

(22) Date of filing: **11.10.2021**

(71) Applicant: **Welltec A/S**
3450 Allerød (DK)

(72) Inventor: **ANDERSEN, Tomas Sune**
3450 Allerød (DK)

(74) Representative: **Dragsted Partners A/S**
Rådhuspladsen 16
1550 Copenhagen V (DK)

further comprises a second downhole self-propelling wireline tool (1b), having similar construction as the first self-propelling tool, wherein each electric motor of the first and second tools comprises a power-limiting unit (31) in order to distribute a first part of the current from the wireline to power the first electric motor and a second part of the current to power the second electric motor.



Description

[0001] The present invention relates to a downhole self-propelling wireline tool string for being connected to and powered by a wireline for propelling a tool forward in a well and/or for providing weight on a bit while performing an operation comprising a first downhole self-propelling wireline tool.

[0002] Well intervention is carried out for various reasons for performing an operation such as pulling a sleeve, milling a nipple, pulling or setting a plug, and is carried out by means of a self-propelling driving unit propelling the operational tool forward in the well. While propelling the tool forward in the well, the driving unit also needs to pull the wireline with it, and as the tool is driven further and further down the well, the power for pulling the wireline increases. Due to the fact that the wireline is rated to the maximum allowable current limit, the speed of the driving unit in the last part of the well is calculated based on the power available in the last part of the well for being able also pull the wireline, and the driving unit is adjusted at surface to drive the calculated speed, even though more power is available in the first part of the well where less power is needed for pulling the wireline as the wireline is shorter. In order to be able to provide sufficient pulling force for pulling the wireline, the self-propelling driving unit is hydraulically driven and has wheels on wheel arms where each wheel is driven by a hydraulic motor in the wheel, and the wheel is pressed against the wall of the casing or the borehole also by means of hydraulics.

[0003] When the hydraulic self-propelling driving unit needs to propel down in a more inaccessible, deviated or horizontal part of the well to the position in which the operation is to be performed, more pulling force is needed in the last part of the well, and then more hydraulically driven drive sections are added, providing more wheels engaging the wall of the well to provide more pulling force. In the known hydraulic self-propelling driving units, the pulling force is approximately doubled when one more drive section is added, but the speed of the self-propelling driving unit is reduced by half.

[0004] In order to increase the speed in the top part of the well, some hydraulic self-propelling driving units have a first section of drive sections and a second section of drive sections, and when driving in the first part of the well the second section is turned off so that all power is distributed to the first section, and in this way the self-propelling driving unit is capable of driving at a higher speed than when both sections are activated. Such driving units can then drive at two different speeds and still provide the pulling force needed in the bottom part of the well.

[0005] It is an object of the present invention to wholly or partly overcome the above disadvantages and drawbacks of the prior art. More specifically, it is an object to provide an improved hydraulically driven self-propelling wireline tool string being able to provide the maximum

available pulling force due to current restriction in the wireline without reducing the ability to drive fast.

[0006] The above objects, together with numerous other objects, advantages and features, which will become evident from the below description, are accomplished by a solution in accordance with the present invention by a downhole self-propelling wireline tool string for being connected to and powered by a wireline for propelling a tool forward in a well and/or for providing weight on a bit while performing an operation comprising a first downhole self-propelling wireline tool, comprising:

- a first tool body,
- a first electric motor operating at a rotational speed,
- a first electric control unit for controlling the rotational speed of the electric motor,
- one first drive section, comprising
 - a plurality of projectable arm assemblies movably connected at a first arm end with the tool body and projectable from the tool body by means of a first fluid having a first fluid pressure, and
 - a plurality of wheels for contacting a wall of the well, each wheel comprising a hydraulic motor for rotation of the wheel and providing a self-propelling movement, and each wheel being connected with a second arm end of one of the arm assemblies,
- a first hydraulic pump driven by the electric motor for generation of a second fluid pressure for driving the hydraulic motor(s) rotating the wheel(s), and

[0007] wherein the downhole self-propelling wireline tool string further comprises a second downhole self-propelling wireline tool, comprising:

- a second tool body,
- a second electric motor operating at a rotational speed,
- a second electric control unit for controlling the rotational speed of the electric motor,
- one second drive section, comprising:
 - a plurality of projectable arm assemblies movably connected at a first arm end with the tool body and projectable from the tool body by means of a first fluid having a third fluid pressure, and
 - a plurality of wheels for contacting the wall of the well, each wheel comprising a hydraulic motor for rotation of the wheel, and each wheel being connected with a second arm end of one of the arm assemblies,
- at least one second hydraulic pump driven by the second electric motor for generation of a fourth fluid

pressure for driving the hydraulic motor(s) rotating the wheel(s), and

wherein each electric motor comprises a power-limiting unit in order to distribute a first part of the current from the wireline to power the first electric motor and a second part of the current to power the second electric motor.

[0008] In addition, the power-limiting unit may be a current-limiting unit limiting the current supplied to the electric motor.

[0009] Also, the power-limiting unit may be a current limiter.

[0010] Furthermore, the power limiting-unit or the current-limiting unit may not be a relay or on-off switch.

[0011] Additionally, the downhole self-propelling wireline tool string may comprise a current distribution unit in order to distribute a first part of the current from the wireline to power the first electric motor and a second part of the current to power the second electric motor.

[0012] Further, the downhole self-propelling wireline tool string may comprise a current distribution unit instead of the power-limiting units in order to distribute a first part of the current from the wireline to power the first electric motor and a second part of the current to power the second electric motor.

[0013] Moreover, the current distribution unit may distribute the current so that the first downhole self-propelling wireline tool and the second downhole self-propelling wireline tool equally consume the current from the wireline when the downhole self-propelling wireline tool string is activated.

[0014] Also, the first downhole self-propelling wireline tool and the second downhole self-propelling wireline tool may be configured to consume an equal part of the current from the wireline when the downhole self-propelling wireline tool string is activated.

[0015] Furthermore, the first drive section may be rotated 90 degrees from the second drive section so that the projectable arm assemblies of the first drive section are rotated 90 degrees from the projectable arm assemblies of the second drive.

[0016] Additionally, the first electric control unit may be connected to the first electric motor, which is connected to the first hydraulic pump, which is connected with the first drive section.

[0017] Further, the first drive section may be connected to the second electric control unit or the second electric motor of the second downhole self-propelling wireline tool.

[0018] Moreover, the first downhole self-propelling wireline tool may further comprise a first pressure sensor continuously measuring the second fluid pressure, and the hydraulic section may comprise a first controllable valve controlling the first fluid pressure based on the second fluid pressure.

[0019] By having a first controllable valve controlling the first fluid pressure based on the second pressure, the wheels are not pressed more outwards than needed. The

higher the second pressure, the higher the first pressure needs to be. When having a low second pressure, the first pressure is adjusted to match the low second pressure so that power is not wasted on providing a first fluid pressure higher than needed. Furthermore, if the first fluid pressure is higher than the optimal first fluid pressure matching the present second fluid pressure, then too much friction is applied to the wall of the well, compromising the maximum available velocity of the downhole driving unit.

[0020] In addition, the first hydraulic section may further comprise a second pressure sensor for measuring the first fluid pressure.

[0021] Also, the first hydraulic section may further comprise a second controllable valve controlling the second fluid pressure.

[0022] Furthermore, the second downhole self-propelling wireline tool may further comprise a third pressure sensor measuring the fourth fluid pressure and a second hydraulic section comprising a third controllable valve controlling the third fluid pressure based on the fourth fluid pressure.

[0023] Additionally, the second hydraulic section may further comprise a third pressure sensor for measuring the fourth fluid pressure.

[0024] Further, the second hydraulic section may also comprise a fourth pressure sensor for measuring the third fluid pressure.

[0025] Moreover, the second hydraulic section may comprise a fourth controllable valve controlling the fourth fluid pressure.

[0026] In addition, the first downhole self-propelling wireline tool may be connected in one end with the wireline and in another end with the second downhole self-propelling wireline tool.

[0027] Also, the first downhole self-propelling wireline tool may comprise two first drive sections, and the second downhole self-propelling wireline tool may comprise two second drive sections.

[0028] Furthermore, compared to a known self-propelling wireline tool with only one motor and one pump for four drive sections, the self-propelling wireline tool string according to the present invention drives at least twice as fast and preferably almost four times as fast, but pulls the same force as four drive sections.

