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(54) **FLUID-WORKING MACHINE WITH DISPLACEMENT CONTROL**

FLUIDARBEITSMASCHINE MIT VERDRÄNGUNGSSTEUERUNG

MACHINE A FLUIDE DE TRAVAIL POURVUE D'UN DISPOSITIF DE COMMANDE DE DEPLACEMENT

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- **PATENT ABSTRACTS OF JAPAN vol. 2000, no. 09, 13 October 2000 (2000-10-13) & JP 2000 161204 A (CATERPILLAR INC), 13 June 2000 (2000-06-13)**

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Description

Background to the Invention

[0001] This invention relates to a fluid-working machine. In operation of the machine the time-averaged flow of fluid is variable in all four quadrants of motion. The invention is applicable to any machine with working chambers, which alternately expand and contract, whether by pistons and cylinders, vanes, lobes or gears and where the primary method of commutating fluid to the working chambers is by a rotating port plate, synchronised to the phase of the chamber expansion and contraction cycle, which alternately connects high and then low pressure fluid manifolds to each working chamber.

[0002] EP-A-1 319 836 describes a digitally controlled fluid translating device having an electronically controlled valving member but no separate commutating means. US-A-5 259 738, which represents the closest prior art, describes a multi-chamber fluid working device having electromagnetically controlled poppet valves which perform commutation without requiring a separate commutating means.

Summary of the Invention

[0003] The invention provides a fluid-working machine according to claim 1. The insertion of a valve into the fluid connection between the commutating means and each of the working chambers allows each working chamber to be isolated from the commutating means. Chambers which are isolated in this way by the valve operate in an idle condition, whereby no useful fluid work is done by the chamber, and thus the displacement per revolution of the machine is reduced. In its simplest embodiment such valves may be controlled mechanically, allowing the machine to be used in a reduced displacement mode when it is desired, for instance, to operate at high speed. Such mechanical control may be automatic, for instance reducing the displacement of the machine as the speed of rotation increases above a threshold. The valves are individually controlled by an electronic signal, allowing each of the chambers to be isolated according to the command of an electronic controller. Preferably such controller has an input signal of the position of the shaft of the machine, allowing the timing of the valve actuation to be phased relative to the position of the shaft, allowing each chamber to be isolated from the commutator on a stroke-by-stroke basis. Preferred or optional features of the machine are set forth in the dependent claims.

Brief Description of the Drawing

[0004] A particular embodiment of the invention is described below in more detail, by way of example only, and with reference to the accompanying drawing, the single figure of which is a schematic section of a machine according to the invention.

Detailed Description of Particular Embodiment

[0005] The drawing shows a machine comprising a working chamber 4 in the form of cylinder containing a piston actuating a crankshaft 5. A conventional commutator plate 2 alternately connects the chamber 4 to port A or, via a toroidal cavity 10, to port B, one of the ports being a high-pressure port and the other a low-pressure port. As shown, the machine operates as a motor with fluid being supplied at high pressure at port A and exhausted at low pressure at port B, but both the pressures and the direction of flow could be reversed separately without changing the apparatus shown.

[0006] By placing an actively controllable on-off valve 1, in series with a rotating commutator plate 2, into the fluid passage 3 between the commutator plate and the working chamber 4, the flow into the working chamber can be controlled. When the machine is working with the shaft 5 rotating, and the on-off valve closed prior to the opening of the fluid inlet port 2a on the commutator, then the expansion stroke of the working chamber will occur in a partial vacuum. If the fluid is a liquid such as oil, a bubble is formed as air is drawn out of the liquid. The return stroke will collapse the bubble by the time the chamber returns to its minimum volume. In doing so the working volume will have exchanged no work with the fluid system while absorbing very little parasitic work. It is alternatively possible to avoid cavitation and air-release by fitting a fluid connection including a non-return valve 4a between the working chamber and the low-pressure line, possibly via the crank case as shown. Operating the working chamber with the on-off valve closed will result in an idle cycle.

