

DESCRIPTION

[Title of Invention]

TORQUE SENSOR

[Technical Field]

[0001]

The present invention relates to a torque sensor for detecting a low torque with excellent accuracy.

[Background Art]

[0002]

Patent Literature 1 discloses an example of a torque sensor in which an elastic body is distorted by a rotational resistance that acts on a gear. This torque sensor includes a planetary gear mechanism that is provided between an input shaft and an output shaft. As the motor starts driving, the input shaft rotates, and the rotary drive of the input shaft is transmitted by the planetary gear mechanism to the output shaft. The planetary gear mechanism includes a sun gear, a plurality of planetary gears, and an internally-toothed gear. The sun gear is attached to the input shaft. The planetary gears mesh with the sun gear and revolve around the sun gear while rotating themselves. The internally-toothed gear is ring-like, and has internal teeth that mesh with the planetary gears to guide them. Also, the planetary gears are rotatably supported by a carrier about an axis. The carrier is attached to the output shaft. Furthermore, an elastic body, with strain gauges attached to the sides thereof, is attached to the outer-ring side of the internally-toothed gear at one end. The elastic body is fixed to the housing at the other end. With this structure, when the rotational resistance acts on the output shaft, the rotational resistance acts on the internally-toothed gear in the circumferential direction thereof, and a bending moment acts on the elastic body. The bending moment causes the elastic body to

be distorted. The distortion is detected by the strain gauges, and the torque can be detected based on the detected distortion.

[Citation List]

[Patent Literature]

[0003]

[Patent Literature 1]

Japanese Patent No. 3659748

[Summary of Invention]

[Technical Problem]

[0004]

In the above torque sensor, the planetary gear mechanism is an indispensable structural element. However, the output torque is amplified by the speed reduction action of the planetary gear mechanism. This increases the rotational resistance that acts on the output shaft. This increases the bending moment that is transmitted to the elastic body via the internally-toothed gear. As a result, the detectable torques are limited to torques that are greater than the input torque, and a small torque cannot be detected. Furthermore, the inertia of the motor that acts on the output shaft is as great as the square of the speed reduction ratio. In this way, in torque sensors having the planetary gear mechanism, the inertia of the motor that acts on the output shaft is great. This increases the impact torque of the output shaft, resulting in various problems such as noise and vibration.

[Solution to Problem]

[0005]

To solve the above problems, the present invention provides 1. A torque sensor comprising: an input shaft rotated by a drive of a drive source; an output shaft; a rotation transmitter transmitting a rotary drive of the input shaft to the output

shaft; an elastic body supporting the rotation transmitter in a rotatable state and distorted as a reaction when a rotational resistance acts on the output shaft; and a distortion detector detecting the distortion of the elastic body.

[0006]

In the above torque sensor, the rotation transmitter may be an intermediate gear, an input gear is attached to the input shaft to be rotatable as one unit therewith, an output gear is attached to the output shaft to be rotatable as one unit therewith, the intermediate gear meshes with the input gear and the output gear to transmit the rotary drive of the input shaft to the output shaft, and the intermediate gear is supported in a rotatable state by the elastic body.

[0007]

In the above torque sensor, the rotation transmitter may be an intermediate sprocket wheel, an input sprocket wheel is attached to the input shaft to be rotatable as one unit therewith, an output sprocket wheel is attached to the output shaft to be rotatable as one unit therewith, a chain is worn around the intermediate sprocket wheel, the input sprocket wheel, and the output sprocket wheel such that the rotary drive of the input shaft is transmitted to the output shaft, and the intermediate sprocket wheel is supported in a rotatable state by the elastic body, and the intermediate sprocket wheel meshes with the chain.

[0008]

In the above torque sensor, the elastic body may be a Roberval type and have a hole.

[0009]

In the above torque sensor, the input gear or the input sprocket wheel may be arranged in the hole of the elastic body, the elastic body is provided with a cutout that communicates with the hole, and the intermediate gear or the intermediate sprocket wheel is arranged in the cutout.

