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(56) Documents Cited:
WO 2009/097461 A1 **WO 2008/076910 A1**
WO 2005/058137 A2 **US 20100113876 A1**

(58) Field of Search:
INT CL **A61B, G02B**
Other: **EPODOC; WPI; TXTE**

(54) Title of the Invention: **An apparatus and a method for determining the position and orientation of a remote end of a boroscope**
Abstract Title: **Determining the position and orientation of a remote end of a boroscope**

(57) An apparatus 64 for determining the position and orientation of a remote end 62 of a boroscope 60 comprises a sensor (66) located at a remote end 62 of the boroscope 60. The sensor produces signals having orientation data, gravitational data or velocity data. A measurement device 68 measures the length of the boroscope 60 inserted through an aperture 52, 56 into a body 10. The sensor sends the orientation data, gravitational data or velocity data to a processor 70 and the measurement device 68 sends a signal indicating the length of the boroscope 60 inserted into the body 10 to the processor 70. The processor 70 determines from the length of the boroscope 60 inserted into the body 10 and the orientation, gravitational or velocity data the three dimensional coordinate and the orientation of the remote end 62 of the boroscope 60 within the body 10. The body 10 may be an assembled apparatus, e.g. an engine, a nuclear reactor, a steam turbine, a heat exchanger or an electrical generator.

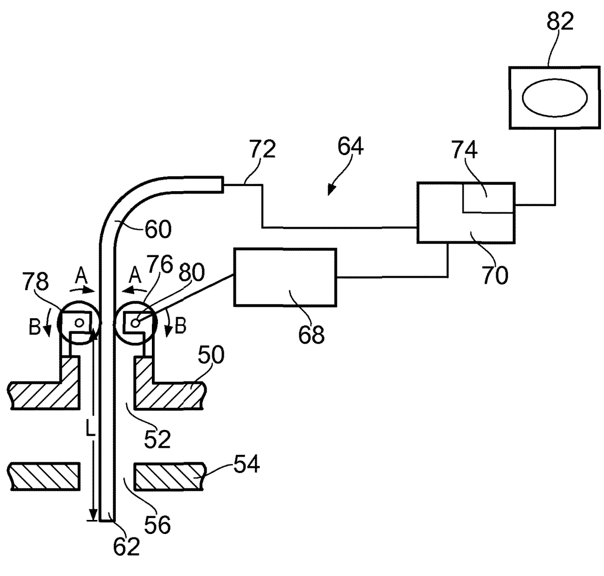

FIG. 4

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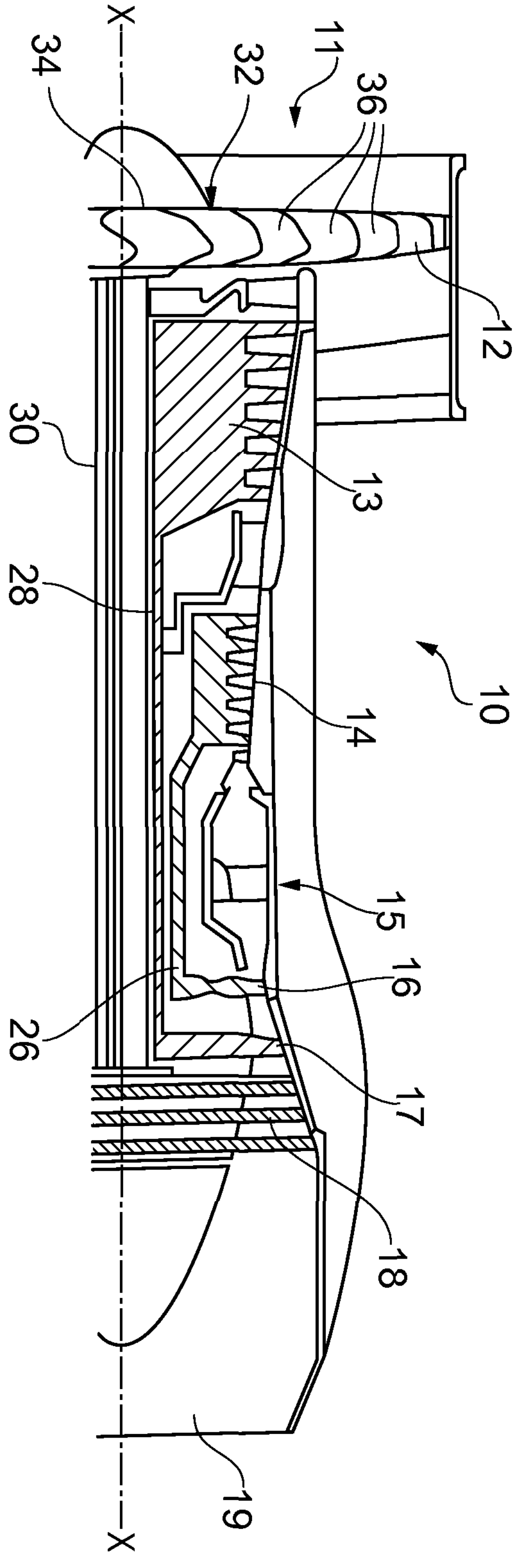