[0007] When the valve 1 is left in the open position the working chamber functions, as normal, to produce a working cycle. The time averaged flow is varied by deciding on a chamber-by-chamber basis whether to effect idle or working cycles. The decisions are taken as each successive chamber nears the minimum volume condition, irrespective of whether the machine is working as a pump or a motor. An electronic controller 6 senses the phase of the working chamber cycle using a once-per-revolution shaft sensor 7, an encoder, a resolver or some similar means. At times coinciding with the minimum working chamber volume the controller can either leave the on-off valve in its de-energised open state or pull it closed through electromagnetic means. In addition to the timing function, the controller reads the system demand, either through an analogue or digital input line or a bus 8, and decides whether the working chamber reaching the minimum volume condition should be left working or idled by closing the valve 1. In the embodiment shown, the on-off valve 1 defaults to the open position and is pulsed to close, but it is possible to see that the opposite operating mode, i.e. default closed, pulse to open would also have application where a power-off freewheel characteristic was required.

[0008] The controller decisions can also be made en-

tirely on the basis of shaft speed in order to limit the rate of increase of shaft power. In such a mode of operation the electronic controller would require no external demand signal and would make the sequential on-off valve actuation decisions on the basis of a pre-programmed flow versus speed function.

[0009] In the instance of a vehicle propulsion circuit, where external demand signals are read by the electronic controller, the decision sequence can be determined in order to limit individual wheel slip, to create a skid steering effect or to create graded changes in torque and thus controlled vehicle accelerations.

Claims

1. A fluid-working machine with variable volume working chambers (4), each of which is connected to a fluid commutating means (2) which alternately connects the working chamber to either of two fluid manifolds (A, B), wherein an electronically controlled valve member (1) is inserted into the flow path (3) between each chamber (4) and the commutating means.

2. A fluid-working machine as clamed in claim 1, wherein a controller (6) for controlling the valve member (1) receives an input signal of the phase angle of a shaft (5) of the machine or at least one electronic pulse per revolution which informs the controller (6) that the shaft is passing a known phase angle.

3. A fluid-working machine as claimed in claim 2, wherein the controller (6) is arranged to choose whether to actuate the valve member (1), each time the working chamber volume is approaching its minimum, such that the valve is closed at a time close to the time the working chamber (4) begins its expansion stroke, if it is desired to isolate the working chamber from the commutating means (2).

4. A fluid-working machine as claimed in claim 3, wherein the controller (6) sums the previous flow demand to create a total displacement demand and compares it with the actual displacement through the machine over the same time period to determine the displacement error and the controller chooses either to isolate the working chamber (4) or to leave it active in order to minimise the ongoing accumulated displacement error.

5. A fluid-working machine as claimed in claim 3, wherein the controller (6) reads a demand from an external signal line and decides whether to isolate working chambers (4), as they reach the minimum volume condition, in order to regulate one of speed, torque, volumetric flow rate, power and volume displaced per revolution.

6. A fluid-working machine as claimed in claim 3, wherein the controller makes decisions to isolate working chambers (4) on the basis of sensed shaft speed so that the ratio of working cylinders (4) to idle cylinders (4) decreases, according to a predetermined function, as the machine speeds up, in order to either maintain a constant level of throughput flow or one which rises less quickly than the shaft speed increase would indicate.

7. A fluid-working machine as claimed in claim 2, wherein the machine is arranged to work as a motor, and the controller (6) can choose to close the valve member (1) some fraction of the way into an expansion stroke of the chamber (4), such that the chamber is connected to the commutating means (2) for only a fraction of the expansion stroke, such that the volume of fluid working to drive the load in that expansion stroke is a fraction of the full geometric displacement of the chamber (4).

8. A fluid-working machine as claimed in claim 2, wherein the machine is arranged to work as a pump, and the controller (6) can choose to close the valve member (1) some fraction of the way into the expansion stroke of the chamber (4), such that the chamber is connected to the commutating means (2) for only a fraction of a full working stroke, such that part of an expansion stroke consists of pulling a partial vacuum in the chamber (4), such that when a next contraction stroke begins, the chamber does not act as a pump immediately but at some fraction of the way into the contraction stroke, such that the contraction stroke displaces only a fraction of the full geometric displacement of the chamber (4) into the commutating means (2).

9. A fluid-working machine as claimed in claim 2, wherein the controller (6) is operable to reduce the loss of energy in the compressed fluid by closing the valve member (1) just before the chamber reaches its maximum volume condition so that the remaining expansion can de-pressurise the fluid contained within the chamber (4) before the commutating valve port is opened to the low-pressure manifold.

Patentansprüche

1. Fluidarbeitsmaschine mit Arbeitskammern (4) mit veränderlichem Volumen, wovon jede mit einem Fluidumschaltmittel (2) verbunden ist, das die Arbeitskammer abwechselnd mit einem von zwei Fluidverteilern (A, B) verbindet, wobei ein elektronisch gesteuertes Ventilelement (1) in den Strömungsweg (3) zwischen jede Kammer (4) und das Umschaltmittel eingesetzt ist.

