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Inventor(s)	Jaganathan; Arun Prakash et al.

Hybrid Hose For Transmission of Fluid, Electrical Power and Data Communication

Abstract

A hybrid hose assembly capable of transmitting fluid, electrical power, and data communications through a single hose assembly is disclosed. By providing the transmission of fluid power, electrical power, and bidirectional communication between the source and destination units connected thereto, the hybrid hose of the present invention can enhance functional capabilities of fluid-powered equipment used in harsh environments, such as subsea operations, aviation, and trenchless applications. A hybrid hose assembly embodying features of the present invention may comprise a hybrid hose having a fluid tube surrounded by at least two conductive metallic braided layers adapted to transmit electrical power and data communications, an electro-fluid hose fitting coupled to the hybrid hose, and an overmold encapsulating at least a portion of the electro-fluid hose fitting.

Inventors: **Jaganathan; Arun Prakash (Monroe, LA), Winiewicz; Anthony (Orlando, FL)**

Applicant: **Louisiana Tech Research Corporation** (Ruston, LA)

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Background/Summary

RELATED APPLICATIONS [0001] This application claims priority to U.S. Provisional Application No. 63/446,566, filed Feb. 17, 2023, which is hereby incorporated by reference.

BACKGROUND

[0002] Hydraulic and pneumatic equipment is widely used in a variety of industries including construction, automotive, aviation, manufacturing, and shipping. The power to these machines is supplied by pressurized fluid pumped through specially designed fluid power hoses. Fluid power hoses can be rated to handle pressures in thousands of pounds-per-square-inch (psi) and constitute a critical component of the overall systems in which they are employed. These hoses come in variety of forms and sizes depending on the application, and they are typically reinforced with either non-metallic or metallic braid layers depending upon their pressure rating. For example, for pressures less than 1,000 psi, only a few layers of textile braids are used for reinforcement, while for higher pressures, up to six layers of metallic braids are used. The metallic braids are commonly made of stainless steel, but steel, brass, aluminum, etc. can also be used.

[0003] A typical fluid power hose for high-pressure applications consists of an inner tube, multiple layers of metallic reinforcement braids layered between separation layers, and an external protective covering. Depending on the needs of the application, the internal tube is typically made of rubber, Teflon, or nylon. The external protective covering is typically a polymeric material, such as synthetic rubber or polyurethane.

[0004] Many hydraulic and pneumatic systems also employ electrical devices near the ends of the hoses. In these applications, providing power and communication to these electrical devices requires an additional cable dedicated to electrical transmission to be routed along with the fluid power hose. In many instances, the additional cable is either unwelcome due to increased cost and complexity or impractical due to the severity of the environment in which the hose is employed, particularly in trenchless applications, as electrical cables are typically not robust enough to handle the high mechanical loads expected in hydraulic and pneumatic equipment.

[0005] For example, steering a conventional impact mole (i.e., a pneumatic ground-piercing tool) used in trenchless technology, such as for laying pipes or cables underground, presents a unique challenge because the mole operates underground and out of direct visual range. Unlike more advanced directional drilling equipment that can be steered in real-time (e.g., horizontal directional drilling (HDD) systems), impact moles have a more rudimentary steering capability that requires the operator to set the angle and direction of the mole accurately according to the planned trajectory at the start of the bore. While it would be desirable to have the capability to electronically control the direction of the impact mole by establishing a communication link with the tool to transmit data from sensors and actuators, the underground environment has made it impractical to run a separate electric cable along with the fluid power hose.

[0006] Even in applications where it is feasible to run a separate electric cable along with the fluid power hose, hose/cable combinations add complexity and cable management issues to projects. For example, robotic devices that operate remotely inside underground pipelines and sewers tend to require pneumatic or hydraulic power in addition to electrical, video, data, and command/control communications. Examples include lateral reinstatement cutters, chemical grouting, cured-in-place piping, and jetter cleaning. Current systems employ a separate dedicated cable to power a camera and bring back a video signal; however, these systems have been plagued with cable management issues that come with deploying two cables/hoses into the sewer simultaneously from two reels.

SUMMARY

[0007] Disclosed herein is a novel hybrid hose assembly capable of transmitting fluid, electrical power, and data communications through a single hose assembly. By providing the transmission of fluid power, electrical power, and bidirectional communication between the source and destination units connected thereto, the hybrid hose of the present invention can enhance functional capabilities of fluid-powered equipment used in harsh environments, such as subsea operations, aviation, and trenchless applications.

[0008] A hybrid hose assembly embodying features of the present invention may comprise a hybrid hose having a fluid tube surrounded by at least two conductive metallic braided layers adapted to transmit electrical power and data communications, an electro-fluid hose fitting coupled to the hybrid hose, and an overmold encapsulating at least a portion of the electro-fluid hose fitting. An insulating layer is disposed between the first and second braid layers, with a protective jacket disposed around the second braid layer. The electro-fluid hose fitting may include a main body, a crimp collar, and at least two contact bands having bonded wires adapted to create electrical connections with the first and second metallic braid layers. The bonded wire of the first contact band is electrically connected to the first braid layer through the crimp collar, while the bonded wire of the second braid contact band is directly connected to the second braid layer. The overmold preferably covers at least the contact bands of the electro-fluid hose fitting.

[0009] In another embodiment employing the inventive concepts of the present invention, the hybrid hose may comprise at least four conductive metallic braided layers adapted to transmit electrical power and data communications. In such embodiments, the electro-fluid hose fitting features four contact bands each having a bonded wire adapted to be coupled to the four conductive metallic braided layers.