[0029] Additionally, the first downhole self-propelling wireline tool may comprise a first hydraulic pump generating the first fluid pressure for projection of the plurality of projectable arm assemblies of the first drive section, and the second downhole self-propelling wireline tool may comprise a second hydraulic pump generating the third fluid pressure for projection of the plurality of projectable arm assemblies of the second drive section.

[0030] Further, the first hydraulic pump may generate the first fluid pressure for projection of the plurality of projectable arm assemblies of the first drive section, and the second hydraulic pump may generate the third fluid pressure for projection of the plurality of projectable arm

assemblies of the second drive section.

[0031] Moreover, a fluid channel for the first fluid or the third fluid for projecting the arm assemblies from the tool body may have a first inner channel diameter, and the drive section may have an outer drive section diameter, where the ratio between the first inner channel diameter and the outer drive section diameter is higher than 0.3/10, preferably higher than 0.4/10, and more preferably higher than 0.5/10.

[0032] In addition, a second channel for the second fluid or the fourth fluid for driving the hydraulic motor(s) rotating the wheel(s) may have a second inner channel diameter, and the drive section may have an outer drive section diameter, where the ratio between the second inner channel diameter and the outer drive section diameter is higher than 0.5/10, preferably higher than 0.8/10, and more preferably higher than 1.0/10.

[0033] Also, the controllable valve(s) may be electronically controllable by means of the electric control unit.

[0034] Finally, the current distribution unit may be arranged in the first electric control unit.

[0035] The invention and its many advantages will be described in more detail below with reference to the accompanying schematic drawings, which for the purpose of illustration show some non-limiting embodiments and in which:

Fig. 1 shows two separately working downhole self-propelling wireline tools mounted as one downhole self-propelling wireline tool string according to the invention,

Fig. 2 shows another downhole self-propelling wireline tool string,

Fig. 3 shows yet another downhole self-propelling wireline tool string having an operational tool with a bit,

Fig. 4 shows a downhole self-propelling wireline tool control method for controlling the downhole self-propelling wireline tool string according to the present invention with some optional steps,

Fig. 5 shows another downhole self-propelling wireline tool control method with some optional steps for performing an operation downhole,

Fig. 6 shows another downhole self-propelling wireline tool control method, and

Fig. 7 shows a graph of the power curve in relation to the pulling force and the speed of the tool.

[0036] All the figures are highly schematic and not necessarily to scale, and they show only those parts which are necessary in order to elucidate the invention, other parts being omitted or merely suggested.

[0037] Fig. 1 shows a downhole self-propelling wireline tool string 1 for propelling a tool forward in a well 2 and potentially also for providing weight on a bit 39 while performing an operation, as shown in the tool string 1 of Fig. 4. The tool string 1 of Fig. 1 is thus two separately driven downhole self-propelling wireline tools mounted as one wireline tool string, where each wireline tool has a separate electric control unit, a separate electric motor, one or two hydraulic pumps, a hydraulic section 15, and one or more drive sections 30.

[0038] The first downhole self-propelling wireline tool 1a comprises a tool body 3, 3a, 3b, a first electric control unit 18 controlling a first electric motor 4 operating at a rotational speed and powered by a wireline 5. The first downhole self-propelling wireline tool 1a further comprises a plurality of projectable arm assemblies 6 movably connected at a first arm end 7 with the tool body 3 and projectable from the tool body 3 by means of a first fluid having a first fluid pressure, and a plurality of wheels 8 for contacting a wall 9 of the well, each wheel 8 comprising a hydraulic motor 10 for rotation of the wheel and providing a self-propelling movement, and each wheel being connected with a second arm end 11 of one of the arm assemblies 6. The first electric motor 4 is configured to drive a first hydraulic pump 12 for generation of a second fluid pressure for driving the hydraulic motor(s) 10 rotating the wheel(s) 8. The second downhole self-propelling wireline tool 1b comprises a second electric control unit 18b, a second electric motor 22, a second hydraulic pump 14, a second hydraulic section 25, and a second drive section 30b with wheels 24 on arm assemblies 23. The plurality of projectable arm assemblies 23 are movably connected at a first arm end 7b with the tool body 3b, and each wheel 24 comprises a hydraulic motor 10b for rotation of the wheel and provides a self-propelling movement, each wheel 24 being connected with a second arm end 11b of one of the arm assemblies 23. The first downhole self-propelling wireline tool 1a is connected to a cable head 44 and the wireline 5, and the downhole self-propelling wireline tool string 1 is a downhole hydraulically driven self-propelling wireline tool string. The downhole self-propelling wireline tool 1a is connected to a second end 47 of the wireline 5, a first end of the wireline being connected to a power supply (not shown) at the surface or seabed.

[0039] Each electric motor 4, 22 of the downhole self-propelling wireline tool string 1 further comprises a power-limiting unit 31, e.g. a current-limiting unit, in order to limit each motor in pulling more power than needed for driving also the second downhole self-propelling wireline tool 1b and thus distributing a first part of the current from the wireline to power the first electric motor 4 and a second part of the current to power the second electric motor 22. The first downhole self-propelling wireline tool 1a and the second downhole self-propelling wireline tool 1b are electrically connected in parallel so that each wireline tool 1a, 1b can pull what is required to drive at the same speed.

[0040] By having an electric motor and pump for each drive section, the downhole self-propelling wireline tool string 1 is able to drive at full speed as one drive section and with double pulling force as two drive sections. This is due to the fact that the pumped fluid does not have to travel past one drive section to be delivered to the next, and thus no energy is wasted in the transition from one drive section to the next drive section. By having one pump for one drive section, the diameter of the fluid channels in the drive section can be made larger than when the pump has to provide fluid to more than one drive section. The overall diameter of the tool string 1 is limited by the well, and the pump is therefore often a limiting factor as more pumping capability would require a larger diameter; by having only one drive section, the pumping force is used directly, and the fluid channel can be made larger, for which reason the limited current in the wireline is used more efficiently than in the known tool strings where several drive sections are driven by one pump.

[0041] When intervening a well, the tool string is often restricted also in length by the rig height and/or a lubricator length, which is why there has been a tendency to avoid duplicates and merely add further drive sections to increase the pulling force as this does not lead to an unnecessary increase in the tool length.

[0042] Furthermore, the low oil price has also led to a focus on offering tool strings with less expensive parts to provide more cost-effective well intervention without focusing on the amount of time spent on the intervention. However, with an increasing oil price the focus has changed from costs to faster intervention. By having drive sections with an individual motor and pump, the tool string is much more expensive, but the intervention is made much faster without reducing the pulling force.

[0043] By each electric motor 4, 22 having a power-limiting unit 31, one drive section does not have to be switched off as both motors drive at the power needed until the motors meet the current limitation, each first and second downhole self-propelling wireline tools 1a, 1b thus being able to propel at a maximum speed until restricted by the power, e.g. the current, available, whereupon the speed and force are continuously adjusted to match the need for pulling the wireline.

[0044] The known self-propelling units can be driven at two different speeds, and in order to avoid exceeding the current limit when driving at all drive sections, the tool string propels at the lowest speed. By having an electric motor and pump for each drive section as in the present invention, each motor is only limited if reaching the current limit, so that each drive section drives at maximum speed and force until restricted.

[0045] The downhole self-propelling wireline tool string 1 may also comprise a current distribution unit 21 in order to distribute a first part of the current from the wireline to power the first electric motor 4 and a second part of the current to power the second electric motor 22. The power to the tool string 1 is thus divided equally between the first and second electric motors 4, 22 so that each motor

is limited to half of the current limit, and the tool string does not exceed the allowed current limit on the wireline 5. The current distribution unit 21 may replace the power-limiting unit 31 in each electric motor 4, 22 or may be a supplement to the power-limiting units.

[0046] The first downhole self-propelling wireline tool 1a further comprises a second pressure sensor 49 continuously measuring the second fluid pressure, and a hydraulic section 15 comprises a first controllable valve 16 controlling the first fluid pressure based on the second pressure. As shown in Fig. 1, the first hydraulic section 15 further comprises a second controllable valve 17 controlling the second fluid pressure. The first hydraulic section 15 is configured to measure the second fluid pressure by means of the first pressure sensor 49 and further comprises a second pressure sensor 48 for measuring the first fluid pressure. The second hydraulic section 25 further comprises a third controllable valve 26 controlling the third fluid pressure and a fourth controllable valve 27 controlling the fourth fluid pressure. The second hydraulic section 25 is configured to measure the third and fourth fluid pressures by means of the third pressure sensor 48b and the fourth pressure sensor 49b, respectively, and to control the valves based on the measured third and fourth fluid pressures. The controllable valve(s) 16, 17, 26, 27 is/are a controllable pressure relief valve(s).

