one form of a continuously variable transmission (CVT). A CVT avoids some of the problems of changing gears in a conventional automatic gear box by allowing any ratio of input and output to be obtained. Mechanical CVTs are well known in automotive applications.

[0011] An extension to CVT design, sometimes known as the Infinitely Variable Transmission (IVT), allows the transmission to drive a vehicle backwards as well as forwards. Transmission input is split into two shafts with one connected to an epicyclic gear set and the other to a CVT. The output from the CVT is connected to a different set of gears in the epicyclic. The gear that does not draw power from engine or CVT transfers torque to the transmission output. The epicyclic gear set acts as a mechanical adding machine to subtract or add one speed from the other.

[0012] Hybrid automobiles also use epicylic gear system to allow both power sources to be connected to the vehicle transmission. US4311066 describes the use of an epicyclic gear system in a dredge pump, to allow steady speed adjustments in dredge pump drive systems.

[0013] An object of this invention is to provide a transmission system that has the advantages of a CVT in a form that can be used effectively in a pump drive system. This object is achieved in the invention by the use of a epicylic gear system.

Disclosure of the invention

[0014] One aspect of the invention comprises a method of performing a hydraulic fracturing operation in an oil or gas well comprising:

- providing multiple pump units, each unit including a fracturing pump system;
- operating the fracturing pumping systems to supply fluid downhole, wherein at least one fracturing pump system comprising a prime mover (D) arranged to drive a fracturing pump via a transmission system, the transmission system comprising:
    - an epicylic gear system comprising a sun gear and a ring gear, and a planet gear engaged between the sun gear and ring gear;

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 2

- a main input drive arranged to be driven by the prime mover;
- an hydraulic auxiliary input drive arranged to be driven by the prime mover; and
- an output drive arranged to drive the pump;

wherein the main input drive is connected to the sun gear and either

(i) the hydraulic auxiliary input drive is connected to the ring gear and the output drive is lead from the planet gear; or
(ii) the hydraulic auxiliary input drive is connected to the planet gear and the output drive is lead from the ring gear.

[0015] By connecting the main and auxiliary hydraulic input drives in this manner, the epicylic gear system acts to mechanically add or subtract the two drives and so provide any input:output ratio according to the speed and direction of each drive. Changes to the ratio can be made without any harsh physical shocks on either the transmission system, prime mover or pump.

[0016] The planet gear typically comprises a number of gears mounted on a carrier, the hydraulic auxiliary input drive or the output drive being connected to the carrier.

[0017] Preferably, the hydraulic auxiliary input drive can operate in forward or reverse directions.

[0018] Another aspect of the invention comprises a fracturing pump system for use in oil or gas well operations comprising a prime mover arranged to drive a pump via a transmission system according to the previous aspect of the invention.

[0019] The main and hydraulic auxiliary input drives can be mechanical or hydraulic.

[0020] It is preferred that a torque converter is provided between the prime mover and the transmission system.

[0021] The pump is preferably a pump such as a triplex or quintuplex pump for use in fracturing, cementing or coil tubing operations in oil wells.

Brief description of the drawings

[0022] Figure 1 shows a schematic of a transmission system according to an embodiment of the invention; and Figures 2-5 show schematic views of various embodiments of the invention.

Mode(s) for carrying out the invention

[0023] The invention is aimed at providing smooth power and/or torque transfer between a prime mover (e.g. diesel engine, electric motor) and the pump, allowing the assembly to have full power and /or torque available irrespective of the speed.

[0024] The basic structure of a system according to the invention based on a single split input that uses an epicylic gear train as differential mechanism, one differential output being used to drive the pump and the second differential output being connected to a speed regulating mechanism (the auxiliary drive) such that this second output is in effect an input and the differential acts to combine the two inputs rather than to split a single input into two outputs. Thus the main input drive (diesel engine or electric motor) can be allowed to run at constant speed at the maximum torque speed and drive the pump from 0 rpm to maximum without the need of step gears. This allows the unit to start from standstill and gradually increase the pump speed to the desired operation speed without any slippage or gear changes and maintaining the primary drive at a constant speed.

