TO: NIT-44/Scientific and Technical Information Division
   Attn: Shirley Peigare

FROM: GP-4/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U.S. Patents in STAR

In accordance with the procedures agreed upon by Code GP-4 and Code NST-44, the attached NASA-owned U.S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U.S. Patent No.: 4,443,724 Issued: 4-17-84

Government or Contractor Employee: California Institute of Technology

Pasadena, CA 90406

NASA Case No.: NPO-15706-1

NOTE - If this patent covers an invention made by a contractor employee under a NASA contract, the following is applicable:

YES

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the specification, following the words "...with respect to an invention of...."
SHAM TRANSDUCER HAVING DC OUTPUT PROPORTIONAL TO ANGULAR VELOCITY

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Appl. No.: 350,475
Filed: Feb. 19, 1982

Int. Cl.: H02K 17/32
U.S. Cl.: 310/171; 310/68 B; 310/154; 335/222

Field of Search: 310/27, 29, 36, 112, 310/154, 267, 68 B, 171; 324/173, 174, 208; 335/229, 222

References Cited

U.S. PATENT DOCUMENTS
3,418,612 12/1968 Beckwith 335/222
3,529,191 9/1970 Baudot 310/178
3,546,508 12/1970 Harvey 310/219
3,610,974 10/1971 Kenyon 310/49
3,611,222 10/1971 Sauvignet 335/222
3,665,227 5/1972 Busch 310/46
3,882,366 5/1975 Clunis 336/120
3,976,965 8/1976 Remus 336/120

FOREIGN PATENT DOCUMENTS


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ABSTRACT

A brushless DC tachometer is disclosed that includes a high strength toroidal permanent magnet (25) for providing a uniform magnetic field in an air gap, an annular pole piece (21) opposite the magnet, and a pickup coil (19) wound around the pole piece (21) and rotating about the axis of the pole piece. The pickup coil is rotated by an input shaft (15) to which the coil (19) is coupled with a friction clip. The output of the coil (19) is conducted to circuitry (31) by a twisted wire pair (29). The input shaft (15) also activates a position transducing potentiometer (13).

16 Claims, 3 Drawing Figures
SHAFT TRANSDUCER HAVING DC OUTPUT PROPORTIONAL TO ANGULAR VELOCITY

BACKGROUND OF THE INVENTION

Origin of the Invention

The invention described herein was made in the performance of work under a NASA Contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 72 STAT 425; 43 USC 2457).

BACKGROUND OF THE INVENTION

The subject invention relates to shaft transducers and encoders for use in servo systems. Shaft transducers and tachometers are utilized in servo systems for providing signals indicative of position, velocity, and acceleration. Those signals are processed for feedback control.

Specifically, the disclosed invention relates to a shaft transducer that produces accurate DC signals at slow angular velocities and small angular displacements.

BRIEF DESCRIPTION OF THE PRIOR ART

Prior art DC tachometers and transducers generally require miniature versions of generators and require high peeks and continuous rotation for operation. Such a prior art tachometer is generally placed in the geartrain between the servo motor and the output shaft.

The disadvantages of such prior art DC tachometers include the required speed and displacement for operation. Further, the outputs provided represent an average velocity. Gear backlash is not taken into account and seriously affects accuracy.

Pulse generators have also been used in servo systems. For example, a pulse generator would provide a series of pulses wherein the frequency of the pulses is proportional to velocity.

The disadvantages of pulse generators include the variation in magnitude of the output pulses, and the limited number of output pulses per revolution and therefore a limited amount of velocity information. Further, at low speed speeds and small displacements, pulse generators present problems relative to resolution and precision which are difficult to overcome.

A further prior art tachometer system utilizes a non-polar (non-reversing or unipolar) and uniform magnetic field and is disclosed in U.S. Pat. No. 3,882,366 issued to Clunis on May 6, 1975. That system is a motor speed control system that includes a Faraday disk or cylinder or some other conductor that is shaped and mounted to uniformly intersect the magnetic field at all rotational positions. The Faraday element or conductor rotates with the motor shaft.

The disadvantages of the prior art Clunis system include the high rotational speeds required to provide an output of any significance. Moreover, since the conductor makes complete revolutions, brushes are utilized to pick up the output of the conductor.

It is therefore an object of this invention to provide in improved shaft transducer having a DC output signal proportional to the angular velocity of the shaft.

Another object of the invention is to provide an improved shaft transducer that is accurate at relatively small displacements.

