

Clamping system and a method for degassing hydraulic fluid

The present invention relates to a clamping system for clamping two mould halves together, a moulding system for encapsulating electronic components, and a
5 method for degassing hydraulic fluid.

Clamping systems for clamping two mould halves together are well known in the semiconductor industry and are capable of exerting high pressures of about 600 bar or $6 \cdot 10^7$ Pa onto a mould half. These high pressures are required to ensure that
10 a closed mould, formed by both mould halves, does not open due to pressure exerted in opposite direction by encapsulating material fed into a mould cavity during transfer moulding.

To obtain these pressures, typically knee joints are employed. It is however also
15 possible to use hydraulic cylinders. Such hydraulic cylinders contain hydraulic fluid. Unlike gas, fluids are hardly compressible. The low compressibility of hydraulic fluids enables obtaining high pressures. Therefore, hydraulic cylinders are useful components of clamping systems. However, hydraulic fluids must not contact the electronics and semiconductors that are to be encapsulated. Even vapours derived
20 from hydraulic fluids can condense on electronic components, resulting in pollution of these components. Remnants of hydraulic fluid present on electronic components negatively affects processing, such as encapsulation, dicing, singulation, etc of these components.

25 As such, semiconductor manufacturers increasingly demand equipment that is either free from any hydraulic fluids, or wherein the hydraulic fluid is contained in a closed system. The latter means that hydraulic fluid is fully contained within a clamping system and the hydraulic fluid is hermetically sealed from the environment. To satisfy these demands, current equipment in the semiconductor
30 industries typically contain only closed fluid systems. These types of systems retain and recirculate fluids, such as hydraulic fluids.

A problem occurring in these closed fluid systems is the accumulation of gas within the closed system. Despite being closed, it is often observed that gas in the form of
35 air makes its way into the closed system. As gas gradually accumulates in the

closed system over time, it remains often difficult to pinpoint the exact points of entry of the gas in the system. This gas impedes proper functioning of the clamping system, as it exerts a constant, albeit low pressure on the hydraulic cylinders. This constant low pressure prevents pistons in hydraulic cylinders in a clamping system from fully retracting. Next to this gas present in the closed system changes the compressive behaviour and with that control of clamping system is impaired. A solution to the problem above is to employ an open hydraulic system, comprising for example a float to degas hydraulic fluid. However, such a solution is in practice undesirable due to the risk of hydraulic fluid, or vapours thereof, escaping from the clamping system and polluting delicate electronic components and semiconductors.

Moulding systems, that contain clamping systems as described hereinabove, often exhibit a high degree of complexity. These moulding systems typically feature a relatively large amount of moving components packed into a relatively small space. Therefore, there is typically little space available for large hydraulic cylinders required to reach the required pressure of about 600 bar.

As such, a goal of the present invention is to eliminate the problems occurring when gas becomes trapped inside a hydraulic clamping system as indicated above. Another goal of the present invention is to minimize the use of space of a clamping system inside a moulding system.

To solve these problems, the present invention provides in a first aspect for a clamping system for clamping two mould halves together, comprising a reservoir for containing hydraulic fluid, at least one hydraulic cylinder, at least one channel that is fluidically connected between the reservoir and the hydraulic cylinder, and at least one pneumatic cylinder comprising a piston and a barrel, wherein the piston is movable within the at least one channel and within the barrel. The clamping system further comprises a degassing tank fluidically connected via a closable valve to the reservoir, and a transfer means for transferring fluid from the reservoir via the valve to the degassing tank. Advantageously, the degassing tank allows for gas to escape from the hydraulic fluid and be contained within the degassing tank. This prevents hydraulic fluid escaping from the closed hydraulic system in either gaseous or fluidic form. The transfer means ensure that the hydraulic fluid is set in motion when moved from the at least one channel, the hydraulic cylinder and/or the

reservoir to the degassing tank. This motion of the hydraulic fluid ensures that gas bubbles present in the hydraulic fluid are transferred to the degassing tank as well. Prior art solutions often use floats to degas hydraulic systems. These are however not suited for a clamping system for clamping two mould halves together as used in the semiconductor industry, as hydraulic fluid or vapours thereof can escape from these floats.