[Advantageous Effects of Invention]

[0010]

In the torque sensor of the present invention, the rotation transmitter is supported in a rotatable state by the elastic body. As a result, when a rotational resistance acts on the output shaft, the rotation transmitter moves in a direction to press the sides of the elastic body, and a bending moment acts on the elastic body. With this structure, the elastic body is distorted and the distortion is detected by the distortion detector, and the torque is detected based on the detected distortion. Furthermore, this structure of the present invention does not require a planetary gear mechanism, and thus the output torque is not amplified, nor is the rotational resistance increased. Therefore the torque sensor of the present invention can detect a low torque.

[Brief Description of Drawings]

[0011]

FIG. 1 illustrates the structure of the torque sensor in the first embodiment.

FIG. 2 is a front cross-sectional view of the torque sensor in the first embodiment.

FIG. 3 is an enlarged view of a main part in a cross-sectional plane view of the torque sensor in the first embodiment.

FIG. 4 illustrates the structure of the torque sensor in the second embodiment.

FIG. 5 is a front cross-sectional view of the torque sensor in the second embodiment.

FIGs. 6A and 6B are enlarged views of main parts in a cross-sectional plane view of the torque sensor in the second embodiment. FIG. 6A indicates the state where the input gear meshes with the first intermediate gear. FIG. 6B indicates the state where the second intermediate meshes with the output gear.

FIG. 7 is a cross-sectional plane view of the torque sensor in the third embodiment.

FIG. 8 is a front cross-sectional view of the torque sensor in the fourth embodiment.

[Description of Embodiments]

[0012] (First Embodiment)

The following describes the first embodiment of the present invention with reference to FIGs. 1 through 3.

[0013]

In FIGs. 1 and 2, the reference sign 1 indicates a torque sensor that includes a Roberval-type elastic body 2 in which a hole 2a is formed. The elastic body 2 is housed in a housing 3 that is composed of an upper lid 3a and a lower lid 3b. The upper surface of the elastic body 2 is covered by the upper lid 3a, and the lower surface of the elastic body 2 is covered by the lower lid 3b. At one end of the elastic body 2, a fixing end 2b is formed as one unit with the elastic body 2. In other word, the fixing end 2b is a part of the elastic body 2. The fixing end 2b is fixed to the lower lid 3b by screws S. Also, as illustrated in FIG. 1, the fixing end 2b is provided with insertion holes 2f in which pins (not illustrated) can be inserted. The upper lid 3a is also provided with insertion holes (not illustrated) in which the pins can be inserted. The elastic body 2 is fixed to the upper lid 3a by the pins inserted in the insertion holes 2f. Furthermore, the elastic body 2 is housed in the housing 3 such that a gap is present between the elastic body 2 (excluding the fixing end 2b) and the inner surface of the housing 3 so that, when the elastic body 2 is distorted by the rotational resistance of an output shaft 8 described below, the elastic body 2 does not contact the inner surface of the housing 3.

[0014]

The torque sensor 1 also has an input gear 5 that is disposed inside the hole 2a of the elastic body 2. The input gear 5 is attached to an input shaft 4 such that they can rotate as one unit. The input shaft 4 is rotated by a drive of a drive source such as a motor (not illustrated), and both ends thereof are held in a rotatable state

by the upper lid 3a and the lower lid 3b of the housing 3 via bearings 10 and 11, respectively.

[0015]

The elastic body 2 is further provided with a cutout 2c that communicates with the hole 2a, the cutout 2c being formed by cutting out one end of the elastic body 2 opposite to the fixing end 2b. An intermediate gear 7 is disposed in the cutout 2c to mesh with the input gear 5. As shown in FIG. 2, the intermediate gear 7 is attached to an intermediate shaft 6, which is held in a rotatable state by the elastic body 2 via bearings 12 and 13, such that they can rotate as one unit. When the input shaft 4 is driven to rotate, the intermediate gear 7 and the intermediate shaft 6 rotate as well. The upper and lower ends of the intermediate shaft 6 extend from the cutout 2c of the elastic body 2 into the upper lid 3a and the lower lid 3b of the housing 3, respectively. The upper lid 3a and the lower lid 3b of the housing 3 are provided with bottomed holes 3c and 3d whose diameters are larger than the diameter of the intermediate shaft 6 so that, when the intermediate shaft 6 moves as one unit with the elastic body 2 by the rotational resistance of the output shaft 8 described below, the intermediate shaft 6 does not contact the housing 3.

