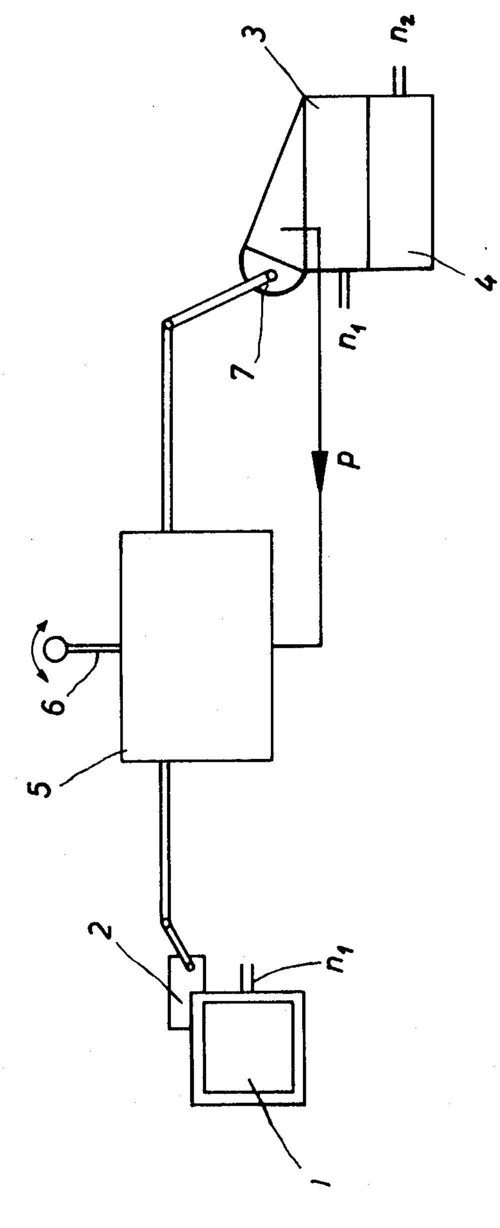
Oct. 5, 1971 W. KOBALD 3,609,964

REGULATED HYDRAULIC DRIVE

Filed April 14, 1970 2 Sheets-Sheet 1

Fig. 1



INVENTOR.
Walter KOBALD
BY Michael S. Striker
Attorney

REGULATED HYDRAULIC DRIVE

Filed April 14, 1970 2 Sheets-Sheet 2

Fig.2

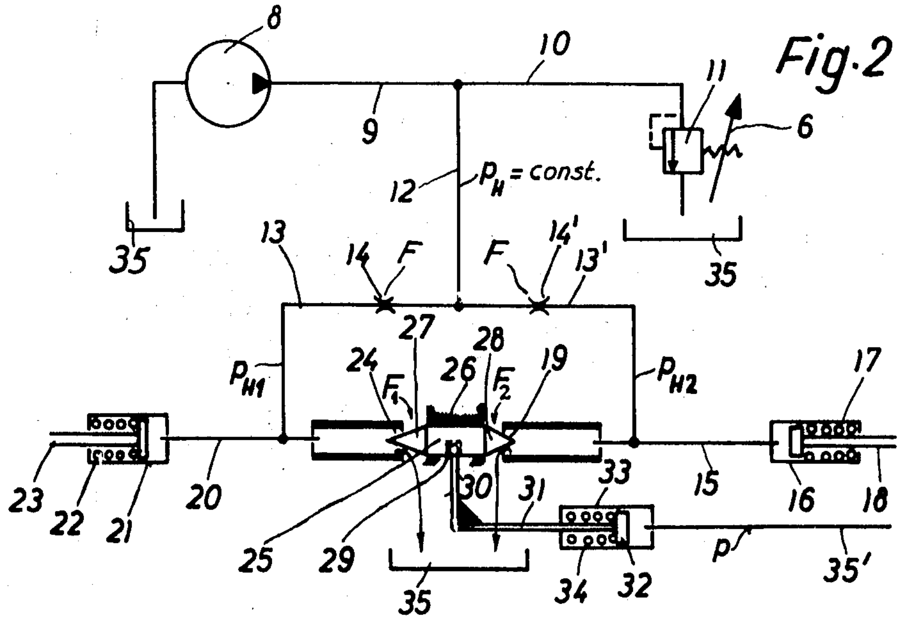


Fig.3

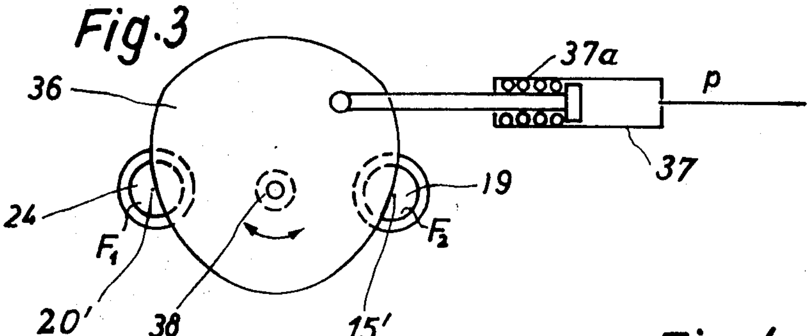
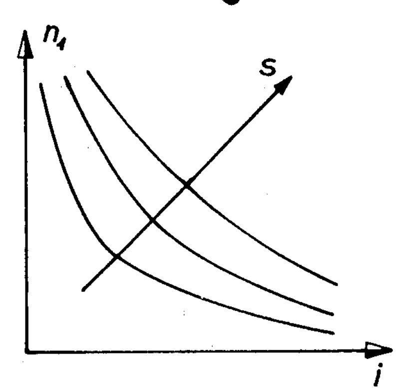


Fig.4



INVENTOR.
Walter KOBALD

BY
Attorney

3,609,964

REGULATED HYDRAULIC DRIVE

Walter Kobald, Stuttgart-Feuerbach, Germany, assignor to Robert Bosch, G.m.b.H., Stuttgart, Germany

Filed Apr. 14, 1970, Ser. No. 28,424
Claims priority, application Germany, Apr. 24, 1969, P 19 20 859.4
Int. Cl. F02b 73/00
U.S. Cl. 60—19 14 Claims

ABSTRACT OF THE DISCLOSURE

A hydraulic drive comprises a combustion engine, a hydraulic transmission whose pump is driven by the engine, and a regulating apparatus including an auxiliary pump discharging through a main conduit, whose pressure is regulated by a pressure-regulating valve under the control of an operator, and through two variable throttles whose throttle cross-sections are simultaneously increased and decreased, respectively, by throttle control means responsive to the pressure in the transmission pump. The different throttled pressures are applied to a first servo motor controlling the rotary speed of the combustion engine, and to a second servo motor controlling the transmission pump to vary the piston stroke and output of the same. When the operator adjusts the pressure-regulating valve, the transmission motor operates at different rotary speeds, and any selected rotary speed is maintained by the regulating apparatus constant and independent of the load, while the regulated hydraulic drive operates at optimal efficiency.

BACKGROUND OF THE INVENTION

The German Pat. 1,204,539 discloses a regulated hydraulic drive with a regulating apparatus which is, on the one hand controlled by the foot pedal determining the rotary speed of the prime mover combustion engine, and, on the other hand, is controlled by the pressure prevailing in the hydrostatic transmission whose pump is driven by the combustion engine.

The apparatus of the prior art permits it to operate the combustion engine and the hydrostatic transmission in a range of high efficiency. However, a great number of regulating devices and control valves are necessary, so that the hydraulic drive of the prior art is very expensive. Another disadvantage is that centrifugal governors are used for regulation which are unreliable in the lower speed range.

SUMMARY OF THE INVENTION

It is one object of the invention to provide a regulated hydraulic drive with a simple regulating apparatus which effects an operation of the drive within the range of optimal efficiencies.

