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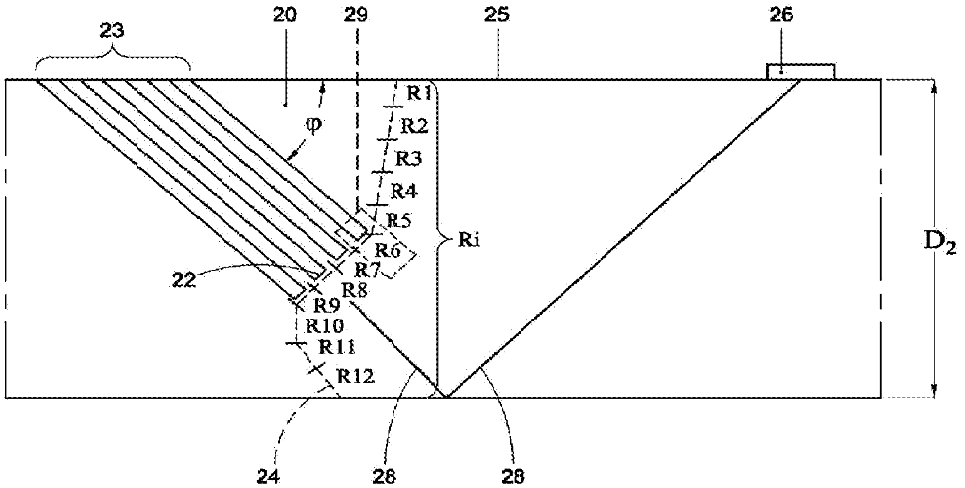
(54) **Method for ultrasonic sizing.**

(57) Method for ultrasonic sizing of at least one defect located at or adjacent to a fusion face of a weld in a wall of an object to be inspected such as a pipeline or a tank. The method includes dividing the fusion face to be inspected in a plurality of facets and selecting a facet of the plurality of facets. The method includes transmitting a first ultrasonic signal to the selected facet and receiving it after being reflected on the selected facet of the object to be inspected. The method includes transmitting a second ultrasonic signal to a reference facet of a calibration object with an artificial defect. The method includes receiving the second ultrasonic signal after being reflected on the reference facet, and comparing the received first ultrasonic signal with the received second ultrasonic signal for determining a size of a possible defect in the selected facet.



Title: Method for ultrasonic sizing

The invention relates to a method for ultrasonic sizing of at least one defect located at or adjacent to a fusion face of a weld in a wall of an object to be inspected such as a pipeline or a tank.

A pipeline or a tank used for fluidum transport or storage usually has one or more welds. These welds can form connections between parts of the pipeline or the tank, or can form connections to another pipeline or tank. Usually such welds form a relatively vulnerable part of the pipeline or the tank. Practical experience shows that defects can relatively easily occur at or adjacent to fusion faces of the welds. If such defects occur, fluidum may leak from the pipeline or the tank into an environment of the pipeline or the tank, which is in general unwanted. The connection may even fail starting from these defects, leading to desintegration of the pipeline or the tank in addition to large spoilage of the fluidum.

A class of pipelines or tanks where prevention of leakage is of utmost importance are pipelines or tanks used for transport or storage of hydrocarbons. Loss of hydrocarbons to the environment of the pipeline or the tank is in general costly, brings damage to the environment and creatures living therein, and is dangerous as often these hydrocarbons are of an inflammable nature.

In practical conditions, pipelines or tanks used for hydrocarbon transport or storage are often loaded heavily. In case of floating off-shore facilities that are used in production and transport of hydrocarbons, welded connections of the pipeline near the facility are subject to relatively large dynamic mechanical loads as a result of tide. Over time, such dynamical loads can easily lead to defects as a result of fatigue. To prevent failure of the welds as a result of fatigue, regular inspection of the welds is necessary. Such inspection can be performed non-destructively by automatic ultrasonic testing. If a defect is detected, it is important to correctly determine its size as this forms important input to methods for assessing a risk of failure and/or leakage from the detected defect.

As hydrocarbons are found in and produced from increasingly deeper waters nowadays, loads on welds steadily increase and risks become unacceptable already for relatively small defect sizes. This causes a continuous demand for improved methods for sizing defects, so that risks can be assessed more accurately.

It is therefore an object of the present invention to provide an improved method for ultrasonic sizing of a defect located at or adjacent to a weld in a wall of an object to be inspected such as a pipeline or a tank.

Thereto the invention provides a method for ultrasonic sizing of at least one defect located at or adjacent to a fusion face of a weld in a wall of an object to be inspected such as a pipeline or a tank, including the steps of: a) dividing the fusion face to be inspected in a plurality of facets i (i=1,2,...n); b) selecting a facet of the plurality of facets; c) transmitting a first ultrasonic signal to the facet selected in step b); d) receiving the first ultrasonic signal transmitted in step c) after being reflected on the selected facet of the object to be inspected; e) transmitting a second ultrasonic signal to a reference facet of a calibration object, which reference facet is associated with the selected facet in step b), wherein the calibration object comprises an artificial defect in the reference facet, wherein the artificial defect has predetermined dimensions; f) receiving the second ultrasonic signal transmitted in step e) after being reflected on the reference facet of the calibration object; g) comparing the received first ultrasonic signal in step d) with the received second ultrasonic signal in step f) for determining a size of a possible defect in the facet selected in step b) of the object to be inspected. Such a combination of using a calibration object and receiving the reflected first ultrasonic signal, enables an accurate and improved method of sizing. Preferably, the reflection of the first ultrasonic signal on the selected facet is caused by the possible defect. Preferably, the reflection of the second ultrasonic signal on the reference facet is caused by the artificial defect. Using such reflective measurements enables the detection of amounts of acoustic energy that are relatively small with respect to a transmitted amount of acoustic energy, so that the sensitivity of the method is high.

The method may be carried out by using zones for obtaining facets, in the object to be inspected and/or in the calibration object, instead of defining the facets directly. It may be clear that, then, dividing the wall of the object to be inspected in a plurality of zones i (i=1,2,...n) leads to dividing the fusion face to be inspected in a plurality of facets i (i=1,2,...n). When the fusion face at least partly crosses one of the zones, that zone defines a facet.

Preferably, the selected facet and/or the reference facet have a planar shape, so that a first direction along the selected facet and/or the reference facet can be distinguished from a second direction transverse to the selected facet and/or the reference facet. Preferably, the selected facet is positioned along the fusion face of the weld, so that the first direction is directed along the fusion face of the weld.

Preferably, determining a type of the weld may precede dividing in step a). Different weld types in general have different shapes. The dividing into facets of step a) preferably is different for each weld type. If the weld type is determined before dividing in step a), a facet division that is optimum for that weld type can be made in step a).

The reference facet of step e) is associated with the facet selected in step b). For example, this means that an angle of incidence of the first ultrasonic signal on the facet selected in step b) is similar to an angle of incidence of the second ultrasonic signal on the reference facet. Alternatively, or additionally, this for example means that a first travel distance of the first ultrasonic signal to and from the facet selected in step b) is similar to a second travel distance of the second ultrasonic signal to and from the reference facet. Alternatively, or additionally, this for example means that a first geometry of a travel path of the first ultrasonic signal to and from the facet selected in step

b) is similar to a second geometry of a travel path of the second ultrasonic signal to and from the reference facet. Alternatively, or additionally, this for example means that the facet selected in step b) and the reference facet have a similar size and/or shape.

In an embodiment, steps e) and f) are carried out before steps c) and d) are carried out. This offers the advantage that positions of one or more transducers used in steps c) and d) can be optimized based on results obtained in steps e) and f).

It may further be clear that, preferably, dividing in step a) is carried out automatically, and is optionally checked and possibly corrected by an operator. Preferably, the dividing in step a) is physically realised by choosing a beam width and/or a beam position of the first ultrasonic signal at or adjacent to the fusion face. The beam width may for example be defined by a -3 dB point, or by a -6 dB point, with respect to a maximum effective power inside the beam. Such choosing may include focussing the beam of the first ultrasonic signal. Hence, dividing in step a) may include focussing the beam of the first ultrasonic signal.

In an embodiment, the method further includes: selecting another facet of the object to be inspected in a step h), wherein step h) further includes repeating steps c)-g) for the other facet selected in step h). In this way, an additional facet can be inspected. Optionally, the reference facet associated with the facet selected in step b), and the reference facet associated with the other facet, are located in distinct calibration objects. However, alternatively they may be located in one and the same calibration object.

In an embodiment, in a step i) step h) is repeated for each of the facets obtained in step a) additionally to the facet and the other facet. In this way, all of the plurality of facets can be inspected.

In an embodiment, a first transmitter is used for transmitting in step c), a first receiver is used for receiving in step d), a second transmitter is used for transmitting in step e), and a second receiver is used for receiving in step f). Preferably, the first transmitter and the first receiver are positioned with respect to the facet selected in step b) similarly as the second receiver and the second transmitter are positioned with respect to the reference facet. In this way, the reference facet of step e) can be associated with the facet selected in step b). For example, in this way it can be achieved that an angle of incidence of the first ultrasonic signal on the facet selected in step b) is similar to an angle of incidence of the second ultrasonic signal on the reference facet.

Preferably, a first plurality of mutually similar transmitters that includes the first transmitter is used for transmitting the respective first ultrasonic signals in steps c) and h). Preferably, a first plurality of mutually similar receivers that includes the first receiver is used for receiving the respective first ultrasonic signals in steps d) and h). Preferably, a second plurality of mutually similar transmitters that includes the second transmitter is used for transmitting the respective second ultrasonic signals in steps e) and h). Preferably, a second plurality of mutually similar receivers that includes the second receiver is used for receiving the respective second ultrasonic signals in steps f) and h).

In an embodiment, one and the same receiving transducer forms the first receiver and the second receiver, and/or one and the same transmitting transducer forms the first transmitter and the second transmitter. This enables more accurate comparing in step g), as errors that occur from differences between individual transducers used for receiving in steps d) and f), and/or differences between individual transducers used for transmitting in steps c) and e), are prevented.

