

SYSTEM AND METHOD AND ARRANGEMENT FOR DAMPING VIBRATORY MOTION OF ROTOR SAIL

TECHNICAL FIELD

- 5 The present disclosure relates to damping systems for rotor sails. The present disclosure also related to methods for damping vibratory motion of rotor sails. The present disclosure also relates to an arrangement for damping vibratory motion of rotor sails.

BACKGROUND

- 10 In an era where lowering reliance on fossil fuels and improving energy efficiency are the main global concerns, the use of rotating cylinders as an auxiliary marine vessel propulsion system has been utilized. Typically, the rotating cylinders are Flettner rotors that usually provide a clean propulsion technology and are arranged to harness wind power for marine
15 vessels. Typically, the Flettner rotor is a cylinder with disc-shaped end plates which is spun along its long axis as air passes it, the Magnus effect causes an aerodynamic force to be generated in the direction approximately perpendicular (usually between 100°-110°) to both the long axis and the direction of airflow. Nowadays, a rotor sail is used
20 having one or more Flettner rotors mounted upright. They are rotated by the marine vessel electrical system and act like sails to propel the marine vessel under wind power.

- Notably, the rotor sail produces greater thrusts the larger they are. In particular, increasing the length rotor sail is the easiest way to increase
25 the amount of thrust produced. In this regard, the height of the rotor sail reaches higher wind speeds as wind speed increases as a function of height from the ground level or sea level. However, when the height of the rotor sail is increased the aspect ratio increases and the rotor sail

become slender. The slenderness equals the lower eigenfrequency of the rotor sail. Thus, creating operational limitations as the operational rpm (rotations per minute) of the rotor sail may reach the same frequency or even go beyond, thereby inducing a risk of resonance vibrations. Also, a
5 reduction in the eigenfrequency, caused by an increase in aspect ratio, may result in issues related to vortex shedding. Conventionally, the rotor sails are designed to operate in sub-critical regions to avoid the risk of inducing resonance (other words natural frequency) vibrations. However, the conventional rotor sails structures and foundations are stiff and
10 heavy.

Therefore, in light of the foregoing discussion, there exists a need to overcome the aforementioned drawbacks associated with the conventional rotor sail.

SUMMARY

15 The present disclosure seeks to provide a damping system for a rotor sail. The present disclosure also seeks to provide a method for damping a vibratory motion of a rotor sail. The present disclosure also relates to an arrangement for a damping system for a rotor sail. An aim of the present disclosure is to provide a solution that overcomes at least partially the
20 problems encountered in prior art.

In one aspect, an embodiment of the present disclosure provides a damping system for a rotor sail, the damping system comprising:

- a support structure having a first end a second end and a predetermined height defined by the first and second ends, the support
25 structure arranged within a rotating cylinder of the rotor sail with the second end coupled to a foundation of the rotor sail for supporting the rotating cylinder; and
- one or more damping units mounted to the support structure so that the distance of the damping unit from the first end towards the second

end is between 0-30% of the predetermined height of the support structure;

and wherein the one or more damping units are operable to dampen a vibratory motion of the rotor sail to allow the rotating cylinder to operate
5 at an operational frequency at and beyond a natural frequency of the rotor sail.

In another aspect, an embodiment of the present disclosure provides a method for damping a vibratory motion of a rotor sail, the method comprising:

10 A method for damping a vibratory motion of a rotor sail, the method comprising:

- providing one or more damping units;
- mounting the one or more damping units to the support structure so that the distance of the damping unit from the first end towards the
15 second end is between 0-30% of the predetermined height (H) of the support structure
- dampening the vibratory motion of the rotor sail to allow the rotating cylinder to operate at an operational frequency at and beyond a natural frequency of the rotor sail.

20 Embodiments of the present disclosure substantially eliminate or at least partially address the aforementioned problems in the prior art, and enable an efficient damping of the rotor sail.

Additional aspects, advantages, features and objects of the present disclosure would be made apparent from the drawings and the detailed
25 description of the illustrative embodiments construed in conjunction with the appended claims that follow.

