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(54) **Method for reducing the transfer of vibrations to a cutter suction dredger generated by a cutter head and cutter suction dredger on which such method is applied**

(57) Cutter suction dredger (1), comprising a cutter dredger ladder (3) with a cutter head (12) movable upwards and downwards by means of a hoisting wire system (22), wherein the hoisting wire system (22) is pro-

vided with vibration reduction means (56) for reducing the transfer of vibrations generated by the cutter head (12) to the cutter suction dredger (1) through the hoisting wire system (22).

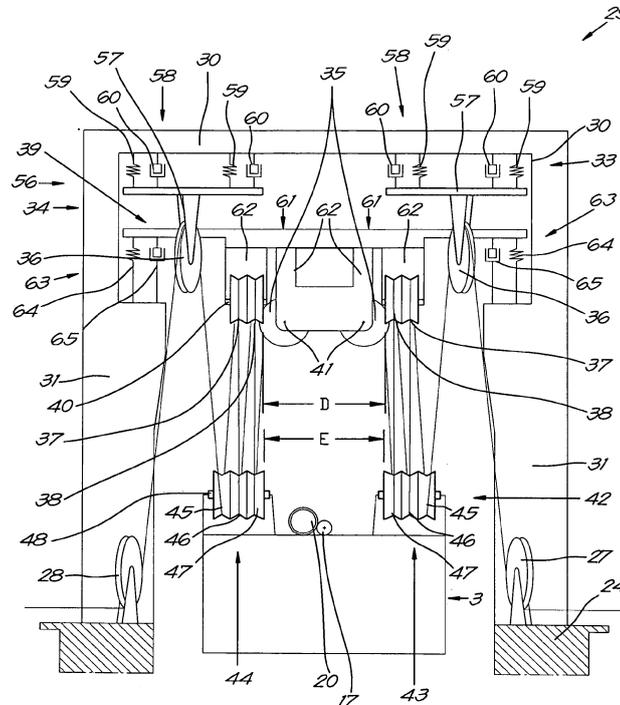


Fig.3

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Description

[0001] The present invention relates to a cutter suction dredger.

[0002] More particularly, the invention relates to such a cutter suction dredger which comprises a cutter dredger ladder mounted rotatably at a first extremity on the cutter suction dredger and having a second extremity on which a cutter head is provided, the second extremity being movable upwards and downwards with respect to the dredger by means of a hoisting wire system.

[0003] Typically the cutter suction dredger of the type to which the invention is related, has a hoisting wire system which comprises at least:

- hoisting means on the cutter suction dredger for winding and unwinding a wire on a reel;
- guiding means on a gantry of the cutter suction dredger for guiding a wire;
- ladder suspension means on the cutter dredger ladder for suspending the ladder by a wire ; and,
- one or more wires by which the cutter ladder is hung, at least one wire section being wound partly on the hoisting means and led over the guiding means on the gantry to the suspension means on the cutter dredger ladder.

[0004] Such types of cutter suction dredgers are known according to the state of the art and they are often used for performing excavation work in difficult soil or hard rock, or when an accurate profile has to be dredged, often at a more restricted depth (25 m to 30 m), since by means of the cutter head almost all types of soil can be attacked and sucked by a pumping system to a dredger vessel or the like, while the cutter head position can be controlled in an accurate way.

[0005] A sometimes very disturbing characteristic however of the cutter suction dredger is that its cutter head is subjected to heavy shock-loads which generate a lot of vibrations and even shock-loads on the cutter dredger ladder during excavation, especially when working in hard rock, which vibrations and shock-loads are inevitably transmitted to the dredger structure.

[0006] In extreme cases the vibrations and shock-loads are causing structural failure to the dredger or failure of sensitive equipments, as for example to electronic equipment and so on.

[0007] Another unpleasant consequence of the vibrations generated by the cutter head is that it causes a lot of discomfort to the crew of the vessel.

[0008] In very extreme cases, dredging of hard soils or rocks is made impossible by the high level of the vibrations and shocks coming from the cutter head.

[0009] It is therefore an objective of this invention to provide a solution to one or more of the above-mentioned negative consequences of the cutter head vibrations, as well as to possibly not-mentioned problems.

[0010] To this end, according to the present invention

in a cutter suction dredger of a type disclosed in the non-characterizing part of claim 1, the hoisting wire system is provided with vibration reduction means for reducing the transfer of vibrations generated by the cutter head to the cutter suction dredger through the hoisting wire system.

[0011] The core of the invention is the discovery of a problem which is unrecognized according to the state of the art.

[0012] Of course, the origin of the vibrations and shock-loads is according to the state of the art well known, i.e. they originate at the cutter head.

[0013] On the other hand, the problem of the transfer of the vibrations and shocks generated by the cutter head to the dredger is according to the state of the art not correctly understood.

[0014] Indeed, the cutter dredger ladder is mounted rotatably at its first extremity to the dredger by means of two trunnion shafts which are supported by bearings in the sides of the cutter dredger ladder well.

[0015] So, the idea which is widespread in the domain of cutter suction dredger design, is that the vibrations and shocks caused by the cutter head are transferred from the cutter dredger ladder to the dredger through the rotatable connection at this first extremity of the cutter ladder.

[0016] According to the present state of the art, apart from the design requirement that the structure and in particular the structure around the support of the cutter ladder by means of the trunnions, must be sufficiently resistant in order to withstand the vibrations and shock loads, no special measures are taken in order to isolate and damp the cutter head vibrations.