[0016]

Furthermore, an output gear 9 is disposed inside the housing 3 at a position where the output gear 9 meshes with the intermediate gear 7. The output gear 9 is attached to the output shaft 8, which is held in a rotatable state by the upper lid 3a and the lower lid 3b of the housing 3 via bearings 14 and 15, such that they can rotate as one unit. When the input shaft 4 is driven to rotate, the output gear 9 and the output shaft 8 rotate as well. That is to say, in the torque sensor 1, the input shaft 4 and the output shaft 8 are arranged at offset positions, and the rotary drive of the input shaft 4 is transmitted to the output shaft 8 via the intermediate gear 7. Here, the input gear 5, intermediate gear 7, and output gear 9 are all spur gears whose teeth are aligned parallel to the axis of rotation. By changing the number of teeth of the gears, the speed of the rotary drive output to the output shaft 8 can be

freely set (to be increased or decreased) relative to the speed of the rotary drive of the input shaft 4. Note that, in the torque sensor 1, the input gear 5 and the output gear 9 have the same number of teeth. In other words, they are structured such that the speed is neither increased nor decreased.

[0017]

Strain gauges 16, 17, 18 and 19, which are an example of distortion detectors, are attached to the elastic body 2. Two strain gauges are attached to either side of the elastic body 2 extending in the longitudinal direction.

[0018]

Next, the action of the torque sensor 1 in the first embodiment is explained with reference to FIG. 3. First, upon receiving a drive force from the motor, the input shaft 4 rotates with torque T_1 as one unit with the input gear 5. Following this, upon receiving a rotation from the input gear 5, the intermediate gear 7 rotates as one unit with the intermediate shaft 6. Furthermore, upon receiving a rotation from the intermediate gear 7, the output gear 9 rotates as one unit with the output shaft 8.

[0019]

Here, when a rotational resistance T_2 is given to the output shaft 8, the rotational resistance T_2 is transmitted to the intermediate gear 7 from the output gear 9. With this transmittance, teeth of the intermediate gear 7 meshing with the output gear 9 are pressed by the output gear 9, and a pressing force F_1 acts on surfaces of teeth in the direction perpendicular to the surfaces of the teeth. On the other hand, surfaces of teeth of the intermediate gear 7 meshing with the input gear 5 are pressed by the input gear 5, and a pressing force F_2 acts on surfaces of teeth in the direction perpendicular to the surfaces of the teeth. As a result, a resultant force $F_1 + F_2$, which is a composition of the pressing force F_1 and the pressing force F_2 , acts on the intermediate gear 7, and the resultant force $F_1 + F_2$ acts on the intermediate shaft 6 holding the intermediate gear 7, as well.

[0020]

Also, the central points of the input gear 5, intermediate gear 7, and output gear 9 are set to be present on a line L that extends in parallel with the longitudinal side of the elastic body 2. Thus a meshing point of the intermediate gear 7 and the output gear 9, and a meshing point of the intermediate gear 7 and the input gear 5 are present on the line L. That is to say, the points of application of the pressing force F1 and the pressing force F2 are present on the line L. Furthermore, the intermediate gear 7 is structured such that the angle formed between the line of application of the pressing force F1 and the line L equals the angle formed between the line of application of the pressing force F2 and the line L. Thus the resultant force $F1 + F2$ acts in the direction perpendicular to the longitudinal side of the elastic body 2. Therefore, on the elastic body 2, the resultant force $F1 + F2$ acts as a bending moment, and the elastic body 2 is distorted at the fixing end 2b working as the point of support. Strain gauges 16, 17, 18 and 19 detect the distortion of the elastic body 2, and the torque is detected based on the detected distortion.

