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Inventor(s)	Nygaard; Mike et al.

INSPECTION SYSTEM FOR MANUFACTURED COMPONENTS

Abstract

An inspection system configured to scan internal surfaces of manufactured components includes an optical probe, a light source, a conical mirror, and an imaging sensor. The optical probe has a field of view. The light source is spaced apart from the optical probe and is positioned within the field of view of the optical probe. The conical mirror is secured to the light source and is configured to transform light emitted from the light source into a light disc. The light disc is configured to be projected onto the internal surfaces of the manufactured components while scanning the internal surfaces. The imaging sensor is configured to receive reflections of the light disc from the internal surfaces via the optical probe while scanning the internal surfaces.

Inventors: **Nygaard; Mike (Grand Blanc, MI), Kujacznski; Nathan (Swartz Creek, MI), Marchi; Nadaly (Holly, MI)**

Applicant: **General Inspection, LLC** (Davisburg, MI)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation of U.S. application Ser. No. 17/684,750 filed Mar. 2, 2022, the disclosure of which is hereby incorporated in its entirety by reference herein.

TECHNICAL FIELD
[0002] The present disclosure relates to inspection systems for manufactured products or components.
BACKGROUND
[0003] Inspection systems may be utilized to detect defects in manufactured products during production of such manufactured products.
SUMMARY
[0004] An inspection system includes an optical probe, a light source, a conical mirror, an imaging sensor, a first actuator, a second actuator, and a controller. The optical probe has an end and a field of view projecting outward from the end. The light source is spaced apart from the end of optical probe and is positioned within the field of view of the optical probe. The conical mirror is secured to light source and is configured to transform light emitted from the light source into a light disc. The optical probe, light source, and conical mirror are configured to extend into and retract out of a cavity defined by a manufactured component, and to rotate within the cavity, to scan an internal surface of the manufactured component. The light disc is projected onto the internal surface during the scan. The imaging sensor is configured to receive reflections of the light disc from the internal surface via the optical probe during the scan. The first actuator is configured to adjust a distance between the conical mirror and the end of optical probe to move an intersection between the light disc and the internal surface of the manufactured component into and of out of the field of view. The second actuator is configured to adjust a distance between the conical mirror and the light source to adjust a focus the light disc radially inward and radially outward from the conical mirror. The controller programmed to operate the first actuator to adjust the distance between the conical mirror and the end of the optical probe to move the intersection between the light disc and the internal surface of the manufactured component into the field of view. The controller is further programmed to operate the second actuator to adjust the distance between the conical mirror and the light source to focus the light disc radially relative to the conical mirror and on the internal surface of the manufactured component.
[0005] An inspection system configured to scan internal surfaces of manufactured components includes an optical probe, a light source, a conical mirror, a first actuator, and a second actuator. The optical probe has a field of view. The light source is spaced apart from an end of the optical probe and is positioned within the field of view of the optical probe. The conical mirror is secured to the light source and is configured to transform light emitted from the light source into a light disc. The light disc is configured to be projected onto the internal surfaces of the manufactured components for scanning the internal surfaces. The first actuator is configured to adjust a distance between the conical mirror and the end of the optical probe to move an intersection between the light disc and the internal surfaces of the manufactured components into and of out of the field of view. The second actuator is configured to adjust a distance between the conical mirror and the light source to adjust a focus of the light disc radially inward and radially outward from the conical mirror.
[0006] An inspection system configured to scan internal surfaces of manufactured components

includes an optical probe, a light source, a conical mirror, and an actuator. The optical probe has a field of view. The light source is positioned within the field of view of the optical probe. The conical mirror is configured to transform light emitted from the light source into a light disc. The light disc is configured to be projected onto the internal surfaces of the manufactured components while scanning the internal surfaces. The actuator is configured to adjust a distance between the conical mirror and the optical probe to move an intersection between the light disc and the internal surfaces of the manufactured components into and of out of the field of view.
[0007] An inspection system configured to scan internal surfaces of manufactured components includes an optical probe, a light source, a conical mirror, and an actuator. The optical probe has a field of view. The light source is positioned within the field of view of the optical probe. The conical mirror is configured to transform light emitted from the light source into a light disc. The light disc is configured to be projected onto the internal surfaces of the manufactured components while scanning the internal surfaces. The actuator is configured to adjust a distance between the conical mirror and the light source to adjust a focus of the light disc radially inward and radially outward from the conical mirror to focus the light disc onto the internal surfaces of the manufactured components.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0008] FIG. **1** is a front view of an inspection system having an inspection station and a conveyance system;
[0009] FIG. **2** is a top view of the inspection system;
[0010] FIG. **3** is diagrammatic view of the inspection system;
[0011] FIG. **4** is a front isometric view of a first embodiment of an inspection device utilized by the inspection station;
[0012] FIG. **5** is a diagrammatic view of an optical probe or endoscope;
[0013] FIG. **6** is a front isometric view of a light projecting system for the inspection device;
[0014] FIG. **7** is a front isometric view of a second embodiment of the inspection device;
[0015] FIGS. **8** is a front isometric view of the light projecting system with an adjustment mechanism for the light projecting system;
[0016] FIGS. **9**A-**9**C are diagrammatic views illustrating a first type of adjustment for the light projecting system;
[0017] FIGS. **10**A-**10**C are diagrammatic views illustrating a second type of adjustment for the light projecting system;
[0018] FIG. **11** is a flowchart illustrating a method for controlling the inspection system; and
[0019] FIGS. **12**A and **12**B illustrate a field of view of an optical probe of the inspection device.
DETAILED DESCRIPTION
[0020] Embodiments of the present disclosure are described herein. It is to be understood, however, that the disclosed embodiments are merely examples and other embodiments may take various and alternative forms. The figures are not necessarily to scale; some features could be exaggerated or minimized to show details of particular components. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a representative basis for teaching one skilled in the art to variously employ the embodiments. As those of ordinary skill in the art will understand, various features illustrated and described with reference to any one of the figures may be combined with features illustrated in one or more other figures to produce embodiments that are not explicitly illustrated or described. The combinations of features illustrated provide representative embodiments for typical applications. Various combinations and modifications of the features consistent with the teachings of this disclosure, however, could be

desired for particular applications or implementations.