[0017] After an extensive measuring campaign on cutter suction dredgers in operation and after having analyzed the resulting vibration measurements as well as the resulting displacement measurements, it was discovered that a significant part of the vibrations and shocks are not transferred through the rotatable connection of the cutter ladder at its first extremity with the dredger, as was always assumed, but that this significant part of the vibrations and shocks are actually transferred through the hoisting wire system by which the cutter ladder is hung on the gantry of the dredger at its other end.

[0018] This is a rather surprising result, since, according to the general thinking in the domain of cutter dredger design, the suspension of the cutter dredger ladder by means of cables or wires is not restraining the movement of the cutter head considerably, so that the part of the vibrations or shock loads generated by the cutter head which is transferred through the hoisting wire system to the dredger was not even considered.

[0019] The discovery that the hoisting wire system is a problem zone for as far as the transfer of vibration and shock-load from the cutter head to the dredger is concerned, has in accordance with the present invention led to a completely different design of the cutter dredger ladder suspension system.

[0020] In particular, the hoisting wire system is according to the invention provided with vibration reduction means for reducing the transfer of vibrations generated by the cutter head to the cutter suction dredger through the hoisting wire system, which has never been the case in cutter suction dredger designs known according to the present state of the art.

[0021] The advantages of such a cutter suction dredger according to the invention, equipped with vibration reduction means at the hoisting wire system, speak for themselves and are of course all related to the reduced vibration and shock load levels felt at the dredger itself, so that discomfort to the crew, failure of equipment and so on are completely vanished or at least significantly reduced.

[0022] The present invention also relates to a method for reducing the transfer of vibrations to a cutter suction dredger generated by a cutter head which is provided on a cutter dredger ladder of the cutter suction dredger, the cutter dredger ladder being mounted as described before.

[0023] Such a method according to the invention at least comprises the step of providing the hoisting wire system by which the cutter dredger ladder is hung, with vibration reduction means.

[0024] According to a first preferred method in accordance with the invention, vibration reduction means of a passive type are provided for supporting the guiding means on the gantry.

[0025] An advantage of such a first preferred method in accordance with the invention is that it is simple in execution and not expensive.

[0026] According to an alternative preferred method in accordance with the invention, vibration reduction means of an active type are provided by which vibration movements in the hoisting wire system are compensated.

[0027] In such an alternative method in accordance with the present invention, the active type vibration reduction means can comprise actuators or electric motors, all kinds of electronic measuring equipment and so on in order to measure and counteract in a dynamic way the vibrations caused by the cutter head.

[0028] An advantage of such an alternative method according to the invention is that it is easily or even automatically adjustable in function of the working conditions, for example when the cutter suction dredger is working in very varying types of soil, causing vibrations or shock loads on the cutter head of very varying frequencies and amplitudes. With the intention of better showing the characteristics of the invention, hereafter, as examples without any limitative character, a preferred form of embodiment is described of a cutter suction dredger in accordance with the invention, as well as a method in accordance with the invention for reducing the transfer of vibrations in the cutter suction dredger, with reference to the accompanying drawings, wherein:

figure 1 represents a schematic side view on a cutter

suction dredger according to the invention; figure 2 represents a schematic top view along arrow F2 on the cutter suction dredger of figure 1; and, figure 3 represents on a larger scale a view on part of the hoisting wire system along arrow F3 in figure 2.

[0029] The cutter suction dredger 1 represented in figures 1 and 2 in accordance with the invention, comprises a vessel 2 on which a cutter dredger ladder 3 is mounted in a rotatable manner within a ladder well 4, which is in this case provided centrally in the bow side 5 of the vessel 2.

[0030] According to the invention it is however not excluded to provide as an alternative a cutter dredger ladder 3 at the other extremity of the vessel 2, i.e. at the stern of the vessel 2.

[0031] The cutter dredger ladder 3 is in the represented example a hollow longitudinal body 6 generally arranged for a rotational movement in a vertical plane through the axial direction AA' of the vessel 2.

[0032] Nevertheless, the cutter dredger ladder 3 can be executed in another manner, for example as a lattice girder or other steel structure.

[0033] At a first extremity 7 the cutter dredger ladder 3 is provided with two trunnion shafts 8, which extend at both sides of the cutter dredger ladder 3 in a lateral direction BB' perpendicular to the axial direction AA' of the vessel 2.

[0034] These trunnion shafts 8 rest in bearings 9 provided in opposite walls 10 of the ladder well 5 in order to obtain the above-mentioned rotatable mounting of the cutter dredger ladder 3 with respect to the vessel 2 at its first extremity 7.

[0035] At its other second extremity 11, the cutter dredger ladder 3 is provided with a rotatable cutter head 12 having teeth 13 for performing excavation works in soil or rock 14 underneath the water level 15.

[0036] This cutter head 12 is mounted at the end 16 of a cutter shaft 17 mounted rotatably on the cutter dredger ladder 3 and driven by an electric motor 18.

[0037] The cutter suction dredger 1 is furthermore provided with suction means which comprises a dredging pump 19 provided in the vessel 2, a hollow suction pipe 20 mounted on the cutter dredger ladder 3 which forms the inlet suction pipe 20 of the dredging pump 19, and a discharge pipe 21 connected at the outlet of the dredging pump 19.

[0038] In line with the invention, the cutter shaft 17 and the hollow suction pipe 20 can be mounted parallel to one another on the cutter dredger ladder 3.

[0039] In still another embodiment it is also not excluded to provide the dredging pump 19 at another position, for example on the cutter dredger ladder 3 instead of being mounted on the vessel 2.