[0047] By having a first controllable valve 16 controlling the first fluid pressure based on the second pressure, the wheels 8 are not pressed more outwards than needed. The higher the second pressure, the higher the first pressure needs to be in order to propel the downhole self-propelling wireline tool string 1 forward in the well in the most optimal manner. When having a low second pressure, the first pressure is adjusted to match the low second pressure so that power is not wasted on providing a first fluid pressure higher than needed. Furthermore, if the first fluid pressure is higher than the optimal first fluid pressure matching the present second fluid pressure, then too much friction is applied to the wall of the well, compromising the maximum available velocity of the downhole self-propelling wireline tool string 1.

[0048] In Fig. 1, the first hydraulic pump 12 generates the first fluid pressure for projection of the plurality of projectable arm assemblies 6, and in Fig. 2 the first and second downhole self-propelling wireline tools 1a, 1b each comprises the first hydraulic pump 12 for generation of the second fluid pressure for driving the hydraulic motor(s) rotating the wheel(s) and the second hydraulic pump 14 for generation of the first fluid pressure for projection of the plurality of projectable arm assemblies 6.

[0049] In Fig. 1, each of the electric control units 18, 18b controls the rotational speed of the electric motors 4, 22 and thus also the rotational speed of the pumps, and thereby also the tool speed of the downhole self-propelling wireline tool string 1 along the longitudinal extension of the well as the pumps generate a fluid flow into the wheels 8. At the beginning of the well, closest to the top of the well, the downhole self-propelling wireline

tool string 1 requires very little force for pulling the wireline 5 along with the tool string 1, but as the downhole self-propelling wireline tool string 1 proceeds down the well, the tool string 1 requires an increasing amount of force for pulling the wireline 5. As the force increases, the wheels 8 need a higher pressure to rotate, and the pumps thus need more rotational force, i.e. motor output torque, from the first and second motors 4, 22, respectively. Wirelines used for intervention operations where such downhole self-propelling wireline tool string 1 is used are rated to a maximum current limit depending on the wireline length and other wireline parameters. Thus, it is important that such current limit is not exceeded. Knowing of the voltage either by assumption, calculation or measurement, a power limit P of the operation is also known, and this power limit P is shown in Fig. 7. When the motor output torque increases, the current demand increases correspondingly, and when the current limit is reached, the downhole self-propelling wireline tool string 1 needs to reduce its speed, i.e. move along the power limit curve in Fig. 7. This is performed in several ways, where one very simple way is illustrated in Fig. 4.

[0050] In Fig. 4, a method 100 for controlling the downhole self-propelling tool string 1 is illustrated. The method comprises running 110 a downhole self-propelling wireline tool string 1 into a wellbore, supplying 120 electric power to the downhole self-propelling wireline tool string to operate the downhole self-propelling wireline tool string at a first speed to urge the downhole self-propelling wireline tool string through the wellbore at a first force, then determining 130 a motor output torque of the motors, and determining 140 a maximum allowable motor rotational speed based on the motor output torque, for comparing 150 the operational rotational speed with the maximum allowable motor rotational speed. The control method 100 further comprises adjusting 160 the operational rotational speed of the electric motors based on the comparison in order to adjust the first speed to a second speed if the operational rotational speed is higher than the maximum allowable motor rotational speed. The operational rotational speed of the first and second motors are regulated simultaneously with the same operational rotational speed.

[0051] Thereby, a very simple way of adjusting the speed of the hydraulically driven downhole self-propelling wireline tool string 1 is provided, as only the motors are adjusted to limit the speed, and the more complex hydraulic sections 15, 25 merely adjust the first controllable valve 16 for controlling the first fluid pressure based on the second pressure and the third controllable valve 26 for controlling the third fluid pressure based upon the fourth fluid pressure, thus optimising to ensure that sufficient power is provided to project the wheel arms, but not more than needed. The speed of the hydraulically driven downhole self-propelling wireline tool string 1 is thus adjusted continuously using all available power, i.e. below the current limit, either for driving at a maximum speed or at the required force and the corresponding

maximum allowable speed, and the hydraulically driven downhole self-propelling wireline tool string 1 is able to drive at maximum speed until the force to pull the wireline increases to a first force F1 at the power limit curve P in Fig. 7, above which first force F1 the speed and thus the rotational speed of the electric motors need to be reduced so that the current limit is not exceeded. The hydraulically driven downhole self-propelling wireline tool string is thus controlled to continuously adjust its speed to a maximum without exceeding the current limit of the wireline. By having first and third controllable valves 16, 26 controlling the first and third fluid pressures based on the second and fourth pressures, the continuous control of the hydraulically driven downhole self-propelling wireline tools 1a, 1b are optimised even further so that no power is wasted on projecting the arm assemblies 6, 23 out towards the wall of the well other than what is needed for optimal friction between the wheels 8, 24 and the wall to drive the hydraulically driven downhole self-propelling wireline tool string 1 forward.

[0052] The step of running 110 comprises running both the first and second downhole self-propelling wireline tools 1a, 1b into a wellbore 2, and step of supplying 120 electric power comprises supplying electric power to both the first and second downhole self-propelling wireline tools to operate the first and second downhole self-propelling wireline tools at a first speed to urge the tool string through the wellbore at a first force, and the step of determining 130 comprises determining a motor output torque of both the first and second electric motors 4, 22, and the step of determining 140 comprises determining a maximum allowable motor rotational speed based on the motor output torque of both the first and second electric motors 4, 22, and the step of comparing 150 comprises comparing the operational rotational speed of both the first and second electric motors 4, 22 with the maximum allowable motor rotational speed, and the step of adjusting 160 comprises adjusting the operational rotational speed of both the first and second electric motors 4, 22 based on the comparison in order to adjust the first speed to a second speed if the operational rotational speed is higher than the maximum allowable motor rotational speed. The current available is distributed so that the first electric motor 4 is limited by one half, and the second electric motor 22 is limited by the other half of the maximum current limit. In this way, the motors are operated to run at the same operational rotational speed, consuming a maximum of half the maximum current limit.

[0053] The power-limiting units 31 and/or the current distribution unit 21 can distribute the current so that the first downhole self-propelling wireline tool 1a and the second downhole self-propelling wireline tool 1b equally consume the current from the wireline when the downhole self-propelling wireline tool string 1 is activated. Therefore, the first downhole self-propelling wireline tool 1a and the second downhole self-propelling wireline tool 1b are configured to consume an equal part of the current from the wireline when the downhole self-propelling wire-

line tool string 1 is activated.

[0054] In Fig. 7, the maximum speed of the hydraulically driven downhole self-propelling wireline tool string 1 is based on the maximum allowed rotational speed of the electric motors 4, 22, and the maximum force is based on the minimum allowed rotational speed of the electric motors.

[0055] Each electric control unit 18, 18b comprises a motor driver 28, a master and/or a voltage inverter. The power or current-limiting unit 31 may be arranged in the motor driver 28. As shown in Fig. 4, the electric control units, determine 145 or the motor drivers 28 measure 145a an operational rotational speed of the electric motors 4, 22, and the motor drivers 28 are configured to measure 125 current over the three phases in the motors for the electric control units 18, 18b to determine 130 a motor output torque of the electric motors 4, 22. The electric control units 18, 18b are configured to determine 140 a maximum allowable motor rotational speed based on the motor output torque and to compare 150 the operational rotational speed with the maximum allowable motor rotational speed and then adjust 160 the operational rotational speed of the electric motors 4, 22 based on the comparison in order to adjust the first speed to a second speed if the operational rotational speed is higher than the maximum allowable motor rotational speed. Optionally, determining 140 a maximum allowable motor rotational speed based on the motor output torque is also based on preset values 142 for maximum power or maximum current. Furthermore, the electric control units 18, 18b may measure 135 a current demand/input of the motor and measure 135b a voltage input of the electric motors 4, 22; and determining 140 a maximum allowable motor speed based on the motor output torque may thus also be based on a measured current and a measured voltage of the electric motors.

