stretching the resonance member and therewith also influencing the resonance frequency f_0.

BRIEF DESCRIPTION

Therefore, it is an object to provide a method and a device which allows to determine the height of a settled bed in a mixture in a loading space accurately and efficiently.

According to an aspect of the embodiments, there is provided a method for determining a height (h_s) of a settled bed in a mixture in a loading space of a vessel while compensating for vessel roll or lateral forces, wherein the mixture consists of a settled bed and a mixture soup which is located above the settled bed, and wherein the method comprises:

a) providing an elongated resonance member in the loading space which extends in a substantial vertical direction,

b) measuring a resonance frequency (f_o) of the resonance member,

c) computing a height (h_s) of the settled bed based on the measured resonance frequency (f_o),

wherein b) comprises determining an indication of or imposing the tensile force (F_s) acting in the longitudinal direction of the resonance member and c) comprises computing a height (h_s) of the settled bed based on the measured resonance frequency (f_o) and the determined indication of the tensile force or the imposed tensile force. The elongated resonance member extends in a vertical direction, i.e. from a lower end, which may be at the bottom of the loading space, to a position above the loading space.

By determining or imposing the tensile force in the resonance member, i.e. the force in the longitudinal direction of the resonance member, the effect of lateral forces acting on the part of the resonance member inside the settled bed, will at least partially be compensated, resulting in a more accurate computation of the height of the settled bed. Also deformation of the vessel and therewith stretching of the resonance member will be at least partially compensated in this way. When the tensile force is imposed, the tensile force is known despite lateral forces and other disturbances. When the tensile force is measured, it is measured repeatedly to take into account changes of the tensile force F_s during the loading process.

For instance, if the settled bed exerts a lateral force to the resonance member, the resonance member will be pushed in a lateral direction, resulting in an increased tensile force and thus in an increased resonance frequency. The measurements and

mass of the flexible connection, n is an integer, which is chosen n = 1 if the resonance member resonates in its ground modus and may be chosen higher in case the resonance member is resonating in higher (n^{th}) order.

The method may further comprise determining any one of these further parameters or indications thereof. Determining may be done in any suitable way, including measurements and receiving, manual input.

The details of this computation are discussed in more detailed in the detailed description.

According to an embodiment action a) comprises imposing a tensile force (F_s) of the elongated resonance member using a tensile device connected to an end of the resonance member.

The tensile device may be provided to exert a predetermined pulling force to the resonance member. This way it is possible to control the tensile force in the resonance member in an accurate way, allowing accurate computation of the free length. The tensile device may be arranged to apply a predetermined, fixed tensile force (for instance using a pulley and a weight) or an adjustable tensile force (for instance using a hydraulic or pneumatic member). In both situations, the tensile force can be set to a predetermined value before measuring the resonance frequency.

According to an embodiment b) comprises measuring the tensile force using a tensile force meter.

This embodiment has the advantage that the tensile force is measured and is thus accurately known, allowing accurate computation of the height of the settled bed. It is noted that this embodiment can be used in combination with a flexible connection of the resonance member. Despite the flexible connection, the tensile force may still vary a little. That's because the flexible connection doesn't compensates the lateral and other deformation forces perfectly . Such variations can be taken into account by measuring them, resulting in an even more accurate computation of the height of the settled bed.

According to an aspect of the embodiments, there is provided a device for determining a height (h_s) of a settled bed in a mixture in a loading space of a vessel while compensating for vessel roll or lateral forces, wherein the mixture consists of a settled bed and a mixture soup which is located above the settled bed, the device comprising an elongated resonance member in the loading space which extends in a substantial vertical direction, the device comprising a resonance frequency meter for determining a resonance frequency (f_o) of the resonance member **characterized in that**

CLAIMS

1. Method for determining a height (h_s) of a settled bed in a mixture in a loading space of a vessel while compensating for vessel roll or lateral forces, wherein the mixture consists of a settled bed and a mixture soup which is located above the settled bed, and wherein the method comprises:

a) providing an elongated resonance member in the loading space which extends in a substantial vertical direction,

b) measuring a resonance frequency (f_o) of the resonance member,

c) computing a height (h_s) of the settled bed based on the measured resonance frequency (f_o),

wherein b) comprises determining an indication of or imposing the tensile force (F_s) acting in the longitudinal direction of the resonance member and c) comprises computing a height (h_s) of the settled bed based on the measured resonance frequency (f_o) and the determined indication of the tensile force (F_s) or the imposed tensile force (F_s).

2. Method according to claim 1, wherein c) comprises solving $h_s = L_{total} - 0.5 (F_s / \sigma)^{0.5} / f_o$, wherein h_s is the height of the settled bed, L_{total} is the total length of the resonance member, F_s the tensile force , σ the mass of resonance member per meter and f_o the resonance frequency.

3. Method according to claim 1, wherein c) comprises computing the height (h_s) by computing a simulation of the elongated resonance member or by comparing the measured resonance frequency (f_o) and the determined indication of the tensile force (F_s) or the imposed tensile force (F_s) with predetermined calibration data.

4. Method according to any one of the preceding claims, wherein the tensile force (F_s) is imposed by mounting the resonance member at its upper end by means of a flexible connection.

5. Method according to claim 4, wherein action c) comprises modeling the flexible connection and compensating for the influence of the flexible connection on the resonance frequency.

6. Method according to any one of the claims 4 – 5 not depending on claim 2, wherein action c) comprises solving $h_s = L_{total} - (O + K(0.5 (F_s / \sigma)^{0.5} / f_o)$, wherein h_s is the height of the settled bed, L_{total} is the total length of the resonance member, F_s the tensile force , σ the mass of resonance member per meter and f_o the resonance frequency, K is a gain and O is an offset.

7. Method according to any one of the claims 4 – 5 not depending on claim 2, wherein action c) comprises solving $h_s = L_{total} - L_0$, wherein

$L_0 = \frac{1}{k}\left(\text{atan}\left(\frac{-F_s\, k}{K_{veer} - m_1 \omega^2}\right) + n \cdot \pi\right)$, wherein $k = \sqrt{\frac{\sigma}{F_s}} \cdot \omega$, wherein h_s is the height of the settled bed , L_{total} is the total length of the resonance member, F_s the tensile force, $\omega = 2\pi f_0$, f_o being the resonance frequency, K_{veer} is the spring constant of a virtual spring representing the flexible connection, m_1 is the virtual mass of the flexible connection, n is an integer, which is chosen n = 1 if the resonance member resonates in its ground modus and is chosen higher in case the resonance member is resonating in higher (n^{th}) order, σ the mass of resonance member per meter and F_s the tensile force.

8. Method according to any one of the preceding claims, wherein action a) comprises imposing a tensile force (F_s) of the elongated resonance member using a tensile device connected to an end of the resonance member.

9. Method according to any one of the preceding claims, wherein b) comprises measuring the tensile force (F_s) using a tensile force meter.

10. Device for determining a height (h_s) of a settled bed in a mixture in a loading space of a vessel while compensating for vessel roll or lateral forces, wherein the mixture consists of a settled bed and a mixture soup which is located above the settled bed, the device comprising an elongated resonance member in the loading space which extends in a substantial vertical direction, the device comprising a resonance frequency meter for determining a resonance frequency (f_o) of the resonance member

characterized in that the device comprises means for determining an indication of the tensile force (F_s) or imposing the tensile force (Fs) acting in the longitudinal direction of the resonance member.