Oct. 13, 1964 J. LOXHAM 3,152,422

DRIVES FOR GEAR GRINDING MACHINES

Filed March 5, 1962 4 Sheets-Sheet 1

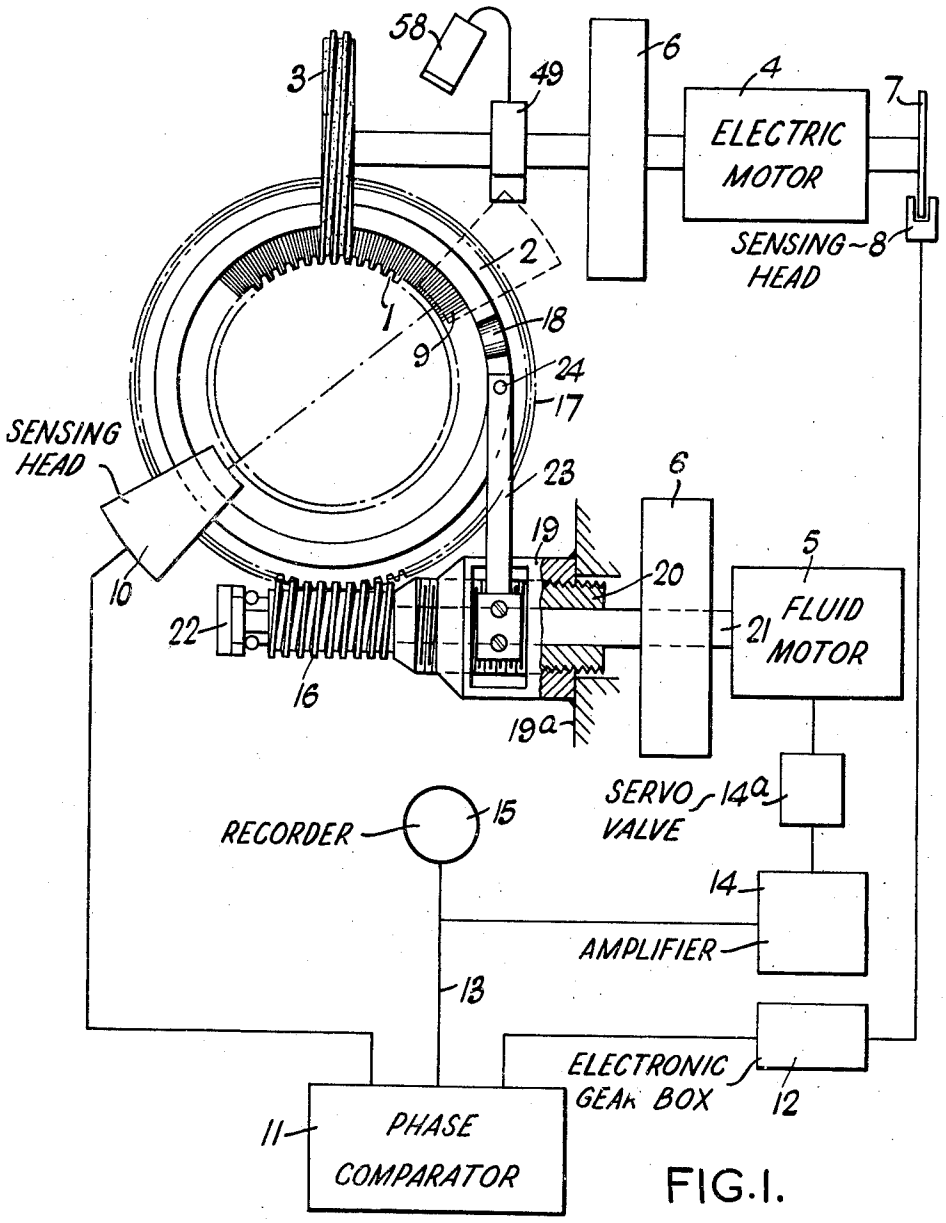


FIG.1.

