

CLAIMS

1. A control device (100) for controlling a blood flow $Q_{\text{pump}}(t)$ of an intravascular blood pump (50) for percutaneous insertion into a patient's blood vessel, the blood pump (50) comprising a pump unit (52) and a drive unit (51) for driving the pump unit that is configured to convey blood from a blood flow inlet (54) towards a blood flow outlet (56), wherein

the control device (100) is configured to operate the blood pump (50) in a selectable zero-flow control mode, wherein a blood flow command signal $Q_{\text{pump}}^{\text{set}}(t)$ is selected, and the control device comprises a first controller (401) and a second controller (402), wherein

the first controller (401) is configured to control the blood flow $Q_{\text{pump}}(t)$ by adjusting a speed command signal $n_{\text{pump}}^{\text{set}}(t)$ for the drive unit (51), and the second controller (402) is configured to control a drive speed $n_{\text{pump}}(t)$ of the drive unit (51).

2. The control device (100) of claim 1, wherein the first controller (401) is further configured to determine the speed command signal $n_{\text{pump}}^{\text{set}}(t)$ based on a difference ΔQ between the blood flow command signal $Q_{\text{pump}}^{\text{set}}(t)$ and the blood flow $Q_{\text{pump}}(t)$.

3. The control device (100) claim 1 or 2, wherein the second controller (402) is configured to control the drive speed $n_{\text{pump}}(t)$ by adjusting a drive current $I_{\text{pump}}(t)$ supplied to the drive unit (51).

4. The control device (100) of any one of claims 1 to 3, wherein the first controller (401) and the second controller (402) are part of a cascade control system, in which the first controller (401) is an outer controller and the second controller is an inner controller (402).

5. The control device (100) of any one of claims 1 to 4, wherein the control device (100) is configured to control the blood flow $Q_{\text{pump}}(t)$ for a predetermined zero-flow control period.

6. The control device (100) of claim 5, wherein the predetermined zero-flow control period is set to last a fraction of one cardiac cycle of an assisted heart; or

the predetermined zero-flow control period is set to last at least one complete cardiac cycle or a predetermined number of complete consecutive heart cycles.

7. The control device (100) of any one of claims 1 to 6, wherein the control device (100) is configured to synchronize the zero-flow control period with an occurrence of at least one characteristic heart cycle event.

8. The control device of claim 7, wherein a beginning and/or end of the zero-flow control period is synchronized with the occurrence of the at least one characteristic heart cycle event.

9. The control device (100) of claim 8, wherein the at least one characteristic heart cycle event is the opening of the aortic valve or the closing of the aortic valve.

10. The control device (100) of any one of claims 1 to 9, wherein the control device (100) is configured to monitor values of one or more characteristic heart parameters.

11. The control device (100) of any one of claims 1 to 10, wherein the control device (100) is configured to operate the blood pump (50) in the zero-flow control mode periodically or randomly.

12. The control device (100) of any one of claims 1 to 11, wherein the control device (100) is configured to identify a trend of the one or more values of monitored characteristic heart parameters.

13. The control device (100) of claim 12, wherein the at least one characteristic heart parameter is at least one of: the arterial pressure pulsatility $AOP|_{\max} - AOP|_{\min}$, the mean arterial pressure, the contractility of the heart $dLVP(t)/dt|_{\max}$, the relaxation of the heart $dLVP(t)/dt|_{\min}$, the heart rate HR.

14. The control device (100) of any one of claims 1 to 13, wherein control device (100) is configured to measure the blood flow $Q_{\text{pump}}(t)$ by means of a sensor or to calculate or estimate the blood flow $Q_{\text{pump}}(t)$.

15. The control device (100) of any one of claims 1 to 14, wherein control device (100) is configured to determine the blood flow $Q_{\text{pump}}(t)$ using a look-up table which represents the relation between the blood flow $Q_{\text{pump}}(t)$, the drive speed $n_{\text{pump}}(t)$, and

at least one of a pressure difference $\Delta P_{pump}(t)$ between the blood flow outlet (56) and the blood flow inlet (54) and a drive current $I_{pump}(t)$ supplied to the drive unit (51).

16. A system comprising an intravascular blood pump (50) for percutaneous insertion into a patient's blood vessel and the control device (100) of anyone of claims 1 to 15.

17. The system of claim 16, wherein the blood pump (50) is a low inertia device by comprising one or more of the following characteristics: moving, in particular rotating, parts, for example a rotor or impeller, of the blood pump having low masses by being made of a low weight material, for example plastic; the drive unit (51), such as an electric motor, being arranged near, preferably very near, most preferably adjacent, to a moving part, for example a rotor or impeller, driven by the drive unit (51), and, if catheter-based, preferably having no rotational drive cable or drive wire; a coupling or connection, for example a shaft, of the drive unit (51) with a rotating part, for example the rotor or the impeller, driven by the drive unit (51) being short; and all moving, in particular rotating, parts of the blood pump having small diameters.

18. The control device (100) of any one of claims 1 to 15, configured to carry out a method for controlling a blood flow $Q_{pump}(t)$ of an intravascular blood pump (50) for percutaneous insertion into a patient's blood vessel, the blood pump (50) comprising a pump unit (52) with a drive unit (51) and being configured to convey blood from a blood flow inlet (54) towards a blood flow outlet (56), wherein the method comprises the steps:

comparing a set blood flow value $Q_{pump}^{set}(t)$ with a blood flow value $Q_{pump}(t)$ resulting in a control error $e(t)$ in a first closed-loop cycle,

determining a set speed value $n_{pump}^{set}(t)$ for the drive means from the control error $e(t)$,

controlling a drive speed $n_{pump}(t)$ of the drive unit (51) by comparing the set speed value $n_{pump}^{set}(t)$ with the drive speed $n_{pump}(t)$ in a second closed-loop cycle.

19. The control device (100) of claim 18, configured to carry out said method which comprises the further steps of:

providing a zero-flow mode in which the set blood flow value $Q_{pump}^{set}(t)$ is zero for a predetermined zero-flow control period, and

preferably setting the predetermined zero-flow control period to last a fraction

of one cardiac cycle of an assisted heart, or to last at least one complete cardiac cycle or a predetermined number of consecutive cardiac cycle fractions and/or complete cardiac cycles.

20. The control device (100) of claim 18 or 19, configured to carry out said method wherein the first closed-loop cycle is an outer control loop and the second closed-loop cycle is an inner control loop of a cascade control.

21. The control device (100) of any one of claims 18 to 20, configured to carry out said method which comprises the further step of:

synchronizing the zero-flow control period with at least one particular characteristic heart cycle event.

22. The control device (100) of any one of claims 18 to 21, configured to carry out said method wherein a beginning and/or an end of the zero-flow control period is synchronized with the occurrence of the at least one characteristic heart cycle event.

23. The control device (100) of any one of claims 18 to 22, configured to carry out said method which comprises the further step of:

monitoring one or more values of characteristic heart parameters.

24. The control device (100) of any one of claims 18 to 23, configured to carry out said method which comprises the further step of:

identifying a trend in the one or more monitored values of the characteristic heart parameters.