



Petitioner's Demonstratives

Case No. IPR2025-00531

Patent No. 9,168,698

Case No. IPR2025-00532

Patent No. 10,556,381

Shenzhen Tuozhu Technology Co. Ltd. (Petitioner)

v.

Stratasys, Inc. (Patent Owner)

EX1043

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Case Overview – '698 Patent (EX 1001)

- Challenged claims 1-15

US009168698B2

(12) United States Patent
Kemperle et al.

(10) Patent No.: **US 9,168,698 B2**
(45) Date of Patent: **Oct. 27, 2015**

(54) THREE-DIMENSIONAL PRINTER WITH FORCE DETECTION

(71) Applicant: **MakerBot Industries, LLC**, Brooklyn, NY (US)

(72) Inventors: **Aljosa Kemperle**, Brooklyn, NY (US); **Filipp Gelman**, Staten Island, NY (US); **Peter Joseph Schmehl**, New York, NY (US)

(73) Assignee: **MakerBot Industries, LLC**, Brooklyn, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 101 days.

(21) Appl. No.: **14/065,516**

(22) Filed: **Oct. 29, 2013**

(65) Prior Publication Data

US 2014/0117575 A1 May 1, 2014

Related U.S. Application Data

(60) Provisional application No. 61/719,874, filed on Oct. 29, 2012.

(51) Int. Cl.

B29C 41/22 (2006.01)

B29C 41/52 (2006.01)

B29C 67/00 (2006.01)

B29C 47/92 (2006.01)

B29C 47/08 (2006.01)

B29C 47/02 (2006.01)

B29C 47/00 (2006.01)

(52) U.S. Cl.

CPC **B29C 67/0055** (2013.01); **B29C 47/025**

(2013.01); **B29C 47/0822** (2013.01); **B29C**

47/92 (2013.01); **B29C 67/0051** (2013.01); **B29C**

67/0088 (2013.01); **B29C 47/0002**

(2013.01); **B29C 47/0864** (2013.01); **B29C**

47/0866 (2013.01); **B29C 2947/9258** (2013.01); **B29C 2947/92704** (2013.01)

(58) Field of Classification Search

CPC **B29C 67/0055**; **B29K 2995/0073**

USPC 2641/29; 176.1; 401.1; 407.3; 308.113;

264/401; 497; 425/145; 150; 375; 112; 113;

425/174.4; 185; 186; 700/118; 119; 120;

226/8; 24; 26; 42; 43; 45

See application file for complete search history.

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"Automated Bed Leveling With Our 3D Printer", by Brian Benchoff—http://hackaday.com/2012/04/23/automated-bed-leveling-with-our-3d-printer, NPL-79, Apr. 23, 2012, 5 pages.

* cited by examiner

Primary Examiner—Joseph S Del Sole
Assistant Examiner—Thakhan T Nguyen
(74) **Attorney, Agent, or Firm**—Strategic Patents, P.C.

(57)

ABSTRACT

An extruder or other tool head of a three-dimensional printer is instrumented to detect contact force against the extruder, such as by a build platform or an object being fabricated. The tool head may also be instrumented to detect deflection forces and the like acting on the tool that might indicate an operating error. The resulting feedback data can be used in a variety of ways to control operation of the three-dimensional printer during fabrication or diagnostics.

15 Claims, 5 Drawing Sheets

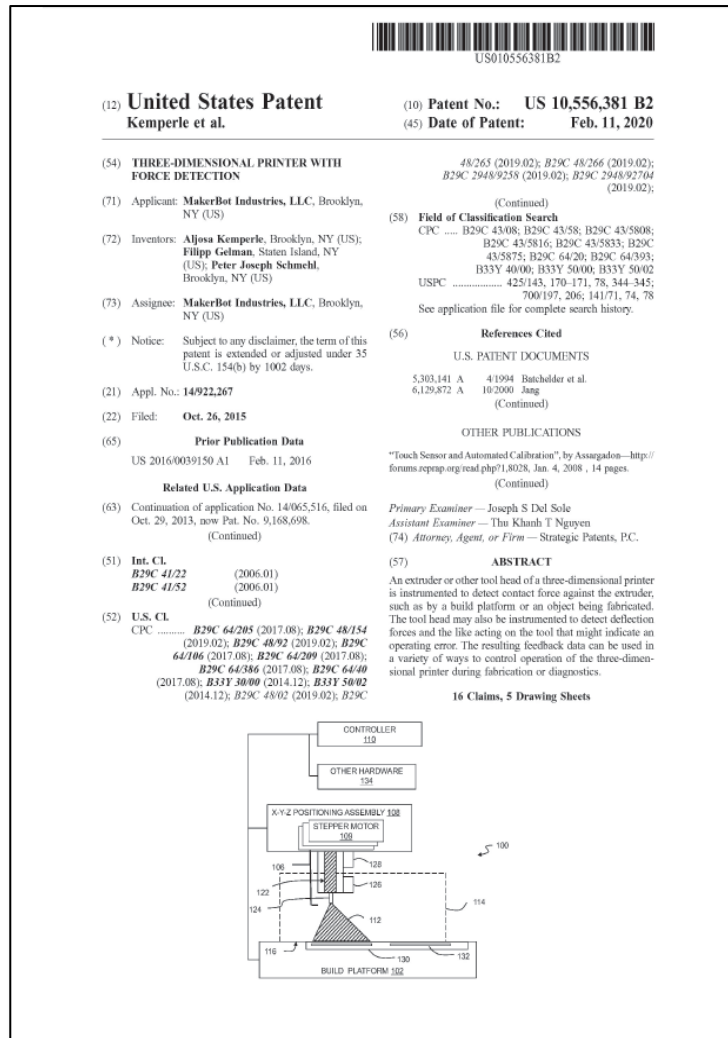
Ground	Claims	§103 Basis
1A	1-6, 8-15	Warren
1B	3, 7, 9	Warren and Eshed
2A	1-5, 7-10, 12-15	Calderon and RepRap20208
2B	11	Calderon, RepRap20208, and Napadensky

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Case Overview – '381 Patent (EX 1001)

- Challenged claims 1-16



Ground	Claims	§103 Basis
1A	1-6, 9-16	Warren
1B	3, 7, 8	Warren and Dunn
2A	1-6, 9-16	Calderon and RepRap20208
2B	3, 7, 8	Calderon, RepRap20208, and Dunn

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Independent Claims Comparison

698 Patent Claim 1	381 Patent Claim 1
1. A method comprising:	1. A three-dimensional printer comprising:
identifying build instructions for fabricating an object;	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
detecting the current contact force based on a sensor signal from the one or more sensors; and	
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.

'698 Patent Dependent Claims

698 Patent Dependent Claims

2. The method of claim 1, wherein the fabrication tool includes an extruder.

9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.

10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.

'381 Patent Dependent Claims

'381 Patent Dependent Claims

11. The three-dimensional printer of claim 1, further comprising:

one or more actuators mechanically coupled to the fabrication tool, and

a control circuit in data communication with the one or more actuators and the one or more sensors, the control circuit configured to control the one or more actuators to achieve a specified contact force between the one or more sensors and the separate structure.

Warren Grounds '698 Grounds 1A & 1B '381 Ground 1A

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DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Independent Claims Comparison

698 Patent Claim 1	381 Patent Claim 1
1. A method comprising:	1. A three-dimensional printer comprising:
identifying build instructions for fabricating an object;	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
detecting the current contact force based on a sensor signal from the one or more sensors; and	
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.
'698 Patent Claim 2	
The method of claim 1, wherein the fabrication tool includes an extruder.	

US 2003/0100824 to Warren – EX 1004


US 2003/0100824A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2003/0100824 A1**
(43) **Pub. Date: May 29, 2003**

(54) **ARCHITECTURE TOOL AND METHODS OF USE**

(76) **Inventors:** William L. Warren, Stillwater, OK (US); Robert L. Parkhill, Stillwater, OK (US); Robert L. Stewart, Stillwater, OK (US); Anatoly M. Kachurin, Stillwater, OK (US); Robert M. Taylor, Perkins, OK (US); Brian H. Hargrave, Stillwater, OK (US); Kenneth H. Church, Stillwater, OK (US); Michael N. Nguyen, Stillwater, OK (US); Mark L. Kargel, Stillwater, OK (US); Mark W. Simpkins, Stillwater, OK (US)

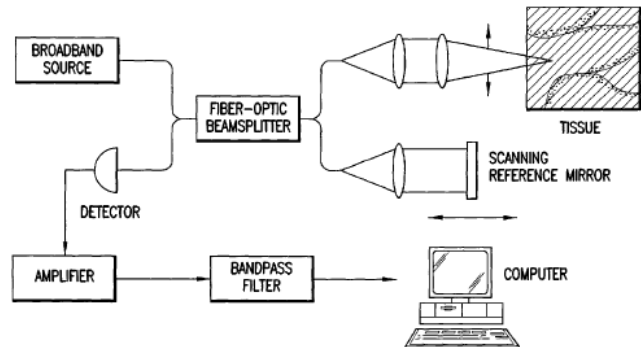
Related U.S. Application Data
(60) Provisional application No. 60/314,344, filed on Aug. 23, 2001. Provisional application No. 60/337,378, filed on Dec. 4, 2001. Provisional application No. 60/337,383, filed on Dec. 4, 2001. Provisional application No. 60/340,706, filed on Dec. 11, 2001.

Publication Classification
(51) **Int. Cl.** A61B 5/05
(52) **U.S. Cl.** 600/407

(57) **ABSTRACT**
The invention provides an apparatus and methods for depositing materials on a substrate, and for performing other selected functions, such as material destruction and removal, temperature control, imaging, detection, therapy and positional and locational control. In various embodiments, the apparatus and methods are suitable for use in a tabletop setting, in vitro or in vivo.

Correspondence Address:
NEEDLE & ROSENBERG P.C.
127 PEACHTREE STREET N.E.
ATLANTA, GA 30303-1811 (US)

(21) Appl. No.: 10/227,146
(22) Filed: Aug. 23, 2002



[0285] As dispensing systems are widely used to deposit materials onto substrates, for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and the surface where deposition is desired. Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the

EX 1004 ¶ [0285]

'698 EX 1003 ¶ 71 / '381 EX 1003 ¶ 71

'698 Pet. pp. 15, 33, 35, 38-39 / '381 Pet. pp. 13-14

[0287] Therefore, a need exists for a system and method for controlling the position of one or more elements of a depositing system that accurately determines the intensity of the contact force between a dispensing tip and a substrate surface to maintain a desired contact force between the dispenser and the substrate.

[0288] The present invention is directed to a system and method for controlling the position of one or more elements of a dispensing system to maintain a desired contact force between the elements.