It will be appreciated that features of the present disclosure are susceptible to being combined in various combinations without departing

from the scope of the present disclosure as defined by the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The summary above, as well as the following detailed description of
5 illustrative embodiments, is better understood when read in conjunction
with the appended drawings. For the purpose of illustrating the present
disclosure, exemplary constructions of the disclosure are shown in the
drawings. However, the present disclosure is not limited to specific
methods and instrumentalities disclosed herein. Moreover, those skilled
10 in the art will understand that the drawings are not to scale. Wherever
possible, like elements have been indicated by identical numbers.

Embodiments of the present disclosure will now be described, by way of
example only, with reference to the following diagrams wherein:

FIG. 1 is a schematic illustration of a damping system arranged on a
15 marine vessel for a rotor sail, in accordance with an
embodiment of the present disclosure;

FIG. 2 is a schematic illustration of a rotor sail, in accordance with an
embodiment of the present disclosure; and

FIG. 3 illustrates steps of a method for damping a vibratory motion of a
20 rotor sail, in accordance with an embodiment of the present
disclosure.

In the accompanying drawings, an underlined number is employed to
represent an item over which the underlined number is positioned or an
item to which the underlined number is adjacent. A non-underlined
25 number relates to an item identified by a line linking the non-underlined
number to the item. When a number is non-underlined and accompanied

by an associated arrow, the non-underlined number is used to identify a general item at which the arrow is pointing.

DETAILED DESCRIPTION OF EMBODIMENTS

The following detailed description illustrates embodiments of the present disclosure and ways in which they can be implemented. Although some modes of carrying out the present disclosure have been disclosed, those skilled in the art would recognize that other embodiments for carrying out or practising the present disclosure are also possible.

In one aspect, an embodiment of the present disclosure provides a damping system for a rotor sail, the damping system comprising:

- a support structure having a first end, a second end and a predetermined height defined by the first and second ends, the support structure arranged within a rotating cylinder of the rotor sail with the second end coupled to a foundation of the rotor sail for supporting the rotating cylinder; and

- one or more damping units mounted to the support structure so that the distance of the damping unit from the first end towards the second end is between 0-30% of the predetermined height (H) of the support structure;

and wherein the one or more damping units are operable to dampen a vibratory motion of the rotor sail to allow the rotating cylinder to operate at an operational frequency at and beyond a natural frequency of the rotor sail.

In another aspect, an embodiment of the present disclosure provides a method for damping a vibratory motion of a rotor sail, the method comprising:

- providing one or more damping units;

- mounting the one or more damping units to the support structure so that the distance of the damping unit from the first end towards the second end is between 0-30% of the predetermined height (H) of the support structure and
- 5 - dampening the vibratory motion of the rotor sail to allow the rotating cylinder to operate at an operational frequency at and beyond a natural frequency of the rotor sail.

The present disclosure provides aforementioned damping system for a rotor sail and aforementioned method for damping a vibratory motion of
10 a rotor sail. The aforementioned system is configured to dampen the vibratory motion of the rotor sail. Typically, the aforementioned system comprises the one or more damping units mounted on the support structure of the rotor sail. Beneficially, the damping system leads to significant cost savings by enabling harnessing the power of wind
15 efficiently to propel the marine vessel thereby increasing fuel efficiency thereby reducing the greenhouse gas emissions, making marine vessel environmentally friendly. The rotor sail using the damping system can help to stabilize the marine vessel efficiently in high winds, making operation safer in rough routes.