[0056] By measuring the actual current demand and the voltage at each electric motor 4, 22, the maximum allowable motor speed can be determined more precisely as the efficiency of the electric motor varies depending on the operational rotational speed of the electric motor. Thus, at a high rotational speed, the current demand is lower than when rotating at a low rotational speed, and the maximum power may therefore vary, being somewhat larger at high rotational speed than when assuming that the maximum power is constant.

[0057] The method as shown in Fig. 4 may further comprise controlling 170 the first fluid pressure based on the second fluid pressure by means of the first controllable valve 16 in the first hydraulic section 15 of the first downhole self-propelling wireline tool 1a and the third fluid pressure based on the fourth pressure by means of the third controllable valve 26 in the second hydraulic section 25 of the second downhole self-propelling wireline tool 1b. The method may optionally further comprise determining 180 the load of motors based on the torque output.

[0058] As can be seen in Fig. 1, the first downhole self-propelling wireline tool string 1 has two wheel sec-

tions 30a, 30b where one is rotated 90 degrees in relation to the other in order to centralise the tool in the well along the circumference of the tool string 1. Thus, the first drive section 30a is rotated 90 degrees from the second drive section 30b so that the projectable arm assemblies 6 of the first drive section 30a are rotated 90 degrees from the projectable arm assemblies 23 of the second drive section 30b. In another embodiment, both the first downhole self-propelling wireline tool 1a and the second downhole self-propelling wireline tool 1b comprise a first drive section 30a and a second drive section 30b which are rotated 90 degrees in relation to each other. The first electric motor 4 and/or the second electric motor 22 is/are a synchronic motor(s). Thus, the first downhole self-propelling wireline tool 1a comprises two first drive sections 30a, and the second downhole self-propelling wireline tool 1b comprises two second drive sections 30b. Compared to a known self-propelling wireline tool with only one motor and one pump for four drive sections, the self-propelling wireline tool string 1 according to the present invention runs at least twice as fast and preferably almost four times as fast, but pulls the same force as four drive sections.

[0059] The tool string of Fig. 2 is thus two downhole self-propelling wireline tools 1a, 1b mounted as one wireline tool where each has a separate electric control unit 18, 18b, a separate electric motor 4, 22, two hydraulic pumps 12, 14, a hydraulic section 15, 25, and one drive section 30, 30a, 30b. The first downhole self-propelling wireline tool 1a comprises the electric control unit 18, the electric motor 4, two hydraulic pumps 12, 14, the first hydraulic section 15, and the drive section 30, 30a with wheels 8 on arm assemblies 6. The second downhole self-propelling wireline tool 1b comprises the electric control unit 18b, the electric motor 22, two hydraulic pumps 12, 14, the hydraulic section 25, and the drive section 30, 30b with wheels 24 on arm assemblies 23. The first downhole self-propelling wireline tool 1a is connected to the cable head 44 and the wireline 5. The hydraulic section 15 is configured to measure the first and second fluid pressures by means of the first pressure sensor 49 and the second pressure sensor 48 and to control the valves based on the measured first and second fluid pressures. The second hydraulic section 25 is configured to measure the third and fourth fluid pressures by means of the third pressure sensor 48b and the fourth pressure sensor 49b and to control the valves based on the measured third and fourth fluid pressures. The controllable valve(s) 16, 17, 26, 27 is/are a controllable pressure relief valve(s). The power to the tool string is thus divided equally between the first and second electric motors 4, 22 so that each motor is limited to half of the current limit to ensure that the tool string 1 does not exceed the allowed current limit on the wireline. The current distribution unit 21 is arranged in the first electric control unit 18.

[0060] As shown in Figs. 1-3, the first drive section 30a is connected to the second electric control unit 18b, or in another embodiment to the second electric motor 22 of

the second downhole self-propelling wireline tool 1b. Thus, the first downhole self-propelling wireline tool 1a is connected in one end with the wireline and in another end with the second downhole self-propelling wireline tool 1b.

[0061] By having one pump to each drive section 30a, 30b, the diameter of the fluid channels in the drive sections can be made much larger than in the known tools where one pump has to provide fluid to all drive sections. By having only one drive section for each pump, the fluid channels can be made larger, and the limited current in the wireline is thus used more efficiently than in known tool strings where all drive sections are driven by one pump. In the present invention, a fluid channel for the first fluid or the third fluid for projecting the arm assemblies 6, 23 from the tool body 3 has a first inner channel diameter, and the drive section has an outer drive section diameter, where the ratio between the first inner channel diameter and the outer drive section diameter is higher than 0.3/10, preferably higher than 0.4/10, and more preferably higher than 0.5/10. A second channel for the second fluid or the fourth fluid for driving the hydraulic motor(s) 10, 10b rotating the wheel(s) 8, 24 has a second inner channel diameter, and the ratio between the second inner channel diameter and the outer drive section diameter is higher than 0.5/10, preferably higher than 0.8/10, and more preferably higher than 1.0/10.

[0062] The downhole self-propelling wireline tool string 1 further comprises a compensator 35 for providing a predetermined overpressure in the tool so that the well fluid does not enter into the tool and jeopardise the function of the tool, and so that the dirty well fluid is not mixed with the hydraulic fluid in the tool.

[0063] As shown in Fig. 1, the downhole self-propelling wireline tool string 1 further comprises a surface readout module 29 communicating instructions from surface to each tool and sending measured tool parameters, such as the first fluid pressure, the second fluid pressure, the third fluid pressure, the fourth fluid pressure, the operational rotational speed of the electric motors 4, 22, and/or the motor output torque to surface.

[0064] In Fig. 3, the downhole self-propelling wireline tool string 1 comprises an operational tool 38 such as a logging tool 38b (shown in Fig. 2) or a machining tool 32 having a bit 39 for performing a machining operation and a compression sub 33 comprising a load cell 34 adjacent to the machining tool in order to measure the actual weight on the bit 39. The operational tool 38 further comprises an electric control unit 40, a compensator 41, an electric motor 42 and a gear section 43 for rotating the bit 39 at another speed than the rotational speed of the motor 42, often at a lower speed. The compression sub 33 comprising the load cell 34 is arranged between the electric control unit 40 and the drive section 30b comprising the wheels 24 on arm assemblies 23.

[0065] The electric control unit(s) 18, 18b further comprises a voltage control unit 19 having an overvoltage protection unit, so that voltage fed to the tool is kept more

constant, and an electric current measuring unit 20. In Fig. 2, the electric control unit 18 comprises a capacitor 50 functioning as an energy storage unit or accumulator. The downhole self-propelling tool string 1 further comprises a machining tool 32 for performing a machining operation and a compression sub 33 comprising a load cell 34 adjacent to the machining tool. In another embodiment, the electric control unit(s) 18, 18b control(s) the controllable valve(s) 16, 17, 26, 27 based on the electric current and/or electric voltage measured by the electric control unit.

[0066] In Fig. 2, the downhole self-propelling wireline tool string 1 is a user interface 36 at surface 37 for controlling at least part of the downhole self-propelling wireline tool string 1. Thus, the field engineer may be informed of the current limit of the wireline/cable and through the user interface 36 set the current limit for each motor of the tool, and the power-limiting units or the current distribution unit distributes the current equally between the first downhole self-propelling wireline tool 1a and the second downhole self-propelling wireline tool 1b so that both are able to drive at the same speed and therefore drive the tool string 1 at the same speed. The first electric motor 4 may require more power than the second electric motor 22 in order to drive the tool string 1 at the same speed, but this is possible as the first and the second downhole self-propelling wireline tools 1a, 1b are electrically connected in parallel. The downhole self-propelling wireline tool string 1 may further comprise a stroking tool, even though not shown.

[0067] In Fig. 5, the method comprises continuously measuring 130d the first/third fluid pressure by means of the first/third pressure sensor 49, and adjusting 160c the rotational speed of the electric motor 4, 22 is based on the first fluid pressure as a supplement to or instead of steps 130-150.

[0068] The method as shown in Figs. 4, 5 and 6 further comprises controlling 170 the first fluid pressure based on the second/fourth pressure by means of a first/third controllable valve 16, 26 in the hydraulic section 15, 25 of the downhole self-propelling wireline tool 1a, 1b. The method may optionally further comprise determining 180 the load on the electric motor 4, 22 based on the torque output.

[0069] In Fig. 5, the method comprises continuously measuring 130b the second/fourth fluid pressure of the second/fourth fluid, and adjusting 160d the operational rotational speed of the electric motors 4, 22 is based on the second/fourth fluid pressure as a supplement to or instead of steps 130-150.