In an embodiment, the method includes the step: j) optimizing a position, with respect to the reference facet, of the second transmitter and the second receiver on the calibration object based on a shape of the fusion face of the weld, wherein optimizing includes pursuing for oblique impact of the transmitted second ultrasonic signal on the artificial defect or includes pursuing for impact of the second ultrasonic signal on the reference facet with an angle between 35 degrees and 70 degrees with a normal of the reference facet, further including using a similar position, with respect to the facet selected in step b), of the first transmitter and the first receiver on the object to be inspected. With these angles, disturbing mode conversions on the reference facet may be substantially prevented. Such optimizing enables an improved way of sizing the possible defect. It is recognised by the inventor that the shape of the fusion face of the weld usually is different between various types of welds that are used in practice. In addition, the inventor recognised that the reflection of the first ultrasonic signal depends on a direction of the first ultrasonic signal relative to an orientation of the possible defect. This orientation is usually strongly influenced by the shape of the fusion face of the weld, as the fusion face usually forms a relatively weak part of the weld. Typically, the possible defect has a planar elongated shape (for example penny-shaped) that is oriented with its plane in a plane of the fusion face of the weld. As the direction of the first ultrasonic signal is determined by the position of the first ultrasonic transducer, optimising this position is important as it may allow for substantially maximizing the amplitude of the second reflected ultrasonic signal. In this way even a small defect, which only reflects a small amount of ultrasonic energy, can still be detected.

In an embodiment, optimizing in step j) is, at least partly, carried out automatically using dedicated design software. The use of such software significantly diminishes a probability for making errors.

In an embodiment, the first ultrasonic signal transmitted in step c) reaches the facet selected in step b) in a direction transverse to the facet selected in step b), and the second ultrasonic signal transmitted in step e) reaches the reference facet in a direction transverse to the reference facet. This enables that one and the same first ultrasonic transducer forms the first receiver and the first transmitter, and one and the same second ultrasonic transducer form the second receiver and the second transmitter. This enables an efficient use of transducers.

In an embodiment, the first ultrasonic signal transmitted in step c) reaches the facet selected in step b) with an angle between 35 degrees and 70 degrees with a normal of the facet selected in step b), and the second ultrasonic signal transmitted in step e) reaches the reference facet with an angle between 35 degrees and 70 degrees with a normal of the reference facet. In this way, facets that cannot be reached with the one and the same first transducer, can still be inspected.

In an embodiment, a size of the facet of the plurality of facets is small enough for determining a required minimum detectable size of the possible defect. The minimum detectable size for example is 0.5 mm or 0.3 mm. If the size of the facet is too large, a signal-to-noise ratio of the first ultrasonic signal reflected from the first defect may be too small. Preferably, a ratio of the size of the facet and the required minimum detectable size is below a predetermined value, this value for example being smaller than twenty, preferably smaller than ten. Preferably, the required minimum detectable size is inferred from a safety criterium for the object to be inspected. Preferably, the required minimum detectable size is smaller than or equal to a maximum size that is still considered safe based on the safety criterium.

In an embodiment, the plurality of facets substantially covers the whole fusion face. It may be clear that, in an embodiment, the plurality of facets cover the whole thickness of the wall of the object. This greatly enhances reliability of the method.

In an embodiment, at least a number of, and preferably all, of the plurality of facets mutually overlap. In this way, interaction criteria between defects in neighbouring facets can be applied more reliably. In addition, it can be more reliably determined whether neighbouring defects are part of one and the same physical defect.

In an embodiment, at least a number of, and preferably all, of the plurality of facets are mutually contiguous. In contiguous facets there may be little, for example less than 10%, overlap between the facets. This enables an efficient use of transducers, for example a total number of transducers for covering the whole wall of the object to be inspected can be relatively low.

In an embodiment, a first number of the plurality of facets mutually overlap and a second number of the plurality of facets are mutually contiguous. Preferably, the sum of the first number and the second number equals the total amount of facets in the plurality of facets. Preferably, overlapping facets are used in relatively weak parts of a weld where defects are known to occur relatively often, and for example contiguous facets are used elsewhere. In this way, the advantages of contiguous facets and overlapping facets can be combined.

In an embodiment, the method includes the step: k) determining a first reflection amplitude A_1 of the first ultrasonic signal received in step d) and a second reflection amplitude A_2 of the second ultrasonic signal received in step f), wherein determining in step g) is based on the first reflection amplitude A_1 and the second reflection amplitude A_2. After carrying out step k), a set of data containing the second reflection amplitude A_2 and the size of the artificial defect are known. Using a similar transducer configuration for, in step k), determining the second reflection amplitude A_2 and for determining the first reflection amplitude A_1, i.e. having the second ultrasonic transducer positioned relative to a location of the artificial defect in a similar way as the first transducer is positioned relative to a location of the possible defect, allows for the quantitative interpretation of the first reflection amplitude A_1. Using the calibration object in combination with the reflective measurement of this embodiment allows for a high sizing accuracy, and leads to an improved sizing method. One of the advantages of such improved sizing is that the number of unnecessary repair jobs can be decreased.

In an embodiment, determining in step g) is further based on a ratio A_1/A_2 of the first reflection amplitude A_1 and the second reflection amplitude A_2, and preferably is based on a multiplication factor times the ratio A_1/A_2.

In an embodiment, the method includes the step: l) determining a first transmission amplitude B_1 of the first ultrasonic signal transmitted in step c), and determining a second transmission amplitude B_2 of the second ultrasonic signal transmitted in step e); wherein determining in step g) is further based on the first transmission amplitude B_1 and the second transmission amplitude B_2. As the first transmission amplitude B_1 and the second transmission amplitude B_2 will influence respectively the first reflection amplitude A_1 and the second reflection amplitude A_2, it may be important to take these into account for determining the size of the possible defect. In this embodiment, the first transmission amplitude B_1 and the second transmission amplitude B_2 need not necessarily be similar, but can be allowed to be different from each other as well.

In an embodiment, determining in step g) is further based on a ratio B_2/B_1 of the second transmission amplitude B_2 and the first transmission amplitude B_1, and preferably is based on the product of the ratio A_1/A_2 and the ratio B_2/B_1.

In an embodiment, determining in step g) includes determining the size of the possible defect by using a predetermined sizing relation that relates the first reflection amplitude A_1 to the size of the possible defect, wherein the predetermined sizing relation is based on, at least, the second reflection amplitude A_2 and the predetermined size of the artificial defect, and/or is based on numerical simulations. Preferably, the predetermined sizing relation is further based on the first transmission amplitude B_1 and/or on the second transmission amplitude B_2. In these numerical simulations, at least steps c)-f) are simulated numerically. The inventor recognised the added value of determining the predetermined sizing relation based on, at least, the second reflection amplitude A_2 and the predetermined size of the artificial defect, and on the numerical simulations. This combines the inherent practical reliability of experimental methods and the inherent versatility of numerical methods.

In an embodiment, the size of the possible defect is a surface area of the possible defect and the predetermined size of the artificial defect is a predetermined surface area of the artificial defect. As the first reflection amplitude A_1 and the second reflection amplitude A_2 are proportional to respectively the surface area of the possible defect and the predetermined surface area of the artificial defect, this embodiment is especially suitable for sizing.

In an embodiment, step g) includes determining the surface area of the first defect by determining the product of the predetermined surface area of the artificial defect and the ratio A_1/A_2 of the first reflection amplitude A_1 and the second reflection amplitude A_2.

In an embodiment, carrying out steps g) and h) includes determining a size of a plurality of defects that includes the possible defect, which plurality of defects is located at or adjacent to the fusion face. Although being detected for more than one facet, at least a number of the plurality of defects may in fact be formed by one and the same defect. Alternatively or additionally, at least a number of the plurality of defects may mutually interact. Preferably, the method includes determining whether the plurality of sized defects mutually interact, preferably using interaction criteria inferred from at least one of the API 1104 standard, the British standard BS 7910, and steel catenary riser criteria.

In an embodiment, the method includes determining whether the plurality of sized defects are formed by one and the same physical defect. This is important, as the size of each possible defect may otherwise be underestimated. Preferably, the method includes using a time-of-flight-diffraction measurement of the plurality of first defects. In this way it can be determined whether the plurality of first defects are formed by one and the same physical defect. However, another method can be used for this as well.

Preferably, a creep-wave measurement along a surface of the wall may be used to determine whether the possible defect or the one and the same defect extends up to or near a surface of the wall. Using creep waves, with or without time-of-flight diffraction, is especially useful in combination with the reflective measurement of the invention as creep wave measurements yield valuable information of near-wall regions that would be difficult to obtain with other methods.

According to an aspect of the invention, the method includes the step: m) designing a dimension of the calibration object based on a type of the weld, so that a position of the artificial defect in the calibration object corresponds with a position of the fusion face of the weld in the object to be inspected. Carrying out such a designing step is especially advantageous for defect sizing as expressed by at least the steps a)-g), as it further improves the sizing accuracy. However, it is recognised by the inventor that it is not necessary to carry out step m) in combination with all of steps a)-g), but that it can be carried out independently as well, or in combination with one or more of steps a)-l). The inventor recognised that especially combination of steps j) and m) is advantageous, as optimizing in step j) may be strongly linked with designing in step m).

In an embodiment, the artificial defect is a hole in the calibration object.

In an embodiment, the hole is a, preferably circular, bore.

In an embodiment, the bottom face of the bore is substantially flat, i.e. the bore has a flat bottom hole. In this way favourable reflections can be obtained.

In an embodiment, a material of the calibration object has similar acoustic properties as a material of the wall of the pipeline or the tank.
In an embodiment, the pipeline is a catenary riser pipeline.

The invention will now be described, in a non-limiting way, with reference to the accompanying drawings, in which:

Figure 1 shows a cross-section of a wall of a pipeline parallel with a longitudinal direction of the pipeline and transverse to the wall;

Figure 2 shows a calibration object, wherein a artificial defect is located that has a predetermined size;

Figure 2A shows a close-up of a part of figure 2;

Figure 2B shows a top angle α of a notch;

Figure 3 shows a case wherein distinct transducers are used for sending and receiving;

Figure 4A shows an artificial defect in cross section substantially parallel with a calibration face;

Figure 4B shows a cross section of the wall of figure 1 along the possible defect, substantially parallel with a fusion face; and

Figure 5 shows geometrical properties of a calibration face.

Unless stated otherwise, like reference numerals refer to like elements throughout the drawings.

Figure 1 shows a cross-section of a wall 2 of a pipeline parallel with a longitudinal direction of the pipeline and transverse to the wall 2. A weld 4, for example a girth weld, is present in the pipeline. The pipeline for example is a catenary riser. Inspection of such catenary riser pipelines is important as dynamic loads can be relatively high for these kind of pipelines, in particular for girth welds present therein. On an outer surface 6 of the wall 2, a first ultrasonic transducer 8 may be positioned. The first ultrasonic transducer may be arranged for transmitting a first ultrasonic signal 10 and receiving the first ultrasonic signal, respectively into and from the wall 2. The first ultrasonic transducer 8 thus forms both a first transmitter and a first receiver. A possible defect 12 is located adjacent to a fusion face 14 of the weld 4. The wall 2 is an example of an object to be inspected.