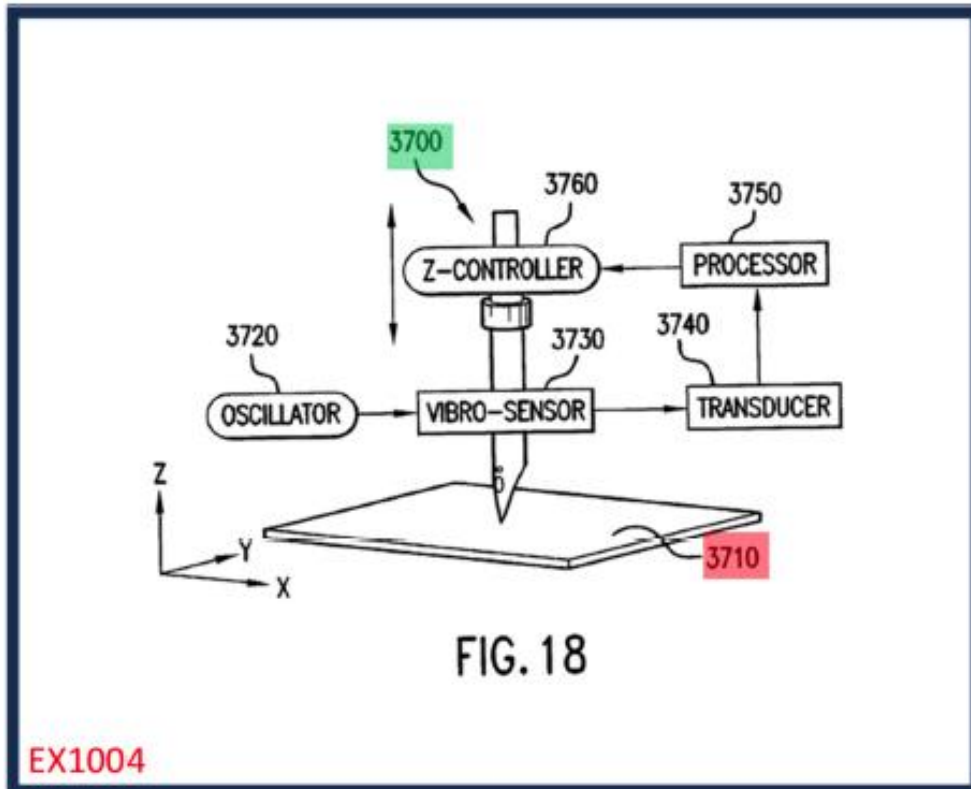
EX 1004 ¶¶ [0287]-[0288]

'698 EX 1003 ¶¶ 45-46 / '381 EX 1003 ¶ 45-46, 94

'698 Pet. pp. 8, 22 / '381 Pet. pp. 7, 23

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Warren Teaches Controlling the Position of the Dispenser Based on Sensor Signals



'698 EX 1003 ¶¶ 45-46 / '381 EX 1003 ¶ 45-46
'698 Pet. pp. 8-9 / '381 Pet. pp. 7-9
'698 POR p. 13 / '381 POR p. 13

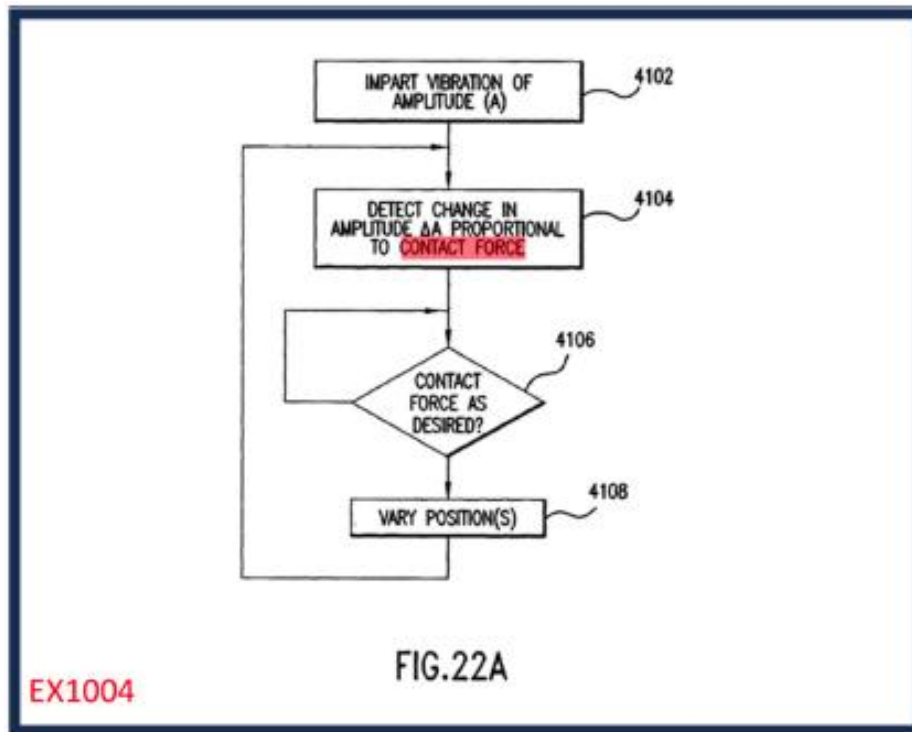
46. As depicted in FIG. 18 (annotated above), Warren discloses “an exemplary system for controlling the position of a dispenser 3700 relative to a substrate 3710 [which] may have irregular surfaces.” *Id.*, [0293]. “A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700.” *Id.*, [0300], [0315] (“vibration sensor ... attached to the dispenser”). Warren teaches imposing

'698 EX 1003 ¶ 46 / '381 EX 1003 ¶ 46
EX 1004 ¶¶ [0293], [0300], [0315], FIG. 18
'698 Pet. p. 9 / '381 Pet. p. 8

“The feedback signal [from vibration sensor 3730 and transducer 3740] is used to control the position of the dispenser 3700 to maintain a desired force of contact between the dispenser 3700 and the substrate 3710.” *Id.* In one example, “the feedback signal may be used by a z-controller processor 3750 to control the z positioning of the dispenser 3700 via a z-controller step motor 3760.” *Id.*; see also

'698 EX 1003 ¶ 91 (citing EX 1004 ¶ [302]) / '381 EX 1003 ¶¶ 93, 133
'698 Pet. pp. 22, 29 / '381 Pet. p. 22, 34

Warren Uses Change in Amplitude, ΔA , Instead of Frequency



'381 EX 1003 ¶ 89
'381 Pet. p. 20-21

87. Warren explains that “the vibration imposed ... does not necessarily have to occur at $f=f_r$ of the piezoelement or the dispensing system” because “when a vibrating element contacts an object, it does not necessarily shift f_r .” EX1004, [0304-0305]. “In contrast, A is inevitably altered.” *Id.* Warren thus emphasizes that the detection of changed amplitude, known as ΔA , “brings additional flexibility and sensitivity to the system.” *Id.*, [0304].

'381 EX 1003 ¶ 87
EX 1004 ¶¶ [0304]-[0306]

amplitude to a contact force. EX2027, ¶194. As Warren and Petitioner’s expert recognizes, the user is responsible for selecting the appropriate frequency / frequencies that correspond to the desired change in amplitude. EX1004, ¶[0306] (“This enables the selection of a working f in a desirable region not limited by the self-resonance of piezoelements.”); EX2020 at 79:13-80:20 (acknowledging that a

'381 POR p. 34

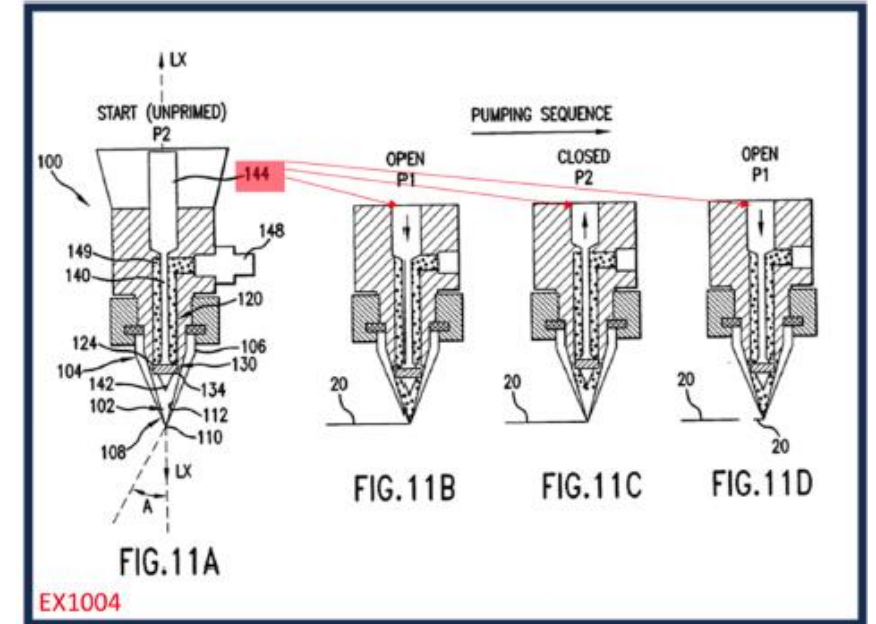
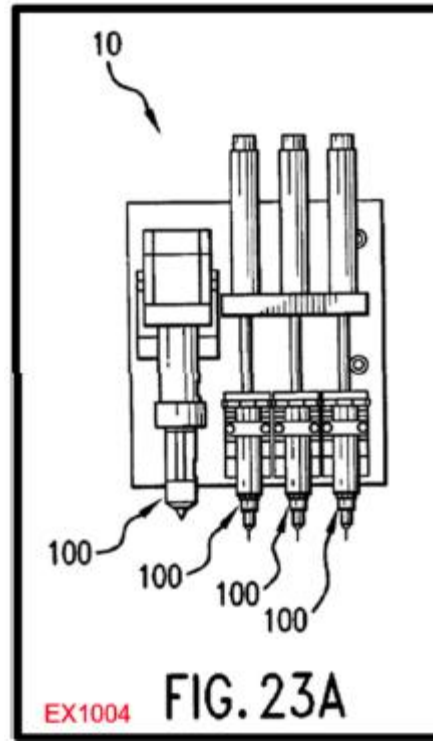
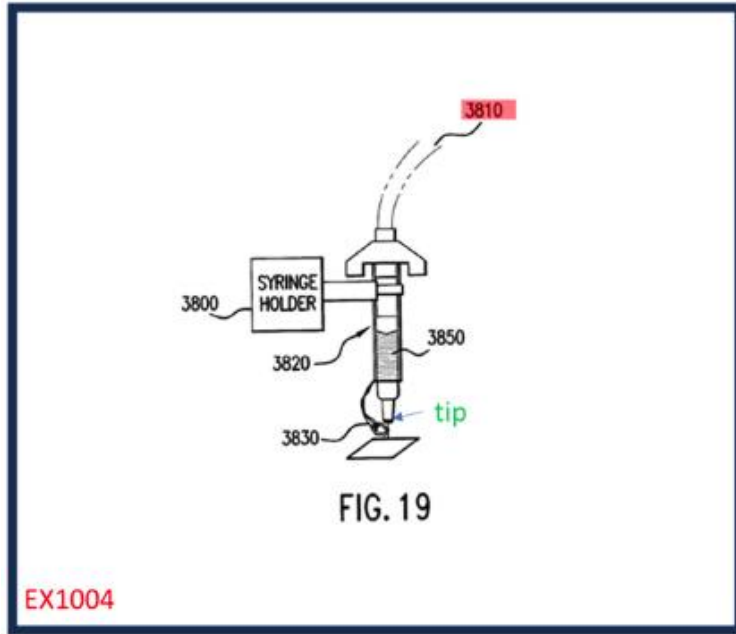
Warren Teaches the Claimed Sensor Coupled to an Extruder

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Warren Teaches a Sensor Coupled to an Extruder

698 Patent Claim 1	381 Patent Claim 1
1. A method comprising:	1. A three-dimensional printer comprising:
identifying build instructions for fabricating an object;	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
detecting the current contact force based on a sensor signal from the one or more sensors; and	
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.
'698 Patent Claim 2	
The method of claim 1, wherein the fabrication tool includes an extruder.	

