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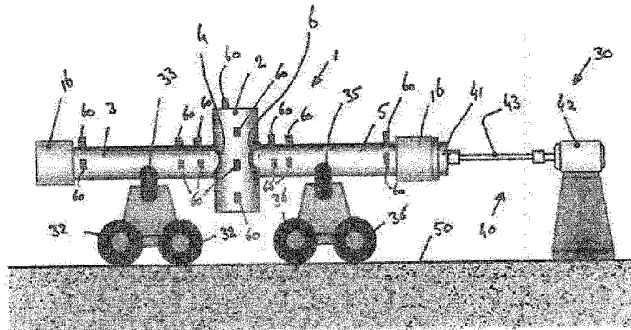
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54 **Fatigue testing of a test specimen.**

- 57 The invention pertains to a combination of a test rig and test specimen for performing a fatigue test, wherein the test specimen is non-axisymmetric and comprises :
- a central element, said central element having a longitudinal axis,
 - a first branch element, said first branch element having a longitudinal axis that extends at an angle to the longitudinal axis of the central element,
 - a joint connecting the first branch element to the central element, which has an in plane bending resonance frequency with an associated in plane bending mode shape, and an out of plane bending resonance frequency with an associated out of plane bending mode shape, wherein the in plane bending resonance frequency and the out of plane bending frequency are substantially the same,
- and wherein the test rig comprises:
- a support for supporting the test specimen,
 - an excitor for subjecting the test specimen to forced vibration at an excitation frequency.



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Fatigue testing of a test specimen

5 The invention pertains to fatigue testing of a test specimen.

In structures that are subjected to varying mechanical loads, damage may occur due to fatigue cracking. Already in the design stage of a structure, the resistance of the structure to fatigue cracking has to be evaluated so that the design can be optimized. However, in practice it is hard to obtain reliable data for evaluating the resistance to fatigue of a structure,
10 in particular when welds or other types of joints are present.

Welds behave different from undisturbed base material. The fatigue strength of welds depends on several parameters, like the geometry of the weld, the welding process that has been applied, the base material and filler material that has been used and the type and direction of the mechanical loads that the weld will be subjected to.

15 In evaluating the resistance of a structure to fatigue, it is common practice to first calculate the expected levels of mechanical stress in the structure. These calculated levels of mechanical stress are then compared to so-called S-N-curves, which show the relationship between the level of mechanical stress and the number of load cycles before failure. S-N-curves are available for typical standard situations, but these standard situations very often
20 differ significantly from the actual situation in the structure, for example because in the actual situation thick walled elements are used that have a different material behavior than thin walled elements. Therefore, the life span of a structure is hard to predict in a reliable way, and often significant safety factors are applied in the calculations. This however may lead to structures that are unnecessarily heavy and/or expensive.

25 In order to be able to make a better prediction of the expected life span of a structure, fatigue tests can be carried out. Often, fatigue tests are carried out on the actual structure (e.g. the blade of a wind turbine). In particular when large structures are to be tested, this is complicated and impractical. Large objects have to be handled and large alternating forces have to be applied, leading to large test rigs and high energy consumption.

30 In the Journal of Offshore Mechanics and Arctic Engineering of August 2012, Vol. 134, an article was published having the title "Resonant Bending Fatigue Test Setup for Pipes With Optical Displacement Measuring System." This article describes the testing of a test specimen that is made up out of two pipes, which pipes are arranged with their longitudinal axes in line with each other, an end of one pipe being connected to an end of the other pipe.
35 The connection between the pipes could be a weld (e.g. a girth weld) or a threaded connection. This results in the test specimen being a long pipe with a weld or threaded connection in the middle.

This known test specimen is arranged on supports, and a drive with an eccentric weight is connected to one of the free ends of the test specimen. The eccentric weight is rotated, which causes imbalance forces that are exerted on the test specimen at an excitation frequency, thus causing forced vibration of the test specimen. The excitation frequency is chosen such that it is close to a natural frequency that has an associated mode shape in the form of a standing wave that rotates at the excitation frequency. So, the standing wave induces rotational bending of the test specimen. The supports of the test rig are arranged such that they support the test specimen in the nodes of the standing wave.

This particular mode shape occurs due to the test specimen having an axisymmetric shape.

This known way of fatigue testing is not suitable for obtaining data that is suitable for determining the life span of joints between structural elements that are non-coaxial, that is, joints between two structural elements that are at a relative angle other than 0° or 180° . For example, the weld geometry and the welding processes that are used to connect non-coaxial structural elements to each other are too different from what is used to connect coaxial structural elements. Also the mechanical loads on joints between structural elements that are non-coaxial and joints between coaxial structural elements are too different, e.g. because these mechanical loads act in a different direction.

It is the object of the invention to provide a suitable way of performing fatigue tests on a test specimen, and to provide a combination of a test rig and test specimen to do so.

This object is achieved with the combination of a test rig and test specimen according to claim 1 and with the method according to claim 21.

The test specimen according to the invention has a non-axisymmetric shape. This allows to test joints that connect elements that extend under an angle other than 0° or 180° relative to each other. Many structures that are subjected to varying loads, e.g. jackets for wind turbines or oil and gas platforms, rely on these kinds of joints for their structural integrity.

The test specimen according to the invention is preferably made of metal. The metal can for example be steel. The steel can be coated or non-coated and/or painted or unpainted. As an alternative, the test specimen can be made of plastic. This plastic can for example be resin or a thermoplastic plastic. The resin of thermoplastic material is optionally provided with fibers, e.g. for reinforcement. Those fibers can be for example glass fibers or carbon fibers.

The test specimen comprises a central element. This central element has a longitudinal axis. The test specimen further comprises a first branch element. This first branch element has a longitudinal axis that extends at an angle other than 0° or 180° to the longitudinal axis

of the central element. A joint connects the first branch element to the central element. This joint will in general be the part of the test specimen that the fatigue test focusses on.

The joint between the first branch element and the central element and/or the joint between the second branch element and the central element can take many forms. It can be
5 for example a weld or a threaded connection or a flange connection or a part of a cast structural element or a glued connection. In case of a flange connection, the flanges can be connected by bolts and nuts or in any other suitable way, for example by a weld or by glue.

As any structural object, the test specimen has a plurality of resonance frequencies with
10 associated mode shapes. These include rigid body modes and mode shapes that cause deformation of the test specimen. Among the mode shapes that cause deformation of the test specimen, two mode shapes are of particular interest in view of the invention.

One of these two interesting mode shapes is what is called the "out of plane bending mode shape". This is the mode shape in which the test specimen deforms in such a way that
15 the first branch element deflects out of the plane that is defined by the longitudinal axis of the central element and the longitudinal axis of the first branch element.

The other interesting mode shape is what is called the "in plane bending mode shape". In this mode shape, the first branch element deflects in this plane that is defined by the longitudinal axis of the central element and the longitudinal axis of the first branch element, in
20 such a way that the central element moves in the direction of its longitudinal axis.

It was found that in test specimens having a certain geometry, the resonance frequencies and preferably also the location of the nodes of these mode shapes are substantially the same.

This is most prominent in a test specimen that comprises a tubular central element, a
25 tubular first branch element and a tubular second branch element. The longitudinal axes of the central element, the first branch element and the second branch element are all in the same plane and the two branch elements are connected to the central element at the same level, that is: at the same distance from the top end or bottom end of the central element, preferably halfway the central element. The angle between the longitudinal axis of the central
30 element and the longitudinal axis of each branch element is between about 45° and about 135°, and preferably this angle is the same for both branch elements.

However, the desired resonance frequencies and optionally also the desired locations of the nodes of the mode shapes can also be achieved with test specimens that have a
35 geometry that is a variant of this particular geometry, e.g. test specimens having just one branch element, or the first branch element being connected to the central element at a different level from the second branch element, or two branch elements extending not in the same plane. With these kinds of geometries, generally the weight distribution within the test

specimen will have to be optimized in order to create the desired proximity of the resonance frequencies and optionally the desired location of the nodes. This can for example be achieved by providing additional test weights at strategic locations of the test specimen, and/or by filling at least a part of the test specimen with a liquid such as water, and/or by locally varying the wall thickness of a branch element and/or the central element. In case two or more branch elements are used, the geometry of different branch elements (e.g. length, diameter, wall thickness) can be different. It is possible that the weight distribution could be non-symmetrical in order to obtain the desired resonance frequencies and/or mode shapes. For example, it could be that an additional test weight has to be added to both the first and the second branch element, but that the size of the additional test weight on the first branch element is different from the additional test weight that has to be added to the second branch element, and/or that the additional test weight on the first branch element would have to be arranged closer to the central element than the additional test weight on the second branch element. Alternatively or in addition, it is possible to arrange one or more additional test weights non-coaxial with a branch element, for example by arranging it such that it is not axisymmetric relative to the longitudinal axis of a branch element. This can be done for example by arranging an additional test weight on the top or to the front of the branch element, and not arranging a further additional test weight diametrically opposite to it.

“Substantially the same resonance frequencies” should be understood as that in case the excitation frequency is chosen close to the two resonance frequencies, both mode shapes are excited without having to apply large amounts of energy in order to obtain enough deformation and mechanical stress in the joint to perform the fatigue test. It was found that if the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency is about 80% or more of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency, this already produces the effect according to the invention. Preferably, the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency is about 85% or more of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency. More preferably, the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency is about 90% or more of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency.

So, when the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency is about 80% or more of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency, the in plane bending resonance frequency and the out of plane bending frequency are considered to the “substantially the same”.

It should be noted that it is generally not desirable to use an excitation frequency that is exactly the same as one of the resonance frequencies. In case the test specimen is excited at exactly one of its resonance frequencies, the vibration levels could go out of control.

5 The advantage of choosing an excitation frequency close to the resonance frequency is that a relative small amount of energy is needed to create and sustain the vibration in the test specimen. In general, an excitation frequency within a range between about 90% of the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency to about 110% of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency produces good results. Having an excitation
10 frequency within a range between about 80% the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency to about 120% of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency is generally acceptable. In the method to the invention the excitation frequency will generally be in the range from about 80% of the lowest of the in plane bending resonance frequency
15 and the out of plane bending resonance frequency to about 120% of the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency. It is not necessary that the excitation frequency is between the two resonance frequencies. In particular when the resonance frequencies are very close together, e.g. 2Hz or less apart, it will often be more practical to use an excitation frequency that is below the lowest resonance
20 frequency of the two or above the highest resonance frequency of the two.

In an advantageous embodiment of the invention, the first node of the in plane bending mode shape and the first node of the out of plane bending mode shape are substantially at the same position at the first branch element. The "first node" is a node of a mode shape that
25 is located at the first branch element. In case the test specimen also has a second branch element, the second node of the in plane bending mode shape and the second node of the out of plane bending mode shape are substantially at the same position at the second branch element. The "second node" is a node of a mode shape that is located at the second branch element.