[0025] A suitable epicylic gear train mechanism consists of a sun gear, a planetary gear, a ring gear and two or more carriers that constrain the planetary gear. In conventional operation of epicylic gear systems, by selecting any two components as, input and output from sun, ring gear and planet gear carrier, and constraining remaining one component, the epicylic gear system is used as reduction or step gear. In the system according to the invention, input or output is given at this constraint point. The differential gear is made by splitting or combining input and output.

[0026] Figure 1 shows a schematic of a transmission system according to an embodiment of the invention for use in driving a fracturing pump in an oil well stimulation operation. Drive from the prime mover D (diesel engine) is lead to the sun gear 10 of the epicylic transmission system. Drive is also lead from the prime mover D to the input end 12 of an auxiliary drive system A via suitable connection 14.

[0027] The auxiliary drive A in the embodiment of Figure 1 is an HST (hydraulic pump/motor), the input drive 12 from the prime mover D being used to drive the HST pump 16 which in turn is used to drive the HST motor 18 in the usual manner. The output end of the auxiliary drive A is provided with a drive connection 20 which is in turn lead to the ring gear 22 of the epicyclic transmission system.

[0028] The output shaft 24 is connected to the carrier 26 of the planet gear 28 in the epicylic transmission system. The output shaft is connected to the fracturing pump P.

[0029] In this embodiment, the auxiliary drive A is acting as a continuously variable input to the epicylic differential. By controlling the auxiliary drive A, a part of the output from the prime mover can be applied to the ring gear of the transmission system to determine the final drive ratio applied to the pump P. Thus speed control of the output shaft 24 is effected by controlling the speed and direction of the auxiliary drive A while the prime mover speed can remain effectively constant.

[0030] Various changes can be made to this embodiment. Figure 2 shows schematically the arrangement of Figure 1 in which the prime mover D is connected to the sun gear 10, the auxiliary drive A (in this case constituted

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 3

by HST H1 which is powered from the prime mover D) is connected to the ring gear 22 and the pump shaft P is connected to the planet gear carrier 26. Figure 3 shows a variation of this embodiment wherein the drive to the sun gear 10 is provided by a further HST H2, also powered by the prime mover (not shown). Figure 4 shows a different configuration in which the prime mover D is connected to the sun gear 10, the auxiliary drive A (constituted by HST H1 which is powered from the prime mover D) is connected to the planet gear carrier 26 and the pump shaft P is connected to the ring gear 22. Figure 5 shows the corresponding arrangement with two HSTs (HST1 and HST2) in pace of the arrangement of the prime mover D and auxiliary HST1 of Figure 4 (cf Figure 3). In another variation, the HST of the auxiliary (or main) drive can be replaced by another form of CVT.

[0031] One particularly preferred variation is to provide a torque converter at the prime mover end to improve its characteristics on start-up and shutdown and during major changes of speed and torque delivery.

[0032] Other changes can be made while remaining within the scope of the invention.

Claims

1. A method of performing a hydraulic fracturing operation in an oil or gas well comprising:

   - providing multiple pump units, each unit including a fracturing pump system;
   - operating the fracturing pumping systems to supply fluid downhole, wherein at least one fracturing pump system comprising a prime mover (D) arranged to drive a fracturing pump via a transmission system, the transmission system comprising:

     - an epicylic gear system comprising a sun gear (10) and a ring gear (22), and a planet gear (28) engaged between the sun gear (10) and ring gear (22);
     - a main input drive arranged to be driven by the prime mover (D);
     - an hydraulic auxiliary input drive arranged to be driven by the prime mover (D); and
     - a output drive arranged to drive the pump (16);

   wherein the main input drive is connected to the sun gear (10) and either

   (i) the hydraulic auxiliary input drive is connected to the ring gear and the output drive is lead from the planet gear; or
   (ii) the hydraulic auxiliary input drive is connected to the planet gear (28) and the output drive is lead from the ring gear.