Warren Teaches a Fabrication Tool with an Extruder



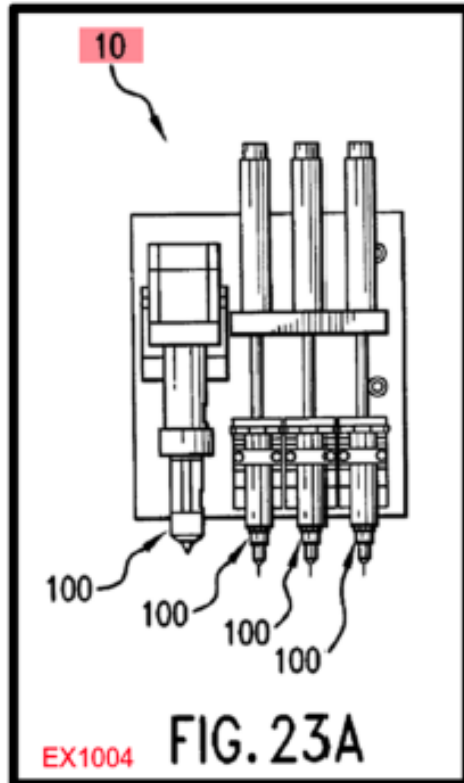
80. As I have explained above under Sections VII.A and VIII.A, Warren teaches a material dispensing system that includes a fabrication tool, e.g., the apparatus 10 shown in FIGS. 23A-23C:

'698 EX 1003 ¶ 80 (citing EX 1003 ¶¶ 47-49 discussing EX 1004 FIGS. 19, 23A, 11A-D)

'381 EX 1003 ¶¶ 36, 77

'698 Pet. pp. 6-13, 18 / '381 Pet. pp. 5-11, 15-18

Warren's Fabrication Tool Can Include a Capillary or Through-Nozzle Dispenser or Both

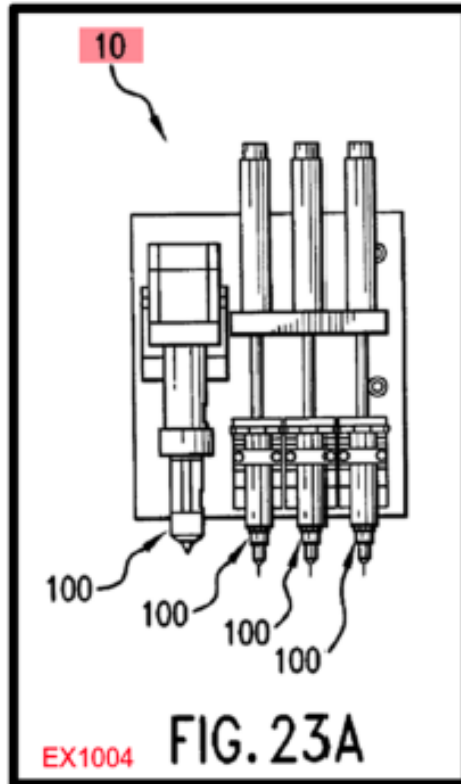


'698 EX 1003 ¶¶ 80 / '381 EX 1003 ¶¶ 77-78
'698 Pet. pp. 9-10 / '381 Pet. pp. 9-10, 15-16

81. Warren's apparatus 10 can include either or both the capillary vibro-sensor dispensing unit or the through-nozzle dispenser – both designated as 100 in FIG. 23A. Warren also provides *one or more sensors* (e.g., vibration sensor 3730 and transducer 3740) *mechanically coupled to the fabrication tool* (e.g., apparatus 10). See e.g., EX1004, [0300] (“A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700”), [0315] (“vibration sensor...attached to the dispenser”), FIG. 18 (annotated below).

EX 1004 ¶ [0300], [0315], FIGS. 18 & 23A
'698 EX 1003 ¶ 81 / '381 EX 1003 ¶¶ 77-78
'698 Pet. pp. 18-19 / '381 Pet. pp. 9-10, 15-16

Warren's Fabrication Tool Is Coupled to a Sensor



'698 EX 1003 ¶¶ 80 / '381 EX 1003 ¶¶ 77-78
'698 Pet. pp. 9-10 / '381 Pet. pp. 9-10, 15-16

81. Warren's apparatus 10 can include either or both the capillary vibro-sensor dispensing unit or the through-nozzle dispenser – both designated as 100 in FIG. 23A. Warren also provides *one or more sensors* (e.g., vibration sensor 3730 and transducer 3740) *mechanically coupled to the fabrication tool* (e.g., apparatus 10). See e.g., EX1004, [0300] ("A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700"), [0315] ("vibration sensor...attached to the dispenser"), FIG. 18 (annotated below).

EX 1004 ¶ [0300], [0315], FIG. 18 & 23A
'698 EX 1003 ¶ 81 / '381 EX 1003 ¶¶ 77-78
'698 Pet. pp. 17-21 / '381 Pet. pp. 9-10, 15-16

Petitioner Consistently Points to the Capillary Vibro-sensor Dispenser as the Extruder ('698 Patent)

94. Each and every element of claim 1 is obvious as explained above. In the context of claim 1, Warren's *fabrication tool* (e.g., the apparatus 10 shown in FIGS. 23A-23C) *includes an extruder* (either the capillary vibro-sensor dispensing unit or the through-nozzle dispenser – both designated as 100 in FIG. 23A). As I have explained above under Sections VII.A & VIII.A, the capillary vibro-sensor dispensing unit is expressly disclosed as used with Warren's vibrating force sensing and a POSITA would also have been motivated to configure the through-nozzle dispenser with Warren's vibrating force sensing. Use of either, or both, provides the claimed *extruder*.

'698 EX 1003 ¶¶ 94-96
'698 Pet. pp. 23-25
'698 Reply pp. 1-2

95. The capillary vibro-sensor dispensing unit is *an extruder* because it “forces, e.g., fluid or paste, in a reservoir 3850 through the tip 3840 of a syringe using air pressure applied from a source 3810.” EX1004, [0295], [0299], FIGS 18-20A, 20B.

96. The through-nozzle dispenser is likewise *an extruder* because it features a “positive-displacement/suck-back pump system,” where “the pump 148 powers a simple process of applying positive pressure to a material in a reservoir 149, and the flow of material is controlled by adjusting the open position P1 and closed position P2 of the valve 130.” EX1004, [0232]; *see also generally* [0230-

Petitioner Consistently Points to the Capillary Vibro-sensor Dispenser as the Extruder ('381 Patent)

78. The fabrication tool includes *an extruder* (e.g., either the capillary vibro-sensor dispensing unit or the through-nozzle dispenser, both designated as 100 in FIG. 23A)) *configured to extrude build material to fabricate an object* (e.g., a modeled structure via the DWDT/HAT technology) *during a build process* (e.g., a 3D direct construction process).

79. As I describe above under Sections VII.A & VIII.A, the capillary vibro-sensor dispensing unit is expressly disclosed as used with Warren's vibrating force sensing and a POSITA would also have been motivated to configure the through-nozzle dispenser with Warren's vibrating force sensing. Use of either, or both, satisfies claim 1.

'381 EX 1003 ¶¶ 78-81
'381 Pet. pp. 16-17
'381 Reply pp. 1-2

80. The capillary vibro-sensor dispensing unit is *an extruder* in that it “forces, e.g., fluid or paste, in a reservoir 3850 through the tip 3840 of a syringe using air pressure applied from a source 3810.” EX1004, [0295], [0299], FIGS 18-20A, 20B.

81. The through-nozzle dispenser is likewise an extruder in that it features a “positive-displacement/suck-back pump system,” where “the pump 148 powers a simple process of applying positive pressure to a material in a reservoir 149, and the

The Board Recognized Petitioner's Mapping of Warren's Capillary Vibro-Dispenser to Claim 1

⁸ Because claim 1 does not limit the “tool” to any particular type beyond one that can be a “fabrication tool” in a “three-dimensional printer,” we consider the “tool” of limitation 1b to encompass Warren’s capillary vibro-sensor dispenser without any modification. For this reason, we invite Petitioner to clarify the extent to which it relies on its showing of motive to modify Warren’s through-nozzle tool with the sensor from the capillary dispenser for its challenge to claim 1.

'698 Institution Decision p. 8

Warren's Capillary Extruder Is Coupled to a Sensor

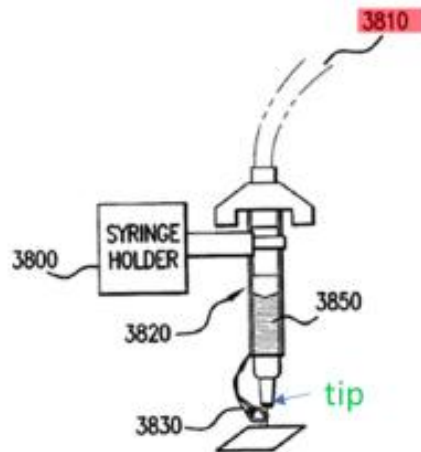


FIG. 19

EX1004

'698 EX 1003 ¶ 48 / '381 EX 1003 ¶¶ 47-48
'698 Pet. pp. 10-11 / '381 Pet. pp. 9-10

48. The capillary-based dispensers, referred to as a capillary vibro-sensor dispensing unit is “shown in FIGS. 19 [annotated below], 20A and 20B”, which can be “implemented in the system shown in in FIG. 18 [where a vibrating force sensor is used].” EX1004, [0299]. According to Warren, “[t]his type of dispenser forces,

'698 EX 1003 ¶ 48 / '381 EX 1003 ¶¶ 47-48
'698 Pet. pp. 10-11 / '381 Pet. pp. 9-10

have explained above under Sections VII.A & VIII.A, the capillary vibro-sensor dispensing unit is expressly disclosed as used with Warren's vibrating force sensing and a POSITA would also have been motivated to configure the through-nozzle dispenser with Warren's vibrating force sensing. Use of either, or both, provides the claimed extruder.

'698 EX 1003 ¶ 94 / '381 EX 1003 ¶ 79
'698 Pet. pp. 23-24 / '381 Pet. pp. 16-17

Patent Owner Does Not Dispute that Warren's Capillary Design Includes a Sensor

Patent Owner's Response

IPR2025-00531

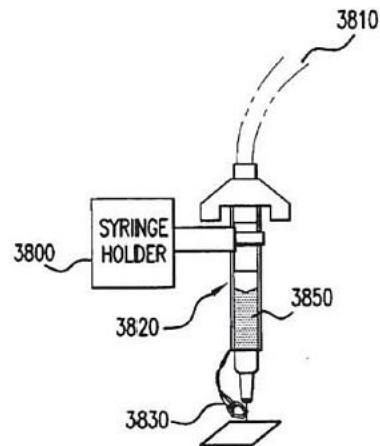


FIG. 19

See *id.* at ¶¶[0295]-[0297], Fig. 19. As shown, the capillary dispensing unit is held by syringe holder 3800 and the system includes a piezomembrane 3830 that may be implemented with an electroceramic sensor and include a vibration actuator and vibration transducer. See *id.*

Patent Owner's Sur-Reply

IPR2025-00531

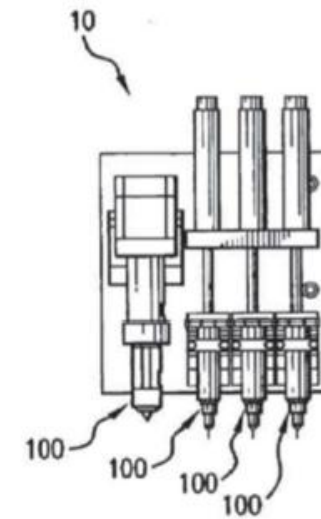


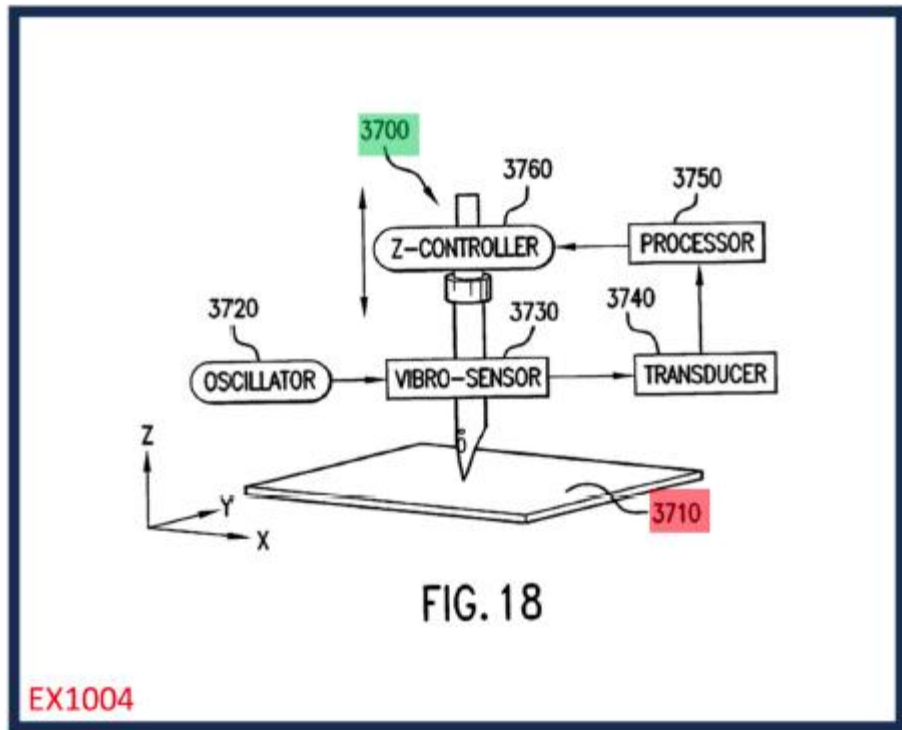
FIG. 23A

This embodiment includes a vibration solution with the capillary designs and also includes a through-nozzle design. Thus, Warren's claims do not expressly refute the Response, but rather they support it. POR, 10-25.

