Jan. 4, 1966 P. FAVROT 3,227,049

MEANS FOR AXIALLY RECIPROCATING A REVOLVING SHAFT

Filed May 26, 1964 2 Sheets-Sheet 1

FIG.1

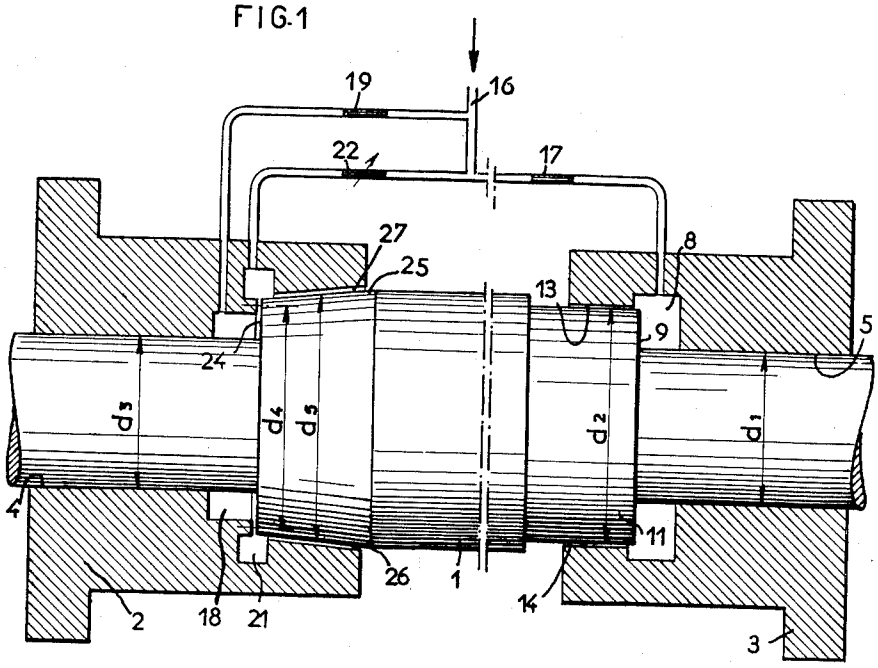


FIG.4

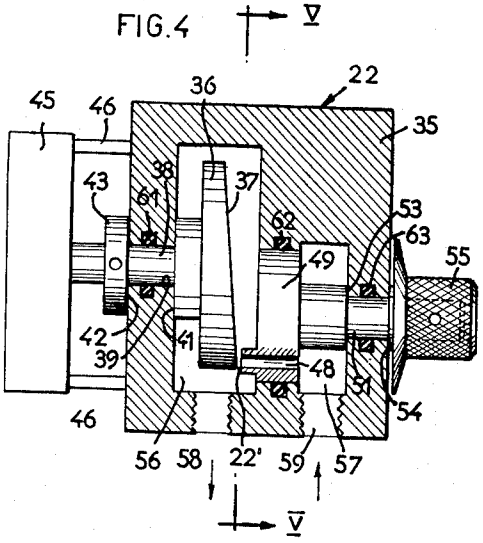
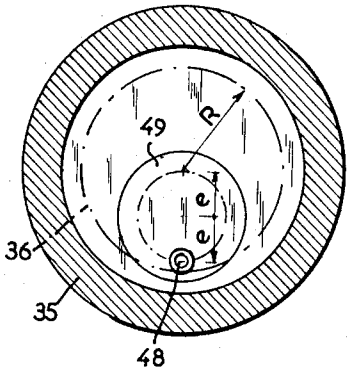