20 Throughout the present disclosure, the term "*damping system*" as used herein refers to the system arranged to restrain the vibratory motion within the rotor sail. Typically, the rotor sail harnesses the wind to provide auxiliary propulsion to marine vessels. Optionally, the marine vessel may include a cargo ship, a passenger ship, a liner and the like. The damping
25 system is configured to prevent vibratory motion such as oscillations, wobbling and the like to induce within the rotor sail due to the operational frequency and the natural frequency of the rotor sail. Typically, the operational frequency of the rotor sail is the rate at which the rotor sail is used or intended to be used. Notably, in the case of the rotor sail,
30 operational frequency is the rate of rotations of the rotor sail per time

unit (such as rotations per minute, rotations per second i.e $1/\text{sec} = \text{Hz}$). Moreover, the natural frequency of the rotor sail is a characteristic of the rotor sail that is determined by its physical properties and boundary conditions. Notably, the natural frequency, also known as the resonant
5 frequency or eigenfrequency is the frequency at which the rotor sail naturally oscillates in the absence of any driving force. The natural frequency of the rotor sail is determined by its mass, stiffness, and damping properties. In addition, the vibratory motion is the oscillatory movement of the rotor sail back and forth about a fixed point or axis.
10 Notably, the vibratory motion is a periodic motion, which repeats the movement itself over time with a constant period and amplitude. The vibratory motion includes frequency, amplitude, phase, and damping. The frequency of the vibratory motion is the number of oscillations per unit of time ($1/\text{sec}$, Hz). The amplitude of the vibratory motion is the
15 maximum displacement of the rotor sail from its equilibrium position. The phase of the vibratory motion is the position of the rotor sail in its oscillation cycle. The damping of the vibratory motion is the rate at which the amplitude of the oscillations decreases over time.

Typically, the operational frequency is a frequency at which a damping
20 system is designed to operate. It is the frequency at which the system or device is intended to perform its intended function. For example, the operational frequency is the frequency at which the rotor sail is designed to rotate to generate thrust.

The damping system is configured to control the movement of the rotor
25 sail by producing the motion, such that the produced motion opposes the natural frequency of the rotor sail to prevent the frequency of the rotor sail to lie in the range of the natural frequency. Optionally, the damping system is designed to reduce or dampen motion or oscillation. The damping system may be used to control the vibratory motion, in order to
30 reduce or eliminate unwanted vibrations or oscillations that may affect

the performance or operation of the system. Beneficially, the damping unit is configured to protect the structural integrity of the rotor sail.

Typically, the rotor sail is configured to provide auxiliary power to marine vessel. It consists of the rotating cylinder that is mounted on the deck of the marine vessel. In an example, when the marine vessel is moving through the water, the wind flows over the rotor sail and creates lift, which generates a forward thrust that propels the marine vessel. Notably, the rotor sail is used in combination with traditional propulsion systems, such as engines or sails, to increase the efficiency of the marine vessel and reduce fuel consumption. In particular, the rotor sail is useful for the marine vessel that operates in areas with strong and steady winds, such as on long ocean voyages or in certain trade routes.

Optionally, the marine vessel may comprise the plurality of rotor sails which are installed thereon to increase the propulsion performance of the marine vessel. It will be appreciated that the plurality of the rotor sails are installed on the marine vessel may have different natural frequencies, because of the difference in the structural stiffnesses of installation locations for each of the plurality of the rotor sail. In particular, the foundations for installation of each of the plurality of the rotor sail can be different due to space limitations or the supporting structure beneath the foundations (such as stiffeners.) can be different. Optionally, each rotor sail has a different length installed on the marine vessel thereby having different natural frequencies for each rotor sail.

The term "*support structure*" as used herein refers to an elongated vertical structure that is used to hold the rotor sail in place on the marine vessel. Optionally, the support structure is fabricated from metals or alloys, composite material, fibres, ceramic, plastic materials and/or combinations thereof. Typically, the support structure has the first end, the second end opposite to the first end and the predetermined height between the first end and the second end. It will be appreciated that the

second end of the support structure is coupled to a foundation of the marine vessel to provide stability for the rotor sail. The term "*rotating cylinder*" as used herein refers to an elongated vertical structure that rotates around the support structure. Optionally, the rotating cylinder is
5 fabricated from metal, non-metal, composite material, ceramics, and a combination thereof. Moreover, the rotating cylinder is mounted over the support structure of the rotor sail and spins around its longitudinal axis, driven by wind passing there through. The rotating cylinder is mounted in rotatable way to the first end of the support structure. Furthermore,
10 the spinning of the rotating cylinder generates lift and drag, further the lift generated provides thrust to push the marine vessel, helping to move it through the water. Optionally, the rotating cylinder is equipped with an automated control system that allows the marine vessel crew to adjust the rotating speed (rpm) automatically based on the speed and direction
15 of the wind of the rotating cylinder, in order to optimize the amount of lift generated.