2. Fluidarbeitsmaschine, wie in Anspruch 1 beansprucht, wobei ein Steuergerät (6) zur Steuerung des Ventilelements (1) ein Eingabesignal des Phasenwinkels einer Welle (5) der Maschine oder mindestens einen elektronischen Puls je Umdrehung empfängt, der das Steuergerät (6) darüber informiert, dass die Welle einen bekannten Phasenwinkel durchläuft.

3. Fluidarbeitsmaschine, wie in Anspruch 2 beansprucht, wobei das Steuergerät (6) dazu eingerichtet ist, auszuwählen, ob das Ventilelement (1) jedesmal, wenn das Arbeitskammervolumen sich seinem Minimum nähert, betätigt werden soll, sodass das Ventil zu einem Zeitpunkt dicht bei dem Zeitpunkt, zu dem die Arbeitskammer (4) ihren Expansionshub beginnt, geschlossen wird, wenn die Arbeitskammer von dem Umschaltmittel (2) isoliert werden soll.

4. Fluidarbeitsmaschine, wie in Anspruch 3 beansprucht, wobei das Steuergerät (6) den vorangehenden Strömungsbedarf addiert, um einen Gesamtverdrängungsbedarf zu erhalten, und ihn mit der tatsächlichen Verdrängung durch die Maschine über den gleichen Zeitraum vergleicht, um den Verdrängungsfehler zu ermitteln, und das Steuergerät wählt, die Arbeitskammer (4) entweder zu isolieren oder sie aktiv zu lassen, um den laufenden kumulierten Verdrängungsfehler auf ein Mindestmaß zurückzubringen.

5. Fluidarbeitsmaschine, wie in Anspruch 3 beansprucht, wobei das Steuergerät (6) einen Bedarf von einer externen Signalleitung abliest und entscheidet, ob Arbeitskammern (4) isoliert werden müssen, wenn sie den Mindest-Volumenzustand erreichen, um eines von Geschwindigkeit, Drehkraft, Volumenstrom, Kraft und verdrängtem Volumen je Umdrehung zu regulieren.

6. Fluidarbeitsmaschine, wie in Anspruch 3 beansprucht, wobei das Steuergerät Entscheidungen trifft, um Arbeitskammern (4) auf Basis der erfassten Wellendrehzahl zu isolieren, sodass das Verhältnis von arbeitenden Zylindern (4) zu Zylindern im Leerlauf (4) gemäß einer vorbestimmten Funktion abnimmt, wenn die Maschine die Drehzahl erhöht, um entweder ein konstantes Durchsatzniveau aufrechtzuerhalten oder eines, das weniger rasch ansteigt, als der Wellendrehzahlanstieg andeuten würde.

7. Fluidarbeitsmaschine, wie in Anspruch 2 beansprucht, wobei die Maschine dazu eingerichtet ist, als Motor zu arbeiten, und das Steuergerät (6) wählen kann, das Ventilelement (1) einen Bruchteil des Wegs in einen Expansionshub der Kammer (4) zu schließen, sodass die Kammer nur für einen Bruchteil des Expansionshubs mit dem Umschaltmittel (2) verbunden ist, sodass das Fluidvolumen, das arbeitet, um die Last anzutreiben, in diesem Expansionshub ein Bruchteil der vollen geometrischen Verdrängung der Kammer (4) ist.

8. Fluidarbeitsmaschine, wie in Anspruch 2 beansprucht, wobei die Maschine dazu eingerichtet ist, als Pumpe zu arbeiten, und das Steuergerät (6) wählen kann, das Ventilelement (1) einen Bruchteil des Wegs in den Expansionshub der Kammer (4) zu schließen, sodass die Kammer nur zu einem Bruchteil eines vollen Arbeitshubs mit dem Umschaltmittel (2) verbunden ist, sodass ein Teil eines Expansionshub aus dem Ziehen eines Teilvakuums in der Kammer (4) besteht, sodass, wenn ein nächster Kontraktionshub beginnt, die Kammer nicht sofort als Pumpe wirkt, sondern bei einem Bruchteil des Wegs in den Kontraktionshub, sodass der Kontraktionshub nur einen Bruchteil der vollen geometrischen Verdrängung der Kammer (4) in das Umschaltmittel (2) verdrängt.