As defined herein, fluidically connected means that a fluid can be transferred from one part of the clamping system to another through the component that is fluidically connected. For example, at least one channel that is fluidically connected between the reservoir and the hydraulic cylinder means that the channel is capable of having fluid transported or transferred through the channel from the reservoir to the hydraulic cylinder, and vice versa. A transfer means can be any means that enables movement of hydraulic fluid throughout the clamping system, such as a pump or a container with an opening covered by a flexible compressible membrane. A channel as such is not limited to a straight conduit or pipe, but can be a network of pipes or conduits as well. In particular, at least part of the channel may be elongated and enclosed, such that a piston of the pneumatic cylinder may be moved back and forth within this part.

In particular, the movability of the piston of the pneumatic cylinder within the at least one channel effectively multiplies the pressure that the hydraulic cylinder can apply by a factor that is a ratio of the surface area of one end of the piston, movable within the channel, and another opposite surface area of the piston, movable within the barrel of the pneumatic cylinder. Pneumatic cylinders are typically not used to apply pressures reaching up to 600 bar, due to the compressibility of gas in pneumatic cylinders. As such, hydraulic cylinders are more suited for applying higher pressures, as fluids are to a much smaller extent compressible.

In an embodiment, a ratio between an outer surface area of a first outer end of the piston of the pneumatic cylinder and another opposite outer surface area of the piston enclosed by a barrel of the pneumatic cylinder may be at least 1:25, preferably at least 1:50, more preferably at least 1:75, and most preferably between 1:75 and 1:125. This multiplies the pressure exerted via the pneumatic cylinder by

the hydraulic cylinder with a factor of 25, 50, 75, or between 75 and 125, respectively. If, for example the exerted pressure of the pneumatic cylinder is 6 bar, and the surface area ratio, as indicated above, is 1:100, the resulting pressure exertable with the hydraulic cylinder is 600 bar. Advantageously, the space
5 required for the pneumatic cylinder is limited, as the pressure required to operate the cylinder only needs to be a couple of bars, such as 1 – 10 bar, obviating the need for excessively large pumps or other means of transferring air.

The degassing tank may comprise a closable venting opening. This in particular
10 offers the option of relieving pressure from the degassing tank, while preventing hydraulic fluid from polluting the environment. The venting opening may for example be connected to a hose, allowing gasses from the degassing tank to be transported to another location, away from delicate semiconductors.

15 the internal volume of the degassing tank is larger than 80% of a total volume of hydraulic fluid containable in the at least one channel, the hydraulic cylinder and the reservoir, preferably larger than 100%, more preferably larger than 120%, and most preferably larger than 150%. This allows gas to be extracted from the tank without running the risk that hydraulic fluid is extracted as well. As the gas escapes
20 from the hydraulic fluid in the degassing tank, the gas is located at an upper part of the degassing tank, at a distance of the upper liquid level of the hydraulic fluid due to the larger volume of the degassing tank. This lowers the risk of hydraulic fluid escaping the degassing tank alongside the gas when extracting the gas.

25 In another embodiment, the transfer means may be a membrane connected to the reservoir and movable from one end of the reservoir to another opposite end of the reservoir. By compressing the membrane and pushing the membrane towards the inner sidewalls of the reservoir, the hydraulic fluid is pushed out of the reservoir and into the degassing tank when the closable valve is open. In line therewith, the
30 clamping system may comprise a second pneumatic cylinder connected to the hydraulic cylinder for retracting a hydraulic piston of the hydraulic cylinder in a barrel of the hydraulic cylinder. By pushing the hydraulic piston back into the barrel of the hydraulic cylinder, the hydraulic fluid contained within the barrel is transferred to the reservoir. In particular, if the pressure exerted by this second pneumatic
35 cylinder is larger than the pressure exerted by the transfer means, a maximum of

hydraulic fluid is transferred to the degassing tank. In addition, the pressure exerted by such a second pneumatic cylinder may be controllable. This allows adjustment of the flow rate of hydraulic fluid from within the barrel of the hydraulic cylinder towards the reservoir. This flow rate can be adjusted such that gas bubbles are most effectively transported to the reservoir and subsequently to the degassing tank. Unlike prior art solutions relying on coil springs to retract a piston of a hydraulic cylinder in a barrel, this allows more precise control over the aforementioned flow rate.