Obvious that Warren's Through-Nozzle Includes a Sensor

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Warren Renders it Obvious to Use Vibration Sensor with Through-Nozzle Dispenser



have explained above under Sections VII.A & VIII.A, the capillary vibro-sensor dispensing unit is expressly disclosed as used with Warren's vibrating force sensing and a POSITA would also have been motivated to configure the through-nozzle dispenser with Warren's vibrating force sensing. Use of either, or both, provides the claimed *extruder*.

'698 EX 1003 ¶¶ 94 / '381 EX 1003 ¶ 79
'698 Pet. pp. 23-24 / '381 Pet. pp. 16-17
'698 Reply pp. 1-2 / '381 Reply pp. 1-2

'698 EX 1003 ¶¶ 45-46 / '381 EX 1003 ¶¶ 45-46
'698 Pet. pp. 8-9 / '381 Pet. pp. 7-9
'698 POR p. 13 / '381 POR p. 13

Warren's Claims Prove Obviousness of a Sensor with the Through-Nozzle Extruder

54. A system for controlling the position of at least one element of a dispensing system including at least one dispenser and at least one substrate, the system comprising:

a vibration imparting device for imparting vibration of a particular amplitude to the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate;

a detector for detecting a change in the amplitude of vibration of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate upon contact with each other; and

a position controller for varying the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate based on the detected change in amplitude of vibration to obtain a desired force of contact between the at least one dispenser and the at least one substrate.

EX 1004 Claim 54

'698 Reply p. 2 / '381 Reply p. 2

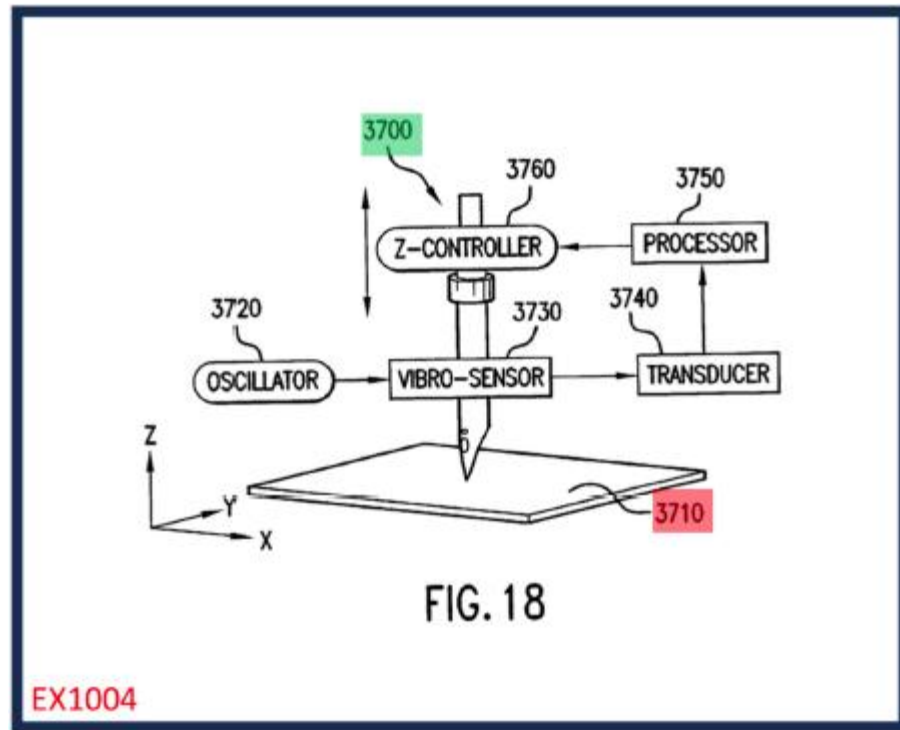
59. The system of claim 54, wherein the at least one dispenser includes at least one of a through-nozzle, a needle valve, a capillary pen, or a quill pen.

70. The method of claim 65, wherein the at least one dispenser includes at least one of a through-nozzle, a needle valve, a capillary pen, or a quill pen.

EX 1004 Claims 59 and 70

'698 Reply p. 2 / '381 Reply p. 2

Warren Recognizes a Desire to Use a Sensor with A Dispenser



'698 EX 1003 ¶¶ 45-46 / '381 EX 1003 ¶¶ 45-46
'698 Pet. pp. 7-9 / '381 Pet. pp. 7-9, 19
'698 POR p. 13 / '381 POR p. 13

[0285] As dispensing systems are widely used to deposit materials onto substrates, for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and the surface where deposition is desired. Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the

EX 1004 ¶ [0285]

'698 EX 1003 ¶ 71 / EX 1003 ¶ 71

'698 Pet. pp. 15, 33, 35, 38-39 / '381 Pet. pp. 13-14

[0287] Therefore, a need exists for a system and method for controlling the position of one or more elements of a depositing system that accurately determines the intensity of the contact force between a dispensing tip and a substrate surface to maintain a desired contact force between the dispenser and the substrate.

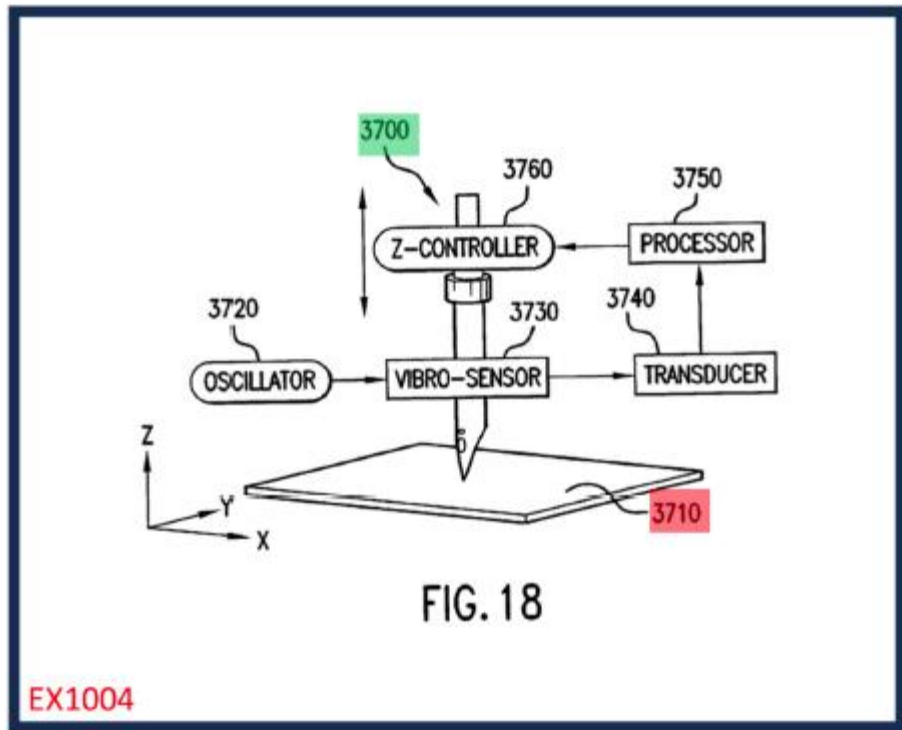
EX 1004 ¶ [0287]

'698 EX 1003 ¶¶ 45-46 / '381 EX 1003 ¶ 45-46

'698 Pet. pp. 8-9 / '381 Pet. pp. 7-8

'698 Reply pp. 4-5 / '381 Reply pp. 4-5

Warren's General Dispenser Includes a Sensor



'698 EX 1003 ¶ 45-46
'698 Pet. pp. 8-9 / '381 Pet. p. 7-8
'698 POR p. 13 / '381 POR p. 13

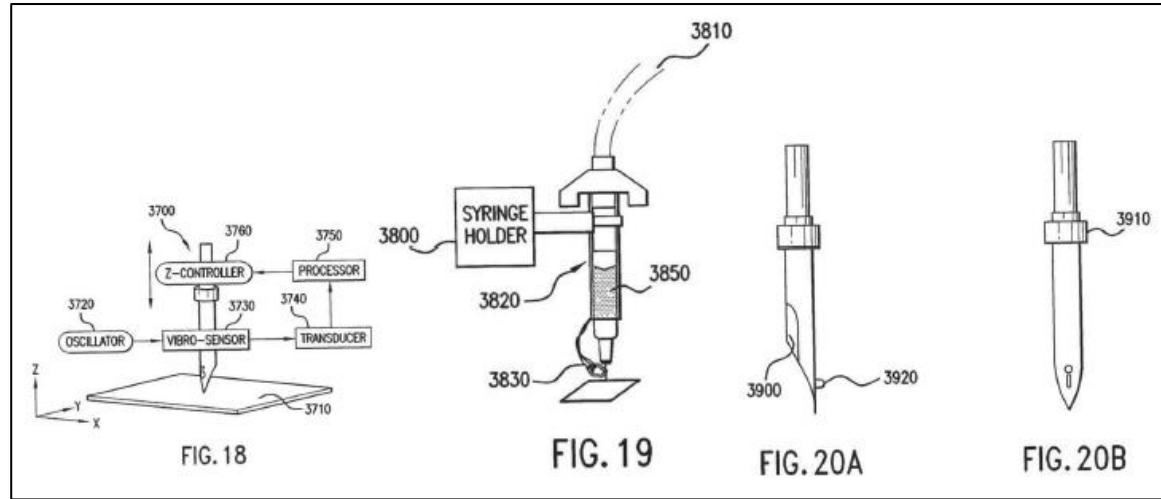
[0300] Referring again to FIG. 19, a vibration oscillator 3720 is attached to the dispenser 3700 for imparting vibration to the dispenser 3700. A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700 for

EX 1004 ¶ [0300]
'698 EX 1003 ¶ 46 / '381 EX 1003 ¶ 46
'698 Pet. pp. 8-9, 18 / '381 Pet. p. 7-8, 19

Id. at Fig. 18, ¶ [0293]. Although the substrate is shown as flat, Warren explains that this is just for the ease of illustration as the dispenser follows irregular or curved surfaces. *Id.* Oscillator 3720 imparts vibration to dispenser 3700, and vibration sensor 3730 and transducer 3740 sense the amplitude and frequency of vibration. *See id.* at ¶ [0300].

