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Ogly et al.

[11] 3,822,972

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[54] MULTISTART HELICAL ROTOR MECHANISM

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[52] **U.S. Cl.** **418/48**

[51] **Int. Cl.** **F01c 1/10**

[58] **Field of Search** 418/48

[56] **References Cited**

UNITED STATES PATENTS

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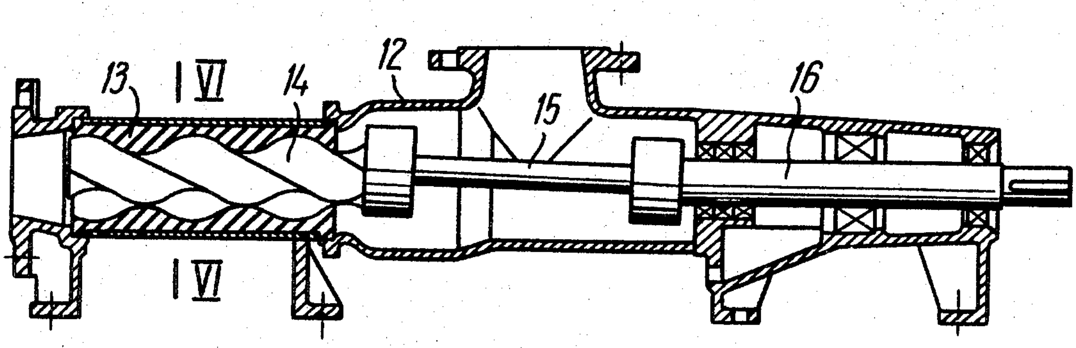
[57] **ABSTRACT**

Proposed geometrical parameters of a multi-start helical rotor mechanism, which can be used both as the working member of hydraulic or neumatic machines and as a reducing device, permit the obtaining of a minimum contact pressure and provide enhanced smoothness of the engagement between the helical surfaces of the rotor and stator of the rotor mechanism.