Figure 2 shows a calibration object 20, wherein an artificial defect 22 is located that has a predetermined size. The artificial defect 22 may be located on an imaginary surface, herein referred to as a calibration face 24. The calibration face 24 has a shape similar to the fusion face 14 of the weld 4, as is clear for example from comparison of figures 1 and 2. Preferably, a material of the calibration object has similar acoustic properties as a material of the wall of the pipeline or the tank, so that it is representative for the wall of the pipeline or the tank. The calibration object may be made of steel. The calibration object 20 may have a first surface 25 and be similarly shaped and have similar dimensions as a part of the pipeline 2 of figure 1. For example, a wall thickness D_1 of the pipeline 2 may be similar to a thickness D_2 of the calibration object. The artificial defect 22 may be one of a plurality of mutually similar artificial defects 22.*i* (i=1,2,...n). The artificial defect 22 may be formed by a hole, for example a circular bore 23, in the calibration object 20. In that case, a bottom part of the bore 23 is regarded as the artificial defect 22. In this example, the plurality of artificial defects 22.*i* is formed by circular flat bottomed holes 23 (see figure 2A). The calibration object is designed in such a way in this example that the plurality of bores 23 end at or near the calibration face 24. As a result, the plurality of artificial defects 22.*i* is located at or near the calibration face 24. The calibration face 24 may be located, with respect to the first surface 25, at a similar position as the fusion face 14 of the weld 4 is located with respect to the outer surface 6.

It may be clear that, in addition to the bores 23 shown in figure 2, additional artificial defects such as bores and slots may be present in the calibration object 20. As a result, the plurality of artificial defects 22.*i* may substantially cover the whole calibration face 24. It may be clear that such whole coverage still allows for spaces in between the artificial defects 22.*i*, and may refer to coverage along one direction along the calibration face 24. The additional bores are not shown in figure 2 for clarity. More in general, the artificial defects 22.*i* may be distributed over more than one calibration object 20.

Figure 2 further shows a second ultrasonic transducer 26 positioned on the first surface 25 of the calibration object 20. The second ultrasonic transducer 26 may be arranged for transmitting and for receiving a second ultrasonic signal 28 respectively into and from the calibration object 20. The second ultrasonic transducer 26 thus forms both a second transmitter and a second receiver. In this example, the second ultrasonic transducer 26 is positioned relative to a location of the artificial defect 22 in a similar way as the first transducer 8 is positioned relative to a location of the possible defect 12. This may mean that a distance vector from the artificial defect 22 to the second ultrasonic transducer 26 has a similar magnitude and direction as a distance vector from the possible defect 12 to the first ultrasonic transducer 8.

As a result of their similar thicknesses D_1 and D_2, the object to be inspected 2 and the calibration object 20 have a similar size respectively in a direction of transmitting the first ultrasonic signal 10 and in a direction of transmitting the second ultrasonic signal 28.

The first and/or second ultrasonic signal may contain ultrasonic shear waves. Preferably, the first ultrasonic signal predominantly contains ultrasonic shear waves, so that most of the energy of the first ultrasonic signal is carried by ultrasonic shear waves. Preferably, the second ultrasonic signal predominantly contains ultrasonic shear waves, so that most of the energy of the second ultrasonic signal is carried by ultrasonic shear waves.

Figure 2A shows a close-up of a part 29 of figure 2, wherein the bottom of one of the plurality of artificial defects 22.i is indicated. The bore 23 may have a circular cross-section. The bottom face of the bore 23 may be substantially flat. More in general, the bottom faces of the artificial defects 22 may be substantially parallel with the calibration face 24.

A first embodiment of a method for ultrasonic sizing according to the invention, hereinafter referred to as the first method, is now illustrated with reference to figures 1 and 2.

The first method includes the step of dividing the fusion face to be inspected in a plurality of facets *i* (*i*=1,2,...*n*). In figure 1, the plurality of facets is indicated with reference numeral *Zi*. In the example of figure 1, *n* equals twelve and each one of the facets 1, 2, ...*n* is indicated with reference numeral *Zi*. Such selecting may be carried out automatically and/or by an operator.

The first method further includes the step of selecting a facet of the plurality of facets. In this example, the facet *Z8* is the selected facet. Selecting may be carried out by choosing a position of the first transducer 8 and by choosing a beam width of the first ultrasonic signal at the fusion face 14.

The first method further includes the step of transmitting the first ultrasonic signal 10 to the selected facet *Z8* of the plurality of facets, and further includes receiving the transmitted first ultrasonic signal after it is reflected on the selected facet, in this example facet *Z8*, of the wall 2.

The first method further includes transmitting the second ultrasonic signal 28 to a reference facet *R8* of the calibration object 20. In general, the reference facet may be one of a plurality of reference facets 1,2,...*n*. The reference facet *R8* is associated with the selected facet *Z8*. The calibration object 2 comprises an artificial defect, in this example formed by a bore 23, in the reference facet *R8* wherein the artificial defect 22 has predetermined dimensions. The first method includes receiving the transmitted second ultrasonic signal 28 after it is reflected on the reference facet of the calibration object, which reflection is caused by the artificial defect 22.

The first method further includes comparing the received first ultrasonic signal 10 with the received second ultrasonic signal 28 for determining a size of the possible defect 12, in the selected facet *Z8* of the wall 2. Such comparing may include comparing a first characteristic of the received ultrasonic signal 10 with a second characteristic of the received second ultrasonic signal 28. Such a first characteristic includes for example a maximum amplitude or a power spectrum of the first ultrasonic signal. The second characteristic includes for example a maximum amplitude or a power spectrum of the second ultrasonic signal. Such characteristics may be sensitive to respectively the size of the possible defect and the predetermined size of the artificial defect. If the first and second characteristic are similar, it may be determined that the size of the possible defect 12 is similar to the size of the artificial defect 22. For such determining, preferably the transmitted first ultrasonic signal before it is reflected on the selected facet is similar to the transmitted second ultrasonic signal before it is reflected on the artificial defect.

The first method may further include selecting another facet of the wall 2, and may include repeating the steps of transmitting and receiving the first ultrasonic signal 10 and the second ultrasonic signal 28 for the other facets *Zi* in addition to facet *Z8* in the wall 2 and for the other reference facets *Ri* in addition to reference facet *R8* in the calibration object 20. This may be achieved by using a first plurality of mutually similar first transducers that includes the first transducer 8 for transmitting and receiving the respective first ultrasonic signals 10 for the plurality of facets *Zi*. In addition, a second plurality of mutually similar second transducers that includes the second transducer 26 may be used for transmitting and receiving the respective second ultrasonic signals 28 for the plurality of reference facets *Ri*.

The first method may also include repeating the comparing of the received first ultrasonic signal 10 with the received second ultrasonic signal 28 for determining a size of a possible defect 12, for the other combinations of selected facet and reference facet in addition to the combination of the selected facet *Z8* and the reference facet *R8*.

It may be clear that, in figures 1 and 2, the first transmitter and the first receiver are positioned with respect to the selected facet Z8 similarly as the second receiver and the second transmitter are positioned with respect to the reference facet.

In the first method, the first ultrasonic signal 10 transmitted by the first ultrasonic transducer 8 reaches the facet *Z8* selected in step b) in a direction transverse to the selected facet *Z8*. In addition, in the first method the second ultrasonic signal 28 transmitted by the second ultrasonic transducer 26 reaches the reference facet *R8* in a direction transverse to the reference facet *R8*. In the first method, one and the same first transducer 8 forms the first receiver and the first transmitter, and one and the same second transducer 26 forms the second receiver and the second transmitter.

While thus in the first method one and the same second transducer 26 was used for both sending and receiving, the inventor recognised that for some parts of the calibration face 24 it is advantageous to use distinct transducers for sending and receiving. Such a case is illustrated for a second embodiment of a method according to the invention (further referred to as the second method) with reference to figure 3, which shows two distinct ultrasonic transducers which respectively form the second transmitter 30 and the second receiver 31. A similar configuration may be used for the first transmitter and the first receiver.

In the second method, a first plurality of mutually similar transmitters that includes the first transmitter may be used for transmitting the respective first ultrasonic signals for the plurality of facets *Ri*, and a first plurality of mutually similar receivers that includes the first receiver may be used for receiving the respective first ultrasonic signals. In addition, a second plurality of mutually similar transmitters that includes the second transmitter 30 may used for transmitting the respective second ultrasonic signals 28, and a second plurality of mutually similar receivers that includes the second receiver 31 may be used for receiving the respective second ultrasonic signals 28.

In the second method, the first ultrasonic signal 10 transmitted by the first transmitter may reach the selected facet with an angle between 35 degrees and 70 degrees with a normal of the selected facet. Analogously, the second ultrasonic signal 28 transmitted by the second transmitter 30 may reach the reference facet, in this example reference facet *R2*, with an angle between 35 degrees and 70 degrees with a normal of the reference facet. Thus, the second ultrasonic signal 28 reaches the reference facet, here reference facet *R2*, at an angle of incidence β (figure 3) with a normal to the calibration face 24 that is between 35 degrees and 70 degrees. Such a situation is illustrated in figure 3.

It may be clear that the artificial defect 22 usually extends in a plane of the calibration face 24. Thus, in the first method, an ultrasonic beam of the second ultrasonic signal 28 reaches the artificial defect 22 transversely to the calibration face 24. Such a situation is illustrated in figure 2. Thus, in the second method, the ultrasonic beam of the second ultrasonic signal 28 reaches the calibration face 24 under an angle with the calibration face 24. Such a situation is illustrated in figure 3. It may be clear that the possible defect 12 usually extends in a plane of the fusion face 12. Thus, in the first method, an ultrasonic beam of the first ultrasonic signal 10 reaches the defect 12 transversely to the fusion face 12. Such a situation is illustrated in figure 1. Thus, in the second method, an ultrasonic beam of the first ultrasonic signal 10 reaches the defect 12 under an angle with the fusion face 12 (not illustrated).

It may be clear that, in the first and second method, the first ultrasonic signal 10 and the second ultrasonic signal 28 may be significantly changed by reflection against respectively the possible defect 12 and the artificial defect 28.

The second method may further include steps similar to steps of the first method. In particular, the second method includes the step of dividing the fusion face 12 to be inspected in the plurality of facets *i* (*i*=1,2,...*n*), and the step of comparing the received first ultrasonic signal 10 with the received second ultrasonic signal 28 for determining the size of the possible defect in the selected facet of the object to be inspected. Such dividing and comparing are further described for the first method.