30 "Substantially the same position" of the nodes of the two mode shapes means that there is an area in each branch element where the deformation of the branch element is low when both the in plane bending mode shape and the out of plane bending mode shape are excited. The deformation in this area is low enough to make it practical for the support or supports of the test rig to engage the test specimen in this particular area. When a support of the test rig
35 engages the test specimen at or close to a node, the support does not have to absorb high deflections of the test specimen during the fatigue test. This also makes that the mechanical loads (force, energy) that have to be absorbed by the support during the fatigue test are

relatively low. In practice, the first node of the in plane bending mode shape and the first node of the out of plane bending mode shape are substantially at the same position at the first branch element” means that the distance from the node in the first branch element in the in plane bending mode shape to the node in the first branch element in the out of plane bending mode shape should be about equal to or less than the diameter of the first branch element. Likewise, if a second branch element is present, the second node of the in plane bending mode shape and the second node of the out of plane bending mode shape are substantially at the same position at the second branch element” means that the distance from the node in the second branch element in the in plane bending mode shape to the node in the second branch element in the out of plane bending mode shape should be about equal to or less than the diameter of the second branch element.

In practice, the distance between the first node of the in plane bending mode shape and the first node of the out of plane bending mode shape will generally be 200 mm or less, preferably 100mm or less.

It is advantageous if the other resonance frequencies of the test specimen are relatively far removed from the in plane bending resonance frequency and the out of plane bending frequency. Preferably, other resonance frequencies are at least 25% higher than the highest of the in plane bending resonance frequency and the out of plane bending resonance frequency or at least 25% lower than the lowest of the in plane bending resonance frequency and the out of plane bending resonance frequency. This way, mainly (or only) the in plane bending mode shape and the out of plane bending mode shape are excited by the excitor during the fatigue test.

Optionally, the test specimen has at least one cavity that can be filled with a liquid (e.g. water) or a gas (e.g. compressed air or helium). If a gas is used, it preferably is a compressed gas, so a gas under pressure. It is possible that the test specimen is entirely hollow, such that a single cavity is present on the inside that extends into the central element as well as into the first branch element and – if present- the second branch element. It is also possible that the test specimen comprises a cavity in the central element and a separate cavity in the first branch element, and if a second branch element is present, a further separate cavity in the second branch element.

The cavity or cavities can be used for several purposes. For example, filling the cavity or cavities with a substance that has mass, such as a liquid, can change the weight distribution over the test specimen. Therewith, it can help to adjust the resonance frequencies of the test specimen, bringing the in plane bending resonance frequency and the out of plane bending frequency closer together or generally lowering the resonance frequencies. It can

also help to adjust the position of the nodes in the in plane bending mode shape and the out of plane bending mode shape, bringing them closer together if desired.

The cavity or cavities can alternatively or in addition be used for crack detection. If the joint or joints to be tested forms part of the cavity wall, and the cavity is filled e.g. with a liquid or a gas, a leak and a drop in pressure will occur once a crack has grown through the thickness of the material of the joint. For example, when the joint is a weld, it is likely that fatigue cracks will form in the weld before they form in the base material. In that case, it makes sense to have the weld form part of the wall of the cavity when the cavity is used for crack detection.

When the cavity or cavities are filled with a gas or liquid for the purpose of crack detection, it is advantageous to measure the pressure of the gas or liquid in the cavity, so that a pressure drop can be detected quickly. Optionally, the test specimen is equipped with one or more sensor supports to which for example a pressure sensor can be mounted.

Another way of crack detection is monitoring changes in the mode shape of the test specimen during the test. As a crack will alter the stiffness of the test specimen, at least locally, the mode shape will change somewhat too. These are generally subtle changes, in particular when the crack is still small. However, it is possible to detect such changes by measuring local displacement, velocity and/or acceleration of the test specimen. Preferably, the local displacement, local velocity and/or local acceleration are measured at a plurality of locations on the test specimen. The local displacement, velocity and/or acceleration can be measured e.g. by arranging sensors on the test specimen (optionally, the test specimen is provided with supports to do so), or contactless, e.g. in an optical way.

Another way of crack detection would be to use strain gauges, as the formation of a crack leads to local stress release near the crack.

Further ways of crack detection are for example penetrant dye testing, eddy current testing, ultrasonic testing or X-ray imaging. However, methods like these generally require that the fatigue test is interrupted or stopped in order for the crack testing to be carried out.

The excitor of the test rig applies a varying mechanical load to the test specimen at an excitation frequency, therewith subjecting the test specimen to forced vibration at this excitation frequency.

A suitable way of doing this involves the use of a rotatable eccentric weight in the excitor. The rotatable eccentric weight causes imbalance forces, which can be applied to the test specimen in order to obtain forced vibration of the test specimen. The imbalance forces can be used to alternatingly excite the in plane bending mode and the out of plane bending mode.

In a possible embodiment, a rotatable eccentric weight is connected to a branch element of the test rig, for example at the free end of the branch element, so at the end of the branch element that is not connected to the central element. The rotatable eccentric weight is rotatable relative to the branch element; the branch element is not rotated. In such an
5 embodiment, the eccentric weight can be coupled to an electric motor by means of a cardan shaft. By selecting a rotational speed of the electric motor, the excitation frequency can be set. Preferably, if an electric motor is used to drive the excitor, the electric motor is provided with a motor control system that allows to accurately control, set and/or adjust the rotational speed of the motor.

10

The test rig comprises at least a first support for supporting the test specimen. When the test specimen is arranged in or on the test rig, the test specimen is preferably arranged such that the first support of the test rig supports the test specimen at or adjacent to the node of the in plane bending mode shape and the out of plane bending mode shape. This way, the
15 test rig will not be subjected to large dynamic forces.

In a possible embodiment, the test rig is provided with a second support. In such an embodiment, the first support of the test rig can engage the first branch element and the second support can engage the second branch element.

Optionally, at least the first support of the test rig is moveable such that its position can
20 be matched to the location of the first node of the in plane bending mode and/or the out of plane bending mode. Optionally, if also a second support is present in the test rig, the second support is moveable too. This is however not necessary, because if just the first support is moveable, it is still possible to support both branches of the test specimen at or close to the first and second nodes of the in plane bending mode and the out of plane bending mode, in
25 particular if the excitor is flexible or moveable too.

Optionally, the test specimen is tested in free floating conditions. However, also in such an embodiment, a strap or the like can be applied over the test specimen for safety reasons. Alternatively, although most likely far less common, the test specimen will be gripped by the supports of the test rig more tightly, such that no free floating conditions are present.

30 Optionally the test rig comprises safety provisions to prevent rotation of the test specimen. These safety provisions for example comprise a strap that is applied over the test specimen, for example at or close to the support or supports of the test rig.

The supports of the test rig are arranged on a base, for example a floor or a structure mounted on a floor. In case one or more supports are moveable, they generally are moveable
35 relative to said base. The excitor will generally also be arranged on a base. This can be the same base as the one onto which the support or supports are arranged, but it can also be a different base. In that case, the base onto which the support or supports are arranged

optionally is isolated with respect to vibration transfer from the base onto which the excitor is arranged.

5 The combination of the test rig and test specimen and the method for fatigue testing according to the invention can be used for a wide range of sizes of test specimens. It is also suitable for very large test specimens, e.g. test specimens having a central element with an outer diameter of 500 to 2000 mm and a wall thickness of 15 to 80 mm, and/or a branch element of 200 to 1000 mm and a wall thickness of 10 to 60 mm. Structural elements of such sizes are used e.g. in offshore jackets. The combination of the test rig and test specimen and
10 the method for performing fatigue tests according to the invention is therefore suitable for evaluating the fatigue strength and/or expected life span of joints in this kind of structures.

It is possible that the test specimen according to the invention further comprises one or more stiffeners, shores or the like. Such a stiffener or shore could for example extend
15 between the central element and the first branch element, and/or, if a second branch element is present, between the central element and the second branch element.

The invention further pertains to a method for designing a fatigue test of a test specimen, in which fatigue test a combination of a test rig and test structure according to the
20 invention is used and which fatigue test is carried out as described above.

This method comprises the following steps:

- selecting a base geometry for the test specimen, including selecting the number of branch elements to be connected to the central element and the position and direction of these branch elements,
25
- selecting the shape of the central element and any branch elements,
- selecting the length and cross sectional sizes (e.g. the outer diameter and/or wall thickness) of the central element and any branch elements,
- calculating the in plane bending resonance frequency, the in plane bending mode shape, the out of plane bending resonance frequency, the out of plane bending mode shape
30 and optionally any further resonance frequencies that might be close to the in plane bending resonance frequency and/or out of plane bending resonance frequency,
- determining the difference between the in plane bending resonance frequency and the out of plane bending resonance frequency,
- evaluating whether this difference between the in plane bending resonance frequency
35 and the out of plane bending resonance frequency is small enough to each other to be able to apply the method for performing a fatigue test according to any of the claims 21-27,

- determining the difference in location of the node each branch element in the in plane bending mode shape and the location of this node in the out of plane bending mode shape,

- optionally evaluating whether this difference in location of the node each branch element in the in plane bending mode shape and the location of this node in the out of plane

5 bending mode shape is small enough to each other to be able to apply the method for performing a fatigue test according to any of the claims 21-27,

- if the difference between the in plane bending resonance frequency and the out of plane bending resonance frequency or the optionally calculated difference in location of the node each branch element in the in plane bending mode shape and the location of this node
10 in the out of plane bending mode shape is too large, adapting the weight distribution in the test specimen and/or the length and cross sectional sizes of the central element and any branch elements in order to shift the location of the nodes and/or the resonance frequencies.

The invention will be described in more detail below under reference to the drawing, in
15 which in a non-limiting manner exemplary embodiments of the invention will be shown.

The drawing shows in:

Fig. 1a : a first example of a test specimen according to the invention, in front view,

Fig. 1b : a first example of a test specimen according to the invention, in top view,

Fig. 2a : a second example of a test specimen according to the invention, in front view,

20 Fig. 2b : a second example of a test specimen according to the invention, in top view,

Fig. 3a : a third example of a test specimen according to the invention, in front view,

Fig. 3b : a third example of a test specimen according to the invention, in top view,

Fig. 4 : the in plane bending mode shape, illustrated in the test specimen according to
fig. 1,

25 Fig. 5 : the out of plane bending mode shape, illustrated in the test specimen according to fig. 1,

Fig. 6 : a first example of a combination of a test rig and test specimen according to the invention,

30 Fig. 7 : a second example of a combination of a test rig and test specimen according to the invention,

Fig. 8-16: further examples of test specimens according to the invention.

Fig. 1a shows a first example of a test specimen 1 according to the invention, in front view. Fig. 1b shows the same test specimen 1 in top view.

35 The test specimen 1 comprises a central element 2. The central element 2 is made of metal. It has a longitudinal axis 12. The test specimen according to fig. 1 further comprises a first branch element 3. The first branch element 3 is also made of metal and has a

longitudinal axis 13. The test specimen according to fig. 1 further comprises a second branch element 5. The second branch element 5 is also made of metal and has a longitudinal axis 15.

5 In the test specimen according to fig. 1, a joint 4, for example a weld, connects the first branch element 3 to the central element 2. A joint 6, for example a weld, connects the second branch element 5 to the central element 2. The longitudinal axis 13 of the first branch element 3 is at a relative angle α_1 to the longitudinal axis 12 of the central element 2.