2 Claims, 10 Drawing Figures



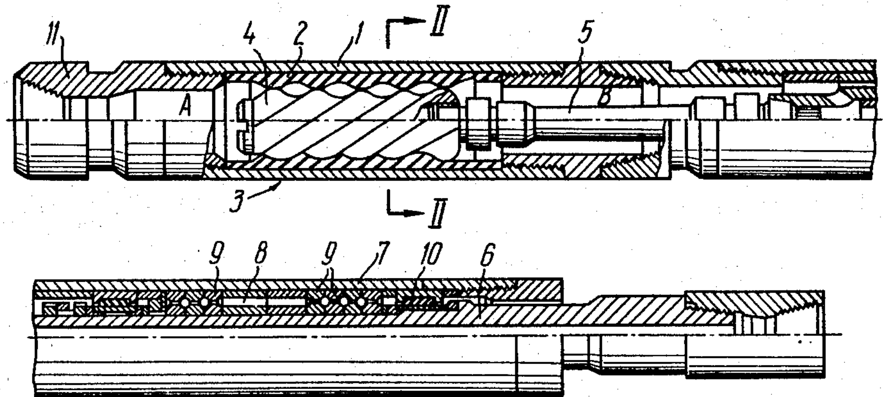


FIG. 1

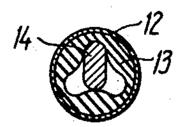


FIG. 6

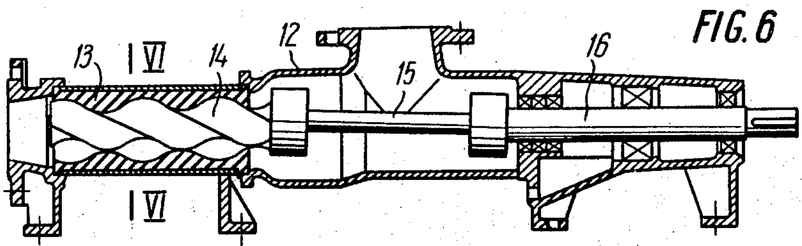


FIG. 5

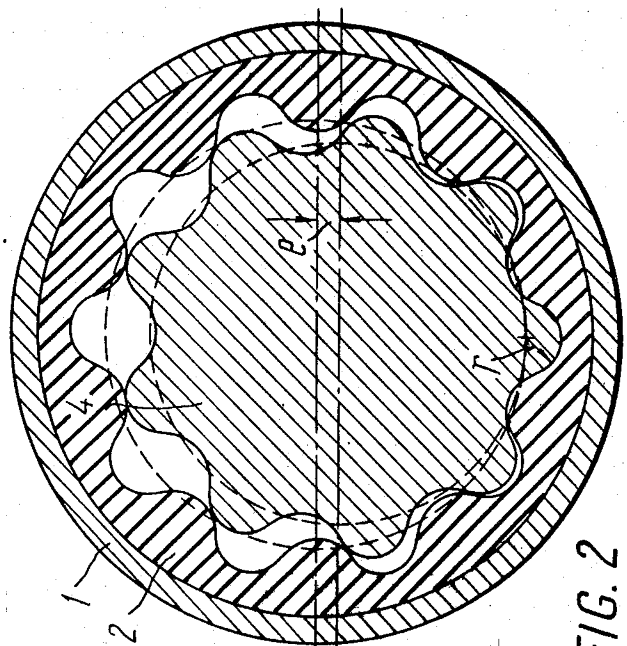


