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(54) ACTUAL VALUE TRANSMITTER FOR GOVERNED-SPEED DRIVES

(71) We, QUICK-ROTAN BECKER & NOTZ KG, a Kommanditgesellschaft, organised and existing under the laws of the Federal Republic of Germany, of 6100 Darmstadt, Grafenhäuser Strasse 85, Germany, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to an actual value transmitter for governed-speed drives, such as positioning drives in sewing technology, and concerns drives comprising a coded disc driven synchronously with a working shaft and having a series of circumferentially distributed light and dark areas and a stator co-operating with the same, which comprises a luminous emitter and a photosensitive receiver.

In a proposed transmitter of this nature, intended to be an actual speed of revolution transmitter of a governed-speed (r.p.m.) clutch motor drive system (British Patent Specification No. 1,026,535), the receiver supplies a signal in which the momentary amplitude depends on whether a light or dark area of the coding disc happens to be positioned in the path of the beam between the emitter and the receiver. This alternating voltage signal drives a discriminator which delivers a direct voltage signal which, for its part, is a function of the frequency of the alternating voltage signal of the receiver. The direct voltage signal thus obtained is compared to a direct datum voltage representing the nominal speed (r.p.m.) value. The clutch and brake of the clutch motor are actuated as a function of the differential signal generated on the basis of this comparison. The light-dark control of the receiver by the light and dark areas of the coding disc occurs perfectly in this known system only as long

as the width of the receiver measured in the direction of displacement of the coding disc is equal to or smaller than the halving division of the coding disc i.e. in the case of identical widths for the light and dark areas, equal to or smaller than the width of a light area or dark area. However, since photosensitive receivers require an appreciable width for the photosensitive surface, in order to obtain a signal of adequate strength for further processing, the known system allows of a relatively coarse graduation only. This means that the diameter of the coding disc becomes undesirably large or that the number of pulses obtained for each complete revolution of the coding disc becomes relatively small. If the receiver is wider than half the width of graduation, parts of the receiver surface are always situated opposite one or more dark areas and other parts of the receiver surface are always situated opposite one or more light areas. This reduces the signal amplitude. The effective signal of the receiver diminishes as the width of the receiver is increased in relation to the graduation of the coding disc. Moreover, the known system has the disadvantage that the effective signal goes down to zero if the width of the receiver is equal to an integral multiple of the semi-graduation. This means that when a coding disc is replaced by a coding disc having a different graduation, the photosensitive receiver must also be replaced by a receiver of different width if appropriate, to obtain an effective signal.

The present invention provides an actual value transmitter for governed-speed drives, suitable for positioning drives in sewing technology, comprising a coding disc arranged to be driven synchronously with a working shaft and having a series of circumferentially distributed light and dark areas; a coding segment having two sections in each of which there are located

light and dark areas of similar distribution and pitch to the said areas of the coding disc, the light and dark areas of said sections being displaced relatively to one another by half a graduation; and a stator which comprises light-emitting means and two photosensitive receivers so arranged that the ray paths extending between the light emitting means and the respective receivers pass in each case via the said coding disc and a respective section of the coding segment whereby light rays are interrupted by the dark areas of the said disc and segment and upon rotation of said disc relatively to the segment corresponding modulated output signals are produced in antiphase at the outputs of the respective photosensitive receivers.

It can easily be shown that, in a system of this nature, the output signal of both receivers always fluctuates between a pronounced minimum value and a pronounced maximum value. The receiver co-ordinated with the one range of light and dark areas always reaches its maximum value when the output signal of the receiver co-ordinated with the other range or row of light and dark areas passes through its minimum value. This offers the possibility of evaluating the output signals of the two receivers via a differential stage. The reliability of evaluation is increased substantially as compared to known systems. The evaluation signal may be subjected to further processing without any problems and with circuitry of particularly low complexity.

In principle, a single light source may be jointly co-ordinated with the receivers. To obtain relatively closely set beams however, and in order to prevent the receivers being deleteriously affected by random light, each of the two photosensitive receivers has preferably co-ordinated with it a separate luminous emitter, appropriately in the form of a light emitting diode.