[0040] The suction pipe 20 is with its open ended extremity 22 located near the cutter head 12 in order to suck up soil or rock 14 excavated by the cutter head 12.

[0041] In order to control the depth of the cutter head

12 the cutter dredger ladder 3 is at its second extremity 11 movable upwards and downwards with respect to the dredger vessel 2 by means of a hoisting wire system 22.

[0042] This hoisting wire system 22 comprises hoisting means 23 on the cutter suction dredger 1 for winding and unwinding a wire on a reel, which hoisting means 23 comprise in this case a pair of winches provided on the deck 24 of the cutter suction dredger 1 behind the first extremity 7 of the cutter dredger ladder 3, i.e. a starboard winch 25 and a port-side winch 26 arranged along opposite sides of the ladder well 4.

[0043] The hoisting means 23 also comprise in the embodiment represented in the figures a pair of deck sheaves, i.e. a star board deck sheave 27 and a port-side deck sheave 28, both provided on the deck 24 at the bow side 5 at a position in axial alignment with the corresponding winches, respectively the star board winch 24 and the port-side winch 25.

[0044] Nevertheless, the star board deck sheave 27 and the port-side deck sheave 28 are oriented somewhat skew with respect to the axial direction AA' of the vessel 2 in order to guide a wire towards the ladder well 4 as considered in the direction of the bow side 5.

[0045] Furthermore, the hoisting wire system 22 comprises a gantry 29 at the bow side 5 of the cutter suction dredger 1, which gantry 29 mainly consists of a central overhead beam 30, which is supported on the deck 24 of the vessel 2 by means of two supporting, vertically extending legs 31, positioned at opposite sides of the ladder well 4.

[0046] This gantry 29 is intended for taking part of the weight of the cutter dredger ladder 3.

[0047] To this aim the hoisting wire system 22 also comprises guiding means 32 on the gantry 29 for guiding a wire.

[0048] These guiding means 32 comprise in the present embodiment a pair of sets of gantry sheaves mounted at opposite sides on the central overhead beam 30 of the gantry 29, i.e. a starboard set 33 of gantry sheaves and a port-side set 34 of gantry sheaves.

[0049] The guiding means 32 on the gantry 29 are additionally provided with an intermediate set 35 of gantry sheaves located on the central overhead beam 30 centrally between the starboard set 33 of gantry sheaves and the port-side set 34 of gantry sheaves.

[0050] In the presently discussed embodiment the starboard set 33 of gantry sheaves and the port-side set 34 of gantry sheaves each consist of three gantry sheaves, mounted symmetrically with respect to a vertical plane through the axial direction AA' of the vessel 2, for forming three symmetrical pairs of gantry sheaves 36, 37 and 38.

[0051] One pair of gantry sheaves 36 is positioned further away from the vertical plane through the axial direction AA' than the other pairs of gantry sheaves 37 and 38, and will hereafter be indicated by the pair of outside gantry sheaves 36.

[0052] As with the deck sheaves 27 and 28, the outside

gantry sheaves 36 are also oriented somewhat skew in respect of the axial direction AA', in order to guide a wire towards the middle of the ladder well 4 as considered in the direction of the bow side 5.

5 [0053] In this case the outside gantry sheaves 36 are integrated in the inside 39 of the central overhead beam 30 structure, but this is not necessarily the case according to the invention.

10 [0054] In the present embodiment the two other pairs of gantry sheaves 37 and 38 are mounted collaterally underneath the central overhead beam 30, at a position somewhat more to the middle of the central overhead beam 30 compared to the position of the outside gantry sheaves 36, and at a distance D from one another which is somewhat smaller than the width W of the cutter dredger ladder 3.

15 [0055] For this reason the pairs of gantry sheaves 37 and 38 will be called hereafter the inside gantry sheaves 37 and 38.

20 [0056] These two pairs of inside gantry sheaves 37 and 38 are axially oriented gantry sheaves, by which is meant that these sheaves are mainly disc shaped having a disc plane parallel to the dredgers axial direction AA' and having an axis of rotation 40 perpendicular to said axial direction AA'.

25 [0057] Furthermore, in the present case the intermediate set 35 of gantry sheaves consists of a pair of sheaves 35 which are transverse sheaves in that these sheaves 35 are mainly disc shaped having a disc plane perpendicular to the dredgers axial direction AA' and having an axis of rotation 41 parallel to said axial direction AA'.

30 [0058] According to the invention on the cutter dredger ladder 3 also ladder suspension means 42 for suspending the cutter dredger ladder 3 by a wire are provided.

35 [0059] In this case, the suspension means 42 on the cutter dredger ladder 3 comprise a pair of ladder suspensions means, i.e. a starboard ladder suspension means 43 and a port-side ladder suspension means 44, positioned at both lateral sides of the cutter dredger ladder 3 at a distance E from one another corresponding to the distance D between the inside gantry sheaves 37 and 38.

40 [0060] More in particular, the starboard ladder suspension means 43 comprise a set of starboard ladder suspension sheaves and the port-side ladder suspension means 44 comprise a set of port-side ladder suspension sheaves.

45 [0061] However, as an alternative it is not excluded from the invention to use other kinds of ladder suspension means 42 which are not sheaves, but which are for example hooks or eyes or the like.

50 [0062] In the presently discussed case, the starboard set of ladder suspension sheaves 43 and the port-side set of ladder suspension sheaves 44 each consist of three ladder suspension sheaves positioned collaterally to one another forming 3 pairs of ladder suspension sheaves, i.e. an outside pair of ladder suspension sheaves 45, an intermediate pair of ladder suspension

sheaves 46 and an inner pair of ladder suspension sheaves 47.