[0070] When the downhole self-propelling wireline tool string 1 further comprises the operational tool 32 having the bit 39 for performing an operation downhole, such as milling, and the downhole self-propelling wireline tool string has propelled itself to the point where the milling operation is to be performed, the method further comprises measuring 130b the second/fourth fluid pressure, estimating 140c a weight on bit (WOB), comparing 150a

the estimated weight on bit with a predetermined weight on bit, and adjusting 160e the second/fourth fluid pressure based on the comparison, as shown in Fig. 5. The steps 130b, 140c, 150a and 160e may be a supplement to or instead of steps 130-160.

[0071] When the downhole self-propelling wireline tool string 1 further comprises the compression sub 33 and the operational tool 32 having the bit 39 for performing an operation downhole, such as milling, the method may further comprise measuring 130c a weight on bit by means of the compression sub, comparing 150b the measured weight on bit with a predetermined weight on bit, and adjusting 160f the second/fourth fluid pressure based on the comparison, as shown in Fig. 5. The steps 130c, 150b and 160f may be a supplement to or instead of steps 130-160.

[0072] As shown in Fig. 6, the adjusting 160a of the operational rotational speed of the electric motor 4 may also be based on a measured current demand of the electric motor or a calculated load on the electric motor.

[0073] The downhole self-propelling wireline tool string 1 may further comprise a stroking tool, even though not shown. A stroking tool is a tool providing an axial force. The stroking tool comprises an electric motor for driving a pump. The pump pumps fluid into a piston housing to move a piston acting therein. The piston is arranged on the stoker shaft. The pump may pump fluid out of the piston housing on one side and simultaneously suck fluid in on the other side of the piston.

[0074] By "fluid" or "well fluid" is meant any kind of fluid that may be present in oil or gas wells downhole, such as natural gas, oil, oil mud, crude oil, water, etc. By "gas" is meant any kind of gas composition present in a well, completion or open hole, and by "oil" is meant any kind of oil composition, such as crude oil, an oil-containing fluid, etc. Gas, oil and water fluids may thus all comprise other elements or substances than gas, oil and/or water, respectively.

[0075] By "casing" or "well tubular metal structure" is meant any kind of pipe, tubing, tubular, liner, string, etc., used downhole in relation to oil or natural gas production.

[0076] Although the invention has been described above in connection with preferred embodiments of the invention, it will be evident to a person skilled in the art that several modifications are conceivable without departing from the invention as defined by the following claims.

Claims

1. A downhole self-propelling wireline tool string (1) for being connected to and powered by a wireline (5) for propelling a tool forward in a well (2) and/or for providing weight on a bit while performing an operation, comprising a first downhole self-propelling wireline tool (1a), comprising:

- a first tool body (3a),
- a first electric motor (4) operating at a rotational speed,
- a first electric control unit (18) for controlling the rotational speed of the electric motor,
- one first drive section (30a), comprising

- a plurality of projectable arm assemblies (6) movably connected at a first arm end (7) with the tool body and projectable from the tool body by means of a first fluid having a first fluid pressure, and
- a plurality of wheels (8) for contacting a wall (9) of the well, each wheel comprising a hydraulic motor (10) for rotation of the wheel and providing a self-propelling movement, and each wheel being connected with a second arm end (11) of one of the arm assemblies,

- a first hydraulic pump (12) driven by the electric motor for generation of a second fluid pressure for driving the hydraulic motor(s) rotating the wheel(s), and

wherein the downhole self-propelling wireline tool string further comprises a second downhole self-propelling wireline tool (1b), comprising:

- a second tool body (3b),
- a second electric motor (22) operating at a rotational speed,
- a second electric control unit (18b) for controlling the rotational speed of the electric motor,
- one second drive section (30a) comprising:

- a plurality of projectable arm assemblies (23) movably connected at a first arm end (7b) with the tool body and projectable from the tool body by means of a first fluid having a third fluid pressure, and
- a plurality of wheels (24) for contacting the wall (9) of the well, each wheel comprising a hydraulic motor (10b) for rotation of the wheel, and each wheel being connected with a second arm end (11b) of one of the arm assemblies,

- at least one second hydraulic pump (14) driven by the second electric motor for generation of a fourth fluid pressure for driving the hydraulic motor(s) rotating the wheel(s) (24), and

wherein each electric motor comprises a power-limiting unit (31) in order to distribute a first part of the current from the wireline to power the first electric motor and a second part of the current to power the second electric motor.

2. A downhole self-propelling wireline tool string according to claim 1, wherein the power-limiting unit is a current-limiting unit limiting the current supplied to the electric motor.
3. A downhole self-propelling wireline tool string according to claim 1 or 2, wherein the downhole self-propelling wireline tool string comprises a current distribution unit (21) in order to distribute a first part of the current from the wireline to power the first electric motor and a second part of the current to power the second electric motor.
4. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the first drive section is rotated 90 degrees from the second drive section so that the projectable arm assemblies of the first drive section are rotated 90 degrees from the projectable arm assemblies of the second drive.
5. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the first electric control unit is connected to the first electric motor, which is connected to the first hydraulic pump, which is connected with the first drive section.
6. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the first drive section is connected to the second electric control unit or the second electric motor of the second downhole self-propelling wireline tool.
7. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the first downhole self-propelling wireline tool further comprises a first pressure sensor (49) measuring the second fluid pressure, and the first hydraulic section comprises a first controllable valve (16) controlling the first fluid pressure based on the second fluid pressure.
8. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the second downhole self-propelling wireline tool further comprises a third pressure sensor (49b) measuring the fourth fluid pressure and a second hydraulic section comprising a third controllable valve (26) controlling the third fluid pressure based on the fourth fluid pressure.
9. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the first downhole self-propelling wireline tool is connected in one end with the wireline and in another end
10. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the first downhole self-propelling wireline tool comprises a second first hydraulic pump generating the first fluid pressure for projection of the plurality of projectable arm assemblies of the first drive section, and the second downhole self-propelling wireline tool comprises a second hydraulic pump generating the third fluid pressure for projection of the plurality of projectable arm assemblies of the second drive section.
11. A downhole self-propelling wireline tool string according to any of claims 1-9, wherein the first hydraulic pump generates the first fluid pressure for projection of the plurality of projectable arm assemblies of the first drive section, and the second hydraulic pump generates the third fluid pressure for projection of the plurality of projectable arm assemblies of the second drive section.
12. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein a fluid channel for the first fluid or the third fluid for projecting the arm assemblies from the tool body has a first inner channel diameter, and the drive section has an outer drive section diameter, where the ratio between the first inner channel diameter and the outer drive section diameter is higher than 0.3/10, preferably higher than 0.4/10, and more preferably higher than 0.5/10.
13. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein a second channel for the second fluid or the fourth fluid for driving the hydraulic motor(s) rotating the wheel(s) has a second inner channel diameter, and the drive section has an outer drive section diameter, where the ratio between the second inner channel diameter and the outer drive section diameter is higher than 0.5/10, preferably higher than 0.8/10, and more preferably higher than 1.0/10.
14. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the controllable valve(s) is/are electronically controllable by means of the electric control unit.
15. A downhole self-propelling wireline tool string according to any of the preceding claims, wherein the current distribution unit is arranged in the first electric control unit.