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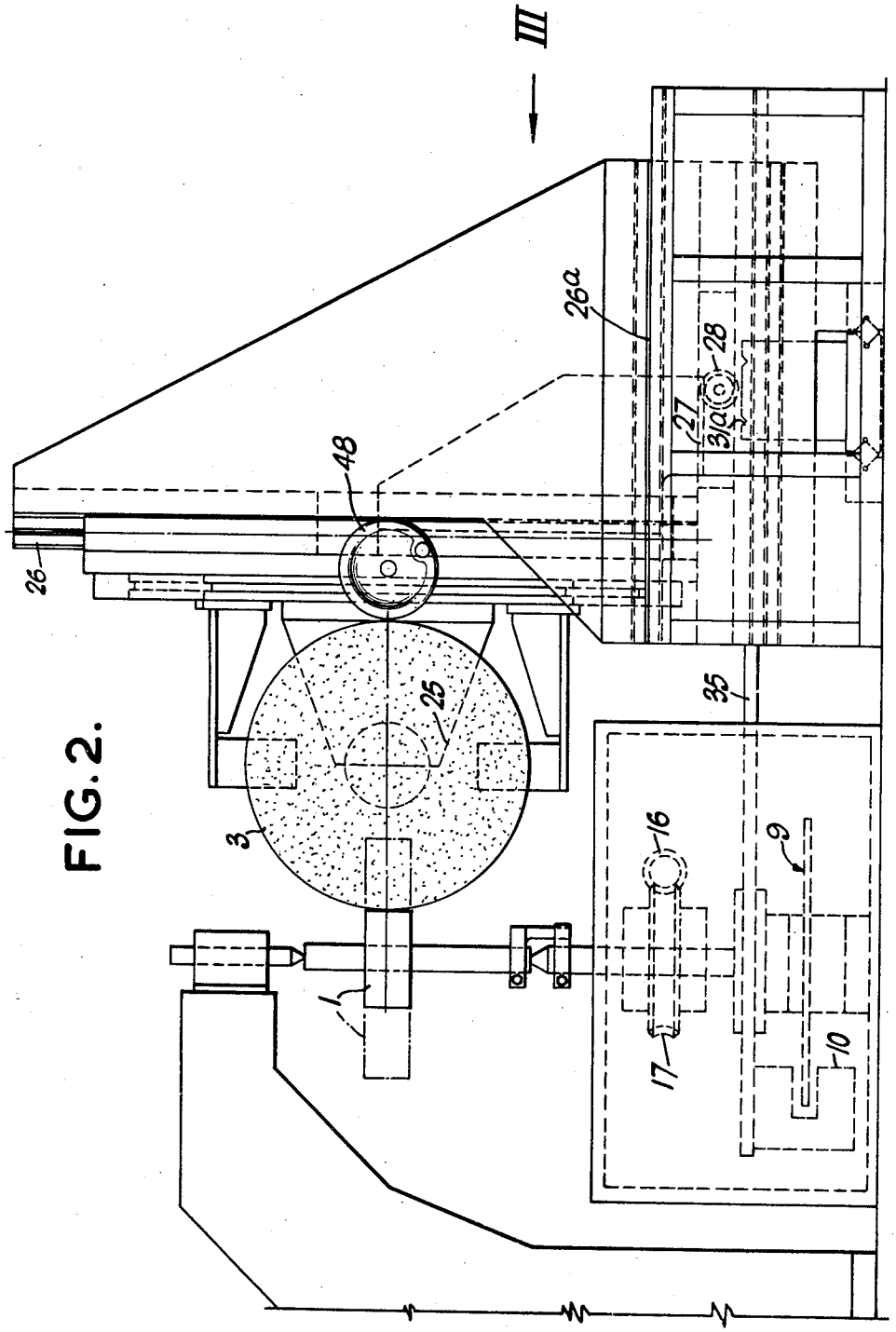


FIG. 2.