10 The longitudinal axis 15 of the second branch element 5 is at a relative angle α_2 to the longitudinal axis 12 of the central element 2. In the example of fig. 1, both angles α_1 and α_2 are 90° .

15 As can be seen in fig. 1a, the first branch element 3 and the second branch element 5 are connected to the central element 2 at the same level, that is: at the same distance from the top end or bottom end of the central element. In the example of fig. 1, the branch elements 3,5 are connected to the central element 2 halfway the central element, so as far from the top end as from the bottom end of the central element 2.

20 As can be derived from fig. 1a and fig. 1b together, the longitudinal axis 12 of the central element 2, the longitudinal axis 13 of the first branch element 3 and the longitudinal axis 15 of the second branch element 5 all lie in the same plane. The first branch element 3 and the second branch element 5 are arranged on opposite sides of the central element 2 and they are coaxial with each other.

In the example of fig. 1, the central element 2 and both branch elements 3,5 are tubular.

25 In the test specimen 1 of fig. 1, in plane bending resonance frequency and the out of plane bending resonance frequency are already close together, without the need for e.g. applying additional weights or locally varying the wall thickness of the central element and/or branch elements.

30 For example, if the central element 2 is 4 meters long, has an outer diameter of 900 mm and a wall thickness of 60mm, and the distance from the center of the central element 2 to the free end of each of the branch elements is 4 meters, and the branch elements have an outer diameter of 600 mm and a wall thickness of 15 mm, then the out of plane bending resonance frequency is 37.9 Hz and the in plane bending frequency is 38.9 Hz. This is close enough to say that the out of plane bending resonance frequency and the in plane bending resonance frequency are substantially the same in the sense of this invention.

35 The next resonance frequency is 55.8 Hz, so that is more than 25% higher than the in plane bending resonance frequency (which is in this example higher than the out of plane bending resonance frequency). This is sufficiently far removed from the out of plane bending resonance frequency and the in plane bending resonance frequency. When the excitation frequency is selected close to the out of plane bending resonance frequency and the in plane

bending resonance frequency, say at somewhere in the range from 35Hz to 42 Hz, the in plane bending mode and the out of plane bending mode will be excited, but the next vibration mode (having the resonance frequency of 55.8 Hz) will not be excited.

5 The nodes of the in plane bending mode and the out of plane bending mode for this test specimen 1, with the dimensions given above, in each of the branch elements 3,5 are also already close together. In both mode shapes, the distance between the first and second node is about 2.12 m. The position of the first node in the in plane bending mode shape and the position of the first node in the out of plane bending mode shape is less than 0.01m, which is negligible when seen in relation to the size of the test specimen. The same applies to the
10 position of the second node in the in plane bending mode shape and the position of the second node in the out of plane bending mode shape. So, there is also no need to e.g. apply additional weights or locally vary the wall thickness of the central element and/or branch elements in order to move the nodes closer together.

15 Fig. 2a shows a second example of a test specimen 1 according to the invention, in front view. Fig. 2b shows the same test specimen 1 in top view.

The test specimen 1 of fig. 2 is a variant of the test specimen 1 of fig. 1. The geometry is the same, except that in the embodiment of the test specimen 1 of fig. 2, the angles α_1 (between the longitudinal axis 12 of the central element 2 and the longitudinal axis 13 of the
20 first branch element 3) and α_2 (between the longitudinal axis 12 of the central element 2 and the longitudinal axis 15 of the second branch element 5) are 45° instead of 90° .

Fig. 3a shows a third example of a test specimen 1 according to the invention, in front view. Fig. 3b shows the same test specimen 1 in top view.

The test specimen 1 of fig. 3 is a variant of the test specimen 1 of fig. 1 and of fig. 2.
25 The geometry is the same, except that in the embodiment of the test specimen 1 of fig. 3, the angles α_1 (between the longitudinal axis 12 of the central element 2 and the longitudinal axis 13 of the first branch element 3) and α_2 (between the longitudinal axis 12 of the central element 2 and the longitudinal axis 15 of the second branch element 5) are 60° instead of 90° or 45° , respectively.

30 In the test specimens 1 of fig. 2 and fig. 3, the out of plane bending resonance frequency and the in plane bending resonance frequency are somewhat farther apart than in the test specimen 1 of fig. 1. Also the nodes in the branch elements of the in plane bending mode and the out of plane bending mode will be a bit farther apart. Whether measures have to be taken to shift the out of plane bending resonance frequency and the in plane bending
35 resonance frequency or optionally the position of the nodes of the in plane bending mode and the out of plane bending mode closer together (e.g. by applying additional weights or locally

varying the wall thickness of the central element and/or branch elements) will depend on the actual geometry of the test specimen 1.

For example, a test specimen 1 with the shape as shown in fig. 3a and 3b, and central element 2 being 4 meters long, having an outer diameter of 900 mm and a wall thickness of 60mm, and the distance from the center of the central element 2 to the free end of each of the branch elements being 4 meters, and the branch elements having an outer diameter of 600 mm and a wall thickness of 15 mm, will still have the nodes of the in plane bending mode and the out of plane bending mode in each of the branch elements close enough together. Also, the out of plane bending resonance frequency and the in plane bending resonance frequency are still close enough together to regarded as “substantially the same” in the sense of the invention: 40.0 Hz for the in plane bending mode and 44.0 Hz for the out of plane bending mode.

The next resonance frequency is 57.6 Hz, so that is more than 25% above the out of plane bending resonance frequency (which in this example is higher than the in plane bending resonance frequency). This is sufficiently far removed from the out of plane bending resonance frequency and the in plane bending resonance frequency.

Fig. 4 shows the in plane bending mode shape, illustrated in the test specimen 1 according to fig. 1.

Dashed line 21 in fig. 4 indicates the direction of the longitudinal axis of the central element 2 when the test specimen 1 is not vibrating or subjected to a mechanical load. Dashed line 20 in fig. 4 indicates the direction of the longitudinal axis of the branch elements 3,5 when the test specimen 1 is not vibrating or subjected to a mechanical load. The solid lines in fig. 4 show the in plane bending mode shape of test specimen 1.

It can be seen that the central element 2 does not deform significantly compared to the branch elements 3,5 in this mode shape. It moves back and forth in the direction of its longitudinal axis. The branch elements 3,5 deflect in the plane that is defined by the longitudinal axis of the central element 2 and the longitudinal axes of the branch elements in their undeflected state.

The in plane bending mode shape has two nodes, one on the first branch element 3 and one on the second branch element 5. The first node, on the first branch element 3, is located in the hatched area 23 that is shown in fig. 4. The second node, on the second branch element 5, is located in the hatched area 25 that is shown in fig. 4.

Fig. 5 shows the out of plane bending mode shape, illustrated in the test specimen according to fig. 1.

Dashed line 20 in fig. 5 indicates the direction of the longitudinal axis of the branch elements 3,5 when the test specimen 1 is not vibrating or subjected to a mechanical load. The solid lines in fig. 5 show the out of plane bending mode shape of test specimen 1.

5 It can be seen that the central element 2 moves back and forth in the direction of dashed line 22. The branch elements 3,5 deflect out of the plane that is defined by the longitudinal axis of the central element 2 and the longitudinal axes of the branch elements in their undeflected state.

The out of plane bending mode shape has two nodes, one on the first branch element 3 and one on the second branch element 5. The first node, on the first branch element 3, is
10 located in the hatched area 23 that is shown in fig. 5. The second node, on the second branch element 5, is located in the hatched area 25 that is shown in fig. 5.

When comparing fig. 4 and fig. 5, it can be seen that the first node, that is located on the first branch element 3, of the in plane bending mode shape is situated at substantially the
15 same location on the first branch element 3 as the first node (located on the first branch element 3) in the out of plane bending mode shape. The same applies for the second node, that is located on the second branch element 5. The second node of the in plane bending mode shape is at substantially the same location on the second branch element 3 as the second node in the out of plane bending mode shape.

20 Therefore, according to the invention, during the test, the test specimen 1 will be supported at the branch elements 3,5, at or adjacent to the position indicated by the hatched areas 23, 25.

Fig. 6 shows a first example of a combination of a test rig 30 and test specimen 1
25 according to the invention.

In the example of fig. 6, a test specimen 1 generally in accordance with fig. 1 is shown. However, in the example of fig. 6, this test specimen 1 has been provided with additional test weights 16 at the free end of each branch elements 3,5. The free end of a branch element 3,5 is the end that is not connected to the central element 2.

30 The additional test weights 16 can have the same mass, but alternatively they have a different mass. For example, the additional test weight 16 that is arranged at the free end of the first branch element 3 can be heavier than the additional test weight 16 that is arranged at the free end of the second branch element 5 in order to compensate for any additional weight that is present due to drive 41 which is connected to the free end of the second branch
35 element 5 as well.

Instead of the test specimen 1 shown in the example of fig. 6, test specimens 1 according to the invention that have a different geometry (e.g. the ones shown in fig. 2, fig. 3, fig. 8, fig. 9, fig. 10) can be used in combination with the test rig 30 that is shown.

5 The test rig 30 that is shown in fig. 6 is arranged on a base 50. This base is preferably flat, smooth and sturdy. In the example of fig. 6 the base is a floor, for example a concrete floor, but alternatively the base can for example be a structure mounted on a floor. In advantageous embodiments of the test rig 30, measures have been taken to reduce the dynamic mechanical loads that are exerted on the base 50 as much as possible. However,
10 the invention allows for testing of large and heavy test specimens. If such large and heavy test specimens are to be tested, the base will still need to be strong.

 The test rig 30 of fig. 6 comprises a first support 33 and a second support 35. The first support 33 supports the first branch element 3 and the second support 35 supports the
15 second branch element 5. The first support 33 is arranged such that it engages the first branch element 3, preferably at or adjacent to the node in the first branch element 3 of the in plane bending mode shape and at or adjacent to the node in the first branch element 3 of the out of plane bending mode shape. The second support 35 is arranged such that it engages
20 the second branch element 5, preferably at or adjacent to the node in the second branch element 5 of the in plane bending mode shape and at or adjacent to the node in the second branch element 5 of the out of plane bending mode shape.

 In the example of fig. 6, both the first and the second support 33,35 are moveable relative to the base 50. In this example, the supports 33, 35 are provided with wheels 32,36. The wheels 32,36 are optionally provided with rubber tires, for reducing the impact of the
25 vibrations of imposed on the test specimen 1 onto the test rig 30 and the base 50.

 The test rig 30 further comprises an excicator 40. The excicator 40 in this example comprises a drive 41 and an electric motor 42, and are coupled by a cardan shaft 43.

 The drive 41 comprises at least one rotatable eccentric weight. The electric motor 42
30 drives the rotation of the eccentric weight via the cardan shaft 42. The rotation of the eccentric weight of the drive 41 produces imbalance forces that subject the test specimen 1 to a forced vibration at an excitation frequency. In practical cases, the excitation frequency could be between 10 Hz and 60 Hz, for example.

 The electric motor 42 is preferably provided with a motor control system, that allows to
35 set and/or adjust the rotational speed of the motor 42, and therewith the excitation frequency of the excicator. Preferably, the motor control system is such that it allows an accurate control of the motor speed and therewith of the excitation frequency.