2. A method as claimed in claim 1, wherein the planet gear comprises a number of gears mounted on a carrier, the hydraulic auxiliary input drive or the output drive being connected to the carrier.

3. A method as claimed in claim 1 or 2, wherein the hydraulic auxiliary input drive can operate in forward or reverse directions.

4. A method as claimed in any of claims 1, 2 or 3, wherein the main input drive is mechanical or hydraulic.

5. A method as claimed in any of claims 1 to 4, wherein the pump system further comprises a torque converter provided between the prime mover and the transmission system.

6. A method as claimed in any of claims 1 to 5, wherein the pump is a triplex or quintuplex pump.

7. A fracturing pump system for use in oil or gas well operations comprising a prime mover arranged to drive a pump via a transmission system; the transmission system comprising:

   - an epicylic gear system comprising a sun gear (10) and a ring gear (22), and a planet gear (28) engaged between the sun gear (10) and ring gear (22);
   - a main input drive arranged to be driven by the prime mover (D);
   - an hydraulic auxiliary input drive arranged to be driven by the prime mover (D); and
   - a output drive arranged to drive the pump (16);

   wherein the main input drive is connected to the sun gear (10) and either

   (i) the hydraulic auxiliary input drive is connected to the ring gear and the output drive is lead from the planet gear;
   or
   (ii) the hydraulic auxiliary input drive is connected to the planet gear (28) and the output drive is lead from the ring gear.

8. A pump system as claimed in claim 7, wherein the pump is a triplex or quintuplex pump.

Patentansprüche

1. Verfahren zum Ausführen einer hydraulischen Zerklüftungsoperation in einem Öl- oder Gasbohrloch, das umfasst:

   - Vorsehen mehrerer Pumpeneinheiten, wobei jede Einheit ein Zerklüftungspumpensystem

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 4

enthält;
- Betreiben der Zerklüftungspumpensysteme, um Fluid im Bohrloch nach unten zu liefern, wobei wenigstens ein Zerklüftungspumpensystem eine Antriebsmaschine (D) enthält, die dazu ausgelegt ist, eine Zerklüftungspumpe (P) über ein Getriebesystem anzutreiben, wobei das Getriebesystem umfasst:

- ein Planetengetriebesystem, das ein Sonnenrad (10) und ein Hohlrad (22) sowie ein Planetenrad (28), das zwischen dem Sonnenrad (10) und dem Hohlrad (22) in Eingriff ist, enthält;
- einen Haupteingangsantrieb, der dazu ausgelegt ist, durch die Antriebsmaschine (D) angetrieben zu werden;
- einen hydraulischen Hilfseingangsantrieb (A), der dazu ausgelegt ist, durch die Antriebsmaschine (D) angetrieben zu werden; und
- einen Ausgangsantrieb (24), der dazu ausgelegt ist, die Pumpe (P) anzutreiben;

wobei der Haupteingangsantrieb mit dem Sonnenrad (10) verbunden ist und wobei entweder

(i) der hydraulische Hilfseingangsantrieb (A) mit dem Hohlrad (22) verbunden ist und der Ausgangsantrieb (24) von dem Planetenrad (28) wegführt; oder
(ii) der hydraulische Hilfseingangsantrieb (A) mit dem Planetenrad (28) verbunden ist und der Ausgangsantrieb (24) von dem Hohlrad (22) wegführt.

2. Verfahren nach Anspruch 1, wobei das Planetenrad (28) mehrere an einem Träger montierte Zahnräder umfasst, wobei der hydraulische Hilfseingangsantrieb (A) oder der Ausgangsantrieb (24) mit dem Träger verbunden ist.

3. Verfahren nach Anspruch 1 oder 2, wobei der hydraulische Hilfseingangsantrieb (A) in Vorwärts- oder in Rückwärtsrichtung arbeiten kann.

4. Verfahren nach einem der Ansprüche 1, 2 oder 3, wobei der Haupteingangsantrieb mechanisch oder hydraulisch ist.

5. Verfahren nach einem der Ansprüche 1 bis 4, wobei das Pumpensystem ferner einen Drehmomentwandler umfasst, der zwischen der Antriebsmaschine und dem Getriebesystem vorgesehen ist.