A third embodiment of a method according to the invention (further referred to as the third method) includes determining a first reflection amplitude A_1 of the received first ultrasonic signal 10 and a second reflection amplitude A_2 of the received second ultrasonic signal 28. The first receiver may be used for determining the first reflection amplitude A_1, after the first ultrasonic signal is reflected from the possible defect. The second receiver may be used for determining the second reflection amplitude A_2, after the second ultrasonic signal is reflected from the artificial defect. In the third method, determining the size of the possible defect is based on the first reflection amplitude A_1 and the second reflection amplitude A_2.

The third method may be carried out in combination with the first method or the second method. However, it may lack steps of the first method or the second method that do not correspond with steps c)-g) of claim 1.

The third method may further include determining a first transmission amplitude B_1 of the transmitted first ultrasonic signal 10, and determining a second transmission amplitude B_2 of the transmitted second ultrasonic signal 28. In the third method, determining the size of the possible defect may further be based on the first and second transmission amplitude B_1, B_2.

More in general, one way of determining the size of the possible defect may include comparing the first reflection amplitude A_1 and the second reflection amplitude A_2, and assign a size to the possible defect 12 that is proportional to the first reflection amplitude A_1 and the predetermined size of the possible defect, and inversely proportional to the second reflection amplitude A_2. In such a method, the first and second transmission amplitudes B_1, B_2 may still be unknown as long as they have a similar value. For example, the size of the possible defect may be determined to be similar, for example equal, to the product of the predetermined surface area of the artificial defect and the ratio A_1/A_2 of the first reflection amplitude A_1 and the second reflection amplitude A_2. Alternatively or additionally, the size of the possible defect 12 may be determined to be equal to the product of the predetermined surface area of the artificial defect and the ratio A_1/A_2, times a multiplication factor.

The multiplication factor may be determined experimentally, numerically, and/or theoretically.

In the third method, determining the size of the possible defect may be carried out by using a predetermined sizing relation that relates the first reflection amplitude A_1 to the size of the possible defect, wherein the predetermined sizing relation is based on, at least, the second reflection amplitude A_2 and the predetermined size of the artificial defect, and/or is based on numerical simulations.

Determining the size of the possible defect 12 by using the predetermined sizing relation will now be illustrated for a variation of the third method. This variation may include transmitting the first ultrasonic signal 10 and determining the first transmission amplitude B_1 of the first ultrasonic signal 10 before it is reflected from the possible defect 12. It may further include transmitting the second ultrasonic signal 28 and determining the second transmission amplitude B_2 of the second ultrasonic signal 28 before it is reflected from the artificial defect 22.

The predetermined sizing relation relates the first reflection amplitude A_1 to the size of the possible defect 12, and is based on, at least, the second reflection amplitude A_2 and the predetermined size of the artificial defect 22. In the variation of the third method, the predetermined sizing relation is further based on the first transmission amplitude B_1 and the second transmission amplitude B_2.

It may be clear that in general the possibility exists that in practice the reflective properties of the artificial defect and the possible defect are somewhat different. To further improve the predetermined sizing relation, the predetermined sizing relation may be determined by using numerical simulation results as well. Such simulations enable determining a simulated first reflection amplitude A_1 of a simulated possible defect that has a size similar to the predetermined size of the artificial defect. In the numerical simulations, the influence of small variations in the orientation of the simulated possible defect on the simulated first reflection amplitude A_1 may for example be determined. This adds to reliability of determination of the size of the possible defect.

Such a predetermined sizing relation may be set up by using the second reflection amplitude A_2, the second transmission amplitude B_2, and the predetermined size of the artificial defect. For example, a plurality of second ultrasonic signals 28 may be generated for a number of positions of the second ultrasonic transducer 26 on the first surface 25 of the calibration object. More in general, additionally or alternatively, the size of one or more of the artificial defects may be varied when setting up the predetermined sizing relation. Additionally or alternatively, the second transmission amplitude B_2 may be varied, although the inventor recognised that this is not always necessary due to the highly linear nature of ultrasonic wave propagation and reflection. Using mathematical fitting techniques based on the results, a mathematical function may be generated that relates, for a certain position of the second ultrasonic transducer and a certain value of the first transmission amplitude B_1, the size of the possible defect with the second reflection amplitude A_2.

The size of the possible defect may be a surface area of the possible defect and the predetermined size of the artificial defect may be a predetermined surface area of the artificial defect. In this case, in a first approximation, the size of the possible defect is proportional to the first reflection amplitude A_1 and the predetermined size of the artificial defect, and inversely proportional to the second reflection amplitude A_2. This is further illustrated with reference to figures 4A and 4B. This choice for the size of the possible defect and the artificial defect is of practical importance, as the surface area of the possible defect is a good indicator for strength reduction of the weld 4.

Figure 4A shows the artificial defect 22, in this example the bottom part of the circular bore, in a cross section of the calibration object 20 substantially parallel with the calibration face 24 in figure 2. Figure 4B shows a cross section of the wall 2 of figure 1 along the possible defect 12, substantially parallel with the fusion face. Figures 4A and 4B also show respectively the reference facet *Ri* and the facet *Zi* around respectively the artificial defect 22 and the possible defect 12. The facet *Zi* and the reference facet *Ri* may respectively coincide with a beam cross section of the first ultrasonic signal 10 and the second ultrasonic signal 28.

In a fourth embodiment of a method according to the invention (further referred to as the fourth method), a step is carried out that includes optimizing a position, with respect to the reference facet, of the second transmitter and the second receiver on the calibration object based on a shape of the fusion face of the weld, further including using a similar position, with respect to the facet selected in step b), of the first transmitter and the first receiver on the object to be inspected.

The fourth method is based on the first, second, and/or third method and may include one or more steps thereof. Carrying out the optimizing of the fourth method for the second ultrasonic transducer positioned on the calibration object offers the advantage that well-controlled laboratory conditions can be used. Once an optimal position in the laboratory is employed, this position can be used for the first transmitter and the first receiver in field practice as well. More in general, optimizing may be carried out for substantially maximizing the amplitude of the second reflected ultrasonic signal. This may increase for example a signal-to-noise-ratio of the received amplitude and thus increases the quality of sizing.

Optimizing in the fourth method combined with the second method may be carried out for the second plurality of transmitters and the second plurality of receivers. Optimizing in the fourth method combined with the first method may be carried out for the second plurality of transducers Alternatively or additionally, optimizing in the fourth method may, at least partly, be carried out automatically using dedicated design software.

The fourth method may include optimizing the positions of the second ultrasonic transducers on the calibration object based on the shape of the fusion face of the weld. In this way optimizing can be carried out for the plurality of second ultrasonic transducers.

A variation of the fourth method includes optimizing a number of the plurality of second transducers, for achieving a required resolution along the fusion face of the weld and/or for covering the whole, or at least a substantial part, of the fusion face of the weld. For example, a required resolution along the fusion face as shown in figure 1 may be achieved by setting the number of the plurality of ultrasonic transducers high enough. Typically, this number is in a range from six to twelve on each side of the weld. This number may be chosen depending on the wall thickness and weld design. The facet height may typically be in a range from 2 to 3 millimeter. More in general, the minimum detectable defect size is smaller than the facet height. More in general, the minimum detectable defect size is around 0.5 millimeter, possibly smaller than 0.5 millimeter, such as 0.3 millimeter or 0.2 millimeter.

A fifth embodiment of a method according to the invention (further referred to as the fifth method) includes determining a plurality of sizes of a respective plurality of defects, which plurality of defects includes the possible defect. The plurality of defects is located at or adjacent to the fusion face. Such a plurality of defects can be detected for example by the repeated transmission and reception of the first ultrasonic signal 10 in the first and second method, by using the first plurality of receivers and the first plurality of transmitters.

The fifth method may include determining whether the plurality of sized defects mutually interact. Such interaction is present for example if a mutual orientation and separation of a first one of the defects and a second one of the defects is such that a stress field around the first one of the defects significantly influences a stress field near the second one of the defects. In this situation, the second defect is significantly weakened by the first defect. Interaction criteria inferred from at least one of the API 1104 standard, the

British standard BS 7910, and steel catenary riser criteria may be used for determining whether the plurality of sized defects mutually interact.

Alternatively or additionally, the fifth method may include determining whether the plurality of sized defects are formed by one and the same physical defect. One way to do this is to determine whether the sized defects are neighbouring defects. If this is the case, the sized defects may be formed by one and the same physical defect. Determining whether the plurality of possible defects are formed by one and the same physical defect is especially relevant when the beam of the first ultrasonic signal does not completely cover the possible defect. In that case, one or more other neighbouring beams will detect the rest of the possible defects. Only after determining whether the plurality of possible defects are determined by one and the same physical defect, the size of the physical defect can be determined.

In the fifth method (and possibly also in other embodiments), information of the size of the possible defect is not limited by the beam width of one transducer, but information from various transducers may be combined. In general, in this way defects that have a size, for example a surface area, that falls outside the beam width of the first ultrasonic signal, can still be detected by combining results from more than one of the plurality of first ultrasonic transducers.

A method according to the invention in a sixth embodiment (the sixth method) can be combined with the first, second, third, fourth, and/or fifth method. However, it can be applied on itself as well, for example without steps a)-g) of claim 1. The sixth method includes designing a dimension of the calibration object, preferably based on a type of the weld, the wall thickness D_1, and/or a diameter of the pipe or the tank. As a result of designing, a position of the artificial defect in the calibration object corresponds with a position of the fusion face of the weld in the object to be inspected. More in general this may mean that the artificial defect is positioned on the calibration face. Designing may, at least partly, be carried out automatically using dedicated design software. In general, the use of such software significantly diminishes a probability for making errors.

More in general, designing of the calibration object may further include at least one, and preferably all, of the steps:

1) choosing the type of weld that corresponds with the weld 4 (figure 1), on which a shape of the calibration face 24 is based. Examples of different types of welds among which can be chosen may include a CRC weld type, a narrow gap weld type, a Serimer weld type, a Swiss weld type, a V-bevel weld type, a J-bevel weld type and a compound bevel weld type, including single sided weld types and double sided weld types. All these weld types are known as such to the skilled person so that a further description is deemed superfluous. In general, all of these weld types have a mutually different shape of the fusion face, so that for a specific weld type a dedicated shape of the calibration face may be chosen. Preferably, the shape and dimensions of the calibration face coincide with the shape and dimensions of the fusion face.

2) Choosing a required number of reference facets for different parts of the calibration face 24, such as a cap part 36A, a fill part 36B, a hot pass part, an LCP part 36D, and a root part 36E, all indicated in figure 5. These parts correspond with similar parts of the weld 4, which parts as such are known to the skilled person. Each part 36A-E has a corresponding part height 38A-E. In general, each of the parts 36A-E may be subdivided into a number of the reference facets. For the fill part 36B, these reference facets are indicated in figure 5 with reference numeral *Ri*. There may be one bore related to each reference facet *Ri*. In general, different parts can be indentified for different types of welds. As a result, step 2) depends on the type of weld that is chosen in step 1).