[0021] Referring to FIGS. **1** and **2**, an inspection system **10** is illustrated. The inspection system **10** includes an inspection station **12** and a conveyance system **14**. It should be noted that the conveyance system **14** may be any type of conveyance system known to a person of ordinary skill in the art and is not limited to the conveyance system **14** depicted herein. For example, the conveyance system **14** may be a belt conveyor that directly transports manufactured components **16** to and from the inspection station **12**, may be a series of rollers that are configured to transport fixtures or pallets that position the manufactured components **16** to and from the inspection station **12**, a walking beam, etc.

[0022] The inspection station **12** includes an inspection device **18** that is configured to extend into an out of cavities or orifices defined by the manufactured components **16** in order to scan and inspect one or more internal features or internal surfaces of the manufactured components **16**. The inspection device **18** is more specifically configured to extend into the cavities or orifices defined by the manufactured components **16** from a retracted position **20** to an advanced position **22** to inspect one or more internal features or internal surfaces of the manufactured components **16**. The inspection device **18** then returns the retracted position **20**.

[0023] The conveyance system **14** is configured to transport the manufactured components **16** to the inspection station **12**. The conveyance system **14** may be configured to halt movement of the manufactured components **16** at the inspection station **12** while the manufactured components **16** are being inspected. The conveyance system **14** may further include a nesting mechanism that engages the bottom the manufactured components **16** or engages a pallet carrying the manufactured components **16** to secure a desired location of the manufactured components **16** at the inspection station **12**. Alternatively, clamps or some type of a clamping mechanism may engage the manufactured components **16** or engage a pallet carrying the manufactured components **16** to secure a desired location of the manufactured components **16** at the inspection station **12**. The conveyance system **14** is then configured to transport the manufactured components **16** away from the inspection station **12** once the manufactured components **16** have been inspected.

[0024] The manufactured components **16** may be directed in a first direction **24** if the one or more internal features or internal surfaces of the manufactured components **16** are within a tolerable range and have “passed” the inspection. The manufactured components **16** may be directed in a second direction **26** if the one or more internal features or internal surfaces of the manufactured components **16** are outside of the tolerable range and have “failed” the inspection. Directing the manufactured components **16** in either the first direction **24** or the second direction **26** may include directing the manufactured components **16** to different branches of the conveyance system **14**. Directing the manufactured components **16** in the first direction **24** and the second direction **26** does not require the additional conveyor portions as illustrated, but may include a drop floor or chutes that direct the parts toward either an “accepted” bin or “rejected” bin, respectively, may include a robot or pick-and-place that places the parts in an “accepted” bin or “rejected” bin, respectively, or any system that directs the parts toward a packaging station or scrap bin, respectively.

[0025] The branch of the conveyance system **14** that corresponds to the manufactured components **16** being directed in the first direction **24** may include directing the manufactured components **16** toward additional steps or processes in the manufacturing process, toward an “accepted” bin that contains parts that “passed” the inspection, or toward a packaging station where the “accepted” parts are packaged and shipped to market or other manufacturing facilities for further processing. The branch of the conveyance system **14** that corresponds to the manufactured components **16** being directed in the second direction **26** may include directing the manufactured components **16** toward an “rejected” bin that contains parts that “failed” the inspection, toward a repair station or loop where the defect in the “rejected” parts is corrected by a tradesman or machine process, or toward a scrap bin where the material of “rejected” parts is recycled for future use.

[0026] The inspection system **10** may include a controller **28** that coordinates the operation of the inspection station **12** and conveyance system **14** based on a programmed control logic or algorithms. The control logic or algorithms includes a program that is configured to determine whether or not the one or more internal features or internal surfaces of the manufactured components **16** are within the tolerable range or if there are defects in the internal features or internal surfaces of the manufactured components **16**. The features may include any attribute of the manufactured components **16** such as, but not limited to, a desired dimension, geometry (e.g., a geometric shape), or a profile of the manufactured component. For example, a feature may include, but is not limited to, (i) an internal diameter of the manufactured components **16** that defines the cavities or orifices of the manufactured components **16**, (ii) the consistency of the internal diameter of the manufactured components **16** along a dimension of the manufactured components **16** (e.g., the controller **28** may determine if a deviation of the internal diameter of the manufactured components **16** is within or outside of a tolerable range along a height, H, of the manufactured components **16**), (iii) a profile of the manufactured components **16** along an internal surface of the manufactured components **16** that defines the cavities or orifices of the manufactured components **16** where the profile could have any particular shape, a (iv) the consistency of the profile of the manufactured components **16** along a dimension of the manufactured components **16** (e.g., the controller **28** may determine if a deviation of the profile of the manufactured components **16** is within or outside of a tolerable range along the height, H, of the manufactured components **16**), (v) a threaded geometry of the internal surface of the manufactured components **16** that defines the cavities or orifices of the manufactured components **16**, (vi) or any other desired shape of the internal surface of the manufactured components **16** that defines the cavities or orifices of the manufactured components **16**.
[0027] Defects may include any deviation beyond a tolerance from a desired dimension, geometry, or profile, diameter, or any other defect of a manufactured component **16**. For example, the defects may include but are limited to, dents, splits, perforations, cracks, scratches, wrinkles, buckles, smudges, surface blemishes, etc. As another example, if the inspection station is being utilized to inspect threaded surfaces, the defect may include a deviation from a desired threading geometry or profile that is greater than a tolerance, or any defect described immediately above (i.e., dents, splits, perforations, cracks, scratches, wrinkles, buckles, smudges, surface blemishes, etc.). In summary, the inspection station **12** may be configured to detect defects including any deviation of a dimension, geometry, or profile that is greater than a tolerance or any of the defects described immediately above (i.e., dents, splits, perforations, cracks, scratches, wrinkles, buckles, smudges, surface blemishes, etc.).
[0028] Defect detection may be conducted by running several image processing algorithms within the controller and then analyzing the resultant pixel brightness values. Groups of pixels whose brightness values exceed a preset threshold are flagged as a “bright defect,” while groups of pixels whose brightness values lie below a preset threshold are flagged as a “dark defect.” Different image processing techniques and threshold values are often needed to inspect for bright and dark defects on the manufactured products or components or within a region of the manufactured products or components. Such imaging techniques to detect defects on manufactured products or components are disclosed in U.S. Pat. No. 9,575,013, the disclosure of which is hereby incorporated in its entirety by reference herein.
[0029] The controller **28** may include a microprocessor or central processing unit (CPU) in communication with various types of computer readable storage devices or media. Computer readable storage devices or media may include volatile and nonvolatile storage in read-only memory (ROM), random-access memory (RAM), and keep-alive memory (KAM), for example. KAM is a persistent or non-volatile memory that may be used to store various operating variables while the CPU is powered down. Computer-readable storage devices or media may be implemented using any of a number of known memory devices such as PROMs (programmable

