



A VIBRATING DEVICE AND A METHOD FOR DRIVING AN OBJECT BY VIBRATION

5 The invention relates to a device for driving an object into the ground by vibration, or removing it therefrom, in particular a pile or sheet piling, which device comprises a first pair of eccentrically rotatable weights and a second pair of eccentrically rotatable weights
10 wherein the two weights of each pair rotate in opposite directions, thus producing vibration substantially in one direction, which pairs of weights are interconnected by a phase shifter which is capable of adjusting the rotational position of the pairs of weights relative to
15 each other.

Vibration can be produced by having an eccentrically rotatable weight, that is, a rotatable mass whose centre of gravity does not lie on the axis of rotation, rotate
20 about its axis. A pair of eccentrically rotatable weights includes two weights rotating in opposite directions, thus producing vibration substantially in one direction. If said vibration comprises sufficient energy, it is possible to set an object vibrating therewith so as to
25 drive said object into the ground by vibration. Although the present description describes the driving into the ground of objects, the device can also be used for removing objects from the ground.

30 By providing the device with two pairs of eccentrically rotatable weights, the degree of vibration can be influenced by changing the relative rotational position of the two pairs of eccentric weights when said weights vibrate at the same speed. Consequently, the device is
35 provided with a so-called phase shifter, which is disposed in the mechanical transmission which connects the two pairs of eccentric weights and which is capable of changing the relative rotational position of the two



pairs of weights.

A device of this kind is known from EP-A-0 524 056, wherein the phase shifter comprises two gears which are
5 coaxially rotatable about a shaft, which gears occupy a fixed position relative to each other during normal operation of the vibrating device, but wherein the rotational position of one gear relative to the rotational position of the other gear can be slightly
10 changed. Since each of the gears is in drivable contact with a pair of eccentrically rotatable weights, the relative rotational position of the two pairs of weights can be adjusted by changing the rotational position of the two gears.

15 The phase shifter which is disclosed in EP-A-0 524 056 comprises a part which is connected with one gear and a part which is connected with the second gear, which parts are in part disposed radially apart, thus forming an
20 annular cylinder space. An annular piston is present within said cylinder space, which piston abuts against each of said parts with a helical camway. The relative rotational position of the two gears can be changed by axial movement of the piston, which movement can be
25 effected by means of fluid pressure.

The object of the invention is to provide a device of the kind as described above which is provided with a phase shifter, wherein said phase shifter can be
30 controlled in a simple and adequate manner, and wherein said phase shifter is reliable and of simple construction.

In order to accomplish that objective, the device is
35 provided with a phase shifter comprising a differential which is provided with three interconnected, rotatable parts, wherein rotation of one part results in rotation

of another part or of both other parts, the first part of which differential is in drivable contact with the first rotatable pair of weights, and the second part of which is in drivable contact with the second rotatable pair of weights, and wherein the rotational position of the third part determines the relative rotational position of the two rotatable pairs of weights. Such a mechanical differential is by itself a tried and tested part, of which there are a number of known embodiments, which are capable of functioning in a satisfactory, efficient and reliable manner. It has become apparent that such a mechanical differential can be used in a surprisingly simple manner in a phase shifter for a vibrating device.

To use a mechanical differential as a phase shifter is disclosed as such in DE-A-2 842 873. However, that document does not deal with driving objects into the ground, but rather with soil compaction.

Preferably, the three parts of the differential are coaxially rotatable relative to each other, and each of said parts comprises a gear which is in mesh with a gear of another part.

In one preferred embodiment, the first and the second part of the differential are coaxially rotatable conical gears whose teeth extend towards each other, and the third part is a coaxially rotatable carrier which carries one or more radially extending, relative to its axis of rotation, conical gears, wherein each of the latter conical gears is in mesh with both former conical gears. This is a type of differential which is also used in the rear axle of vehicles for driving the two rear wheels thereof.