Another object of the invention is to operate the control means determining the speed of the combustion engine, and also the control means determining the output of the transmission pump, by control throttles which are simultaneously adjusted in response to the pressure in the transmission.

Another object of the invention is to maintain any selected speed of the transmission motor constant and independent of the load variations.

With these objects in view, the present invention provides a regulating apparatus having an input flow of a pressure medium under constant pressure which is divided into two branch streams respectively flowing through first and second throttles. The first throttles are of equal and constant throttle cross-section, while the second throttles have throttle cross-sections which are variable and

are simultaneously varied by control means responsive to the pressure in the hydrostatic transmission. One of the branch streams controls the supply of fuel to the combustion engine, and the other controls the stroke of the transmission pump.

A regulating apparatus according to a preferred embodiment of the invention includes a source of pressure medium, such as an auxiliary pump, conduit means including a main conduit receiving the medium from the source and first and second branch conduits, first hydraulic operating means communicating with the first branch conduit and operatively connected with the first control means for operating the same, second hydraulic operating means communicating with the second branch conduit and operatively connected with the second control means for operating the same, a first throttle means communicating with the first branch conduit, a second throttle means communicating with the second branch conduit, a throttle control means for varying the throttle cross-sections of the first and second throttle means, and throttle operating means operatively connected with the throttle control means and hydraulically connected with the hydrostatic transmission for operating the throttle control means in response to the pressure in the hydrostatic transmission. Operator-controlled means preferably including a pressure-regulating valve in the main conduit, are provided for producing selected pressures in the main conduit so that in every position of the operator-controlled means, a different rotary speed is maintained constant and independent of the load variations of the hydraulic motor, while the engine and hydraulic transmission operate at optimal efficiency.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic view illustrating a regulated hydraulic drive according to the invention;

FIG. 2 is a fragmentary schematic view illustrating a regulating apparatus used in the drive of FIG. 1;

FIG. 3 is a fragmentary schematic view illustrating a modified throttle control means; and

FIG. 4 is a diagram graphically illustrating speed variations of the prime mover engine over the ratio of the hydrostatic transmission.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring first to FIG. 1, a diesel motor **1** serves as prime mover and has a first control means **2** which can be adjusted to vary the speed of the output shaft of the combustion engine **1** which is schematically indicated by the number of revolutions n_1 of the output shaft of the combustion engine **1**. The output shaft is connected with the input shaft of a hydraulic pump **3** which consequently also rotates at the rotary speed n_1. Hydraulic pump **3**, which is preferably an axial piston pump with a wobble plate, drives a corresponding hydraulic motor **4** whose output shaft has n_2 revolutions. The wheels of the vehicle, not shown, are driven by hydraulic motor **4** at n_2 revolutions per minute. A regulating apparatus, which is illustrated in detail in FIG. 2, has an operator-controlled means **6**, preferably a foot pedal, which influences the regulating apparatus **5**, which is also influenced by the pressure p prevailing in the hydrostatic transmission **3, 4**, and more particularly in the pump **3**. The regulating apparatus is connected with the first control means 2 of the combustion engine 1 for varying the rotary speed n_1, and also connected with second control means 7 for varying the length of the piston stroke and the output of the pump 3 which drives hydraulic motor 4 accordingly.

Referring now to FIG. 2, which illustrates schematically the regulating apparatus 5, an auxiliary pump 8 is provided as part of the regulating apparatus, and pumps a pressure medium into a main conduit 9, 12 which is connected with a conduit 10 in which a pressure-regulating valve 11 is located which is controlled by the foot pedal 6, or other adjusting means controlled by the driver of the vehicle. Auxiliary pump 8 pumps the pressure medium out of container means 35 into which also conduit 10 discharges.

Pressure medium flowing through main conduit 9, 12 at a pressure p_H which is constant for each adjusted position of the pressure-regulating valve 11. The pressure medium flows from main conduit 12 into two branch conduits 13 and 13′ in which throttles 14 and 14′ are provided which have the same throttle cross-section F.