read-only memory), EPROMs (electrically PROM), EEPROMs (electrically erasable PROM), flash memory, or any other electric, magnetic, optical, or combination memory devices capable of storing data, some of which represent executable instructions, used by the controller in controlling the inspection system **10**.

[0030] The control strategies and/or logic may be implemented by the controller **28** using one or more processing strategies such as event-driven, interrupt-driven, multi-tasking, multi-threading, and the like. As such, various steps or functions of the control strategies and/or logic may be performed in a desired sequence, in parallel, or in some cases omitted. Although not always explicitly illustrated, one of ordinary skill in the art will recognize that one or more of the steps or functions may be repeatedly performed depending upon the particular processing strategy being used. Similarly, an order of processing is not necessarily required to achieve the features and advantages described herein. The control logic may be implemented primarily in software executed by a microprocessor-based controller, such as controller **28**. Of course, the control logic may be implemented in software, hardware, or a combination of software and hardware in one or more controllers depending upon the particular application. When implemented in software, the control logic may be provided in one or more computer-readable storage devices or media having stored data representing code or instructions executed by a computer to control the inspection system **10**, its subcomponents, or its subsystems. The computer-readable storage devices or media may include one or more of a number of known physical devices which utilize electric, magnetic, and/or optical storage to keep executable instructions and associated calibration information, operating variables, and the like.

[0031] The inspection system **10** may include a human machine interface (HMI) **30**. The HMI **30** may include an interface that allows an operator or user to operate the inspection system **10**. For example, the HMI **30** may include control buttons or a touch screen that allow an operator to initiate automated or manual operation of the inspection system **10** as a whole, the inspection station **12**, the conveyance system **14**, or any of the subcomponents of the inspection system **10**, inspection station **12**, or conveyance system **14** further described herein.

[0032] A display unit may be a subcomponent of the HMI **30** (e.g., a touchscreen). Alternatively, the display unit may be a separate component from the HMI **30**. The display unit may be configured to display whether or not the inspection system **10**, the inspection station **12**, the conveyance system **14**, or any of the subcomponents of the inspection system **10**, inspection station **12**, or conveyance system **14** are in an “on” or “off” state; the current operating condition of the inspection system **10**, the inspection station **12**, the conveyance system **14**, or any of the subcomponents of the inspection system **10**, inspection station **12**, or conveyance system **14** (e.g., whether the system or the subcomponents of the system are operating in an automated or manual mode); whether or not there are any faults within the inspection system **10**, the inspection station **12**, the conveyance system **14**, or any of the subcomponents of the inspection system **10**, inspection station **12**, or conveyance system **14** (e.g., a manufactured component is jamming the inspection station **12** or conveyance system **14**; one or more of the sensors described herein are not communicating with the controller **28**; any of the other components are not communicating with the controller **28**; etc.); whether or not a “passed parts” bin or a “failed or rejected parts” bin is full; etc.

[0033] The inspection system **10**, the inspection station **12**, the conveyance system **14**, and any of the subcomponents of the inspection system **10**, inspection station **12**, or conveyance system **14** may be wired to receive electrical power and to communicate with the controller **28** and other components of the system. However, for ease of illustration, the power cables that connect the system to a power grid or other source and any various commination wires have been omitted.

[0034] Referring to FIGS. **4-6**, the inspection device **18** and the various subcomponents of the inspection device **18** are illustrated in further detail. The inspection device **18** includes an endoscope or optical probe **32**. The optical probe **32** has a distal end **34** and a field of view **36** projecting outward from the distal end **34**. The inspection device **18** includes a light source **38** that is spaced apart from the distal end **34** of optical probe **32** and positioned within the field of view **36** of the optical probe **32**. More specifically, the light source **38** may be a laser light source that includes a laser diode **40** and a collimating lens **42**. The light source **38** may also include a plate **44** defining a pinhole **46**. The light source is configured to direct a beam of light (e.g., laser light) onto a conical mirror **48** that may be secured within a transparent housing **50**. The conical mirror **48** may be secured to the light source **38**. More specifically, the conical mirror **48** may be secured to the light source **38** via the transparent housing **50**.