[0010] In another aspect of the invention, a trenchless boring method is disclosed that utilizes the novel hybrid hose assembly. The trenchless boring method may comprise utilizing a boring system comprising a boring head, a surface controller, and a hybrid hose assembly. The boring head can include a steering actuator and a displacement sensor. The surface controller is configured to transmit steering signals to the steering actuator and receive location signals from the displacement sensor. The hybrid hose assembly comprises a fluid tube, at least two layers of conductive, metallic reinforcement braids, an insulating layer separating the conductive braids, and a protective jacket. The fluid tube is configured to transmit fluid power to the boring head, while the conductive braids are configured to transmit electric power to the steering actuator and location signals to the surface controller. The foregoing boring system may be utilized by positioning the boring head in a subterranean bore; transmitting steering signals from the surface controller to the steering actuator, through the hybrid hose assembly to drive the boring head along an intended path; and receiving location signals at the surface controller in order to determine whether the boring head is progressing along the intended path.

[0011] In another aspect of the invention, a trenchless pipeline inspection and rehabilitation method is disclosed that utilizes the novel hybrid hose assembly. The trenchless pipeline inspection and rehabilitation method may comprise utilizing a robotic crawler system comprising a robotic crawler, a surface controller, and a hybrid hose assembly. The robotic crawler includes a camera orientation actuator, a camera, and a hydraulic or pneumatic peripheral tool. The surface controller is configured to transmit command signals to the camera orientation actuator, receive and display video feed from the camera, and operate the peripheral tool. The hybrid hose assembly comprises a fluid tube, at least two layers of conductive, metallic reinforcement braids, an insulating layer separating the conductive braids, and a protective jacket. The fluid tube is configured to transmit fluid power to the peripheral tool, and the conductive braids are configured to transmit electric power to the camera and the camera orientation actuator, video feed to the surface controller, and command signals to the peripheral tool. The foregoing robotic crawler system may be utilized by positioning the robotic crawler in a subterranean pipeline; transmitting command signals from the surface controller to the camera orientation actuator through the hybrid hose assembly, in order to pan, tilt, zoom, adjust camera settings, adjust lighting, start and stop recording, or control any other camera operations; transmitting command signals from the surface controller to the peripheral tool;

and receiving video feed at the surface controller in order to visually inspect the pipeline for damage and to monitor repair progress.
[0012] The above summary is not intended to describe each illustrated embodiment or every possible implementation. These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0013] The accompanying figures, where like reference numerals refer to identical or functionally similar elements throughout the separate views, which are not true to scale, and which, together with the detailed description below, are incorporated in and form part of the specification, serve to illustrate further various embodiments and to explain various principles and advantages in accordance with the present invention:
[0014] FIG. **1** is a perspective view of an embodiment of a hybrid hose assembly employing features of the present invention.
[0015] FIG. **2** is a perspective view of the hybrid hose assembly depicted in FIG. **1** with the overmold removed.
[0016] FIG. **3** is an exploded view of the hybrid hose assembly depicted in FIG. **1**.
[0017] FIGS. **4**A and **4**B are perspective views of an embodiment of an electrical insulator suitable for usage with the hybrid hose assembly depicted in FIG. **1**.
[0018] FIG. **5** is a sectional view of the hybrid hose assembly depicted in FIG. **1**.
[0019] FIG. **6** is a perspective view of the hybrid hose assembly depicted in FIG. **1** with additional conductive elements.
[0020] FIG. **7** is a perspective view of the hybrid hose assembly depicted in FIG. **6** with the overmold removed.
[0021] FIG. **8** is a sectional view of the hybrid hose assembly depicted in FIG. **6**.
[0022] FIG. **9** is a perspective view of an alternative embodiment of a hybrid hose assembly employing features of the present invention.
[0023] FIG. **10** is an exploded view of the hybrid hose assembly depicted in FIG. **9**.
[0024] FIG. **11**A is a perspective view of an embodiment of an electrical insulator suitable for usage with the hybrid hose assembly depicted in FIG. **9**.
[0025] FIG. **11**B is a sectional view of an embodiment of an electrical insulator suitable for usage with the hybrid hose assembly depicted in FIG. **9**.
[0026] FIG. **12** is a perspective view of the hybrid hose assembly depicted in FIG. **9** with the overmold removed.
[0027] FIG. **13** is a perspective view of a hose fitting suitable for usage with the hybrid hose assembly depicted in FIG. **9**.
[0028] FIG. **14** is a sectional view of the hybrid hose assembly depicted in FIG. **9**.
[0029] FIG. **15** is a perspective view of another alternative embodiment of a hybrid hose assembly employing features of the present invention.
[0030] FIG. **16** is a perspective view of the hybrid hose assembly depicted in FIG. **15** with the overmold removed.
[0031] FIG. **17** is a sectional view of the hybrid hose assembly depicted in FIG. **15**.
[0032] FIG. **18** is a flow diagram depicting a process by which a hybrid hose assembly employing features of the present invention may transmit electrical signals between computing devices located at each end of the hybrid hose assembly.
[0033] FIG. **19** is a diagram depicting a hybrid hose assembly employing features of the present

invention being utilized in a trenchless application.

[0034] FIG. **20** is a diagram depicting a hybrid hose assembly employing features of the present invention being utilized to connect a surface controller to a submersible robotic crawler system in order to conduct a sewer inspection and rehabilitation.

DETAILED DESCRIPTION

[0035] Detailed embodiments of the present invention are disclosed herein; however, it is to be understood that the disclosed embodiments are merely exemplary of the invention, which can be embodied in various forms. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the present invention in virtually any appropriately detailed structure. Alternate embodiments may be devised without departing from the spirit or the scope of the invention. Further, the terms and phrases used herein are not intended to be limiting; but rather, to provide an understandable description of the invention. While the specification concludes with claims defining the features of the invention that are regarded as novel, it is believed that the invention will be better understood from a consideration of the following description in conjunction with the drawing figures, in which like reference numerals are carried forward.