Still another object of the invention is to provide an improved shaft transducer that can be coupled directly to an output shaft in a servo system.

A further object of the invention is to provide an improved shaft transducer that operates over less than a complete revolution of a servo system output shaft.

Another object of the invention is to provide a shaft transducer that does not utilize brushes.

SUMMARY OF THE INVENTION

The foregoing and other objects of the invention are achieved in a shaft transducer that includes a magnetic circuit that produces a uniform magnetic field of substantially constant flux in an air gap. A movable coil is coupled to a rotatable input shaft which causes the coil to move in the uniform magnetic field. The movable coil provides an output that can be utilized by circuitry to determine velocity and acceleration.

BRIEF DESCRIPTION OF THE DRAWING

The advantages and features of the disclosed and claimed invention will be readily understood from the detailed description when read in conjunction with the drawing wherein:

FIG. 1 is a cross section diagram of the disclosed shaft transducer.

FIG. 2 is a detailed cross section diagram of the magnetic circuit in the shaft transducer of FIG. 1.

FIG. 3 illustrates the pole piece of the magnetic circuit of FIG. 2.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, like elements in the different figures are referred to by like numbers as shown in the drawing.

Referring now to FIG. 1, the shaft transducer includes a housing which is made from a magnetically conductive material. Mounted within the housing is a potentiometer which is actuated by an input shaft. The input shaft is coupled to an output shaft (not shown) of a servo system. The input shaft is rotatably supported by a plurality of precision bearings. The potentiometer provides an output that is indicative of the angular position of the input shaft. The use of a potentiometer for providing position information is well known.

Within the housing, a pickup coil is coupled to the input shaft by a friction coupling. The friction coupling prevents damage to the pickup coil in the event rotation of the input shaft goes beyond the range of movement of the pickup coil. The pickup coil is around an annular pole piece which is supported by a magnetically conductive support member which is attached to the housing. A high strength, rare-earth toroidal permanent magnet is supported by a magnetically conductive support member. The permanent magnet is situated opposite the annular pole piece and provides a uniform magnetic field of substantially constant flux in the air gap between the magnet and the pole piece. The pole piece and the permanent magnet are on a common axis.

A twisted wire pair is attached to the pickup coil and passes through the toroidal magnet to a group...
of electrical components 31. The electrical components 31 include well known circuitry for processing the output of the pickup coil 19 to provide outputs indicative of velocity and acceleration of the pickup coil 19. The electrical components 31 should also include circuitry for utilizing the potentiometer 13 to provide an output indicative of the position of the input shaft 15. Such circuitry is also well known.

The electrical components 31 that form the circuitry for providing signals indicative of position, velocity, and acceleration are advantageously located in the housing 11. That preserves the accuracy of the signal produced by the pickup coil 19. The electrical components 31 are coupled to external circuitry by a multiple pin connector 33.

Referring now to FIG. 2, shown in detail therein is the magnetic circuit of the shaft transducer 10. Particularly, the high strength rare-earth toroidal magnet 25 provides the uniform unipolar (non-reversing) magnetic field across an air gap to the annular pole piece 21. The support members 23 and 27, and the housing 11 are magnetically conductive, and therefore complete the magnetic circuit. As shown, the pickup coil 19 is wound around the annular pole piece 21 so that the coil 19 can be angularly displaced about the pole piece 21. Coil 19 comprises a plurality of individual wire turns with the turns being generally transverse to the axis of rotation of the coil. A section of the coil is disposed within the uniform magnetic field in the air gap between magnet 25 and pole piece 21. That section of coil 19 on the opposite side of pole piece 21 is substantially outside the uniform magnetic field. Thus, the electromotive force produced by the electrical conductors which form the section of coil 19 disposed within the air gap is much larger that the opposite electromotive force produced by the electrical conductors which form the section of coil 19 which is positioned outside the gap.

FIG. 3 shows the annular shape of the pole piece 21 and the location of the support member 23. The support member 23 extends only for a small portion of the outer circumference of the pole piece 21 so that the coil 19 can move through a range of about 270 degrees. The friction coupling of the pickup coil 19 to the input shaft 15 prevents damage to the coil in the event rotation of the magnetic circuit means is composed of an annular magnet and an annular pole piece separated by an annular air gap with said annular magnet, said annular pole piece and said air gap having the same axis of revolution, and with the flux in said air gap being generally parallel to said axis of revolution; and output means for electrically coupling said at least one electrical conductor to an output.