In a further embodiment of the invention, the dark areas of the coding disc and/or of the coding segment are wider than the interposed light areas. This ensures total occultation of the beams even with allowance for particular tolerances for the delimitations of the light and dark areas, without appreciably affecting the magnitude of the maximum value signal of the receiver.

The width of the photosensitive area of the receivers in the direction of displacement of the coding disc is preferably at least equal to the pitch of the light and dark areas in the direction of displacement of the coding disc. It is accomplished thereby that the output signals of the receivers become independent of the orientation of the receivers with respect to the

ranges of light and dark areas of the coding segment. A precise mutual adjustment becomes unnecessary.

It is appropriate moreover for the photosensitive area of the receivers to be formed substantially rectangulary, and to ensure that their longitudinal axis of symmetry subtends an angle of approximately 45° with the corresponding radius of the coding disc.

The receivers may comprise two or more photoelectric cells connected in parallel, which are situated under a common lens and are appropriately connected in parallel for evaluation purposes.

A third or additional pair or pairs of luminous emitters and receivers is or are preferably incorporated, co-operating with one or more individual markings of the coding disc, which are situated on one or more radii of the coding disc differing from the radius of the sequence of light and dark areas. This renders it possible to make use of the actual value transmitter not only for determination of the r.p.m., but instead of this or complementarily thereto, for determining the angular position of the working shaft. A single marking of a single light area may appropriately be formed by an interruption in a dark ring.

Instead of using one or more complementary pairs of light emitters and receivers for angle measurement purposes; at least one magnet, which preferably consists of a permanent magnet, may also be incorporated in further embodiment of the invention, which revolves together with the coding disc and co-operates with a Hall generator installed in unit with the housing. The combination of an opto-electric measurement system with an angular measurement system making use of magnet carried past Hall generators, is particularly reliable and uncomplicated; it allows of very precise positioning.

The coding disc and/or the coding segment may appropriately consist of photographically imprinted acrylic glass. In accordance with a modified form of embodiment, the dark areas thereof may be formed by a copper layer from which light areas are etched out.

The invention will now be described by way of example with reference to the accompanying drawings in which:—

Figure 1 shows an axial cross-section through a first embodiment of an actual value transmitter in accordance with the invention;

Figure 2 shows a plan view of a coding disc of the actual value transmitter according to Figure 1;

Figure 3 shows a plan view of the coding segment of the actual value transmitter according to Figure 1;

Figure 4 shows a partial view of the coding disc and of the coding segment in a particular angular position of the coding disc;

5 Figure 5 shows a partial view analogous to Figure 4, in which the coding disc has been moved onward by a distance corresponding to half a graduation, with respect to the coding segment;

10 Figure 6 shows a considerably enlarged diagrammatical illustration of the mutual coverage of the sequence of the light and dark areas of the coding disc and coding segment for the position according to Figure 4;

15 Figure 7 shows a diagrammatic illustration corresponding to Figure 6, for the position according to Figure 5, and

20 Figure 8 shows an axial cross-section through an actual value transmitter in accordance with a modified second form of embodiment.

The actual value transmitter according to Figure 1 comprises a stub shaft 10 which is enlarged into a receiving portion 11 at its extremity which is shown at the left in Figure 1. The receiving portion 11 may be pushed on to one extremity of a working shaft, which is not illustrated, and may be joined to the same by means of set screws which are screwed into tapped bores 12, 13 of the receiving portion. Two ball-bearings 14 are drawn on to the stub shaft 10, whereby the shaft is rotatably journaled in a housing 15. A locating ring 16 secures the housing in the axial direction with respect to the shaft 10, in conjunction with a shoulder 17 of the housing 15. A flanged sleeve 18 which is joined to the shaft 10 in force-locked manner, e.g. in a press fit, is situated on the other extremity of the stub shaft 10 opposed to that of the receiving portion 11. A coding disc 23 which is preferably produced from acrylic glass and is connected to an entraining sleeve 24, for example by pins, bears via a washer 20 against the side of the flange 19 of the flanged sleeve 18 which is at the right in figure 1. An adjusting plate 25 is connected to the outer extremity of the entraining sleeve 24, for example by means of pins. A thrust plate 26 which may be pressed against the adjusting plate 25 by means of a clamping screw 27 screwed into the end of the shaft 10, bears against the outer surface of the adjusting plate 25.