[0036] As used herein, the terms “a” or “an” are defined as one or more than one. The term “plurality,” as used herein, is defined as two or more than two. The term “another,” as used herein, is defined as at least a second or more. The terms “comprises,” “comprising,” or any other variation thereof are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements, but may include, other elements not expressly listed or inherent to such process, method, article, or apparatus. An element proceeded by “comprises” does not, without more constraints, preclude the existence of additional identical elements in the process, method, article, or apparatus that comprises the element. The terms “including,” “having,” or “featuring,” as used herein, are defined as comprising (i.e., open language). The term “coupled,” as used herein, is defined as connected, although not necessarily directly, and not necessarily mechanically. As used herein, the term “about” or “approximately” applies to all numeric values, whether or not explicitly indicated. These terms generally refer to a range of numbers that one of skill in the art would consider equivalent to the recited values (i.e., having the same function or result). In many instances these terms may include numbers that are rounded to the nearest significant figure. Relational terms such as first and second, top and bottom, right and left, and the like may be used solely to distinguish one entity or action from another entity or action without necessarily requiring or implying any actual such relationship or order between such entities or actions.

[0037] The hybrid hose assembly of the present invention comprises (1) a hydraulic or pneumatic hose comprising conductive elements incorporated into the hose and configured to allow the flow of data, electricity, and fluid through the hose and (2) a hose fitting on each end of the hose configured to transmit the data, electricity, and fluid to and from the hose. This hybrid hose assembly acts not only as a robust conduit to transport hydraulic or pneumatic fluid, but also serves as an electrical transmission line for establishing a communication link between peripheral devices located at either ends of the hose. In addition to these modulated communication signals, electrical power (AC or DC) is also sent through the hose to power actuators, sensors, and other devices connected to the hose. A transformer-based coupling circuit is used to isolate the low frequency (50 or 60 Hz) power signals from damaging circuitry that is used to transmit the high frequency data communication signals (in the range of kHz to several MHz). Thus, the hose serves three functions: transmission of mechanical power, transmission of electrical power, and bidirectional communication between the source and peripheral devices connected to it.

[0038] In applications where only low amounts and quality of data are needed, a low to medium bandwidth communication link may be established through the hose using standard narrow bandwidth telecommunication protocols such as Frequency Shift Keying (FSK), Orthogonal Frequency-Division Multiplexing (OFDM), etc. In applications where high amounts and quality of data are required, a high bandwidth communication link may be established through the hose using a standard high data rate communication method such as Gigabit Home Networking (G.hn). Experiments conducted using G.hn protocols and modulation techniques with the hybrid hose designs discussed herein demonstrated data rates on the order of 200 Mbps, which enables transmission of Ultra High-Definition video and sophisticated remote control of tools and equipment. In addition, such high data rates of bidirectional communication enable processing of high bandwidth information such as ground penetrating radar and sonar. Utilization of powerful computers on the surface can enable rapid processing and subsequent closed loop control of advanced sensors and systems downhole, which would not be possible without a high bandwidth data link.

[0039] Additionally, the transmission of data signals through the hybrid hose assembly may be used to monitor the health of the hose itself. For instance, a frequency sweep can be carried out and the power received through the hose can be recorded, and then any variations observed in future sweeps would indicate an anomaly in the hose. Once an anomaly is detected, other sophisticated sensor techniques that are used for cable fault location (e.g., time domain and frequency domain reflectometry) can be applied to the hose to enhance the reliability. Thus, the operator could be warned of an impending failure before it happens and utilize preventative maintenance measures to either reinforce or repair the hose in a weak location or entirely replace the hose before it fails. This prevents loss of production time, prevents environmental contamination, and lowers the risk of a safety hazard. One skilled in the art can easily imagine the multitude of applications in which the ability to monitor the health of the hose is critically important.

[0040] As stated above, the hybrid hose assembly of the present invention may comprise (1) a hydraulic or pneumatic hose comprising conductive elements incorporated into the hose and configured to allow the flow of data, electricity, and fluid through the hose and (2) a hose fitting on each end of the hose configured to transmit the data, electricity, and fluid to and from the hose. The hose must comprise at least two conductive elements—one for grounding, and one for transmission of data and electrical signals. Using more conductive elements significantly increases the data rate possible because of the availability of parallel conductors to transmit multiple data-carrying signals simultaneously in both directions of the hose. Modern PLC communication modulation schemes utilize three or more conductors to enable multiple-input-multiple-output (MIMO) transmission, as opposed to the single-input-single-output (SISO) transmission possible when only two conductors are used. The use of MIMO technology increases data rates and signaling distance of the conductive elements of the hose.

[0041] The conductive elements may comprise wires embedded into the body of the hose, or the reinforcing metallic braid layers already used in high-pressure hoses may act as the conductors through which the electrical signals are transmitted. The metallic braid layers may be formed of steel, copper, aluminum, or any other conductive metal, or a composite of multiple materials. In other embodiments, one conductive metallic braid layer may also serve a structural function, while the additional, non-structural layers are formed of lighter conductive materials. This would allow the use of multiple braid layers to provide high rates of data transmission without significantly increasing the weight of the hose for applications that do not need several layers of reinforcing braids. Further, in embodiments where the conductive elements are embedded wires, any required reinforcing braid layers need not be metallic at all and may instead be formed of plastics or strong textile materials in order to optimize for applications where lighter and/or thinner hoses are required.

[0042] The description which follows, and the embodiments described therein, is provided by way of illustration of examples of particular embodiments of principles and aspects of the present invention. These examples are provided for the purposes of explanation—and not of limitation—of those principles of the invention.

[0043] Viewing FIGS. **1-8**, in a first exemplary embodiment of the hybrid hose assembly of the present invention, the hose assembly **100** comprises a hybrid hydraulic or pneumatic hose **110** connected to hose fitting **120**. Viewing FIG. **5**, the hose **110** comprises a core tube **112**, a first layer of conductive metallic braids **114***a* surrounding the core tube **112**, a layer of insulating material **116** surrounding the first conductive braid layer **114***a*, a second layer of conductive metallic braids **114***b* surrounding the insulating layer **116**, and a protective jacket **118** surrounding the second braid layer **114***b*. The insulating layer **116** and the second braid layer **114***b* are shorter than the first braid layer **114***a*, leaving a portion of first braid layer **114***a* exposed. In addition, the protective jacket **118** is shorter than the second braid layer **114***b*, leaving a portion of the second braid layer **114***b* exposed.