1. A transducer for measuring the angular velocity of a rotatable member such as a shaft, said transducer comprising:
   at least one electrical conductor moveable through an arcuate path;
   coupling means for coupling said conductor to the rotatable member and for driving said electrical conductor along said arcuate path at a velocity proportional to the angular velocity of the rotatable member;
   limiting means for limiting movement of said conductor along said arcuate path to less than, but at least one-half of, a complete rotation;
   magnetic circuit means for producing a substantially uniform unipolar magnetic field along said arcuate path of said electrical conductor wherein said magnetic circuit means is composed of an annular magnet and an annular pole piece separated by an annular air gap with said annular magnet, said annular pole piece and said air gap having the same axis of revolution, and with the flux in said air gap being generally parallel to said axis of revolution; and
   output means for electrically coupling said at least one electrical conductor to an output.

2. The transducer of claim 1 wherein said at least one electrical conductor comprises a first section of a wire coil having a plurality of turns disposed within said magnetic field with a second section of said wire coil being disposed outside said field.

3. The transducer of claim 2 wherein said limiting means includes means for decoupling said coil from the rotatable member.

4. The transducer of claim 3 wherein said output means includes a twisted wire pair.

5. The transducer of claim 1 further comprising a housing with said wire coil, said magnet and said pole piece being disposed within said housing and said magnetic circuit means further comprises a magnetically conductive support means attached to said pole piece for supporting said pole piece within said housing.

6. The transducer of claim 5 wherein said housing is fabricated from a magnetically conductive material and comprises part of said magnetic circuit means.

7. The transducer of claim 6 wherein said limiting means includes said magnetically conductive support means.

8. The transducer of claim 7 wherein said limiting means further includes means for decoupling said coil from the rotatable member.

9. The transducer of claim 8 wherein said decoupling means of said limiting means comprises a friction clip.

10. The transducer of claim 9 wherein said coupling means further comprises a rotatably-mounted shaft coaxial with said annular pole piece.

11. A transducer for producing a signal indicative of the movement of a rotatable body, said transducer comprising:
   magnetic circuit means for producing a substantially uniform unipolar magnetic field along an arcuate path wherein said magnetic circuit means is composed of an annular magnet and an annular pole piece separated by an annular air gap with said annular magnet, said annular pole piece and said air
5 gap having the same axis of revolution, and with
the flux in said air gap being generally parallel to
said axis of revolution;
an electrical conductor in the form of a coil moveable
over said arcuate path;
mechanical coupling means for coupling said wire
coil to the rotatable body and driving said coil
along said arcuate path with a first section of said
coil being disposed in said magnetic field and a
second section of said coil being disposed outside
said field; and
electrical coupling means for electrically coupling
said coil to an output; and
whereby said signal indicative of the movement of
said rotatable body is produced at said output.

12. The transducer of claim 11 further comprising
limiting means for limiting movement of said coil along
said arcuate path to less than a full rotation.
13. The transducer of claim 12 further comprising a
housing with said magnet, pole piece and coil being
disposed within said housing and said limiting means
is also a means for supporting said pole piece within and
spaced apart from said housing.
14. The transducer of claim 13 wherein said limiting
means is fabricated from a magnetically conductive
material.
15. A transducer for measuring the movement of a
shaft, said transducer comprising:
an electrical conductor in the form of a coil;
coupling means for coupling said coil to the shaft and
for driving said coil along an arcuate path;
magnetic circuit means for providing a substantially
uniform unipolar magnetic field in said arcuate
path, said magnetic circuit means comprising an
annular magnet, an annular pole piece fabricated
from a magnetically conductive material spaced
apart from said annular magnet and having a com-
mon axis of rotation with said annular magnet so as
to form an air gap between said pole piece and said
annular magnet, said air gap also having said com-
mon axis of rotation, with the flux in said air gap
being generally parallel to said axis of revolution,
and with said coil encircling a portion of said annu-
lar pole piece and rotatable about said common axis
of said pole piece, and magnetic coupling means
fabricated from a magnetically conductive material
for magnetically coupling said annular pole piece
to said annular magnet;
limiting means for limiting rotation of said coil along
said arcuate path to less than a full rotation; and
output means for electrically coupling said coil to an
output.
16. The transducer of claim 15 further comprising:
a magnetically conductive housing, with said magnet,
pole piece and coil disposed within said housing,
said housing forming part of said magnetic cou-
pling means; and
magnetically conductive support means attached to
said housing for supporting said annular pole piece
and for forming part of said magnetic coupling
means.