A directional drilling tool is provided, which comprises a first end (2) attachable to a drill string, and a second end (4) attachable to a drill bit. A swivel section (6) is provided intermediate the first and second ends (2,4) and has a first swivel member (18) non-rotatably attached to the first end (2) and a second swivel member (20) rotatably coupled to the first swivel member (18) and rotatable relative thereto about a first axis of rotation which is co-axial with a longitudinal axis (L1) of the tool. A first actuator is adapted to selectively rotate the second swivel member (20) about the first axis of rotation. An adjustable bend section (12) has a first bend member (118) non-rotatably attached to the second swivel member (20) and a second bend member (120) rotatably coupled to the first bend member (118), where the first bend member (118) is co-axial with the longitudinal axis (L1), and the second bend member (120) is rotatable relative to the first bend member (118) about a second axis of rotation (R) which is at a non-zero angle relative to the longitudinal axis (L1). A second actuator is adapted to selectively rotate the second bend member (120) about the second axis of rotation (R). A directional drilling system incorporating the tool, a control process for the tool, and a motor drive for rotating a second body relative to a first body are also provided.
Start

Surface input data by driller

Measured data from MWD

Processing inputs from driller and/or MWD

Are there any driller inputs?

Yes → No →

Does MWD data exceed the target error (compared to the last input data)?

Yes → Apply modifications to meet the required targets

No → Display current status

System stop activated?

Yes → End

Fig. 9
DIRECTIONAL DRILLING TOOL

TECHNICAL FIELD

[0001] The present invention relates to the field of oil and gas exploration, and in particular downhole drilling activities. More specifically, the present invention is a remotely controlled directional drilling tool for use in downhole drilling.

BACKGROUND ART

[0002] It is known to utilise a Surface-Adjustable Bent (SAB) housing when drilling a well which has to follow a particular geometric path rather than one which is a “straight-hole”. The SAB housing typically forms part of a downhole drilling motor and is located between the power and bearing sections of the motor. The SAB housing comprises a fixed upper section connected to the power section of the motor, and a lower section which is rotatable relative to the upper section and connected to the bearing section and drill bit. The joint between the upper and lower sections of the SAB housing is angled such that the rotational axis of the lower section is at an angle \( \alpha \) relative to the longitudinal axis of the upper section. The angle \( \alpha \) is typically in the range of 0° to 3°, and the angle may be adjusted manually at the surface prior to commencing a drilling operation.

DISCLOSURE OF INVENTION

[0003] These SAB housings have several drawbacks. Firstly, the maximum bend angle between the longitudinal axes of the upper and lower sections of the housing is 2\( \alpha \), but the maximum angle is limited to a smaller angle downhole due to space constraints within the borehole. Secondly, any adjustment of the housing must be carried out manually at the surface, adding to the time and associated costs of the drilling operation.

[0004] A solution to these problems was presented in U.S. Patent No. 4,836,303, in which the upper section of the housing is radially offset from the longitudinal axis of the motor such that the longitudinal axis of the upper section is at an angle to the longitudinal axis of the motor. In addition, the device can be remotely adjusted downhole, thereby avoiding the need for the drill string to be recovered to the surface for adjustment of the housing. These two features provide a greater range of angle adjustment for the housing. However, the drilling operation has to be halted and the drill string lifted off-bottom in order for the angular displacement of the upper and/or lower sections to be adjusted, thereby still involving a significant amount of non-drilling time (NDT) in any drilling operation.

[0005] It is an aim of the present invention to obviate or mitigate one or more of these disadvantages with existing tools.

[0006] According to a first aspect of the present invention there is provided a directional drilling tool, comprising:

[0007] a first end attachable to a drill string, and a second end attachable to a drill bit;

[0008] a swivel section intermediate the first and second ends and having a first swivel member non-rotatably attached to the first end and a second swivel member rotatably coupled to the first swivel member about the first axis of rotation; and

[0009] an adjustable bend section having a first bend member non-rotatably attached to the second swivel member and a second bend member rotatably coupled to the first bend member, wherein the first bend member is co-axial with the longitudinal axis, and the second bend member is rotatable relative to the first bend member about a second axis of rotation which is at a non-zero angle relative to the longitudinal axis; and

[0010] a second actuator adapted to selectively rotate the second bend member about the second axis of rotation.