Due to the rotating nature of the imbalance forces, the in plane bending mode shape and the out of plane bending mode shape are excited in an alternating way.

The excitation frequency is set close to the in plane bending resonance frequency and the out of plane bending resonance frequency, so that both the in plane bending mode and
5 the out of plane bending mode are excited by the imbalance forces.

In the example of fig. 6, the test specimen 1 has been instrumented with a number of sensors 60. Optionally, the test specimen 1 is provided with a number of supports for holding these sensors 60. The sensors 60 are for example displacement transducers, velocity
10 transducers or acceleration transducers. These transducers can be used for example to monitor any changes in mode shape that could be indicative for the presence of a fatigue crack. It is possible that as an alternative or in addition, a sensor 60 in the form of a pressure transducer is present.

The use of a pressure transducer is useful when the test specimen 1 comprises a cavity
15 that is filled with e.g. a gas or a liquid. If one or both of the joints 4,6 form part of the wall of that cavity, and a fatigue crack appears that extends through the entire thickness of the joint, the pressure in the cavity will drop. The pressure transducer should be arranged such that it detects such a pressure drop. So, if a pressure drop is measured by this pressure transducer, this indicates that a crack has formed. In case the joints 4,6 are welds, they have a lower
20 resistance to fatigue than the base material of the central element 2 and the branch elements 3,5, it is likely that this crack is present in one of the joints 4,6.

Fig. 7 shows a second example of a combination of a test rig 30 and test specimen 1 according to the invention.

25 The test rig 30 in this example is similar to the one shown in fig. 6. It has been modified to be suitable for test specimens 1 that have a central element 2 and only one branch element 3. Therefore, the test rig 30 of fig. 7 has only one support 33. This support 33 in the example of fig. 7 is moveable, so that it can be arranged in such a way that it engages the branch element 3 at or adjacent to the node in the first branch element 3 of the in plane
30 bending mode shape and at or adjacent to the node in the first branch element 3 of the out of plane bending mode shape.

Optionally, the geometry of the test specimen is adjusted such that the center of gravity of the test specimen is close the nodes and/or close to the support 33. Optionally, further provisions are made to stabilize the test specimen during the test. These provisions could for
35 example include springs or straps.

In the example of fig. 7, a strap 34 is present to hold the test specimen 1 in place relative to the support 33. The strap 34 is merely a safety measure, as the support 33

engages the first branch element 3 at or adjacent to a node of both excited mode shapes. The strap 34 helps to prevent undesired rotation of the test specimen relative to the test rig.

Straps 34 can be used in the test rig 30 that is shown in fig. 6 too.

5 The excitator 40 and the sensors 60 in the example of fig. 7 are the same as in the example of fig. 6.

Figures 8 to 16 show further examples of test specimens according to the invention.

Fig. 8 shows a variant of the test specimen 1 according to fig. 1. Fig. 8a shows the test specimen 1 in front view, fig. 8b shows the test specimen 1 in top view.

10 In the variant of fig. 8, the first branch element 3 and second branch element 5 are not arranged halfway the central element 2. In his example, the branch elements 3,5 are arranged closer to the top of the central element 2. This makes that when the test specimen 1 is arranged in a test rig according to the invention, e.g. the test rig of fig. 6, gravity will hold the test specimen 1 in place in a more stable way, with the longer, and therefore heavier, part of the central element pointing downwards. This reduces the risk of undesired rotation of the test specimen relative to the test rig.

Test specimens 1 of the types as shown in fig. 2 and fig. 3 can be modified likewise, as can the other test specimens according to the invention, such that they have their branch elements 3,5 not halfway the central element 2.

20 Another variant (not shown) is to arrange the branch elements 3,5 halfway the central element, but to add additional weight to the lower part of the central element 2, at the bottom end or between the bottom end and the middle of the central element 2. This can be done by adding additional test weights or by filling a cavity in the lower part of the central element with for example a liquid (e.g. water). This can be done in any of the test specimens shown in figures 1 - 3 and 8 - 16.

Fig. 9 shows another variant of the test specimen 1 according to fig. 1. Fig. 9a shows the test specimen 1 in front view, fig. 9b shows the test specimen 1 in top view.

30 In the variant of fig. 9, the first and second branch elements 3,5 extend under an angle relative to each other. This will cause a shift in the position of the nodes of the in plane bending mode shape and/or the out of plane bending mode shape, and probably also a shift in the in plane bending resonance frequency and the out of plane bending resonance frequency. This variant of the test specimen can be used for adapting the resonance frequencies and/or position of the nodes in case the rest of the geometry of the test specimen requires this.

35 In the embodiment of fig. 9, the longitudinal axes of the central element and the branch elements are no longer in one flat plane. The "plane" in "in plane bending" and "out of plane

bending” now refers to the curved plane extending through the longitudinal axes of the central element and the branch elements. This means that in the in plane bending mode, the central element still vibrates in the direction indicated by arrow A in fig. 9a, and in the out of plane bending mode in the direction indicated by arrow B in fig. 9b. The branch elements 3,5 deflect accordingly.

This variant is also possible in combination with the test specimens as shown in fig. 2 and fig. 3. In those situations, the longitudinal axes 13,15 of the branch elements 3,5 extend under an angle relative to the longitudinal axis 12 of the central element and the longitudinal axes 13,15 of the branch elements 3,5 extend under an angle relative to each other. Also the other test specimens according to the invention can be modified this way.

Fig. 10 shows another variant of the test specimen 1 according to fig. 1. Fig. 10a shows the test specimen 1 in front view, fig. 10b shows the test specimen 1 in top view.

In the variant of fig. 10, shores or stiffeners 10 are provided between the branch elements 3,5 and the central element 2. This changes to load distribution in the test specimen 1. Using this variant of the test specimen 1 can be useful if the actual structure also contains such shores or stiffeners.

Shores and/or stiffeners 10 as shown in fig. 10 can also be applied in the other test specimens according to the invention.

Fig. 11 shows another variant of the test specimen 1 according to fig. 1. Fig. 11a shows the test specimen 1 in front view, fig. 11b shows the test specimen 1 in top view.

The test specimen 1 of fig. 11 is similar to the test specimen 1 of fig. 1, only it has just one branch element 3. As a result, the in plane bending resonance frequency and the out of plane bending frequency are farther apart than in the test specimen 1 of fig. 1. Also the nodes in the branch element 3 for the in plane bending mode shape and the out of plane bending mode shape are farther apart. Therefore, for the test specimen 1 of fig. 11, the weight distribution has to be optimized in order to obtain the desired values of the in plane bending resonance frequency and the out of plane bending frequency and position of the node on the branch element 3 for the in plane bending mode shape and the out of plane bending mode shape.

Fig. 12 shows a variant of the test specimen 1 according to fig. 2. Fig. 12a shows the test specimen 1 in front view, fig. 12b shows the test specimen 1 in top view.

The test specimen 1 of fig. 12 is similar to the test specimen 1 of fig. 2, only it has just one branch element 3. As a result, the in plane bending resonance frequency and the out of plane bending frequency are farther apart than in the test specimen 1 of fig. 1. Also the nodes

in the branch element 3 for the in plane bending mode shape and the out of plane bending mode shape are farther apart. Therefore, for the test specimen 1 of fig. 11, the weight distribution has to be optimized in order to obtain the desired values of the in plane bending resonance frequency and the out of plane bending frequency and position of the node on the branch element 3 for the in plane bending mode shape and the out of plane bending mode shape.

Fig. 13 shows a variant of the test specimen 1 according to fig. 3. Fig. 13a shows the test specimen 1 in front view, fig. 13b shows the test specimen 1 in top view.

10 The test specimen 1 of fig. 13 is similar to the test specimen 1 of fig. 3, only it has just one branch element 3. As a result, the in plane bending resonance frequency and the out of plane bending frequency are farther apart than in the test specimen 1 of fig. 1. Also the nodes in the branch element 3 for the in plane bending mode shape and the out of plane bending mode shape are farther apart. Therefore, for the test specimen 1 of fig. 11, the weight distribution has to be optimized in order to obtain the desired values of the in plane bending resonance frequency and the out of plane bending frequency and position of the node on the branch element 3 for the in plane bending mode shape and the out of plane bending mode shape.

20 Fig. 14 shows another variant of the test specimen 1 according to fig. 1. Fig. 14a shows the test specimen 1 in front view, fig. 14b shows the test specimen 1 in top view.

In the embodiment, the first branch element 3 and the second branch element 5 have a different geometry. The first branch element 3 has a larger diameter than the second branch element 5 and the second branch element 5 is longer than the first branch element 3.

25 This different geometry of the two branch elements can also occur in the embodiments shown in figures 2, 3, 8, 9 and 10.

Fig. 15 shows another variant of the test specimen 1 according to fig. 1. Fig. 15a shows the test specimen 1 in front view, fig. 15b shows the test specimen 1 in top view.

30 In the embodiment of fig. 15, the test specimen 1 has been provided with flanges $4^*a, 4^*b$ and $6^*a, 6^*b$ to connect the first branch element 3 and the second branch element 5, respectively to the central element 2. The central element has two transition zones 4^{**} and 6^{**} that are present adjacent to the flanges 4^*b and 6^*b of the central element 2.

35 The flange 4^*a of the central element 2 and the flange 4^*b of the first element 3 are for example connected to each other by bolts and nuts, by a weld or by glue. The flange 6^*a of the central element 2 and the flange 6^*b of the second element 5 are also for example connected to each other by bolts and nuts, by a weld or by glue.

A joint with flanges can also occur in the embodiments of figures 2, 3, 8, 9, 10, 11, 12, 13 and 14.

Fig. 16 shows another variant of the test specimen 1 according to fig. 1. Fig. 16a shows
5 the test specimen 1 in front view, fig. 16b shows the test specimen 1 in top view.

In the embodiment of fig. 16, the central element 2, the first branch element 3 and the
second branch element 5 are made as a single part, for example by casting or as a single
part from fiber reinforced resin. In this embodiment, the joint 4 is formed by the connection
between the central element 2 and the first branch element 3. Joint 6 is formed by the
10 connection between the central element 2 and the second branch element 5.

A joint of this type can also occur in the embodiments of figures 2, 3, 8, 9, 10, 11, 12, 13
and 14.

15

C O N C L U S I E S

1. Combinatie van een proefopstelling en een proefstuk voor het uitvoeren van een vermoeiingstest op het proefstuk,

5 waarbij het proefstuk niet-axisymmetrisch is en omvat:

- een centraal element, welk centraal element een longitudinale as omvat,
- een eerste vertakkingselement, welke eerste vertakkingselement een longitudinale as heeft die zich onder een hoek ten opzichte van de longitudinale as van het centrale element uitstrekt,

10 - een verbinding die het eerste vertakkingselement verbindt met het centrale element, waarbij het niet-axisymmetrische proefstuk meerdere resonantiefrequenties met bijbehorende trilvormen heeft,

welke meerdere resonantiefrequenties een in-het-vlak buigresonantiefrequentie met een bijbehorende in-het-vlak buigtrilvorm en een uit-het-vlak buigresonantiefrequentie met een

15 bijbehorende uit-het-vlak buigtrilvorm omvatten,

waarbij de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie in hoofdzaak gelijk zijn,

en waarbij de proefopstelling omvat:

- een eerste steun voor het ondersteunen van het proefstuk,
- 20 - een excitorator voor het onderwerpen van het proefstuk aan een gedwongen trilling bij een excitatiefrequentie.