'698 POR p. 13 / '381 POR p. 13

Any of Warren's Extruders Includes a Sensor



'698 POR p. 17
EX 1004 FIGS. 18-20

tion to the dispenser 3700. A vibration sensor 3730 and a transducer 3740 are attached to the dispenser 3700 for sensing the A and f of vibration of the dispenser 3700. The oscillator 3720 and the transducer 3740 may be implemented with any suitable conventional devices. These ele-

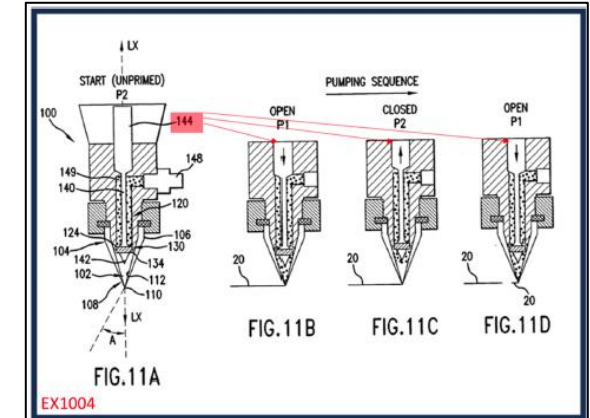
EX 1004 ¶ [0300]

'698 EX 1003 ¶ 46, 81-82, 143 / '381 EX 1003 ¶

'698 Pet. pp. 8-9 / '381 Pet. pp.

FISH.

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE



EX 1004 FIGS. 18-20

'698 EX 1003 ¶ 49 / '381 EX 1003 ¶
'698 Pet. pp. 11-12 / '381 Pet. pp.

[0299] The material dispensers illustrated in FIGS. 19, 20A and 20B are shown by way of example only. The dispenser 3700 need not be limited to these implementations. In addition, the dispensers shown in FIGS. 19, 20A and 20B are not limited to being implemented in the system shown in FIG. 18.

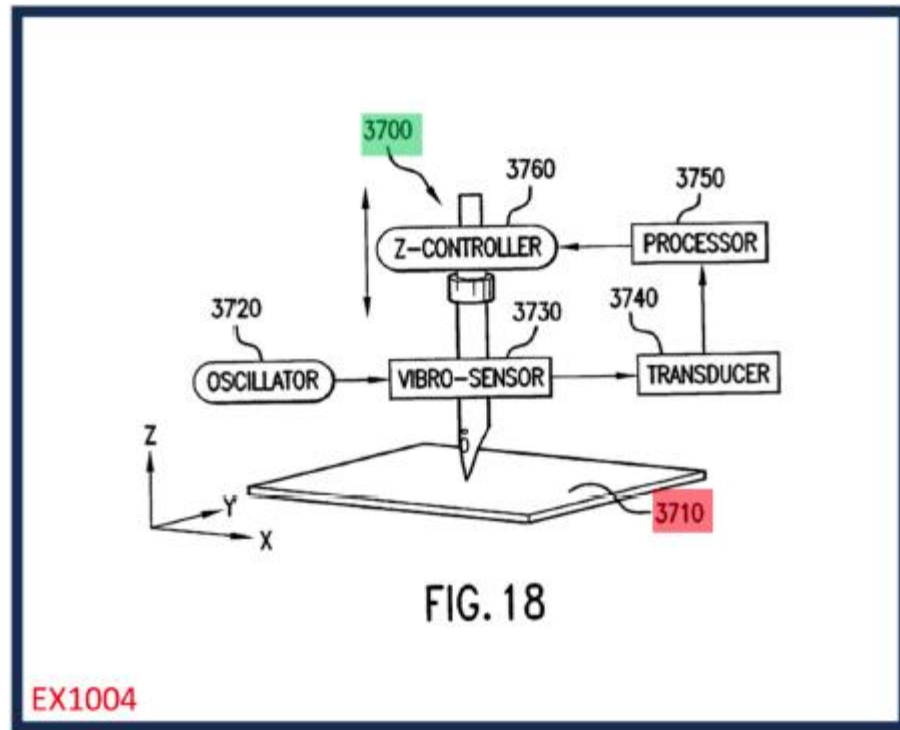
EX 1004 ¶ [0299]

'698 EX 1003 ¶ 68 / '381 EX 1003 ¶

'698 Pet. pp. 13-14 / '381 Pet. pp.

'698 POR pp. 16-17 / '381 POR pp.

Warren Invites the Use of a Sensor with the Through-Nozzle Extruder



'698 EX 1003 ¶¶ 45-46 / '381 EX 1003 ¶¶ 45-46
'698 Pet. pp. 8-9 / '381 Pet. pp. 7-9
'698 POR p. 13 / '381 POR p. 13

68. As a *first* reason, Warren invites the use of the vibrating force sensor concepts with other configurations of dispenser when it explains that the capillary dispensing unit is shown with the vibrating force sensor “by way of example only,” “[t]he dispenser 3700 need not be limited to [the capillarity dispensing unit] implementations.” EX1004, [0299], *see also*, [0294] (“dispenser 3700 may be implemented differently”). Doing so merely involves combining known elements using known techniques to achieve predictable and advantageous results.

EX 1004 ¶ [0299], [0294]
'698 EX 1003 ¶ 68 / '381 EX 1003 ¶ 68
'698 Pet. pp. 13-14 / '381 Pet. pp. 12-13

Warren Recognizes the Advantages of Vibration Sensing to Different Deposition Processes

Second, a POSITA would have been motivated by the precise flow control capability of Warren's through-nozzle design, in which "linear actuator 144 controls the material dispensing rate and improves start and stop characteristics by controlling the position of the valve piston 140 and speed of displacement." EX1004, [0243]. "During the initial valve opening, the motion of the piston 140 transfers a momentum to the material and causes the material to flow at a specific flow rate...so that the material flowing through the valve 130 will have the same flow velocity, thereby leading to a smooth dispensing start." *Id.* A POSITA would have found it advantageous to employ features from Warren's through-nozzle design in dispenser 3700 so that "the initiation of material flow...can be smooth, seamless, and very reproducible." *Id.*; EX1003, ¶69 (citing "inconsistent volumes and inaccurate start times" in the absence of actuator control (*id.*)).

'698 EX 1003 ¶ 69 / '381 EX 1003 ¶ 69

'698 Pet. p. 14 / '381 Pet. pp. 12-13

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Rebuttal – Warren Claims Multiple Dispensers in Other Claims

embodiments. Rather, claims 54, 59, 65, and 70 refer to the table-top dispenser in Warren that can include multiple tool designs, including capillary designs and through-nozzle designs. See EX1004, at Fig. 23A (below), Figs. 23B-C, ¶¶[0278], [0318] (“multiunit system”); POR, 15-16.

'698 Sur-reply p. 2 / '381 Sur-reply p .

60. The system of claim 54, wherein for a dispensing system including multiple dispensers, the position controller independently varies the position of each respective dispenser or the position of the least one substrate.

71 The method of claim 65, wherein for a dispensing system including multiple dispensers, the step of varying includes independently varying the position of each respective dispenser or the position of the at least one substrate.

'698 Patent [1b]
'381 Patent [1b]
**Warren's Sensor Detects / Senses
Contact Force**

FISH.

Warren's Application to '698 [1b] and '381 [1b]

698 Patent Claim 1	381 Patent Claim 1
1. A method comprising:	1. A three-dimensional printer comprising:
identifying build instructions for fabricating an object;	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
detecting the current contact force based on a sensor signal from the one or more sensors; and	
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.

The '698 / '381 Patents Define Sensor Function Broadly

In some implementations, sensors 302 may include one or more of capacitive sensors, optical sensors, potentiometric sensors, piezoelectric sensors, or other electromechanical, electromagnetic (e.g., those relying on inductance, the Hall effect, electromagnetic eddy currents, linear variable differential transformers, etc.), acoustical, or other sensors, as well as other sensors or combinations of the foregoing. Strain gauges are one common sensor used for such measurements, and may be suitably adapted for use with the systems and methods disclosed herein, such as by affixing one or more strain gauges to an extruder or other location along a mechanical chain that supports an extruder in an intended position during fabrication. By using a pair of strain gauges, deflection forces may be isolated from normal force.

EX 1001, 8:62-9:8

'698 EX 1003 ¶¶ 55-61 / '381 EX 1003 ¶ 36

'698 Pet. pp. 45-46 / '381 Pet. pp. 57

directions, etc. More generally, sensors that are collectively operable to sense any force or displacement of the fabrication tool and separate structure, or any related properties such as compression or strain, may be used as sensors 302, so long as the contact force(s) described above may be calculated from the sensed physical characteristics.

EX 1001, 8:56-61

'698 EX 1003 ¶¶ 36, 86 / '381 EX 1003 ¶¶ 36, 90

'698 Pet. pp. 4, 20 / '381 Pet. pp. 4, 21

Strain Gauges and Piezoelectric Sensors Meet the Claimed Sensor

What is claimed is:

1. A method comprising:

identifying build instructions for fabricating an object;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;
detecting the current contact force based on a sensor signal from the one or more sensors; and
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.

EX 1001, Claim 1

13. The method of claim 1 wherein the one or more sensors include a strain gauge.

14. The method of claim 1 wherein the one or more sensors include a piezoelectric sensor.

15. The method of claim 1 wherein the one or more sensors include at least one of a capacitive sensor, and optical sensor, an electromechanical sensor, an electromagnetic sensor, and an acoustical sensor.

EX 1001, Claims 13-15

Strain Gauges Detect Contact Force by Sensing Strain

directions, etc. More generally, **sensors** that are collectively operable to sense any force or displacement of the fabrication tool and separate structure, or **any related properties** such as compression or **strain, may be used as sensors** **302**, so long as the contact force(s) described above may be calculated from the sensed physical characteristics.

EX 1001, 8:56-61

'698 EX 1003 ¶¶ 36, 86 / '381 EX 1003 ¶¶ 36, 90

'698 Pet. pp. 3-4, 20-21 / '381 Pet. pp. 4, 21

'698 Reply p. 3 / '381 Reply p. 3

'698 POR pp. 32-33 / '381 POR pp. 33-34

Based on my experience and knowledge, **a strain gauge is an electromechanical sensor** because it was general knowledge to use a strain gauge to **convert a mechanical input (e.g., strain) to an electrical readout (e.g., a differential voltage between two parallel voltage dividers on a Wheatstone bridge configuration).** *See e.g., EX1018 at 302-304, 284-290.*

'698 EX 1003 ¶ 233 / '381 EX 1003 ¶ 120

'698 Pet. p. 36-37 / '381 Pet. p. 30

Warren Teaches a Piezoelectric Sensor that Detects Contact Force

In some implementations, **sensors 302** may include one or more of capacitive sensors, optical sensors, potentiometric sensors, **piezoelectric sensors**, or other electromechanical, electromagnetic (e.g., those relying on inductance, the Hall effect, electromagnetic eddy currents, linear variable differential transformers, etc.), acoustical, or other sensors, as well as other sensors or combinations of the foregoing. Strain

EX 1001, 8:62-9:8

'698 EX 1003 ¶¶ 55-61 / '381 EX 1003 ¶ 36

'698 Pet. pp. 45-46 / '381 Pet. pp. 57

3830. The **piezomembrane 3830** may be implemented with an **electroceramic sensor** and include a **vibration actuator** and **vibration transducer**, described in more detail below.