[0011] The first actuator may be housed in the first swivel member. The first actuator may be a first motor drive comprising a first motor having a first rotating drive shaft, wherein the first motor drive transforms an initial rotational motion of the first drive shaft into an intermediate axial motion, and transforms the axial motion into a final rotational motion of the second swivel member.

[0012] The first motor drive may further comprise:

[0013] a first drive member rotatably engaged with the first drive shaft;

[0014] a second drive member non-rotatably engaged with the first swivel member and adapted to move axially relative to the first swivel member in response to rotation of the first drive member; and

[0015] a first helical output shaft having a first end engaged with the second drive member and a second end attached to the second swivel member, wherein axial movement of the second drive member rotates the first output shaft and the second swivel member.

[0016] The first output shaft may be a follower shaft and the second drive member may include a socket cam in which the first end of the first output shaft is engaged.

[0017] The second actuator may be a second motor drive housed in the first bend member, the second motor drive lying along a drive axis which is at the non-zero angle relative to the longitudinal axis of the tool.

[0018] The second motor drive may comprise a second motor having a second rotating drive shaft, wherein the second motor drive transforms an initial rotational motion of the second drive shaft into an intermediate axial motion, and transforms the axial motion into a final rotational motion of the second bend member.

[0019] The second motor drive may further comprise:

[0020] a third drive member rotatably engaged with the second drive shaft;

[0021] a fourth drive member non-rotatably engaged with the first bend member and adapted to move axially relative to the first bend member in response to rotation of the third drive member; and

[0022] a second helical output shaft having a first end engaged with the fourth drive member and a second end attached to the second bend member, wherein axial movement of the fourth drive member rotates the second output shaft and the second bend member.

[0023] The second output shaft may be a follower shaft and the fourth drive member may include a socket cam in which the first end of the second output shaft is engaged.

[0024] The drilling tool may further comprise a remote control system having an operator control interface, the control system adapted to activate the first and second actuators in response to pre-programmed instructions and/or manual inputs at the control interface.

[0025] The control interface may include a graphical display means indicating the path of the tool.
According to a second aspect of the invention there is provided a directional drilling system, comprising:

- a directional drilling tool according to the first aspect of the invention;
- a drill bit attached to the second end of the tool;
- a measuring device adapted to monitor the orientation and position of the drill bit;
- a remote control system having an operator control interface adapted to receive manual tool control inputs; and
- an electronic controller adapted to selectively activate the first and/or second actuators of the tool in response to pre-programmed instructions and/or signals from the measuring device and/or remote control system.

Each of the swivel and adjustable bend sections may further comprise one or more positional sensors adapted to communicate the rotational position of the swivel and adjustable bend sections to the controller.

According to a third aspect of the invention there is provided a control process for a directional drilling tool having a first swivel member non-rotatably attached to a first end of the tool and a second swivel member rotatably coupled to the first swivel member and rotatable relative thereto about a first axis of rotation which is co-axial with a longitudinal axis of the tool; a first actuator adapted to selectively rotate the second swivel member about the first axis of rotation; a first bend member non-rotatably attached to the second swivel member and a second bend member rotatably coupled to the first bend member, wherein the first bend member is co-axial with the longitudinal axis, and the second bend member is rotatable relative to the first bend member about a second axis of rotation which is at a non-zero angle relative to the longitudinal axis; and a second actuator adapted to selectively rotate the second bend member about the second axis of rotation, the process comprising the steps of:

- receiving pre-programmed instructions and/or manual control inputs from a remote control system regarding a desired drilling path of a drill bit attached to the drilling tool;
- applying the instructions and/or control inputs to the first and/or second actuators and commencing drilling on the desired path;
- establishing the current orientation and position of the drill bit;
- determining whether the current orientation and position of the drill bit indicates that the drill bit remains on the desired drilling path;
- checking for additional manual control inputs from the control system; and
- applying any necessary modifications to the first and/or second actuator positions based upon the determination step and/or additional control inputs.

The desired drilling path is selected based upon the pre-programmed instructions and/or manual control inputs. The determining step compares the current orientation and position of the drill bit with the desired drilling path set by the pre-programmed instructions and/or manual control inputs. The step of applying any necessary modifications therefore includes applying corrective feedback from the control system should the determining step have established that the drill bit has diverged from the desired drilling path.

The process may further comprise the step of displaying the current drilling path on an operator control interface of the remote control system.