9. Fluidarbeitsmaschine, wie in Anspruch 2 beansprucht, wobei das Steuergerät (6) betreibbar ist, um den Energieverlust in dem komprimierten Fluid durch Schließen des Ventilelements (1) kurz bevor die Kammer ihren maximalen Volumenzustand erreicht, zu reduzieren, sodass die verbleibende Expansion das in der Kammer (4) enthaltene Fluid drucklos machen kann, bevor die Umschaltventilöffnung zu dem Niederdruckverteiler geöffnet wird.

Revendications

1. Machine de traitement de fluide comprenant des chambres de traitement (4) à volume variable, qui sont chacune reliées à un moyen de commutation de fluide (2) qui relie en alternance la chambre de traitement à l'un ou l'autre de deux collecteurs de fluide (A, B), dans laquelle un membre (1) faisant office de soupape à commande électronique est inséré dans la voie d'écoulement (3) entre chaque chambre (4) et le moyen de commutation.

2. Machine de traitement de fluide selon la revendication 1, dans laquelle un contrôleur (6) pour la commande du membre (1) faisant office de soupape reçoit un signal d'entrée de l'angle de phase d'un arbre (5) de la machine ou au moins une impulsion électronique par révolution, qui informe le contrôleur (6) du fait que l'arbre passe par un angle de phase connu.

3. Machine de traitement de fluide selon la revendication 2, dans laquelle le contrôleur (6) est arrangé pour savoir s'il doit actionner ou non le membre (1) faisant office de soupape, à chaque fois que le vo-

lume de la chambre de traitement s'approche de son minimum, si bien que la soupape est fermée à un moment proche du moment auquel la chambre de traitement (4) entame sa course de détente, lorsqu'on souhaite isoler la chambre de traitement du moyen de commutation (2).

4. Machine de traitement de fluide selon la revendication 3, dans laquelle le contrôleur (6) additionne les demandes d'écoulement précédentes pour créer une demande de déplacement totale et la compare au déplacement en vigueur à travers la machine pendant le même laps de temps afin de déterminer l'erreur de déplacement et le contrôleur choisi, soit d'isoler la chambre de traitement (4), soit de la laisser active, afin de minimiser les erreurs de déplacement accumulées en cours.

5. Machine de traitement de fluide selon la revendication 3, dans laquelle le contrôleur (6) lit une demande à partir d'un circuit de transmission externe et décide d'isoler ou non les chambres de traitement (4), lorsqu'elles atteignent leur état de volume minimal, afin de réguler un membre du groupe comprenant la vitesse, le couple, le débit volumique, la puissance et le volume déplacé par révolution.

6. Machine de traitement de fluide selon la revendication 3, dans laquelle le contrôleur prend ses décisions pour l'isolation des chambres de traitement (4) sur base de la vitesse détectée de l'arbre, de façon à diminuer le rapport des cylindres (4) en état d'activité aux cylindres (4) en état de marche à vide, conformément à une fonction prédéterminée, lorsque la vitesse de la machine augmente, pour pouvoir maintenir un niveau de débit soit constant, soit qui augmente moins rapidement que l'augmentation indiquée de la vitesse de l'arbre.

7. Machine de traitement de fluide selon la revendication 2, dans laquelle la machine est arrangée pour travailler à la manière d'un moteur, et le contrôleur (6) peut décider de fermer le membre (1) faisant office de soupape sur une certaine fraction du chemin menant à la course de détente de la chambre (4), de telle sorte que la chambre est reliée au moyen de commutation (2) sur seulement une fraction de la course de détente, si bien que le volume du fluide qui travaille pour entraîner la charge dans cette course de détente représente une fraction du déplacement géométrique total de la chambre (4).

8. Machine de traitement de fluide selon la revendication 2, dans laquelle la machine est arrangée pour travailler à la manière d'une pompe, et le contrôleur (6) peut décider de fermer le membre (1) faisant office de soupape sur une certaine fraction du chemin menant à la course de détente de la chambre (4), de telle sorte que la chambre est reliée au moyen de commutation (2) sur seulement une fraction de la course de travail, si bien qu'une partie de la course de détente consiste à introduire un vide partiel dans la chambre (4) de telle façon que, lorsque la course de contraction suivante commence, la chambre n'agit pas directement à la manière d'une pompe, mais après une certaine fraction du chemin menant à la course de contraction, si bien que la course de contraction déplace seulement une fraction du déplacement géométrique total de la chambre (4) dans le moyen de commutation (2).