FIG. 1

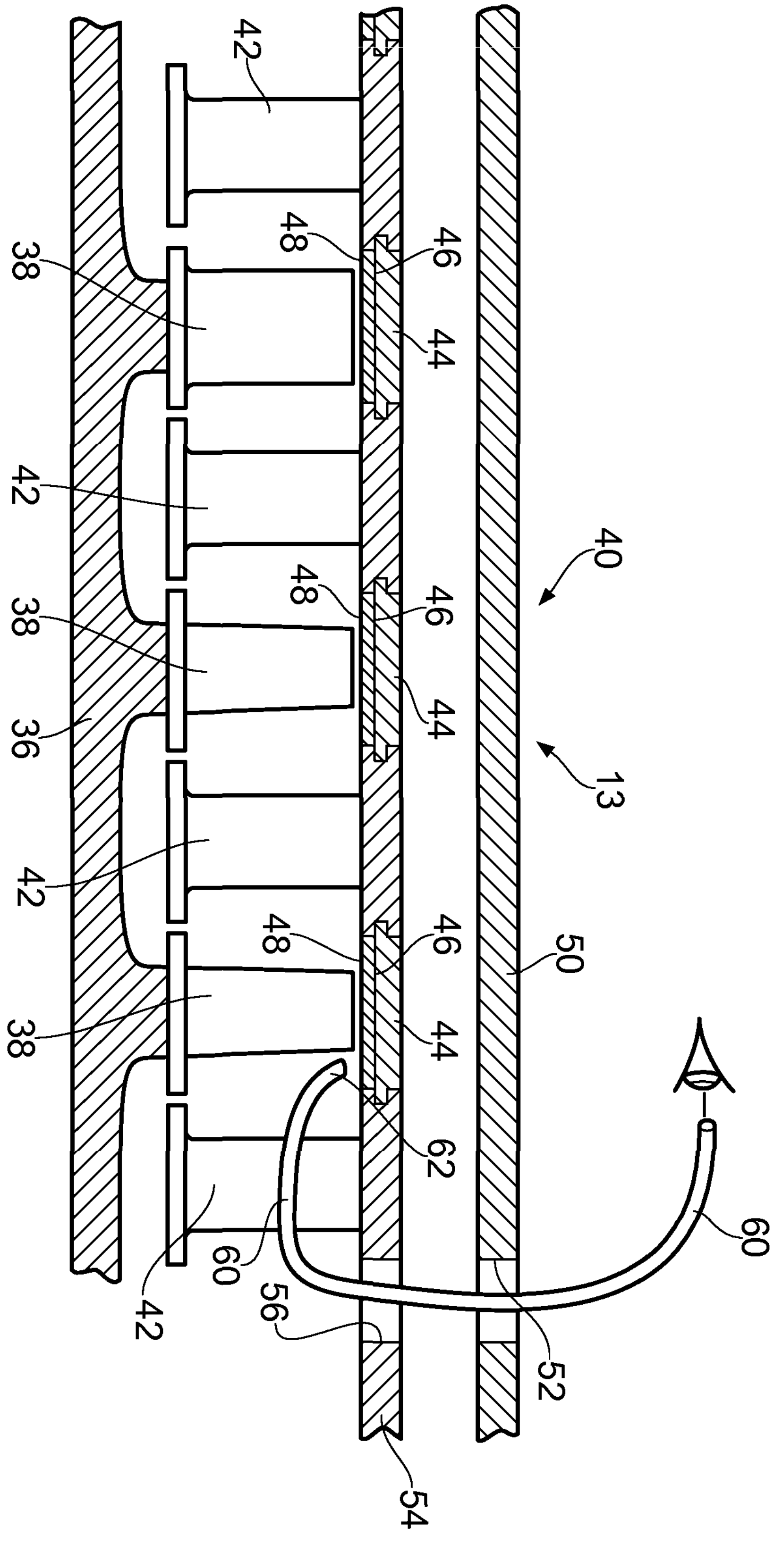

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FIG. 2

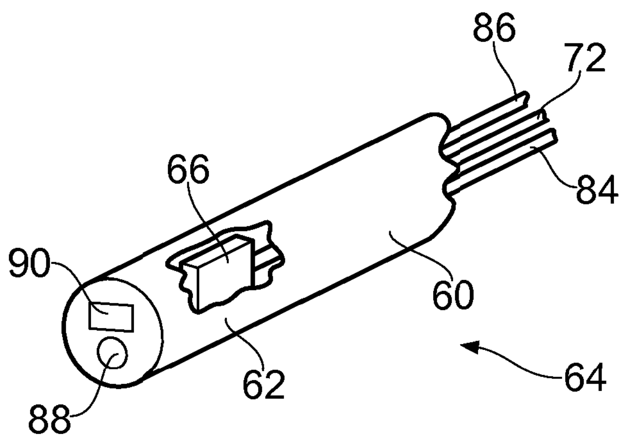

FIG. 3

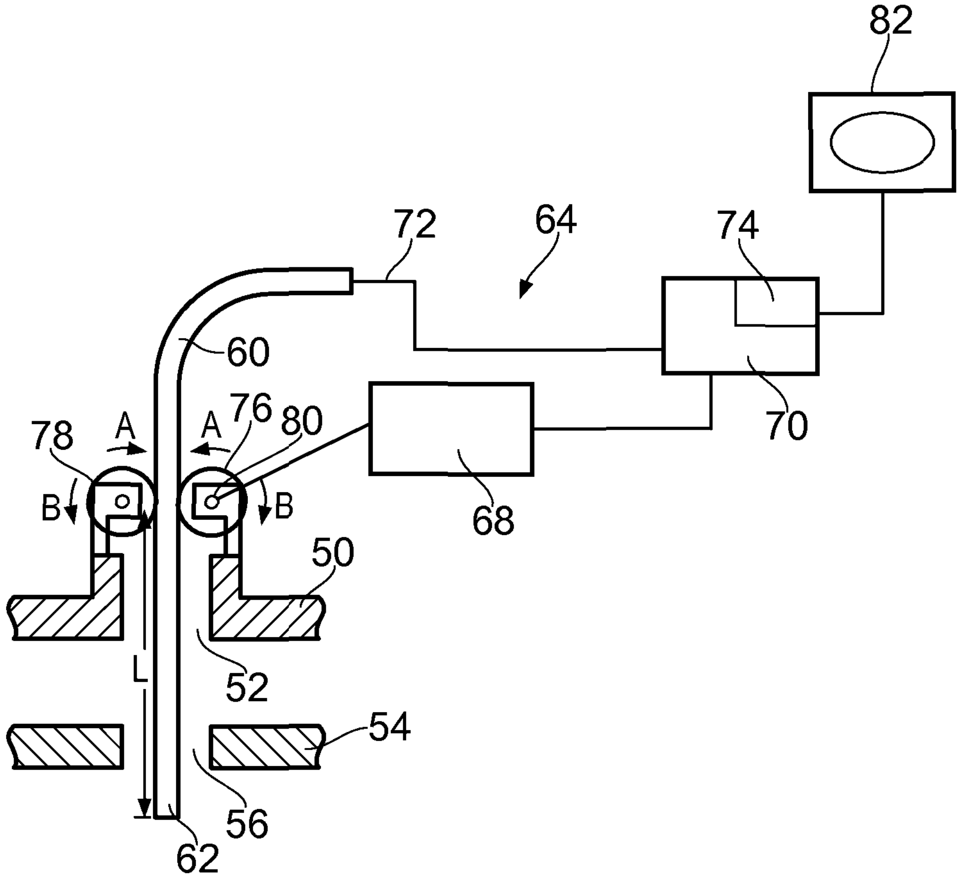

FIG. 4

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AN APPARATUS AND A METHOD FOR DETERMINING THE POSITION AND ORIENTATION OF A REMOTE END OF A BOROSCOPE