The chosen weld type and the required number of reference facets may be entered into the dedicated design software. The software in turn may yield a suggestion for the number of reference facets per part of the weld, dependent on the wall thickness.

More in particular, it may be clear that dividing the fusion face 14 to be inspected in the plurality of facets *Zi*, may be achieved indirectly by dividing the weld 4 in a number of weld zones that extend through the weld 4 parallel with the wall. In that case, the weld zones are associated with the plurality of facets *Zi*, which can be selected. Each facet *Zi* that can be selected may substantially coincide with an intersection of the associated weld zone and the fusion face 14. In addition, selecting a facet of the plurality of facets *Zi* may be achieved by selecting a weld zone of the plurality of weld zones. Preferably, the shape of the fusion face and/or the weld type is determined before the dividing of the fusion face to be inspected in the plurality of facets.

3) determining the diameter of the pipeline, and optionally entering a value of this diameter into the design software.

4) Determining the wall thickness 2 of the pipeline, and optionally entering a value of this thickness into the design software.

5) Determining dimensions, i.e. part heights 38A-E and/or angles γ_A-γ_E with a direction 39 perpendicular to the first surface 25 and/or the second surface, of the parts 36A-E of the calibration face 24 (figure 5), and optionally entering values of these dimensions into the design software.

6) Determining dimensions, such as the thickness D_2, of the calibration object 20, and optionally drawing the calibration object 20. Drawing may be carried out by using the software.

7) Choosing, for each of the reference facets *Ri*, a required diameter d_b of the bore (figure 2A), an angle φ of the bore (figure 2), and a vertical offset (in a direction transverse to the wall 2). An option is to choose to give all bores a similar diameter. An option is to have a number of bores aligned with each other, i.e. these bores end on one and the same plane, preferable a part of the calibration face. Optionally, the software determines the number of reference facets *Ri* and height of the reference facets *Ri*, preferably followed by checking whether the summed height of all reference facets equals the wall thickness.

8) Choosing whether a first notch is present at the first surface 25 and/or whether a second notch is present at a second surface of the calibration object opposite to the first surface 25. The first and second notch may be representative for surface breaking defects (like cracks or lack of fusion) in or adjacent to the weld. These surface breaking defects may extend along the weld. If one or both of the first notch and the second notch are chosen to be present, a notch depth, a notch width, a notch length, a position of the notch, and/or a rotation angle of the notch may be chosen for one of the first and second notch, or for both notches. An orientation of the notch typically corresponds with an orientation of the corresponding part of the calibration face. The rotation angle, here defined as the angular difference of a depth direction of the notch and a normal to the first surface 25 or to the second surface, for example equals the angle γ_A or the angle γ_E. The notch may be positioned adjacent to the cap portion and/or the root.

9. Choosing whether a third notch 41 is present in the calibration object 20, that can be used for a time-of-flight diffraction measurement. The included top angle α is for example at most 60 degrees, in order to enable diffraction instead of reflection (see figure 2B). Depending on the required coverage with the time-of-flight diffraction measurement multiple notches with different depths can be used located at the first surface 25 and/or the second surface.

10. Choosing whether a transverse notch is present in the calibration object. Such a transverse notch may be representative for a defect oriented transverse to the weld direction). In addition, designing may include assigning a width, length, height and shape of the transverse notch.

Each of these steps 1)-10) on itself is already valuable for designing the calibration object, while the combination of two or more steps, especially all steps, is valuable for further improving designing of the calibration object 20. It is recognised by the inventor that, more in general, steps 1) and 2) may be important for optimising the position of the second ultrasonic transducer and the plurality of ultrasonic transducers in the second and third method. The software may be arranged for determining an optimal position of the second ultrasonic transducer and the plurality of second ultrasonic transducers.

In one or more of the first, second, third, fourth, fifth, and sixth embodiment, the first ultrasonic transducer may be a piezoelectric transducer, and transmitting the first ultrasonic signal and determining the first reflection amplitude A_1 may be carried out by means of a suitable signal processing system, known as such to the skilled person. The piezoelectric first electronic transducer may be arranged for generating an electrical signal based on the received first ultrasonic signal. The signal processing system is arranged for measuring a maximum of the electrical signal relative to a base level of the electrical signal. This maximum may represent the first reflection amplitude A_1. In this way the first reflection amplitude A_1 can be determined by means of the signal processing system.

It may be clear that the second ultrasonic transducer may as well be a piezoelectric ultrasonic transducer, while transmitting the second ultrasonic signal and determining the second reflection amplitude A_2 may be carried out in a similar way as transmitting the first ultrasonic signal and determining the first reflection amplitude A_1.

The invention is not limited to any embodiment herein described and, within the purview of the skilled person, modifications are possible which may be considered within the scope of the appended claims. For example, the invention is also applicable to welds that extend along the pipeline. Equally all kinematic inversions are considered inherently disclosed and to be within the scope of the present invention. The use of expressions like: "preferably", “in particular”, “typically”, “especially”, etc. is not intended to limit the invention. The indefinite article “a” or “an” does not exclude a plurality. Features which are not specifically or explicitly described or claimed may be additionally included in the structure according to the present invention without deviating from its scope.

Conclusies

1. Werkwijze voor het ultrasoon bepalen van een grootte van tenminste een defect dat op of nabij een fusiefront ligt van een las in een wand van een te inspecteren object zoals een pijplijn of een tank, welke werkwijze de stappen omvat:

a) het verdelen van het te inspecteren fusiefront in een veelvoud van facetten i (i=1,2,…n);

b) het selecteren van een facet van het veelvoud van facetten;

c) het uitzenden van een eerste ultrasoon signaal naar het in stap b) geselecteerde facet;

d) het ontvangen van het eerste ultrasone signaal uitgezonden in stap c) nadat het is gereflecteerd op het geselecteerde facet van het te inspecteren object;

e) het uitzenden van een tweede ultrasoon signaal naar een referentiefacet van een calibratieobject, welk referentiefacet is geassocieerd met het in stap b) geselecteerde facet, waarbij het calibratieobject een artificieel defect omvat in het referentiefacet, waarbij het artificiele defect vooraf bepaalde dimensies heeft;

f) het ontvangen van het tweede ultrasone signaal uitgezonden in stap e) nadat het is gereflecteerd op het referentiefacet van het calibratieobject;

g) het vergelijken van het in stap d) ontvangen eerste ultrasone signaal met het in stap f) ontvangen tweede ultrasone signaal voor het bepalen van een grootte van een mogelijk defect in het in stap b) geselecteerde facet van het te inspecteren object.

2. Werkwijze volgens conclusie 1, die verder omvat: het selecteren van een ander facet van het te inspecteren object in een stap h), waarbij stap h) verder het herhalen van stappen c)-g) omvat voor het andere facet dat is geselecteerd in stap h).

3. Werkwijze volgens conclusie 2 waarbij in een stap i) stap h) wordt herhaald voor elk van de facetten verkregen in stap a) aanvullend op het facet en het andere facet.

4. Werkwijze volgens een der conclusies 1-3, waarbij een eerste zender wordt gebruikt voor het zenden in stap c), een eerste ontvanger wordt gebruikt voor het ontvangen in stap d), een tweede zender wordt gebruikt voor het zenden in stap e), en een tweede ontvanger wordt gebruikt voor het ontvangen in stap f), waarbij de eerste zender en de eerste ontvanger vergelijkbaar zijn gepositioneerd ten opzichte van het in stap b) geselecteerde facet als de tweede ontvanger en de tweede zender zijn gepositioneerd ten opzichte van het referentiefacet.

5. Werkwijze volgens conclusies 2 en 4, waarbij een eerste veelvoud van onderling soortgelijke zenders dat de eerste zender omvat wordt gebruikt voor het uitzenden van de respectievelijke eerste ultrasone signalen in stappen c) en h), een eerste veelvoud van onderling soortgelijke ontvangers dat de eerste ontvanger omvat wordt gebruikt voor het ontvangen van de respectievelijke eerste ultrasone signalen in stappen d) en h), een tweede veelvoud van onderling soortgelijke zenders dat de tweede zender omvat wordt gebruikt voor het zenden van de respectievelijke tweede ultrasone signalen in stappen e) en h), en een tweede veelvoud van onderling soortgelijke ontvangers dat de tweede ontvanger omvat wordt gebruikt voor het ontvangen van de respectievelijke tweede ultrasone signalen in stappen f) en h).

6. Werkwijze volgens conclusie 4 of 5, waarbij een en dezelfde ontvangende transducer de eerste ontvanger en de tweede ontvanger vormt, en/of waarbij een en dezelfde zendende transducer de eerste zender en de tweede zender vormt.

7. Werkwijze volgens een der conclusies 4-6, die de stap omvat:
j) het optimaliseren van een positie, ten opzichte van het referentiefacet, van de tweede zender en de tweede ontvanger van het calibratieobject gebaseerd op een vorm van het fusiefront van de las, waarbij het optimaliseren het streven naar schuine inslag van het uitgezonden tweede ultrasone signaal op het artificiele defect omvat of het streven naar inslag van het tweede ultrasone signaal op het referentiefacet met een hoek tussen 35 graden en 70 graden met een normaal van het referentiefacet omvat, verder omvattende het gebruiken van een vergelijkbare positie, ten opzichte van het in stap b) geselecteerde facet, van de eerste zender en de eerste ontvanger op het te inspecteren object.

8. Werkwijze volgens conclusies 5 en 7, waarbij het optimaliseren in stap j) wordt uitgevoerd voor het tweede veelvoud van zenders en het tweede veelvoud van ontvangers.

9. Werkwijze volgens conclusie 7 of 8, waarbij het optimaliseren in stap j), tenminste deels, automatisch wordt uitgevoerd door gebruik te maken van functiegebonden ontwerpsoftware.

10. Werkwijze volgens een der conclusies 1-9, waarbij het eerste ultrasone signaal uitgezonden in stap c) het in stap b) geselecteerde facet bereikt in een richting dwars op het in stap b) geselecteerde facet, en het tweede ultrasone signaal uitgezonden in stap e) het referentiefacet bereikt in een richting dwars op het referentiefacet.

11. Werkwijze volgens een der conclusies 1-9, waarbij het eerste ultrasone signaal uitgezonden in stap c) het in stap b) geselecteerde facet met een hoek tussen 35 en 70 graden met een normaal van het in stap b)

geselecteerde facet bereikt, en waarbij het tweede ultrasone signaal uitgezonden in stap e) het referentiefacet met een hoek tussen 35 en 70 graden met een normaal van het referentiefacet bereikt.