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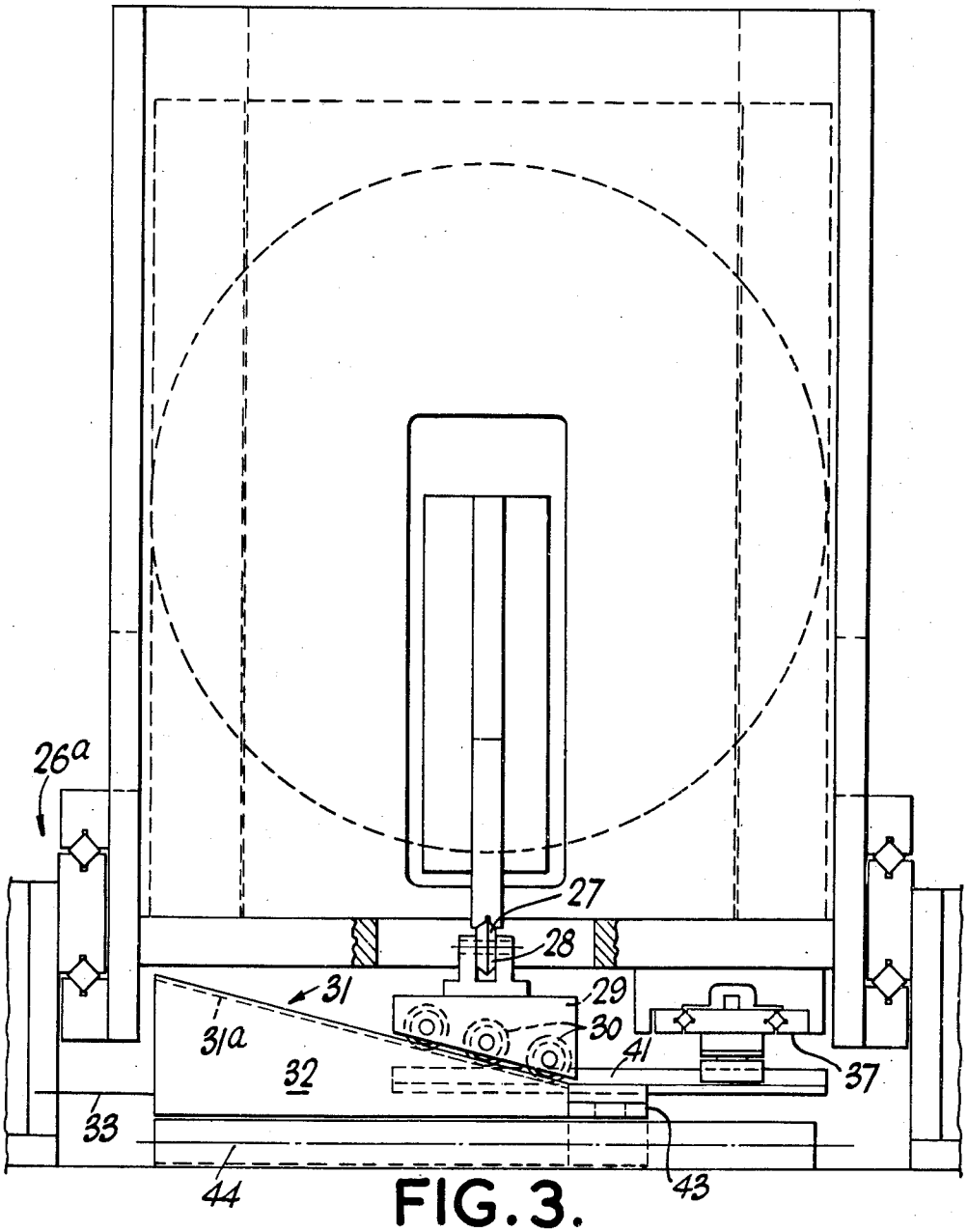


FIG. 3.

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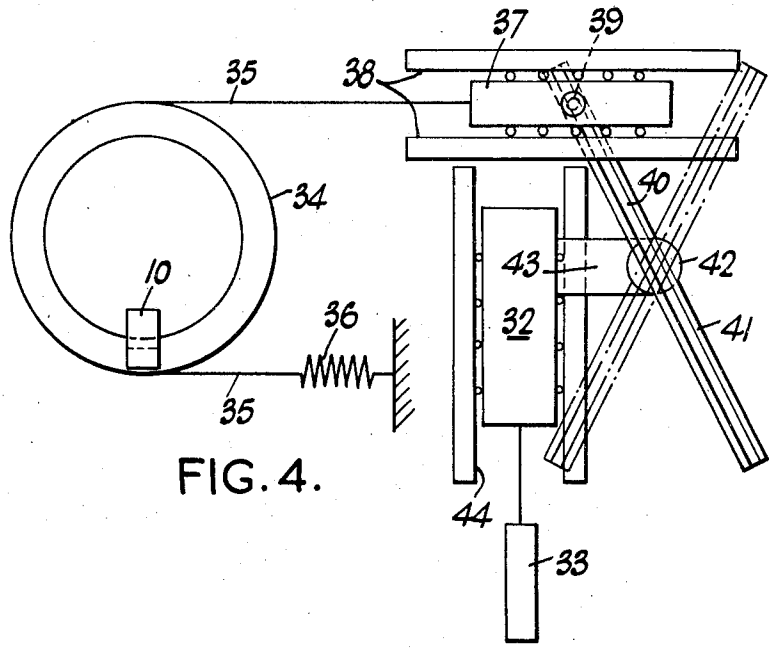


FIG. 4.