It will be appreciated that the second end of the support structure is coupled with the foundation of the marine vessel. Notably, the foundation provides support and stability to the support structure. Typically, the
20 foundation is anchored to the deck of the marine vessel and is designed to withstand the loads and forces imposed on the support structure by the wind and the rotation of the rotating cylinder. Moreover, the foundation is also configured to accommodate the loads due to vibration and other loads that may not be related to the vibrations but imposed for
25 example, due to vessel movements (for example, rolling), green sea loads against the rotor sail and the like. Optionally, the foundation includes a base plate that is fixed to the deck of the marine vessel. More optionally, the foundation also includes one or more stiffeners that extend downward to provide additional support thereof. Suitably, the one or
30 more stiffeners are bolted or welded to the base plate and the support structure.

The term "*damping unit*" as used herein refers to a unit that is configured to dissipate or reduce the amplitude of the vibratory motion. Typically, the one or more damping units is configured to absorb the kinetic energy generated during the operation of the rotor sail. In this regard, the one or more damping units is configured to absorb the vibratory motion caused due to natural frequency of the rotor sail. The one or more damping units help to reduce the amplitude of the vibratory motion and stabilize the damping system. Optionally, the one or more damping units are selected, but not limited to shock absorbers, viscous dampers, dashpots and the like. Indeed the damping unit dissipates the vibration by converting vibration related movements to kinetic energy. In addition the damping unit changes effective weight of the support structure thus changing its natural frequency and the natural frequency of the rotor sail. The one or more damping units are mounted to the support structure so that the distance of the damping unit from the first end towards the second end is between 0-30% of the predetermined height (H) of the support structure. As an example if the height of the support structure is 10 meters the damping units are arranged between 0 to 3 meters from the first end towards the second end. When the rotor sail is in use the height of the damping units is thus 7 to 10 meters from the foundation (or deck). Alternatively the damping unit can be arranged between 5, 10, 15, 20, 25% and 10, 15, 20, 25 and 30% of the predetermined height H from the first end towards the second end.

Optionally, the predetermined height of the support structure is in a range of 50% to 100% of a height of the rotor sail. The predetermined height of the support structure is a specific height that has been established in advance for the support structure. Optionally, the predetermined height of the support structure lies in the range of 60, 70, 80, 90 or 100% up to 50, 60, 70, 80 or 90%.

Optionally, the each of the one or more damping units comprises

- a mounting structure,
- one or more isolators or springs coupled to the mounting structure, and
- one or more mass-elements coupled to the one or more isolators or springs.

5 In this regard, the term "*mounting structure*" as used herein refers to an arrangement to provide means to mount and also stability to the damping unit. It will be appreciated that the mounting structure of the damping unit is arranged to hold up or secure the one or more damping units, in order to prevent it from collapsing or falling. Optionally, the mounting

10 structure may be fabricated from but not limited to a material, such as metal, non-metal, alloy, composite materials or any combination thereof. The term "*isolator or spring*" as used herein refers to a device configured to isolate the damping system from external forces or vibratory motion. Typically, the one or more isolators or springs are used to reduce the

15 transmission of force and vibratory motion between different components of the damping system. Suitably, the one or more isolators or springs are elastic components or mechanisms that could absorb, store and release energy through a change in characteristics arranged over the mounting structure. Notably, the one or more isolators or springs is coupled to the