12. Werkwijze volgens een der conclusies 1-11, waarbij het veelvoud van facetten het hele fusiefront in hoofdzaak bedekt.

13. Werkwijze volgens een der conclusies 1-12, waarbij tenminste een aantal van, en bij voorkeur alle, van het veelvoud van facetten onderling overlappen.

14. Werkwijze volgens een der conclusies 1-12, waarbij ten minste een aantal van, en bij voorkeur alle, van het veelvoud van facetten onderling contigu zijn.

15. Werkwijze volgens een der conclusies 1-12, waarbij een eerste aantal van het veelvoud van facetten onderling overlappen en een tweede aantal van het veelvoud van facetten onderling contigu zijn, waarbij bij voorkeur de som van het eerste aantal en het tweede aantal gelijk is aan de totale hoeveelheid facetten in het veelvoud van facetten.

16. Werkwijze volgens een der conclusies 1-15, die de stap omvat:
k) het bepalen van een eerste reflectieamplitude A_1 van het eerste ultrasone signaal ontvangen in stap d) en een tweede reflectieamplitude A_2 van het tweede ultrasone signaal ontvangen in stap f);
waarbij het bepalen in stap g) is gebaseerd op de eerste reflectieamplitude A_1 en de tweede reflectieamplitude A_2.

17. Werkwijze volgens conclusie 16, waarbij het bepalen in stap g) verder is gebaseerd op een ratio A_1/A_2 van de eerste reflectieamplitude A_1 en

de tweede reflectieamplitude A_2, en bij voorkeur is gebaseerd op een vermenigvuldigingsfactor keer de ratio A_1/A_2.

18. Werkwijze volgens conclusie 16 of 17, die de stap omvat:
l) het bepalen van een eerste transmissieamplitude B_1 van het eerste ultrasone signaal uitgezonden in stap c), en het bepalen van een tweede transmissieamplitude B_2 van het tweede ultrasone signaal uitgezonden in stap e);
waarbij het bepalen in stap g) verder is gebaseerd op de eerste transmissieamplitude B_1 en de tweede transmissieamplitude B_2.

19. Werkwijze volgens conclusie 18, waarbij het bepalen in stap g) verder is gebaseerd op een ratio B_2/B_1 van de tweede transmissieamplitude B_2 en de eerste transmissieamplitude B_1, en bij voorkeur is gebaseerd op het product van de ratio A_1/A_2 en de ratio B_2/B_1.

20. Werkwijze volgens een der conclusies 16-19, waarbij het bepalen in stap g) het bepalen van de grootte van het mogelijke defect omvat door gebruik te maken van een vooraf bepaalde relatie voor groottebepaling die de eerste reflectieamplitude A_1 aan de grootte van het mogelijke defect relateert, waarbij de vooraf bepaalde relatie voor groottebepaling is gebaseerd op, ten minste, de tweede reflectieamplitude A_2 en de vooraf bepaalde grootte van het artificiele defect, en/of is gebaseerd op numerieke simulaties.

21. Werkwijze volgens een der conclusies 1-20, waarbij de grootte van het mogelijke defect een oppervlaktegebied van het mogelijke defect is en de vooraf bepaalde grootte van het artificiele defect een vooraf bepaald oppervlaktegebied van het artificiele defect is.

22. Werkwijze volgens tenminste conclusie 2 van conclusies 2-21, waarbij het uitvoeren van stappen g) en h) het bepalen van een grootte van een veelvoud van defecten omvat die het mogelijke defect omvat, waarbij het veelvoud van defecten op of nabij het fusiefront ligt.

23. Werkwijze volgens conclusie 22, die het bepalen of het veelvoud van defecten waarvan de grootte is bepaald onderling op elkaar inwerken omvat, bij voorkeur door gebruik te maken van interactiecriteria afgeleid van tenminste een van de API 1104 standaard, de Britse BS 7910 standaard, en steel catenary riser criteria.

24. Werkwijze volgens conclusie 22 of 23, die het bepalen of het veelvoud van defecten waarvan de grootte is bepaald zijn gevormd door een en hetzelfde fysische defect omvat.

25. Werkwijze volgens een der conclusies 1-24, die de stap omvat:
m) het ontwerpen van een dimensie van het calibratieobject gebaseerd op een type van de las, zo dat een positie van het artificiele defect in het calibratieobject correspondeert met een positie van het fusiefront van de las in het te inspecteren object.

26. Werkwijze volgens een der conclusies 1-25, waarbij het artificiele defect een gat in het calibratieobject is.

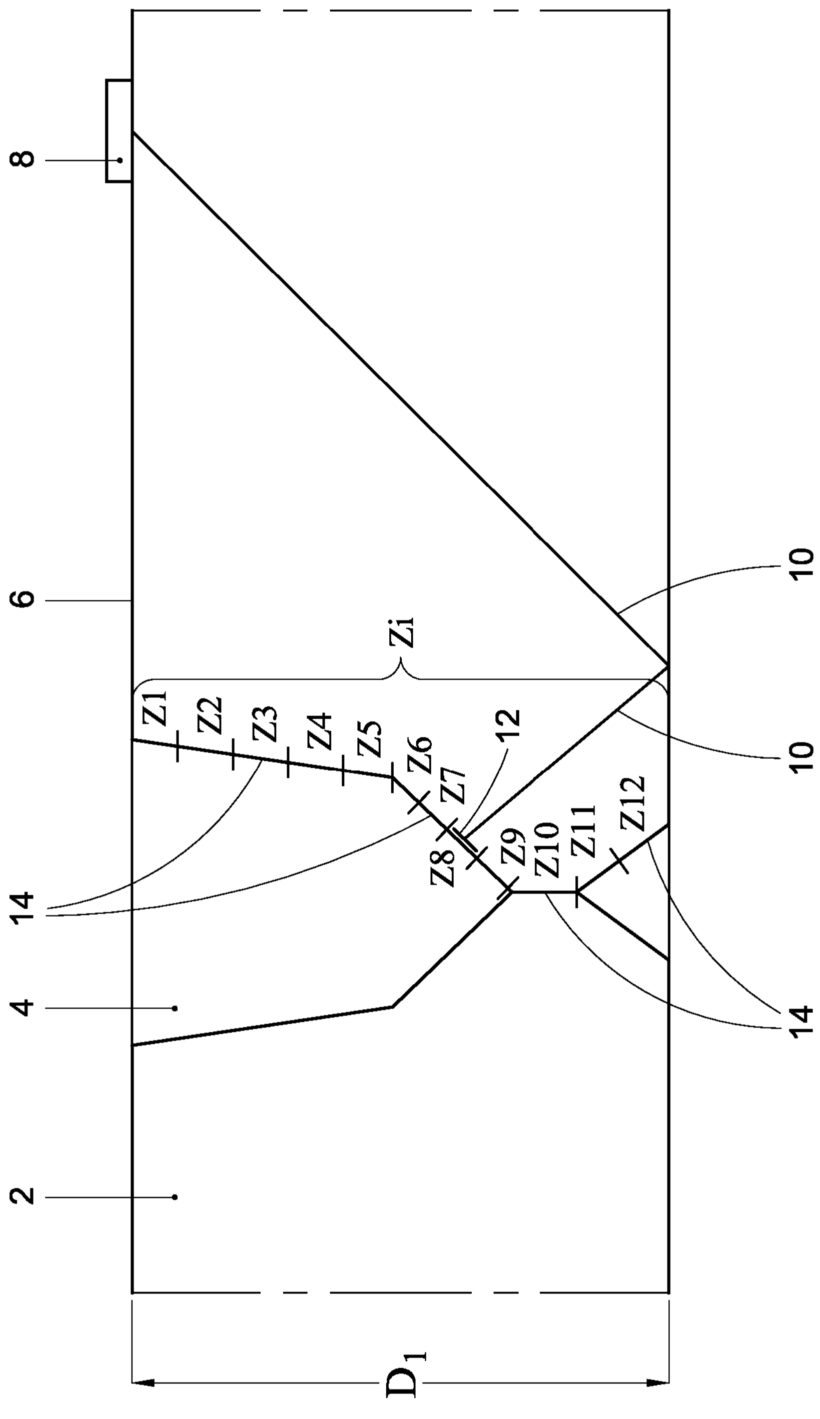
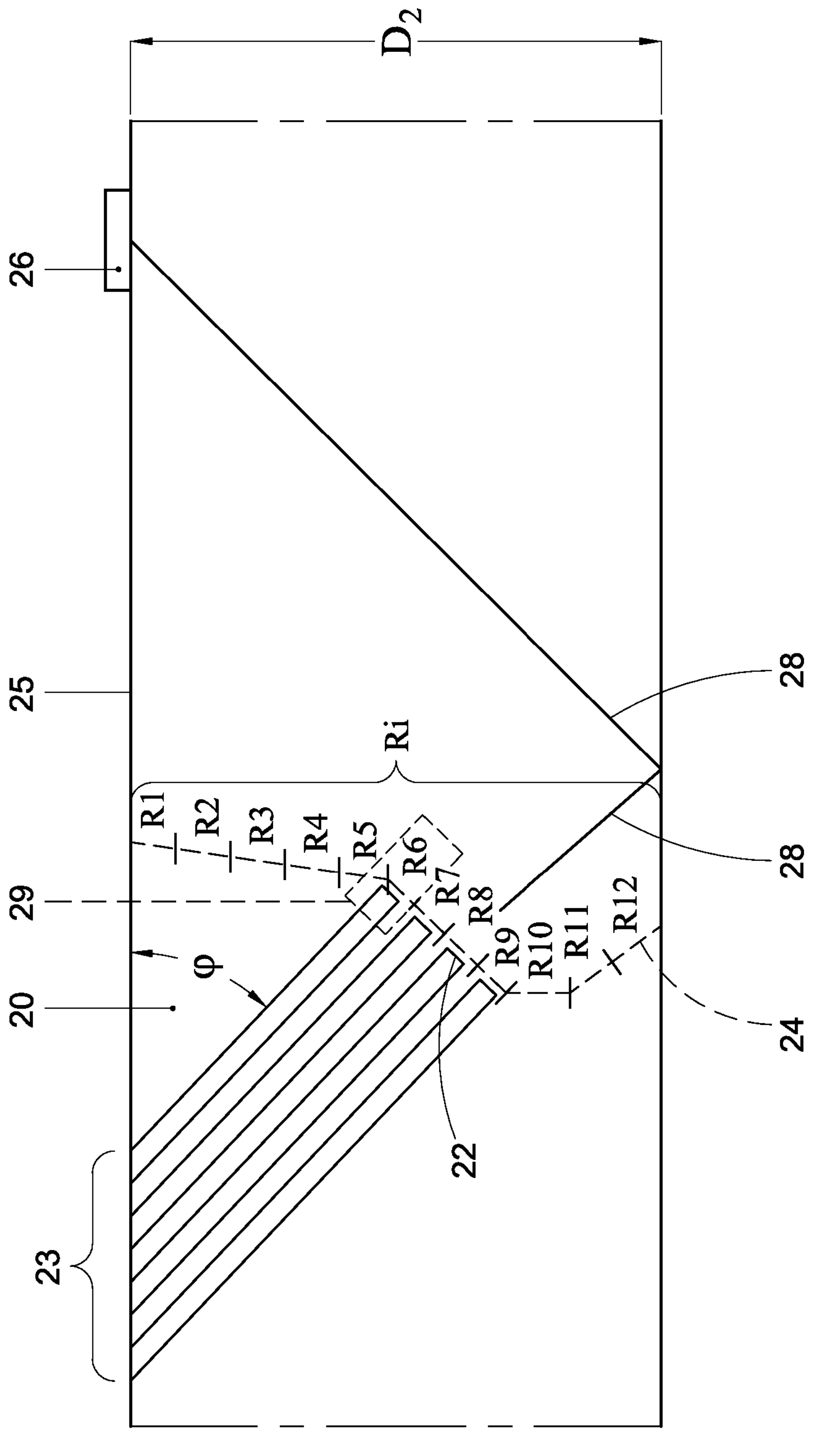