According to a fourth aspect of the invention there is provided a motor drive for rotating a first body relative to a second body, the motor drive comprising a motor having a rotating drive shaft, wherein the motor drive transforms an initial rotational motion of the drive shaft into an intermediate axial motion, and transforms the axial motion into a final rotational motion of the second body.

The motor drive may further comprise:

- a first drive member rotatably engaged with the drive shaft;
- a second drive member non-rotatably engaged with the first body and adapted to move axially relative to the first body in response to rotation of the first drive member; and
- a helical output shaft having a first end engaged with the second drive member and a second end attached to the second body, wherein axial movement of the second drive member rotates the helical output shaft and the second body.

The helical output shaft may be a follower shaft and the second drive member may include a socket cam in which the first end of the helical output shaft is engaged.

**BRIEF DESCRIPTION OF DRAWINGS**

A preferred embodiment of the present invention will now be described by way of example only, with reference to the accompanying drawings in which:

- FIG. 1 is a schematic representation of a directional drilling tool;
- FIGS. 2(a) and 2(b) are vertical section and side views, respectively, of a motorised swivel forming part of the drilling tool of FIG. 1;
- FIG. 3 is a projected view of socket and shaft components of the swivel of FIG. 2;
- FIG. 4 is a horizontal section through the swivel along line B-B of FIG. 2(a);
- FIGS. 5(a) and 5(b) are vertical section and side views, respectively, of an adjustable bent sub forming part of the drilling tool of FIG. 1;
- FIGS. 6(a) and 6(b) are vertical section and side views, respectively, of the adjustable bent sub of FIG. 5 in a first state;
- FIGS. 7(a) and 7(b) are vertical section and side views, respectively, of the adjustable bent sub of FIG. 5 in a second state;
- FIG. 8 is a schematic representation of a downhole drilling system incorporating the drilling tool of FIG. 1; and
- FIG. 9 is a flow chart illustrating the control process of the system of FIG. 8.

**BEST MODE FOR CARRYING OUT THE INVENTION**

FIG. 1 schematically shows a directional drilling tool according to the present invention. The drilling tool, generally designated 1, comprises a first or upper end 2 connectable to a drill string (not shown) and a second or lower end 4 connectable to a drill bit (not shown in FIG. 1). The tool 1 further comprises a motorised swivel 6 having a first swivel member non-rotatably attached to the first end 2 and a second swivel member attached to the remainder of the tool 1. As will
be explained in more detail below, the first and second swivel members may be selectively rotated relative to one another so as to rotate the tool 1 relative to the drill string.

[0059] Below the swivel 6, the tool 1 further comprises a dump valve section 8 and a power section 10, both of which are of a type known in the art. Below the power section 10 is an adjustable bend section, also known as a bent sub, 12 having a first bend member attached to the power section 10 and a second bend member attached to the remaining downstream components of the tool 1. The first and second bend members may be selectively rotated relative to one another so as to rotate an attached drill bit (not shown) relative to the swivel 6, dump valve 8 and power sections 10 of the tool 1. Completing the downstream elements of the tool 1 are a transmission assembly 14 and a bearing section 16, which are again both of a type known in the art.

[0060] FIGS. 2, 3 and 4 show the components of the swivel 6 in more detail. The swivel comprises a first tubular member 18 and a second tubular member 20. The free end of the first member 18 is attached to a drill string by way of a threaded connection (not shown). The free end of the second member 20 is non-rotatably attached, either directly or indirectly, to the power section 10 by a threaded connection (not shown). A bore 22 extends longitudinally through the swivel so as to permit drilling mud to pass into the power section 10 from the drill string above.

[0061] The swivel 6 includes an actuator adapted to selectively rotate the second member 20 relative to the first member 18. In this preferred embodiment, the actuator is a motor drive housed in the first member 18. The motor drive includes a motor compartment 24 located between the outer wall of the first member 18 and the bore 22. Located within the motor compartment 24 is a high voltage (400-600V) electric motor 26, which has a thermally insulated coil and is adapted so as to be highly resistant to corrosion and abrasion. The motor 26 has a drive shaft 28 which is supported by a bearing 30 on a support plate 32 having a niche 34 in which the bearing 30 is located. FIG. 4 shows that the support plate 32 is non-rotatably fixed to the first tubular member 18 by four splines 36 that ensure the plate 32 and niche 34 are properly aligned with the drive shaft 28 and bearing 30. A sealing sleeve 38 seals the motor 26 and motor compartment 24 from the bore 22.