[0044] Viewing FIGS. **2-3** and **5**, the hose fitting **120** primarily comprises (1) a main fitting body **122** that is generally shaped like a hollow cylinder, (2) a crimp collar **130**, (3) insulator **140**, and (4) contact bands **150**. The fitting body **122** has a tapered end **124** that is inserted into the core tube **112** of the hose **110**. The core tube **112** electrically insulates the tapered end **124** of the fitting body **122** from the first metallic braid layer **114***a*. The fitting body **122** further comprises a working end **128** that serves to complete the hydraulic or pneumatic fluid connection from the core tube **112** to a peripheral device. The working end **128** can be any shape standard to hose fittings for hydraulic and pneumatic hoses. The hose **110** is secured around the tapered end **124** of the hose fitting **120** using a crimp collar **130**, which is separated from the metallic fitting body **122** by an electrical insulator **140** wrapped around the fitting body **122**. The hose fitting **120** further comprises a retaining boss **126**, which secures the electrical insulator **140** in place.

[0045] Turning to FIGS. **4***a***-4***b*, the electrical insulator **140** can be two c-shaped halves **142** that align to cover the entire circumference of the fitting body **122** when the insulator halves **142** are placed around the fitting body **122**, as shown in the Figures, but in other embodiments, the insulator **140** can be a single piece formed of an elastomeric material that can stretch around the fitting body **122** to be put into position. Insulator **140** comprises an internal retention groove **146** into which the retaining boss **126** fits. The insulator **140** further comprises an upper lip **144**, which forms an exterior pocket **148** in which the upper portion **132** of the crimp collar **130** sits when crimped over the insulator **140**. The upper lip **144** ensures complete separation between the crimp collar **130** and the working end **128** of the fitting **120** (see FIG. **5**). The electrical insulator **140** described herein is merely exemplary of the myriad of different methods and materials, both known and developed in the future, which could be used to insulate the crimp collar **130** from the hose fitting **120**. The insulator **140** should be made of a material with insulating properties and with a high compressive strength, such as Garolite™ or a phenolic resin, for example.

[0046] The use of the electrical insulator **140** to insulate the fitting main body **122** from the crimp collar **130** allows the crimp collar **130** to be used as an electrical conductor. Viewing FIG. **5**, an upper portion **132** of the crimp collar **130** is crimped around the electrical insulator **140**, while a lower portion **134** of the crimp collar **130** compresses the exposed portion of the first conductive braid layer **114***a* and the core tube **112** against the fitting body **122**, establishing an electrical connection between the first braid layer **114***a* and the collar **130** while the core tube **112** insulates the lower portion **134** of the crimp collar **130** from the tapered end **124** of the fitting body **122**. A first contact band **150***a* is wrapped around the lower portion **134** of crimp collar **130**, and a bonded wire **152***a* on contact band **150***a* extends towards the working end **128** of main fitting body **122**. A second contact band **150***b* is wrapped around the exposed portion of the second conductive braid layer **114***b*. The second contact band **150***b* also includes an attached bonded wire **152***b* that extends towards the working end **128** of main fitting body **122**. The terminal ends of the bonded wires **152** can be operatively connected to transceiver modules **3** to allow data exchange between the hybrid hose assembly **100** and external computing devices **5**.

[0047] Finally, an overmold **160** (pictured in FIGS. **1** and **3**) may surround the hose fitting **120** and adjacent end of the hybrid hose **110** to protect the electrically active connections and wires. The overmold **160** can be formed of Scotchcast™M or another electrical insulating resin that can adhere to the materials of this design and provide a robust, watertight seal. In other embodiments, an electrical receptacle could be embedded into the overmold **160** to facilitate removal. Viewing FIG. **1**, the terminal ends of the bonded wires **152** and the working end **128** of the fitting body **122** protrude from the overmold **160** so that the operator may access these connection points. In another embodiment, transceiver module **3** could be incorporated into the overmold **160**, and any connections between transceiver module **3** and computing device **5** would protrude from the overmold instead of the bonded wires **152**.

[0048] Because the exemplary embodiment of FIGS. **1-5** only uses two layers of conductive braids, this hose is more limited in the amount of data it can transmit. However, the design of hybrid hose assembly **100** is adaptable to more braid layers, providing the capability for high bandwidth data transmission. For example, FIGS. **6-8** illustrate hybrid hose assembly **100** with four braid layers **114**. Viewing FIG. **8**, each successive braid layer **114***a*, **114***b*, **114***c*, **114***d* and corresponding insulating separation layer **116** is shorter than the braid layer **114** below it, leaving a portion of each braid layer **114** exposed. Like in the embodiment pictured in FIGS. **1-5**, the first metallic braid layer **114***a* is surrounded by the lower portion **134** of crimp collar **130**, establishing an electrical connection. The exposed portions of each of the second **114***b*, third **114***c*, and fourth **114***d* braid layers are surrounded by braid contact bands **150***b*, **150***c*, **150***d* with bonded wires **152** to establish electrical connections with the braids **114**. The remaining aspects of the design remain unchanged from the embodiment of FIGS. **1-5**. Thus, hybrid hose assembly **100** is easily adapted to use additional or fewer braid layers depending on the desired bandwidth and weight limitations of the particular application.