20 mounting structure using fastener, interlock, weld, adhesive bond, magnetic coupling, snap fit and the like. Optionally, the one or more isolators or springs is fabricated from a metal i.e., copper, iron, beryllium, titanium, and the like. The metal alloys include for example stainless steel, carbon steel, chrome silicon (chromium and silicon alloy), chrome

25 vanadium (chromium and vanadium alloy), elgiloy (cobalt, chromium and nickel alloy) phosphor bronze, brass, and the like. It will be appreciated that the one or more isolators or springs could be fabricated from rubber and plastic for example plastic composites, polyphenylene sulfide, Acrylonitrile butadiene styrene (ABS), nylon, acrylic, polyamide-imide

30 (PAI) and the like. Optionally, the one or more isolators or springs is fabricated from composite material, fiber and the like. More optionally,

the one or more isolators or springs is viscous damper (such as non-Newtonian fluid damper, Newtonian fluid damper), gas damper and the like. The one or more isolators or springs are designed to undergo large deflections over the usage, the fabrication material must also have an
5 extensive elastic range to dampen the vibratory motion throughout use. It will be appreciated that the rotor sail may begin to vibrate due to external (such as, wind, tides, machines on the marine vessel e.g., propeller blade passing frequency) or internal (such as, rotor sail operation) vibration. The one or more mass-elements prevent the rotor
10 sail to induce vibratory motion which may lead to decrease the damping systems lifetime significantly. Optionally, the rotor sail starts to resonate if one or more mass-elements are not arranged in the rotor sail and the rotor sail is not rotating, and the marine vessel vibrations are close to the natural frequency of the rotor sail. Notably, the vibrational motion occurs
15 in the rotor sail, the one or more mass-elements resists the forces according to Newton's first law of inertia causing a counterforce which is lead to the support structure via the one or more isolators or springs and the support structure. The one or more damping units are in practice mounted to the support structure using the mounting structure of the
20 damping unit. The mounting can be done using means of screws, bolts, welding or fastenings. This way the damping units can be provided as "ready" packages for installation. Without mounting structure springs and/or isolators should be connected directly to the supporting structure which would complicate the installation.

25 Optionally, the one or more damping units further comprises a protective cover configured to hold the support structure, the one or more isolators or springs and the one or more mass-elements. In this regard, the term "*protective cover*" as used herein refers to a protective layer that is configured to surround the one or more damping units at least partly or
30 completely. The protective cover contains the support structure, the one or more isolators or springs and the one or more mass-elements.

Optionally, the protective cover prevents environmental factors to affect the support structure, the one or more isolators or springs and the one or more mass-elements. Optionally, the protective cover may be implemented to have a substantially cuboidal or rectangular shape.

- 5 Alternatively, the protective cover can be implemented to have a substantially any polygonal shape. In addition to protective cover reduces risk of accidents during maintenance of the rotor sail as mass-elements, which could move, are isolated from maintenance person.

- Optionally, the one or more damping units are mounted on the support structure in one of a stacked manner or a side-by-side manner. Optionally, the one or more damping units are mounted on the support structure in the stacked manner. In this regard, the each of the one or more damping units are arranged vertically on top of each other. Moreover, the stacked manner arrangement of the one or more damping units forms layers, such that each layer of the one or more damping units is configured to provide damping to the rotor sail. Optionally, the one or more damping units are mounted on the support structure in the side-by-side manner. This allows to add and remove damping units to tune the rotor sail to operate in wider frequency range and at an operational frequency and beyond.

- It will be appreciated that the one or more damping units is adjustable, such the one or more damping units can be modified to be placed at a specific place. Notably, the arrangement of the one or more damping units mounted on the support structure in the stacked manner or the side-by-side manner allows to position the one or more damping units equally around the circumference of the support structure to distribute the load evenly.

- Optionally, the one or more damping units are mounted on an inner surface or an outer surface of the support structure. Optionally, the one or more damping units are mounted on the inner surface of the support

structure. Optionally, the one or more damping units are mounted on the outer surface of the support structure. Beneficially, the one or more damping units that are mounted on the outer surface of the support structure are responsible for providing the structural integrity of the support structure. The one or more damping units mounted on the inner surface of the support structure allows easy access for maintenance and repair.