[0062] The drive shaft 28 is engaged with an annular gear 40 which is co-axial with the bore 22. The gear 40 is integrally formed with, or non-rotatably attached to, an upper end of a first drive member in the form of a power screw 42. The screw 42 is located within a second drive member, or socket, 44, which has an internal thread which engages with an external thread on the screw 42. The socket 44 has a plurality of external splines 46 which engage with corresponding splines 47 on the inner surface of the first tubular member 18. The splines 46, 47 prevent relative rotation between the socket 44 and first tubular member 18, but permit relative movement between the two in the axial direction. Thus, rotation of the gear 40 and power screw 42 by the motor 26 effects an axial movement of the socket 44 relative to the screw 42 and first tubular member 18.

[0063] An output shaft 48 is connected to the socket 44 via a spiral socket cam 50, as best seen in FIG. 3. The output shaft 48 is a helical, or spiral, follower shaft with a polygonal cross section that could alternatively be hexagonal, octagonal or square, for example, and is threaded at its remote end 49. The socket cam 50 and follower shaft 48 cooperate with one another so that as the socket 44 moves axially, the output shaft 48 rotates. The threaded end 49 of the output shaft 48 is connected to the second tubular member 20 of the swivel 6. Hence, operation of the motor 26 will rotate the second tubular member 20 relative to the first tubular member 18, such that the tool 1 and drill bit rotate relative to the remainder of the drill string.

[0064] The socket 44 cannot move axially unless the power screw 42 is rotated. Consequently, the socket 44 isolates the motor 26 from any reaction moments from the second tubular member 20. In the same way, the socket 44 provides a locking mechanism to the swivel 6 and tool 1 that locks the first and second tubular members 18, 20 at the chosen rotational angle relative to one another. This arrangement adds to the overall reduction ratio of the drive and increases the accuracy and sensitivity of the output.

[0065] The axial motion of the power screw 42 is limited in the downward direction (when viewed in FIG. 2) by a stopper (not shown) located on the splines 47 of the first tubular member 18 at the lower end of the member 18, whilst axial motion is limited in the upward direction by a thrust bearing 52 and a locking nut 54 on the lower side of the support plate 32. The thrust bearing 52 reduces friction during rotation of the power screw 42, thus minimizing the required driving torque from the electric motor 26.

[0066] The swivel 6 is preferably filled with oil to reduce friction and to avoid sticking of the moving components. Accordingly, a number of seals are provided to prohibit mud flowing through the bore 22 from contaminating the oil. A first oil seal is provided between the first tubular member 18 and the output shaft 48 where the output shaft 48 exits the lower end of the tubular member 18. A second oil seal 58 is provided between the lower end of the power screw 42 and the output shaft 48, whilst a third oil seal 60 is provided between the annular gear 40 and the sealing sleeve 38. A sealing gasket 62 is deployed between the adjacent ends of the first and second tubular members 18, 20 to prevent any contamination or leakage between the mud flowing through the bore 22 and the oil inside the swivel 6.

[0067] FIGS. 5 to 7 show the bent sub 12 in various states of operation. The bent sub 12 includes an actuator, which in this preferred embodiment is housed in a first tubular member 118 and is comprised of components which are near-identical to those of the swivel 6. The sub 12 comprises a first tubular member 118 having a longitudinal axis L1 shared with the overall tool 1, and a second tubular member 120 having a longitudinal axis L2. The free ends of the first and second members 118, 120 are attached to the power section 10 and transmission assembly 14 of the tool 1, respectively, as shown schematically in FIG. 1. A bore 122 extends longitudinally through the sub 12, and houses the output shaft 123 from the power section 10. The main difference between the swivel 6 and bent sub 12 is that in the bent sub 12 the second member 120 is mounted relative to the first member 118 such that it is rotatable about a rotational axis R which is at an angle α relative to the longitudinal axis L1 of the tool 1. The drive system components of the bent sub 12 and the manner in which they effect rotation of the second member 120 relative to the first member 118 are the same as those of the swivel 6 described above, but the drive system of the bent sub 12 lies along a rotational axis K at the angle α relative to the axis L1. Those components will therefore not be described again in detail here.