2. Combinatie van een proefopstelling en een proefstuk volgens conclusie 1,

waarbij de in-het-vlak buigtrilvorm een eerste knoop omvat, welke eerste knoop zich bevindt

25 in het eerste vertakkingselement, en waarbij de uit-het-vlak buigtrilvorm een eerste knoop omvat, welke eerste knoop zich bevindt in het eerste vertakkingselement,

waarbij de eerste knoop van de in-het-vlak buigtrilvorm en de eerste knoop van de uit-het-

vlak buigtrilvorm zich op in hoofdzaak dezelfde positie in het eerste vertakkingselement bevinden.

30

3. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,

waarbij het proefstuk verder omvat:

- een tweede vertakkingselement, welk tweede vertakkingselement een longitudinale as heeft die zich onder een hoek ten opzichte van de longitudinale as van het centrale element uitstrekt,
- 35 - een verbinding die het eerste vertakkingselement verbindt met het centrale element,

en waarbij de proefopstelling verder een tweede steun omvat voor het ondersteunen van het proefstuk.

4. Combinatie van een proefopstelling en een proefstuk volgens conclusie 3,
5 waarbij de in-het-vlak buigtrilvorm een tweede knoop omvat, welke tweede knoop zich bevindt in het tweede vertakkingselement, en waarbij de uit-het-vlak buigtrilvorm een tweede knoop omvat, welke tweede knoop zich bevindt in het tweede vertakkingselement, waarbij de tweede knoop van de in-het-vlak buigtrilvorm en de tweede knoop van de uit-het-vlak buigtrilvorm zich op in hoofdzaak dezelfde positie in het tweede vertakkingselement
10 bevinden.
5. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij de verbinding tussen het eerste vertakkingselement en het centrale element en/of de
15 verbinding tussen het tweede vertakkingselement en het ventrale element een las is, of een geschroefde verbinding of een flensverbinding of een deel van een gegoten verbinding of een gelijmde verbinding.
6. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande
20 conclusies,
waarbij het centrale element en/of ten minste een vertakkingselement van het proefstuk buisvormig is, waarbij optioneel het centrale element en alle vertakkingselementen buisvormig zijn.
- 25 7. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij in het proefstuk de hoek tussen de longitudinale as van het centrale element en de longitudinale as van ten minste een vertakkingselement tussen 45° en 135° is.
- 30 8. Combinatie van een proefopstelling en een proefstuk volgens conclusie 3,
waarbij in het proefstuk de hoek tussen de longitudinale as van het eerste vertakkingselement en de longitudinale as van het centrale element in hoofdzaak gelijk is aan de hoek tussen de longitudinale as van het tweede vertakkingselement en de longitudinale as van het centrale element.
35
9. Combinatie van een proefopstelling en een proefstuk volgens conclusie 3,
waarbij in het proefstuk het eerste vertakkingselement en het tweede vertakkingselement coaxiaal met elkaar zijn, en/of

waarbij het eerste vertakkingselement en het tweede vertakkingselement zich aan tegenoverliggende zijden van het centrale element bevinden, en/of

5 Waarbij het eerste vertakkingselement en het tweede vertakkingselement op hetzelfde niveau verbonden zijn met het centrale element, optioneel halverwege de uiteinden van het centrale element, en/of

waarbij de longitudinale as van het eerste vertakkingselement, de longitudinale as van het tweede vertakkingselement en de longitudinale as van het centrale element in hetzelfde vlak liggen.

10 10. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,

15 waarbij het proefstuk ten minst een holte omvat, welke holte optioneel gevuld is met een vloeistof of een gas, optioneel een samengedrukt gas, en/of welke holte bij voorkeur ten minste deels wordt begrensd door ten minste een verbinding tussen het centrale element en een vertakkingselement.

11. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,

20 waarbij het proefstuk voorzien is van een additioneel testgewicht aan het centrale element en/of aan ten minste een vertakkingselement, waarbij optioneel het testgewicht niet-coaxiaal met het vertakkingselement is opgesteld.

12. Combinatie van een proefopstelling en een proefstuk volgens de conclusies 3 en 11, waarbij het eerste vertakkingselement van het proefstuk is voorzien van een eerste
25 additioneel testgewicht en het tweede vertakkingselement is voorzien van een tweede additioneel testgewicht,

30 waarbij optioneel het eerste testgewicht verschillend is van het tweede testgewicht en/of waarbij de locatie waarop het eerste testgewicht is aangebracht aan het eerste vertakkingselement verschillend is van de locatie waarop het tweede testgewicht is aangebracht aan het tweede vertakkingselement.

13. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,

35 waarbij het proefstuk verder voorzien is van ten minst een steun voor een sensor.

14. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,

waarbij ten minste de eerste steun van de proefopstelling beweegbaar is zodat zijn positie kan worden afgestemd op de positie van de eerste knoop in de in-het-vlak buigtrilvorm en/of de uit-het-vlak buigtrilvorm.

- 5 15. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij de excitator een roteerbaar excentrisch gewicht omvat,
en waarbij optioneel het roteerbaar excentrisch gewicht van de excitator van de proefopstelling verbonden is met een vertakkingselement van het proefstuk.
- 10 16. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij de excitator instelbaar is, zodanig dat de excitatiefrequentie ingesteld kan worden op een gewenste waarde.
- 15 17. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij het proefstuk een verder resonantiefrequentie heeft die niet de in-het-vlak buigresonantiefrequentie is en ook niet de uit-het-vlak buigresonantiefrequentie, welke
20 verdere resonantiefrequentie ten minste 25% hoger is dan de hoogste van de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie of ten minste 25% lager dan de laagste van de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie.
- 25 18. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij het proefstuk verder een verstijvingelement of een schoor omvat die zich uitstrekt tussen het eerste vertakkingselement en het centrale element en/of, indien een tweede vertakkingselement aanwezig is, tussen het tweede vertakkingselement en het centrale
30 element.
- 35 19. Combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
waarbij het proefstuk gemaakt is van metaal, bijvoorbeeld staal, waarbij het staal optioneel voorzien is van een coating en/of geverfd is, of waarbij het proefstuk gemaakt is van kunststof, bijvoorbeeld hars of een thermoplastisch materiaal, met of zonder glasvezel en/of koolstofvezel.

20. Combinatie van een proefopstelling en een proefstuk volgens conclusie 1, waarbij het proefstuk verder omvat:

- 5 - een tweede vertakkingselement, welk tweede vertakkingselement een longitudinale as heeft die zich onder een hoek ten opzichte van de longitudinale as van het centrale element uitstrekt,
- een verbinding die het eerste vertakkingselement verbindt met het centrale element, Waarbij de in-het-vlak buigtrilvorm een tweede knoop omvat, welke tweede knoop zich bevindt in het tweede vertakkingselement, en waarbij de uit-het-vlak buigtrilvorm een tweede knoop omvat, welke tweede knoop zich bevindt in het tweede vertakkingselement, 10 Waarbij de tweede knoop van de in-het-vlak buigtrilvorm en de tweede knoop van de uit-het-vlak buigtrilvorm zich op in hoofdzaak dezelfde positie in het tweede vertakkingselement bevinden, Waarbij de longitudinale assen van het centrale element, het eerste vertakkingselement en het tweede vertakkingselement alle in hetzelfde vlak liggen en de twee 15 vertakkingselementen op hetzelfde niveau, bij voorkeur halverwege het centrale element verbonden zijn met het centrale element, en Waarbij de hoek tussen de longitudinale as van het centrale element en de longitudinale as van ten minste een vertakkingselement tussen 45° en 135° is, waarbij bij voorkeur deze hoek gelijk is voor beide vertakkingselementen, 20 en waarbij de proefopstelling verder een tweede steun omvat voor het ondersteunen van het proefstuk.

21. Werkwijze voor het uitvoeren van vermoeiingstesten op een proefstuk, welke werkwijze de volgende stappen omvat:

- 25 - het verschaffen van een combinatie van een proefopstelling en een proefstuk volgens een van de voorgaande conclusies,
- het aanbrengen van het proefstuk in de proefopstelling, optioneel zodanig dat de eerste steun van de proefopstelling het eerste vertakkingselement ondersteunt nabij de eerste knoop van zowel de in-het-vlak buigtrilvorm als de uit-het-vlak buigtrilvorm,
- 30 - het onderwerpen van het proefstuk aan een gedwongen trilling door de excitator bij een excitatiefrequentie die nabij de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie ligt, en het daardoor exciteren van de in-het-vlak buigtrilvorm en de uit-het-vlak buigtrilvorm.

35 22. Werkwijze volgens conclusie 21, waarbij een combinatie van een proefopstelling en een proefstuk volgens conclusie 3 of 4 wordt verschaft, en waarbij optioneel het proefstuk wordt aangebracht in de proefopstelling zodanig dat de tweede steun van de proefopstelling het tweede vertakkingselement van dhet

proefstuk ondersteunt in of direct nabij de tweede knoop van zowel de in-het-vlak buigtrilvorm als de uit-het-vlak buigtrilvorm.

23. Werkwijze volgens een van de conclusies 21-22,

5 waarbij de in-het-vlak buigtrilvorm en de uit-het vlak buigtrilvorm afwisselend worden aangestoten.

24. Werkwijze volgens een van de conclusies 21-23,

10 waarbij een combinatie van een proefopstelling en een proefstuk volgens conclusie 14 wordt verschaft,
en waarbij voorafgaand aan of tijdens het aanbrengen van het proefstuk in de proefopstelling, de positie van de eerste en/of tweede steun van de proefopstelling wordt aangepast.

25. Werkwijze volgens een van de conclusies 21-24,

15 waarbij een combinatie van een proefopstelling en een proefstuk volgens conclusie 10 wordt verschaft,
en waarbij de werkwijze verder de stap omvat van het vullen van de holte van het proefstuk met een vloeistof of een gas, optioneel een samengeperst gas, en waarbij optioneel de druk van de vloeistof of het gas wordt gemeten tijdens de test.

20

26. Werkwijze volgens een van de conclusies 21-25,

waarbij verplaatsing, snelheid en/of versnelling wordt gemeten aan het proefstuk tijdens de test.

25

27. Werkwijze volgens een van de conclusies 21-26,

waarbij de excitatiefrequentie tussen 10 en 60 Hz ligt.