Optionally, the operational frequency of the rotor sail is in a range of 0 to 6 Hz and the rotor sail natural frequency and the operational frequency of the each of the one or more damping units is in a range of 1 to 6 Hz. Optionally, the operational frequency of the rotor sail lies in the range of 0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5 or 5.5 Hz up to 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5 or 6 Hz. Optionally, the rotor sail natural frequency lies in the range of 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5 or 5.5 Hz up to 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5 or 6 Hz. Optionally, the operational frequency of the each of the one or more damping units lies in the range of 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5 or 5.5 Hz up to 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5 or 6 Hz.

Optionally, the one or more damping units is configured to dampen the vibratory motion of the rotor sail in x, y and z-direction. Optionally, the one or more damping units is configured to dampen the vibratory motion of the rotor sail in x direction. Optionally, the one or more damping units is configured to dampen the vibratory motion of the rotor sail in y direction. Optionally, the one or more damping units is configured to dampen the vibratory motion of the rotor sail in z direction. Typically, due to the wind's fluctuating nature, the rotor sail is subject to vibratory motion in the x, y, and z-directions. In order to reduce this unwanted motion and increase the efficiency of the rotor sail, one or more damping units are used. These units are designed to absorb and dissipate the energy of the vibratory motion, effectively reducing the amplitude of the

vibrations. Notably, the one or more damping units are strategically mounted on the surface of the support structure of the rotor sail to dampen vibrations in the x, y, and z-directions. This helps to improve the stability and performance of the rotor sail, making it more efficient and
5 reducing wear and tear on the damping system. Also, the arrangement of the damping units helps in load sharing, space and maintenance requirements.

The present disclosure also relates to the method for damping the vibratory motion of the rotor sail as described above. Various
10 embodiments and variants disclosed above apply mutatis mutandis to the method for damping the vibratory motion of the rotor sail.

According to one aspect an arrangement is provided, wherein the arrangement, a rotor sail is arranged on a deck of a marine vessel and the rotor sail comprises a damping system. Alternatively there can be
15 multiple such as 2, 3, 4, 5, 6, 7, 8, 9, 10 etc. of individual rotor sails. Each of the damping systems in this aspect can be as discussed above.

Optionally or alternatively least one of: a stiffness of one or more isolators or springs , a position of a mass elements, or mass of the mass elements of a damping unit of the damping system is adjustable. Adjustment might
20 be needed to reduce the vibratory motion of the rotor sail even further. This provides means to finetune the damping system after installation and to calibrate the damping system from time to time. The adjustments can be optionally carried out in real time. In such case vibrations of the rotor sail are measured and adjustments are done based on
25 measurements to change the frequency.

According to an embodiment of the arrangement the damping system comprises two or more damping units and each of the damping units are adjustable individually in respect to each other's. This can take in account

for example possible tilting (due to wind or uneven load of cargo) of the vessel.

As an example the adjusting of the stiffness of the spring or isolator can be performed for example electrically (using "smart materials" which change properties when electricity is applied to the material), by adjusting the spring constant, or in the case of an isolator also electrically it is possible to adjust the stiffness of isolator (for example by using electroactive materials, like electroactive polymers) to reduce the vibratory motion of the rotor sails. The weight of the mass also might be adjustable, so that the mass can be a container which can be filled with fluid like water, and the water amount can be regulated and therefore the weight of the mass changes. Also, the centre of the gravity of the mass element might be adjustable, for example when the mass element consists of many (smaller) masses, the by removing or adding individual masses, the centre of gravity (of the mass) might be changed.

Also, optionally, the location of the mass element(s) can be controlled, for example when the mass element is formed in a movable manner on a rail (which rail or similar is formed on the support structure or in the mounting structure, in the lengthwise manner to the support structure) or guide, where it can be moved for example hydraulically, pneumatically (using actuators) or by other suitable means for moving the element.