[0068] An additional straight sleeve 119 is fitted to the upper end of the first member 118 to ensure a straight con-
nection with the power section 10 above. The output shaft 123 passes through the bore 122 with enough space to accommodate the eccentricity in the shaft motion, which is shown in FIG. 6. FIG. 7 shows the maximum bend angle of the sub 12 and shows the shaft 123 passing freely through the bore 122 at that maximum angle.

[0069] The relative angular displacement θ between the longitudinal axes L1.L2 of the first and second members 118,120 will follow an elliptical path with a maximum bend angle between them of 2α, where α is the angle of the rotational axis R relative to the longitudinal axis L1 of the first member 118, as shown in FIG. 7. The bent sub 12 thus can create any desired bend angle for drilling between θ and 2α.

[0070] Rotation of the swivel 6 then rotates the bend sub 12 to adjust the drilling direction. Tests have been carried out to show the correlation between the rotation of the second member 120 relative to the first member 118 and the resulting bend angle between the axes L1 and L2 in addition to the corresponding direction of the tool face. The study was made for a bent sub where the angle is α. The results indicated that the second member 120 rotates 180° relative to the first member 118, the bend angle between the longitudinal axes L1.L2 of the first and second members 118,120 reaches 2α and then decreases as the second member 120 rotates through 360°.

[0071] Closed form expressions have been developed for calculating the bend angle and direction based on simple trigonometry rules. The closed form expressions for the bend direction are as follows:

- Bend Angle β
  \[ β = 2\sin^{-1}\left(\sin\left(\frac{θ}{2}\right)\right) \]
- Direction Angle D
  \[ D = \tan^{-1}\left(\frac{\cos(θ) - \cos(2θ)}{\sin(θ)}\right) \]

where θ is the relative angular displacement between the longitudinal axes L1 and L2, and α is the angle of the rotational axis R relative to the longitudinal axis L1.

[0072] FIG. 8 schematically illustrates a directional drilling system incorporating the directional drilling tool 1. The system comprises a drill bit 70 which is attached to the bearing section 16 of the tool 1 in a conventional manner, and a measuring device adapted to monitor the real time orientation and position of the drill bit 70. The measuring device is preferably a measurement while drilling (MWD) tool 72. The MWD tool 72 transmits its measurements to an electronic controller 74. In two-way communication with the controller 74 is a remote control system, which is preferably a remote surface steering (RSS) unit 76. The RSS unit 76 may be provided with a display means to graphically illustrate to an operator the bend angle and drilling direction of the tool based upon data received from the MWD tool 72 and the controller 74. The RSS unit 76 also includes controls to allow the operator to manually input drilling control commands to the controller 74.

[0073] The controller 74 can operate in automatic mode, where it will send control signals to the motors of the swivel 6 and/or bent sub 12 based on data received from the MWD tool 72 in order to keep the drill bit 70 on a preset path, or else in manual mode where it will send signals to the motors in response to manual inputs by the operator on the RSS unit 76. One or more sensors may be provided in each of the swivel 6 and bent sub 12 to send positional data back to the controller 74 so that the controller has real time positional information on the operational positioning of the swivel 6 and bent sub 12.

[0074] The flow diagram of FIG. 9 shows a control process for the system shown in FIG. 8. Following a system start-up step 200, the process will await an input of the desired drilling path by an operator at input step 202. At process step 204, drilling operations will begin on the basis of data of input step 202. At decision step 206, the process will establish if there have been any further data inputs from the operator since the start of drilling. If not, the process will move to a further decision step 208 where it is determined whether measurement data from the MWD tool indicates that the drilling process is within pre-set parameters relating to the desired drilling path. If the data indicates that the drilling is no longer within the required parameters, process step 210 applies corrections to the swivel and/or bent sub in order to bring the drilling process back to the target path. If the process establishes at decision step 206 that further inputs have been made by the operator, this overrides any automated corrections and the process will skip decision step 208 and proceed straight to process step 210 to implement the adjustment manually requested by the operator.