[0063] All the pairs of ladder suspension sheaves 45 to 47 are axially oriented ladder suspension sheaves, by which is meant that these sheaves are mainly disc shaped having a disc plane parallel to the dredgers' axial direction AA' and having an axis of rotation 48 perpendicular to said axial direction AA'.

[0064] Furthermore, according to the invention the cutter ladder 3 is hung to the gantry 29, in general terms realized by one or more wires, at least one wire section being wound partly on the hoisting means 23 and led over the guiding means 32 on the gantry 29 to the ladder suspension means 42 on the cutter dredger ladder 3.

[0065] In the present case, a starboard wire section 49 is wound with an extremity part 50 of the starboard wire section 49 on the starboard winch 25 and a remaining part 51 of the starboard wire section 49 is led over the starboard set 33 of gantry sheaves and guided to the starboard set 43 of ladder suspension means.

[0066] Similarly, a port-side wire section 52 is wound with an extremity part 53 of the port-side wire section 52 on the port-side winch 26 and a remaining part 54 of the port-side wire section 52 is led over the port-side set 34 of sheaves on the gantry 29 and guided to the port-side set 44 of ladder suspension means.

[0067] According to a preferred embodiment of cutter suction dredger in line with the present invention, and as is also the case in the represented figures 1 tot 3, the starboard wire section 49 and the port-side wire section 52 are sections of a single wire 55 which is led from the starboard winch 25 to the port-side winch 26 over the gantry guiding means 32 and the ladder suspension means 42, which are in this case all sheaves.

[0068] This is in this case realized by passing the wire 55 from the starboard ladder sheave of the inside pair of ladder sheaves 47 over the intermediate set 35 of gantry sheaves to the port-side ladder suspension sheave of the inside pair of ladder suspension sheaves 47.

[0069] So, in the presently discussed embodiment, at the starboard side the wire section 49 of the single wire 55 passes from the starboard winch 26 subsequently over the following elements:

- the starboard deck sheave 27;
- the starboard gantry sheave of the outside pair of gantry sheaves 36;
- the starboard ladder suspension sheave of the outside pair 45 of ladder suspensions sheaves;
- the starboard gantry sheave of the inside pair 37 of gantry sheaves;
- the starboard ladder suspension sheave of the intermediate pair 46 of ladder suspensions sheaves;
- the starboard gantry sheave of the inside pair 38 of gantry sheaves;
- the starboard ladder suspension sheave of the intermediate pair 46 of ladder suspensions sheaves;
- and the starboard gantry sheave of the intermediate

set 35 of gantry sheaves.

[0070] Similarly, the port-side wire section 52 of the single wire 55 is passing over the corresponding port-side elements, so that a symmetrical arrangement is obtained.

[0071] Nevertheless, all kinds of other configurations in which more wires or wire sections, more or less sheaves or other kinds of suspension means and guiding means are applied in order to hang the cutter dredger ladder 3 to the vessel 2 are not excluded from the invention.

[0072] As explained in the introduction, the core of the invention lies in the discovery that the vibrations and shock-loads caused by the cutter head 12 are in a considerable part transferred to the vessel 2 through the hoisting wire system 22, in particular through the single wire 55 or in other embodiments through multiple wires of the hoisting wire system 22, whereas according to the state of the art it was always believed that such vibrations and shock loads are mainly transferred to the vessel through the rotatable connection of the cutter dredger ladder 3 at its first extremity 7 by means of the trunnion shafts 5 and bearings 9.

[0073] To solve the problem of the transfer of vibrations generated by the cutter head 12 to the vessel 2, it is therefore proposed by the present invention to provide the hoisting wire system 22 with vibration reduction means 56 for reducing the transfer of vibrations through the hoisting wire system 22.

[0074] According to a preferred embodiment of a cutter suction dredger in accordance with the invention, the vibration reduction means 56 comprise vibration damping means, like dashpots, rubber cushions or blocks, etc...

[0075] Alternatively or additionally, according to the invention the vibration reduction means 56 comprise vibration isolation means.

[0076] For example, the vibration reduction means 56 can comprise one or more of the following vibration reducers:

- an elastic element;
 - a rubber element;
 - a spring;
 - a pneumatic damper;
 - a hydraulic damper;
 - a dashpot;
 - a shock absorber; and/or
- An electrical compensator.

[0077] Vibration damping means are intended for absorbing mechanical vibration energy and to reduce in that way the amplitude of the vibration oscillations, in this case the amplitude of the vibration forces exerted on the vessel 2 through the hoisting wire system 22.

[0078] The technique of isolating vibrations is a technique known according to the state of the art and is for example an excellent technique when it comes to reduce

the effects of a vibration load which has a certain main frequency, which is mostly the case in devices with rotating mechanical parts.

[0079] In the present application of cutter suction dredging the cutter head 12 is also rotating at a certain speed.

[0080] However, due to the interaction with the rock or soil, the induced vibration forces can have a rather varying frequency spectrum, so that the simple principles of vibration isolation known from applications with a single main frequency, which will be explained hereafter for the purpose of better understanding what is meant by vibration isolation, might not be sufficient for designing adapted vibration isolation means in the present application and in practice some more complex analysis might be required.

[0081] This technique of isolating vibrations can be explained in a simplified manner as follows on a system with a single mass M supported by an ideal spring with a stiffness k on a base.

[0082] It is known that such a mass M will oscillates at its natural frequency on the spring under a small, temporary excitation action, which natural frequency F_n depends on the mass M and stiffness k of the spring as follows $F_n = C \cdot (k/M)^{1/2}$.