6. Verfahren nach einem der Ansprüche 1 bis 5, wobei die Pumpe eine Dreifach- oder Fünffachpumpe ist.

7. Zerklüftungspumpensystem für die Verwendung in Öl- oder Gasbohrlochoperationen, das eine Antriebsmaschine (D) umfasst, die dazu ausgelegt ist, über ein Getriebesystem eine Pumpe anzutreiben; wobei das Getriebesystem umfasst:

- ein Planetengetriebesystem, das ein Sonnenrad (10) und ein Hohlrad (22) sowie ein Planetenrad (28), das zwischen dem Sonnenrad (10) und dem Hohlrad (22) in Eingriff ist, enthält;
- einen Haupteingangsantrieb, der dazu ausgelegt ist, durch die Antriebsmaschine (D) angetrieben zu werden;
- einen hydraulischen Hilfseingangsantrieb (A), der dazu ausgelegt ist, durch die Antriebsmaschine (D) angetrieben zu werden; und
- einen Ausgangsantrieb (24), der dazu ausgelegt ist, die Pumpe (P) anzutreiben;

wobei der Haupteingangsantrieb mit dem Sonnenrad (10) verbunden ist und wobei entweder

(i) der hydraulische Hilfseingangsantrieb (A) mit dem Hohlrad (22) verbunden ist und der Ausgangsantrieb (24) von dem Planetenrad (28) wegführt; oder
(ii) der hydraulische Hilfseingangsantrieb (A) mit dem Planetenrad (28) verbunden ist und der Ausgangsantrieb (24) von dem Hohlrad (28) wegführt.

8. Pumpensystem nach Anspruch 7, wobei die Pumpe eine Dreifach- oder Fünffachpumpe ist.

Revendications

1. Procédé pour réaliser une opération de fracturation hydraulique dans un puits de pétrole ou de gaz, comprenant les étapes consistant à :

- prévoir plusieurs unités de pompe, chaque unité comprenant un système de pompe de fracturation ;
- actionner les systèmes de pompe de fracturation pour alimenter le fluide au fond du puits, dans lequel

au moins un système de pompe de fracturation comprend un moteur principal (D) agencé pour entraîner une pompe de fracturation via un système de transmission, le système de transmission comprenant :

- un système d'engrenage planétaire comprenant un planétaire (10) et une couronne (22), et une roue planétaire (28) mise en prise entre le planétaire (10) et la couronne (22) ;
- un entraînement d'entrée principal agencé

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 5

pour être entraîné par le moteur principal (D) ;
- un dispositif d'entraînement d'entrée auxiliaire hydraulique agencé pour être entraîné par le moteur principal (D) ; et
- un dispositif d'entraînement de sortie agencé pour entraîner la pompe (16) ;

dans lequel le dispositif d'entraînement d'entrée principal est connecté au planétaire (10) et soit (i) le dispositif d'entraînement d'entrée auxiliaire hydraulique est connecté à la couronne et le dispositif d'entraînement de sortie est mené par la roue planétaire ; ou soit

(ii) le dispositif d'entraînement d'entrée auxiliaire hydraulique est connecté à la roue planétaire (28) et le dispositif d'entraînement de sortie est mené par la couronne.

2. Procédé selon la revendication 1, dans lequel la roue planétaire comprend un certain nombre d'engrenages montés sur un support, le dispositif d'entraînement d'entrée auxiliaire hydraulique ou le dispositif d'entraînement de sortie étant connecté au support.

3. Procédé selon la revendication 1 ou 2, dans lequel le dispositif d'entraînement d'entrée auxiliaire hydraulique peut fonctionner dans les directions en marche avant ou en marche arrière.

4. Procédé selon l'une quelconque des revendications 1, 2 ou 3, dans lequel le dispositif d'entraînement d'entrée principal est mécanique ou hydraulique.

