CLAIMS

1. A method for measuring erosive cavitation of a hydraulic machine in operation, the hydraulic machine comprising walls delimiting a duct for the passage of liquid water and at least one mobile member, which is located in the duct for the passage of liquid water and which is set in motion during operation of the hydraulic machine, characterized in that the method comprises the following steps:

in a first step, transmitting at least one first wideband pulsed ultrasonic signal (e) by at least one transmitting ultrasonic transducer, which is positioned on a first side of at least one first of the walls and which is oriented through the duct for the passage of liquid water to another side of the first wall or to the at least one mobile member,

in a second step, receiving, by at least one receiving ultrasonic transducer, which is positioned on the first side of the first wall, at least one second ultrasonic signal (x) received in response to the first ultrasonic signal (e) that has been transmitted,

in a third step, calculating, by a computing unit connected to the at least one transmitting ultrasonic transducer and to the at least one receiving ultrasonic transducer, from the first ultrasonic signal (e) that has been transmitted and from the second ultrasonic signal (x) that has been received, at least one indicator of erosive cavitation of the hydraulic machine, from the calculation by the computing unit of at least one time of arrival (TOA_n) of the second ultrasonic signal (x) that has been received relative to the first ultrasonic signal (e) that has been transmitted and/or from the calculation by the computing unit of an instantaneous spectral band (BW_k) defined by a frequency range, for which a value representative ($DSP^{(k)}(f)$) of the power spectral density ($DSP_i^{(k)}(f)$) of the second ultrasonic signal (x) that has been received is greater than a first given non-zero percentage (A) of the calculated mean value (DSP_{mean}) of the representative value ($DSP^{(k)}(f)$) of the power spectral density ($DSP_i^{(k)}(f)$) over time.

2. The method according to claim 1, characterized in that the first wideband pulsed ultrasonic signal (e) comprises a plurality of pulses (n) transmitted with a prescribed pulse repetition period (T_r), which is not zero.

3. The method according to claim 2, characterized in that each pulse (n) has, in a modulation duration (L_p) less than the prescribed pulse repetition period (T_r), a frequency modulation greater than or equal to a low frequency modulation value (f_1), which is not zero, and less than or equal to a high frequency modulation value (f_2), which is not zero.

4. The method according to claim 3, characterized in that the frequency modulation is linear or cubic and goes from the low frequency modulation value (f_1) to the high frequency modulation value (f_2) over the modulation duration (L_p) or from the high frequency modulation value (f_2) to the low frequency modulation value (f_1) over the modulation duration (L_p).

5. The method according to any one of claims 2 to 4, characterized in that during the third step, the computing unit calculates for each pulse (n) of the first ultrasonic signal e(t) that has been transmitted the time of arrival TOA_n of the second ultrasonic signal x(t) that has been received with respect to the first ultrasonic signal e(t) that has been transmitted according to the following equations:

$$\mathrm{TOA_n} = \mathrm{argmax_t}[\mathrm{G(t)}]^2$$

$$G(t) = \int_{-\infty}^{\infty} x(\tau) \cdot e(t-\tau) d\tau$$

where n is the index of each pulse.

6. The method according to any one of claims 2 to 4, characterized in that during the third step, the computing unit calculates for each pulse (n) of the first ultrasonic signal e(t) that has been transmitted the time of arrival TOA_n of the second ultrasonic signal x(t) that has been received with respect to the first ultrasonic signal e(t) that has been transmitted according to the following equations:

$$\mathrm{TOA_n} = \mathrm{argmax_t}[\mathrm{G(t)}]^2$$

$$G(t) = FFT^{-1}[FFT\{x\} * \overline{FFT}\{e\}]]$$

where n is the index of each pulse,

FFT{x} is the fast Fourier transform of the second ultrasonic signal x(t) that has been received,

$\overline{FFT}\{e\}$ is the complex conjugate of the fast Fourier transform of the first ultrasonic signal e(t),

FFT^{-1} is the inverse fast Fourier transform.