FIG.5



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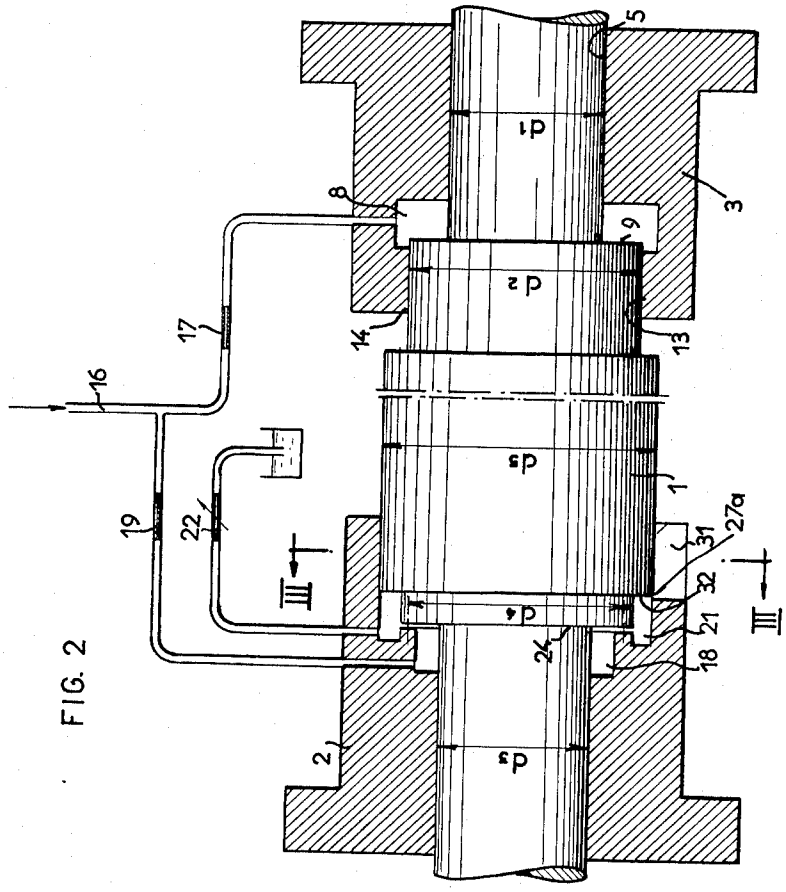


FIG. 2

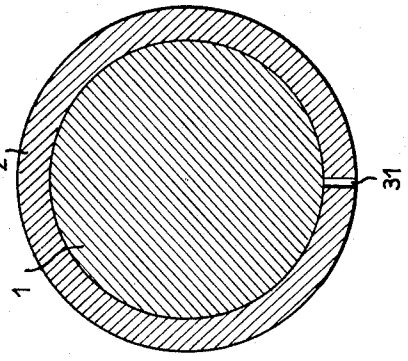


FIG. 3

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MEANS FOR AXIALLY RECIPROCATING A REVOLVING SHAFT

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4 Claims. (Cl. 91—39)

This invention relates to a device for imparting controllable axial reciprocations to a rotatable and reciprocable shaft while the shaft is simultaneously being driven in rotation.

The invention is particularly, although not exclusively, useful in the field of machine-tool construction, as for controlling the reciprocatory movement of a rapidly revolving spindle carrying a grinding wheel or other tool in a grinder, rectifier, milling cutter or the like.

Objects of the invention are to provide simple and effective fluid-pressure means whereby a rapidly revolving member can be smoothly and regularly reciprocated cyclically in an axial direction during its rotation, and wherein the rate or cycle period and amplitude of the reciprocatory motion can be easily and efficiently controlled over a wide range.

In an important aspect, the invention is directed to a device for axially reciprocating a revolving shaft, comprising means supporting the shaft for rotation and axial reciprocation; means for rotating the shaft; a pair of pressure chamber means surrounding the shaft; oppositely directed pressure-responsive surfaces formed on the shaft and exposed to the pressure in the respective chamber means; pressure fluid inlets into the respective chamber means; means defining fluid exhaust passages from the respective chamber means, and so formed that the effective exhaust flow section area from at least one of the chamber means is variable with the axial position of the shaft; pressure-fluid flow circuit means connected for continuously circulating pressure fluid from each inlet through the associated chamber means and out through the associated exhaust passage means; and means for cyclically varying the fluid pressure in the circuit means associated with at least one of the chamber means whereby to reciprocate the shaft in synchronism with such cyclic pressure variations.