[0075] Referring back to FIGS. 2 to 5, process steps 204 and 210 will generate one or more control signals from the controller 74 to the motor 26,126 of the swivel 6 and/or bent sub 12. In response to a signal from the controller 74, the drive shaft 28,128 of the motor 26,126 will rotate clockwise or anti-clockwise as required. This rotation of the drive shaft 28,128 will in turn rotate the gear 40,140 and power screw 42,142, and the socket 44,144 will axially slide towards or away from the output shaft 48,148, depending on the rotational direction of the motor drive shaft 28,128. The engagement of the spiral socket cam 50,150 on the end of the socket 44,144 with the spiral follower output shaft 48,148 will result in the rotation of the output shaft 48,148 as the socket 44,144 slides towards or away from the shaft 48,148. In this manner, whether in the swivel 6 or bent sub 12, the second member 20,120 attached to the output shaft 48,148 will rotate relative to the fixed first member 18,118 in response to the signal(s) generated at process steps 204 and 210.

[0076] Once modification process step 210 has been completed, an optional display step 212 may display the current drilling data on the RSS unit for the operator. If the decision step 208 determines that the drilling procedure is still within the desired limits, the process will skip the process step 210 and proceed straight to display step 212. Following the display step 212, the decision step 214 will determine whether a system stop has been initiated, either manually by the operator or automatically due to a malfunction detected by the controller 74. If no stop is initiated, the process will continue to input step 216 where the real-time data being received from the MWD tool is received. The process will then begin a further loop through the steps at processing step 204. If a system stop is determined at decision step 214, the process will pass to step 218 and shut down.

INDUSTRIAL APPLICABILITY

[0077] The present invention provides a directional drilling tool whose drilling angle and direction can be remotely adjusted simultaneously without interrupting the drilling
operation. As the tool can be steered whilst drilling is ongoing, drilling process efficiency is maximised with minimal NDT.

The motor drive arrangements employed in both the swivel and bent sub provide high accuracy rotational movements, as well as locking the rotating second portions at the desired angle relative to the fixed first portions. The drive arrangements also isolate the motors from any reactive loads from the drill bit.

The tool, system and method of the present invention are particularly suited to coiled tubing drilling operations. However, they may also be employed in other direction drilling operations if desired.

Whilst the preferred embodiment of the directional drilling tool includes dump valve as a top sub, it should be appreciated that in certain applications the dump valve is not necessary. In such instances, the dump valve may be replaced by an alternative top sub such as, for example, a crossover sub, float sub or flex sub.

Furthermore, although the preferred actuators for the swivel and bent sub within the tool are motor drives other actuator arrangements may be used instead. For example, the actuators may be hydraulically-operated clutches utilising the reactive torque coming from the power section of the tool. In this instance, the second members of the swivel and bent sub would only rotate in one (anticlockwise) direction. The clutches may be engaged and disengaged by adjusting the hydraulic pressure on a conical part male against a cooperating female part. This engagement and disengagement would be carried out by the remote control system on the surface.

The motor drive of the present invention is not limited to use in directional drilling tools and systems. The motor drive can be used in other applications, downhole or otherwise, where a first body is to be rotated relative to a second body. For example, the motor drive could be employed in a swivel sub for use where rotation of the lower part of a work string relative to an upper part of the string is desired.

These and other modifications and improvements may be incorporated without departing from the scope of the present invention.

1. A directional drilling tool, comprising:
   a first end attachable to a drill string, and a second end attachable to a drill bit;
   a swivel section intermediate the first and second ends and having a first swivel member non-rotatably attached to the first end and a second swivel member rotatably coupled to the first swivel member and rotatable relative thereto about a first axis of rotation which is coaxial with a longitudinal axis of the tool;
   a first actuator adapted to selectively rotate the second swivel member about the first axis of rotation;
   an adjustable bend section having a first bend member non-rotatably attached to the second swivel member and a second bend member rotatably coupled to the first bend member, wherein the first bend member is coaxial with the longitudinal axis, and the second bend member is rotatable relative to the first bend member about a second axis of rotation which is at a non-zero angle relative to the longitudinal axis; and
   a second actuator adapted to selectively rotate the second bend member about the second axis of rotation.

2. The drilling tool of claim 1, wherein the first actuator is housed in the first swivel member.

3. The drilling tool of claim 2, wherein the first actuator is a first motor drive comprising a first motor having a first rotating drive shaft, wherein the first motor drive transforms an initial rotational motion of the first drive shaft into an intermediate axial motion, and transforms the axial motion into a final rotational motion of the second swivel member.