Fig. 1



D2
26
25
28
28
Ri
R1
R2
R3
R4
R5
R6
R7
R8
R9
R10
R11
R12
29
φ
20
24
22
23

Fig. 2

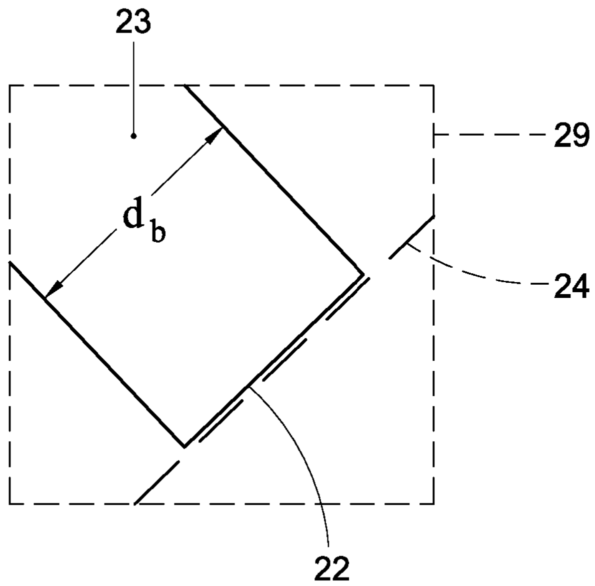


Fig. 2A

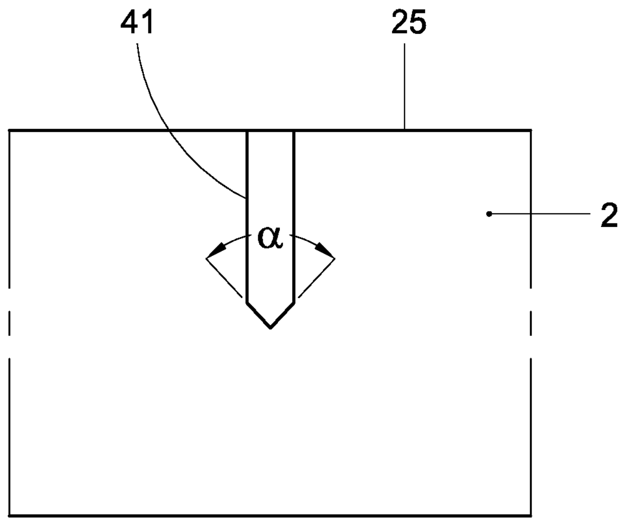


Fig. 2B

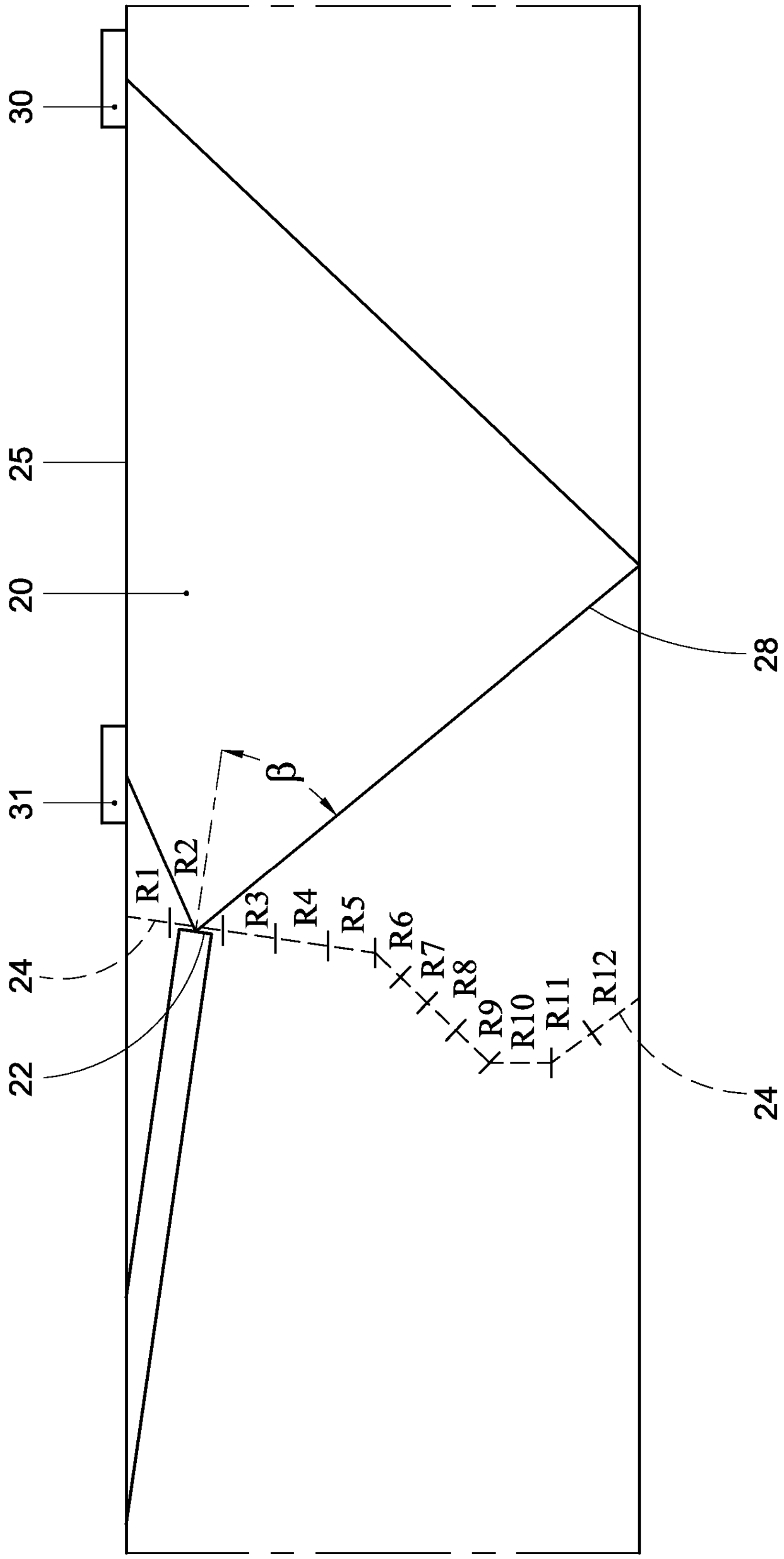


Fig. 3

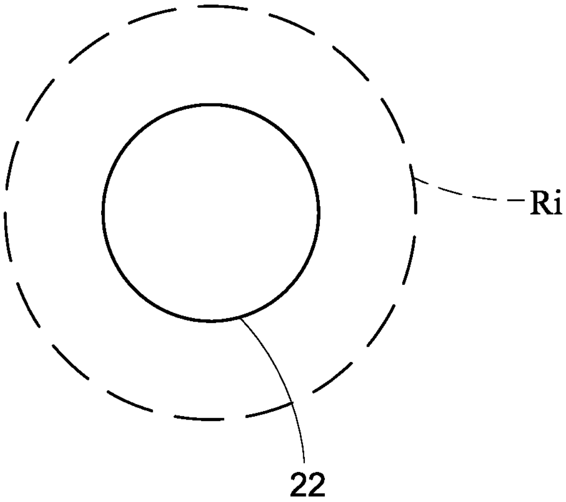


Fig. 4A

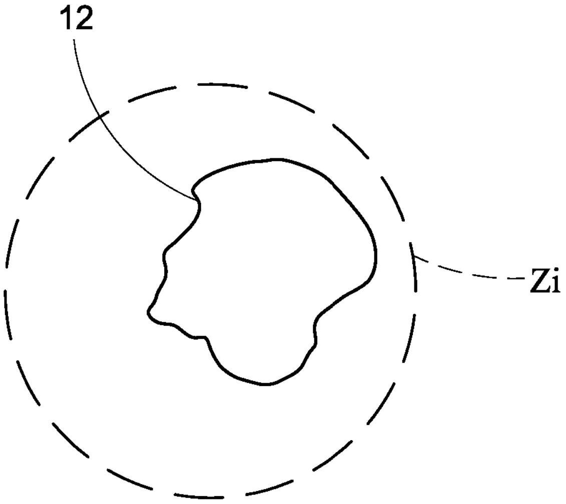


Fig. 4B

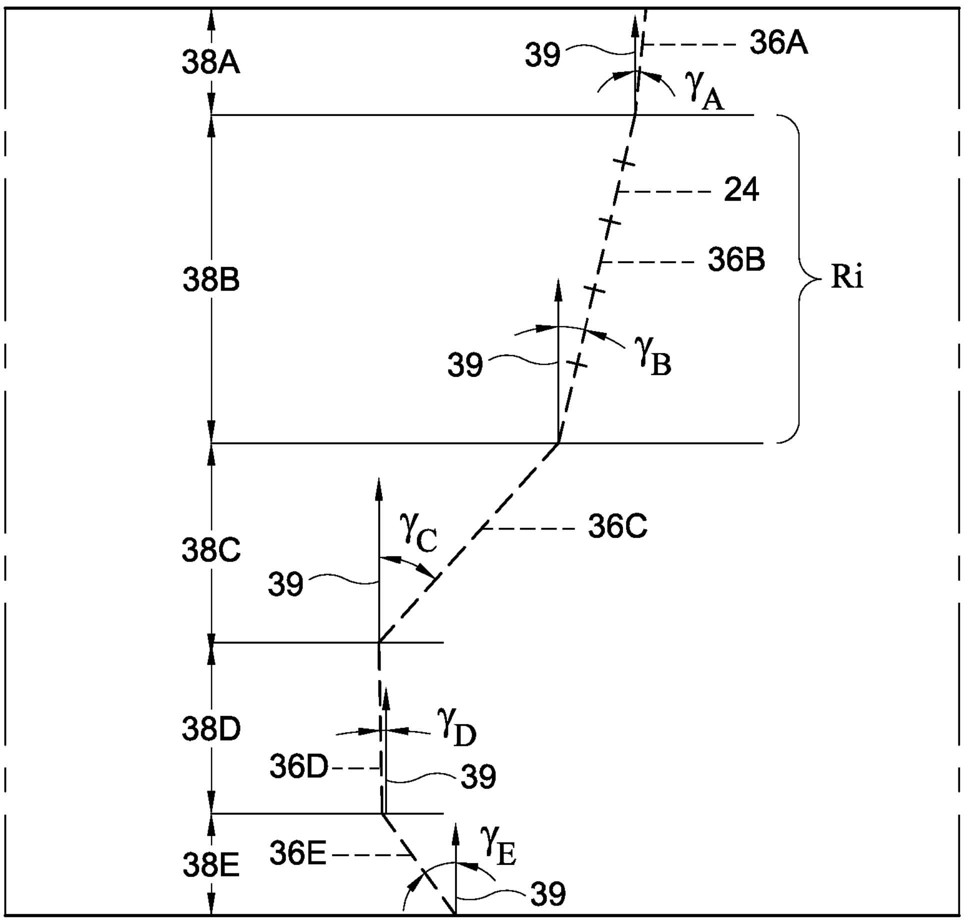

38A
39
36A
γ_A
24
38B
36B
Ri
39
γ_B
38C
36C
γ_C
39
38D
γ_D
36D
39
38E
36E
γ_E
39

Fig. 5

SAMENWERKINGSVERDRAG (PCT)

RAPPORT BETREFFENDE NIEUWHEIDSONDERZOEK VAN INTERNATIONAAL TYPE

IDENTIFICATIE VAN DE NATIONALE AANVRAGE	KENMERK VAN DE AANVRAGER OF VAN DE GEMACHTIGDE
	P82537NL00
Nederlands aanvraag nr. **2003154**	Indieningsdatum **08-07-2009**
	Ingeroepen voorrangsdatum
Aanvrager (Naam) **Röntgen Technische Dienst B.V.**	
Datum van het verzoek voor een onderzoek van internationaal type **03-11-2009**	Door de Instantie voor Internationaal Onderzoek aan het verzoek voor een onderzoek van internationaal type toegekend nr. **SN 53169**

I. CLASSIFICATIE VAN HET ONDERWERP (bij toepassing van verschillende classificaties, alle classificatiesymbolen opgeven)

Volgens de internationale classificatie (IPC)

G01N29/07 **G01N29/30** **G01N29/44**

II. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte minimumdocumentatie

Classificatiesysteem	Classificatiesymbolen
IPC8	**G01N**

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

III.	☐	**GEEN ONDERZOEK MOGELIJK VOOR BEPAALDE CONCLUSIES**	(opmerkingen op aanvullingsblad)
IV.	☐	**GEBREK AAN EENHEID VAN UITVINDING**	(opmerkingen op aanvullingsblad)

Form PCT/ISA 201 A (11/2000)

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 2003154

A. CLASSIFICATIE VAN HET ONDERWERP
INV. G01N29/07 G01N29/30 G01N29/44
ADD.

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

B. ONDERZOCHTE GEBIEDEN VAN DE TECHNIEK

Onderzochte miminum documentatie (classificatie gevolgd door classificatiesymbolen)
G01N

Onderzochte andere documentatie dan de mimimum 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	WO 2008/075943 A2 (ROENTGEN TECH DIENST BV [NL]; DIJKSTRA FREDERIK HENDRIK [NL]) 26 juni 2008 (2008-06-26) * bladzijde 1, laatste alinea - bladzijde 2, alinea 1 * * bladzijde 2, laatste alinea - bladzijde 4, alinea 1 * * bladzijde 6, alinea 6 - bladzijde 7, alinea 5 * -----	1-3,7,9, 10,12, 14,16, 17,20-26
X	WO 2008/105109 A1 (JFE STEEL CORP [JP]; IIZUKA YUKINORI [JP]; KENMOCHI KAZUHITO [JP]; YOK) 4 september 2008 (2008-09-04) * het gehele document * -/--	1-3,7,9, 10,12, 14,16, 17,20-26

[X] Verdere documenten worden vermeld in het vervolg van vak C.

[X] Leden van dezelfde octrooifamilie 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 octrooiaanvrage vermeld

"E" eerdere octrooi(aanvrage), 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 octrooiaanvrage, 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 octrooifamilie of overeenkomstige octrooipublicatie

Datum waarop het onderzoek naar de stand van de techniek van internationaal type werd voltooid	Verzenddatum van het rapport van het onderzoek naar de stand van de techniek van internationaal type
4 juni 2010	

Naam en adres van de instantie	De bevoegde ambtenaar
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Savage, John

1

Formulier PCT/ISA/201 (tweede blad) (Januari 2004)

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 2003154

C.(Vervolg). VAN BELANG GEACHTE DOCUMENTEN

Categorie °	Geciteerde documenten, eventueel met aanduiding van speciaal van belang zijnde passages	Van belang voor conclusie nr.
E	& EP 2 116 847 A1 (JFE STEEL CORP [JP]) 11 november 2009 (2009-11-11) * alinea [0021] * * alinea [0038] * * alinea [0110] - alinea [0113] * -----	1-3,7,9, 10,12, 14,16, 17,20-26