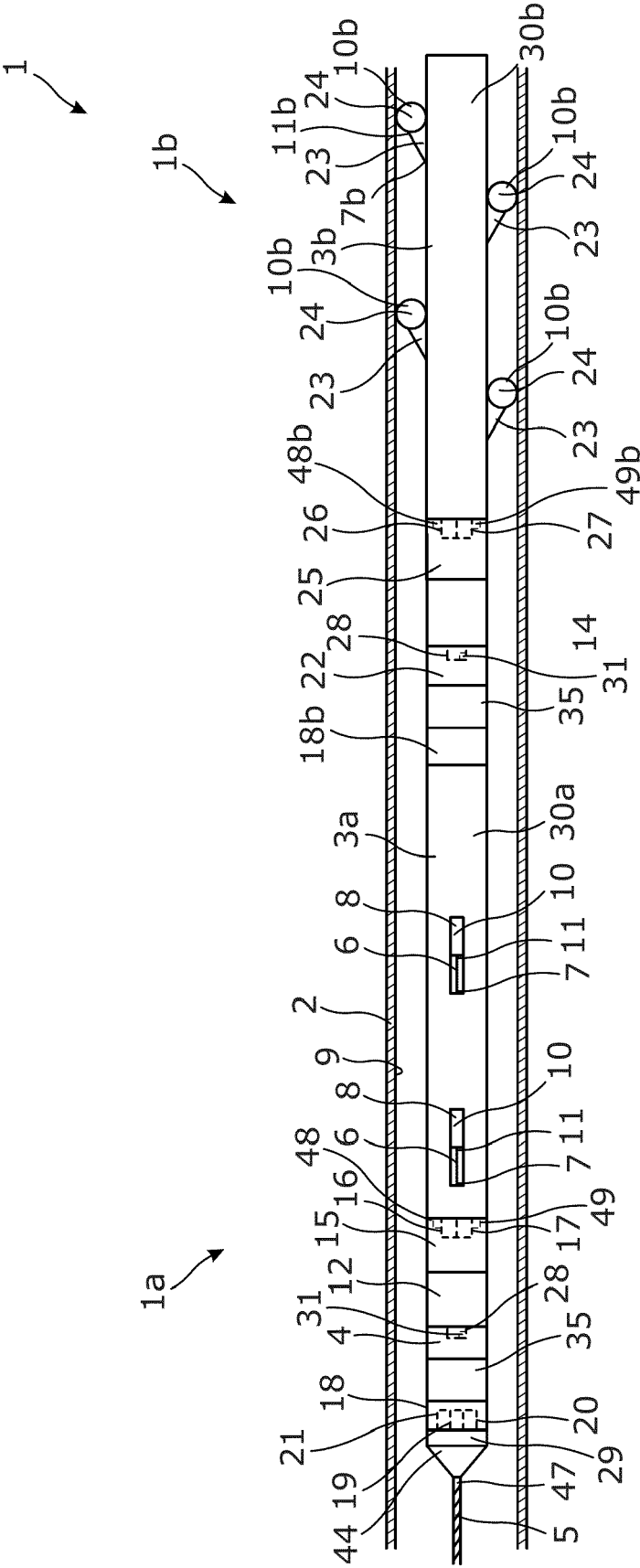


Fig. 1

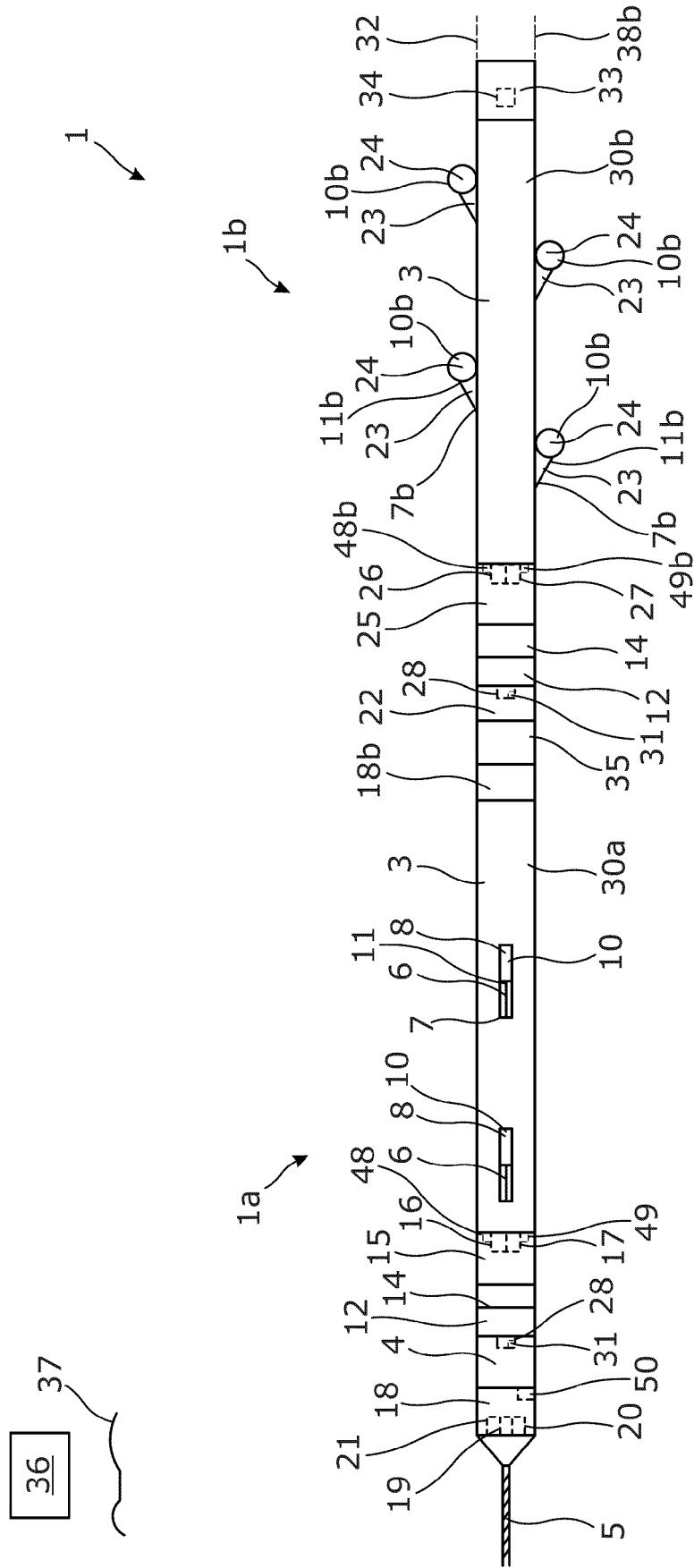


Fig. 2

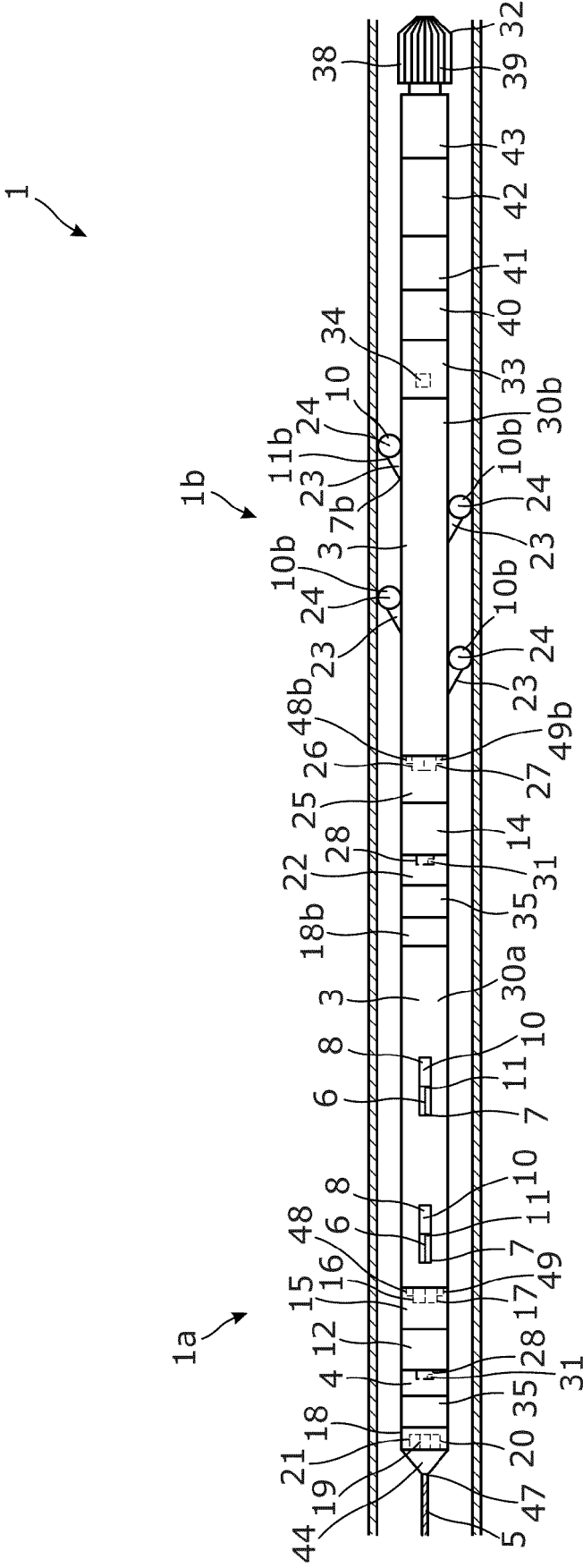


Fig. 3

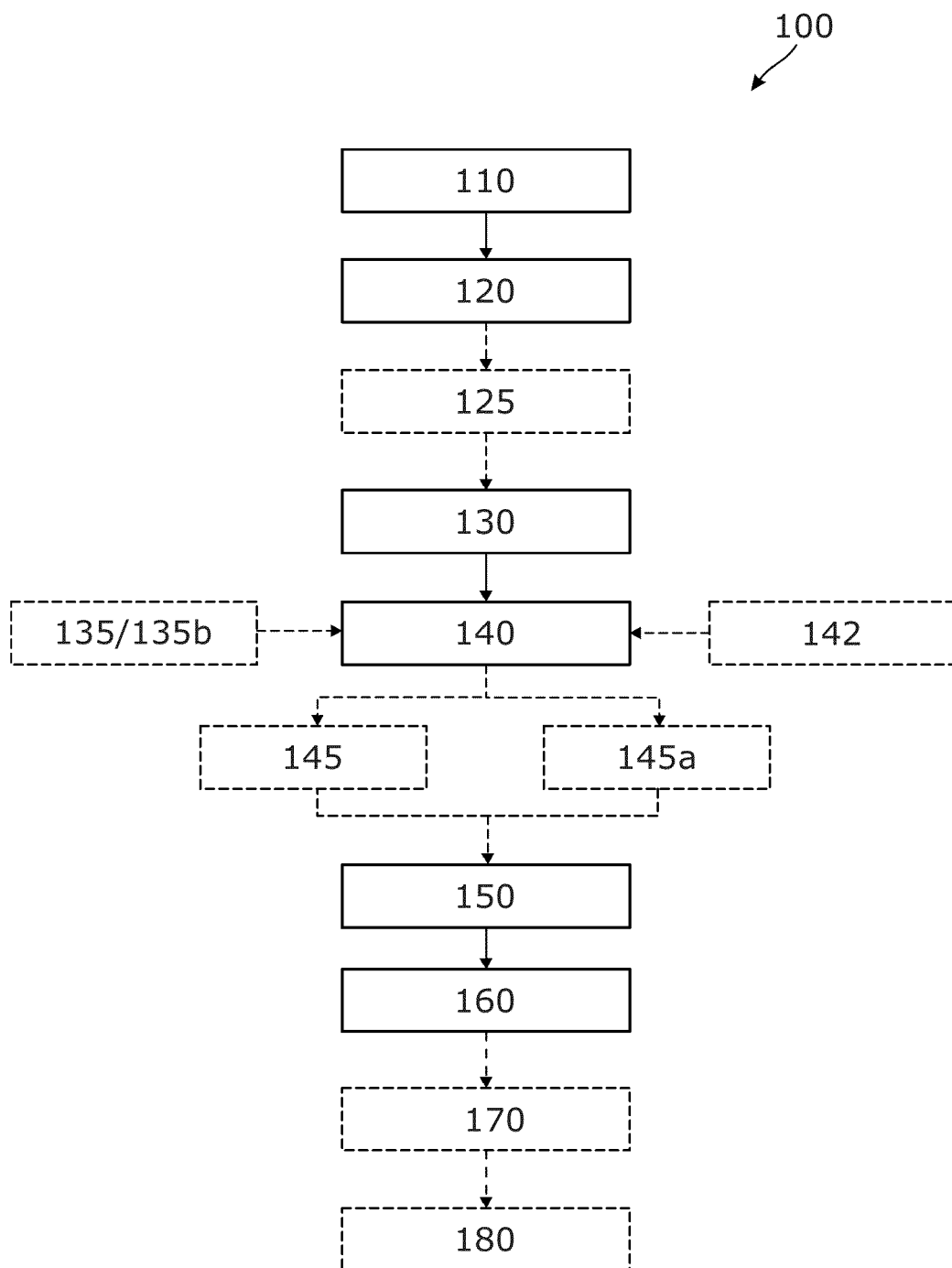


Fig. 4

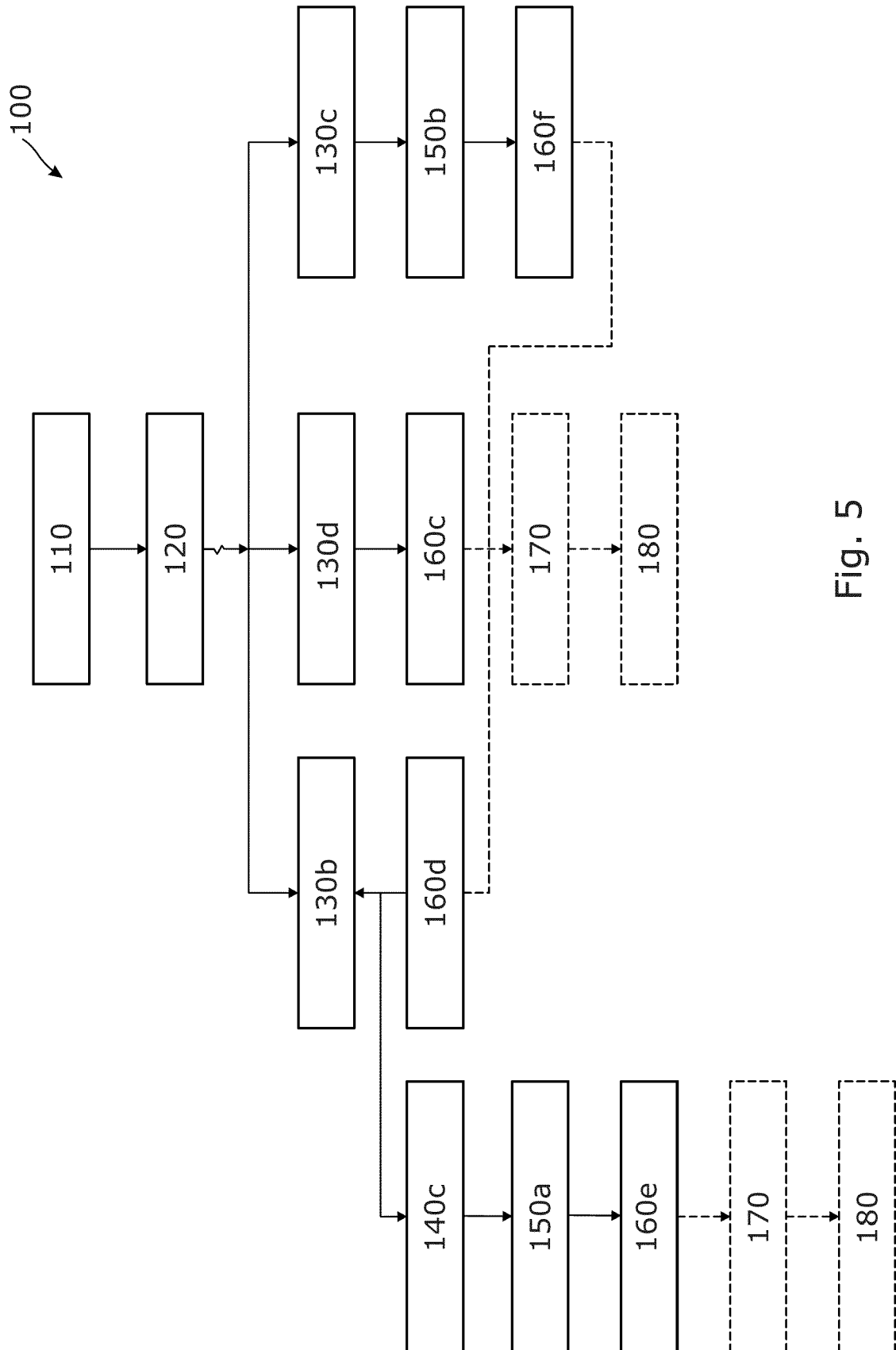


Fig. 5

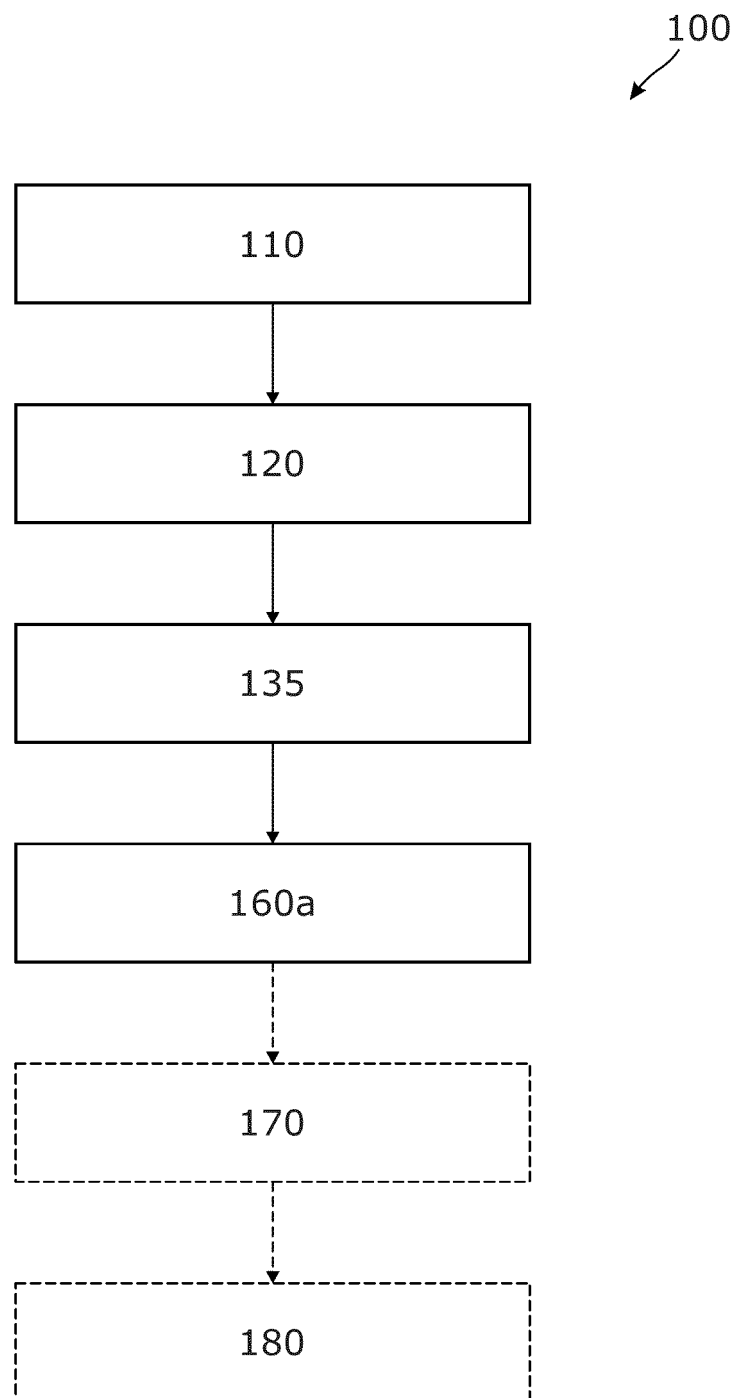


Fig. 6

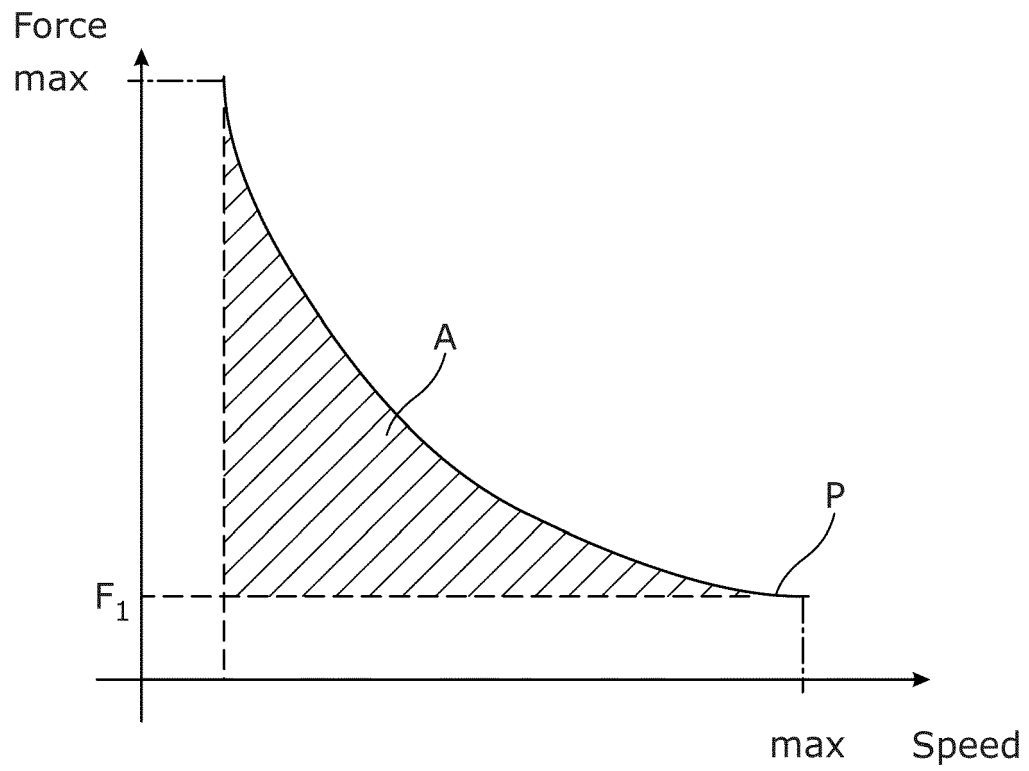


Fig. 7



EUROPEAN SEARCH REPORT

Application Number

EP 21 20 2037

5

10

15

20

25

30

35

40

45

50

55

EPO FORM 1503 03.82 (P04C01)

| DOCUMENTS CONSIDERED TO BE RELEVANT | | | |
|---|--|---|--|
| Category | Citation of document with indication, where appropriate, of relevant passages | Relevant to claim | CLASSIFICATION OF THE APPLICATION (IPC) |
| Y | WO 2019/004834 A1 (QINTERRA TECH AS [NO]) 3 January 2019 (2019-01-03) * column 5, lines 11-14 * * page 11, lines 8-29; figures 1-6 * ----- | 1-15 | INV. E21B4/18 E21B23/14 E21B23/00 |