[0035] The conical mirror **48** is configured to transform the light emitted from the light source **38** into a light disc **52** that is projected outward in all directions along a plane and onto internal surfaces **54** of the manufactured components **16**. The plane along which the light disc **52** is projected may extend outward in a substantially horizonal direction. Substantially horizonal may include any incremental angle between exactly horizonal and 15° from exactly horizonal. Please note the manufactured component **16** depicted in FIG. **4** is shown in cross-section for illustrative purposes. The intersection between the light disc **52** and the internal surfaces **54** of the manufactured components **16** needs be within the field of view **36** of the optical probe **32** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. The optical probe **32**, light source **38**, and conical mirror **48** are collectively configured to extend into and retract out of the cavities or orifices **56** defined by the manufactured components **16** between the advanced position **22** and the retracted position **20** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. The inspection device **18** further includes a vision or imaging sensor **58** configured to receive reflections of the light disc **52** from the internal surfaces **54** of the manufactured components **16** via the optical probe **32** during scans or inspections of the internal surfaces **54** of the manufactured components **16**.

[0036] The light source **38** is secured to the distal end **34** of the optical probe **32** via an adapter such as a brace or bracket **60**. The bracket **60** may comprises a pair of cuffs **62** that are spaced apart by a linking rod or linking bar **64**. The distance between the cuffs **62** is adjustable so that the position of the of the light disc **52** within the field of view **36** may be adjusted. The bracket **60** (or more specifically the linking bar **64**) and any power or communication cables wires that are routed to the light source **38** along the bracket **60** (or more specifically the linking bar **64**) may partially block the internal surfaces **54** of the manufactured components **16** within the field of view **36** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. A proximal end **66** of the optical probe **32** may be secured to the imaging sensor **58** via an adapter **68**. The adapter **68** may comprise an aperture **65** to adjust the amount of light allowed into the optical probe **32**, a focus adjustment **67**, and a locking ring **69** to secure the position of the optical probe **32**. More specially, the adapter may engage the eyepiece portion **108** of the optical probe to secure the position of the optical probe **32**.

[0037] The optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, and adapter **68** may all be directly or indirectly affixed to a bracket **70** that is connect to an actuator, such as rotational motor **72**. The rotational motor **72** may be a servo motor. The optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, adapter **68**, and bracket **70** are configured to collectively rotate about a common axis **74**. The axis **74** may extend in a substantially vertical direction. Substantially vertical may include any incremental angle between exactly vertical and 15° from exactly vertical. More specifically, the rotational motor **72** is configured to collectively rotate the optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, adapter **68**, and bracket **70** about the axis **74** to adjust a radial position of the field of view **36** of the optical probe **32** relative to the internal surfaces **54** of the manufactured components **16** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. Even more specifically, the rotational motor **72** is configured to collectively rotate the optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, adapter **68**, and bracket **70** about the axis **74** from a first radial position to second radial position during scans or inspections of the internal surfaces **54** of the manufactured components **16**.

[0038] The rotational motor **72** is secured to a linear motion slide **76** via bracket **78**. A proximity sensor **80** is also secured to bracket **78**. The proximity sensor **80** is configured to detect a protrusion **82** extending from bracket **70** to determine if the optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, adapter **68**, and bracket **70** are in the first or second radial position. The proximity sensor **80** detecting the protrusion **82** may indicate that the optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, adapter **68**, and bracket **70** are in the first radial position while the proximity sensor **80** not detecting the protrusion **82** may indicate that the optical probe **32**, light source **38**, imaging sensor **58**, bracket **60**, adapter **68**, and bracket **70** are in the second radial position, or vice versa. The proximity sensor **80** is configured to communicate the radial position (e.g., the first or second radial position) to the controller **28**. The linear motion slide **76** is configured to collectively extend and retract the optical probe **32**, light source **38**, conical mirror **48**, imaging sensor **58**, bracket **60**, adapter **68**, bracket **70**, rotational motor **72**, bracket **78**, and proximity sensor **80** along the axis **74**. More specifically, the linear motion slide **76** is configured to collectively extend and retract the optical probe **32**, light source **38**, and conical mirror **48** into and out of the cavities or orifices **56** defined by the manufactured components **16** between the advanced position **22** and the retracted position **20** during scans or inspections of the internal surfaces **54** of the manufactured components **16**.

[0039] The linear motion slide **76** may be any type of linear motion device that is driven by an actuator. For example, the linear motion device may be a ball screw and ball nut combination, a bearing block and rail combination, etc., while the actuator driving the linear motion device may be a servo motor, a pneumatic cylinder, a hydraulic cylinder, an electric solenoid etc. The linear motion slide **76** may then be secured to a frame or framework **84** of the inspection station **12** (See FIGS. **1-2**).

[0040] Alternatively, the inspection device **18** may secured to a robot or robot arm that is part of the inspection station **12** and configured to extend the optical probe **32**, light source **38**, and conical mirror **48** into and retract the optical probe **32**, light source **38**, and conical mirror **48** out of the cavities or orifices **56** defined by the manufactured components **16**. The robot may be a six-axis robot, a robot arm having any number of axes, or any type or robot. If the inspection device **18** is secured to a robot or robot arm, the motion of the inspection device **18** into an out of the cavities or orifices **56** defined by the manufactured components **16** may be in any direction along any orientation and is not limited to the up and down motion illustrated herein.

[0041] The optical probe **32** may include a second light source **86** that is configured to illuminate the field of view **36**. The second light source **86** may be a non-laser light source, including, but not limited to incandescent lights, halogen lights, light emitting diodes, fluorescent lights, etc. The second light source **86** may be secured to a port **88** on the optical probe **32** and optical guides within the optical probe **32** may be configured to direct the light emitted from the second light source **86**, to the distal end **34** of optical probe **32**, and out into the field of view **36** in order to illuminate the field of view **36** and the internal surfaces **54** of the manufactured components **16** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. A second conical mirror **90** may utilized to concentrate the light from the second light source **86** onto the internal surfaces **54** of the manufactured components **16**. The second conical mirror **90** may be disposed within a second transparent housing **92** and may be disposed on top of the transparent housing **50** containing conical mirror **48** such the pointed end of the second conical mirror **90** faces the distal end **34** of the optical probe **32**.