FIG. 2

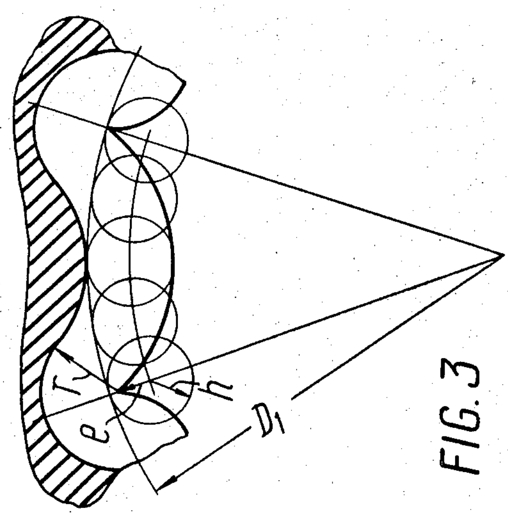


FIG. 3

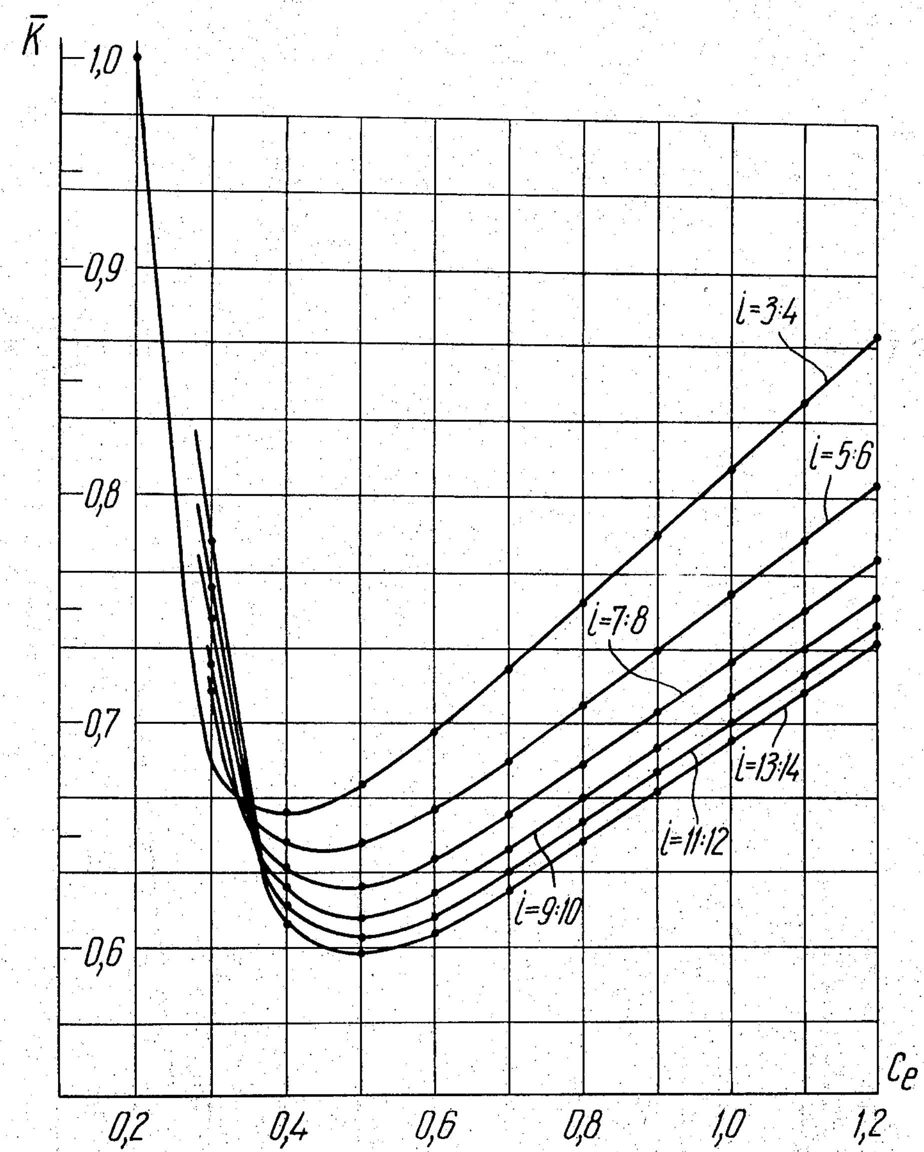

$\bar{K}$
1,0
0,9
0,8
0,7
0,6
i=3:4
i=5:6
i=7:8
i=9:10
i=11:12
i=13:14
C_e
0,2
0,4
0,6
0,8
1,0
1,2