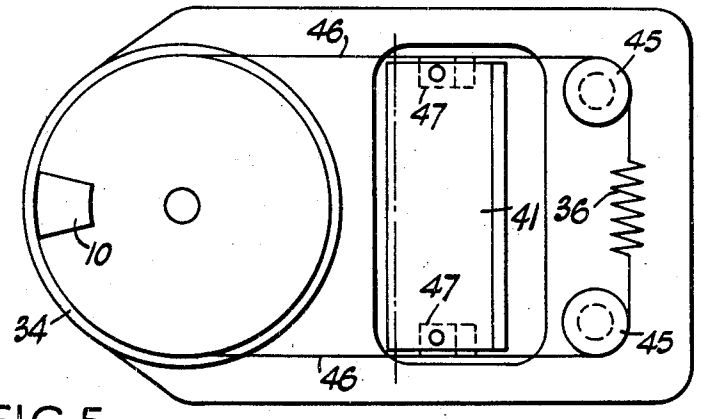


FIG. 5.

United States Patent Office 3,152,422 Patented Oct. 13, 1964

3,152,422

DRIVES FOR GEAR GRINDING MACHINES

John Loxham, Cranfield, Bletchley, England, assignor to National Research Development Corporation, London, England, a British company

Filed Mar. 5, 1962, Ser. No. 177,324
Claims priority, application Great Britain Mar. 9, 1961
8 Claims. (Cl. 51—52)

This invention relates to the manufacture of gears by generative processes in which the gear blank is held to a support that rotates slowly and a rotating tool engages the edge of the blank and forms teeth around that edge. The term "gear" will be used in this specification to include not only those toothed wheels in which the teeth lie parallel to, or make a small angle with, the axis of the wheel, but also those in which the angle is large and which are normally known as worms or threads. In processes to which this invention relates the tool rotates much faster than the blank and the blank usually rotates many times in the course of a complete manufacturing operation. It is normal to traverse the tool down the gear face it is grinding, in a direction parallel to the axis of the gear blank, while grinding proceeds. It is also normal to start grinding with a roughing cut and then to set the centres of blank and tool closer together for a finishing cut.

Processes of this type include, for instance, gear hobbing in which teeth are cut in a plain blank by a hobbing tool, and gear grinding in which roughly cut gear teeth are ground accurately to shape by a grinding wheel; the latter is usually a single-start worm made of a hard ceramic material.

In apparatus for the working of processes of this type it has been usual to drive both the blank and the tool by a single motor. It has been customary to interpose trains of gears at least between the drive shaft of the motor and one of the driven parts, and perhaps between the motor and each of the driven parts. Such trains of gears clearly limit the accuracy of the gears the apparatus can cut. The combined effects of inaccuracies in the gears used in the apparatus and of the flexibility that is inherent in any long train of gears lead to an unsatisfactory correlation between the movements of the tool and the blank.

Broadly speaking, the present invention aims to do away with some of the inaccuracies imparted to gear manufacturing machines by reason of the gear trains they contain, by substituting electrical motion monitoring devices for these trains. Since such electrical devices can only monitor a motion but cannot provide the power to drive it, separate motors are used to drive blank and tool. The movements of blank and of tool are caused to generate electrical signals indicative of the speed of rotation of these two parts, and the signals are compared and an error signal is produced which operates on one of the motors so as to maintain the two original sets of signals "in step" with each other.

In order that a machine according to this invention should be able to manufacture gears with different numbers of teeth, it is clearly necessary that the relationship between the rotational speeds of blank and tool should be variable. In a conventional machine this would be done by altering the gear train linking the single motor with either the blank or the tool. In apparatus according to the present invention, from which such gear trains are absent, it is proposed that it should be done by feeding the electrical signals indicative of one of these rates of rotation into a batching counter or "electronic gear box" (for instance as described in the article entitled "Precision Control of Shaft Speed," by W. H. P. Leslie in the September 1956 issue of "Electrical Energy"), which

processes these signals so that they nominally correspond with the signals indicative of the rotation of the other of the two parts.

