Claims

1. A hydrostatic drive system (101, 201) comprising:

a first hydraulic drive unit (102) wherein the first hydraulic drive unit is a variable displacement type of hydraulic drive unit comprising a first displacement control (104) for controlling the displacement of the first hydraulic drive unit (102);

a second hydraulic drive unit (103);

a first drive shaft (105) connected to the first hydraulic drive unit (102);

a second drive shaft (106) connected to the second hydraulic drive unit (103);

a first fluid line (107) fluidly connecting the first hydraulic drive unit (102) to the second hydraulic drive unit (103);

characterized in that the hydrostatic drive system further comprises

a variable damping device (109) connected to the first fluid line (107) and fluidly connected to the first and second hydraulic drive units (102, 103), wherein the variable damping device (109) comprises at least one variable element providing for variation in the attenuation frequency of the variable damping device (109); and

a first linkage apparatus (113) between the first displacement control (104) of the first hydraulic drive unit (102) and the variable element of the variable damping device (109) and operable to control the variable element in accordance with the displacement of the first displacement control (104).

2. The hydrostatic drive system of claim 1 wherein the first hydraulic drive unit (102) is a pump and the second hydraulic drive unit (103) is a motor,

or wherein the first hydraulic drive unit (102) is a motor and the second hydraulic drive unit (103) is a pump.

3. The hydrostatic drive system of claim 1 wherein the variable damping device (109) is a Helmholtz resonator.

4. The hydrostatic drive system of claim 3 wherein the variable element is a piston (110) forming an end of the Helmholtz resonator, whereby the volume of the Helmholtz resonator changes with the displacement of the piston (110),

or wherein the variable element is a variable length neck on the Helmholtz resonator, whereby the volume of the Helmholtz resonator changes with the displacement of the neck.

5. The hydrostatic drive system of claim 1 wherein the variable damping device (109) is a coaxial chamber resonator or a Quincke tube.

6. The hydrostatic drive system of claim 1 wherein the first linkage apparatus (113) is a mechanical apparatus mechanically linking the first displacement control (104) of the first hydraulic drive unit (102) to the variable element of the variable damping device (109).

7. The hydrostatic drive system of claim 6 wherein the variable damping device (109) is a Helmholtz resonator and the variable element is a piston forming an end of the Helmholtz resonator, and the mechanical apparatus comprises:

a lever arm (114) attached to the first displacement control (104) of the first hydraulic drive unit (102); and

a push-pull rod (115) attached to the piston of the Helmholtz resonator.

8. The hydrostatic drive system of claim 7 wherein the first hydraulic drive unit (102) is a bent axis type of unit comprising a yoke and the lever arm (114) is attached to the yoke of the bent axis,
or wherein the first hydraulic drive unit (102) is a bent axis type of unit comprising a sector plate and the lever arm (114) is attached to the sector plate of the bent axis,
or wherein the first hydraulic drive unit (102) is an axial piston type of unit and the lever arm (114) is attached to the swash plate of the unit,
or wherein the first hydraulic drive unit (102) is a radial piston motor type of unit and the lever arm (114) is attached to the eccentric displacement control ring of the unit.

9. The hydrostatic drive system of claim 6 wherein the mechanical apparatus comprises a multi-bar linkage, a cam mechanism, an eccentric mechanism or a screw mechanism.

10. The hydrostatic drive system of claim 6 wherein the variable damping device (109) is a Helmholtz resonator and the variable element is a variable length neck on the Helmholtz resonator, and the mechanical apparatus comprises:

a lever arm (114) attached to the first displacement control (104) of the first hydraulic drive unit (102); and

a push-pull rod (115) attached to the neck of the Helmholtz resonator.

11. The hydrostatic drive system of claim 1 wherein the first linkage apparatus (113) comprises a position sensor attached to the first displacement control (104) of the first hydraulic drive unit (102), an actuator connected to the variable element of the variable damping device (109), and a controller

wherein the controller input is connected to the position sensor and the controller output is connected to the actuator.

12. The hydrostatic drive system of claim 1 wherein the second hydraulic drive unit (403) is a variable displacement type of hydraulic drive unit comprising a second displacement control (404).

13. The hydrostatic drive system of claim 12 additionally comprising:

a second linkage apparatus (419) between the second displacement control (404) of the second hydraulic drive unit (403) and the variable element of the variable damping device and operable to control the variable element in accordance with the displacement of the second displacement control (404); and

a summation device (420) connected to the first and second linkage apparatus (413, 419) and operable to vary the effect of the first and second linkage apparatus on the variable element.

14. The hydrostatic drive system of claim 12 wherein the variable damping device (109) comprises an additional variable element providing for variation in the attenuation frequency of the variable damping device and the hydrostatic drive system additionally comprises a second linkage apparatus (419) between the second displacement control (404) of the second hydraulic drive unit (403) and the additional variable element of the variable damping device (109) and preferably wherein the first and second linkage apparatuses (413, 419) are interconnected.

15. The hydrostatic drive system of claim 1 comprising a second fluid line (108) fluidly connecting the first hydraulic drive unit (102) to the second hydraulic drive unit (103).

16. A power split infinitely variable transmission comprising the hydrostatic drive system of claim 1.

17. A continuously variable transmission comprising the hydrostatic drive system of claim 1.

18. A method for attenuating vibration in a hydrostatic drive system, the hydrostatic drive system comprising:

a first hydraulic drive unit (102) wherein the first hydraulic drive unit is a variable displacement type of hydraulic drive unit;

a second hydraulic drive unit (103);

a first drive shaft (105) connected to the first hydraulic drive unit (102);

a second drive shaft (106) connected to the second hydraulic drive unit (103);

a first fluid line (107) fluidly connecting the first hydraulic drive unit (102) to the second hydraulic drive unit (103);

a variable damping device (109) connected to the first fluid line (107) and fluidly connected to the first and second hydraulic drive units (102, 103), wherein the variable damping device (109) comprises at least one variable element providing for variation in the attenuation frequency of the variable damping device,

the method comprising:

incorporating a first displacement control (104) for controlling the displacement of the first hydraulic drive unit (102) into the variable displacement first hydraulic drive unit;

incorporating a first linkage apparatus (113) between the first displacement control (104) of the first hydraulic drive unit (102) and the variable element of the variable damping device (109); and

controlling the variable element in accordance with the displacement of the first displacement control (104).