FIG. 4

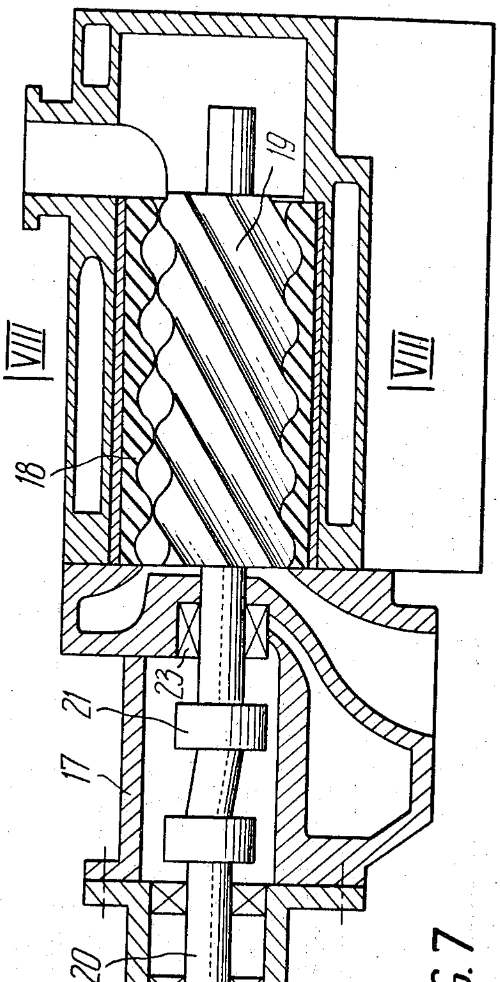


FIG. 7

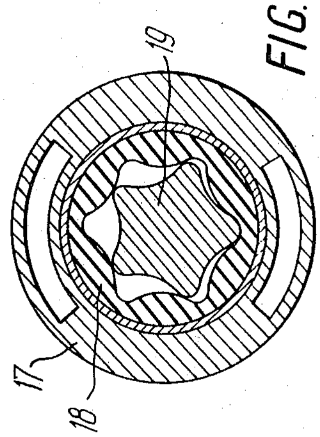


FIG. 8

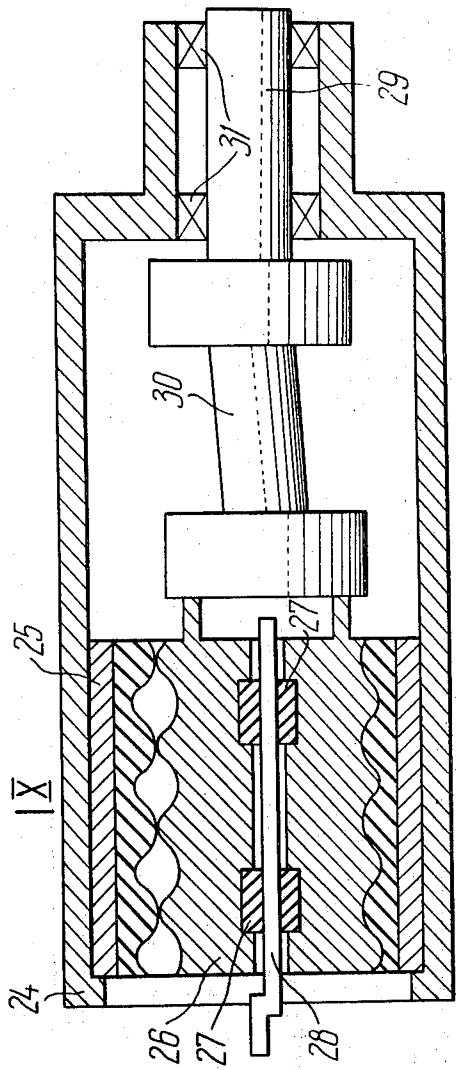


FIG. 9

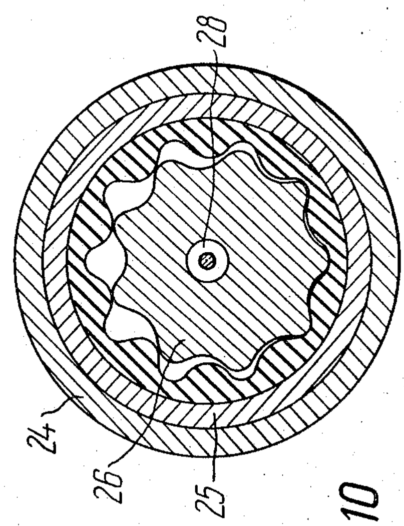


FIG. 10

MULTISTART HELICAL ROTOR MECHANISM

The present invention relates to hydraulic and pneumatic machines, and more particularly to multistart helical rotor mechanisms.

The present invention may be the most advantageously used in the downhole hydraulic motors for boring wells, in the hydraulic pumps, compressors, as well as in all the cases, where operating conditions require that the mechanism be accommodated within a restricted space, while retaining the possibility of achieving relatively high torque or output (for pumps).

Prior art multistart helical rotor mechanism used in a downhole helical hydraulic motor comprises a housing accommodating a stator having an internal elastic lining. A helical groove is made on the surface of the lining.

A rotor is eccentrically disposed in the stator, the external surface of the rotor being also provided with a helical groove.

The rotor and the stator form a kinematic pair with the permanent contact similarly to a gearwheel and pinion with internal gearing and define closed chambers.

The rotor axis is shifted with respect to the stator axis over the distance of the eccentricity "*e*." The number of teeth of the helical surfaces of the stator and rotor corresponds to the number of entries of a screw thread. In the prior art helical rotor mechanism the number of teeth Z_1 of the stator is one tooth greater than the number of teeth Z_2 of the rotor. The ratio between the pitches T and t of the stator and rotor respectively is directly proportional to the ratio between the teeth numbers:

$$T/t = Z_1/Z_2$$

The ratio between the numbers of teeth of the helical surfaces of the rotor and the stator is referred to as a kinematic ratio i.

In the prior art multistart helical rotor mechanism the cross sectional profile thereof is formed on the basis of cycloidal gearing (hypocycloid or epicycloid).

The stator profile in the cross section represents alternating portions of cycloidal curves and circle arcs. The cross sectional profile of the rotor represents an envelope of the stator profile formed by rolling of the initial maximum circle of the rotor selected based on the condition of continuous contact between the helical surfaces of the rotor and stator, inside of the predetermined starting circle of the stator.

The stator circle is assumed to be the starting one. In this case the cross sectional profile of the stator is considered to be the base one, and the rotor profile — the conjugated one. The stator profile is equidistant of the cycloidal curve spaced from the latter at the distance corresponding to the radius r of the stator tooth. The cycloidal curve proper is formed by rolling without sliding over a predetermined starting stator circle of another conventional circle, the radius h of this circle being equal to the excentricity in the centroid gearing. The diameter D_1 of the starting circle of the stator is assumed to be

$$D_1 = 2eZ_1$$

The conjugated profile of the rotor is formed as an envelope of the base profile of the stator by rolling of the initial circle of the rotor over the initial circle of the stator.