Optionally there are sensors formed to the support structure to measure the vibration (i.e the frequency of vibration), and using the vibration information, the damping system(s) can be adjusted, for example by changing the properties (the spring constant/stiffness of the spring) of the spring by for example by using electrical means, or the mass or position of the mass elements might be changed also. Indeed the measured frequency value can be compared to known resonance (natural) frequency values and desired operating frequency. If there is

indication that rotor sail is experiencing unwanted vibrations a control signal can be provided to make needed adjustments.

Optionally, the spring(s) or the isolator(s) or the mass element(s) might be controlled and/or adjusted by wireless means. The operation/control
5 and adjustment of the damping unit (the spring, the isolator, the mass element) can be cloud-based (i.e using cloud servers etc.).

DETAILED DESCRIPTION OF THE DRAWINGS

Referring to FIG. 1, illustrated is schematic illustration of a damping system **100** arranged on a marine vessel **102** for a rotor sail **104**, in
10 accordance with an embodiment of the present disclosure. As shown, the marine vessel **102** is a ship having a rotor sail **104** arranged on the marine vessel **102** and attached to a foundation **106** of the rotor sail. The foundation **106** is further attached to a deck of the marine vessel **102**. As shown, the damping system **100** comprises a support structure
15 **108** having a first end **108A**, a second end **108B** and a predetermined height **H** defined by the first end **108A** and second end **108B**. I.e, the height **H** is distance between the first and the second ends.

As shown, the support structure **108** arranged within a rotating cylinder **110** of the rotor sail **104** with the second end **108B** coupled to the
20 foundation **106** of the rotor sail **104** for supporting the rotating cylinder **110**. The rotating cylinder is supported by the first end **108A** of the support structure in rotatable manner (i.e. for example bearings).

The damping system **100** comprises one or more damping units **112** mounted to the support structure **108**, wherein the one or more damping
25 units **112** are operable to dampen a vibratory motion of the rotor sail **104** to allow the rotating cylinder **110** to operate at an operational frequency at and beyond a natural frequency of the rotor sail **104**.

The one or more damping units **112**, **204** are be mounted to the support structure, to the first end **108A** of the support structure **108**, wherein the distance of the damping unit from the first end **108A** towards the second end **108B** is between 0-30% of the predetermined height (H) of the support structure. As illustrated the damping units are in a upper
5 portion of the support structure when the rotor sail is in use.

Referring to FIG. 2, illustrated is schematic illustration of a rotor sail **200**, in accordance with an embodiment of the present disclosure. As shown, a zoomed figure of the damping unit **204**. The one or more damping units
10 comprises a mounting structure **206**, one or more isolators or springs (as depicted by a first isolator or spring **208A** and a second isolator or spring **208B**) coupled to the support structure **206** and one or more mass-elements **210** coupled to the one or more isolators or springs **208A**, **208B**. The one or more mass-elements **210** is suspended upon the one
15 or more isolators or springs **208A**, **208B**. Moreover, the one or more damping units further comprises a protective cover **212** configured to hold the mounting structure **206**, the one or more isolators or springs **208A**, **208B** and the one or more mass-elements **210**.

Referring to FIG. 3, there is shown steps of a method for damping a
20 vibratory motion of a rotor sail, in accordance with an embodiment of the present disclosure. At step **302** one or more damping units is provided. At step, **304** the one or more damping units are mounted at a first end (or within certain distance from the first end depending on the setup) of a support structure of the rotor sail, wherein the support structure having
25 a predetermined height is arranged within a rotating cylinder of the of the rotor sail with a second end of the support structure coupled to a foundation of the rotor sail for supporting the rotating cylinder. At step **306** the vibratory motion of the rotor sail is to dampen to allow the rotating cylinder to operate at an operational frequency at and beyond a
30 natural frequency of the rotor sail.

The steps **302**, **304** and **306** are only illustrative and other alternatives can also be provided where one or more steps are added, one or more steps are removed, or one or more steps are provided in a different sequence without departing from the scope of the claims herein.