The invention is also directed in another of its aspects to improved means for creating cyclically variable pressure surges in a pressure fluid circuit which will be controllable over a wide range both in cycle period and amplitude.

Embodiments of the invention will now be described for purposes of illustration but not of limitation with reference to the accompanying drawings wherein:

FIG. 1 is a simplified view mainly in axial section of a first embodiment of a reciprocable revolving shaft provided with the reciprocating means of the invention;

FIG. 2 is a similar view of a modified embodiment;

FIG. 3 is a cross section on line III—III of FIG. 2;

FIG. 4 illustrates, mainly in axial section, a form of cyclic fluid pressure varying device according to the invention which is suitable for use in conjunction with the reciprocating means shown in FIGS. 1–3; and

FIG. 5 is a cross section on line V—V of FIG. 4.

Illustrated in FIG. 1 is a revolving spindle or shaft **1**, e.g., a spindle carrying a grinding wheel (not shown) in a grinder or similar machine-tool. The shaft **1** is supported in a pair of axially spaced bearing blocks **2** and **3** formed with cylindrical bores in which complementary cylindrical journal sections **4** and **5** of the shaft are rotatable, and axially reciprocable. It will be understood

that the shaft **1** may be driven in rapid rotation by any suitable motor means, not shown, and connected to an end of the shaft beyond one of the bearings, or possibly to an intermediate section of the shaft between the bearings **2** and **3**.

Formed in the bearing block is an annular chamber **8** surrounding the journal section **5** and having one of its side walls defined by a transverse wall portion **9** formed by a shoulder or increased-diameter section **11** of the spindle **1**, which section is positioned in a bore **13** of the bearing block **3**, providing a coaxial extension of chamber **8**. The shaft section **11** has a diameter *d2* which is greater than the diameter *d1* of the journal section **5**. The bore **13** in which this large-diameter shaft section **11** is positioned is slightly larger in diameter than the diameter *d2* of said section **11**, so as to define a narrow annular gap **14** providing an exhaust passage from the pressure chamber **8**, as will presently appear.

Chamber **8** has a side inlet, as shown, with which connects a pressure delivery line connected as at **16** with a suitable source of pressure fluid not shown, said delivery line having interposed in it, as schematically shown a calibrated orifice nozzle **17**.

The other bearing block **2** has an annular chamber **18** surrounding the shaft journal **4** and having one of its side walls defined by a transverse wall section **24** of the shaft **1**. The transverse wall **24** constitutes the end surface of a conically tapered section **25** of the spindle **1**, which cooperates with a complementary conical bore **26** of the bearing block **2**. Communicating with the inner end of the conical bore **26** is another annular chamber **21**, of larger radius than the chamber **18**, and communicating with this latter chamber as shown by way of a radial annular space extending across the transverse wall surface **24**.

Chamber **18** has a side inlet which connects with the pressure fluid supply line **16** by way of a branch line including a calibrated orifice nozzle **19**, and chamber **21** likewise has a side inlet which connects with the pressure line **16** by way of another branch line in which is interposed a cyclically variable pressure device **22**. An exemplary construction suitable for the variable pressure device **22** will be described later with reference to FIGS. 4 and 5.

It will be seen that the pressure fluid circuit associated with the chamber **21** extends from pressure line **16** through variable pressure device **22**, through chamber **21** and out therefrom by way of the conical annular exhaust passage **27** defined between the complementary conical surfaces **25** and **26**. This exhaust passage **27** has a variable flow section area which depends on the axial position of the spindle **1** in its bearings, the exhaust section area increasing with increasing axial displacements of the spindle **1** in the rightward direction as here shown. The pressure fluid circuit associated with chamber **18** extends from pressure line **16**, through fixed orifice **19**, through chamber **18**, then radially outward across the end surface **24** of the spindle, into chamber **21** and out therefrom through variable exhaust passege **27**.