[0042] The second conical mirror **90** is illustrated as being secured to the transparent housing **50** containing the conical mirror **48** in FIG. **6**. It is noted that FIG. **6** shows an alternative position where the conical mirror **48** and the transparent housing **50** are positioned on top of the light source **38** as opposed to the configuration in FIG. **4** where the light source **38** is positioned on top of the conical mirror **48** and transparent housing **50**. It is noted that either configuration is acceptable as long as the intersection between the light disc **52** and the internal surfaces **54** of the manufactured components **16** is within the field of view **36** of the optical probe **32**.

[0043] The optical probe **32** may include a first window **94** at the distal end **34** and a second window **96** at the proximal end **66**. The optical probe **32** may include negative lens **98** at the distal end **34** and an ocular or eyepiece lens **100** at the proximal end **66**. Objective lenses **102** and relay lenses **104** may be disposed between the negative lens **98** and the eyepiece lens **100**. The negative lens **98**, objective lenses **102**, and relay lens **104** may be disposed within an optical carrier tube **106**. The second window **96** and eyepiece lens **100** may be disposed within an eyepiece portion **108**. A fiber optic or illumination fiber **110** may extend from the port **88** to the distal end **34** to transport light from the second light source **86** to the distal end **34** and into the field of view **36**. The optical carrier tube **106** and the illumination fiber **110** may be housed within an outer tube **112**.

[0044] Referring to FIGS. **7-10**C, an alternative embodiment of inspection device **18′** is illustrated. It should be understood that inspection device **18′** has all the same subcomponents and functionality as inspection device **18** unless otherwise stated or illustrated herein. Furthermore, it should be understood that any component having a callout number in FIGS. **7-10** that includes a prime symbol (') should be construed as having the same structure, subcomponents, and functionality as a component illustrated in FIGS. **1-6** that includes the same callout number but without the prime symbol, unless otherwise stated or illustrated herein.

[0045] The inspection device **18′** includes an optical probe **32′** having a distal end **34′** and a proximal end **66′**. The optical probe **32′** has a field of view **36′** projecting outward from the distal end **34′**. The inspection device **18′** also includes a light source **38′**, a conical mirror **48′**, a transparent housing **50′**, an imaging sensor **58′**, an adapter **68′**, a bracket **70′**, a rotational motor **72′**, a linear motion slide **76′**, a bracket **78′**, and a proximity sensor **80′**. The optical probe **32′** may also include a port **88′** and a second light source **86′** may be secured to a port **88′**.

[0046] The conical mirror **48′** is configured to transform the light emitted from the light source **38′** into a light disc **52′** that is projected outward in all directions along a plane, which is projected onto internal surfaces **54** of the manufactured components **16** in order to inspect the in internal surfaces **54**. The intersection between the light disc **52′** and the internal surfaces **54** of the manufactured components **16** needs be within the field of view **36′** of the optical probe **32′** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. The optical probe **32′**, light source **38′**, and conical mirror **48′** are collectively configured to extend into and retract out of the cavities or orifices **56** defined by the manufactured components **16** between an advanced position **22′** and a retracted position **20′** during scans or inspections of the internal surfaces **54** of the manufactured components **16**. The vision or imaging sensor **58′** is configured to receive reflections of the light disc **52′** from the internal surfaces **54** of the manufactured components **16** via the optical probe **32′** during scans or inspections of the internal surfaces **54** of the manufactured components **16**.

[0047] The optical probe **32′**, light source **38′**, imaging sensor **58′**, bracket **60′**, adapter **68′**, and bracket **70′** are configured to collectively rotate about a common axis **74′**. The proximity sensor **80′** is configured to detect a protrusion **82′** extending from bracket **70′** to determine if the optical probe **32′**, light source **38′**, imaging sensor **58′**, bracket **60′**, adapter **68′**, and bracket **70′** are in a first or second radial position.

[0048] The linear motion slide **76′** may be secured to the frame or framework **84** of the inspection station **12**. Alternatively, the inspection device **18′** may secured to a robot or robot arm that is part of the inspection station **12** and configured to extend the optical probe **32′**, light source **38′**, and conical mirror **48′** into and retract the optical probe **32′**, light source **38′**, and conical mirror **48′** out of the cavities or orifices **56** defined by the manufactured components **16**. The robot may be a six-axis robot, a robot arm having any number of axes, or any type or robot. If the inspection device **18′** is secured to a robot or robot arm, the motion of the inspection device **18′** into an out of the cavities or orifices **56** defined by the manufactured components **16** may be in any direction along any