Downstream of the constant throttles 14 and 14′, the pressures p_{H1} and p_{H2} prevail which correspond to the pressure p_H selected by the operator by correspondingly placing the foot pedal 6. Branch conduit 13 communicates with a conduit 20 leading to a first hydraulic operating means shown to be a servo motor having a cylinder 21, a piston 23, and a spring 22 urging piston 23 to oppose the pressure medium flowing from conduit 20 into cylinder 21. Piston 23 is mechanically connected with the first control means 2, see FIG. 1, by which the speed and number of revolutions of the combustion engine 1 is adjusted. The first control means are conventional, and determine the amount of fuel flowing into the combustion engine.

The second branch conduit 13′ communicates with the conduit 15 which opens into a second hydraulic operating means shown to be a servo motor having a cylinder 16, a piston 18, and a spring 17 urging piston 18 to oppose the pressure medium flowing from conduit 15 into cylinder 16. Piston 18 is connected with second control means 7 by which the stroke of pump 3, and thereby its output, is adjusted.

The end of conduit 20 remote from cylinder 21 is shown in axial section, and has a throttle opening 24. The end of conduit 15 remote from cylinder 16 is shown in axial section and has a throttle opening 19 confronting throttle opening 24 and being aligned with the same. Throttle openings 24 and 19 are spaced a predetermined distance. A throttle control member 25 has a central cylindrical portion guided in a guideway 26 for longitudinal movement, and has two conical end portions 27 and 28 which respectively project into throttle openings 24 and 19, forming annular throttle cross-sections F_1 and F_2 in the same. When throttle control member 25 is displaced in guideway 26 into throttle opening 24, the throttle cross-section F_1 is decreased, and the throttle cross-section F_2 is increased. During opposite movement of throttle control member 25, throttle cross-section F_2 is decreased, and throttle cross-section F_1 is increased so that the two throttles are always simultaneously operated and adjusted. An arm 30 passes through a cut-out in the guideway 26 to throttle control member 25. Arm 30 is fixedly secured to a piston rod 31 of a piston 32 of a throttle-operating means which includes a spring 33 urging piston 32 to the right as viewed in FIG. 2 against the pressure of the pressure medium supplied through a conduit 35 from the transmission pump 3 at a pressure p. When the pressure p increases, throttle control member 25 is moved into throttle opening 24, and when the pressure p decreases, the spring 34 causes movement of throttle control member 25 into throttle opening 19.

In the embodiment of FIG. 3, the conduits 15′ and 20′ are connected with the branch conduits 13 and 13′ as explained above for conduits 20 and 15, but are parallel so that the throttle openings 24 and 19 are located in a plane. A throttle control member 36 has the form of a non-circular plate whose peripheral edge crosses throttle openings 24 and 19, reducing the free throttle cross-sections F_1 and F_2. Throttle-control member 36 is turned about a shaft 38 by throttle-operating means including a cylinder 37, corresponding to cylinder 33 and a piston 37*a* connected with throttle-control member 36. The pressure medium is supplied through conduits 35′ from the pump 3 into cylinder 37. In accordance with variations of the pressure p in the hydrostatic transmission 3, 4, throttle-control member 36 is turned to increase the free flow cross-section F_1 when the free flow cross-section F_2 is reduced, and vice versa.

OPERATION

The operator or driver of a vehicle displaces the adjusting means 6, such as a foot pedal, so that the pressure-regulating valve 11 determines a pressure p_H in conduit 12 on which the speed of the vehicle depends whose wheels are driven by the hydraulic motor 4. The displacement of the foot pedal 6 is proportional to the vehicle speed V_F and to the number of revolutions n_2 of hydraulic motor 4. For each position of the foot pedal, a different constant pressure p_H and a different number of revolutions n_2 is obtained. Excess pressure medium discharged through the throttle openings 24 and 19, and by the pressure-regulating valve 11 flow into container means 35 which is connected with the suction inlet of the auxiliary pump 8 so that the pressure medium is circulated by the auxiliary pump 8.