28. Werkwijze voor het ontwerpen van een vermoeiingstest van een proefstuk, in welke

30 vermoeiingstest een combinatie van een proefopstelling en een proefstuk volgens een van de conclusies 1-20 wordt gebruikt en welke vermoeiingstest wordt uitgevoerd volgens een van de conclusies 21-27,

welke werkwijze de volgende stappen omvat:

35

- het kiezen van een basisgeometrie voor het proefstuk, inclusief het selecteren van het aantal vertakkingselementen die verbonden worden met het centrale element en de positie en richting van deze vertakkingselementen,
- het kiezen van de vorm van het centrale element en de vertakkingselementen,
- het kiezen van de lengte en dwarsdoorsnede-afmetingen van het centrale element en de vertakkingselementen,

- het berekenen van de in-het-vlak buigresonantiefrequentie, de in-het-vlak buigtrilvorm, de uit-het-vlak buigresonantiefrequentie, de uit-het-vlak buigtrilvorm en optioneel verdere resonantiefrequenties die mogelijk nabij de in-het-vlak buigresonantiefrequentie en/of de uit-het-vlak buigresonantiefrequentie liggen,
- 5 - het bepalen van het verschil tussen de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie,
- het nagaan of dit verschil tussen de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie klein genoeg is om de werkwijze voor het uitvoeren van de werkwijze voor het uitvoeren van een vermoeiingstest volgens een van de
- 10 conclusies 21-27 te kunnen toepassen,
- optioneel het bepalen van het verschil in locatie van de knoop in elk vertakkingselement in de in-het-vlak buigtrilvorm en de locatie van de betreffende knoop in de uit-het-vlak buigtrilvorm,
- optioneel het nagaan of dit verschil in locatie van de knoop in elk vertakkingselement
- 15 in de in-het-vlak buigtrilvorm en de uit-het-vlak buigtrilvorm klein genoeg is om de werkwijze voor het uitvoeren van een vermoeiingstest volgens een van de conclusies 21-27 te kunnen toepassen,
- indien het verschil tussen de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie of het optioneel berekende verschil tussen de locatie van de
- 20 knoop in elk vertakkingselement in de in-het-vlak buigtrilvorm en de locatie van deze knoop in de uit-het-vlak buigtrilvorm te groot is, het aanpassen van de gewichtsverdeling en/of de lengte en dwarsdoorsnede afmetingen van het centrale element en/of de vertakkingselement om de locatie van de knopen en/of de resonantiefrequenties te verschuiven.

25

29. Proefstuk voor toepassing in een combinatie van een proefopstelling en een proefstuk volgens een van de conclusies 1-20 of in de werkwijze volgens een van de conclusies 21-27, waarbij het proefstuk niet-axisymmetrisch is en omvat:

- een centraal element, welk centraal element een longitudinale as omvat,
 - 30 - een eerste vertakkingselement, welke eerste vertakkingselement een longitudinale as heeft die zich onder een hoek ten opzichte van de longitudinale as van het centrale element uitstrekt,
 - een verbinding die het eerste vertakkingselement verbindt met het centrale element, waarbij het niet-axisymmetrische testelement meerdere resonantiefrequenties met
 - 35 bijbehorende trilvormen heeft,
- welke meerdere resonantiefrequenties een in-het-vlak buigresonantiefrequentie met een bijbehorende in-het-vlak buigtrilvorm en een uit-het-vlak buigresonantiefrequentie met een bijbehorende uit-het-vlak buigtrilvorm omvatten,

waarbij de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie in hoofdzaak gelijk zijn,

waarbij optioneel de in-het-vlak buigtrilvorm een eerste knoop omvat, welke eerste knoop zich bevindt in het eerste vertakkingselement, en waarbij de uit-het-vlak buigtrilvorm een eerste

5 knoop omvat, welke eerste knoop zich bevindt in het eerste vertakkingselement, waarbij de eerste knoop van de in-het-vlak buigtrilvorm en de eerste knoop van de uit-het-vlak buigtrilvorm zich op in hoofdzaak dezelfde positie in het eerste vertakkingselement bevinden, en

waarbij het proefstuk verder voorzien is van ten minste een steun voor een sensor, en/of

10 waarbij het proefstuk verder is voorzien van een additioneel testgewicht aan het centrale element en/of ten minste een vertakkingselement, waarbij optioneel het additionele testgewicht niet-coaxiaal met het vertakkingselement is opgesteld.