7. The method according to claim 5 or 6, characterized in that, during the third step, the computing unit calculates the at least one erosive cavitation indicator of the hydraulic machine as comprising the mean (m_{TOA}) of the times of arrival of arrival TOA_n for the pulses (n) of the first ultrasonic signal e(t) that have been transmitted and/or the variance (σ^2_{TOA}) of the times of arrival TOA_n for the pulses (n) of the first ultrasonic signal e(t) that have

been transmitted and/or the standard deviation (σ_{TOA}) of the times of arrival TOA_n for the pulses (n) of the first ultrasonic signal e(t) that have been transmitted.

8. The method according to claim 7, characterized in that, during the third step, the computing unit determines that cavitation (C) is present, when the mean (m_{TOA}) of the times of arrival TOA_n is less than a first determined threshold (S_m).

9. The method according to claim 7 or 8, characterized in that, during the third step, the computing unit determines that cavitation (C) is present, when the variance (σ_{TOA}^2) of the times of arrival TOA_n is greater than a determined threshold (V, V_C).

10. The method according to any one of claims 7 to 9, characterized in that, during the third step, when the computing unit has determined that cavitation (C) is present, the computing unit determines a position (P_C) of the cavitation (C) in the region defined by the product ($c.m_{TOA}/2$) between the propagation speed (c) of the ultrasonic signals (e, x) and the mean (m_{TOA}) of the times of arrival TOA_n divided by 2.

11. The method according to any one of claims 7 to 10, characterized in that, during the third step, when the computing unit has determined that cavitation (C) is present, the computing unit determines a lifetime (DV_C) of cavitation (C) from the variance (σ_{TOA}^2) of the times of arrival TOA_n and/or from the mean (m_{TOA}) of the times of arrival.

12. The method according to any one of the preceding claims, when dependent at least on claim 3, characterized in that during the third step, the computing unit calculates:

the power spectral density $DSP_i^{(k)}(f)$ of the second ultrasonic signal $x_k(t)$ that has been received for each of several reception time windows F_i having a prescribed duration W covering the pulse n, the reception time windows F_i being temporally shifted sequentially for i ranging from 1 to M, according to the following equation:

$$DSP_i^{(k)}(f) = \frac{1}{W}\left|\int_{(i-1)\cdot W+1}^{i\cdot W} x_k(t)\cdot exp(-j2\pi ft)\cdot dt\right|^2$$

where M is a prescribed number of reception time windows F_i,

the representative value $DSP^{(k)}(f)$ of the power spectral density $DSP_i^{(k)}(f)$ of the second ultrasonic signal $x_k(t)$ that has been received being equal to the mean power spectral density $DSP^{(k)}(f)$ for the power spectral density $DSP_i^{(k)}(f)$ over the M reception time windows F_i, according to the following equation:

$$DSP^{(k)}(f) = \frac{1}{M}\sum_{i=1}^{M} DSP_i^{(k)}(f)$$

the calculated value DSP_{mean} of the representative value $DSP^{(k)}(f)$ of the power spectral density $DSP_i(k)$ over time according to the following equation:

$$DSP_{mean} = \frac{1}{(f2 - f1)} \int_{f1}^{f2} DSP^{(k)}(f) df$$

the instantaneous spectral band BW_k defined by the frequency range $supp_f$, for which the representative value $DSP^{(k)}(f)$ of the power spectral density $DSP_i^{(k)}(f)$ of the second ultrasonic signal $x_k(t)$ that has been received is greater than the first given non-zero percentage A of the calculated mean value DSP_{mean} of the representative value $DSP^{(k)}(f)$ the power spectral density $DSP_i^{(k)}(f)$ over time according to the following equation:

$$BW_k = supp_f\left[DSP^{(k)}(f) \geq A \cdot DSP_{mean}\right]$$

where f_1 is the low frequency modulation value,

f_2 is the high frequency modulation value,

f is the frequency,

t is the time.