The invention also covers some devices that may be incorporated in the machine to cancel out the known errors of certain parts of the machine, where the errors of these parts would otherwise interfere with the control of the motors over the movements of tool and blank. It also includes a modification which may be incorporated in the machine to enable it to manufacture helical gears.

The scope of the present invention is formally defined by the appended claims, and apparatus according to it will now be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of a gear grinding machine.

FIGURE 2 is a side elevation of part of a gear grinding machine modified so as to grind helical gears.

FIGURE 3 is a partly sectioned view in the direction of the arrow **3** in FIGURE 2.

FIGURE 4 is a simplified and diagrammatic view of part of FIGURES 2 and 3, and

FIGURE 5 is a diagrammatic view of a refinement that may be incorporated in the machine modified to grind helical gears.

FIGURE 1 shows a rough-hobbed spur gear blank **1**, which is mounted on a rotatable table **2** and is being ground accurately to shape by a grinding wheel **3**. This wheel is in the form of a single-start worm of hard ceramic material. The teeth of the grinding wheel **3** mesh with those of the gear blank **1**. When grinding begins, the axes of blank and wheel are first spaced well apart so that a roughing cut can be made. When this cut is complete they will be moved closer together for a finishing cut.

The grinding wheel **3** is driven by a squirrel cage motor **4** set to run at constant speed, and the table **2** by a hydraulic motor **5**. The electric motor **4** functions as a master and the hydraulic motor **5** functions as a slave, as will be understood from the following discussion. Flywheels **6** ensure that high frequency fluctuations in the speeds of the motors **4** and **5** are not transmitted to the wheel **3** and table **2**.

A radial optical grating **7** is fixed to the shaft of the motor **4** and rotation of this grating is detected by a photo-electric sensing head **8**. Another radial grating **9** is mounted on the table **2**, and rotation of this grating is detected by a photo-electric sensing head **10**. The A.C. electrical signal generated by passage of the grating **9** past the head **10** is converted to pulse form and fed to a phase comparator **11**. Phase comparator **11**, which may also be identified as a phase detector or phase discriminator, functions to receive two nominally in phase input signals and to generate an error signal which is proportioned to any phase difference between the input signals: examples of such phase comparators may be found in, for example, Scheppmann et al., U.S. Patent No. 1,749,304, Morton, U.S. Patent No. 1,811,860, and/or Van de Mark, U.S. Patent No. 1,845,368. The similar signal generated by the head **8** is also converted to pulses and fed to the comparator **11**, after passing through an electronic gear box or batching counter **12** which processes it by multiplying or dividing the pulses it receives so that the two signal inputs of the comparator **11** should nominally be the same. The gear box **12** is pre-set to allow for the number of teeth on the gear blank **1**. Should the two signal inputs of the comparator **11** fall out of step with one another, an error signal output **13** is generated, and passes by way of an amplifier **14** to a servo valve **14***a*, which controls the supply of fluid to the hydraulic motor **5**. A recorder **15** provides a convenient

indication of the frequency of incidence of the error output **13**.

Theoretically it would be an advantage if the table **2** were driven directly by the motor **5**, but in practice it is found convenient for the drive to be effected through the engagement of a worm **16** with a worm wheel thread **17** formed on the edge of the table **2**. There will inevitably be irregularities in the engagement of worm **16** and worm wheel thread **17**, and if they are left uncorrected the movements of the table **2** will not accurately follow those of the motor **5**. The errors in the engagement of worm and worm wheel are therefore first discovered, by using the worm **16** to rotate the table **2** once under controlled conditions, and an annular face cam **18** is made on which the crests and troughs represent the errors of engagement. The cam is mounted on the face of the table **2**. **21** represents the shaft of the motor **5** and the worm **16** is splined to that shaft so that worm and shaft may move axially but may not rotate relative to each other. A pressure pad **22** urges the worm **16** towards an internally threaded nut **19** welded to the frame **19***a* of the gear grinding machine. An externally threaded bush **20** makes a snug sliding fit over the shaft **21**; one end of this bush bears against the worm **16**, the other screws into the nut **19**. One end of an arm **23** is mounted firmly on the bush **20** and a plunger **24** on the other end of this arm is loaded into contact with the face cam **18**. The arm **23** is thus caused to rock to and fro slightly as the table **2** rotates and the undulations of the cam **18** are translated into rotary movements of the bush **20** relative to the nut **19**, then into slight axial movements of the worm **16**, and then into slight rotational movements of the table **2** supplementary to its main rotational movements derived from the motor **5**.