In FIG. 1, *d3* designates the diameter of the shaft journal section **4**, *d4* designates the mean diameter of the effective annular part of the transverse surface **24**, and *d5* the mean diameter of the conical surface **25**. The calibrated orifices **17** and **19** may be so selected and adjusted that the pressure normally obtaining in chamber **18** is about one half the source pressure in pressure line **16**, and thep ressure in chamber **8** exerts an opposing axial thrust which substantially balances the pressure in chamber **18**.

The system operates as follows. Assume first the variable pressure orifice **22** is completely shut off, so that the pressures in both chamber **18** and **21** are equivalent.

In these conditions it will be evident that the fixed calibrated orifices 17 and 19 can be so adjusted in relation to one another that the shaft 1 can be made to be retained floatingly at a stationary axial position as determined by equilibrium between the rightward thrust exerted by the pressure in chambers 18–21 upon an effective surface area determined by the difference between the diameters *d*3 and *d*4 on one side, and the leftward thrust exerted by the pressure in chamber 8 upon the effective surface area determined by the difference between diameters *d*1 and *d*2 on the other side. Assuming now that variable-orifice device 22 is progressively opened, the pressure in chamber 21 rises, the rightward thrust predominates over the leftward thrust, and the spindle 1 shifts axially in the rightward direction. This causes a concurrent gradual increase in the section area of the exhaust passage 27, so that the rightward pressure progressively diminishes and eventually the spindle 1 attains a new position of equilibrium in which the opposing pressure thrusts are once again balanced, with the spindle 1 shifted rightward from its initial position. If now the variable orifice 22 is again closed somewhat, the rightward pressure in the left-hand chambers 18 and 21 drops below the equilibrium value, and a leftward shift of spindle 1 results. It will thus be apparent that if cyclic variations are imparted to the section area of orifice 22 by any suitable means, such as those to be presently described, then the spindle 1 will move to and fro in its bearings 2 and 3, at a rate determined by the rate of said variations.

The form of embodiment illustrated in FIG. 2 differs from the construction just described in two ways, which may be applied separately if desired.

A first modification resides in the fact that the variable section orifice 22 instead of being interposed in the inlet leg of the fluid circuit associated with chamber 21, is interposed in the discharge leg of said circuit. That is, the chambers 18 and 21 are here disopsed in series in a common pressure fluid circuit rather than being disposed in the parallel relation shown in FIG. 1. The common circuit is traced from pressure line 16, through fixed-calibrated orifice 19, through chamber 18, chamber 21 and out to the exhaust or sump by way of the variable-section orifice 22. This flow circuit arrangement may be substituted in the system illustrated in FIG. 1 if desired.

According to the other modification applied in this embodiment, the tapered conical shaft section of the first construction is omitted, and the chamber 21 has one side wall defined by a transverse annular wall 32 of a large-radius cylindrical section (diameter *d*6) of spindle 1 slidable in a complementary cylindrical bore of bearing 2. This annular wall 32 constitutes a shoulder between said large-diameter spindle section (diameter *d*5) and an intermediate-diameter shaft section of diameter *d*7 providing the transverse wall exposed to the pressure in chamber 18 as in the first embodiment.

In order to provide a variable exhaust passage for the pressure fluid from chamber 21 with a section area increasing with rightward axial displacement of the spindle, in this case the bearing block 2 has a radial axially-extending slot 31 formed in it, e.g., as a saw cut, which communicates at its radially inner end with the large-diameter cylindrical bore formed in the bearing block. With this arrangement it will be clear that when the spindle 1 is moved axially rightward the uncovered portion of the slot 31 is gradually increased, and the effective cross section of the exhaust passage from chamber 21 increases, as required in accordance with the invention.