The present invention relates to an apparatus and a method for determining the position and orientation of a remote end of a boroscope and in particular to an apparatus and a method for determining the position and orientation of a remote end of a boroscope when the boroscope is inserted into a body, e.g. an assembled apparatus.

Boroscopes are predominantly used to view one or more components within an assembled apparatus, for example a gas turbine engine, instead of disassembling the apparatus to view the components. Boroscopes are used extensively, but the operators of the boroscopes require a high degree of training and skill in order to make optimum use of the boroscope. One of the major problems experienced by an operator of a boroscope is knowing exactly where the remote end of the boroscope is located within the assembled apparatus and which direction the remote end of the boroscope is facing within the assembled apparatus. Without the knowledge of the position and the orientation of the remote end of the boroscope the image, or images, of a component returned by the boroscope are of little value, because it is difficult to identify the location of the component under examination.

Accordingly the present invention seeks to provide a method for determining the position and orientation of a remote end of a boroscope within a body, e.g. an assembled apparatus.

Accordingly the present invention provides a method for determining the position and orientation of a remote end of a boroscope, the method comprising providing a sensor at a remote end of the boroscope, the sensor producing signals having orientation data, gravitational data or velocity data, inserting the boroscope through an aperture into a body, measuring the length of the boroscope inserted into the body, determining from the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

The method may comprise determining from the length of the boroscope inserted into the body and the orientation data, the gravitational data and the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

The method may comprise sending the signals through a wire, the wire being arranged within the boroscope or attached to the boroscope.

The sensor may be a miniature electro mechanical system motion sensor.

The method may comprise providing a mathematical model of the body and determining from the mathematical model of the body, the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

The method may comprise mapping the three dimensional coordinate and orientation of the remote end of the boroscope into the mathematical model of the body.

The mathematical model of the body may be a CAD (Computer Aided Design) model of the body.

The measuring of the length of the boroscope inserted into the body may comprise passing the boroscope between friction drive wheels and measuring the rotation of at least one of the friction drive wheels.

The method may comprise rotating at least one of the friction drive wheels to insert the boroscope into the body. The method may comprise rotating the at least one of the friction drive wheels to retract the boroscope from the body.

The method may comprise securing the friction drive wheels to the body to guide the boroscope through the aperture in the body.

The body may be an assembled apparatus.

The method may comprise inserting the boroscope through an aperture in a casing of the assembled apparatus.

The method may comprise inserting the boroscope into a gas turbine engine, an internal combustion engine, a diesel engine, a nuclear reactor, a steam turbine, a heat exchanger or an electrical generator.

The present invention also provides an apparatus for determining the position and orientation of a remote end of a boroscope, the apparatus comprises a sensor located at a remote end of the boroscope, the sensor producing signals having orientation data, gravitational data or velocity data, a measurement device to measure the length of the boroscope inserted through an aperture into a body, the sensor is arranged to send the orientation data, gravitational data or velocity data to a processor, the measurement device is arranged to send a signal indicating the length of the boroscope inserted into the body to the processor, the processor is arranged to determine from the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

The processor may be arranged to determine from the length of the boroscope inserted into the body and the orientation data, the gravitational data and the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

The sensor may be arranged to send the signals through a wire, the wire being arranged within the boroscope or attached to the boroscope.

The sensor may be a miniature electro mechanical system motion sensor.

The processor may comprise a mathematical model of the body and the processor is arranged to determine from the mathematical model of the body, the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

The processor may be arranged to map the three dimensional coordinate and orientation of the remote end of the boroscope into the mathematical model of the body.

The mathematical model of the body may be a CAD (Computer Aided Design) of the body.

The measurement device may comprise friction drive wheels, the boroscope is arranged to pass between the friction drive wheels and the measurement device is arranged to measure the rotation of at least one of the friction drive wheels.