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Preferably, said carrier is fixedly mounted on a coaxial shaft, on which shaft said two former conical gears are

mounted in a manner which allows coaxial rotation, and wherein the phase shift can be adjusted by rotation of the central coaxial shaft. This makes it possible to control the phase shift in an simple, mechanical manner.

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In another preferred embodiment, said carrier is rotatably mounted on said central, coaxial shaft, and the carrier is fixed in the desired position by fixing means which are disposed outside the carrier, seen in
10 radial direction. Said fixation may for example be carried out by moving a radially extending handle which is mounted on the carrier.

In the device according to the aforesaid EP-A-0 524 056,
15 the two gears of the phase shifter rotate in the same direction. In the above-described device, the two gears of the phase shifter rotate in opposite directions. This does not complicate matters as regards the drive of the two pairs of eccentric wheels, since the direction in
20 which the eccentrically rotatable wheels rotate has no influence on the generation of the rectilinear vibration.

In another preferred embodiment, the differential
25 comprises planetary gearing comprising a sun gear, a satellite carrier and a planet gear, which are coaxially rotatable relative to each other. The advantage of a differential of this kind is that it has a limited dimension in axial direction. One drawback of such a
30 planetary differential is the fact that when one of the parts is kept stationary, the two other parts will always rotate at different rotational speeds. When the two gears of the phase shifter have different diameters, however, this difference in rotational speed can be
35 compensated in such a manner that the two gears rotate at the same peripheral velocity.

Preferably, the first part of the differential is the sun gear, the second part is the satellite carrier and the third part is the planet gear. The planet gear can be engaged from outside thereby so as to keep it in a stationary position, whilst one of the two gears of the phase shifter can be fixed on the central, coaxial shaft together with the sun gear.

In another preferred embodiment, the first part of the differential is the planet gear, the second part is the satellite carrier and the third part is the sun gear, which sun gear is fixedly mounted on the coaxial shaft, about which shaft the satellite carrier and the planet gear can rotate. The phase shift of the weights can thereby take place by rotation of the central shaft, in the same manner as described before.

The invention furthermore relates to a method for driving an object into the ground by vibration, or removing it therefrom, in particular a pile or sheet piling, wherein said object is fixed to a vibrating device in which a first eccentric pair of weights and a second eccentric pair of weights are rotated, wherein the rotational positions of the pairs of the weights are adjusted relative to each other by means of a phase shifter, whereby said phase shifter comprises a differential which is provided with three interconnected, rotatable parts, wherein rotation of one part results in rotation of another part or of both other parts, and wherein said rotational position is adjusted by rotating part of said differential, whilst each of the other two parts is in drivable contact with an eccentric pair of weights.

Further aspects, which can be used separately as well as in combination with each other, are described by means of two embodiments and defined in the claims.

In order to explain the invention more fully, three embodiments of a device for putting objects into the ground by vibration will now be described with reference to the drawings.

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Figure 1 is a schematic side view of the device according to the prior art;

Figure 2 is a sectional view along line II-II in Figure 1;

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Figure 3 shows a first embodiment of the invention;

Figure 4 shows a second embodiment; and

Figures 5 and 6 shows a third embodiment.

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The figures are merely schematic representations, wherein corresponding parts are indicated by the same numerals.

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Figure 1 shows a first pair of eccentrically rotatable weights 1, 2, as well as a second pair of eccentrically rotatable weights 3, 4. Each of said eccentric weights 1, 2, 3, 4 is mounted on a gear 5, 6, 7, 8, wherein the gears 5, 6, 7, 8 of each pair of weights are in mesh with each other. The weights 1, 2; 3, 4 of each pair rotate in opposite directions relative to each other, 25 therefore, as is indicated by means of the arrows.

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Figure 1 shows two hydraulic motors 9, 10 for driving the eccentric weights, which motors are each in mesh with a gear 5, 7 of an eccentric weight 1, 3. Gears 6, 8 of eccentric weights 2, 4 are each in mesh with a gear 11, 12 of a phase shifter, which gears coincide in the view according to Figure 1.