Regulating apparatus controls the speed n_2 and, depending on any selected position of the foot pedal 6 and on the pressure p in the hydrostatic transmission 3, 4; the transmission ratio i of the hydrostatic transmission 3, 4, and the number of revolutions n_1 of the combustion engine 1 are adjusted to values at which combustion engine 1 and the hydrostatic transmission operate at optimal efficiency. At the same time, the regulating apparatus of FIG. 2 must also assure that, while optimal efficiency is maintained, the selected vehicle speed V_F remains constant even if the vehicle encounters resistance, and the load on the hydraulic motor 4 varies. This can be obtained when the regulating graph has the shape of a hyperbola.

As shown in FIG. 4, the abscissa represents the transmission ratio i of the hydrostatic transmission 3, 4, and the ordinate represents the number of revolutions n_1 of the combustion engine 1, and of the pump 3. Each position s of the foot pedal 6 is associated with a different hyperbolic regulating graph some of which are shown in FIG. 4. The regulation is obtained in the following manner:

The auxiliary pump 8, or any other source of a pressure medium, such as an accumulator, which need not be driven in synchronism with the combustion engine or transmission, pumps a pressure medium into the main conduit 9, 10, 12. The pressure medium in conduit 12 flows into the two branch conduits 13 and 13′, and each of the branch streams of the pressure medium flows through the identical throttles 14, 14′ having the throttle cross-section F, so that the pressure of the respective branch streams p_{H1} and p_{H2} are accordingly reduced.

The pressure medium in branch conduit 13 flows through conduit 20 and through the free throttle cross-section F_1 into the container 35, and the same is the case with the pressure medium in branch conduit 13′ which flows through the free throttle cross-section F_2 into container 35. The throttle cross-sections F_1 and F_2 are increased or reduced, depending on the position of throttle control member 25 which is displaced in accordance with the pressure in the throttle-operating means 32, 33 to which pressure fluid is supplied at a pressure p from the hydrostatic transmission. A pressure p_{H1} is produced in branch conduit 13, and the pressure p_{H2} is produced in branch conduit **13'**. Pressure p_{H1} acts on servo motor **21, 22, 23** so that piston **23** operates the control means **2** of combustion engine **1**, influencing the number of revolutions n_1 of the output shaft of combustion engine **1**, and of the input shaft of pump **3**. The pressure p_{H2} acts in the cylinder **16** of the servo motor **16, 17, 18** so that piston **18** is displaced accordingly, and adjusts control means **7** by which the piston stroke of the pump **3** is adjusted, for example by tilting the wobble plate of an axial piston pump. The pressure p of the fluid circulating in the hydrostatic transmission, is supplied to the cylinder **33** of the throttle-operating servo motor **32, 33, 34.**

As a result, the pressure p_{H1} is proportional to the number of revolutions and to the rotary speed n_1 of the combustion engine and of pump **3**, while the pressure p_{H2} is proportional to the transmission ratio i of the hydrostatic transmission **3, 4**. The speed V_F of the vehicle driven by hydraulic motor **4** is proportional to the product of the number of revolutions of combustion engine n_1 and the transmission ratio i of the hydrostatic transmission **3, 4**. It follows that V_F is proportional to $p_{H1} \cdot p_{H2}$. This means that for a selected speed of the vehicle, which should be constant, and in the event of variations of the pressure p_{H1} and p_{H2} during regulation, the system of coordinates shown in FIG. 4 will show a hyperbolic graph.

This may be mathetically expressed as follows:

$$V_F \text{ prop. } p_{H1} \cdot p_{H2} = \frac{K \cdot p_H{}^2}{\left(\frac{F_1{}^2}{F^2}+1\right)\cdot\left(\frac{F_2{}^2}{F^2}+1\right)}$$

which represents a hyperbola with p_{H1} and p_{H2} as variables while K is a constant factor. The vehicle speed V_F varies with the pressure p_H which is obtained by displacing foot pedal **6** and adjusting pressure-regulating valve **11**. F is the throttle cross-section of throttles **14** and **14'**, F_1 is the annular throttle cross-section of throttle **24, 27**, and F_2 is the throttle cross-section of throttle **19, 28**.