The measurement device may comprise a motor arranged to rotate at least one of the friction drive wheels to insert the boroscope into the body. The motor may be arranged to rotate the at least one of the friction drive wheels to retract the boroscope from the body.

The friction drive wheels may be secured to the body to guide the boroscope through the aperture in the body.

The body may be an assembled apparatus.

The aperture may be in a casing of the assembled apparatus.

The assembled apparatus may comprise a gas turbine engine, an internal combustion engine, a diesel engine, a nuclear reactor, a steam turbine, a heat exchanger or an electrical generator.

The present invention also provides a method for determining the position and orientation of a remote end of a boroscope, the method comprising providing a sensor at a remote end of the boroscope, the sensor producing signals having orientation data, gravitational data or velocity data, inserting the boroscope through an aperture into an assembled apparatus, measuring the length of the boroscope inserted into the assembled apparatus, determining from the length of the boroscope inserted into the assembled apparatus and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the assembled apparatus.

The present invention also provides an apparatus for determining the position and orientation of a remote end of a boroscope, the apparatus comprises a sensor located at a remote end of the boroscope, the sensor producing signals having orientation data, gravitational data or velocity data, a measurement device to measure the length of the boroscope inserted through an aperture into an assembled apparatus, the sensor is arranged to send the orientation data, gravitational data or velocity data to a processor, the measurement device is arranged to send a signal indicating the length of the boroscope inserted into the assembled apparatus to the processor, the processor is arranged to determine from the length of the boroscope inserted into the assembled apparatus and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the assembled apparatus.

The present invention will be more fully described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a partially cut away view of a turbofan gas turbine engine.

Figure 2 is an enlarged cross-sectional view through a portion of a compressor of the turbofan gas turbine engine showing an apparatus for determining the position and orientation of a remote end of a boroscope according to the present invention.

Figure 3 is an enlarged view of a remote end of a boroscope showing a sensor.

Figure 4 is a schematic view of an apparatus for determining the position and orientation of a remote end of a boroscope according to the present invention.

A turbofan gas turbine engine 10, as shown in figure 1, comprises in flow series an intake 11, a fan 12, an intermediate pressure compressor 13, a high pressure compressor 14, a combustor 15, a high pressure turbine 16, an intermediate pressure turbine 17, a low pressure turbine 18 and an exhaust 19. The high pressure turbine 16 is arranged to drive the high pressure compressor 14 via a first shaft 26. The intermediate pressure turbine 17 is arranged to drive the intermediate pressure compressor 14 via a second shaft 28 and the low pressure turbine 19 is arranged to drive the fan 12 via a third shaft 30. In operation air flows into the intake 11 and is compressed by the fan 12. A first portion of the air flows through, and is compressed by, the intermediate pressure compressor 13 and the high pressure compressor 14 and is supplied to the combustor 15. Fuel is injected into the combustor 15 and is burnt in the air to produce hot exhaust gases which flow through, and drive, the high pressure turbine 16, the intermediate pressure turbine 17 and the low pressure turbine 18. The hot exhaust gases leaving the low pressure turbine 18 flow through the exhaust 19 to provide propulsive thrust. A second portion of the air bypasses the main engine to provide propulsive thrust.

The intermediate pressure compressor 13, as shown more clearly in figure 2, comprises a rotor 36 carrying a plurality of stages of compressor rotor blades 38 and a stator 40 carrying a plurality of stages of compressor stator vanes 42. The compressor rotor blades 38 in each stage are circumferentially spaced and extend generally radially outwardly from the rotor 36. The compressor stator vanes 42 in each stage are circumferentially spaced and extend generally radially inwardly from the stator 40. The stator 40 also comprises a plurality of shrouds 44 axially interconnecting the stages of compressor stator vanes 42 and the shrouds 44 are positioned radially around a corresponding one of the stages of compressor rotor blades 38. The stator 40 of the intermediate pressure compressor 28 also comprises an outer compressor casing 50 and the outer compressor casing 50 is provided with one or more apertures 52, 53 to allow access for boroscopes. In addition the radially outer platforms 54 of one or more of the compressor stator vanes 42 have one or more apertures 56, 57 to allow access for boroscopes and/or repair devices. The shrouds 44 axially interconnecting the stages of compressor stator vanes 42 form a portion of an inner compressor casing 58. The compressor stator vanes 42 also have radially inner platforms 55.