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It will be apparent that when gears 11, 12 of the phase shifter are fixedly interconnected, the two hydraulic motors 9, 10 will rotate the eccentric weights 1, 2, 3, 4 in such a manner that the device is caused to vibrate

rectilinearly in vertical direction, that is, from top to bottom in Figure 1. In the illustrated position of the eccentric weights, the resulting vibration will be the sum of the vibration of each of the pairs of
5 eccentric weights, at least when the rotational speed of all weights is equal. By changing the rotational position of weights 1, 2 of the first pair relative to the rotational position of the weights 3, 4 of the second pair, the vibration being imposed on the device
10 will be attenuated, whereby there will no longer be resulting vibration once the rotational position of one of the pairs of eccentric weights has been turned through 180° in comparison with the situation as shown in Figure 1.

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The changing of the rotational position, or the shifting of the phase of the vibration of one of the pairs of eccentric weights relative to the other pair is effected by a phase shifter 13, which changes the rotational
20 position of the two gears 11 and 12 relative to each other.

Figure 2 is a sectional view of the device, wherein the phase shifter 13 comprising the two gears 11, 12 to be
25 moved relative to each other is schematically indicated by means of a chain-dotted line. The whole is present within a housing 14, which housing can be fixed to an object which is to be vibrated.

30 Figures 1 and 2 show a device as known from EP-A-0 524 056, wherein the two gears 11, 12 of phase shifter 13 have the same diameter and rotate in the same direction. This is not the case in the three illustrated embodiments of the invention. In the first and the
35 third embodiment (Figure 3 and Figures 5, 6, respectively) the two gears 11, 12 of phase shifter 13 rotate in opposite directions, so that a situation is

obtained wherein gears 7, 8, 12 rotate in the direction which is indicated in Figures 1, 2 by an arrow illustrated in chain-dotted lines. This other direction of rotation has no consequences as regards the vibrating
5 effect of the device, however.

In the second embodiment of the invention (Figure 4), the rotational speed of gear 11 is not the same as the rotational speed of gear 12 of the phase shifter, which
10 is compensated by using gears 11, 12 having different diameters, so that the peripheral velocity of said gears 11, 12 will be the same for both gears. As a result of, the position of phase shifter 13 will slightly differ from the position as shown in Figures 1 and 2, so that
15 the gears 11, 12 having different diameters will correctly mesh with gears 6, 8 of the pairs of weights.

Figure 3 schematically shows a phase shifter which is provided with a differential comprising three parts
20 which rotate relative to each other, a first part provided with a conical gear 20, which is fixed to gear 11, a second part provided with a conical gear 21 fixed to gear 12, and a third part consisting of a number of conical gears 23, which are in mesh with the aforesaid
25 two conical gears 20, 21, which conical gears 23 are rotatable about shafts 24, which extend perpendicularly to the shaft 25 about which the three parts of the differential can rotate.

30 In the embodiment of Figure 3, conical gear 20 is rotatably mounted on shaft 25, together with gear 11, by means of a bearing 26, and gears 12, 21 are jointly and rotatably mounted on the same shaft 25 by means of bearing 27. Conical gears 23 are freely rotatable on
35 shaft 24, which shaft is fixedly mounted on shaft 25.

It will be apparent that when shaft 25 is kept in a

fixed position, gears 11, 20 on the one hand and gears 12, 21 on the other hand will rotate at the same speed, albeit in opposite directions, at all times. By means of this phase shifter, the weights 1, 2 which are shown in
5 Figure 1 will rotate as indicated by the arrows, and weights 3, 4 and hydraulic motor 10, as well as gear 11 in Figure 1, will rotate in the direction indicated by the arrows which are illustrated in dash lines.

10 According to Figure 3, shaft 25 is rotatably mounted in housing 14 of the device by means of bearings 28. Rotation of shaft 25, and thus of shafts 24 of conical gears 23, will effect a change of the phase of the vibration produced by first pair of weights 1, 2
15 relative to the vibration produced by the second pair of weights 3, 4. The intensity of the vibration of the device can therefore be controlled by rotating shaft 25, which rotation can take place from a location outside housing 14, for example by fitting shaft 25 with a gear
20 which can be rotated through a particular angle.