If the vehicle speed V_F is to be constant, the following equation is valid:

$$\left(\frac{F_1{}^2}{F^2}+1\right)\cdot\left(\frac{F_2{}^2}{F^2}+1\right)=K'$$

From this equation the function $F_1=f(F_2)$ can be determined. Due to the thus obtained optimal efficiency, a saving of fuel supplied to the combustion engine **1** is obtained.

In the modification of FIG. 3, the peripheral shape of the throttle control member **36** is selected so that the throttle cross-sections F_1 and F_2 are determined in accordance with the required mathematical conditions. In the embodiment of FIG. 2, the throttle control member **25** has conical end portions slanted at different angles for obtaining the required relationship between the throttle cross-sections F_1 and F_2.

In both embodiments, the pressure p_{H1} and p_{H2} depend on the free area of the throttle cross-sections.

The conduits are shown in FIG. 2 in a schematic manner, and it will be understood that the conduits can be constructed as channels and bores in the walls of a regulator casing, in which the throttles and the pressure-regulating valve **11** are provided.

In the above description, it was assumed that hydraulic motor **4** cannot be adjusted. If hydraulic motor **4** is adjustable, and has a tiltable wobble plate, for example, a hydraulic servo motor operating the wobble plate is hydraulically connected with the main conduit **12** in which a constant selected pressure prevails.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of regulated hydraulic drives differing from the types described above.

While the invention has been illustrated and described as embodied in a regulating apparatus for a hydraulic drive provided with two regulating throttles controlled by

the pressure of the transmission pump, and controlling the speed of the prime mover and the output of the transmission pump, it is not intended to be limitedto the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims:

1. Regulated hydraulic drive comprising a prime mover engine having first control means for varying the speed of said engine; a hydrostatic transmission including a hydraulic pump driven by said engine, and a hydraulic motor driven by said pump, said transmission having second control means for varying the output of said pump whereby the speed of said hydraulic motor is varied; a regulating apparatus including a source of a pressure medium, conduit means including a main conduit receiving said medium from said source and first and second branch conduits, first hydraulic operating means communicating with said first branch conduit and operatively connected with said first control means for operating the same, second hydraulic operating means communicating with said second branch conduit and operatively connected with said second control means for operating the same, a first throttle means communicating with said first branch conduit, a second throttle means communicating with said second branch conduit, a throttle control means for varying the throttle cross-section of said first and second throttle means, and throttle operating means operatively connected with said throttle control means and hydraulically connected with said hydrostatic transmission for operating said throttle control means in response to the pressure in said hydrostatic transmission whereby the pressure in said first and second branch conduits are proportional to the speed of said engine and to the ratio of said transmission, respectively; and operator controlled means in said main conduit for producing selected pressures in said main conduit so that in every position of said operator controlled means a different rotary speed of said hydraulic motor is maintained constant and independent of the load variations of said hydraulic motor while said engine and hydraulic transmission operate at optimal efficiency.

2. Regulated hydraulic drive as claimed in claim **1** wherein said regulating apparatus includes first and second throttles having the same throttling cross section and connecting said main conduit with said first and second branch conduits, respectively.

3. Regulated hydraulic drive as claimed in claim **1** wherein said engine is a combination engine; wherein said first control means controls the admission of a fuel mixture into said combustion engine; wherein said pump is a piston pump; and wherein said second control means adjusts the length of the stroke of said pump.

4. Regulated hydraulic drive as claimed in claim **1** wherein said throttle operating means is hydraulically connected with said pump and responds to the pressure in the same.

5. Regulated hydraulic drive as claimed in claim **1** wherein said source of pressure medium is an auxiliary pump; and wherein said first and second throttle means have outlets for discharging said pressure medium.

6. Regulated hydraulic drive as claimed in claim **1** wherein said throttle control means include a throttle control member increasing the throttling cross section of said first throttle means when decreasing the throttling cross section of said second throttle mean, and vice versa.