10 Additionally or alternatively, the degassing tank may comprise a centrifuge for centrifuging hydraulic fluid. By utilizing a difference in density of hydraulic fluid and gas, gas can effectively be separated from hydraulic fluid by centrifugation. A centrifuge allows the more dense hydraulic fluid to collect at a location farthest away from a centre of rotation of the centrifuge, while the gas collects at a location more close to the centre of rotation. As such, the time required to separate gas from the hydraulic fluid is decreased. In addition, compared to other means of degassing that allow on suction, such as vacuum systems, the risk of evaporation of the hydraulic fluid due to low pressures, and removing these fluids from the hydraulic system, is further reduced.

20 The clamping system may comprise between 300 and 750 ml hydraulic fluid, preferably between 400 and 600 ml at a temperature of 20°C and a pressure of 1 atm. For clamping systems present in moulding systems, these volumes of hydraulic fluid are most optimal.

25 Preferably, the clamping system is a closed fluid system. This means that fluid is unable to enter or exit the system. This has the advantage that hydraulic fluid or vapours thereof are unable to contaminate other equipment or semiconductor products in the vicinity of the clamping system.

30 In yet another embodiment, the clamping system may comprise a detector for detecting or inferring a presence of gas in the at least one channel, hydraulic cylinder, and/or reservoir, and the clamping system may comprise a controller connected to the valve and the transfer means, for transferring hydraulic fluid to the degassing tank when the amount of gas exceeds a predetermined threshold.

Advantageously, this allows the clamping system to automatically and periodically degas the system. As such, pressure build-up in the clamping system due to undesired gas accumulating in the system over time is prevented. As a result, the clamping system continues to function properly over time, as there is no
5 accumulation of gas in the system that impairs proper functioning of the clamping system. As such, performance and reliability of the clamping system is improved.

The clamping system may comprise a vacuum pump connected to the venting opening. The vacuum pump can create a low pressure in the degassing tank. This
10 low pressure facilitates separation of gas and hydraulic fluid, as the tendency of gas dissolved or present as bubbles in the hydraulic fluid to migrate to the vacuum or low pressure zone is increased. As such, the speed of separation of gas and hydraulic fluid is increased and more gas is removed from the hydraulic fluid.

15 The clamping system may comprise at least two groups of hydraulic cylinders and/or at least two pneumatic cylinders. By combining multiple hydraulic cylinders and/or multiple pneumatic cylinders within a single clamping system, the clamping system is more compact. As such, the limited space available in moulding systems that comprise the clamping system is used more effectively. In line therewith, the at
20 least one channel may comprise a first channel and a second channel, the at least one hydraulic cylinder may comprise a first group of hydraulic cylinders and a second group of hydraulic cylinders, and the at least one pneumatic cylinder may comprise a first pneumatic cylinder and a second pneumatic cylinder, and wherein the first channel may be fluidically connected to the first group of hydraulic cylinders
25 and to the first pneumatic cylinder, and wherein the second channel may be fluidically connected to the second group of hydraulic cylinders and to the second pneumatic cylinder, and wherein the first channel and the second channel may be connected to the reservoir, preferably to one single reservoir. Preferably, the first and the second channel are not directly connected to each other. As such, the first
30 channel, the first group of hydraulic cylinders, and the reservoir may form a first closed system when a valve between the second channel and the reservoir is closed. Likewise, the second channel, the second group of hydraulic cylinders, and the reservoir may form a second closed system when another valve between the first channel and the reservoir is closed. By sharing a reservoir between two

(groups of) hydraulic cylinders, each connected to separate channels, the clamping system is more compact, and valuable space is saved.

5 In a second aspect, the present invention relates to a moulding system for encapsulating electronic components, comprising: at least two mould halves, movable towards and away from each other, and a clamping system as specified hereinabove, wherein the hydraulic cylinder is configured to move at least one of the at least two mould halves. The moulding system has all the advantages of the clamping system as specified hereinabove.