[0083] In a system where a certain vibrating force with a forced frequency F is applied, the mass will vibrate at the same frequency F as the excitation force, however with a certain phase shift.

[0084] Furthermore, depending on the ratio $R = F/F_n$ between the natural frequency F_n of the mass-spring system and the forced frequency F , the resulting amplitude of the vibration felt at the mass M will differ considerably.

[0085] In particular, when the exerted vibration force has a frequency F which is much higher than the natural frequency F_n of the supported mass-spring system, the amplitude of the vibration at the mass M will be small and in that case it is said that the mass-spring (and in practice also damper) system isolates the vibrating force from its base.

[0086] As is clear from the above formula the natural frequency F_n can be decreased by augmenting the mass M or by decreasing the stiffness k of the spring.

[0087] Applied to the presently discussed application, it is clear that the transfer of vibrations through the hoisting wire system 22 can be reduced by applying similar vibration isolation techniques, by adapting the dynamic behavior of the complete hoisting wire system, for example by adapting the stiffness of the elements by which the cutter dredger ladder 3 is suspended or by adapting the masses involved, etc...

[0088] Of course the above explanations are just a simplified way of explaining things in order to provide a better understanding of what is meant by vibration isolation means.

[0089] In practice the complete hoisting wire system 22 can obviously not be simplified by a single mass-spring-damper system, but is a complex system of which

the dynamic behavior can for example by modeled in computer aided design systems, for example with finite element analysis software, etc...

[0090] What's more, there are actually two fundamentally different methods by which the transfer of vibrations can be reduced, a first of which consists in using vibration reduction means 56 of a passive type, for example for supporting the guiding means 32 on the gantry 29.

[0091] According to a preferred embodiment of a cutter suction dredger 1 in line with the present invention the guiding means 32 are mounted on the gantry 29 by means of one or more base members, while the vibration reduction means 56 are at least partly provided between the concerned base members and the gantry 29.

[0092] In the present case, as is clearly demonstrated by means of figure 3, both outside gantry sheaves of the pair of outside gantry sheaves 36 are each mounted on the gantry 29 by means of a base member 57 which forms a foot 57 of the concerned sheave.

[0093] Furthermore, this foot 57 of each concerned outside gantry sheave of the pair of outside gantry sheaves 36 is mounted on a separate vibration reductor 58.

[0094] In figure 3 these vibration reducers 58 are represented as a combination of spring elements 59 and dashpot elements 60, but of course all types of vibrations reducers 58 can be used which are suitable in the actual application.

[0095] Furthermore, in the case of figure 3 the central overhead beam 30 of the gantry 29 is forming a supporting structure 30 on which a base member 61 in the form of a mounting base 61 is provided.

[0096] The gantry sheaves of the pairs of inside gantry sheaves 37 and 38, as well as the gantry sheaves of the intermediate set of gantry sheaves 35 are mounted in a direct manner with a foot 62 of the concerned sheaves on this mounting base 61, without any additional intermediate structure being provided between the mounting base 61 and the feet 62.

[0097] On the other hand, vibration reduction means 56 formed by vibration reducers 63 are partly provided between the supporting structure formed by the central overhead beam 30 of the gantry 29 and the mounting base 61 of the gantry 29, so that multiple sheaves of the guiding means 32 are simultaneously supported in a flexible manner on the central overhead beam 30.

[0098] In figure 3 these vibration reducers 63 are again represented as a combination of spring elements 64 and dashpot elements 65, but this again just one way of representation and it is not excluded from the invention to use other kinds of vibrations' reducers 63.

[0099] It is also obvious that the invention does also not exclude configurations in which more or less sheaves or other elements of the hoisting wire system 22 are mounted by means of a vibration reductor on a supporting structure, regardless whether multiple sheaves or other elements are mounted together on a single vibration reductor, or that one or more single sheaves or other single

elements are mounted on their individual vibration reducer.

[0100] In still another embodiment of a cutter suction dredger 1 according to the invention the vibration reduction means 56 are at least partly provided between the cutter dredger ladder 3 and the ladder suspensions means 42.

[0101] It is clear that by having vibration reduction means 56 at this position similar effects of reduction of vibration transfer from the cutter head 12 to the vessel 2.

[0102] According to a preferred embodiment of a cutter suction dredger 1 in accordance with the present invention the vibration reduction means 56 of the hoisting wire system 22 is suitable for substantially reducing the transfer of vibrations from the cutter head 12 to the cutter suction dredger 1, which have a frequency between 0,5 Hz and 10 Hz.

[0103] For that purpose, during design and afterwards during evaluation of the design, a simplified model can be used in first instance, such as a most realistic simplified model of the suspension of the cutter dredger ladder 3 on the vessel 2 by means of a mass-spring-damper model.

[0104] It is an aim of the design to select vibration reduction means 56 for the hoisting wire system 22 in such a way that an optimized vibration damping can be obtained for the particular application.

[0105] Depending on the actual situation, during design and evaluation of the design, a certain criterion can be used, for example that the simplified mass-spring-damper model should have a damping ratio of for example at least 0,5.

[0106] In a similar way, another criterion can be used, i.e. that in a most realistic simplified model of the suspension of the cutter dredger ladder 3 on the vessel 2 in the form of a mass-spring-damper model, the vibration reduction means 56 of the hoisting wire system 22 should be such that the mass-spring-damper model has an undamped natural frequency of not more than a certain amount of Hz.