In the prior art downhole motor during the operation the helical rotor mechanism develops rather high torque, whereby specific pressures arise at the points of contact between the rotor and the stator resulting in rapid wear thereof.

In addition, in prior art helical rotor mechanisms different gear-cutting tools are required for making the rotor and the stator, thereby complicating the technological process of the motor manufacturing as a whole.

It is an object of the present invention to provide a multistart helical rotor mechanism which has higher reliability and durability in operation, while being less time-consuming in manufacture.

The above and other objects of the invention are accomplished in a multistart helical rotor mechanism comprising a stator having a helical groove on the internal surface thereof and a rotor eccentrically disposed in the stator and having the external helical surface, the cross sectional profile of the stator comprising serially arranged circle arcs, each arc being conjugated on both sides with portions of a cycloidal curve formed by rolling without sliding over a predetermined starting circle of the stator of another conventional circle, the radius of this circle being selected corresponding to the amount of said eccentricity, whereas the cross sectional profile of the rotor comprises an envelope of the stator profile formed by rolling of the initial maximum circle of the rotor selected based upon the condition of continuous contact between the helical surfaces of the rotor and stator inside of the predetermined starting circle of the stator.

According to the invention the ratio between the amount of the eccentricity of the mechanism and the radius of the circle arc of the stator cross sectional profile should be within the range from 0.3 to 0.85.

Due to the selection of the above-mentioned ratio minimum contact pressure in the pair "rotor-stator" is achieved, whereby the reliability and durability of the mechanism are increased.

In the multistart helical rotor mechanism according to the invention the cross sectional profile thereof is formed on the basis of extracentroidal gearing, wherein the radius of the conventional circle used for plotting of cycloidal curve is not equal to the eccentricity.

Extracentroidal gearing is characterized by the ratio between the amount of eccentricity and the radius of the above-mentioned conventional circle.

In this case according to the invention, the ratio between the amount of eccentricity and the radius of the conventional circle is selected within the range from 0.9 to 0.98.

Due to this fact the smoothness of the helical surfaces of the rotor and the stator is improved, thereby reducing relative sliding therebetween, and hence, the wear.

In addition, according to the invention the helical surfaces of the stator and rotor may be cut with one and the same tool, whereby the technological process of manufacture of the mechanism as a whole is simplified.

The invention will now be described in detail with reference to the specific embodiments shown in the accompanying drawings, in which:

FIG. 1 shows a general view partially in longitudinal section of the embodiment of a multistart helical rotor mechanism used in a downhole hydraulic motor;

FIG. 2 is a sectional view taken along the line II—II in FIG. 1;

FIG. 3 shows a diagram of plotting the cross sectional profile of the stator;

FIG. 4 is a plot showing the relative specific pressure versus a parameter C_e;

FIG. 5 shows a general view in longitudinal section of the embodiment of the helical rotor mechanism used in a hydraulic pump;

FIG. 6 is a sectional view taken along the line VI—VI in FIG. 5;

FIG. 7 shows a general view in longitudinal section of the embodiment of the helical rotor mechanism used in a compressor;

FIG. 8 is a sectional view taken along the line VIII—VIII in FIG. 7;

FIG. 9 shows a general view in longitudinal section of the embodiment of the helical rotor mechanism used in a reduction gear;

FIG. 10 is a sectional view taken along the line X—X in FIG. 9.

A downhole helical hydraulic motor (FIG. 1) comprises a housing 1 in which there is rigidly mounted an elastic lining 2 provided with a tenthread helical groove on the internal surface thereof. The housing 1 with the lining 2 form a stator 3 of the helical rotor mechanism. A rotor 4 is disposed in the stator 3 with an excentricity "e," the external surface of the rotor being provided with a ninethread helical groove. Accordingly, the kinematic ratio of the helical rotor mechanism is equal to $i = 9:10$.