5. Procédé selon l'une quelconque des revendications 1 à 4, dans lequel le système de pompe comprend en outre un convertisseur de couple prévu entre le moteur principal et le système de transmission.

6. Procédé selon l'une quelconque des revendications 1 à 5, dans lequel la pompe est une pompe triplex ou une pompe quintuplex.

7. Système de pompe de fracturation destiné à être utilisé pour réaliser des opérations dans des puits de pétrole ou de gaz, comprenant un moteur principal agencé pour entraîner une pompe via un système de transmission ; le système de transmission comprenant :

- un système d'engrenage planétaire comprenant un planétaire (10) et une couronne (22), et une roue planétaire (28) mise en prise entre le planétaire (10) et la couronne (22) ;
- un dispositif d'entraînement d'entrée principal agencé pour être entraîné par le moteur principal (D) ;
- un dispositif d'entraînement d'entrée auxiliaire hydraulique agencé pour être entraîné par le moteur principal (D) ; et
- un dispositif d'entraînement de sortie agencé pour entraîner la pompe (16) ;

dans lequel le dispositif d'entraînement d'entrée principal est connecté au planétaire (10) et soit (i) le dispositif d'entraînement d'entrée auxiliaire hydraulique est connecté à la couronne et le dispositif d'entraînement de sortie est mené par la roue planétaire ; ou soit

(ii) le dispositif d'entraînement d'entrée auxiliaire hydraulique est connecté au planétaire (28) et le dispositif d'entraînement de sortie est mené par la couronne.