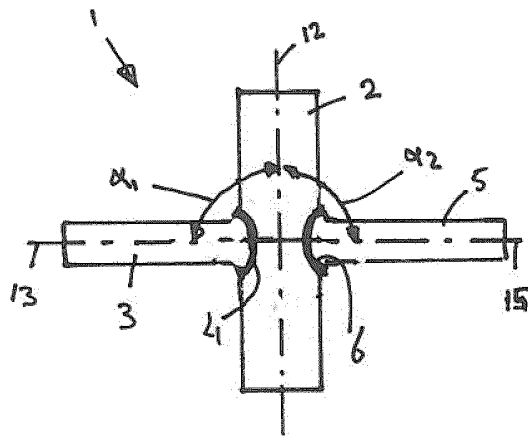


Fig. 1a

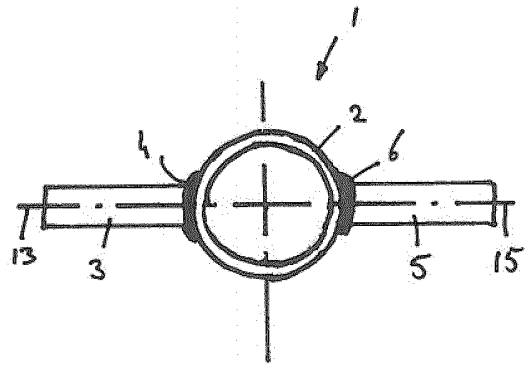


Fig. 1b

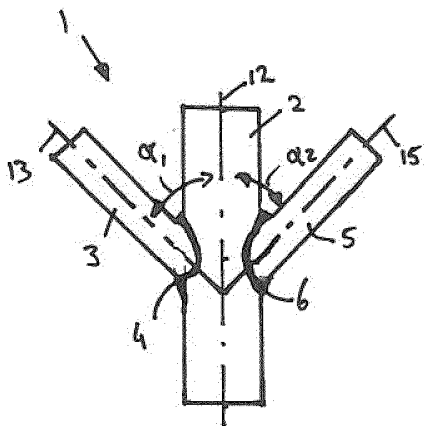


Fig. 2a

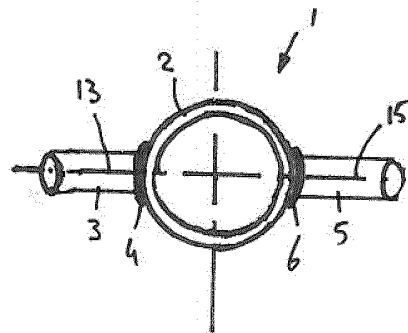


Fig. 2b

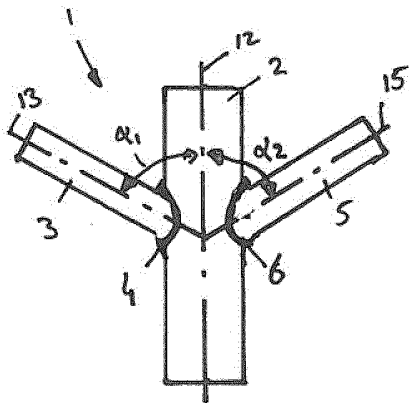


Fig. 3a

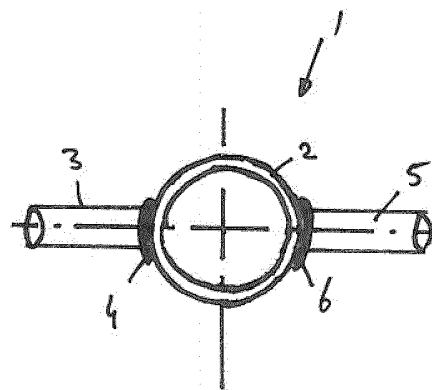


Fig. 3b

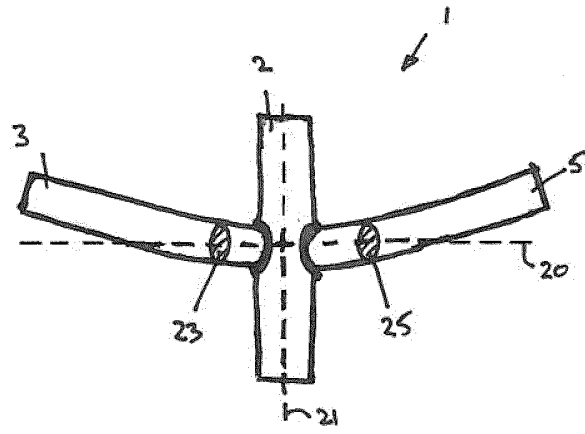


Fig. 4

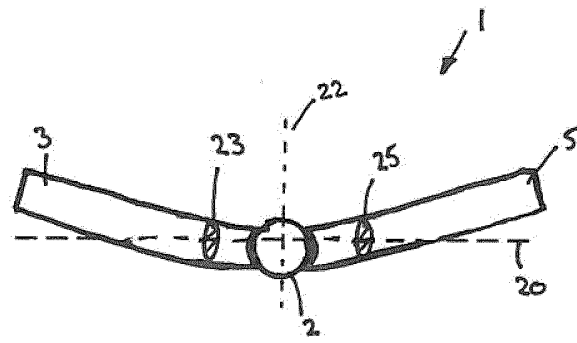


Fig. 5

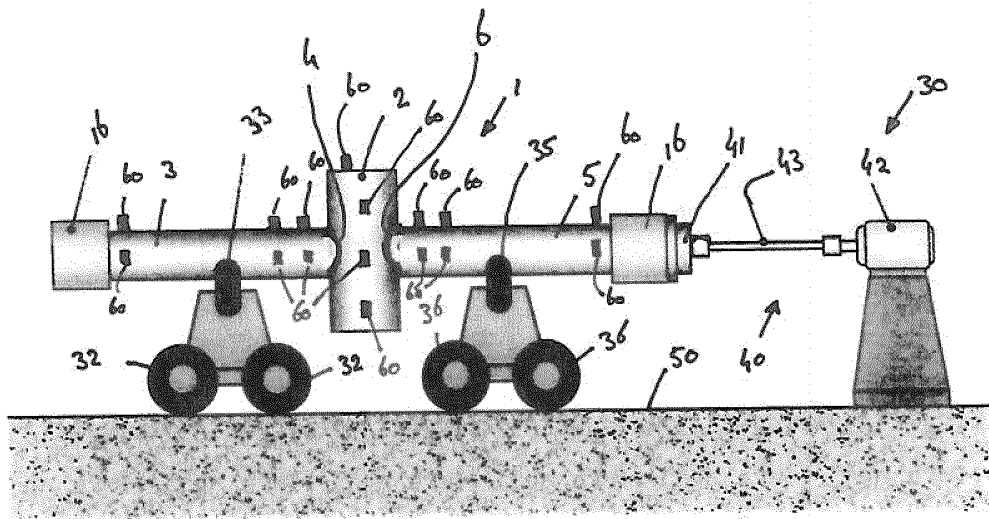


Fig. 6

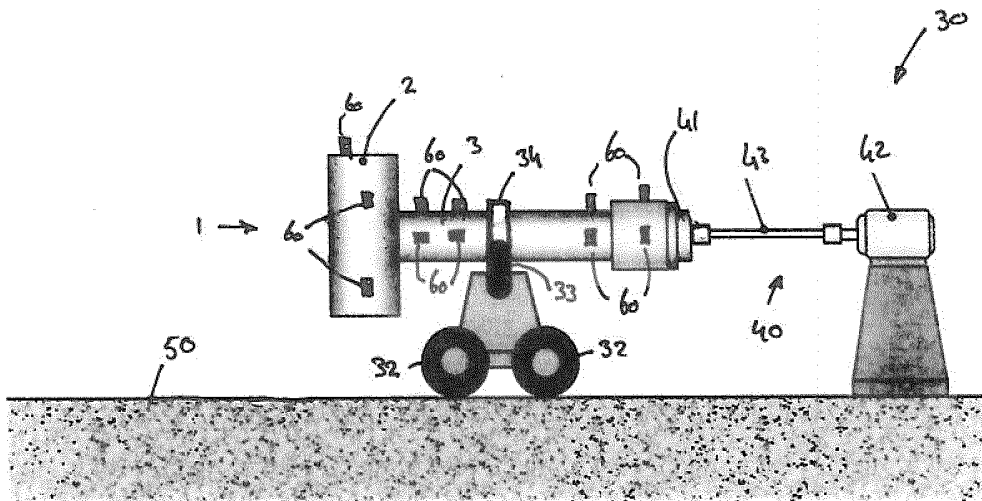


Fig. 7

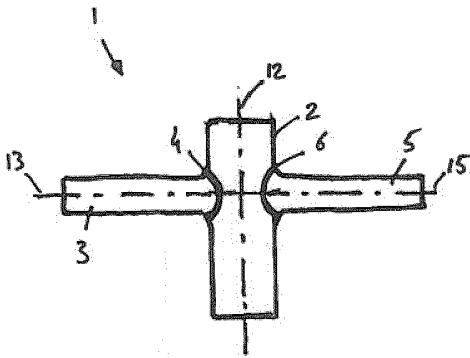


Fig. 8a

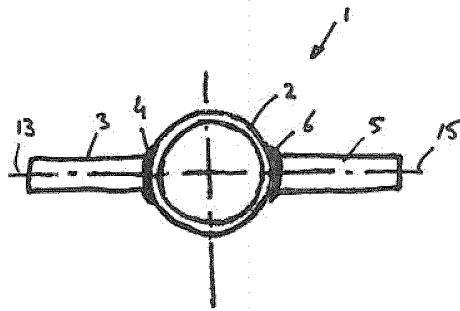


Fig. 8b

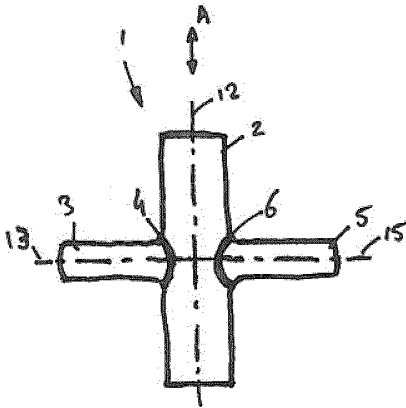


Fig. 9a

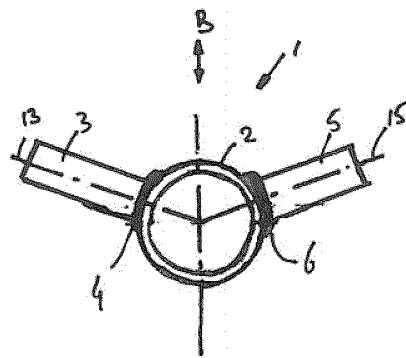


Fig. 9b

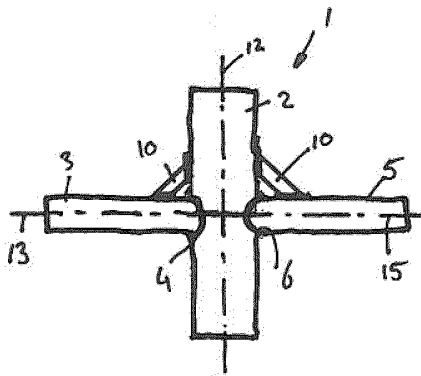


Fig. 10a

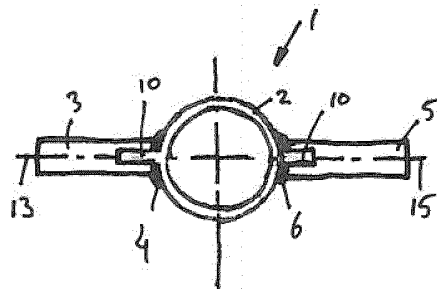


Fig. 10b

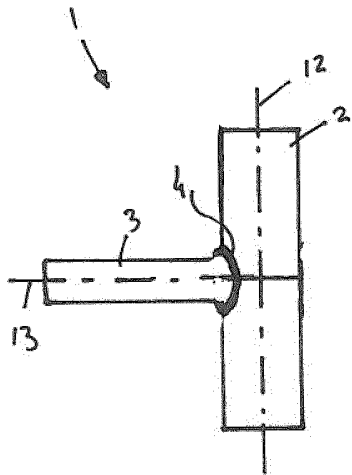


Fig. 11 a

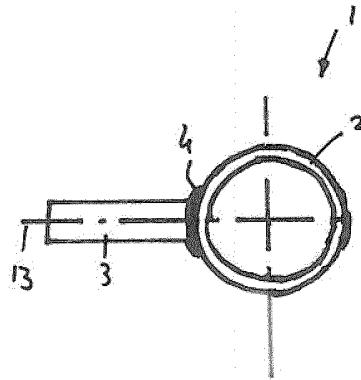


Fig. 11 b

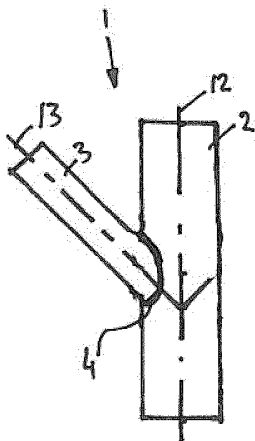


Fig. 12 a

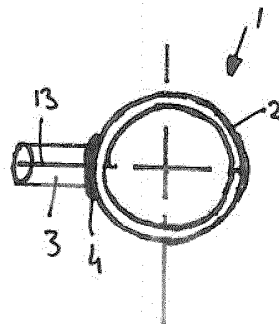


Fig. 12 b

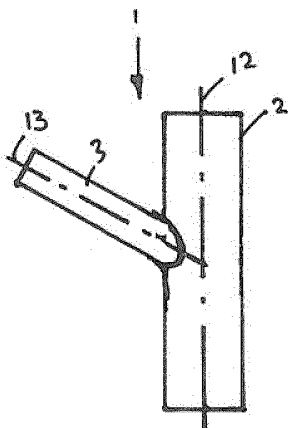


Fig. 13 a

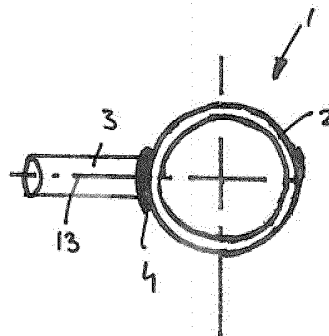


Fig. 13 b

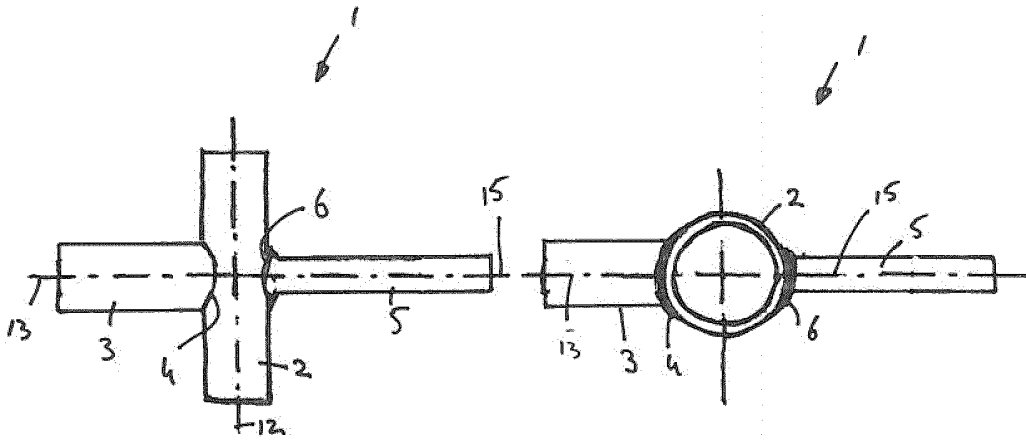


Fig. 14a

Fig. 14b

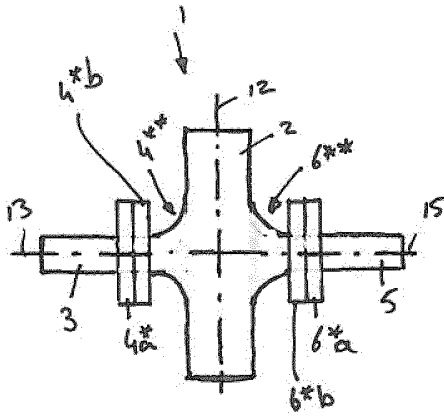


Fig. 15 a

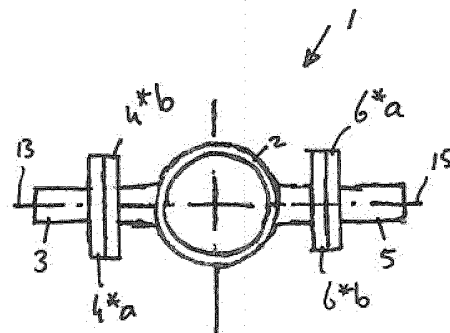


Fig. 15 b

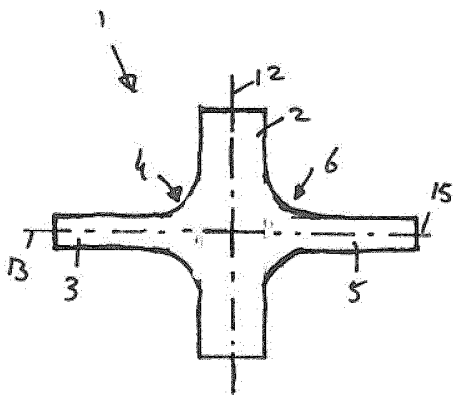


Fig. 16a

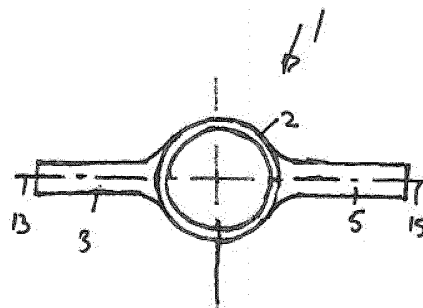


Fig. 16 b

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	P31538NL00/NBL
Nederlands aanvraag nr.	Indieningsdatum
2010556	03-04-2013
	Ingeroepen voorrangsdatum
Aanvrager (Naam)	
Onderzoekscentrum voor aanwending van staal N.V.	
Datum van het verzoek voor een onderzoek van internationaal type	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr.
15-06-2013	SN 60245
I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)	
Volgens de internationale classificatie (IPC)	
G01N3/32	G01M7/02
II. ONDERZOCHE GEBIEDEN VAN DE TECHNIEK	
Onderzochte minimumdocumentatie	
Classificatiesysteem	Classificatiesymbolen
IPC	G01N G01M
Onderzochte andere documentatie dan de minimum documentatie, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen	
III.	<input type="checkbox"/> GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES (opmerkingen op aanvullingsblad)
IV.	<input type="checkbox"/> GEBREK AAN EENHEID VAN UITVINDING (opmerkingen op aanvullingsblad)

**ONDERZOEKSRAPPORT BETREFFENDE HET
RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Nummer van het verzoek om een onderzoek naar
de stand van de techniek

NL 2010556

A. CLASSIFICATIE VAN HET ONDERWERP
INV. G01N3/32 G01M7/02
ADD.

Volgens de Internationale Classificatie van octrooien (IPC) of zowel volgens de nationale classificatie als volgens de IPC.