| Y | US 2008/308318 A1 (MOORE NORMAN BRUCE [US]) 18 December 2008 (2008-12-18) * paragraph [0138] * ----- | 1-15 | |
| A | WO 2008/024881 A1 (WESTERN WELL TOOL INC [US]) 28 February 2008 (2008-02-28) * the whole document * ----- | 1-15 | |
| A | US 2006/042835 A1 (GUERRERO JULIO C [US] ET AL) 2 March 2006 (2006-03-02) * the whole document * ----- | 1-15 | |
| | | | TECHNICAL FIELDS SEARCHED (IPC) |
| | | | E21B |
| <p>1 The present search report has been drawn up for all claims</p> | | | |
| Place of search Munich | | Date of completion of the search 23 February 2022 | Examiner Manolache, Iustin |
| CATEGORY OF CITED DOCUMENTS | | T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document | |
| X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document | | | |

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 21 20 2037

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

23-02-2022

10

15

20

25

30

35

40

45

50

55

| Patent document cited in search report | Publication date | Patent family member(s) | Publication date |
|---|---------------------|----------------------------|---------------------|
| WO 2019004834 A1 | 03-01-2019 | CA 3065212 A1 | 03-01-2019 |
| | | DK 202070038 A1 | 10-02-2020 |
| | | GB 2578552 A | 13-05-2020 |
| | | NO 343461 B1 | 18-03-2019 |
| | | US 2020200194 A1 | 25-06-2020 |
| | | WO 2019004834 A1 | 03-01-2019 |
| ----- | | | |
| US 2008308318 A1 | 18-12-2008 | CA 2688348 A1 | 24-12-2008 |
| | | US 2008308318 A1 | 18-12-2008 |
| | | US 2011067926 A1 | 24-03-2011 |
| | | WO 2008157428 A2 | 24-12-2008 |
| ----- | | | |
| WO 2008024881 A1 | 28-02-2008 | US 2008217024 A1 | 11-09-2008 |
| | | WO 2008024881 A1 | 28-02-2008 |
| ----- | | | |
| US 2006042835 A1 | 02-03-2006 | CA 2517753 A1 | 01-03-2006 |
| | | GB 2417740 A | 08-03-2006 |
| | | MX PA05009239 A | 03-03-2006 |
| | | US 2006042835 A1 | 02-03-2006 |
| ----- | | | |