The end of the housing 15 is provided with a recess 30 wherein is inset a circuit board 31. The circuit board 31 is releasably connected to the housing 15 by means of a screw 32. At a first radial distance from the axis of the stub shaft 10, it carries a light-emitting diode 33 and, at a second radial distance from the axis of the

shaft 10, two additional light-emitting diodes 34, 35 staggered with respect to each other in the peripheral direction, whereof one only is apparent from Figure 1. The diodes act as infrared emitters. A coding segment 36 which is preferably also made of acrylic glass is situated on the inner surface of the end wall of the housing 15 in the area of the recess 30.

A second circuit board 37 carries three photosensitive receivers 38, 39, 40, each of these being in axial alignment in each case with one of the light-emitting diodes 33, 34, 35 and openings 41, 43, and 44 of the end side of the housing 15 which are coordinated with these diodes. The housing 15 is closed by a cover 45.

As apparent in particular from Figure 2, the coding disc 23 acting as a shutter is equipped with a series of circumferentially distributed light and dark areas in its radially outwardly situated area 47. The radially inwardly adjacent annular area 48 is dark throughout its greater portion and has a single light area 49.

The coding segment 36 acting as a screen, is illustrated in particular in Figure 3, and comprises a first section of light and dark areas 50 and a second section 51 of light and dark areas, which are separated from each other by means of a wider dark area 52. Radially inwardly from the sections 50, 51 is situated a dark area 53 which is interrupted by a single light area 54. The light area 54 is radially aligned with the dark area 52 and confronts the light area 49 in the assembled condition.

The light and dark areas of the coding disc and coding segment are preferably applied by photogravure.

As apparent from Figures 4 and 5, the receivers each comprise two photoelectric cells with rectangular photosensitive surfaces 56 and 57. The longitudinal axis of symmetry of the surfaces 56, 57 subtends an angle of approximately 45° with the corresponding radius. The surfaces 56, 57 are situated beneath a common lens which is shown at 58 and 59 in Figure 1, for the receivers 38, 39.

When the working shaft turns, it drives the stub shaft 10 of the actual value transmitter via the receiving portion 11. The coding disc 23 revolves as a result. The light and dark areas of the coding disc alternately pass the light and dark areas of the coding segment 36 in the beam path between the diodes 33 to 35 and the photosensitive receivers 38 to 40.

In the greatly enlarged diagrammatical illustration according to Figures 6 and 7, the radius of the coding disc and of the coding segment has been assumed to be infinite, to simplify matters. Moreover, the

light and dark areas of the coding disc are shown offset at right angles to their direction of displacement with respect to the light and dark areas of the coding segment, in order to demonstrate the co-operation of the coding disc and coding segment even more clearly.

The width of a pair of light and dark areas is now referred to as the pitch T . The pitch of the coding disc and of the coding segment is the same. The dark areas are a little wider than the light areas, however. In the form of the embodiment illustrated, the width of a dark area 60 is equal to $0.6 T$ for example, and the width of a light area 61 is equal to $0.4 T$. The width of the dark area 52 is so selected that the series of light areas and dark areas in the section 50 is staggered by the amount $T/2$ in the direction of displacement of the coding disc with respect to the series of the light and dark areas in the section 51.

In the case of the relative position of the coding disc 23 and coding segment 36 depicted in Figures 4 and 6, the dark areas of the coding disc confront the light areas of the coding segment in the section 50, so that the beam path between the luminescence diode 34 and the receiver 39 is obscured. By contrast, the dark areas of the coding disc are aligned with the dark areas of the section 51 of the coding segment 36. A maximum amount of light energy thus impinges on the receiver 40.