X	WO 02/31487 A2 (CHICAGO BRIDGE & IRON CO [US]) 18 april 2002 (2002-04-18) * bladzijde 22, regel 21 - bladzijde 3, regel 11 * * bladzijde 9, regel 23 - bladzijde 10, regel 8; figuren * -----	1-3,7,9, 10,12, 14,16, 17,20-26
X	US 2005/223807 A1 (BARDOUX OLIVIER [FR] ET AL) 13 oktober 2005 (2005-10-13) * alinea [0020] * * bladzijde 2, alinea 0038 * * alinea [0098] - alinea [0099] * -----	1-3,7,9, 10,12, 14,16, 17,20-26

1

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 2003154

In het rapport genoemd octrooigeschrift		Datum van publicatie	Overeenkomend(e) geschrift(en)			Datum van publicatie
WO 2008075943	A2	26-06-2008	CA	2593894	A1	01-10-2007
WO 2008105109	A1	04-09-2008	CA	2679123	A1	04-09-2008
			CN	101617223	A	30-12-2009
			EP	2116847	A1	11-11-2009
			JP	2008209356	A	11-09-2008
			US	2010107725	A1	06-05-2010
WO 0231487	A2	18-04-2002	AR	030996	A1	03-09-2003
			AR	052679	A2	28-03-2007
			AT	430309	T	15-05-2009
			AU	9674501	A	22-04-2002
			AU	2001296745	B2	20-07-2006
			BR	0114581	A	06-01-2004
			CA	2424265	A1	18-04-2002
			CN	1430727	A	16-07-2003
			EP	1327140	A2	16-07-2003
			JP	3848254	B2	22-11-2006
			JP	2004511774	T	15-04-2004
			MX	PA03003232	A	15-10-2003
			NO	20031676	A	11-04-2003
			NZ	524789	A	29-10-2004
			TW	490553	B	11-06-2002
			US	6497150	B1	24-12-2002
			US	6405596	B1	18-06-2002
			ZA	200302208	A	12-02-2004
US 2005223807	A1	13-10-2005	AU	2003263235	A1	31-12-2003
			EP	1516178	A1	23-03-2005
			FR	2840991	A1	19-12-2003
			WO	03106994	A1	24-12-2003

OCTROOICENTRUM NEDERLAND

WRITTEN OPINION

File No.	Filing date *(day/month/year)*	Priority date *(day/month/year)*	Application No.
SN53169	08.07.2009		NL2003154

International Patent Classification (IPC)
INV. G01N29/07 G01N29/30 G01N29/44

Applicant
R ntgen Technische Dienst B.V. te Rotterdam

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
Savage, John

Application number
NL2003154

WRITTEN OPINION

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	4-6, 8, 11, 13, 15, 18, 19
	No:	Claims	1-3, 7, 9, 10, 12, 14, 16, 17, 20-26
Inventive step	Yes:	Claims	4-6, 8, 11, 13, 15, 18, 19
	No:	Claims	1-3, 7, 9, 10, 12, 14, 16, 17, 20-26
Industrial applicability	Yes:	Claims	1-26
	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

Reference is made to the following document(s):

D1 WO 2008/075943 A2 (ROENTGEN TECH DIENST BV [NL]; DIJKSTRA FREDERIK HENDRIK [NL]) 26 juni 2008 (2008-06-26)

D2 WO 2008/105109 A1 (JFE STEEL CORP [JP]; IIZUKA YUKINORI [JP]; KENMOCHI KAZUHITO [JP]; YOK) 4 september 2008 (2008-09-04) ; & EP 2 116 847 A1 (JFE STEEL CORP [JP]) 11 november 2009 (2009-11-11)

D3 WO 02/31487 A2 (CHICAGO BRIDGE & IRON CO [US]) 18 april 2002 (2002-04-18)

D4 US 2005/223807 A1 (BARDOUX OLIVIER [FR] ET AL) 13 oktober 2005 (2005-10-13)

The present application does not meet the criteria of patentability, because the subject-matter of claim 1 is not new.

Document D1 discloses a method for sizing of defects using ultrasound in which a weld is divided into facets and each facet separately scanned, this document further discloses that a reference object or defect is created and scanned in the same geometry for each facet, thus allowing comparison between the reference and the actual weld to determine defect size. See for example D1, page 1, last paragraph - page 2, first paragraph and page 3, last paragraph - page 4, first paragraph. Similar arrangements and methods are also disclosed in documents D2-D4.

Dependent claims 2, 3, 7, 9, 10, 12, 14, 16, 17 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of novelty, see Documents D1-D4 for example.