[0049] Referring now to FIGS. **9-14**, a second embodiment of the hybrid fluid power hose assembly **200** is depicted. The hybrid hose **210** comprises: a core tube **212**, a first layer of conductive metallic braids **214***a*, an insulating layer **216**, a second layer of conductive metallic braids **214***b*, and then a protective jacket **218**. Viewing FIGS. **10**, **13** and **14**, hose fitting **220** primarily comprises (1) a main fitting body **222** that is generally shaped like a hollow cylinder, (2) a crimp collar **230**, (3) insulator **240**, and (4) contact bands **250**. Fitting body **222** comprises a tapered end **224** that fits inside the core tube **212** and a working end **228** that protrudes from the core tube **212**. Fitting body **222** also comprises a retaining boss **226**, which secures in place electrical insulator **240**, which wraps around fitting body **222**.

[0050] The electrical insulator **240** can be two c-shaped halves **242** that align to cover the entire circumference of the fitting body **222** when the insulator halves **242** are placed around the fitting body **222**, but in other embodiments, the insulator **240** can be a single piece formed of an elastomeric material that can stretch around the fitting body **222** to be put into position. Turning to FIGS. **11***a*-**11***b*, each c-shaped insulator half **242** comprises an internal retention groove **244** for retaining boss **226** of the hose fitting **220**. The insulator halves **242** also comprise an upper lip **244**, which forms an exterior pocket **245** in which the upper portion **232** of the crimp collar **230** sits when crimped over the insulator **240**. The upper lip **244** ensures complete separation between the crimp collar **230** and the working end **228** of the fitting **220** (see FIG. **14**). The insulator **240** should be made of a material with insulating properties and with a high compressive strength, such as Garolite™ or a phenolic resin, to withstand the crimping force and other forces applied to the fitting and crimp collar. The electrical insulator **240** described herein is merely exemplary of the myriad of different methods and materials, both known and developed in the future, which could be used to insulate the conductive elements of hose assembly **200**.

[0051] The electrical connection of hybrid hose assembly **200** is established by barbed contact bands **250***a*, **250***b* (best seen in FIG. **10**) used to electrically engage the ends of the braid layers **214***a*, **214***b*, which are the same length and thus do not have exposed portions as in hybrid hose assembly **100**. Each contact band **250** must be precisely sized to be the same diameter as its corresponding braid layer **214**, and the barbs **254** must be sufficiently sharp to penetrate into and engage the internal braids **214** of the hose **210**. Each contact band **250** also comprises a conductive rod **252** that extends towards the working end **228** of fitting body **222**. Because of their different diameters, first contact band **250***a* nests inside second contact band **250***b* (see FIG. **12**).

[0052] Turning back to FIGS. **11***a*-**11***b*, the contact bands **250***a*, **250***b* fit into specially formed grooves in c-shaped insulators **242***a*, **242***b*. In each insulator half **242***a*, **242***b*, first contact band **250***a* sits inside first band groove **248***a*, and second contact band **250***b* sits inside second band groove **248***b*. The conductive protrusions **252***a*, **252***b* travel through and protrude from passageways **249***a*, **249***b* in c-shaped insulators **242***a*, **242***b* that connect to the band grooves **248***a*, **248***b*. The protruding ends of the conductive rods **252***a*, **252***b* are accessible so that they may be soldered or welded to wires, connected to an electrical receptacle, or used in any other suitable configuration for electrical connectivity. In the embodiment pictured, which is designed for a hose **210** with two layers of braids **214***a*, **214***b*, the first insulator half **242***a* comprises the passageway **249***a* for the conductive rod **252***a* of first contact band **250***a*, while the second insulator half **242***b* houses the passageway **249***b* for the conductive rod **252***b* of second contact band **250***b*. However, in other embodiments comprising additional braid layers **214**, each insulator half **242** may comprise additional band grooves **248** and multiple passageways **249** for additional conductive rods **252**, as long as the band grooves **248** and passageways **249** are arranged inside insulator **240** such that the contact bands **250** and attached conductive rods **252** are completely insulated from each other.

[0053] Returning to FIG. **14**, hose assembly **200** may use a crimp collar **230** to secure the hose **210** and insulator **240** to the fitting **220**. An upper portion **232** of the crimp collar **230** compresses the c-shaped insulators **242** against the fitting body **222**, and a lower portion **234** of the crimp collar **230** compresses the core tube **212**, hose layers **214**, insulating layers **216**, and protective jacket **218** against the fitting body **222**. No overmold is required in this design because the contact bands **250** and conductive rods **252** run between the hose fitting **222** and the crimp collar **230** instead of around the crimp collar **230** like in hybrid hose assembly **100**. Although not pictured, this embodiment could also include third and fourth layers of conductive metallic reinforcement braids, separated by additional layers of insulating material, and connected to third and fourth contact bands. Further, other embodiments may combine elements of the hybrid hose assembly **100** and the hybrid hose assembly **200**, having first braid layer extend out past the second braid layer and electrically engaged by the crimp collar, while subsequent braid layers are engaged by a barbed contact band.

[0054] The design of hybrid hose assembly **200** is advantageous because it may be simpler to utilize in practice. Instead of skiving back hose layers to create exposed portions that must be individually wrapped with contact bands, the fitting **220** in this design may come with the barbed conductors **250** and electrical insulators **240** already installed, as shown in FIG. **13**, so that all a field operator needs to do to install fitting **220** is mark the depth the fitting **220** needs to be hammered into place on hose **210**, drive it onto the hose **210**, then crimp it in place with crimp collar **230**, which is all already standard field practice. Other envisioned embodiments of this fitting could employ an electrical receptacle integral to the fitting, further simplifying the fitting installation process.