13. The method according to claim 12, characterized in that the reception time windows F_i overlap sequentially.

14. The method according to claim 12 or 13, characterized in that the prescribed duration W of the reception time window F_i is greater than or equal to 1 time or 2 times or 3 times the prescribed pulse repetition period (T_r).

15. The method according to any one of claims 12 to 14, characterized in that, during the third step, when the computing unit has determined that cavitation (C) is present, the computing unit determines a direction of movement (D_C) of the cavitation from the instantaneous spectral band (BW_k).

16. The method according to any one of the preceding claims, characterized in that the first non-zero percentage A given is greater than or equal to 50% or 70% or 90% or 95%.

17. The method according to any one of the preceding claims, characterized in that the at least one transmitting ultrasonic transducer comprises an active mode, which can be controlled by the computing unit and in which the first step), the second step and the third step are carried out, and a passive mode, which can be controlled by the computing unit and in which the first step, the second step and the third step are not carried out and the at least one transmitting ultrasonic transducer does not transmit,

the computing unit in the third step controlling by default the at least one

transmitting ultrasound transducer in passive mode, in which the at least one receiving ultrasound transducer receives a third signal (x_y),

the computing unit calculates the power spectral density ($DSP_y^{(k)}(f)$, $DSP'_y{}^{(k)}(f)$) of the third signal (x_y) that has been received in each of several time slots (k-1, k) following one another and each having an identical time slot duration (D),

the computing unit controlling in the third step the at least one transmitting ultrasonic transducer in the active mode, when the power spectral density ($DSP_y^{(k)}(f)$, $DSP'_y{}^{(k)}(f)$) of the third signal (x_y) received in a current time slot (k) differs by more than a given second non-zero percentage (B) from the power spectral density ($DSP_y^{(k)}(f)$, $DSP'_y{}^{(k)}(f)$) of the third signal (x_y) received in a time slot (k-1) prior to the current time slot (k).

18. The method according to claim 17, characterized in that the time slot (k-1) prior to the current time slot (k) is the time slot (k-1) preceding the current time slot (k).

19. A device for measuring erosive cavitation of a hydraulic machine in operation, the hydraulic machine comprising walls delimiting a duct for the passage of liquid water and at least one mobile member, which is located in the duct for the passage of liquid water and which is set in motion during operation of the hydraulic machine,

characterized in that the device comprises:

at least one transmitting ultrasonic transducer, which is positioned on a first side of at least one first of the walls and which is oriented through the duct for the passage of liquid water to another side of the first wall or to the at least one mobile member, the at least one transmitting ultrasonic transducer being capable of transmitting at least one first wideband pulsed ultrasonic signal (e),

at least one receiving ultrasonic transducer, which is positioned on the first side of the first wall, and which is able to receive at least one second ultrasonic signal (x) received in response to the first ultrasonic signal (e) that has been transmitted,

a computing unit connected to the at least one transmitting ultrasonic transducer and to the at least one receiving ultrasonic transducer, the computing unit being able to calculate, from the first ultrasonic signal (e) that has been transmitted and from the second ultrasonic signal (x) that has been received, at least one indicator of erosive cavitation of the hydraulic machine, from the calculation by the computing unit of at least one time of arrival (TOA_n) of the second ultrasonic signal (x) that has been received relative to the first ultrasonic signal (e) that has been transmitted and/or from the calculation by the computing unit of an instantaneous spectral band (BW_k) defined by a frequency range, for which a value representative ($DSP^{(k)}(f)$) of the power spectral density ($DSP_i^{(k)}(f)$) of the second ultrasonic

signal (x) that has been received is greater than a first given non-zero percentage (A) of the calculated mean value (DSP_{mean}) of the representative value ($DSP^{(k)}$ (f)) of the power spectral density ($DSP_i^{(k)}$ (f)) over time.

20. A computer program, comprising code instructions for implementing the third step of the method for measuring erosive cavitation of a hydraulic machine according to any one of claims 1 to 18, when it is implemented on a calculator.