[0107] In a special preferred embodiment the vibration reduction means 56 are provided with tuning means for modifying the frequency response of the vibration reduction means 56.

[0108] Such tuning means can in practice for example comprise means for modifying the damping characteristics of the vibration reduction means 56.

[0109] A known manner often used for example in dashpot elements 60 and 65 is an orifice through which oil is flowing during operation, the damping characteristics of such a dashpot 60 or 65 being adaptable by changing the size of the orifice.

[0110] Of course multiple other means for making tunable damping characteristics are not excluded from the invention.

[0111] In still another embodiment the tuning means can comprise as an alternative or additionally means for modifying the stiffness of the vibration reduction means

56.

[0112] A possible manner for obtaining such a means for modifying the stiffness of the vibration reduction means 56 can consist in the application of hydropneumatic suspensions elements.

[0113] In still another embodiment of a cutter suction dredger 1 according to the present invention the tuning means can also comprise means for modifying the weight of certain elements of the hoisting wire system 22.

[0114] An easy way to significantly modify the weight of elements of the hoisting wire system 22 consists for example of one more ballast tanks which can be filled with water or air, and so on.

[0115] Contrary to the above-described method in which passive elements are used, also an alternative method can be applied, wherein vibration reduction means 56 of an active type are used by which vibration movements in the hoisting wire system 22 are compensated in a more dynamic way.

[0116] With such a method with vibration reduction means 56 of an active type, apart from possible passive elements as described above, also other types of elements are used, such as:

- measuring devices, for example electric or electronic measuring devices such as accelerometers, frequency measuring devices etc...,
- one or more controllers for processing the measured characteristics, such as for example on-off controllers, proportional controllers, proportional-derivative controllers (PD-controllers), proportional-integral-derivative controllers (PID-controllers), etc... and
- actuator means such as electric motors, hydraulic or pneumatic pumps, etc...

[0117] These elements can be configured in a feedback loop in order to interfere actively by means of the actuator means for compensating the vibration motions.

[0118] In the present application of a cutter suction dredger 1, the vibration reduction means 56 can for example be provided with vibration frequency and vibration amplitude measuring means for measuring the amplitude of the vibrations generated by the cutter head 12 as a function of the vibration frequency and/or for measuring the frequency response of the vibration reduction means on the vibrations generated by the cutter head 12.

[0119] Still another element or other elements that can make a contribution to a reduction of the transmission of vibrations from the cutter head 12 to the vessel 2, consist in one or more wire tensioners.

[0120] For example a pair of wire tensioners can be applied, in particular, on the one hand, a starboard wire tensioner applied in the starboard wire section 49, between the starboard winch 25 and the starboard deck sheave 27, and, on the other hand, a port-sided wire tensioner applied in the port-side wire section 52, between the port-side winch 26 and the port-side deck sheave 28.

[0121] Such a wire tensioner can be formed of two or

more sheaves which guide the wire in a zigzag manner. One of the sheaves is preferably mounted in a movable manner with respect to the other sheave or sheaves, which are mounted fixedly and wherein the movable sheave is tensioned under the force of springs or the like in order to tension the wire.

[0122] It is obvious that such a wire tensioner does not only avoid situations wherein the wire is hanging loose, but such a wire tensioner also forms a vibration reduction means 56, if properly designed.

[0123] The present invention is by no means limited to the embodiment of a cutter suction dredger 1 according to the invention described as an example and illustrated in the drawings, but a cutter suction dredger 1 according to the invention can be realised in all kinds of variants, without departing from the scope of the invention.

Claims

1. Cutter suction dredger (1), comprising a cutter dredger ladder (3) rotatably mounted at a first extremity (7) on the cutter suction dredger (1) and having a second extremity (11) on which a cutter head (12) is provided, movable upwards and downwards with respect to the dredger (1) by means of a hoisting wire system (22), which hoisting wire system (22) at least comprises:

- hoisting means (23) on the cutter suction dredger (1) for winding and unwinding a wire on a reel;
- guiding means (32) on a gantry (29) of the cutter suction dredger (1) for guiding a wire;
- ladder suspension means (42) on the cutter dredger ladder (3) for suspending the cutter dredger ladder (3) by a wire; and,
- one or more wires (55) by which the cutter dredger ladder (3) is hung, at least one wire section (49,52) being wound partly on the hoisting means (23) and led over the guiding means (32) on the gantry (29) to the ladder suspension means (42) on the cutter dredger ladder (3), **characterized in that** the hoisting wire system (22) is provided with vibration reduction means (56) for reducing the transfer of vibrations generated by the cutter head (12) to the cutter suction dredger (1) through the hoisting wire system (22).

2. Cutter suction dredger (1) according to claim 1, **characterized in that** the hoisting means (23) comprise a pair of winches (25,26) on the cutter suction dredger (1), i.e. a starboard winch (25) and a port-side winch (26); that the guiding means (32) comprise a pair of sets (33,34) of gantry sheaves on the gantry (29) of the cutter suction dredger (1), i.e. a starboard set (33)

of gantry sheaves and a port-side set (34) of gantry sheaves;

that the suspension means (42) on the cutter dredger ladder (3) comprise a pair of sets (43,44) of ladder suspension means, i.e. a starboard set of ladder suspension means (43) and a port-side set (44) of ladder suspension means; that a starboard wire section (49) is wound with an extremity part (50) of the starboard wire section (49) on the starboard winch (25) and that a remaining part (51) of the starboard wire section (49) is led over the starboard set (33) of gantry sheaves and guided to the starboard set (43) of ladder suspension means; and that a port-side wire section (52) is wound with an extremity part (53) of the port-side wire section (52) on the port-side winch (26) and that a remaining part (54) of the port-side wire section (52) is led over the port-side set (34) of gantry sheaves on the gantry (29) and guided to the port-side set (44) of ladder suspension means.