If the machine already described is to be used to grind worm wheel grooves in the gear blank **1**, it might be unnecessary to give the grinding wheel **3** any movement parallel to the axis of rotation of the table **2** during the grinding operation. However, if the grooves separating the teeth of the gear being ground are to be of flat root even depth, as is the case with ordinary spur or helical gears, it will be necessary for the grinding wheel to traverse down the wall of the the gear blank in a direction parallel to the axis of the blank as it grinds. During the grinding of any gear by a generative process in which the grinding wheel is a single start worm, one revolution of the grinding wheel must be accompanied by such as angular movement of the blank that the wheel comes into grinding engagement with the blank tooth adjacent to that which was previously being ground. When a spur gear is ground, the speed at which the grinding wheel traverses down the blank is theoretically unimportant; it is only necessary that for every revolution of the gear blank the grinding wheel makes as many revolutions as the gear blank has teeth. The axis of the grinding wheel must lie perpendicular to the crests of the teeth of the gear being ground, whether the gear be helical or spur. When a helical gear is ground, however, the speed at which the grinding wheel traverses down the blank is important, and the same relationship between the angular velocities of blank and grinding wheel is no longer appropriate. Should the two velocities be set in this relation, and should the wheel then start traversing down the blank, then although blank and wheel might engage properly at the top of the traverse the combined effect of the downward movement of the wheel and the sideways slope of the teeth would instantly cause the two to fall out of mesh and the grinding wheel would simply plough through the teeth of the blank. What is required for a helical gear is that the relation already noted as being appropriate for a spur gear should be modified by a component that takes account of the helix angle of the gear. It is very useful if a gear grinding machine can easily be adapted to grind helical gears, and

modifications whereby a machine according to this invention may be used to grind such gears will now be described with reference to FIGURES 2 to 5.

In FIGURE 3 the grinding wheel **3** is seen to be mounted in a bracket **25** running in a vertical slideway **26**. The slideway **26** is itself mounted to slide horizontally along a slide **26***a*, so that the position of the wheel **3** may be altered to suit gear blanks of different diameter. A V-groove **27** in the base of the bracket runs over a roller **28** rotatably mounted in a block **29**. Rollers **30** mounted in the block **29** run along grooves **31***a* in the inclined surface **31** of a wedge **32** mounted to slide horizontally. Whatever the positions of block **29** and wedge **32** as they slide relative to each other, the axis of the roller **28** remains horizontal.

Driving means **33** are provided to move the wedge back and forth horizontally at an even speed. When the wedge is at one end of its travel, the grinding wheel **3** lies above and out of contact with the gear **1**. When the wedge is at the other end of its travel, the grinding wheel **3** is beneath the gear **1** and again out of contact with it.

In order to alter the standard relationship between the angular speeds of table and gear blank by an amount appropriate to the helix angle of a particular helical gear that requires grinding, the sensing head **10** is mounted rotatably coaxial with the grating **9** on a drum **34**. A flexible but inextensible steel band **35**, held taut by a spring **36**, passes round the wall of the drum and is attached to a slider **37** mounted to move within supports **38**. A pin **39** projects from the slider and slides within a slot **40** in a bar **41** rotatably mounted at **42** on a lug **43** projecting from the wedge **32**. It will be apparent that a given movement of the wedge along its slideway **44** will impart a related movement to the slider **37** and so to the sensing head **10**, the size of the movement being dependent upon the setting of the bar **41** relative to the lug **43**. The appropriate setting of bar **41** relative to lug **43** for various helix angles can easily be calculated once the dimensions of the apparatus are settled. It can even be arranged that if the bar is set so that it makes a certain angle with the slideway **44**, then the apparatus is set to grind a helical gear of the same helix angle.

There are cases in which it is important that one of two intermeshing helical gears should have a certain right-hand helix angle while the other has exactly the same angle but is left-handed. FIGURE **5** shows how the apparatus of FIGURES 2 to 4 may easily be adapted to grind first one gear of such a pair and then the other. The steel band **35** is made continuous, passing round the drum **34** as before but also round two pulleys **45**. It is again held taut by a spring **36**. The runs of band **46** leaving each side of the drum **34** are parallel to each other, and a slider **47** similar to the slider **37** is fastened to each of these runs. In order to use the machine to cut first one of the pair of gears and then the other, the bar **41** is engaged first with one of the sliders **47** and then with the other.