[0021]

Conventional torque sensors adopting the planetary gear mechanism cannot avoid amplifying the output torque. On the other hand, the torque sensor 1 in the first embodiment does not amplify the output torque and thus the rotational resistance does not increase. As a result, the rotational resistance, which reflects the torque having been output without being amplified, acts on the elastic body 2. This makes it possible to detect a low torque. Furthermore, due to the structure where the resultant force $F1 + F2$ acts in the direction perpendicular to the longitudinal side of the elastic body 2, even a small bending moment can distort the elastic body 2. This makes it possible to detect a low torque with excellent accuracy. Also, compared with the torque sensors adopting the planetary gear mechanism, the torque sensor 1 in the first embodiment has a simple gear mechanism where three gears are arranged in line, and thus can reduce the number of parts. Furthermore, since the input gear 5 and the intermediate gear 7 are disposed inside the elastic body 2, it is possible to downsize the torque sensor 1.

[0022] (Second Embodiment)

The following describes the second embodiment of the present invention with reference to FIGs. 4 through 6. In a torque sensor 21 of the second embodiment, the elastic body 2 of the torque sensor 1 described in the first embodiment is arranged vertically and other parts are arranged in compliance with this positional change of the elastic body.

[0023]

As shown in FIGs. 4 and 5, the torque sensor 21 includes an elastic body 22 in which a Roberval-type hole 22a is formed. The elastic body 22 is arranged so that its longitudinal side extends in the same direction as an intermediate shaft 26 described below. At the upper end of the elastic body 22, a fixing end 22b is formed as one unit with the elastic body 22, the fixing end 22b being fixed to a housing 23.

[0024]

Also, the torque sensor 21 includes an input shaft 24 which is rotated by a drive of a drive source such as a motor (not illustrated), and extends in the same direction as the longitudinal side of the elastic body 22. An input gear 25 is attached to the input shaft 24 such that they can rotate as one unit.

[0025]

A first intermediate gear 27a that meshes with the input gear 25 is disposed at the upper end of the elastic body 22, and a second intermediate gear 27b is disposed at the lower end of the elastic body 22. These intermediate gears 27a and 27b are attached to an intermediate shaft 26, which extends from the upper and lower ends of the elastic body 22 and is held in a rotatable state by the elastic body 22 via bearings 30 and 31, such that they can rotate as one unit, and when the input shaft 24 is driven to rotate, the intermediate gears are rotated as well.

[0026]

The second intermediate gear 27b meshes with an output gear 29. The output gear 29 is attached to an output shaft 28, which is held in a rotatable state by

a housing 23 via bearings 32 and 33, such that they can rotate as one unit, and when the input shaft 24 is driven to rotate, the output gear 29 is rotated as well. With this structure, the rotary drive of the input shaft 24 is output to the output shaft 28 via the first intermediate gear 27a and the second intermediate gear 27b. Here, the input gear 25, first intermediate gear 27a, second intermediate gear 27b, and output gear 29 are all spur gears whose teeth are aligned parallel to the axis of rotation. By changing the number of teeth of the gears, the speed of the rotary drive output to the output shaft 28 can be freely set (to be increased or decreased) relative to the speed of the rotary drive of the input shaft 24. Note that, in the torque sensor 21, the input gear 25 and the output gear 29 have the same number of teeth.

[0027]

As shown in FIG. 4 and 5, strain gauges 34, 35, 36 and 37, which are an example of distortion detectors, are attached to the elastic body 22. Two strain gauges are attached to either side of the elastic body 22 extending in the longitudinal direction.

[0028]

Next, actions of the torque sensor 21 in the second embodiment are explained with reference to FIGs. 6A and 6B. First, as the motor starts driving, the input shaft 24 rotates forward with torque T_1 as one unit with the input gear 25. Following this, upon receiving the rotation of the input gear 25, the first intermediate gear 27a and second intermediate gear 27b rotate as one unit with the intermediate shaft 26. Furthermore, as shown in FIG. 6B, upon receiving the rotation of the second intermediate gear 27b, the output gear 29 rotates as one unit with the output shaft 28.