EX 1004, ¶ [0295]

'698 EX 1003 ¶ 141 / '381 EX 1003 ¶ 117

'698 Pet. pp. 36-37 / '381 Pet. p. 29-30

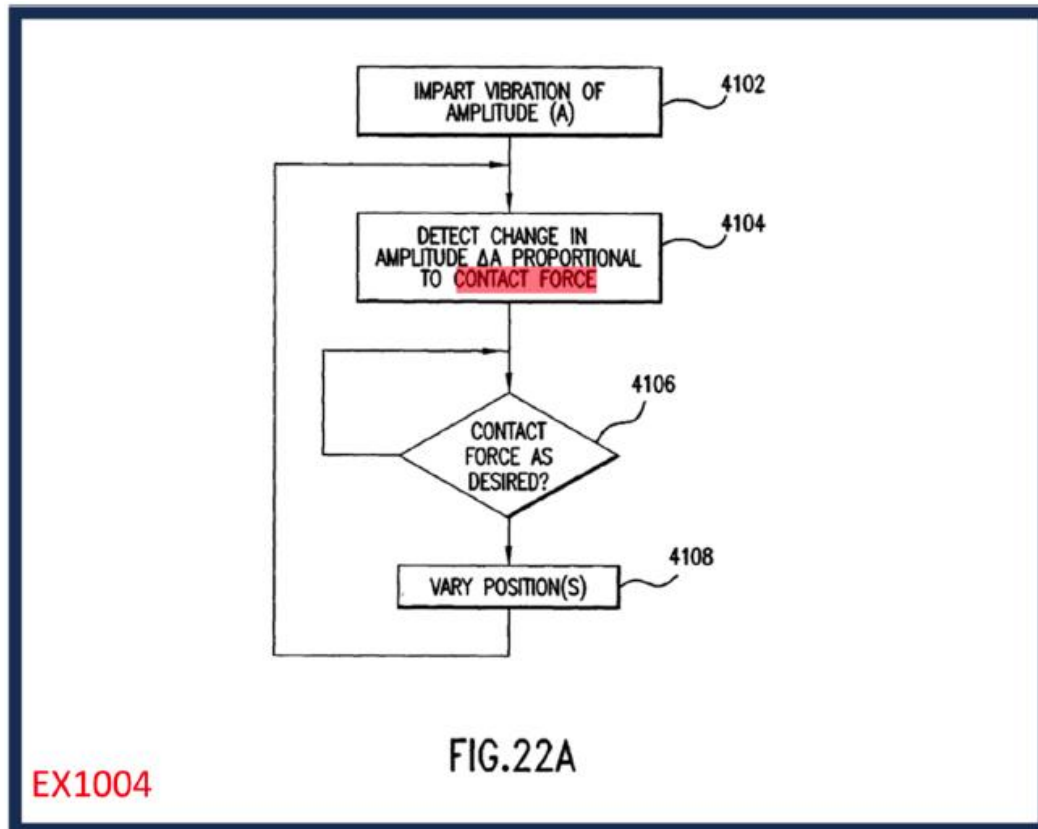
141. Each and every element of claim 1 is obvious as explained above. In this context, the one or more sensors include a *piezoelectric sensor* (e.g., a piezoelement). For example, Warren describes “piezoelement” when explaining its sensor operation to **detect changed amplitude, known as ΔA** , which “brings additional flexibility and sensitivity to the system.” EX1004, [0304], [0306-07] (examples of **“a dispensing system with a piezoelement attached”**). A POSITA would have recognized that the **piezoedelement** refers to a piezo electric sensor. I note that the terms are used interchangeably as seen in EX1004, [0305] (“piezotransducer”), [0300] (“transducer”), [0295-96] (“piezomembrane”).

EX 1004, ¶¶ [0295]-[0296], [0300], [0304]-[0307]

'698 EX 1003 ¶ 141 / '381 EX 1003 ¶ 117

'698 Pet. pp. 36-37 / '381 Pet. pp. 29-30

Warren's Sensor Detects a Change in Amplitude, ΔA , Proportional to Contact Force



EX 1004 FIG. 22A

'698 EX 1003 ¶¶ 85-86 / '381 EX 1003 ¶¶ 87-90

'698 Pet. pp. 19-21, 28, 38 / '381 Pet. pp. 19-21

[0313] FIG. 22A illustrates an exemplary method for controlling the position of one or more elements of a dispensing system including at least one dispenser and at least one substrate. The method begins at step 4102 at which vibration of a particular amplitude is imparted to the dispenser and/or the substrate. At step 4104, a change in the amplitude of vibration of the dispenser and/or the substrate is detected. This change in amplitude is proportional to the force of contact between the dispenser and the substrate. At step 4106, a determination is made whether the contact force is that which is desired, based on the detected change in amplitude. If the contact force is that which is desired, the process may stop, or this step may be repeated to ensure the

EX 1004 ¶ [0313]

'698 EX 1003 ¶¶ 65, 85, 91 / '381 EX 1003 ¶¶ 87-90

'698 Pet. pp. 19-21, 28, 38 / '381 Pet. pp. 8-9, 20-21

Contact Force Can Be Readily Calculated from ΔA

86. In view of the proportionality, a POSITA would have understood or found it obvious that the *contact force* can be calculated from the detected “change in the amplitude.” EX1004, [0313]. I have provided additional details of Warren’s sensing operations above and under Section VII.A, where I have cited, among others, Warren’s disclosure at [0301-0307] as well as FIGS. 18 and 19. Warren’s vibration sensor and transducer thus align with the specification of the ’698 patent, which describes its sensors broadly to sense anything, “so long as the contact force(s)...may be calculated from the sensed physical characteristics,” EX1001, 8:49-61.

’698 EX 1003 ¶ 86 / ’381 EX 1003 ¶ 90
’698 Pet. pp. 20-21 / ’381 Pet. pp. 20-21

(“touch detecting measuring force”) and Igasaki (EX1017) at FIG. 4. Calculating contact force from a sensor intended to produce a signal proportional to contact force was rudimentary engineering and commonplace long before 2012 and would have led to many advantages in a control system designed to “maintain a desired contact force” by virtue of directly operating in the force domain for simplicity. EX1004, [0286-287]. Among other reasons, a POSITA would have known that the

’381 EX 1003 ¶ 95
’381 Pet. pp. 22-24

Patent Owner Recognizes that Warren's Sensor Detects ΔA

current contact force based on the sensor signal. Warren repeatedly refers to detecting a change in amplitude of a vibration, not detecting or calculating a current contact force. Warren states that a “change in the amplitude of vibration (ΔA) of the dispenser, the substrate, or both the dispenser and the substrate upon contact with each other, is detected by the system.” EX1004 at ¶[0289]; *see also id.* (“The position of one or more of the elements is varied, based on the detected ΔA , to maintain a desired force of contact between the dispenser and the substrate.”).

'698 POR at 26

from a change in amplitude. *See* EX2027, ¶¶170-189. It simply states that in general the “amplitude of the modulation in the signal is proportional to the force applied between the dispenser and the substrate.” EX1004 at ¶[0315].

'698 POR at 27

'698 Patent [1c] Warren Detects a Contact Force

FISH.

Warren's Application to '698 [1c]

698 Patent Claim 1	381 Patent Claim 1
1. A method comprising:	1. A three-dimensional printer comprising:
identifying build instructions for fabricating an object;	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
detecting the current contact force based on a sensor signal from the one or more sensors ; and	
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.

Detecting Is Distinguishable from Calculating a Current Contact Force

698 Patent Claim 1	381 Patent Claim 1
1. A method comprising:	1. A three-dimensional printer comprising:
identifying build instructions for fabricating an object;	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
detecting the current contact force based on a sensor signal from the one or more sensors ; and	
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.

Warren Seeks to Protect the Dispenser and Substrate Using Knowledge of Contact Force

[0285] As dispensing systems are widely used to deposit materials onto substrates, for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and the surface where deposition is desired. Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the

EX 1004 ¶ [0285]

'698 EX 1003 ¶ 71

'698 Petition pp. 15, 33, 35, 38-39

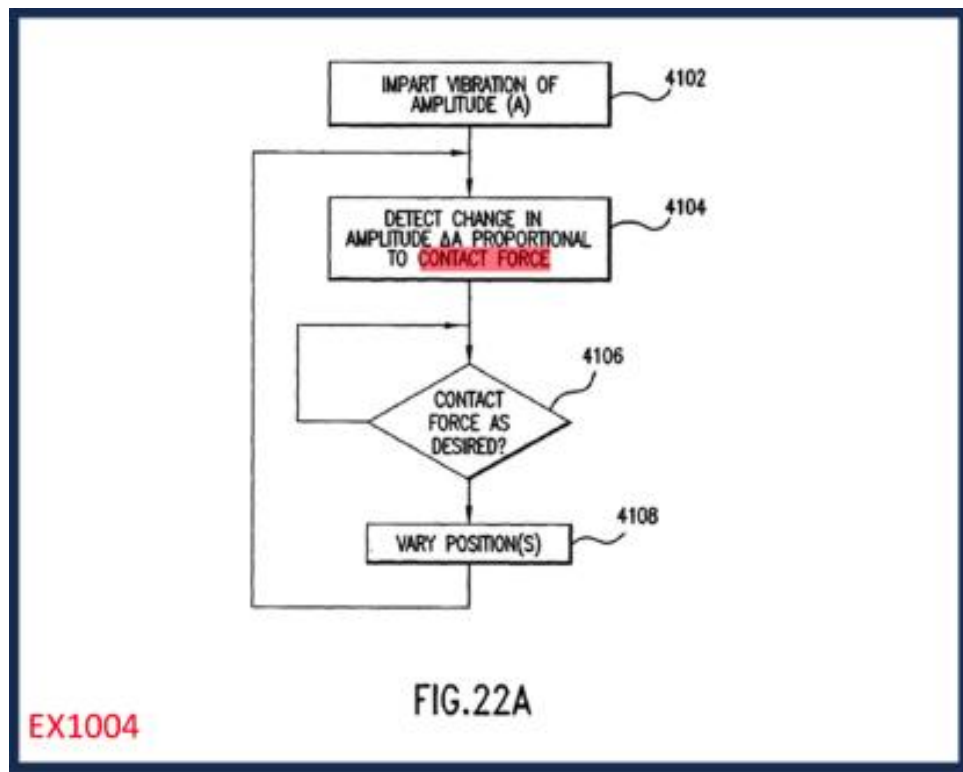
capabilities. As Warren explains, “for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and surface where deposition is desired.” EX1004, [0286]. “Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the tip crashes into the substrate material, or little to no control of the deposition geometry

'698 EX 1003 ¶ 71 (quoting EX 1004 ¶ [0285])

'698 Pet. pp. 15-16

'698 Reply pp. 4-5

Change in Amplitude, ΔA , Is Proportional to Contact Force



EX 1004 FIG. 22A
'698 EX 1003 ¶ 85
'698 Pet. pp. 19-21

85. Warren further explains that “a change in the amplitude of vibration of the dispenser and/or the substrate is *detected*,” where “this change in amplitude is proportional to the force of contact between the dispenser and the substrate.” *Id.*, [0313] (discussing FIG. 22A (annotated below showing “detect change in amplitude ΔA proportional to contact force”)).

'698 EX 1003 ¶ 85
'698 Pet. p.

Control applied in this manner also enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force, and to break contact on command and find it again. The system has been demonstrated to be sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface and even as the material protruding from a nozzle on a dispenser contacts the substrate surface.

EX 1004 ¶ [0316]
'698 Reply p. 5
'698 Pet. pp. 21-22

Warren Uses the Detected Contact Force to Control the Dispenser

88. Warren's combined teachings provide *detecting the current contact* (e.g., "the force of contact between the dispenser and the substrate") *based on a sensor signal* (e.g., "a change in the amplitude of vibration of the dispenser and/or the substrate") *from the one or more sensors* (e.g., vibration sensor 3730 and transducer 3740). See e.g., EX1004, [0313] ("At step 4104, a change in the amplitude of vibration of the dispenser and/or the substrate is detected," where "[t]his change in amplitude is proportional to the force of contact between the dispenser and the substrate."), [0302] (transducer 3740 senses and transfers the changed vibration signal to an amplifier); *supra* Element [1.b].

EX 1003 ¶ 88

'698 Pet. pp. 21-22

'698 Reply p. 4-6

As PO correctly points out, Warren teaches *varying the position of one or more elements of the dispenser* "to maintain a desired force of contact between the dispenser and the substrate." POR, 26 (citing Warren ¶[0289]); *see also* Warren ¶¶[0283] (introducing controlling position of the dispensing system using force feedback"), [0313]-[0316], FIG. 22A, claims 54-56, 61, 65-67, and 72; Petition 21-22. Warren varies the position based on a comparison between a detected contact force and a desired contact force. E.g., EX1004 ¶[0313], FIG. 22A ("whether the contact force is that which is desired"); Petition, 22; EX1003 ¶91.