Figures 5 and 7 demonstrate the conditions which result when the coding disc 23 has moved onward by a distance corresponding to $T/2$ with respect to the coding segment 36. In this case, the dark areas of the coding disc are aligned with the dark areas of the section 50 of the coding segment, whereas the dark areas of the coding disc confront the light areas of the section 51 of the coding segment. Consequently, a maximum of light energy is incident upon the receiver 39, whereas the receiver 40 is acted upon by a minimum of light energy.

This changeover is repeated. The output signal of the receiver 39 reaches its maximum value in each case, whilst the output signal of the receiver 40 passes through a minimum value, and *vice versa*. If the output terminals of the receivers 39, 40 are connected to a differential amplifier, an enhanced evaluating signal is obtained which may be subjected to further processing in a reliable manner, with apparatus of little complexity. The differential amplifier may be installed directly on the circuit board 37, if appropriate together with any other electronic components of the evaluation circuit, such as pulse transformer stages, amplifiers and counters.

The conditions described in the foregoing

are obtained notwithstanding the manner in which the individual emitters and receivers are aligned in the direction of displacement of the coding disc with respect to the stationary coding segment 36. This means that a costly adjustment of the coding segment 36 with respect to the receivers and emitters is superfluous.

In conjunction with the light area 54, the light area 49 allows light to reach the photosensitive receiver 38 briefly from the light-emitting diode 33, once in every complete revolution of the coding disc 23. Consequently, the receiver 38 generates one pulse per revolution of the coding disc 23.

Use may be made of the actual value transmitter described, in order to determine the actual value of the speed rotation as well as the actual value of the angular position of the coding disc and thus of the working shaft. Appropriate evaluation circuits are available to one versed in the art and consequently do not require more detailed description at this juncture. For example, the number of output pulses of the receivers 39, 40 or rather of the differential circuit connected to these receivers, which occur per unit of time, may be used to determine the speed (r.p.m.). The actual value of the angular position may be determined in analogue as well as digital manner, by the application of the actual value transmitter described. For the purpose of analogue determination of the angular position, use need merely be made of the light area 49 of the annular portion 48, for example. If, after loosening the clamping screw 27, the coding disc 23 is so adjusted by means of the adjusting plate 25 that the light area 49 corresponds to a particular position of the working shaft, for example to the "needle up" or "needle down" position in the case of a sewing machine positioning drive, the receiver 38 generates a pulse every time this position is reached.

The evaluation system may however also be so organised that for the purpose of determining the actual value of the angular position, the pulses attributable to the light and dark areas of the portion 47 of the coding disc 23 are counted by means of a counter, and by resetting this counter on the basis of the pulse generated by the light area 49 traversing the beam path between the light-emitting diode 33 and the receiver 38.

Numerous modifications are possible within the scope of the invention. For example, a light area of corresponding width may also be incorporated for separation of the two sections 50 and 51 of light and dark areas of the coding segment 36, instead of a dark area 52. The area of separation may also be wider than illus-

trated. The sole essential condition is that the displacement $T/2$ between the series of light and dark areas in the section 50 and the series of light and dark areas in the section 51 should be maintained. The number of light and dark areas in the portion 47 of the coding disc 23 may be adapted to the prevailing requirements. Complementarily to the annular portion 48, one or more additional annular portions comprising a single light area in each case may be incorporated to allow a fixed presetting of particular angular positions. A single dark area may be present instead of a single light area, and the portion 48 may correspondingly be arranged as an uninterrupted light area.

In the modified embodiment according to Figure 8, the photoemitter/receiver pair 33, 38 used to measure the angle of rotation is replaced by a permanent magnet 65 fastened on the coding disc 23 and magnetised parallel to the axis of the stub shaft 10, and by a Hall generator 66 which is situated on the circuit board 37 at the same radial spacing from the stub shaft axis. Accordingly, this eliminates the light and dark portions 48, 49 and the light and dark areas 53, 54 of the coding disc 23 and coding segment 36, which are otherwise constructed in the same manner as described above with reference to Figures 2 to 7. When the coding disc 23 rotates, and the permanent magnet 65 consequently revolves around the stub shaft axis, the Hall generator 66 delivers a voltage pulse each time the permanent magnet 65 passes before it. In this case too, the coding disc 23 may be so adjusted by means of the adjusting plate 25 after loosening the clamping screw 27, that the switch-off signal produced by the Hall generator 66 occurs at the required angular position of the working shaft.