An apparatus 64 for determining the position and orientation of a remote end 62 of a boroscope 60 is shown in figures 3 and 4. The apparatus 64 comprises a sensor 66 located at a remote end 62 of the boroscope 60, the sensor 66 produces signals having orientation data, gravitational data and/or velocity data, a measurement device 68 to measure the length L of the boroscope 60 inserted through the apertures 52 and 56 in the casings 50 and 54 respectively into the assembled turbofan gas turbine engine 10. The sensor 66 is arranged to send the orientation data, gravitational data and/or velocity data to a processor 70 and the measurement device 68 is arranged to send a signal indicating the length L of the boroscope 60 inserted into the assembled turbofan gas turbine engine 10 to the processor 70. The processor 70 is arranged to determine from the length L of the boroscope 60 inserted into the assembled turbofan gas turbine engine 10 and the orientation data, the gravitational data and/or the velocity data the three dimensional coordinate and the orientation of the remote end 62 of the boroscope 60 within the assembled turbofan gas turbine engine 10. The processor 70 is arranged to determine from the length L of the boroscope 60 inserted into the assembled turbofan gas turbine engine 10 and the orientation data, the gravitational data and the velocity data the three dimensional coordinate and the orientation of the remote end 62 of the boroscope 60 within the assembled turbofan gas turbine engine 10. The sensor 66 is arranged to send the signals through a wire 72 and the wire 72 is arranged within the boroscope 60, as shown in figure 3, or is attached to the boroscope 60. The sensor 66 is a miniature electro mechanical system (MEMS) motion sensor. An example of a MEMS motion sensor is a LGA 14 sensor which has dimensions of 3mm, 5mm and 0.5mm.

The processor 70 comprises a mathematical model 74, e.g. a three dimensional mathematical model, of the assembled turbofan gas turbine engine 10 and the processor 70 is arranged to determine from the mathematical model 74 of the assembled turbofan gas turbine engine 10, the length L of the boroscope 60 inserted into the assembled turbofan gas turbine engine 10 and the orientation data, the gravitational data and/or the velocity data the three dimensional coordinate and the orientation of the remote end 62 of the boroscope 60 within the assembled turbofan gas turbine engine 10.

The processor 70 is arranged to map the three dimensional coordinate and orientation of the remote end 62 of the boroscope 60 into the mathematical model 74 of the assembled turbofan gas turbine engine 10. The mathematical model 74 of the assembled turbofan gas turbine engine 10 is CAD (Computer Aided Design) model of the assembled turbofan gas turbine engine 10. The mapping of the three dimensional coordinate and orientation of the remote end 62 of the boroscope onto the mathematical model 74 of the assembled turbofan gas turbine engine 10 allows a clearer understanding of what, e.g. component, is being inspected and allows the operator to fully visualise where the end 62 of the boroscope 60 is positioned in the turbofan gas turbine engine 10. The three dimensional coordinate and orientation of the remote end 62 of the boroscope 60 within mathematical model 74 may be displayed in a display unit 82.

The measurement device 68 comprises friction drive wheels 76 and 78 and the boroscope 60 is arranged to pass between the friction drive wheels 76 and 78 and the measurement device 68 is arranged to measure the rotation of at least one of the friction drive wheels 76 and 78 and hence measure the length of the boroscope 60 inserted into the assembled turbofan gas turbine engine 10. The measurement device 68 also comprises a motor 80 arranged to rotate at least one of the friction drive wheels 76 and 78 to insert the boroscope 60 into the assembled turbofan gas turbine engine 10. The motor 80 is also arranged to rotate the at least one of the friction drive wheels 76 and 78 to retract the boroscope 60 from the assembled turbofan gas turbine engine 10 after the boroscope 60 has been used to view a component in the assembled turbofan gas turbine engine 10.

The friction drive wheels 76 and 78 may be secured to the assembled turbofan gas turbine engine 10 to guide the boroscope 60 through the apertures 52 and 56 in the casings 50 and 54 respectively of the assembled turbofan gas turbine engine 10. The drive wheels 76 and 78 may be temporarily attached to the casing 50 by locking them into the bolt holes normally used to secure a plug into the aperture 52.