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In a third aspect, the present invention relates to a method for degassing hydraulic fluid, comprising the following steps:

- a) providing a clamping system as specified hereinabove,
- b) opening the valve,
- 15 c) transferring hydraulic fluid from the reservoir to the degassing tank,
- d) closing the valve,
- e) degassing the hydraulic fluid in the degassing tank to obtain degassed hydraulic fluid, and
- f) opening the valve and transferring the degassed hydraulic fluid to the
- 20 reservoir.
- g) closing the valve

When the valve between the reservoir and the degassing tank is opened in step b), a fluidic connection is established between the hydraulic fluid and gas present in the reservoir, the at least one channel, and the hydraulic cylinder. Subsequently,

25 hydraulic fluid is transferred from the reservoir to the degassing tank. This transfer can take place by for example pushing a flexible membrane present on the reservoir inwards towards the inner sides of the reservoir. As such, the internal volume of the reservoir is decreased, and hydraulic fluid is pushed out of the reservoir.

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To ensure that the hydraulic fluid is transferred to the degassing tank, the method may optionally comprise a step of pushing a piston of the hydraulic cylinder inside a barrel of the hydraulic cylinder. This pushing action may be performed prior to step c) and after step b). The pushing action may be performed by a second pneumatic

35 cylinder, but also via other means, such as a retracting action of coil springs

attached to the piston and the barrel. As such, hydraulic fluid is forced out of the hydraulic cylinder, through the at least one channel and into the reservoir. From the reservoir, the hydraulic fluid is transferred to the degassing tank and gas, present in the hydraulic fluid, is transferred to the degassing tank along with the hydraulic
5 fluid. Advantageously, a maximum amount of hydraulic fluid present in the reservoir, the at least one channel, and the hydraulic cylinder is as such transferred to the degassing tank where it is degassed after closing the valve. The degassing can occur spontaneously over time, but can also take place by applying a vacuum or via centrifugation as described hereinabove.

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When the hydraulic fluid is degassed it is transferred back to the reservoir after opening the valve. The transfer of hydraulic fluid from and to the reservoir can occur via suitable transfer means, such as pumps, cylinders, or other means. After the degassed hydraulic fluid has been transferred back to the reservoir, the valve is
15 closed, such that a closed fluid system is once again obtained.

Advantageously, this method circumvents the need for servicing the clamping system when gas has built up in the clamping system to such an extent that in hampers proper functioning of the clamping system. As such, the time wherein a
20 machine or device containing the clamping system properly functions is very much increased. In line therewith, in step e) the degassing of the hydraulic fluid may be performed with a vacuum pump. This greatly accelerates separation of gas and hydraulic fluid. In addition, a larger amount of gas is removed from the hydraulic fluid as compared to an equilibrium between dissolved gas and gas present in a
25 headspace of the degassing tank at atmospheric pressure.

In step c) at least 70% of the volume of the hydraulic fluid may be transferred to the degassing tank, more preferably at least 80%, most preferably at least 90%. When a relatively large percentage of the volume of hydraulic fluid is transferred to the
30 degassing tank, all of this fluid can be degassed. As such, it is advantageous for the at least one channel to have a relatively small volume. When more of the hydraulic fluid is degassed, the number of times the hydraulic fluid needs to be degassed is reduced. As a result the time wherein the clamping system properly functions is further increased. To further reduce the effort required to degas
35 hydraulic fluid in the clamping system, steps b) to g) may be performed

automatically by a controller when a detected amount of gas in the at least one channel, hydraulic cylinder, and/or reservoir exceeds a threshold. The detection can occur by for example a pressure sensor connected to the controller. The threshold can be set to provide an optimal trade-off between optimal functioning of the clamping system and time lost due to degassing of the clamping system.

The transfer of hydraulic fluid in steps c) and/or f) may be performed by applying a pressure between 0.1 – 5 bar, preferably 0.3 – 2.5 bar, more preferably 0.4 – 1.2 bar on the hydraulic fluid. A relatively low pressure ensures that the clamping system is not damaged, while these pressures are still sufficient for rapid transfer of the hydraulic fluid in the clamping system.

Additionally or alternatively, a transferred volume of degassed hydraulic fluid in step f) may be controlled by a controller. This allows filling of the hydraulic cylinder, the at least one channel, and the reservoir to such an extent that sufficient space remains for the hydraulic fluid to expand under operating temperatures. These temperatures may be in the range of 50 – 70 °C. From room temperature up to such temperatures, expansion of the hydraulic fluid and its effect on pressure inside the clamping system has to be kept into account.