In the example referred to the helical rotor mechanism has extracentroidal cycloidal gearing. FIG. 2 shows the cross sectional profile of the helical rotor mechanism, wherein the cross sectional profile of the stator 3 comprises successively alternating portions of a cycloidal curve defining the teeth of the stator 3 and arcs of circles of the radius "r" defining tooth spaces in the stator cross section. The cycloidal curve which constitutes the basis for the formation of the profile of the stator 3, is formed by rolling without sliding over a predetermined starting circle of the stator 3 of another conventional circle, the diameter of this circle being selected depending upon the amount of eccentricity "e." The predetermined starting circle of the stator is generally determined by the operational conditions of the mechanism and depends upon maximum diameter possible under these conditions.

The cross sectional profile of the rotor 4 is conjugated with the profile of the stator 3 and is formed as an envelope of the base profile of the stator 3 by rolling the initial circle of the rotor 4 over the initial circle of the stator 3.

Specific pressures arise in points of contact between the rotor 4 and stator 3. The value of the specific pressure is analytically expressed in the following general form:

$$K = f(M, i, C_e, L, E, \mu),$$

wherein:

M — is torque developed by the motor;

$i = Z_2/Z_1$ — is kinematic ratio of the helical rotor mechanism;

$C_e = e/r$ — is dimensionless geometric parameter of the helical rotor mechanism;

L — is length of the rotor and stator;

E, μ — are physical and mechanical constants of the stator elastic lining material.

With the values M, L, E and μ being constant, the expression may be written in the following form:

$$K = f(i\ C_e)$$

FIG. 4 shows the plot of the relative specific pressure K versus C_e for helical rotor mechanisms having different kinematic ratios. As will be apparent from FIG. 4, the helical rotor mechanisms have the range of C_e values which corresponds to minimum specific pressures. The analysis has shown that for all mechanisms the range of the values of $C_e = 0.3 - 0.85$ is optimal for all mechanisms, wherein the specific pressures do not exceed the minimum ones by more than 15–20 percent. In this example the helical rotor mechanism has the parameter $C_e = 0.55$. This allows the reduction of the specific pressure by about 17 percent as compared to the prior art downhole helical hydraulic motor.

The extracentroidal gearing used in this embodiment is characterized by the extracentroid factor:

$$C_o = e/h,$$

wherein:

h — is the radius of the conventional circle used for plotting the cycloidal curve.

In order to reduce relative sliding between the stator 3 and the rotor 4 and to improve the smoothness of the helical surfaces thereof, it is advisable to select the extracentroid factor within the range of $C_o = 0.9–0.98$ depending upon the operational conditions and materials of the stator 3 and the rotor 4.

In this example the extracentroid factor is

$$C_o = e/h = 0.95$$

The rotor 4 of the helical rotor mechanism is connected to the output shaft 6 by means of a double-hinged coupling 5, the actuating tool of the downhole motor (not shown) being secured at the end of the shaft. The output shaft 6 is mounted in a spindle 7 by means of radial bearings 8. Thrust bearings 9 mounted in the spindle 7 take up the axial load during the downhole motor operation. The end of the shaft 6 extends outwards through a gland 10. The housing 1 of the downhole motor is connected to a hydraulic pump by means of a reducer 11 and piping (not shown in the drawing).

The downhole motor functions as follows.

The hydraulic pump feeds fluid under pressure into a cavity A of the motor to establish the same pressure therein. The cavity A is referred to as the high-pressure cavity. The helical teeth of the rotor 4 and the stator 3 contact each other, thereby defining chambers closed along the pitch "T" of the helical surface of the stator 3. Therefore, a number of chambers are connected to the high-pressure cavity A, and a number of chambers — to a low-pressure cavity B. For that reason an unbalanced force, and hence, torque arises in every cross section of the mechanism. Under the action of these forces the radial deformation of the elastic lining 2 of the stator takes place together with the shift of the rotor 4 in the direction transversal with respect to its axis, whereupon the rotor performs planetary motion rolling over the teeth of the stator **3.**

In so doing, the axis of the rotor **4** performs the translatory motion in the counter clockwise direction, while the rotor itself rotates in the clockwise direction.

The rotor **4** imparts rotation to the output shaft via the double-hinged coupling **5,** which rotation is then transmitted to the actuating tool of the downhole motor fixed at the end of the shaft.

During the movement of the rotor **4** the radial forces determine the amount of contact pressure in the pair "rotor-stator." In addition, the contact pressure also depends upon the pressure difference between the chambers of the motor in communication with the high-pressure cavity A and the low-pressure cavity B respectively.