The boroscope 60 also comprises an optical fibre 84 which has a viewing end 88 at the remote end 62 of the boroscope 60 and electrical leads 86 to a light emitting diode 90, or other suitable light source, at the remote end 62 of the boroscope 60.

Boroscoping, using a boroscope, is difficult and requires a high degree of training in order for it to return useful information. Boroscopes are also liable to become stuck within an assembled apparatus. The present invention allows an operator to visualise where the remote end of the boroscope is positioned in the assembled apparatus rather than having to imagine where it is. The present invention improves the confidence in the imaging data returned by the boroscope and also assists an operator to un-stick a boroscope if it were to become stuck in the assembled apparatus. The present invention also reduces the training time for an operator. The present invention may enable the boroscope to be inserted and directed to a component, or point, within an assembled apparatus by several different routes and the present invention may be used to select one of these

several different routes. The processor and mathematical model of the assembled apparatus may be used to model the insertion and direction of the boroscope to a component, or point, within an assembled apparatus by several different routes in order to determine the route which is the least likely for the boroscope to become stuck and hence reduce the likelihood of the boroscope becoming stuck in the assembled apparatus and save the time and expense of having to disassemble the apparatus to remove the boroscope.
In addition the boroscope may comprise a tool, or the boroscope may be used with a tool, to perform one or more processes, e.g. dye penetrant inspection, cleaning, machining, welding etc, on a component within the assembled apparatus.

Although the present invention has been described with reference to determining the position and orientation of a remote end of a boroscope in an assembled turbofan gas turbine engine, the present invention is equally applicable to determining the position and orientation of a remote end of a boroscope within any other type of gas turbine engine, an internal combustion engine, a diesel engine, a nuclear reactor, a steam turbine, a heat exchanger or an electrical generator or any other assembled apparatus and may be used on vehicles, e.g. ships, aircraft, trains etc.

Although the present invention has been described with reference to determining the position and orientation of a remote end of a boroscope in an assembled apparatus, the present invention may be suitable for use in the medical industry for keyhole surgery and may be used in determining the position and orientation of a remote end of a boroscope in a body of a patient, whether human or animal.

The term boroscope is intended to include endoscope, fibrescope, videoscope, insertion tube or other device which is inserted into an assembled apparatus or a body of a patient.

CLAIMS

1. A method of determining the position and orientation of a remote end of a boroscope, the method comprising providing a sensor at a remote end of the boroscope, the sensor producing signals having orientation data, gravitational data or velocity data, inserting the boroscope through an aperture into a body, measuring the length of the boroscope inserted into the body, determining from the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

2. A method as claimed in claim 1 comprising determining from the length of the boroscope inserted into the body and the orientation data, the gravitational data and the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

3. A method as claimed in claim 1 or claim 2 comprising sending the signals through a wire, the wire being arranged within the boroscope or attached to the boroscope.

4. A method as claimed in any of claims 1 to 3 wherein the sensor is a miniature electro mechanical system motion sensor.

5. A method as claimed in any of claims 1 to 4 comprising providing a mathematical model of the body and determining from the mathematical model of the body, the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

6. A method as claimed in any of claims 1 to 5 comprising mapping the three dimensional coordinate and orientation of the remote end of the boroscope into a mathematical model of the body.

7. A method as claimed in claim 5 or claim 6 comprising providing a CAD (Computer Aided Design) model of the body.

8. A method as claimed in any of claims 1 to 7 wherein the measuring of the length of the boroscope inserted into the body comprises passing the boroscope between friction drive wheels and measuring the rotation of at least one of the friction drive wheels.

9. A method as claimed in claim 8 comprising rotating at least one of the friction drive wheels to insert the boroscope into the body.

10. A method as claimed in claim 8 or claim 9 comprising rotating the at least one of the friction drive wheels to retract the boroscope from the body.

11. A method as claimed in claim 8, claim 9 or claim 10 comprising securing the friction drive wheels to the body to guide the boroscope through the aperture in the body.

12. A method as claimed in any of claims 1 to 11 wherein the body is an assembled apparatus.

13. A method as claimed in claim 12 comprising inserting the boroscope through an aperture in a casing of the assembled apparatus.