7. Regulated hydraulic drive as claimed in claim 6 wherein said throttle control member is reciprocable along a straight path between said first and second throttle means.

8. Regulated hydraulic drive as claimed in claim 6 wherein said throttle control member is mounted for turning movement for simultaneously varying the throttling cross sections of said first and second throttle means.

9. Regulated hydraulic drive as claimed in claim 1 wherein said first and second throttle means have aligned throttle openings located opposite each other; and wherein said throttle control means includes a throttle control member located between said throttle openings and having substantially conical end portions projecting into said throttle openings so that the throttle cross sections of said first and second throttle means are annular, said throttle control member being movable by said throttle operating means into one and out of the respective other throttle opening for simultaneously reducing the throttle cross section of one of said first and second throttle means while increasing the throttle cross section of the respective other of said first and second throttle means.

10. Regulated hydraulic drive as claimed in claim 1 wherein said first and second throttle means have spaced throttle openings; and wherein said throttle control means includes a throttle member mounted for movement about an axis, said throttle member having a periphery crossing said throttle openings for partly closing the same, said throttle member being turnable by said throttle operating means between angular positions for simultaneously reducing the open throttle cross section of one of said first and second throttle openings while increasing the open throttle cross section of the respective other of said first and second throttle openings.

11. Regulated hydraulic drive as claimed in claim 1 wherein said first and second hydraulic operating means include first and second hydraulic servo motors, respectively, said first servo motor including a first cylinder communicating with said first branch conduit and a first piston connected with said first control means, and said second servo motor including a second cylinder communicating with said second branch conduit and a second piston connected with said second control means.

12. Regulated hydraulic drive as claimed in claim 1 wherein said operator controlled means includes a pressure-regulating valve communicating with said main conduit, and an adjusting means adapted to be operated by an operator for setting said pressure-regulating valve to maintain a selected pressure in said main conduit.

13. Regulated hydraulic drive as claimed in claim 12 wherein said pump is a rotary piston pump; wherein said second control means adjusts the length of the piston stroke of said pump; wherein said throttle operating means is hydraulically connected with said pump and responds to the pressure in the same; and wherein said throttle control means include a throttle control member increasing the throttling cross section of said first throttle means when decreasing the throttling cross section of said second throttle means, and vice versa.

14. Regulated hydraulic drive as claimed in claim 1 wherein said operator controlled means includes a pressure-regulating valve communicating with said main conduit, and an adjusting means adapted to be operated by an operator for setting said pressure-regulating valve to maintain a selected pressure in said main conduit means; wherein said regulating apparatus includes first and second throttles having the same throttling cross-section and connecting said main conduit with said first and second branch conduits, respectively; wherein said engine is a combustion engine; wherein said first control means controls the admission of a fuel mixture into said combustion engine; wherein said pump is a piston pump; wherein said second control means adjusts the length of the stroke of said pump; wherein said throttle operating means is hydraulically connected with said pump and responds to the pressure in the same; wherein said source of pressure medium is an auxiliary pump; wherein said first and second throttle means have outlets for discharging said pressure medium; wherein said throttle control means include a throttle control member increasing the throttling cross section of said first throttle means when decreasing the throttling cross section of said second throttle means, and vice versa; and wherein said first and second hydraulic operating means include first and second hydraulic servo motors, respectively, said first servo motor including a first cylinder communicating with said first branch conduit and a first piston connected with said first control means, and said second servo motor including a second cylinder communicating with said second branch conduit and a second piston connected with said second control means.

References Cited

UNITED STATES PATENTS

3,175,354	3/1965	Firth et al.	60—19
3,533,230	10/1970	Draper	60—19
3,543,508	12/1970	Schwab	60—19

FOREIGN PATENTS

1,204,539	11/1965	Germany.

CARLTON R. CROYLE, Primary Examiner

R. J. SHER, Assistant Examiner

U.S. Cl. X.R.

417—15