orientation and is not limited to the up and down motion illustrated herein.
[0049] The collective position the light source **38**′, conical mirror **48**′, and transparent housing **50**′ are adjustable relative to the optical probe **32**′. More specifically, a bracket **60**′ secures the light source **38**′, conical mirror **48**′, and transparent housing **50**′ to an actuator **114**. The actuator **114** may any type actuator, such as a servo motor, that is part of a linear motion device such a ball screw and ball nut combination, a bearing block and rail combination, etc. The actuator **114** is secured to bracket **70**′ and is configured to adjust a linear position of the bracket **60**′, the light source **38**′, the conical mirror **48**′, and the transparent housing **50**′ to adjust a distance between the conical mirror **48**′ and the optical probe **32**′. More specifically, the intersection between the light disc **52**′ and the internal surfaces **54** of the manufactured components **16** may be adjusted into and of out of the field of view **36**′. Such an adjustment may be desirable if an internal dimension (e.g., an internal diameter) of the manufactured components **16** in not the same for each manufactured component **16**.
[0050] For example, in FIG. **9**A, a first manufactured component **16***a* is being in inspected via the inspection device **18**′. The distance between the conical mirror **48**′ and the optical probe **32**′ is set at a first value, dA, the internal diameter of the first manufactured component **16***a* is D**1**, and the light disc **52**′ is shown to be within the field of view **36**′ of the optical probe **32**′. After the first manufactured component **16***a* has been inspected, a second manufactured component **16***b* having an internal diameter is D**2**, which is larger than internal diameter D**1**, is then inspected via the inspection device **18**′. However, the light disc **52**′ is shown to be outside of the field of view **36**′ of the optical probe **32**′ while the distance between the conical mirror **48**′ and the optical probe **32**′ is set at the first value, dA, which is shown in FIG. **9**B. Also illustrated in FIG. **9**B, the reflection **116** of the light disc **52**′ extends beyond the end of the to the optical probe **32**′ and is therefore not detected by the optics of the optical probe **32**′. To properly inspect the internal surface **54** of the second manufactured component **16***b*, the distance between the conical mirror **48**′ and the optical probe **32**′ is adjusted (e.g., increased) to a second value, dB, in FIG. **9**C, so that the light disc **52**′ is within the field of view **36**′ of the optical probe **32**′ and so that the reflection **116** of the light disc **52**′ from the internal surface **54** is directed to the end optical probe **32**′ where the optics of the optical probe **32**′ are able to detect the reflection **116** of the light disc **52**′. It should be understood, the distance between the conical mirror **48**′ and the optical probe **32**′ may be adjusted by any incremental value to inspect a multitude of manufactured components having internal diameters or profiles of any size and is not limited to the two positions illustrated in FIGS. **9**A-**9**C.
[0051] The position of the conical mirror **48**′ relative to the light source **38**′ is also adjustable. The transparent housing **50**′ may include a threaded portion **118** that engages a tapped hole defined by the housing of the light source **38**′. Threading the transparent housing **50**′ into the tapped hole defined by the housing of the light source **38**′ decreases a distance between the conical mirror **48**′ and the light source **38**′, or more specifically decreases a distance between the conical mirror **48**′ and a laser diode **40**′ of the light source **38**′. Threading the transparent housing **50**′ out of the tapped hole defined by the housing of the light source **38**′ increases a distance between the conical mirror **48**′ and the light source **38**′, or more specifically increases a distance between the conical mirror **48**′ and the laser diode **40**′ of the light source **38**′.
[0052] A gear **120** may engage teeth **122** on the transparent housing **50**′ in order to thread the transparent housing **50**′ into an out of the tapped hole defined by the housing of the light source **38**′. An actuator **124** may be secured to a shaft **126** that turns the gear **120**. The actuator **124** may be a motor, such as a servo motor. The gear **120**, actuator **124**, and shaft **126** may also be secured to actuator **114** so that the gear **120**, actuator **124**, and shaft **126** collectively move linearly along with the bracket **60**′, the light source **38**′, the conical mirror **48**′, and the transparent housing **50**′.
[0053] The distance between the conical mirror **48**′ and the light source **38**′ (or more specifically the distance between the conical mirror **48**′ and the laser diode **40**′ of the light source **38**′) is adjustable so that the light disc **52**′ may be focused onto the internal surface **54** of the manufactured

components **16**.

[0054] For example, in FIG. **10**A, the first manufactured component **16***a* is being in inspected via the inspection device **18**′. The distance between the conical mirror **48**′ and the light source **38**′ (or more specifically the distance between the conical mirror **48**′ and the laser diode **40**′) is set at a first value, d.sub.C, the internal diameter of the first manufactured component **16***a* is D.sub.1, and the light disc **52**′ has an area of focus **128** that corresponds to the intersection between the light disc **52**′ and the internal surface **54** of the first manufactured component **16***a*. After the first manufactured component **16***a* has been inspected, the second manufactured component **16***b* having the internal diameter of D.sub.2, which is larger than the internal diameter D.sub.1, is then inspected via the inspection device **18**′. However, the area of focus **128** of the light disc **52**′ does not correspond to the intersection between the light disc **52**′ and the internal surface **54** of the second manufactured component **16***b* since the distance between the conical mirror **48**′ and the light source **38**′ was not adjusted in FIG. **10**B relative to FIG. **10**A. Therefore, to properly focus the light disc **52**′ onto the internal surface **54** of the second manufactured component **16***b*, the distance between the conical mirror **48**′ and the light source **38**′ is adjusted (e.g., decreased) to a second value, d.sub.D, so that the area of focus **128** of the light disk **52**′ corresponds to the intersection between the light disc **52**′ and the internal surface **54** of the second manufactured component **16***b*. It should be understood that the area of focus **128** could be adjusted by any incremental value to inspect a multitude of manufactured components having internal diameters or profiles of any size and is not limited to the two positions illustrated in FIGS. **10**A-**10**C.

[0055] The actuators (i.e., actuator **114** and actuator **124**) that are configured to make the adjustments to the to the inspection device **18**′ to ensure the light disc **52**′ is in the field of view **36**′ of the optical probe **32**′ and to ensure the light disc **52**′ is focused onto the internal surfaces **54** of the manufactured components **16** may be in communication with and controlled by the controller **28**. The actuators (i.e., rotational motor **72** and linear motion slide **76**, or alternatively a robot) that are configured to control extending and retracting the optical probe **32**, light source **38**, and conical mirror **48** into and out of the cavities or orifices **56** defined by the manufactured components **16** between the advanced position **22** and the retracted position **20** during scans or inspections of the internal surfaces **54** of the manufactured components **16** may also be in communication with and controller by the controller **28**.