14. A method as claimed in claim 12 or claim 13 comprising inserting the boroscope into a gas turbine engine, an internal combustion engine, a diesel engine, a nuclear reactor, a steam turbine, a heat exchanger or an electrical generator.

15. A method of determining the position and orientation of a remote end of a boroscope substantially as hereinbefore described with reference to the accompanying drawings.

16. An apparatus for determining the position and orientation of a remote end of a boroscope, the apparatus comprises a sensor located at a remote end of the boroscope, the sensor producing signals having orientation data, gravitational data or velocity data, a measurement device to measure the length of the boroscope inserted through an aperture into a body, the sensor is arranged to send the orientation data, gravitational data or velocity data to a processor, the measurement device is arranged to send a signal indicating the length of the boroscope inserted into the body to the processor, the processor is arranged to determine from the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

17. An apparatus as claimed in claim 16 wherein the processor is arranged to determine from the length of the boroscope inserted into the body and the orientation data, the gravitational data and the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

18. An apparatus as claimed in claim 16 or claim 17 wherein the sensor is arranged to send the signals through a wire, the wire being arranged within the boroscope or attached to the boroscope.

19. An apparatus as claimed in any of claims 16 to 18 wherein the sensor is a miniature electro mechanical system motion sensor.

20. An apparatus as claimed in any of claims 16 to 19 wherein the processor comprises a mathematical model of the body and the processor is arranged to determine from the mathematical model of the body, the length of the boroscope inserted into the body and the orientation data, the gravitational data or the velocity data the three dimensional coordinate and the orientation of the remote end of the boroscope within the body.

21. An apparatus as claimed in any of claims 16 to 20 wherein the processor comprises a mathematical model of the body and the processor is arranged to map the three dimensional coordinate and orientation of the remote end of the boroscope into the mathematical model of the body.

22. An apparatus as claimed in claim 20 or claim 21 wherein the mathematical model is a CAD (Computer Aided Design) model of the body.

23. An apparatus as claimed in any of claims 16 to 22 wherein the measurement device comprises friction drive wheels, the boroscope is arranged to pass between the friction drive wheels and the measurement device is arranged to measure the rotation of at least one of the friction drive wheels.

24. An apparatus as claimed in claim 23 wherein the measurement device comprises a motor arranged to rotate at least one of the friction drive wheels to insert the boroscope into the body.

25. An apparatus as claimed in claim 24 wherein the motor is arranged to rotate the at least one of the friction drive wheels to retract the boroscope from the body.

26. An apparatus as claimed in claim 23, claim 24 or claim 25 wherein the friction drive wheels are secured to the body to guide the boroscope through the aperture in the body.

27. An apparatus as claimed in any of claims 16 to 26 wherein the body is an assembled apparatus.

28. An apparatus as claimed in claim 27 wherein the aperture is in a casing of the assembled apparatus.

29. An apparatus as claimed in claim 27 or claim 28 wherein the assembled apparatus comprises a gas turbine engine, an internal combustion engine, a

diesel engine, a nuclear reactor, a steam turbine, a heat exchanger or an electrical generator.

30. An apparatus for determining the position and orientation of a remote end of a boroscope substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

Application No: GB1114275.9 **Examiner:** Donal Grace

Claims searched: 1 to 30 **Date of search:** 19 December 2011

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1 to 14 and 16 to 29	WO 2009/097461 A1 (NEOGUIDE SYSTEMS) see paragrphs [00094] and [000107]
X	1 to 14 and 16 to 29	WO 2005/058137 A2 (SOPER et al) see especially page 23 lines 30 to 32
X	1 to 14 and 16 to 29	WO 2008/076910 A1 (LOEWKE et al) see figures 17 and 18 and related description
X	1 to 14 and 16 to 29	US 2010/0113876 A1 (ISHIHARA) see figure 1

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^X :

Worldwide search of patent documents classified in the following areas of the IPC

A61B; G02B

The following online and other databases have been used in the preparation of this search report

EPODOC; WPI; TXTE

International Classification:

Subclass	Subgroup	Valid From
G02B	0023/24	01/01/2006
A61B	0001/00	01/01/2006