Due to the multiplicity of starts of the stator **3** and the rotor **4** the number of chambers and of contact lines is increased, and the interthread pressure difference is reduced.

Therefore, the helical rotor mechanism according to the invention exhibits higher efficiency and can withstand greater load as compared to a mechanism of the same size which does not possess the abovedescribed structural features.

FIG. **5** shows a hydraulic pump, wherein the helical rotor mechanism according to the invention is used. The pump comprises a housing **12** having suction and discharge nozzles. The housing **12** accommodates an elastic lining **13** provided with a helical surface. The housing **12** with the lining **13** forms a stator in which there is eccentrically disposed a rotor **14** connected to a drive (not shown) by means of a universal shaft **15** and an intermediate shaft **16.** In this embodiment the helical rotor mechanism has the kinematic ratio $i = Z_2/Z_1 = 2:3$ and the parameter $C_e = 0.5$.

The drive rotates the rotor **14,** whereby reduced pressure is established in the zone of the suction nozzle, and fluid is sucked into the cavity of the housing **12.** During the rotation of the rotor **14** relative to the stator redistribution of pressure and growth of fluid head take place.

The multiplicity of starts of the helical rotor mechanism ensures rather high output of the pump and small size thereof. In this example the specific contact pressure in the helical rotor mechanism is reduced by about 24 percent as compared to the prior art construction.

FIG. **7** shows the example of the use of the helical rotor mechanism according to the invention in a compressor.

The compressor comprises a housing **17** having a passage for supply of a liquid coolant, a stator **18** accommodated in the housing **17** and a rotor **19.** The rotor is driven via an output shaft **20** and a universal shaft **21.** Bearings **22** take up axial and radial loads, and a sealing **23** is adapted to seal the suction chamber of the compressor.

This device is similar in operation to well-known rotary compressors.

In this embodiment of the compressor the helical rotor mechanism has the kinematic ratio $i = 5:6$ and the parameter $C_e = 0.5$. This ensures the reduction of the specific contact pressure in the pair "rotor-stator" by 18 percent as compared to the prior art device of the helical rotor mechanism.

FIG. **9** illustrates the use of the multistart helical rotor mechanism as a reduction gear. A housing **24** of the reduction gear accommodates the helical rotor mechanism comprising a stator **25** and a rotor **26.** As differs from hydraulic and pneumatic devices, wherein the length "L" of the mechanism should be at least equal to the pitch "T" of the helical surface of the stator, in this case the length of the mechanism is determined based upon the contact pressure and the rigidity of the reduction gear. Mounted in the bore of the rotor **26** are bearings **27** supporting a carrier **28.** The latter is made in the form of a crankshaft, the axis of the shank of the shaft being displaced from the axis of the shaft itself by the amount of eccentricity "e" of the helical rotor mechanism. The rotor **26** is connected to the output shaft **29** of the reduction gear by means of a universal shaft **30.**

Bearings **31** take up axial and radial loads.

The torque transmitted by this device is reduced by Z_2 times, since the multistart helical rotor mechanism kinematically represents a planetary gearing having the gear ratio equal to Z_2. By changing the gear ratio of the helical rotor mechanism various degrees of reduction of speed and torque can be achieved.

The helical rotor mechanism used ensures minimum specific pressure in the working parts of the reduction gear.

What is claimed is:

1. A multistart helical rotor mechanism comprising a stator and a rotor eccentrically disposed in the stator; said stator having a helical groove on the internal surface thereof; said rotor having a helical groove on the external surface thereof; the cross sectional profile of said stator comprising serially conjugated arcs of circle alternating with portions of a cycloidal curve formed by rolling without sliding over a predetermined starting circle of the stator of another conventional circle, the radius of this circle being selected depending upon the amount of said eccentricity; the cross sectional profile of said rotor comprising an envelope of the profile of said stator formed by rolling of the initial maximum circle of the rotor, selected based upon the condition of continuous contact between the helical surfaces of the rotor and stator inside of said predetermined starting circle of said stator; the ratio between the amount of said eccentricity and the radius of the arc of circle of the cross sectional profile of said stator being within the range from 0.3 to 0.85.

2. A multistart helical rotor mechanism as claimed in claim **1,** wherein the ratio between the amount of eccentricity and the radius of the conventional circle is within the range of 0.9 to 0.98.

* * * * *