[0055] Referring now to FIGS. **15-17**, a third embodiment of the hybrid hose assembly is depicted. Hybrid hose assembly **300** may comprise a hose **310** with, starting at the innermost layer: a core tube **312**, an elastomeric insulating layer **314** embedded with conductive wires **315**, reinforcement braids **316**, and a protective jacket **318**. Best shown in FIG. **16**, the wires **315** may be embedded in the elastomeric layer **314** in a spiral pattern down the length of the hose **310**, and the ends of the wires **315** protrude from hose **310** so they may be used for electrical connection. The exposed ends of the wires **315** may be covered in heat shrink tubing to protect and insulate them. Additional wires embedded separately from the first wires **315** may be added to increase the bandwidth of the hose assembly **300**. Alternatively, another embodiment may incorporate an insulating layer with embedded wires into hybrid hose assemblies **100** or **200**, allowing for additional bandwidth and/or

fewer braid layers in those designs.
[0056] Still viewing FIG. **17**, hybrid hose assembly **300** further comprises a hose fitting **320**, which primarily comprises (1) a fitting body **322** shaped like a hollow cylinder and (2) a compression socket **330**. Fitting body **322** comprises a tapered end **324** designed to fit inside core tube **312** and a working end **328** that protrudes from the core tube **312** and serves to complete the hydraulic or pneumatic fluid connection from the core tube **312** to an external device. The tapered end **324** comprises external threads **326**. Hose **310** is secured to hose fitting **320** by compression socket **330**, which comprises a hollow body **332**, with a mouth **334** on one end comprising internal threads **336** designed to engage the external threads **326** of fitting **320**. Compression socket **330** further comprises apertures **338** through which the ends of the conductive wires **315** can pass to engage a transceiver module **3** (see FIG. **15**).
[0057] To install the fitting **320** on hose **310**, the exposed ends of wires **315** are fed through apertures **338**, and the compression socket **330** is hammered down on hose **310**. Then, the fitting body **322** is threaded into the mouth **334** of compression socket **330** and into core tube **312** of the hose **310**. As the fitting body **322** is threaded into compression socket **330**, it expands hose **310** and compresses it against the inside of the hollow body **332** of compression socket **330**. This type of fitting has the benefit of being reusable because it uses threading, as opposed to a crimp collar which must be permanently deformed into place. However, in alternative embodiments, a crimp collar and unthreaded hose fitting could also be used, so long as the crimp collar also had apertures for the conductive wires.
[0058] Referring now to FIG. **18**, a process by which the hybrid hose assembly **1** of the present invention transmits electrical signals between computing devices **5** located at each end of the hybrid hose assembly **1** is depicted. At each of its ends, the hybrid hose assembly **1** connects to a transceiver module **3**, which in turn connects to a computing device **5**. In some embodiments, the transceiver module **3** may be incorporated into the hose assembly **1** itself, but in others it is external to the hose assembly **1**. Data generated by a first computing device **5***a* can be digitally communicated to the first transceiver module **3***a*, which then modulates the data and sends it to the hose assembly **1**. The conductive elements of the hose assembly **1** transmit the data through the hose to the second transceiver module **3***b* at the other end of the hose assembly **1**. The second transceiver module **3***b* then demodulates the data and digitally communicates it to a second computing device **5***b*. Notably, the hybrid hose assembly **1** allows bidirectional communication between the two devices **5***a*, **5***b*, so data signals can be sent from the second computing device **5***b* to the first computing device **5***a* as well. The transceiver modules **3** and hose assembly **1** may use modulated communication via line coupling circuitry, such as G.hn communications module MaxLinear Wave-2 Eval kit, or any other similar modulated communication circuitry. The transceiver modules **3** and computing devices **5** may communicate with each other via ethernet, USB, Wi-Fi, RS232, RS485, SPI, or any other suitable digital connection.
PROPHETIC EXAMPLES
[0059] The description which follows, and the embodiments described therein, is provided by way of illustration of examples of particular embodiments of principles and aspects of the present invention. These examples are provided for the purposes of explanation—and not of limitation—of those principles of the invention.
Example 1
[0060] The hybrid hose assembly **1** may be particularly suited for use in high pressure environments, such as in trenchless applications. For example, if used in impact moling, as shown in FIG. **19**, hybrid hose assembly **14** may be used to connect impact mole **12** to a surface controller **16**. In this exemplary application, the impact mole **12** may comprise a steering actuator and a displacement sensor, and the surface controller **16** may simultaneously transmit hydraulic or pneumatic power to the impact mole **12**, transmit electric power and steering commands to the steering actuator, and receive location signals from the displacement sensor. In one example, the

steering actuator may be a hydraulic tensioning unit configured to rotate a tapered steering head when torque is applied to the tensioning unit, thereby steering the impact mole **12**. The displacement sensor may be an inertial measurement unit (IMU) or any other suitable displacement sensor. During impact moling, the operator positions the impact mole **12** in a subterranean bore, and then uses the surface controller **16** to transmit steering commands through the hybrid hose assembly **14** to the steering actuator in order to drive the impact mole **12** along an intended path. As the impact mole **12** digs through the ground, the surface controller **16** will receive location signals from the displacement sensor through the hybrid hose assembly **14** so that the operator can determine whether the impact mole **12** is progressing along the intended path. Additionally, the surface controller **16** may also report an impedance change in the data signals sent through the hybrid hose assembly **14** to warn the operator of damage to the hose.