8. Système de pompe selon la revendication 7, dans lequel la pompe est une pompe triplex ou une pompe quintuplex.

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 6

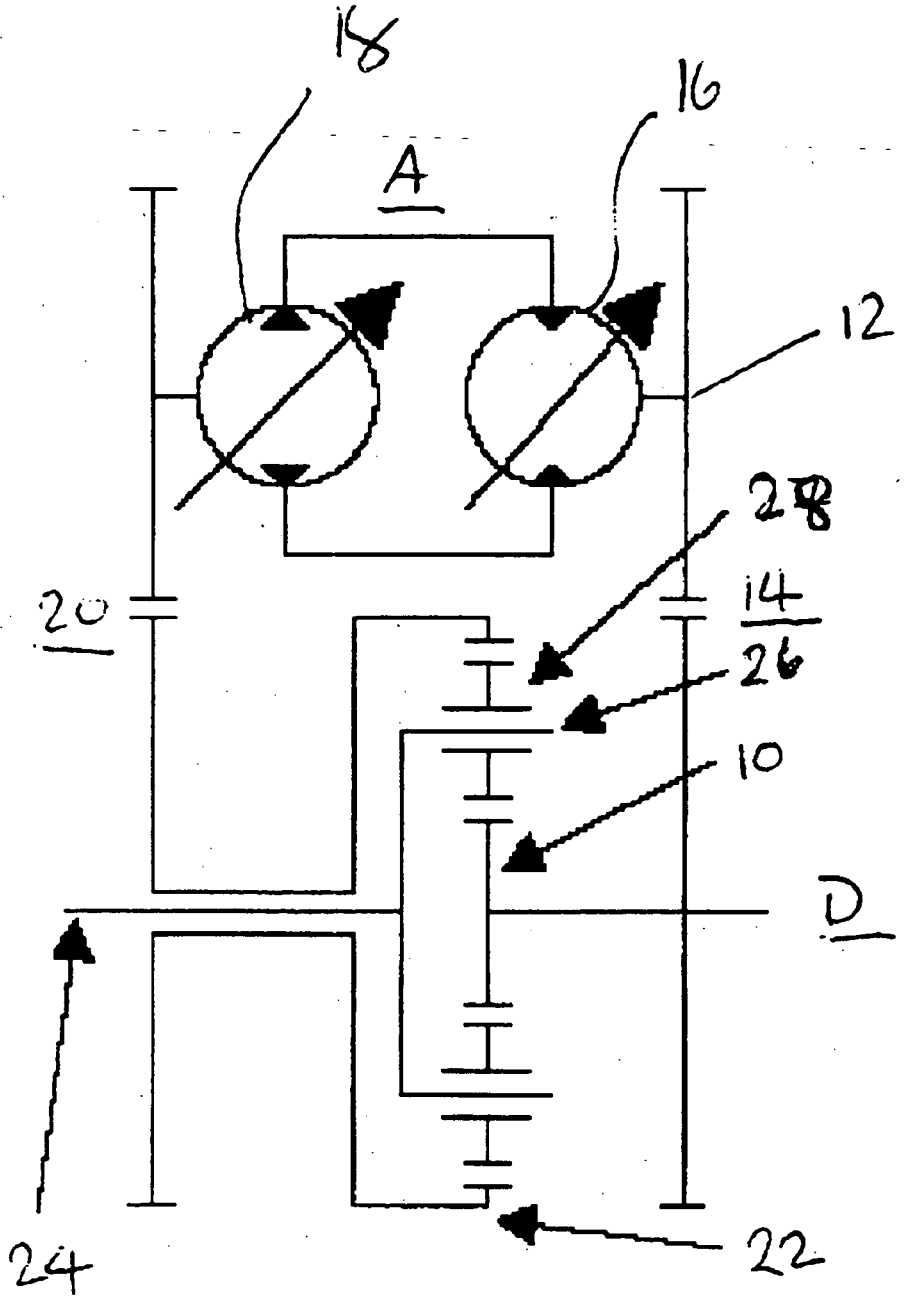


Figure 1

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 7

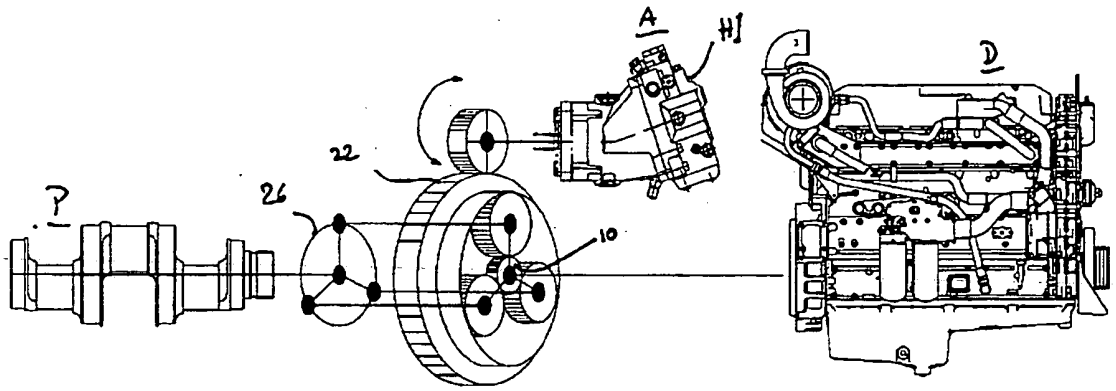


Figure 2

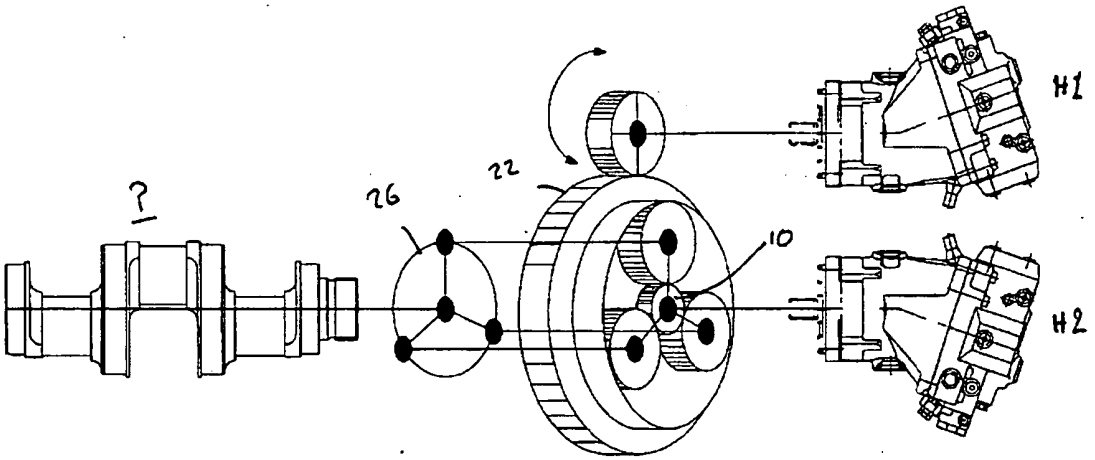


Figure 3