3. Cutter suction dredger (1) according to claim 2, **characterized in that** the starboard (43) set of ladder suspension means comprises a set of starboard ladder suspension sheaves (45-47), that the port-side ladder suspension means (44) comprise a set of port-side ladder suspension sheaves (45-47) and that the starboard wire section (49) and the port-side wire section (52) are sections of a single wire (55) which is led from the starboard winch (25) to the port-side winch (26) over the gantry sheaves and the ladder suspension sheaves.

4. Cutter suction dredger (1) according to claim 3, **characterized in that** the guiding means (32) on the gantry (29) are additionally provided with an intermediate set (35) of gantry sheaves located centrally between the starboard set (33) of gantry sheaves and the port-side set (34) of gantry sheaves and that the wire (55) is passing from one of the starboard ladder sheaves over the intermediate set (35) of gantry sheaves to one of the port-side ladder sheaves.

5. Cutter suction dredger (1) according to claim 4, **characterized in that** the starboard set (33) of gantry sheaves and the port-side set (34) of gantry sheaves each consist of three gantry sheaves forming three pairs (36-38) of symmetrically mounted gantry sheaves and that also the starboard set (43) of ladder suspension sheaves and the port-side set (44) of ladder suspension sheaves each consist of three ladder sheaves forming three pairs (45-47) of symmetrically mounted ladder suspension sheaves.

6. Cutter suction dredger (1) according to claim 5, **characterized in that** the pair of sets (33,34) of gantry sheaves comprises two pairs (37,38) of axially oriented gantry sheaves and the ladder suspension

means (42) comprises three pairs (45-47) of axially oriented ladder suspension sheaves, wherein the aforementioned axially oriented sheaves are mainly disc shaped having a disc plane parallel to the dredgers axial direction (AA') and having an axis of rotation (40,48) perpendicular to said axial direction (AA').

7. Cutter suction dredger (1) according to any of claims 4 to 6, **characterized in that** the intermediate set (35) of gantry sheaves consists of a pair of sheaves which are transverse sheaves **in that** these sheaves are mainly disc shaped having a disc plane perpendicular to the dredgers axial direction (AA') and having an axis of rotation (41) parallel to said longitudinal direction (AA').

8. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) comprise vibration damping means (60,65).

9. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) comprise vibration isolation means.

10. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) comprise one or more of the following vibration reductor elements:

- an elastic element;
- a rubber element;
- a spring;
- a pneumatic damper;
- a hydraulic damper;
- a dashpot;
- a shock absorber; and/or,
- an electrical compensator.

11. Cutter suction dredger (1) according to any of claims 8 to 10, **characterized in that** the guiding means (32) are mounted on the gantry (29) by means of one or more base members (57,61) and that the vibration reduction means (56) are at least partly provided between the concerned base members (57,61) and the gantry (29).

12. Cutter suction dredger (1) according to claim 11, **characterized in that** the guiding means (32) of the gantry (29) comprises multiple sheaves (36) each mounted on the gantry (29) by means of a base member (57) in the form of a foot (57) of the concerned sheave (36), the foot (57) of each concerned sheave (36) being mounted on a separate vibration reductor (58).

13. Cutter suction dredger (1) according to claim 11,

characterized in that the gantry (29) is provided with a supporting structure (30) on which a base member (61) in the form of a mounting base (61) is provided, the guiding means (32) of the gantry comprising multiple sheaves (35,37,38) each mounted directly on the mounting base (61) and the vibration reduction means (56) being at least partly provided between the supporting structure (30) of the gantry (29) and the mounting base (61) of the gantry (29).

14. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) are at least partly provided between the cutter dredger ladder (3) and the ladder suspensions means (42).

15. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) is suitable for substantially reducing the transfer of vibrations from the cutter head (12) to the cutter suction dredger (1) which have a frequency between 0,5 Hz and 10 Hz.

16. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** in a simplified model of the suspension of the cutter dredger ladder (3) on the dredger (1) by means of a mass-spring-damper model, the vibration reduction means (56) of the hoisting wire system (22) are such that the mass-spring-damper model has a damping ratio of at least 0,5.

17. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** in a most realistic simplified model of the suspension of the cutter dredger ladder (3) on the dredger (1) by means of a mass-spring-damper model, the vibration reduction means (56) of the hoisting wire system (22) are such that the mass-spring-damper model has an undamped natural frequency (Fn) of not more than 15 Hz.

18. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) are provided with vibration frequency and vibration amplitude measuring means for measuring the amplitude of the vibrations generated by the cutter head (12) as a function of the vibration frequency and/or for measuring the frequency response of the vibration reduction means (56) on the vibrations generated by the cutter head (12).

19. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) are provided with tuning means for modifying the frequency response of the vibration reduction means (56).