It is also possible to effect a change in the rotational position of shafts 24 with the conical gears 23 in a different manner. Thus, said shafts can be mounted on
25 shafts 25 via a bearing, wherein one of the shafts 24 is lengthened, so that said shaft 24 can be held in position at a particular location. The rotational position 24 and thus the phase shift can be controlled by changing the location of said shaft 24.

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Figure 4 shows a second embodiment, wherein the phase shifter is provided with a differential comprising planetary gearing. The central shaft 25 in this embodiment is likewise rotatably mounted in housing 14
35 by means of bearings 28. Mounted on said central shaft 25 is the sun gear 30 of the planetary gearing. Sun gear 30 is in mesh with a number of satellite gears 31, which

are rotatably supported in gear 12 by means of bearings 32. Gear 12 is rotatably mounted on shaft 25 by means of bearings 27.

- 5 Gears 31 are on the other hand in mesh with planet gear 33 of the planetary gearing, which planet gear 33 is mounted on gear 11. Gear 11 is rotatably mounted on shaft 25 by means of bearings 26.
- 10 It will be apparent that when shaft 25 carrying gear 30 is kept in a stationary position, and gear 12, which forms the satellite carrier of the planetary gearing, is rotated, planet gear 33 and gear 11 will rotate in the same direction, albeit at greater speed. The diameters
- 15 of the gears 11 and 12 have been so selected that the gears 11, 12 will rotate at the same peripheral velocity when shaft 25 is kept stationary. As a result, they will interconnect the pairs of weights 1, 2; 3, 4 in such a manner that all weights will rotate at the same speed.
- 20 It is possible thereby to effect a phase shift of the vibration which is produced by the first pair of weights 1, 2 relative to the vibration which is produced by the second pair of weights 3, 4 by rotating shaft 25 through a particular angle.

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- Figures 5 and 6 show a third embodiment of the phase shifter 13. Also in this embodiment a central shaft 25 is supported in a housing 14 by means of bearings 28. A carrier 47 is fixedly mounted on central shaft 25, which
- 30 carrier comprises two disc-shaped plates, between which gears 43, 44, 45, 46 are mounted, which gears are supported in said two plates by means of bearings 48. Figure 6 schematically illustrates carrier 47 and shows that gears 43, 44 as well as gears 45, 46 are in mesh
- 35 with each other, which enables them to rotate in the direction indicated by the arrows.

According to Figure 6, carrier 47 is furthermore provided with connecting elements 49, which are secured to both plates by means of bolts 50.

- 5 In Figure 5 gears 43 and 45 are shown for the sake of clarity, in reality, however, said gears are not disposed opposite each other (see Figure 6).

Gears 43, 44, 45, 46 are satellite gears, which are
10 surrounded by two planet gears, namely the internal gears 41, 42, which are rotatably supported on shaft 25 by means of bearings 26, 27. Internal gear 41 is in mesh with gears 44 and 45 and internal gear 42 is in mesh with gears 43 and 46. It will be apparent that when
15 carrier 47 is kept stationary, internal gears 41 and 42 will rotate at the same speed in opposite directions. Since gears 11 and 12 are integrally connected to internal gears 41 and 42, respectively, gears 11 and 12 will likewise rotate at the same speed in opposite
20 directions when carrier 47, or shaft 25, is kept stationary.

By rotating central shaft 25 through a particular angle, a difference in speed between gears 11 and 12 is created
25 temporarily, so that a phase shift will take place.

In the above embodiments, the angular position of shaft 25 thus determines the relative rotational position of the pairs of eccentrically rotatable weights 1, 2, 3, 4,
30 as a result of which the desired intensity of vibration of the device can be adjusted by changing the angular position of the device.