4. The drilling tool of claim 3, wherein the first motor drive further comprises: a first drive member rotatably engaged with the first drive shaft; a second drive member non-rotatably engaged with the first swivel member and adapted to move axially relative to the first swivel member in response to rotation of the first drive member; and
   a first helical output shaft having a first end engaged with the second drive member and a second end attached to the second swivel member, wherein axial movement of the second drive member rotates the first output shaft and the second swivel member.

5. The drilling tool of claim 4, wherein the first output shaft is a follower shaft and the second drive member includes a socket cam in which the first end of the first output shaft is engaged.

6. The drilling tool of claim 3, wherein the second actuator is a second motor drive housed in the first bend member, the second motor drive lying along a drive axis which is at the non-zero angle relative to the longitudinal axis of the tool.

7. The drilling tool of claim 6, wherein the second motor drive comprises a second motor having a second rotating drive shaft, wherein the second motor drive transforms an initial rotational motion of the second drive shaft into an intermediate axial motion, and transforms the axial motion into a final rotational motion of the second bend member.

8. The drilling tool of claim 7, wherein the second motor drive further comprises:
   a third drive member rotatably engaged with the second drive shaft;
   a fourth drive member non-rotatably engaged with the first bend member and adapted to move axially relative to the first bend member in response to rotation of the third drive member; and
   a second helical output shaft having a first end engaged with the fourth drive member and a second end attached to the second bend member, wherein axial movement of the fourth drive member rotates the second output shaft and the second bend member.

9. The drilling tool of claim 8, wherein the second output shaft is a follower shaft and the fourth drive member includes a socket cam in which the first end of the second output shaft is engaged.

10. The drilling tool of claim 1, further comprising a remote control system having an operator control interface, the control system adapted to activate the first and second actuators in response to pre-programmed instructions and or manual inputs at the control interface.

11. The drilling tool of claim 10, wherein the control interface includes a graphical display means indicating the path of the tool.

12. A directional drilling system, comprising:
   the directional drilling tool of claim 1;
   a drill bit attached to the second end of the tool;
   a measuring device adapted to monitor the orientation and position of the drill bit;
   a remote control system having an operator control interface adapted to receive manual tool control inputs; and
an electronic controller adapted to selectively activate the first and/or second actuators of the tool in response to pre-programmed instructions and/or signals from the measuring device and/or remote control system.

13. The drilling system of claim 12, wherein each of the swivel and adjustable bend sections further comprises one or more positional sensors adapted to communicate the rotational position of the swivel and adjustable bend sections to the controller.

14. A control process for a directional drilling tool having a first swivel member non-rotatably attached to a first end of the tool and a second swivel member rotatably coupled to the first swivel member and rotatable relative thereto about a first axis of rotation which is co-axial with a longitudinal axis of the tool; a first actuator adapted to selectively rotate the second swivel member about the first axis of rotation; a first bend member non-rotatably attached to the second swivel member and a second bend member rotatably coupled to the first bend member, wherein the first bend member is co-axial with the longitudinal axis, and the second bend member is rotatable relative to the first bend member about a second axis of rotation which is at a non-zero angle relative to the longitudinal axis; and a second actuator adapted to selectively rotate the second bend member about the second axis of rotation; the process comprising the steps of:

   - receiving pre-programmed instructions and/or manual control inputs from a remote control system regarding a desired drilling path of a drill bit attached to the drilling tool;
   - applying the instructions and/or control inputs to the first and/or second actuators and commencing drilling on the desired path;

   - establishing the current orientation and position of the drill bit;
   - determining whether the current orientation and position of the drill bit indicates that the drill bit remains on the desired drilling path;
   - checking for additional manual control inputs from the control system; and
   - applying any necessary modifications to the first and/or second actuator positions based upon the determination step and/or additional control inputs.

15. The process of claim 14, further comprising the step of displaying the current drilling path on an operator control interface of the remote control system.

16. A motor drive for rotating a second body relative to a first body, the motor drive comprising:

   - a motor having a rotating drive shaft;
   - a first drive member rotatably engaged with the drive shaft;
   - a second drive member non-rotatably engaged with the first body and adapted to move axially relative to the first body in response to rotation of the first drive member;
   - a helical output shaft having a first end engaged with the second drive member and a second end attached to the second body, wherein axial movement of the second drive member rotates the helical output shaft and the second body.

17. The motor drive of claim 16, wherein the helical output shaft is a follower shaft and the second drive member includes a socket cam in which the first end of the helical output shaft is engaged.