If desirable, the permanent magnet 65 may also be situated on a carrier separate from the coding disc 23. Two or more permanent magnets may be incorporated moreover which co-operate with one or more Hall generators in manner known per se (British Patent Specification No. 1,274,308).

A high degree of resolution of 200 to 300 pulses per revolution may be obtained without difficulty, for a compact overall diameter of the actual value transmitter described. A stable governing action thereby also becomes possible even at working shaft speeds of revolution of 50 r.p.m. and less. An angular measurement to within approximately 1° may be performed precisely by counting the pulses subjected to immediate further processing and not requiring conversion. On the whole, the actual value transmitter does

not work out any more expensive than the synchronisers applied until now in sewing technology in particular.

WHAT WE CLAIM IS:—

1. An actual value transmitter for governed-speed drives, suitable for positioning drives in sewing technology, comprising a coding disc arranged to be driven synchronously with a working shaft and having a series of circumferentially distributed light and dark areas; a coding segment having two sections in each of which there are located light and dark areas of similar distribution and pitch to the said areas of the coding disc, the light and dark areas of said sections being displaced relatively to one another by half a graduation; and a stator which comprises light-emitting means and two photosensitive receivers so arranged that the ray paths extending between the light-emitting means and the respective receivers pass in each case via the said coding disc and a respective section of the coding segment whereby light rays are interrupted by the dark areas of the said disc and segment and upon rotation of said disc relatively to the segment corresponding modulated output signals are produced in antiphase at the outputs of the respective photosensitive receivers.
2. An actual value transmitter according to Claim 1, in which each of the two photosensitive receivers has its own photo-emissive emitter co-ordinated with it.
3. An actual value transmitter according to Claim 1 or 2, in which the dark areas of the coding disc and/or of the coding segment are wider than the interposed light areas.
4. An actual value transmitter according to any one of the preceding Claims, in which the width of the photosensitive surfaces of the receivers is at least equal to the pitch of the light and dark areas in the direction of displacement of the coding disc.
5. An actual value transmitter according to any one of the preceding Claims, in which the photosensitive surfaces of the receivers are substantially rectangular and their longitudinal axis of symmetry subtends an angle of approximately 45° with the corresponding radius.
6. An actual value transmitter according to any one of the preceding Claims, in which the receivers each comprise two or more photoelectric cells connected in parallel, and which are situated beneath a common lens.
7. An actual value transmitter according to any one of the preceding Claims, in which the emitters comprise light-emitting diodes.
8. An actual value transmitter accord-

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trated. The sole essential condition is that the displacement $T/2$ between the series of light and dark areas in the section 50 and the series of light and dark areas in the section 51 should be maintained. The number of light and dark areas in the portion 47 of the coding disc 23 may be adapted to the prevailing requirements. Complementarily to the annular portion 48, one or more additional annular portions comprising a single light area in each case may be incorporated to allow a fixed presetting of particular angular positions. A single dark area may be present instead of a single light area, and the portion 48 may correspondingly be arranged as an uninterrupted light area.

In the modified embodiment according to Figure 8, the photoemitter/receiver pair 33, 38 used to measure the angle of rotation is replaced by a permanent magnet 65 fastened on the coding disc 23 and magnetised parallel to the axis of the stub shaft 10, and by a Hall generator 66 which is situated on the circuit board 37 at the same radial spacing from the stub shaft axis. Accordingly, this eliminates the light and dark portions 48, 49 and the light and dark areas 53, 54 of the coding disc 23 and coding segment 36, which are otherwise constructed in the same manner as described above with reference to Figures 2 to 7. When the coding disc 23 rotates, and the permanent magnet 65 consequently revolves around the stub shaft axis, the Hall generator 66 delivers a voltage pulse each time the permanent magnet 65 passes before it. In this case too, the coding disc 23 may be so adjusted by means of the adjusting plate 25 after loosening the clamping screw 27, that the switch-off signal produced by the Hall generator 66 occurs at the required angular position of the working shaft.