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 8

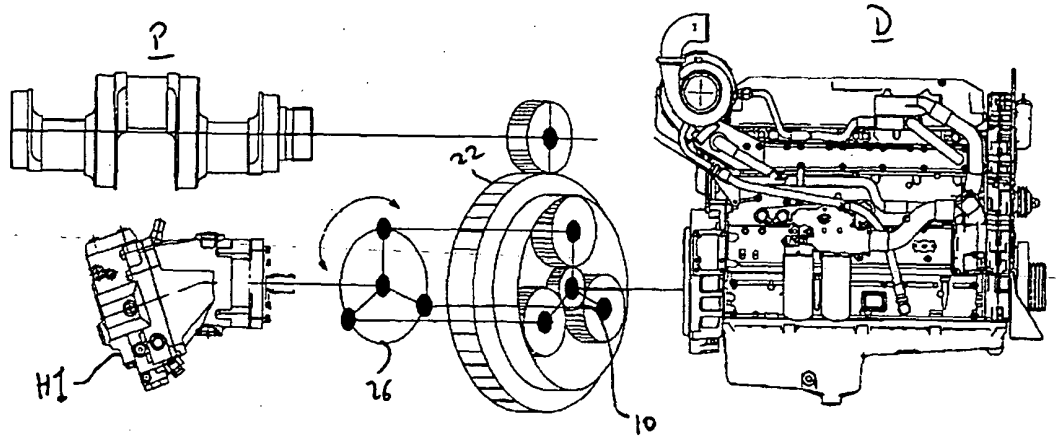


Figure 4

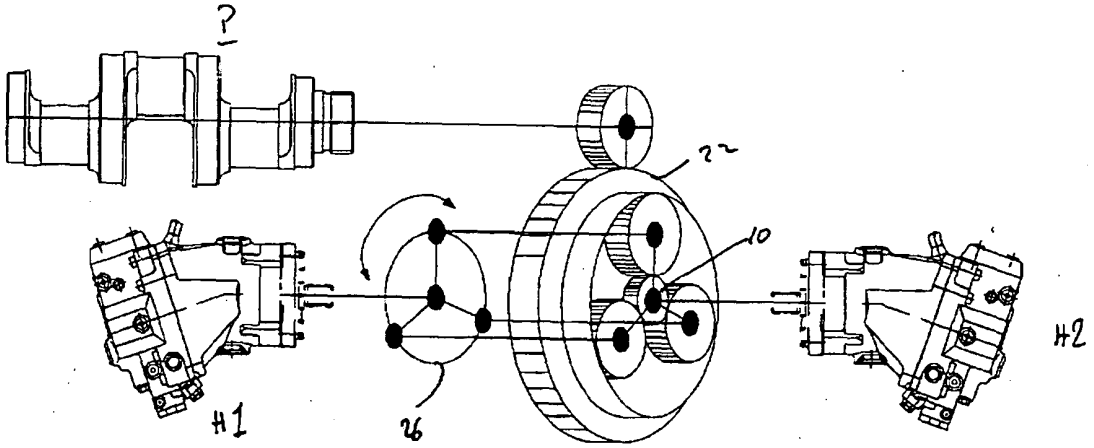


Figure 5

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 9

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4311066 A **[0012]**

HALLIBURTON EXHIBIT 1020
Halliburton Energy Services, Inc. v. U.S. Well Services, LLC, IPR2023-00558, Page 10