With this in mind, it will be apparent that the device of FIGS. 2–3 operates in a manner similar to that of FIG. 1, except for the fact that closure (not opening) of the variable-orifice nozzle 22 will produce a leftward shift of the shaft 1 in order to restore pressure equilibrium, while opening of the nozzle 22 will cause a rightward shift of the shaft. This of course is because the variable orifice 22 in this instance is interposed in the exhaust leg of the flow circuit associated with chamber 21. Thus cyclic variations of the orifice 22, produced e.g. in the manner to be described, will again result in an axial reciprocation of the shaft 1 at a frequency determined by the frequency of the cyclic pressure variations.

An exemplary embodiment of a cyclically variable orifice device usable as either of the devices 22 referred to above, will now be described with reference to FIGS. 4 and 5.

The device shown in those figures comprises a generally cylindrical casing or body 35 formed with a first large-diameter chamber 56 coaxial with the casing near one end of it, and another, smaller chamber 57 near its other end in eccentric relation to chamber 56. Rotatable in the chamber 56 is a disc-like member 36 having a bevelled outer face 37, and formed integral with an axial shaft 38 rotatable in a central bore 39 formed in the end wall of casing 35. The shaft 38 connects with disc 36 by way of a hub section having a flat face 41 seated against the inner wall surface of casing 35 to fix the axial position of the disc member in chamber 56. Pinned to the outer end of shaft 38 is a stop collar 43 having a flat face 42 seated against the outer wall surface of the casing. The projecting end of shaft 38 is adapted for coupling to any suitable motor means, such as a small electric motor and reducer unit schematically indicated at 45 as being secured to the casing 35 through bolts or spacers 46. Preferably the motor unit 45 has provision for adjusting its speed, so as to make it possible to impart a desired angular velocity to the disc member 36 within a range of values, say about a mean value of about 1 revolution per second.

A nozzle member including a hub 49 and an excentric nozzle orifice 48 formed through said hub in a direction parallel to its axis and near its periphery, is mounted a tight friction fit in a bore formed in the separating wall between the chambers 56 and 57 as shown. The nozzle passage 48 has a tip projecting into the chamber 56 towards the disc member 36, so as to define with the bevel face 37 of that member a variable gap 22′ the width of which is a minimum for one angular position of the disc member 36 about its axis, the position shown in FIG. 4, and is a maximum for the diametrically opposite angular position of the disc member.

The nozzle hub 49 has an axial pivot 51 projecting from it through the inlet chamber 57 and through the opposite end wall of casing 35, and an adjusting knob 55 is keyed on to the projecting outer end of said pivot. The axial position of the nozzle hub 49 in the casing is fixed by the seating of a shoulder surface 53 of pivot 51 against a wall of chamber 57 as shown. The flat face 54 of knob 55 is seated against the outer end wall surface of casing 35. Seal rings 61, 62 and 63 are seated in grooves formed in the casing 35 around the shaft 38, nozzle hub 49 and pivot 51 respectively.

The nozzle orifice 48 is spaced from the centre axis of nozzle hub 49 by a distance *e* which is substantially equal to the off-centre displacement of the axis of said nozzle disc 49 from the axis of the revolving disc member 36 and each of said excentricity values *e* is substantially equal to one half the radius R of the disc member 36.

Outlet chamber 56 and inlet chamber 57 have side openings 58 and 59 respectively, threaded for connection with pressure fluid lines. Referring to FIG. 1, it will be understood that the inlet chamber opening 59 would there be connected with pressure line 16 and outlet chamber opening 58 would be connected with the chamber 21. In the arrangement of FIG. 2, opening 59 would be connected with chamber 21 and outlet opening 58 would be connected to the sump.