9. Machine de traitement de fluide selon la revendication 2, dans laquelle le contrôleur (6) peut être actionné pour réduire la perte d'énergie dans le fluide comprimé en fermant le membre 1 faisant office de soupape juste avant que la chambre n'atteigne son état de volume maximal, si bien que la détente restante peut soumettre le fluide contenu dans la chambre (4) à une dépressurisation, avant d'ouvrir l'orifice de la soupape de commutation sur le collecteur basse pression.

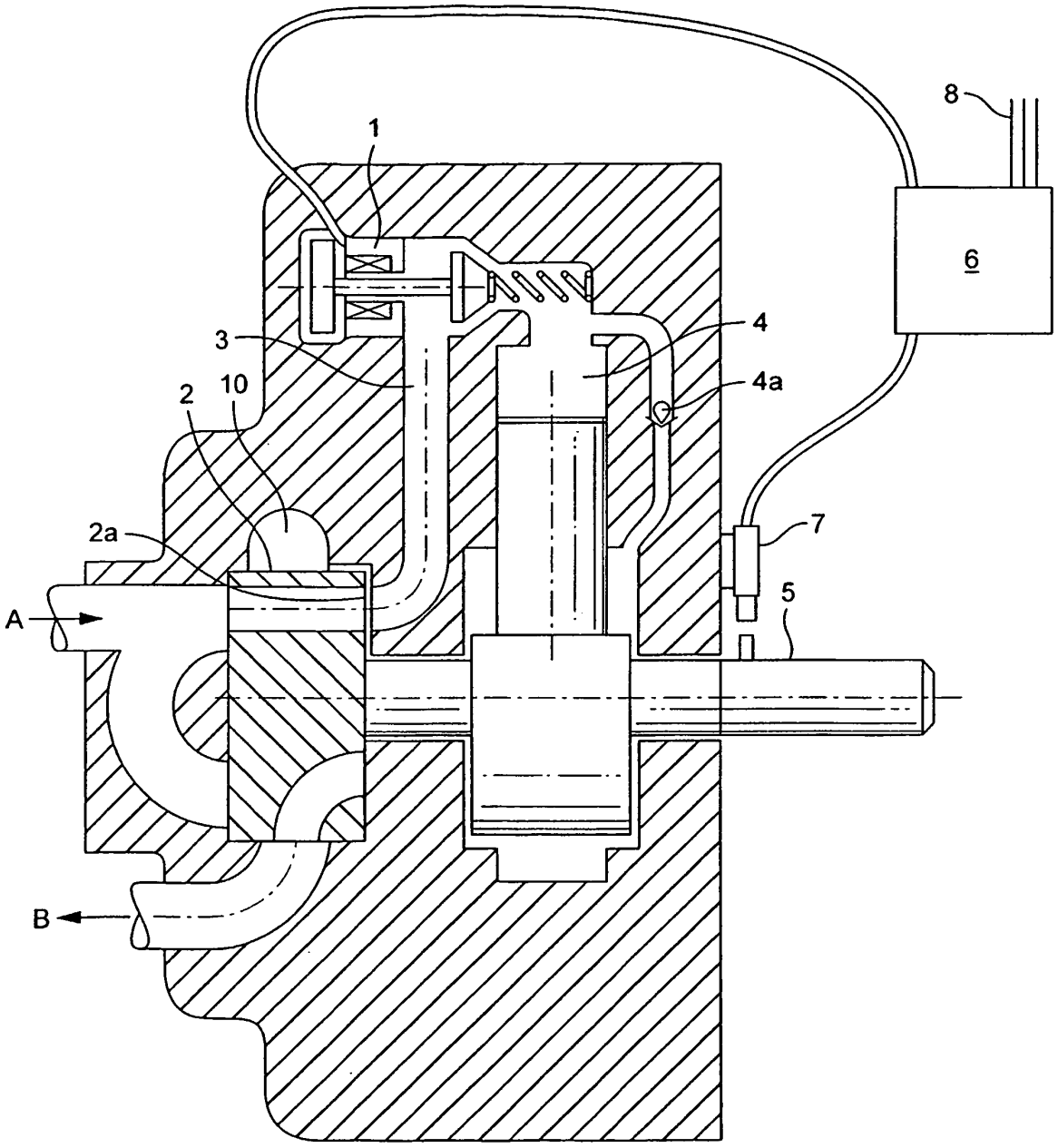

FIG. 1

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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