- 5 Modifications to embodiments of the present disclosure described in the foregoing are possible without departing from the scope of the present disclosure as defined by the accompanying claims. Expressions such as "including", "comprising", "incorporating", "have", "is" used to describe and claim the present disclosure are intended to be construed in a non-
- 10 exclusive manner, namely allowing for items, components or elements not explicitly described also to be present. Reference to the singular is also to be construed to relate to the plural.

CLAIMS

1. A damping system (100) for a rotor sail (104, 200), the damping system comprising:
 - a support structure (108,) having a first end (108A), a second end
5 (108B) and a predetermined height (H) defined by the first and second ends, the support structure arranged within a rotating cylinder (110) of the rotor sail with the second end coupled to a foundation (106) of the rotor sail for supporting the rotating cylinder; and
 - 10 - one or more damping units (112, 204) mounted to the support structure so that the distance of the damping unit from the first end (108A) towards the second end (108B) is between 0-30% of the predetermined height (H) of the support structure;and wherein the one or more damping units are operable to dampen a
15 vibratory motion of the rotor sail to allow the rotating cylinder to operate at an operational frequency at and beyond a natural frequency of the rotor sail.
2. The damping system (100) according to claim 1, wherein the predetermined height (H) of the support structure (108) is in a range of
20 50% to 100% of a height of the rotor sail (104, 200).
3. The damping system (100) according to claim 1, wherein the each of the one or more damping units (112, 204) comprises
 - a mounting structure (206),
 - one or more isolators or springs (208A-B) coupled to the mounting
25 structure, and
 - one or more mass-elements (210) coupled to the one or more isolators or springs.

4. The damping system (100) according to claim 3, wherein the one or more damping units (112, 204) further comprises a protective cover (212) configured to hold the mounting structure (206), the one or more isolators or springs (208A-B) and the one or more mass-elements (210).
- 5 5. The damping system (100) according to any of the preceding claims, wherein the one or more damping units (112, 204) are mounted on the support structure (108) in one of a stacked manner or a side-by-side manner.
6. The damping system (100) according to any of the preceding claims,
10 wherein the one or more damping units (112, 204) are mounted on an inner surface or an outer surface of the support structure (108).
7. The damping system (100) according to claim 1, wherein the operational frequency of the rotor sail (104, 200) is in a range of 0 to 6 Hz and the rotor sail natural frequency and the each of the operational
15 frequency of the one or more damping units (112, 204) is in a range of 1 to 6 Hz.
8. The damping system (100) according to any of the preceding claims, wherein the one or more damping units (112, 204) is configured to dampen the vibratory motion of the rotor sail (104, 200) in x, y and z-
20 direction.
9. A method for damping a vibratory motion of a rotor sail (104, 200), the method comprising:
- providing one or more damping units (112, 204);
 - mounting the one or more damping units to the support structure so
25 that the distance of the damping unit from the first end (108A) towards the second end (108B) is between 0-30% of the predetermined height (H) of the support structure; and

- dampening the vibratory motion of the rotor sail to allow the rotating cylinder to operate at an operational frequency at and beyond a natural frequency of the rotor sail.

10. The method according to claim 9, wherein the predetermined height
5 of the support structure (108) is in a range of 50% to 100% of a height of the rotor sail (104, 200).

11. The method according to claims 9-10, wherein the each of the one or more damping units (112, 204) comprises

- a mounting structure (206),
- 10 - one or more isolators or springs (208A-B) coupled to the support structure, and
- one or more mass-elements (210) coupled to the one or more isolators or springs.

12. The method according to claims 9-11, wherein the operational
15 frequency of the rotor sail (104, 200) is in a range of 0 to 6 Hz and the natural frequency of the rotor sail and the each of the operational frequency of the one or more damping units (112, 204) is in a range of 1-6 Hz.

13. The damping system (100) according to any of preceding claims 1 -
20 8, wherein the damping system comprises two or more damping units and each of the damping units are adjustable individually in respect to each other's.