'698 Reply p. 4-6

'698 Pet. pp. 21-22

Warren Uses the Detected Contact Force to Control the Dispenser

Warren consistently teaches comparing the detected contact force intensity to a desired value when determining whether or not to reposition the dispenser or substrate. Specifically, Warren teaches that if “the contact force is that which is desired,” the process may stop; and if “it is determined that the contact force is not as desired, the position(s) of the dispenser and/or the substrate are varied.”

Warren ¶[0313]. So, not only does Warren teach detecting the contact force (e.g., to micronewton precision), Warren teaches controlling the position of the dispenser by comparing the detected contact force to a desired intensity. Petition, 15, 19-27, 33; EX1003 ¶¶80-19; Warren ¶¶[0301]-[0316], [0322], [0324], FIG. 22A.

'698 Reply p. 4-6

'698 Pet. pp. 20-23, 33-35

Warren Demonstrated Detecting Contact Force to Control the Dispenser

[0316] Control applied in this manner allows for dispensing to be accomplished onto conformal surfaces as the force feedback control continuously corrects the dispensing structure's z-height position as the z height of the substrate surface changes, either by modifying the dispenser's position, the substrate's position, or both. This enables the writing of fine lines, e.g., 20 μm wide, and writing on curved surfaces, e.g., placing electronic elements on a cylinder. Control applied in this manner also enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force, and to break contact on command and find it again. The system has been demonstrated to be sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface and even as the material protruding from a nozzle on a dispenser contacts the substrate surface.

EX 1004 ¶ [0316]

'698 Pet. 22-23, 31

'698 EX 1003 ¶¶ 90-91, 120

Petition, 23, 25-27, 33; EX1003 ¶91. Warren has “demonstrated” that the system is

“sufficiently sensitive to allow for the sensing of the contact force as a dispenser

contacts a substrate surface.” Warren ¶[0316]. Contrary to PO's arguments, these

passages expressly support the conclusion that Warren does indeed convert ΔA

from its vibrating sensor into a “quantitative contact force.” POR, 27.

'698 Reply pp. 4-5

'698 Pet. pp.

Warren Calculates Force to Compare to a Desired Intensity

[0289] According to exemplary embodiments, vibration of particular amplitude (A) is imparted to one or more of the elements of the dispensing system. The vibration may be imparted to the dispenser, the substrate, or both the dispenser and the substrate. A change in the amplitude of vibration (ΔA) of the dispenser, the substrate, or both the dispenser and the substrate upon contact with each other, is detected by the system. This ΔA may be a change in amplitude of the primary harmonic vibration of the dispenser or the substrate, selected secondary harmonics of either, or combinations. The position of one or more of the elements is varied, based on the detected ΔA , to maintain a desired force of contact between the dispenser and the substrate. The positions of the dispenser, the substrate, or the dispenser and the substrate may be controlled in this manner.

EX 1004 ¶ [0289]
'698 Reply pp. 4-5
'698 Pet. pp. 7-9

The necessity of detecting contract force from the vibrating sensor output is built directly into Warren's operating principles. In order for Warren "to maintain a desired force of contact between the dispenser and the substrate," Warren must compare the vibrating force sensor's reading against the desired force. Warren ¶ [0289]. To do so, the system must either convert the desired force into vibration amplitude units or convert the sensor's amplitude output into units of force. And

'698 Reply pp. 4-5
'698 Pet. pp. 7-9

Petitioner Pointed Out the Difference Between Detecting and Calculating Contact Force

82. Warren's *one or more sensors are configured to detect a current contact force* (e.g., the force of contact) *between the fabrication tool* (including, e.g., either capillary vibro-sensor dispensing unit or the through-nozzle dispenser) *and a separate structure* (e.g., substrate 3710). For example, Warren's system includes "a vibration oscillator 3720...for imparting vibration to the dispenser 3700" and "[a] vibration sensor 3730 and a transducer 3740...for sensing the A and f of vibration of the dispenser 3700." EX1004, [0300]. According to Warren, "[t]he vibration imposed on the dispenser 3700 is changed, e.g., modulated, by the contact of the 3700 [sic] dispenser with the substrate 3710" such that "[t]he transducer 3740 senses and transfers the changed vibration signal to an amplifier." EX1004, [0302], [0313] ("the contact force" determined "based on the detected change in amplitude").

'698 EX 1003 ¶ 82, 86
'698 Pet. pp. 17-21

86. In view of the proportionality, a POSITA would have understood or found it obvious that the *contact force* can be calculated from the detected "change in the amplitude." EX1004, [0313]. I have provided additional details of Warren's sensing operations above and under Section VII.A, where I have cited, among others, Warren's disclosure at [0301-0307] as well as FIGS. 18 and 19. Warren's vibration sensor and transducer thus align with the specification of the '698 patent, which describes its sensors broadly to sense anything, "so long as the contact force(s)...may be calculated from the sensed physical characteristics," EX1001, 8:49-61.

Petitioner Pointed Out the Difference Between Detecting and Calculating Contact Force

the '698 patent does not claim calculating a contact force—only “detecting the current contact force.” EX1001, cl.1; *compare* '381 patent, cl.1 (“calculate the contact force”). And as discussed in Section III, *supra*, Warren’s sensors provide ΔA , from which contact force is detected.

'698 Reply p. 4

Warren Renders Calculating Contact Force Obvious

86. In view of the proportionality, a POSITA would have understood or found it obvious that the *contact force* can be calculated from the detected “change in the amplitude.” EX1004, [0313]. I have provided additional details of Warren’s sensing operations above and under Section VII.A, where I have cited, among others, Warren’s disclosure at [0301-0307] as well as FIGS. 18 and 19. Warren’s vibration sensor and transducer thus align with the specification of the ’698 patent, which describes its sensors broadly to sense anything, “so long as the contact force(s)...may be calculated from the sensed physical characteristics,” EX1001, 8:49-61.

’698 EX 1003 ¶ 86
’698 Pet. pp. 20-21

V. DETERMINING FORCE IS OBVIOUS

Beyond demonstrating that Warren detects contact force, the Petition further demonstrates that it was obvious that Warren determines a contact force from ΔA . *E.g.*, Petition, 17-21; EX1004, [0313], [0301]-[0307]; EX1003, ¶86 (explaining additional details of Warren’s sensing operations). Consistent with the discussion of Warren in §IV, *supra*, a POSITA would have understood that to control to a desired force intensity, one would need to know the difference between the desired force and a detected force. *E.g.*, EX1004 ¶[0313]-[0316]; Petition, 19-21; EX1003 ¶91.

’698 Reply pp. 6-9

PO's Evidence Proves Properties for Determining Contact Force Were Obtainable

Even still, PO's arguments support, rather than detract from, a conclusion that determining the contact force is feasible. POR, 32 (citing EX2024, FIG. 4.1). PO's own evidence demonstrates that the properties that it says are relevant to calculating force, such as Young's Modulus, were well-known for a wide variety of materials. EX2024, 6-8 (showing Young's Modulus displayed in three different styles of graphical representation to show how material properties can be displayed); EX1042, 80:2-81:6 (can look up modulus for commonly printed materials). A POSITA would simply look up those properties, which reinforces Dr. Wolfe's testimony that "[c]alculating contact force from ... a signal proportional to contact force was rudimentary engineering, commonplace and typical long before 2012." EX1003, ¶95; Petition, 23. Nothing in PO's discussion of Young's Modulus

'698 Reply pp. 6-9
'698 Pet. p. 23

¶182. Moreover, PO's arguments assume first principle calculations are the only manner of correlating Warren's stated proportionality to force values, wholly ignoring that the correlation could be established by measurement and calibration. See, e.g., EX1042, 102:7-103:11 (testifying a force-frequency relationship is obtainable experimentally); 100:13-104:14.

'698 Reply pp. 6-9
EX 1042 100:13-104:14

Warren Supports the Necessity of Determining Force

[0285] As dispensing systems are widely used to deposit materials onto substrates, for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and the surface where deposition is desired. Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the

EX 1004 ¶ [0285]

'698 EX 1003 ¶ 71

'698 Petition pp. 15, 33, 35, 38-39

is detected. This change in amplitude is proportional to the force of contact between the dispenser and the substrate. At step 4106, a determination is made whether the contact force is that which is desired, based on the detected change in amplitude. If the contact force is that which is desired, the process may stop, or this step may be repeated to ensure the contact force remains as desired. If at step 4106 it is determined that the contact force is not as desired, the position(s) of the dispenser and/or the substrate are varied at step 4108, causing a change in the amplitude of vibration.

EX 1004 ¶ [0313]

'698 Reply pp. 5-6

'698 Pet. pp. 21-23, 28-29, 35

The necessity of detecting contact force from the vibrating sensor output is built directly into Warren's operating principles. In order for Warren "to maintain a desired force of contact between the dispenser and the substrate," Warren must compare the vibrating force sensor's reading against the desired force. Warren ¶[0289]. To do so, the system must either convert the desired force into vibration amplitude units or convert the sensor's amplitude output into units of force. And Warren consistently teaches comparing the detected contact force intensity to a desired value when determining whether or not to reposition the dispenser or substrate. Specifically, Warren teaches that if "the contact force is that which is desired," the process may stop; and if "it is determined that the contact force is not as desired," the position(s) of the dispenser and/or the substrate are varied." Warren ¶[0313]. So, not only does Warren teach detecting the contact force (e.g.,

'698 Reply pp. 5-6

'698 Pet. pp. 21-23, 28-29, 35

'381 Patent [1c] Warren Teaches Calculating Contact Force

FISH.

Warren Desires Accurately Determining Contact Force Intensity

[0287] Therefore, a need exists for a system and method for controlling the position of one or more elements of a depositing system that accurately determines the intensity of the contact force between a dispensing tip and a substrate surface to maintain a desired contact force between the dispenser and the substrate.

[0288] The present invention is directed to a system and method for controlling the position of one or more elements of a dispensing system to maintain a desired contact force between the elements.

The position of one or more of the elements is varied, based on the detected ΔA , to maintain a desired force of contact between the dispenser and the substrate. The positions of the dispenser, the substrate, or the dispenser and the substrate may be controlled in this manner.

EX 1004 ¶¶ [0287]-[0289]

'381 EX 1003 ¶ 94

'381 Pet. pp. 7, 22-24; '381 Reply p. 4

'381 POR at 26

[0316] Control applied in this manner allows for dispensing to be accomplished onto conformal surfaces as the force feedback control continuously corrects the dispensing structure's z-height position as the z height of the substrate surface changes, either by modifying the dispenser's position, the substrate's position, or both. This enables the writing of fine lines, e.g., 20 μm wide, and writing on curved surfaces, e.g., placing electronic elements on a cylinder. Control applied in this manner also enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force, and to break contact on command and find it again. The system has been demonstrated to be sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface and even as the material protruding from a nozzle on a dispenser contacts the substrate surface.

EX 1004 ¶¶ [0316]

'381 EX 1003 ¶ 94

Warren Desires Accurately Determining Contact Force Intensity to Maintain a Desired Contact Force

94. Warren also explains the significance “to determine the intensity of contact force between elements” in that a system that “accurately determines the intensity of the contact force between a dispensing tip and a substrate surface” can be provided to further Warren’s objective, namely, “to maintain a desired contact force between the dispenser and the substrate.” EX1004, [0286-287], [0313-0316], FIG. 22A.

'381 EX 1003 ¶ 94

'381 Pet. pp. 6-8

'381 Reply pp. 4-5

Warren Desires Accurately Determining Contact Force Intensity

More specifically, Warren explains that its system addresses a need for “a depositing system that accurately determines the intensity of the contact force between a dispensing tip and a substrate surface.” Warren ¶[0287]. Warren explains that its system controls “the contact force between the dispensing structure and the substrate surface,” to “maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force.” Warren ¶[0316]; Petition, 23, 25-27, 33.¹ Warren has “demonstrated” that the system is

'381 Reply p. 4

'381 Pet. p. 7

'381 EX 1003 ¶¶ 45, 94

Warren Desired (and Demonstrated) Accurate Determination of Contact Force Intensity

Control applied in this manner also enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force, and to break contact on command and find it again. The system has been demonstrated to be sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface and even as the material protruding from a nozzle on a dispenser contacts the substrate surface.