It will be apparent that one motor 9, 10 (Figure 1)
35 already suffices for driving the device. Figure 1, however, shows an embodiment comprising two hydraulic motors, which increases the power of the device. If only

one hydraulic motor 9, 10 is present, the phase shifter 13 not only functions to arrange the relative rotational position of the pairs of weights, but also to fully drive one of the two pairs of eccentric weights 1, 2; 3, 4. The phase shifter 13 is loaded less heavily, therefore, when two hydraulic motors 9, 10 are used.

CLAIMS

1. A device for driving an object into the ground by vibration, or removing it therefrom, in particular a
5 pile or sheet piling, which device comprises a first pair of eccentrically rotatable weights (1,2) and a second pair of eccentrically rotatable weights (3, 4), wherein the two weights of each pair rotate in opposite directions, thus producing vibration
10 substantially in one direction, which pairs of weights (1,2;3,4) are interconnected by a phase shifter (13) which is capable of adjusting the rotational position of the pairs of weights (1,2;3,4) relative to each other, characterized in
15 that the device is provided with a phase shifter (13) comprising a differential which is provided with three interconnected, rotatable parts, wherein rotation of one part results in rotation of another part or of both other parts, the first part of which
20 differential is in drivable contact with the first rotatable pair of weights (1,2), and the second part of which is in drivable contact with the second rotatable pair of weights (3,4), and wherein the rotational position of the third part determines the
25 relative rotational position of the two rotatable pairs of weights (1,2;3,4).
2. A device according to claim 1, characterized in that
30 the three parts of the differential are coaxially rotatable relative to each other, and in that each of said parts comprises a gear (21,11,23) which is in mesh with a gear (21,11,23) of another part.
3. A device according to any one of the preceding
35 claims, characterized in that the first and the second part of the differential are coaxially rotatable conical gears (21,20) whose teeth extend

towards each other, and the third part is a coaxially rotatable carrier (24) which carries one or more radially extending, relative to its axis of rotation, conical gears (23) wherein each of the latter conical gears is in mesh with both former conical gears (21,20).

4. A device according to claim 3, characterized in that said carrier (24) is fixedly mounted on a coaxial shaft (25), on which shaft said two former conical gears (21,20) are mounted in a manner which allows coaxial rotation, and wherein the phase shift can be adjusted by rotation of the central coaxial shaft (25).

5. A device according to claim 3, characterized in that said carrier (24) is rotatable about a coaxial shaft (25), about which at least one of said former conical gears (21,20) is rotatable, and in that means are present for controlling the angular displacement of the carrier (24).

6. A device according to any one of the claims 1 or 2, characterized in that said differential comprises planetary gearing comprising a satellite carrier (12;47) and a planet gear (33;41,42), which are coaxially rotatable relative to each other.

7. A device according to claim 6, characterized in that the first part of the differential is a sun gear (30), the second part is the satellite carrier (12) and the third part is the planet gear (33).

8. A device according to claim 6, characterized in that the first part of the differential is the planet gear, the second part is the satellite carrier and the third part is a sun gear (30),

which sun gear (30) is fixedly mounted on a coaxial shaft (25), about which shaft (25) said carrier (12) and said planet gear (33) can rotate.

- 5 9. A device according to claim 6, characterized in that the first and the second part of said differential each comprise a planet gear (42,41), which is in mesh with a satellite gear (43,46;44,45), wherein satellite gears (43,46;44,45) are
10 in mesh with each other and are mounted on a carrier (47) which is fixedly mounted on a central shaft (25) and which forms part of the third part of the differential.
- 15 10. A method for driving an object into the ground by vibration, or removing it therefrom, in particular a pile or sheet piling, wherein said object is fixed to a vibrating device in which a first eccentric pair of weights (1,2) and a second eccentric pair of
20 weights (3,4) are rotated, wherein the rotational positions of the pairs of the weights (1,2;3,4) are adjusted relative to each other by means of a phase shifter (13), characterized in that said phase shifter (13) comprises a differential which is
25 provided with three interconnected, rotatable parts, wherein rotation of one part results in rotation of another part or of both other parts, and wherein said rotational position is adjusted by rotating part of said differential, whilst each of the other
30 two parts is in drivable contact with an eccentric pair of weights (1,2;3,4).