[0029]

Here, as shown in FIG. 6B, when a rotational resistance T_2 is given to the output shaft 28, the rotational resistance T_2 is transmitted to the first intermediate gear 27a and second intermediate gear 27b from the output gear 29. With this transmittance, surfaces of teeth of the second intermediate gear 27b meshing with

the output gear 29 are pressed by the output gear 29, and a pressing force F1 acts on the surfaces of the teeth in the direction perpendicular to the surfaces of the teeth. On the other hand, surfaces of teeth of the first intermediate gear 27a, which are meshing with the input gear 25, are pressed by the input gear 25, and a pressing force F2 acts on the surfaces of the teeth in the direction perpendicular to the surfaces of the teeth. As a result, a resultant force $F1 + F2$, which is a composition of the pressing forces F1 and F2, acts on the intermediate shaft 26 that holds the first intermediate gear 27a and second intermediate gear 27b.

[0030]

Also, the central point of the input gear 25 and the first intermediate gear 27a and a central point of the second intermediate gear 27b and the output gear 29 are set to be present on a line L that extends in parallel with the width direction of the longitudinal side of the elastic body 22. Thus a meshing point of the second intermediate gear 27b and the output gear 29 and a meshing point of the first intermediate gear 27a and the input gear 25 are present on the line L. That is to say, the points of application of the pressing force F1 and the pressing force F2 are present on the line L. Furthermore, the first intermediate gear 27a and second intermediate gear 27b are structured such that an acute angle formed between the line of application of the pressing force F1 and the line L equals an acute angle formed between the line of application of the pressing force F2 and the line L. Thus the resultant force $F1 + F2$ acts in the direction perpendicular to the longitudinal side of the elastic body 22. Therefore, on the elastic body 22, the resultant force $F1 + F2$ acts as a bending moment, and the elastic body 22 is distorted at the fixing end 22b working as the point of support. Strain gauges 34, 35, 36 and 37 detect the distortion of the elastic body 22, and the torque is detected based on the detected distortion.

[0031] (Third Embodiment)

The following describes the third embodiment of the present invention with reference to FIG. 7. In a torque sensor 41 of the third embodiment, sprocket

wheels 45, 47 and 49 are used in place of the input gear 5, intermediate gear 7 and output gear 9 included in the torque sensor 1 of the first embodiment.

[0032]

In FIG. 7, the reference sign 41 indicates a torque sensor in which an input sprocket wheel 45 is attached to an input shaft 44 such that they can rotate as one unit. On the other hand, an output sprocket wheel 49 is attached to an output shaft 48 such that they can rotate as one unit. A chain 50 is worn around the sprocket wheels 45 and 49 such that the rotary drive of the input shaft 44 is transmitted to the output shaft 48. Also, an intermediate sprocket wheel 47 is attached to an intermediate shaft 46 such that they can rotate as one unit. The intermediate sprocket wheel 47 is arranged on the outer-ring side of the chain 50, and meshes with the chain 50 to guide it.

[0033]

As shown in FIG. 7, in the torque sensor 41 of the third embodiment, as the motor starts driving, the input shaft 44 rotates with torque T_1 as one unit with the input sprocket wheel 45. Following this, the chain 50 moves cyclically, and the output sprocket wheel 49 rotates passively. At this time, the intermediate sprocket wheel 47 located on the outer-ring side of the chain 50 rotates when the chain 50 moves cyclically. Here, when a rotational resistance T_2 is given to the output shaft 48, the rotational resistance is transmitted to the intermediate sprocket wheel 47 via the chain 50. At this time, a pressing force F_1 acts on surfaces of teeth of the intermediate sprocket wheel 47. Furthermore, a counteraction of this acts on surfaces of other teeth of the intermediate sprocket wheel 47 via the chain 50, and a pressing force F_2 acts on the surfaces of the teeth. As a result, a resultant force $F_1 + F_2$, which is a composition of the pressing force F_1 and the pressing force F_2 , acts on the intermediate shaft 46 holding the intermediate sprocket wheel 47. Therefore, on the elastic body 2, the resultant force $F_1 + F_2$ acts as a bending moment, and the elastic body 2 is distorted at the fixing end working as the point of support. Strain gauges 16, 17, 18 and 19 detect the distortion of the elastic body 2, and the torque is

detected based on the detected distortion.