[0056] Referring to FIG. **11**-**12**B, a flowchart of a method **200** for controlling the inspection of the manufactured parts **16** via the inspection system **10** and the different positions of the field of view **36** of the optical probe **32** are illustrated. The method **200** may be stored as control logic and/or algorithms within the controller **28**. The controller **28** may implement the method **200** by controlling the various actuators of the inspection system **10**. The method **200** is initiated at start block **202**. The method **200** may be initiation via a manufactured component **16** entering the inspection station **12**. The presence of the manufactured component **16** may be detected by proximity sensors, optical sensors, laser sensors, or any other sensor know to one of ordinary skill in the art that is capable of detecting the presence of an object. Such a sensor may then communicate the presence of the manufactured component **16** to the controller **28**.

[0057] Next, at block **204**, the optical probe **32**, light source **38**, and conical mirror **48** are advanced into the cavity **56** defined by the manufactured component **16** from the retracted position **20** to a desired depth corresponding to the advanced position **22**, while the optical probe **32**, light source **38**, and conical mirror **48** are at a first radial position, to scan and inspect the internal surface **54** of the manufactured component **16**. Once the optical probe **32**, light source **38**, and conical mirror **48** are at the desired depth, the optical probe **32**, light source **38**, and conical mirror **48** are rotated from the first radial position to a second radial position via an actuator (e.g., rotational motor **72**) at block **206** while at the desired depth. The optical probe **32**, light source **38**, and conical mirror **48** are then retracted while the optical probe **32**, light source **38**, and conical mirror **48** are at the second radial position at block **208** from the advanced position **22** to the retracted position **20**, to further scan and inspect the internal surface **54** of the manufactured component **16**. The internal surface **54** of the manufactured component **16** may be continually scanned during the steps at blocks **204**, **206**, and **208**.

[0058] If the second embodiment of the inspection device **18′** is utilized, at some point before or upon initiation of block **204**, the distance between the conical mirror **48′** and the optical probe **32′** may be adjusted to ensure the light disc **52′** is within the field of view **36′** and/or the distance between the conical mirror **48′** and the light source **38′** may be adjusted to ensure the light disc **52′** is focused onto the internal surface **54** of the manufactured component **16**. Such adjustments may be automatic. Such adjustments may be in response to the imaging sensor **58′** not receiving reflections of the light disc **52′** from the internal surface **54** or the imaging sensor not receiving focused reflections of the light disc **52′** from the internal surface **54**.

[0059] The bracket **60** any associated wires (or any of the components that extend between the optical probe **32′** and the light source **38′** if the second embodiment of the inspection device **18′** is utilized) may obstruct a first portion **130** of the internal surface **54** of the manufactured component **16** within the field of view **36** of the optical probe **32** while the optical probe **32**, light source **38**, and conical mirror **48** are in the first radial position (See FIG. **12**A). The bracket **60** any associated wires (or any of the components that extend between the optical probe **32′** and the light source **38′** if the second embodiment of the inspection device **18′** is utilized) may obstruct a second portion **132** of the internal surface **54** of the manufactured component **16** within the field of view **36** of the optical probe **32** while the optical probe **32**, light source **38**, and conical mirror **48** are in the second radial position (See FIG. **12**B). The first portion **130** of the internal surface **54** does not overlap the second portion **132** of the internal surface. This lack of overlap ensures that the entire internal surface **54** of the manufactured component **16** is scanned, since the optical probe **32**, light source **38**, and conical mirror **48** are advanced into the cavity **56** at the first radial position and retracted from the cavity **56** at the second radial position.

[0060] During the scan, the reflections of the light disc **52** from the internal surface **54** of the manufactured component **16** are directed to the imaging sensor **58**. The reflections of the light disc **52** from the internal surface **54** that are received by the imaging sensor **58** during the scan are compiled to generate a scanned profile of the internal surface **54** or internal features of the manufactured component **16** at block **210**. The scanned profile or internal features are then compared to a model profile or model internal features at block **212** to determine if the scanned profile or internal features are within a tolerable range of the model profile or model features, or if there are any defects on the manufactured component **16**. If the scanned profile or internal features are within the tolerable range or ranges and there are no defects on the manufactured component **16**, the method **200** moves on to block **214** where the manufactured component **16** is directed toward the first direction **24**, which is indicative that the manufactured component **16** has “passed” the inspection. If the scanned profile or features are not within the tolerable range or ranges, or if there are defects on the manufactured component **16**, the method **200** moves on to block **216** where the manufactured component **16** is directed toward the second direction **26**, which is indicative that the manufactured component **16** has “failed” the inspection.

[0061] It should be understood that the flowchart in FIG. **11** is for illustrative purposes only and that the method **200** should not be construed as limited to the flowchart in FIG. **11**. Some of the steps of the method **200** may be rearranged while others may be omitted entirely.

[0062] It should be understood that the designations of first, second, third, fourth, etc. for any component, state, or condition described herein may be rearranged in the claims so that they are in chronological order with respect to the claims. Furthermore, it should be understood that any component, state, or condition described herein that does not have a numerical designation may be given a designation of first, second, third, fourth, etc. in the claims if one or more of the specific component, state, or condition are claimed.

[0063] The words used in the specification are words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the disclosure. As previously described, the features of various embodiments may be combined to form further embodiments that may not be explicitly described or illustrated. While various embodiments could have been described as providing advantages or being preferred over other embodiments or prior art implementations with respect to one or more desired characteristics, those of ordinary skill in the art recognize that one or more features or characteristics may be compromised to achieve desired overall system attributes, which depend on the specific application and implementation. As such, embodiments described as less desirable than other embodiments or prior art implementations with respect to one or more characteristics are not outside the scope of the disclosure and may be desirable for particular applications.