If desirable, the permanent magnet 65 may also be situated on a carrier separate from the coding disc 23. Two or more permanent magnets may be incorporated moreover which co-operate with one or more Hall generators in manner known per se (British Patent Specification No. 1,274,308).

A high degree of resolution of 200 to 300 pulses per revolution may be obtained without difficulty, for a compact overall diameter of the actual value transmitter described. A stable governing action thereby also becomes possible even at working shaft speeds of revolution of 50 r.p.m. and less. An angular measurement to within approximately 1° may be performed precisely by counting the pulses subjected to immediate further processing and not requiring conversion. On the whole, the actual value transmitter does

not work out any more expensive than the synchronisers applied until now in sewing technology in particular.

WHAT WE CLAIM IS:—

1. An actual value transmitter for governed-speed drives, suitable for positioning drives in sewing technology, comprising a coding disc arranged to be driven synchronously with a working shaft and having a series of circumferentially distributed light and dark areas; a coding segment having two sections in each of which there are located light and dark areas of similar distribution and pitch to the said areas of the coding disc, the light and dark areas of said sections being displaced relatively to one another by half a graduation; and a stator which comprises light-emitting means and two photosensitive receivers so arranged that the ray paths extending between the light-emitting means and the respective receivers pass in each case via the said coding disc and a respective section of the coding segment whereby light rays are interrupted by the dark areas of the said disc and segment and upon rotation of said disc relatively to the segment corresponding modulated output signals are produced in antiphase at the outputs of the respective photosensitive receivers.

2. An actual value transmitter according to Claim 1, in which each of the two photosensitive receivers has its own photo-emissive emitter co-ordinated with it.

3. An actual value transmitter according to Claim 1 or 2, in which the dark areas of the coding disc and/or of the coding segment are wider than the interposed light areas.

4. An actual value transmitter according to any one of the preceding Claims, in which the width of the photosensitive surfaces of the receivers is at least equal to the pitch of the light and dark areas in the direction of displacement of the coding disc.

5. An actual value transmitter according to any one of the preceding Claims, in which the photosensitive surfaces of the receivers are substantially rectangular and their longitudinal axis of symmetry subtends an angle of approximately 45° with the corresponding radius.

6. An actual value transmitter according to any one of the preceding Claims, in which the receivers each comprise two or more photoelectric cells connected in parallel, and which are situated beneath a common lens.

7. An actual value transmitter according to any one of the preceding Claims, in which the emitters comprise light-emitting diodes.

8. An actual value transmitter accord-



- ing to any one of the preceding Claims, in which one or more photoemitter/receiver pairs are incorporated, which co-operate with one or more individual markings of the coding disc which are situated on one or more radii of the coding disc differing from the radius of the series of light and dark areas.
9. An actual value transmitter according to Claim 8, in which the individual marking consists of a single light area within a dark ring which is otherwise uninterrupted.
10. An actual value transmitter according to any one of the preceding Claims, in which a circuit board carries the receivers and co-ordinated evaluating systems such as pulse transformer stages, amplifies and counters.
11. An actual value transmitter according to any one of Claims 1 to 7, comprising at least one magnet which revolves with the coding disc and co-operates with a stationary Hall effect generator.
12. An actual value transmitter according to any one of the preceding Claims, in which the coding disc and/or the coding segment consists or consist of acrylic glass imprinted by photogravure.
13. An actual value transmitter according to any one of Claims 1 to 11, in which the dark areas of the coding disc and/or the coding segment are formed by a copper layer from which light areas are etched out.
14. An actual value transmitter for governed-speed drives substantially as hereinbefore described with reference to and as illustrated in Figures 1 to 7, or in Figures 1 to 7 as modified by Figure 8.
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