20. Cutter suction dredger (1) according to claim 19, **characterized in that** the tuning means comprise means for modifying the damping characteristics of the vibration reduction means (56). 5
21. Cutter suction dredger (1) according to claim 19 or 20, **characterized in that** the tuning means comprise means for modifying the stiffness of the vibration reduction means (56). 10
22. Cutter suction dredger (1) according to any of claims 19 to 21, **characterized in that** the tuning means comprise means for modifying the weight of certain elements of the hoisting wire system (22). 15
23. Cutter suction dredger (1) according to any of the preceding claims, **characterized in that** the vibration reduction means (56) comprise actuator means for dynamically compensating the vibrations generated by the cutter head (12). 20
24. Method for reducing the transfer of vibrations to a cutter suction dredger (1) generated by a cutter head (12) which is provided on a cutter dredger ladder (3) of the cutter suction dredger (1), the cutter dredger ladder (3) being mounted rotatably at a first extremity (7) on the cutter suction dredger (1) and having a second extremity (11) on which the cutter head (12) is provided, which second extremity (11) is movable upwards and downwards with respect to the dredger (1) by means of a hoisting wire system (22), the hoisting wire system (22) comprising at least: 25
- hoisting means (23) on the cutter suction dredger (1) for winding and unwinding a wire on a reel; 35
 - guiding means (32) on a gantry (29) of the cutter suction dredger (1) for guiding a wire;
 - ladder suspension means (42) on the cutter dredger ladder (3) for suspending the cutter dredger ladder (3) by a wire; and, 40
 - one or more wires (55) by which the cutter dredger ladder (3) is hung, at least one wire section (49,52) being wound partly on the hoisting means (23) and led over the guiding means (32) on the gantry (29) to the suspension means (42) on the cutter dredger ladder (3), **characterized in that** the method comprises the step of providing the hoisting wire system (22) with vibration reduction means (56). 45
25. Method according to claim 24, **characterized in that** vibration reduction means (56) of a passive type are provided for supporting the guiding means (32) on the gantry (29). 50
26. Method according to claim 24 or 25, **characterized in that** vibration reduction means (56) of an active type are provided by which vibration movements in the hoisting wire system (22) are actively compensated. 55

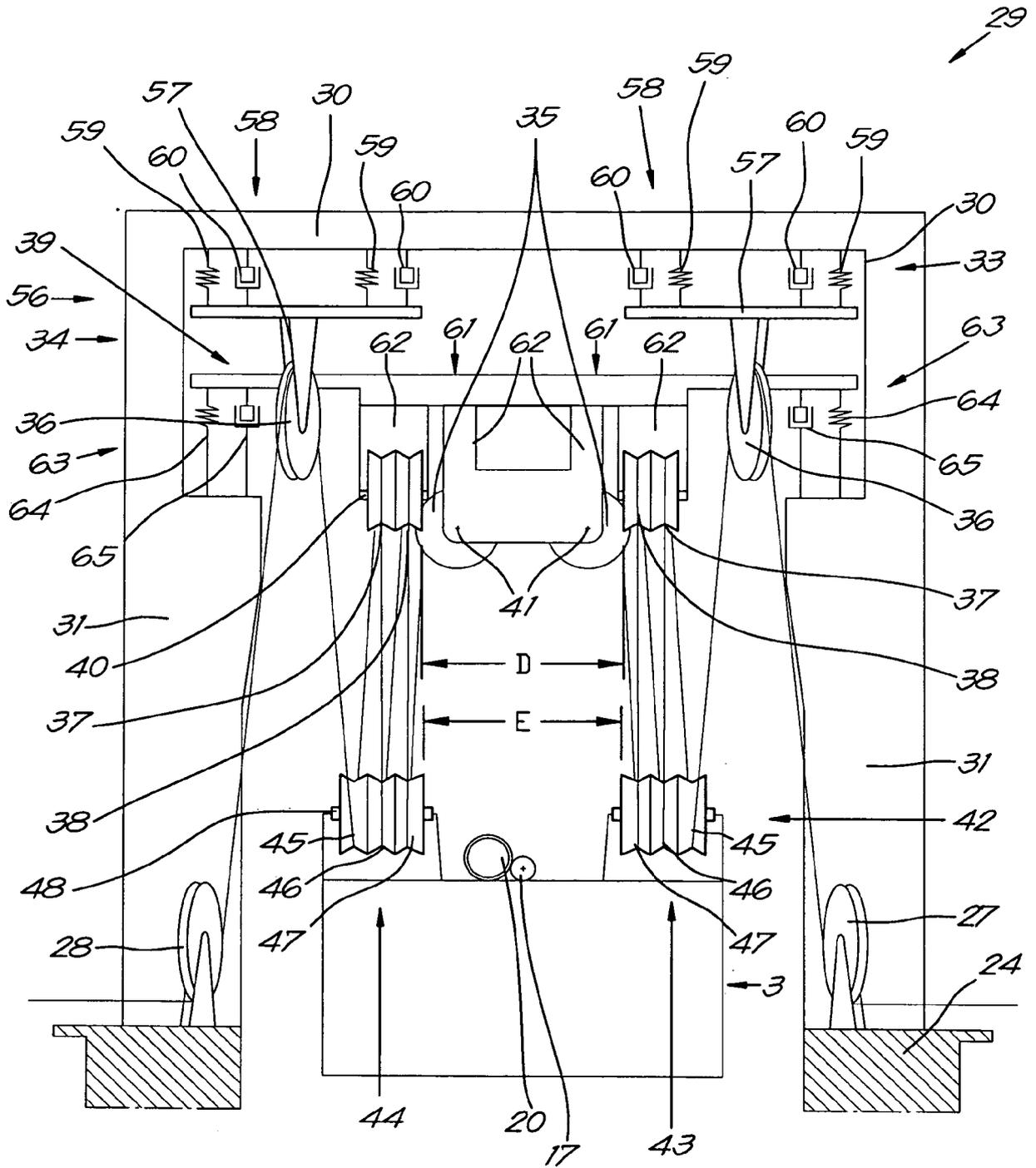


Fig.3



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