Claims

1. An inspection system comprising: an optical probe having an end and a field of view projecting outward from the end; a light source spaced apart from the end of optical probe and positioned within the field of view of the optical probe; a conical mirror secured to light source and configured to transform light emitted from the light source into a light disc, wherein the optical probe, light source, and conical mirror are configured to (i) extend into and retract out of a cavity defined by a manufactured component and (ii) rotate within the cavity to scan an internal surface of the manufactured component, and wherein the light disc is projected onto the internal surface during the scan; an imaging sensor configured to receive reflections of the light disc from the internal surface via the optical probe during the scan; a first actuator configured to adjust a distance between the conical mirror and the end of optical probe to move an intersection between the light disc and the internal surface of the manufactured component into and of out of the field of view; a second actuator configured to adjust a distance between the conical mirror and the light source to adjust a focus the light disc radially inward and radially outward from the conical mirror; and a controller programmed to, operate the first actuator to adjust the distance between the conical mirror and the end of the optical probe to move the intersection between the light disc and the internal surface of the manufactured component into the field of view, and operate the second actuator to adjust the distance between the conical mirror and the light source to focus the light disc radially relative to the conical mirror and on the internal surface of the manufactured component.
2. The inspection system of claim 1 further comprising a third actuator configured to rotate the optical probe, light source, conical mirror, and imaging sensor about an axis.
3. The inspection system of claim 2, wherein the controller is further programmed to operate the third actuator to rotate the optical probe, light source, conical mirror, and imaging sensor about the axis from a first radial position to a second radial position during the scan.
4. The inspection system of claim 1 further comprising a third actuator configured to extend and retract the optical probe, light source, and conical mirror along an axis.
5. The inspection system of claim 4, wherein the controller is further programmed to: operate the third actuator to extend the optical probe, light source, and conical mirror along the axis from a retracted position to an advanced position during the scan; and operate the third actuator to retract the optical probe, light source, and conical mirror along the axis from the advanced position to the retracted position during the scan.
6. The inspection system of claim 1, wherein the controller is further programmed to: generate a profile of the internal surface based on the reflections of the light disc from the internal surface received by the imaging sensor during the scan; in response to the profile being within a tolerable range, operate a conveyance system to direct the manufactured component toward a first direction; and in response to the profile being outside of the tolerable range, operate the conveyance system to direct the manufactured component toward a second direction.
7. An inspection system configured to scan internal surfaces of manufactured components

comprising: an optical probe having a field of view; a light source spaced apart from an end of the optical probe and positioned within the field of view of the optical probe; a conical mirror secured to the light source and configured to transform light emitted from the light source into a light disc, wherein the light disc is configured to be projected onto the internal surfaces of the manufactured components for scanning the internal surfaces; a first actuator configured to adjust a distance between the conical mirror and the end of the optical probe to move an intersection between the light disc and the internal surfaces of the manufactured components into and of out of the field of view; and a second actuator configured to adjust a distance between the conical mirror and the light source to adjust a focus of the light disc radially inward and radially outward from the conical mirror.

8. The inspection system of claim 7 further comprising a third actuator configured to rotate the optical probe, light source, and conical mirror about an axis to adjust a radial position of the field of view relative to the internal surfaces of the manufactured components while scanning the internal surfaces.

9. The inspection system of claim 8 further comprising a fourth actuator configured to extend and retract the optical probe, light source, and conical mirror along the axis, and into and out of cavities defined by the internal surfaces of the manufactured components, while scanning the internal surfaces.

10. The inspection system of claim 7 further comprising an imaging sensor configured to receive reflections of the light disc from the internal surfaces via the optical probe while scanning the internal surfaces.

11. An inspection system configured to scan internal surfaces of manufactured components comprising: an optical probe having a field of view; a light source positioned within the field of view of the optical probe; a conical mirror configured to transform light emitted from the light source into a light disc, wherein the light disc is configured to be projected onto the internal surfaces of the manufactured components while scanning the internal surfaces; and an actuator configured to adjust a distance between the conical mirror and the optical probe to move an intersection between the light disc and the internal surfaces of the manufactured components into and of out of the field of view.

12. The inspection system of claim 11 further comprising a second actuator configured to adjust a distance between the conical mirror and the light source to adjust a focus of the light disc radially inward and radially outward from the conical mirror.

13. The inspection system of claim 11 further comprising a second actuator configured to rotate the optical probe, light source, and conical mirror about an axis while scanning the internal surfaces.

14. The inspection system of claim 11 further comprising a second actuator configured to extend and retract the optical probe, light source, and conical mirror along an axis, and into and out of cavities defined by the internal surfaces of the manufactured components, while scanning the internal surfaces.

15. The inspection system of claim 11 further comprising an imaging sensor configured to receive reflections of the light disc from the internal surfaces via the optical probe while scanning the internal surfaces.

16. An inspection system configured to scan internal surfaces of manufactured components comprising: an optical probe having a field of view; a light source positioned within the field of view of the optical probe; a conical mirror configured to transform light emitted from the light source into a light disc, wherein the light disc is configured to be projected onto the internal surfaces of the manufactured components while scanning the internal surfaces; and an actuator configured to adjust a distance between the conical mirror and the light source to adjust a focus of the light disc radially inward and radially outward from the conical mirror to focus the light disc onto the internal surfaces of the manufactured components.

17. The inspection system of claim 16 further comprising a second actuator configured to adjust a distance between the conical mirror and the optical probe to move an intersection between the light disc and the internal surfaces of the manufactured components into and of out of the field of view.

18. The inspection system of claim 16 further comprising a second actuator configured to rotate the optical probe, light source, and conical mirror about an axis while scanning the internal surfaces.

19. The inspection system of claim 16 further comprising a second actuator configured to extend and retract the optical probe, light source, and conical mirror along an axis, and into and out of cavities defined by the internal surfaces of the manufactured components, while scanning the internal surfaces.

20. The inspection system of claim 16 further comprising an imaging sensor configured to receive reflections of the light disc from the internal surfaces via the optical probe while scanning the internal surfaces.