The invention will be further elucidated on the basis of the non-limitative exemplary embodiments shown in the following figures. Corresponding elements are designated in the figures with corresponding reference numerals. Herein shows:

- Figure 1 a cross sectional view on a clamping system according to the present invention in an operating position;
- Figure 2 a cross sectional view on a clamping system according to the present invention in a degassing position;

Figure 1 shows a cross sectional view on a clamping system 1 according to the present invention comprising a reservoir 2, a channel 3, a pneumatic cylinder 4, a hydraulic cylinder 5, and a degassing tank 6. The clamping system 1 contains hydraulic fluid 7 that is present in the reservoir 2, the channel 3, and in a barrel 8 of the hydraulic cylinder 5. The clamping system 1 as shown in Figure 1 is in operation. The pneumatic cylinder 4 (partly cutaway) comprises a pneumatic piston

9 having two opposite outer ends 10, 11. An upper surface 12 of the first outer end 10 is much larger than an upper surface 13 of the second outer end 11 of the pneumatic piston 9. Air 14 is pumped in the pneumatic cylinder 4, driving the piston 9, and in particular the second outer end 11 thereof towards the hydraulic cylinder 5. A surface area ratio between the upper surface 12 of the first outer end 10 and the upper surface 13 of the second outer end 11 is about 100:1.

The surface area ratio of about 100:1 ensures that a pressure of the air 14 inside the pneumatic cylinder 4 is converted to a pressure of the hydraulic fluid 7 inside the channel 3 and the barrel 8 of the hydraulic cylinder 5 that is a factor 100 higher. To prevent hydraulic fluid 7 from exiting the channel 3 and entering the reservoir 2, a reservoir valve 15 is present in the clamping system 1. Likewise, to prevent hydraulic fluid 7 from exiting the channel 3 and entering the degassing tank 6, a degassing tank valve 16 is present.

Air 14 has been pumped in the reservoir 2 at one side of a flexible membrane 17 by a pump 18. The pump 18 has provided a relatively low pressure of 1 bar to add additional hydraulic fluid to the channel 3 and a major part of the barrel 8 of the hydraulic cylinder 5 with hydraulic fluid, such that the hydraulic piston 19 has moved upwards in contact with a component to be clamped (not shown). The pneumatic piston 9 further forces the hydraulic piston 19 upwards after closure of the valves 15, 16 at a much higher pressure of about 600 bar. Due to the relatively small volume of hydraulic fluid 7 displaced by the second outer end 11 of the pneumatic piston 9, the hydraulic piston 19 is further urged upwards by a small distance. Due to the surface area ratio between the upper surface 12 of the first outer end 10 and the upper surface 13 of the second outer end 11 of about 100:1, the relatively small distance covered by the hydraulic piston 19 occurs at a high pressure.

Figure 2 shows a cross sectional view of the clamping system 1 in a degassing position. Both the reservoir valve 15 and the degassing tank valve 16 are in an open position. The hydraulic piston 19 is urged downwards with a pressure that exceeds a pressure urging the membrane 17 of the reservoir 2 towards the reservoir valve 15. This downward urging may be effected via coil springs or via a separate pneumatic cylinder (both not shown). A majority of the hydraulic fluid 7

- has been transferred to the degassing tank 7 and air 14 in the form of bubbles is present in the hydraulic fluid. A venting valve 20 has been opened in a venting tube 21. Air 14 is allowed to exit the degassing tank 6 via the venting tube 21. A vacuum pump may be connected to the venting tube 21 to accelerate this process. The
- 5 second outer end 11 of the pneumatic piston 9 has been moved downwards, such that hydraulic fluid 7 can be transferred from both the barrel 8 of the hydraulic cylinder 5 and from the reservoir 2 to the degassing tank 6.

Claims

1. Clamping system for clamping two mould halves together, comprising:
 - a reservoir for containing hydraulic fluid,
 - 5 - at least one hydraulic cylinder,
 - at least one channel that is fluidically connected to the reservoir and the hydraulic cylinder, and
 - at least one pneumatic cylinder comprising a piston and a barrel,
 - wherein the piston is movable within the at least one channel and within the
 - 10 barrel,

characterized in that,

the clamping system comprises a degassing tank fluidically connected via a closable valve to the reservoir, and