The device operates as follows. With the angular position of nozzle disc 49 determined by the setting of knob 55 so that nozzle 48 assumes a position of maximum ec-

centricity with respect to the axis of disc member **36**, as shown in FIGS. 4 and 5, it will be understood that each revolution of the disc member **36** produces a maximum amount of variation in the width **22'** of the gap through which the fluid is constrained to pass in flowing to the outlet **58**. If on the other hand knob **55** is rotated to the diametrically opposite setting nozzle orifice **48** becomes substantially aligned with the centre of disc member **36** so that there is no variation in the width of gap **22'**. It will thus be seen that rotation of knob **55** permits adjusting the amplitude of the cyclic pressure variations produced in the operation of the device, while adjustment of the speed of rotation of disc member **36** varies the frequency of said cyclic variations. The cyclically varying pressure drop to which the fluid is subjected as it is forced through the variable gap **22'** creates the pressure variations or surges in chamber **21**, referred to in the description of FIGS. 1–3.

It will thus be apparent that if the variable pressure device of FIGS. 4–5 is used as the device designated **22** in either of the embodiments of the invention first described, the reciprocation of the shaft **1** during rotation thereof in the bearings **2** and **3** can be adjusted over a wide range.

It will be understood that various modifications may be introduced into the forms of the invention disclosed herein without exceeding the scope of the invention. As one example, in the constructions both of FIG. 1 and of FIGS. 2–3, the fixed and variable orifice nozzles designated **19** and **22** may be interchanged while still providing an operant device.

Or the variable-orifice device may be associated with the chamber having a constant-section exhaust passage, i.e. provided in place of the fixed-orifice nozzle designated **17** in the figures, and in which case the vairable-section exhaust passage **27** or **31** may be arranged to have its effective cross-section increased with leftward rather than rightward displacement of the shaft (as by reversing the taper of the conical surfaces **25**, **26** in FIG. 1).

The exhaust passages from both side chambers (rather than from only one) may be made variable with shaft position, and/or the cyclic pressure vairations may be applied to both side chambers in a properly synchronized manner.

The constant pressure chamber **18** may be omitted.

The opposite pressure chambers may be defined within a common cylindrical capacity surrounding the shaft, on opposite sides of a piston-like flange carried by the shaft and movable in said capacity.

Such modifications and many others will be readily conceivable in the light of present disclosure.

What I claim is:

1. Mechanism comprising a shaft; bearing means supporting the shaft for rotation and axial reciprocation; a first and a second pressure chambers surrounding axially spaced sections of the shaft; oppositely-directed first and second pressure-responsive surfaces on the shaft exposed to the pressure in the first and second chambers respectively; a third pressure chamber surrounding the shaft adjacent said first chamber and a third pressure-responsive surface on the shaft directed in the same axial direction as said first pressure responsive surface and exposed to the pressure in said third chamber; pressure fluid inlets into the respective chambers; means defining fluid exhaust passages from the respective chambers with the effective exhaust flow section area through the exhaust passage means from at least one of the chambers being variable with the axial position of the shaft in its bearing means; pressure fluid flow circuit means connected for circulating pressure fluid from each inlet through the associated chamber means and out through the associated exhaust passage means, said circuit means including means for producing substantially equally and oppositely-acting pressure in said first and second chambers to tend to maintain the shaft floatingly in a balanced axial position in its bearing means; and means for cyclically varying the fluid pressure in said third chamber whereby to reciprocate the shaft about its said balanced position in synchronism with said cyclic pressure variations.

2. The mechanism defined in claim **1**, wherein the flow circuit means is connected to supply pressure fluid from a source to both said first and third chambers in parallel and the cyclic pressure varying means is interposed in the flow connection from said source to an inlet of said third chamber.

3. The mechanism defined in claim **1**, wherein the flow circuit means is connected to supply pressure fluid from a source first to said first chamber then to said third chamber in series, and the cyclic pressure varying means is interposed in a flow connection from an outlet of said third chamber.

4. The mechanism defined in claim **1**, further comprising calibrated orifices interposed in the flow circuit means between said source and an inlet to said first chamber and between said source and an inlet to said second chamber.

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