Example 2

[0061] In another exemplary application depicted in FIG. **20**, the hybrid hose assembly **24** may be used to connect a surface controller **26** to a submersible robotic crawler system **22** in order to conduct sewer inspection and rehabilitation. The robotic crawler system **22** may comprise one or more peripheral tools, such as a jetting machine, a hydro-jetting hose, a descaling machine, a concrete/shotcrete nozzle, a lateral liner reinstatement robot, a chemical grouting robot, a liner installation robot, or any other robot tool combination that benefits from pneumatic or hydraulic power supplied by a hybrid hose assembly **24**. The robotic crawler system **22** may further include a steering actuator and displacement sensor, allowing the operator to use the hybrid hose assembly **24** to send electric power and steering command signals from the surface controller **25** to the steering actuator to steer the robotic crawler **22** along an intended path and simultaneously send location signals from the displacement sensor to the surface controller **26** to determine whether the robotic crawler **22** is proceeding along the intended path. The robotic crawler system **22** may further comprise a camera, a light to illuminate the camera's view, a camera orientation actuator, and a cameral displacement sensor. The camera could be an axial camera, a self-leveling camera, a 360-degree camera, a pan-tilt-zoom camera, a camera array, or any other camera combination preferentially arranged to allow visual inspection of the pipeline and supervision of repair progress. The operator may use the surface controller **26** to receive and display video feed sent from the camera through the hybrid hose assembly **24**. The operator may then send commands from surface controller **26** through the hybrid hose assembly **24** to the camera orientation actuator to pan, tilt, zoom, adjust camera settings, adjust lighting, start and stop recording, or control any other camera operations. At the same time, the camera displacement sensor can send orientation data back to the surface controller **26** through the hybrid hose assembly **24** so that the operator can ensure the commands sent to the camera are being followed. Further, the robotic crawler system may comprise one or more inspection sensors, such as an Inertial Measurement Unit, a LiDAR sensor, a structured light system, a sonar device, a radar and ultrasonic sensor, an environmental monitoring system, and/or any other inspection sensor that could be utilized in pipeline inspection and remediation. The hybrid hose assembly **24** can transmit command signals from the surface controller **26** to the inspection sensor(s) **22** in order to collect inspection data and then send the captured data back to the surface controller **26** to collect environmental information about the pipeline.

[0062] Many modifications and other embodiments of the inventions set forth herein will come to mind to one skilled in the art to which these inventions pertain having the benefit of the teaching presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the inventions are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

Claims

1. A trenchless boring method comprising the steps of: a) providing a boring system comprising: (i) a boring head including: (1) a steering actuator and (2) a displacement sensor; (ii) a surface controller configured to (1) transmit steering signals to the steering actuator and (2) receive location signals from the displacement sensor; and (iii) a fluid power hose assembly comprising (1) a core tube, (2) at least two layers of conductive, metallic braids, (3) an insulating layer separating the conductive braids, and (4) a protective jacket; (iv) wherein (1) the core tube is configured to transmit fluid power to the boring head, and (2) the conductive braids are configured to transmit electric power to the steering actuator and location signals to the surface controller; b) positioning the boring head in a subterranean bore; c) transmitting steering signals from the surface controller to the steering actuator, through the fluid power hose assembly, in order to drive the boring head along an intended path; and d) receiving location signals at the surface controller in order to determine whether the boring head is progressing along the intended path.

2. The method of claim 1, wherein the boring head is a pneumatic piercing tool.

3. The method of claim 1, wherein the steering actuator comprises a fluid-powered tensioning unit configured to rotate a tapered steering head when torque is applied to the tensioning unit, thereby steering the boring head.

4. The method of claim 1, wherein the steering signals and the location signals are encoded prior to being transmitted across at least one of the conductive braids using either standard narrow band telecommunication protocols or wide band communication protocols.

5. The method of claim 1, wherein the boring head bores at a depth of less than 50 feet below surface level.

6. The method of claim 1, wherein hose damage is detected by an impedance change in the data signals during transit.

7. A trenchless pipeline inspection and rehabilitation method comprising the steps of: a) providing a robotic crawler system comprising: (i) a robotic crawler including: (1) a camera orientation actuator, (2) a camera, and (3) a fluid-powered peripheral tool; (ii) a surface controller configured to (1) transmit command signals to the camera orientation actuator, (2) receive and display video feed from the camera, and (3) operate the peripheral tool; and (iii) a fluid power hose assembly comprising (1) a core tube, (2) at least two layers of conductive, metallic braids, (3) an insulating layer separating the conductive braids, and (4) a protective jacket; (iv) wherein (1) the core tube is configured to transmit fluid power to the peripheral tool, and (2) the conductive braids are configured to transmit electric power to the camera and the camera orientation actuator, video feed to the surface controller, and command signals to the peripheral tool. b) positioning the robotic crawler in a subterranean pipeline; c) transmitting command signals from the surface controller to the camera orientation actuator, through the fluid power hose assembly, in order to pan, tilt, zoom, adjust camera settings, adjust lighting, start and stop recording, or control any other camera operations; d) transmitting command signals from the surface controller to the peripheral tool; and e) receiving a high-definition video feed through a high bandwidth link at the surface controller in order to visually inspect the pipeline for damage and to monitor repair progress.

8. The method of claim 7, wherein the robotic crawler further comprises a camera displacement sensor; the conductive braids are further configured to transmit orientation signals to the surface controller, and the surface controller is further configured to receive orientation signals from the camera displacement sensor.

9. The method of claim 8, further comprising the step of receiving orientation signals at the surface controller in order to determine the positioning of at least one of the camera and the fluid-powered peripheral tool.

