SUMMARY ~~OF THE DISCLOSURE~~

[0003a] In an aspect, the present disclosure refers to a load sensor for attachment in surrounding relationship to a linear load transmission medium comprising: a solid flexure body of high modulus of elasticity material having a longitudinal axis, a circumferential outer surface having opposite ends and a passage extending fully through the body along the longitudinal axis and between said ends; said circumferential outer surface having rounded sides and opposite generally planar surface portions; said body having a lateral aperture extending through the body and intersecting the longitudinal passage; said body further having lateral slots extending across said planar surface portions in parallel with said lateral aperture to create stress concentration areas in said circumferential outer surface; said body having strain sensing elements mounted on at least one of said planar surface portions proximate said concentration areas to produce electrical signals representing forces transmitted trough said medium and transferred to said flexure body; means for mechanically connecting said body to said medium only at points proximate said ends; an insulative and flexible lead carrier film attached to said body and extending from said outer surface portion circumferentially fully around said body at right angles to said longitudinal axis; and conductive leads attached to said strain sensing elements and bonded to said lead carrier film so as to extend fully around the circumferential outer surface of said body.

[0004] As disclosed herein according to an example, a force sensor is attached to a linear medium without the need to interrupt, bend or otherwise alter the medium. This is accomplished by providing an instrumented flexure body with a longitudinal passage that allows the medium to pass uninterrupted through the body, and firmly affixing the flexure body to the medium at two spaced points along the passage, preferably at the opposite ends of the flexure. In this fashion, a portion of the flexure body is elastically deformed when the medium stretches or compresses under

load. The flexure body is strategically configured as hereinafter described to provide a strain-concentration area between the ends that can deform in one or both of tension and compression modes. This area can be instrumented such as by bonded-in-place strain gages or similar devices to produce electrical outputs correlated to the force being transmitted through the medium. Various modes of instrumentation are hereinafter described.

[0005] In the illustrated ~~embodiments~~ examples hereinafter shown and described in detail, the flexure body is made of a high modulus of elasticity material such as stainless steel, aluminum or Inconel. The flexure body has a longitudinal passage that accepts the medium fully through it. Adhesives and/or other means are used to affix the flexure body to the medium only at or near the flexure body ends. The flexure body is further configured, for example by means of a second aperture or hole which passes laterally through the body and orthogonally intersects the longitudinal passage, to create the afore-mentioned stress-concentration area. The flexure body has top and bottom flat surfaces and strain gages are attached by bonding to one or more of these surfaces along with contact pads so that the gages can be connected in, for example, a Wheatstone bridge circuit directly on the device. The bridge circuit can be connected externally to a power source and/or a display or other signal processor through conductive leads in various ways; a specific lead arrangement that provides strain relief being hereinafter described.

[0006] Further in accordance with an illustrative ~~embodiment~~example, the flexure body is partially enclosed or "jacketed" to provide a wrap-around surface for a conductive lead carrier as well as clearances for the carrier as it passes around and away from the flexure body. The enclosure can lend both aesthetic and functional characteristics to the device.

[0007] The device described herein lends itself to miniaturization for use in fields such as surgical robotics where precise control of remotely-operated instruments during a surgical procedure is of the utmost importance.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Illustrative embodiments are hereinafter described in accordance with 35 U.S.C. §112 and these descriptions are to be taken with the accompanying drawings in which:

[0009] FIG. 1 is a perspective drawing of an instrumented flexure body installed on a rod-like force-transmitting medium;

[0010] FIG. 2 is a perspective view of a flexure body with a variation in configuration;

[0011] FIG. 3 is a sectional view of the flexure body 12 with a medium C extending through it;

[0012] FIG. 4 is a Wheatsone bridge circuit for the strain gages in the embodiment of FIG. 1;

[0013] FIG. 5 is a view of the sensor body deformed in the strain-concentration area by a tension load in the attached medium showing areas 34 and 37 that are deformed in compression and tension modes, respectively;

[0014] FIG. 6 and 7 show portions of a first mechanism for attaching the sensor to a cable or rod medium;

[0015] FIGS. 8 and 9 show a second mechanism for attaching the sensor body to a force-transmitting medium;

What is claimed is:

~~1. A force sensor (10) of the type including a solid flexure body (12) having a longitudinal passage (30) extending fully therethrough to receive a linear force transmitting medium (C) therein wherein the body (12) further included means (53, 55 in FIG, 6; 18, 20 in FIG. 7; 22, 24, 26, 28 in FIGS. 8 and 9) for attachment to said medium only at spaced points proximate the ends of said body (12) whereby tension and compression forces in the medium C are transmitted to the flexure body (12), characterized in that:~~

1. ~~the flexure body (12) has an exterior~~A load sensor for attachment in surrounding relationship to a linear load transmission medium comprising:

a solid flexure body of high modulus of elasticity material having a longitudinal axis, a circumferential outer surface ~~(11, 13, 14, 15) extending fully around said longitudinal~~ having opposite ends and a passage ~~(30) and a lateral aperture (32)~~ extending fully through the body ~~and orthogonally~~ along the longitudinal axis and between said ends;

said circumferential outer surface having rounded sides and opposite generally planar surface portions;

said body having a lateral aperture extending through the body and intersecting the longitudinal passage ~~(30) to create areas (34, 37) of stress concentration on~~; said ~~exterior surface~~body further having lateral slots extending across said planar surface portions in parallel with said lateral aperture to create stress concentration areas in said circumferential outer surface; said body having strain sensing elements mounted on at least one of said planar surface portions proximate said concentration areas to produce electrical signals representing forces transmitted trough said medium and transferred to said flexure body;

~~strain sensing elements (38, 40, 42, 44) disposed on said exterior surface in said stress concentration areas (34, 37) and connected into a bridge circuit (FIG. 21)to create electrical signals representative of the forces transmitted through said medium to said body (12);~~

~~conductive leads (46, 48. 50, 52) electrically connected to said circuit;~~

~~a jacket (54) attached to and extending around said exterior surface and configured to leave a clearance (56) for said strain sensing elements;~~

~~said conductive leads extending under said jacket (54) through said clearance (56) and thereafter circumferentially wrapping around said jacket.(54).~~

~~2. The force sensor (10) as described in claim 1 wherein said jacket includes an arch (61) creating an opening passage (63) therethrough, said leads (46, 48, 50 and 52) extending through said opening passage (63).~~

~~3. A force sensor (10) as described in claim 1 furthering including a non conductive~~means for mechanically connecting said body to said medium only at points proximate said ends;

an insulative and flexible lead carrier film ~~(58)~~attached to said body and extending from said outer surface portion circumferentially ~~adhered to and extending~~ fully around said ~~jacket (54) wherein said~~ body at right angles to said longitudinal axis; and conductive leads ~~are~~ attached to said strain sensing elements and bonded to said lead carrier film ~~(58).~~

~~4. A force sensor (10) as described in claim 1 wherein the exterior surface of the flexure body has at least one generally planar surface area (14) wherein said strain sensing elements (38, 40, 42, 44) are mounted on said generally planar surface (14).~~

~~5. A force~~so as to extend fully around the circumferential outer surface of said body.

2. The load sensor defined in claim 1 further including a jacket having an outer circumferential surface and an inner circumferential surface, said jacket being applied with said inner circumferential surface in contact and in surrounding relationship with said outer circumferential surface of said flexure body to cover a majority of said body outer circumferential surface; said jacket forming a space between the inner circumferential surface of said jacket and said strain sensing elements to allow space for said lead carrier to extend circumferentially out from under the jacket and thereafter wrap fully circumferentially around the outer circumferential surface of the jacket.

3. The load sensor as defined in claim 2 wherein the jacket hasan arch formed thereon over said outer surface portion and creating a passage, the lead carrier, after extending around said body, passing through said arch passage and away from said body.

4. The load sensor as defined in claim 1 wherein said flexure body is approximately 5mm in longitudinal dimension.

~~1.~~5. The load sensor ~~(10)~~ as ~~described in claim 1 wherein the flexure body (12) has opposite planar surfaces (13 and 14) wherein half of the bridge circuit is~~ defined in claim 1 further including strain sensing elements mounted on ~~each~~both of said planar ~~surfaces (13, 14).~~surface portions and joined into a bridge circuit by leads extending from said elements on to said lead carrier.

~~6. A force~~
The load sensor ~~(10)~~ as ~~described~~defined in claim 41 wherein said ~~carrier film (58) is made~~flexure body has integral tubular axial extensions co aligned with said passage; said means for connecting the flexure body to said medium including compression of ~~an insulative material.~~

~~2.~~6. said tubular extensions.