a transfer means for transferring fluid from the reservoir via the valve to the

 - 15 degassing tank.
2. Clamping system according to claim 1, **characterized in that** the degassing tank comprises a closable venting opening.
- 20 3. Clamping system according to claim 1 or 2, **characterized in that** the internal volume of the degassing tank is larger than 80% of a total volume of hydraulic fluid containable in the at least one channel, the hydraulic cylinder and the reservoir, preferably larger than 100%, more preferably larger than 120%, and most preferably larger than 150%.
- 25 4. Clamping system according to any one of claims 1 – 3, **characterized in that** the transfer means is a membrane connected to the reservoir and movable from one end of the reservoir to another opposite end of the reservoir.
- 30 5. Clamping system according to any one of claims 1 – 4, **characterized in that** the clamping system comprises a second pneumatic cylinder connected to the hydraulic cylinder for retracting a hydraulic piston of the hydraulic cylinder in a barrel of the hydraulic cylinder.

6. Clamping system according to any one of claims 1 – 5, **characterized in that** the degassing tank comprises a centrifuge for centrifuging hydraulic fluid.
7. Clamping system according to any one of claims 1 – 6, **characterized in that** the clamping system comprises between 300 and 750 ml hydraulic fluid, preferably between 400 and 600 ml at a temperature of 20°C and a pressure of 1 atm.
8. Clamping system according any one of claims 1 – 7, **characterized in that** the clamping system is a closed fluid system.
9. Clamping system according to any one of claims 1 – 8, **characterized in that** the clamping system comprises a detector for detecting or inferring a presence of gas in the at least one channel, hydraulic cylinder, and/or reservoir, and
10. Wherein the clamping system comprises a controller connected to the valve and the transfer means, for transferring hydraulic fluid to the degassing tank when the amount of gas exceeds a predetermined threshold.
10. Clamping system according to any one of claims 1 – 9, **characterized in that** the clamping system comprises a vacuum pump connected to the closable venting opening.
11. Clamping system according to any one of claims 1 – 10, **characterized in that** the clamping system comprises at least two groups of hydraulic cylinders and/or at least two pneumatic cylinders.
12. Clamping system according to any one of claims 1 – 11, **characterized in that** the at least one channel comprises a first channel and a second channel, the at least one hydraulic cylinder comprises a first group of hydraulic cylinders and a second group of hydraulic cylinders, and the at least one pneumatic cylinder comprises a first pneumatic cylinder and a second pneumatic cylinder, and
- wherein the first channel is fluidically connected to the first group of hydraulic cylinders and to the first pneumatic cylinder, and wherein the second channel is fluidically connected to the second group of hydraulic cylinders and to the second pneumatic cylinder, and

wherein the first channel and the second channel are connected to the reservoir.

13. Moulding system for encapsulating electronic components, comprising:
 5 at least two mould halves, movable towards and away from each other,
 characterized in that,
 the moulding system comprises a clamping system according to any one of
 claims 1 – 12, wherein the hydraulic cylinder is configured to move at least one of
 the at least two mould halves.
14. Method for degassing hydraulic fluid, comprising the following steps:
 10 a) providing a clamping system according to any one of claims 1 – 12,
 b) opening the valve,
 c) transferring hydraulic fluid from the reservoir to the degassing tank,
 15 d) closing the valve,
 e) degassing the hydraulic fluid in the degassing tank to obtain degassed
 hydraulic fluid, and
 f) opening the valve and transferring the degassed hydraulic fluid to the
 reservoir.
- 20 g) closing the valve
15. Method according to claim 14, **characterized in that** in step e) the
 degassing of the hydraulic fluid is performed with a vacuum pump.
- 25 16. Method according to claim 14 or 15, **characterized in that** in step c) at least
 70% of the volume of the hydraulic fluid is transferred to the degassing tank, more
 preferably at least 80%, most preferably at least 90%.
17. Method according to any one of claims 14 – 16, **characterized in that** steps b)
 30 to g) are performed automatically by a controller when a detected amount of gas in
 the at least one channel, hydraulic cylinder, and/or reservoir exceeds a threshold.
18. Method according to any one of claims 14 – 17, **characterized in that** the
 transfer of hydraulic fluid in steps c) and/or f) is performed by applying a pressure

between 0.1 – 5 bar, preferably 0.3 – 2.5 bar, more preferably 0.4 – 1.2 bar on the hydraulic fluid.

19. Method according to any one of claims 14 – 18, **characterized in that** a
5 transferred volume of degassed hydraulic fluid in step f) is controlled by a controller.