[0034] (Fourth Embodiment)

In the torque sensors 1, 21 and 41 in the first, second and third embodiments, each of the intermediate gears 7, 27a, 27b and the intermediate sprocket wheel 47 is attached to the intermediate shaft 6 or 26 such that each pair of a gear (sprocket wheel) and a shaft can rotate as one unit, wherein each of the intermediate shaft 6 and 26 is held in a rotatable state by the elastic body 2 or 26 via bearings. Here, as shown in FIG. 8, in the torque sensor 81 of the fourth embodiment, an intermediate shaft 86 is fixed to the elastic body 2, and in connection with this, an intermediate gear 87 is attached in a rotatable state to the intermediate shaft 86 via bearings 88 and 89. This structure also produces the same effect as the torque sensor 1 of the first embodiment.

[0035]

Note that, in the torque sensors 1 and 21 in the first and second embodiments, the input shafts 4 and 24 and the input gears 5 and 25 may be omitted, and the intermediate shafts 6 and 26 may be directly driven by the motor. In that case, the pressing force F2 shown in FIGs. 3 and 6 does not act on the intermediate shaft 6 and 26, but the pressing force F1 acts as the bending moment. Even with this structure, the elastic bodys 2 and 26 are distorted, and therefore the distortion can be detected, and the torque can be detected based on the detected distortion.

[Reference Signs List]

[0036]

- 1 torque sensor
- 2 elastic body
- 2a hole
- 2b fixing end
- 2c cutout
- 2d upper shaft attaching part

2e	lower shaft attaching part
2f	pin insertion hole
3	housing
3a	upper lid
3b	lower lid
3c	bottomed hole
3d	bottomed hole
4	input shaft
5	input gear
6	intermediate shaft
7	intermediate gear
8	output shaft
9	output gear
10	bearing
11	bearing
12	bearing
13	bearing
14	bearing
15	bearing
16	strain gauge
17	strain gauge
18	strain gauge
19	strain gauge
21	torque sensor
22	elastic body
22a	hole
22b	fixing end
23	housing
24	input shaft

25	input gear
26	intermediate shaft
27a	first intermediate gear
27b	second intermediate gear
28	output shaft
29	output gear
30	bearing
31	bearing
31	bearing
32	bearing
33	bearing
34	strain gauge
35	strain gauge
36	strain gauge
37	strain gauge
41	torque sensor
44	input shaft
45	input sprocket wheel
46	intermediate shaft
47	intermediate sprocket wheel
48	output shaft
49	output sprocket wheel
50	chain
81	torque sensor
86	intermediate shaft
87	intermediate gear
88	bearing
89	bearing

CLAIMS

1. A torque sensor comprising:

- an input shaft rotated by a drive of a drive source;
- an output shaft;
- a rotation transmitter transmitting a rotary drive of the input shaft to the output shaft;
- an elastic body supporting the rotation transmitter in a rotatable state and distorted as a reaction when a rotational resistance acts on the output shaft; and
- a distortion detector detecting the distortion of the elastic body.

2. The torque sensor of Claim 1, wherein

- the rotation transmitter is an intermediate gear,
- an input gear is attached to the input shaft to be rotatable as one unit therewith,
- an output gear is attached to the output shaft to be rotatable as one unit therewith,
- the intermediate gear meshes with the input gear and the output gear to transmit the rotary drive of the input shaft to the output shaft, and
- the intermediate gear is supported in a rotatable state by the elastic body.

3. The torque sensor of Claim 1, wherein

- the rotation transmitter is an intermediate sprocket wheel,
- an input sprocket wheel is attached to the input shaft to be rotatable as one unit therewith,
- an output sprocket wheel is attached to the output shaft to be rotatable as one unit therewith,
- a chain is worn around the intermediate sprocket wheel, the input sprocket wheel, and the output sprocket wheel such that the rotary drive of the input shaft is

transmitted to the output shaft, and

the intermediate sprocket wheel is supported in a rotatable state by the elastic body, and the intermediate sprocket wheel meshes with the chain.

4. The torque sensor of one of Claims 1 to 3, wherein
the elastic body is a Roberval type and has a hole.

5. The torque sensor of Claim 4, wherein
the input gear or the input sprocket wheel is arranged in the hole of the elastic body,
the elastic body is provided with a cutout that communicates with the hole,
and
the intermediate gear or the intermediate sprocket wheel is arranged in the cutout.