B. ONDERZOCHETE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimum documentatie (classificatie gevolgd door classificatiesymbolen)
G01N G01M

Onderzochte andere documentatie dan de minimum documentatie, voor dergelijke documenten, voor zover dergelijke documenten in de onderzochte gebieden zijn opgenomen

Tijdens het onderzoek geraadpleegde elektronische gegevensbestanden (naam van de gegevensbestanden en, waar uitvoerbaar, gebruikte trefwoorden)

EPO-Internal, WPI Data

C. VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
X	US 2011/041617 A1 (COTRELL JASON [US] ET AL) 24 februari 2011 (2011-02-24) * samenvatting * * figuren 11,17 * * alinea's [0034] - [0037], [0087] - [0091] *	1-28
X	US 2010/263448 A1 (HUGHES SCOTT [US] ET AL) 21 oktober 2010 (2010-10-21) * samenvatting * * figuren 1,5 * * alinea's [0027] - [0030], [0042] *	1-29



Verdere documenten worden vermeld in het vervolg van vak C.



Leden van dezelfde octroofamilie zijn vermeld in een bijlage

° Speciale categorieën van aangehaalde documenten

"A" niet tot de categorie X of Y behorende literatuur die de stand van de techniek beschrijft

"D" in de octrooiaanvraag vermeld

"E" eerdere octrooi(aanvraag), gepubliceerd op of na de indieningsdatum, waarin dezelfde uitvinding wordt beschreven

"L" om andere redenen vermelde literatuur

"O" niet-schriftelijke stand van de techniek

"P" tussen de voorrangsdatum en de indieningsdatum gepubliceerde literatuur

"T" na de indieningsdatum of de voorrangsdatum gepubliceerde literatuur die niet bezwarend is voor de octrooiaanvraag, maar wordt vermeld ter verheldering van de theorie of het principe dat ten grondslag ligt aan de uitvinding

"X" de conclusie wordt als niet nieuw of niet inventief beschouwd ten opzichte van deze literatuur

"Y" de conclusie wordt als niet inventief beschouwd ten opzichte van de combinatie van deze literatuur met andere geciteerde literatuur van dezelfde categorie, waarbij de combinatie voor de vakman voor de hand liggend wordt geacht

"&" lid van dezelfde octroofamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid

16 januari 2014

Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type

Naam en adres van de instantie

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

De bevoegde ambtenaar

Seifter, Achim

**ONDERZOEKSRAPPORT BETREFFENDE HET
 RESULTAAT VAN HET ONDERZOEK NAAR DE STAND
 VAN DE TECHNIEK VAN HET INTERNATIONALE TYPE**

Informatie over leden van dezelfde octrooifamilie

Nummer van het verzoek om een onderzoek naar
 de stand van de techniek

NL 2010556

In het rapport genoemd octrooigeschrift	Datum van publicatie	Overeenkomend(e) geschrift(en)	Datum van publicatie
US 2011041617	A1 24-02-2011	US 2011041617 A1	24-02-2011
		WO 2009135136 A2	05-11-2009

US 2010263448	A1 21-10-2010	US 2010263448 A1	21-10-2010
		WO 2009097049 A2	06-08-2009



OCTROOICENTRUM NEDERLAND

WRITTEN OPINION

File No. SN60245	Filing date (<i>day/month/year</i>) 03.04.2013	Priority date (<i>day/month/year</i>)	Application No. NL2010556
International Patent Classification (IPC) INV. G01N3/32 G01M7/02			
Applicant Onderzoekscentrum voor aanwending van staal N.V.			

This opinion contains indications relating to the following items:

- Box No. I Basis of the opinion
- Box No. II Priority
- Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- Box No. IV Lack of unity of invention
- Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- Box No. VI Certain documents cited
- Box No. VII Certain defects in the application
- Box No. VIII Certain observations on the application

	Examiner Seifter, Achim
--	----------------------------

WRITTEN OPINION

Application number
NL2010556

Box No. I Basis of this opinion

1. This opinion has been established on the basis of the latest set of claims filed before the start of the search.
2. With regard to any **nucleotide and/or amino acid sequence** disclosed in the application and necessary to the claimed invention, this opinion has been established on the basis of:
 - a. type of material:
 - a sequence listing
 - table(s) related to the sequence listing
 - b. format of material:
 - on paper
 - in electronic form
 - c. time of filing/furnishing:
 - contained in the application as filed.
 - filed together with the application in electronic form.
 - furnished subsequently for the purposes of search.
3. In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.
4. Additional comments:

Box No. V Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty	Yes: Claims	2-20, 22-29
	No: Claims	1, 21
Inventive step	Yes: Claims	
	No: Claims	1-29
Industrial applicability	Yes: Claims	1-29
	No: Claims	

2. Citations and explanations

see separate sheet

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1 Reference is made to the following documents:

D1 US 2011/041617 A1 (COTRELL JASON [US] ET AL) 24 februari 2011 (2011-02-24)

D2 US 2010/263448 A1 (HUGHES SCOTT [US] ET AL) 21 oktober 2010 (2010-10-21)

2 The present application does not meet the criteria of patentability, because the subject-matter of claims 1 and 21 is not new.

2.1 D1 discloses (references in parentheses are referring to this document):

Combinatie van een proefopstelling en een proefstuk voor het uitvoeren van een vermoeiingstest op het proefstuk (abstract),

waarbij het proefstuk niet-axisymmetrisch is en omvat:

- een centraal element, welk centraal element een longitudinale as omvat (figure 11, 17; paragraph 0087-0091),

- een eerste vertakkingselement, welke eerste vertakkingselement een longitudinale as heeft die zich onder een hoek ten opzichte van de longitudinale as van het centrale element uitstrekt (figure 11, 17; paragraph 0087-0091),

- een verbinding die het eerste vertakkingselement verbindt met het centrale element, waarbij het niet-axisymmetrische proefstuk meerdere resonantiefrequenties met bijbehorende trilvormen heeft (figure 11, 17; paragraph 0087-0091),

welke meerdere resonantiefrequenties een in-het-vlak buigresonantiefrequentie met een bijbehorende in-het-vlak buigtrilvorm en een uit-het-vlak buigresonantiefrequentie met een bijbehorende uit-het-vlak buigtrilvorm omvatten (paragraph 0034-0037),

waarbij de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie in hoofdzaak gelijk zijn (paragraph 0034-0037), en waarbij de proefopstelling omvat:

- een eerste steun voor het ondersteunen van het proefstuk (abstract; figure

- 11, 17),
- een excitator voor het onderwerpen van het proefstuk aan een gedwongen trilling bij een excitatiefrequentie (abstract; paragraph 0087-0091).
- 2.2 Similar arguments against the novelty of independent claim 1 are brought forward by the subject matter of D2 (abstract; figure 1; paragraph 0027-0030).
- 2.3 The same reasoning applies, mutatis mutandis, to the subject-matter of the corresponding independent claim 21, which therefore is also considered not new.
- 3 The present application does not meet the criteria of patentability, because the subject-matter of claim 29 does not involve an inventive step.
- 3.1 D2 is regarded as being the prior art closest to the subject-matter of claim 29, and discloses (references in parentheses are referring to this document):
Proefstuk voor toepassing in een combinatie van een proefopstelling en een proefstuk volgens een van de conclusies 1-20 of in de werkwijze volgens een van de conclusies 21-27, waarbij het proefstuk niet-axisymmetrisch is en omvat:
- een centraal element, welk centraal element een longitudinale as omvat (abstract; figure 5),
- een eerste vertakkingselement, welke eerste vertakkingselement een longitudinale as heeft die zich onder een hoek ten opzichte van de longitudinale as van het centrale element uitstrekt (abstract; figure 5),
- een verbinding die het eerste vertakkingselement verbindt met het centrale element, waarbij het niet-axisymmetrische proefstuk meerdere resonantiefrequenties met bijbehorende trilvormen heeft (abstract; figure 5), welke meerdere resonantiefrequenties een in-het-vlak buigresonantiefrequentie met een bijbehorende in-het-vlak buigtrilvorm en een uit-het-vlak buigresonantiefrequentie met een bijbehorende uit-het-vlak buigtrilvorm omvatten, waarbij de in-het-vlak buigresonantiefrequentie en de uit-het-vlak buigresonantiefrequentie in hoofdzaak gelijk zijn (paragraph 0027-0030), en
waarbij het proefstuk verder voorzien is van ten minste een steun voor een sensor (paragraph 0029), en/of waarbij het proefstuk verder is voorzien van een additioneel testgewicht aan het centrale element en/of ten minste een vertakkingselement, waarbij optioneel het additionele testgewicht niet-coaxiaal met het vertakkingselement is opgesteld (paragraph 0042; figure 5).

- 3.2 The subject-matter of claim 29 therefore differs from this known device in that optioneel de in-het-vlak buigtrilvorm een eerste knoop omvat, welke eerste knoop zich bevindt in het eerste vertakkingselement, en waarbij de uit-het-vlak buigtrilvorm een eerste knoop omvat, welke eerste knoop zich bevindt in het eerste vertakkingselement, waarbij de eerste knoop van de in-het-vlak buigtrilvorm en de eerste knoop van de uit-het-vlak buigtrilvorm zich op in hoofdzaak dezelfde positie in het eerste vertakkingselement bevinden, and is therefore new.
- 3.3 The problem to be solved by the present invention may therefore be regarded as how to modify the prior art in order to use a test specimen with certain locations of nodes of the in of plain and out of plain bending resonance frequencies.
- 3.4 The solution proposed in claim 29 of the present application cannot be considered as involving an inventive step for the following reasons: There are no technical features given in claim 29 in order to teach the person skilled in the art on how to achieve a test specimen with the above mentioned properties. It only teaches that a test specimen with those properties is utilized. It is apparent to the person skilled in the art, that any test specimen which happens to possess those properties (location of the nodes for different bending modes) can also be utilized with the test set-up disclosed in D2.
- 4 Dependent claim 2-20 and 22-28 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty and/or inventive step, because these features are merely design options which are well known to the person skilled in the art.