10. The method of claim 7, wherein the orientation signals and the location signals are encoded

prior to being transmitted across at least one of the conductive braids using either standard narrow band telecommunication protocols or wide band communication protocols.
11. The method of claim 7, wherein the camera is one of an axial camera, a self-leveling camera, a 360° camera, Pan Tilt Zoom Camera, or Camera Array.
12. The method of claim 7, wherein the robotic crawler further comprises a light to illuminate the camera's line of vision.
13. The method of claim 7, wherein the peripheral tool is one of a jetting machine, a hydro-jetting hose, a descaling machine, a concrete/shotcrete nozzle, Lateral Liner Reinstatement Robot, a Chemical Grouting Robot, a Liner Installation Robot, or any other robot tool combination that benefits from fluid power supplied by a hose.
14. The method of claim 7, wherein the robotic crawler further comprises an inspection sensor; the conductive braids are further configured to transmit inspection data to the surface controller, and the surface controller is further configured to receive and display inspection data from the inspection sensor.
15. The method of claim 14, further comprising the steps of: a) transmitting control signals from the surface controller to the inspection sensor, through the fluid power hose assembly, in order to collect inspection data; and b) receiving and displaying inspection data at the surface controller in order to collect environmental information about the pipeline.
16. The method of claim 14, wherein the inspection sensor is one of an inertial measurement unit, a LiDAR sensor, a structured light system, a sonar device, a radar and ultrasonic sensor, an environmental monitoring system, or any other inspection sensor that can be utilized on the same communication channel.
17. The method of claim 7, wherein the robotic crawler system is submersible.
18. The method of claim 7, wherein a) the robotic crawler further comprises (4) a steering actuator and (5) a displacement sensor; b) the conductive braids are further configured to transmit electric power to the steering actuator and location signals to the surface controller; and c) the surface controller is further configured to (4) transmit steering signals to the steering actuator and (5) receive location signals from the displacement sensor.
19. The method of claim 18, further comprising the steps of: a) transmitting steering signals from the surface controller to the steering actuator, through the fluid power hose assembly, in order to drive the robotic crawler along an intended path; and b) receiving location signals at the surface controller in order to determine whether the robotic crawler is progressing along the intended path.
20. A fluid power hose assembly comprising: a) a fluid power hose comprising: (i) a core tube; (ii) at least three layers of conductive metallic braids, comprising a first, second, and third conductive braid layer, wherein each successive braid layer includes an exposed end offset from an exposed end of the previous braid layer; (iii) insulating layers that separate the braid layers; and (iv) a protective jacket; b) a hose fitting comprising: (i) a fitting body; (ii) a crimp collar, comprising an upper portion and a lower portion; (iii) an electrical insulator situated between the upper portion of the crimp collar and the fitting body; wherein the lower portion of the crimp collar compresses an innermost, first braid layer and core tube against the fitting body, to create an electrical connection between the first braid layer and the collar; and (iv) braid contact bands with bonded wires, wherein a first contact band creates an electrical connection with the lower portion of the crimp collar, and second and third contact bands create electrical connections with the second and third braid layers respectively, thereby allowing electrical communication through each braid layer to its respective bonded wire; and c) an overmold covering the contact bands.
21. The fluid power hose assembly of claim 20, wherein the fitting body comprises a tapered end that sits inside the core tube and a boss that holds the insulator in place around the fitting body.
22. The fluid power hose assembly of claim 20, wherein the contact bands are copper, bronze, aluminum, or some other electrically conductive material.
23. The fluid power hose assembly of claim 20, wherein the crimp collar is crimped on the upper

portion to affix itself and the insulator to the fitting body.
24. The fluid power hose assembly of claim 23, wherein the crimp collar is crimped on the lower portion to affix the hose fitting to the fluid power hose.
25. The fluid power hose assembly of claim 20, wherein the insulator comprises two c-shaped insulators align to cover an entire circumference of the fitting body when the insulators are placed around the fitting body.
26. The fluid power hose assembly of claim 20, wherein the fluid power hose further comprises a fourth conductive braid layer; wherein the hose fitting further comprises a fourth contact band with a bonded wire; and wherein the fourth contact band creates an electrical connection with the fourth braid layer, thereby allowing electrical communication through the fourth braid layer to the bonded wire.
27. A fluid power hose assembly comprising: a) a fluid power hose comprising: a core tube, a first and second layer of conductive metallic braids, an insulating layer between the conductive braids, and a protective jacket; and b) a hose fitting comprising: (i) a fitting body; (ii) contact bands with bonded wires, wherein the contact bands comprise barbs that wedge into the braids to create an electrical connection between the braids and the bonded wires; (iii) a crimp collar, comprising an upper portion and a lower portion; and (iv) an insulator seated between the fitting body and crimp collar, wherein the insulator separates the copper bands and bonded wires from the fitting body and crimp collar.
28. The fluid power hose assembly of claim 27, wherein the crimp collar is crimped on the upper portion to affix itself and the insulator to the fitting body.
29. The fluid power hose assembly of claim 28, wherein the crimp collar is crimped on the lower portion to affix the hose fitting to the fluid power hose.
30. The fluid power hose assembly of claim 27, wherein the insulator comprises two c-shaped insulators that align to cover an entire circumference of the fitting body when the insulators are placed around the fitting body.
31. The fluid power hose assembly of claim 27, wherein the fitting body comprises a tapered end that sits inside the core tube and a boss that holds the insulator in place around the fitting body.
32. The fluid power hose assembly of claim 27, wherein the contact bands are copper, bronze, aluminum, or some other electrically conductive material.
33. A fluid power hose assembly comprising a fluid power hose, wherein the fluid power hose comprises: a) a core tube; b) an elastomeric insulating layer, wherein the insulating layer is embedded with at least one pair of conductive wires, wherein the conductive wires are configured to transmit data signals, electric power, or a combination thereof; c) at least one layer of reinforcement braids; and d) a protective jacket;
34. The fluid power hose of claim 33, wherein the conductive wires are wrapped in a spiral pattern around the core tube.
35. The fluid power hose assembly of claim 33, wherein the reinforcement braids are nonmetallic.
36. The fluid power hose assembly of claim 33, further comprising a hose fitting configured to establish an electrical connection between the fluid power hose and a peripheral device, wherein the hose fitting comprises: a threaded fitting body and a compression socket.
37. The fluid power hose assembly of claim 36, wherein the compression socket further comprises apertures through which the conductive wires of the core tube can pass.
38. The fluid power hose assembly of claim 36, wherein the fitting body is configured to expand the core tube to compress the hose assembly when it is threaded into the compression socket.
39. The fluid power hose assembly of claim 33, further comprising a hose fitting configured to establish an electrical connection between the fluid power hose and a peripheral device, wherein the hose fitting comprises: a hose fitting body and a compression collar.
40. The fluid power hose assembly of claim 39, wherein the compression collar further comprises apertures through which the conductive wires of the core tube can pass.