To inspect the engagement of grinding wheel **3** and blank **1** a light **58** is directed onto the region where the two meet. The switch of this light is operated by a single acting cam **49** mounted on the driving shaft of the master motor **4**. This causes the light to flash once every revolution of the wheel **3**. For every revolution of the grinding wheel, the blank should rotate so as to move each partly ground tooth into the position previously occupied by the tooth in front. Assuming therefore that blank and grinding wheel are moving at the correct relative speeds, it will be seen that the flashing of the light **58** gives rise to a stroboscopic effect under which blank and grinding wheel appear stationary. Therefore when it is necessary to align the grinding wheel and a hobbed blank at the start of a grinding operation, or to re-start a grinding operation that has been stopped before completion, the following procedure should be followed. First, restart both the motors **4** and **5** and run them up to their

correct relative speeds. Second, connect the light **58** to its power source so that it flashes once per revolution of the grinding wheel. Viewed under this light, the crests of the grinding wheel and the troughs of the blank will almost certainly be found to be out of alignment. The necessary re-adjustment can be done manually through controls, for instance by adjusting the cross slide of the mounting of the bracket **25** by means of hand wheel **48** shown in FIG. 2, and once this is done blank and grinding wheel may be re-engaged.

In all the drawings only a single reading head (**10**) has been shown in co-operation with the radial grating that records the rotational movement of the gear blank. It is in fact advantageous if two interconnected heads are used at opposite ends of a diameter of the grating. The resultant signal obtained from these two heads may be the average of their readings, and may avoid inaccuracies due, for instance, to eccentric mounting or distortion of the grating.

In the machine already described for grinding helical gears, the grinding wheel has been arranged to traverse at constant speed, and means have been provided to set the rotational speed of the gear blank to suit its helix angle.

I claim:

1. A gear manufacturing machine comprising a rotatable support member to receive a gear blank and a rotatable tool member to engage the blank and form gear teeth on it, in which tool member and support member are driven by separate motors, in which one of these motors acts as a master and the other as a slave, in which tool member and support member are each coupled to a generating device to produce electrical signals nominally indicative of the rotation of the associated member, in which electrical processing means receive the signals from one of the generating device whereby that signal may be processed so as nominally to correspond with the signal generated by the second device, and in which a comparator receives the signal generated by the second device and the output from the processing means and compares them and produces an error signal whenever the relationship between the signals received differs from what is desired, and in which the error signal is applied to control the performance of the slave motor so that the rotations remain in a desired relationship.

2. A gear manufacturing machine according to claim 1 in which the generating devices include as integers rotatable patterns and means to scan these whereby passage of the pattern past the scanning means causes variation of the signal generated.

3. A gear manufacturing machine according to claim 2 in which the patterns are radial optical gratings and the means to scan them include photo-electrical devices.

4. A gear manufacturing machine according to claim 2 in which the pattern used to indicate the rotation of the support rotates in synchronism with a worm wheel, in which the drive to the support from its motor is made through the engagement of a worm with this worm wheel, in which the worm is movable axially relative to its shaft, in which a cam is provided to rotate in synchronism with the support, and in which the cam and the worm are operatively connected so that the rotation of the cam alters the relative positions of the worm and its shaft, the cam being so shaped as to compensate for irregularities of engagement between worm and worm wheel.

5. A gear manufacturing machine according to claim 2, being adapted to form helical gears, and including a motor adapted to traverse the tool in a direction parallel to the axis of the gear being ground, in which means are provided to vary the relationship between the speed of this motor and the rotational speed of the support during a grinding operation, said means including a member indicative of the traversing of the tool and an operative connection between this member and one of the integers of one of the generating devices, whereby movement of the member may shift this integer relative to the corresponding integer of the same generating device.

6. A gear manufacturing machine according to claim 5 in which the scanning means of the generating device associated with the support member are mounted to rotate coaxially with the corresponding pattern of the same device, and in which the operative connection is made between these scanning means and the member indicative of the traversing of the tool.

7. A gear manufacturing machine according to claim 6 in which the means for scanning the pattern rotatable with the support are mounted on a rotatable drum, and in which the operative connection includes a flexible band passing round the drum.

8. A gear manufacturing machine according to claim 7 in which the member indicative of the traversing of the tool includes a slotted bar adjustably mounted, and in which the band carries a pin to slide within the slot, whereby movement of the bar may move the band and rotate the drum.

References Cited in the file of this patent

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