EX 1004 ¶ [0316]

'381 Pet. pp. 25-27

'381 EX 1003 ¶¶ 105-107

'381 Reply p. 4

Warren has “demonstrated” that the system is “sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface.” Warren ¶[0316]. Contrary to PO’s arguments, these passages expressly support the conclusion that Warren does indeed convert the change in amplitude in its vibrating sensor “into a calculated or quantitative contact force.” POR, 27 (citing EX2027 ¶185).

'381 Reply p. 4

Warren Calculates Contact Force Based on Proportionality to ΔA

95. Thus, in my opinion, a POSITA would have known, or found it obvious, that Warren's controller calculates the contact force based on the feedback signal using proportionality and other commonly used sensor conditioning math functions. The sensors discussed above are routinely used to measure force and the calculation of force values from the sensor signals was routine at the time. Indeed, specific

'381 EX 1003 ¶ 95

'381 Pet. p. 23

[0286-287]. Among other reasons, a POSITA would have known that the comparison between the sensor signal and a "desired contact force" requires a conversion of the values to the same domain. Moreover, it was obvious to a POSITA

'381 EX 1003 ¶ 95

'381 Pet. p. 23

Warren Calculates Contact Force Based on Proportionality to ΔA to Control the Dispenser

is detected. This change in amplitude is proportional to the force of contact between the dispenser and the substrate. At step 4106, a determination is made whether the contact force is that which is desired, based on the detected change in amplitude. If the contact force is that which is desired, the process may stop, or this step may be repeated to ensure the contact force remains as desired. If at step 4106 it is determined that the contact force is not as desired, the position(s) of the dispenser and/or the substrate are varied at step 4108, causing a change in the amplitude of vibration. This change in amplitude is detected again at step 4104. Steps 4104, 4106 and 4108 are repeated as necessary to obtain a desired contact force between the substrate and the dispenser, e.g., to maintain contact of a desired force between the substrate and the dispenser, seek contact between the substrate and the dispenser, or break contact and seek contact again.

EX 1004 ¶ [0313]

'381 Pet. pp. 7-9

'381 EX 1003 ¶¶ 89-90, 94, 133

tion, the substrate's position, or both. This enables the writing of fine lines, e.g., 20 μm wide, and writing on curved surfaces, e.g., placing electronic elements on a cylinder. Control applied in this manner also enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force, and to break contact on command and find it again. The system has been demonstrated to be sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface and even as the material protruding from a nozzle on a dispenser contacts the substrate surface.

EX 1004 ¶ [0316]

'381 Pet. pp. 25-27

'381 EX 1003 ¶¶ 106

Warren Supports the Necessity of Determining Force

[0285] As dispensing systems are widely used to deposit materials onto substrates, for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and the surface where deposition is desired. Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the

EX 1004 ¶ [0285]

'381 EX 1003 ¶ 71

'381 Petition pp. 13-14

is detected. This change in amplitude is proportional to the force of contact between the dispenser and the substrate. At step 4106, a determination is made whether the contact force is that which is desired, based on the detected change in amplitude. If the contact force is that which is desired, the process may stop, or this step may be repeated to ensure the contact force remains as desired. If at step 4106 it is determined that the contact force is not as desired, the position(s) of the dispenser and/or the substrate are varied at step 4108, causing a change in the amplitude of vibration.

EX 1004 ¶ [0313]

'381 Reply pp. 4-5

'381 Pet. pp. 8-9, 19-23, 33-35

'381 EX 1003 ¶¶ 93-95, 133

The necessity of calculating contract force from the vibrating sensor output is built directly into Warren's operating principles. In order for Warren "to maintain a desired force of contact between the dispenser and the substrate," Warren must compare the vibrating force sensor's reading against the desired force. Warren ¶[0289]. To do so, the system must either convert the desired force into vibration amplitude units or convert the sensor's amplitude output into units of force. And Warren consistently teaches comparing the detected contact force intensity to a desired value when determining whether or not to reposition the

'381 Reply pp. 4-5

'381 Pet. pp. 21-23, 33-35

Warren Claims *Obtaining* a Desired Contact Force to Micronewton Precision - Rebuttal

61. The system of claim 54, wherein the position controller varies the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate to obtain a desired force of contact accurate to a precision of micronewtons of force.

EX 1004 Claim 61

72. The method of claim 65, wherein the step of varying varies the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate to obtain a desired force of contact accurate to a precision of micronewtons of force.

EX 1004 Claim 72

'381 Patent [1c] Warren Renders Calculating Contact Force Obvious

FISH.

A POSITA Would Have Been Motivated to Calculate Contact Force to Prevent Destruction of the Dispenser

capabilities. As Warren explains, “for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and surface where deposition is desired.” EX1004, [0286]. “Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the tip crashes into the substrate material, or little to no control of the deposition geometry

'381 EX 1003 ¶ 71 (quoting EX 1004 ¶ [0285])
'381 Pet. pp. 13-14, 22-24

94. Warren also explains the significance “to determine the intensity of contact force between elements” in that a system that “accurately determines the intensity of the contact force between a dispensing tip and a substrate surface” can be provided to further Warren’s objective, namely, “to maintain a desired contact force between the dispenser and the substrate.” EX1004, [0286-287], [0313-0316], FIG. 22A.

'381 EX 1003 ¶ 94
'381 Pet. p. 22-24

A POSITA Would Have Been Motivated to Calculate Contact Force to Prevent Destruction of the Dispenser

the dispenser tip and the surface where deposition is desired. Improper prediction of the intensity of this force may result in either destruction of the dispenser or the substrate as the tip crashes into the substrate material, or little to no control of the deposition geometry due to a large spacing between the tip and the substrate surface.

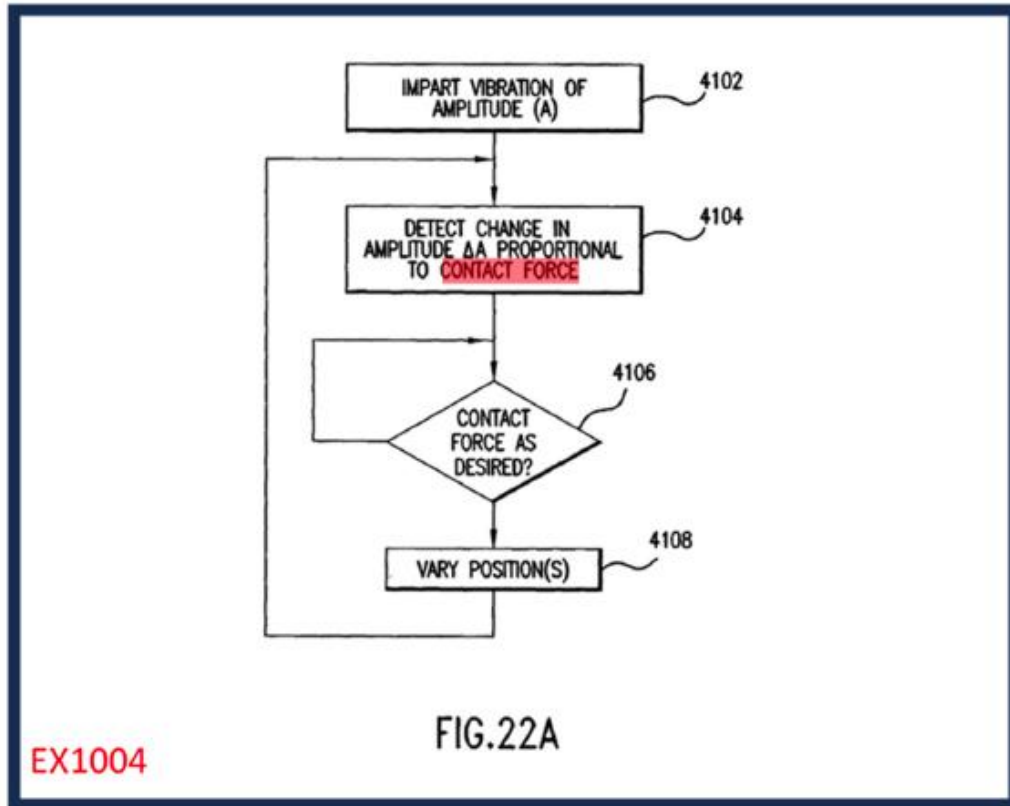
EX 1004 ¶ [0285]
'381 Pet. pp. 22-24
'381 EX 1003 ¶ 95

Warren also explains it is significant “to determine the intensity of contact force between elements” to further Warren’s objective “to maintain a desired contact force between the dispenser and the substrate” and prevent their “destruction.”

EX1004, [0286-287], [0313-0316], FIG. 22A. A POSITA would have known, or

'381 Pet. pp. 22-24
'381 EX 1003 ¶ 95

Warren's Sensor Detects a Change in Amplitude, ΔA , Proportional to Contact Force



'381 EX 1003 ¶ 89
'381 Pet. pp. 20-22

89. Warren further explains that “a change in the amplitude of vibration of the dispenser and/or the substrate is *detected*,” where “this change in amplitude is proportional to the force of contact between the dispenser and the substrate.” *Id.*, [0313] (discussing FIG. 22A (annotated below showing “detect change in amplitude ΔA proportional to contact force”)).

'381 EX 1003 ¶ 89
'381 Pet. pp. 19-22
'381 Reply p. 3

90. In view of the proportionality, calculating contact force is simple, predictable, math. In other words, a POSITA would have understood that the *contact force* can be calculated from the detected “change in the amplitude.” EX1004, [0313]. I have provided additional details of Warren's sensing operations

'381 EX 1003 ¶ 90
'381 Pet. pp. 20-21

Obvious to Compare Values in Force Domain

[0286-287]. Among other reasons, a POSITA would have known that the comparison between the sensor signal and a “desired contact force” requires a conversion of the values to the same domain. Moreover, it was obvious to a POSITA to either compare the values in the force domain or in the sensor domain, and there are advantages of the controller operating in a force, rather than sensor signal, domain. For example, calculating the contact force would facilitate programming Warren’s controller to a desired contact force setpoint because the setpoint used by the controller and the desired contact force would be in the same units (force). Or, if the controller were configured to allow a user to change the setpoint, calculating contact force would facilitate a user’s interaction with the controller. The controller’s settings values could more readily be set, adjusted or displayed in meaningful (to a user) force-based units rather than in values of the proportional signal from Warren’s vibrating force sensor.

'381 EX 1003 ¶ 95
'381 Pet. pp. 22-24

is detected. This change in amplitude is proportional to the force of contact between the dispenser and the substrate. At step 4106, a determination is made whether the contact force is that which is desired, based on the detected change in amplitude. If the contact force is that which is desired, the process may stop, or this step may be repeated to ensure the contact force remains as desired. If at step 4106 it is determined that the contact force is not as desired, the position(s) of the dispenser and/or the substrate are varied at step 4108, causing a change in the amplitude of vibration.

EX 1004 ¶ [0313]
'381 EX 1003 ¶ 95
'381 Pet. pp. 20-21, 23
'381 Reply p. 3-5, 11-12

Intensity Is Magnitude in Newtons

[0316] Control applied in this manner allows for dispensing to be accomplished onto conformal surfaces as the force feedback control continuously corrects the dispensing structure's z-height position as the z height of the substrate surface changes, either by modifying the dispenser's position, the substrate's position, or both. This enables the writing of fine lines, e.g., 20 μm wide, and writing on curved surfaces, e.g., placing electronic elements on a cylinder. Control applied in this manner also enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force, if not smaller units of force, and to break contact on command and find it again. The system has been demonstrated to be sufficiently sensitive to allow for the sensing of the contact force as a dispenser contacts a substrate surface and even as the material protruding from a nozzle on a dispenser contacts the substrate surface.

'381 EX 1004 ¶ [0316]

'381 Pet. pp. 21-24

'381 Reply p. 6-7

'381 EX 1003 ¶ 106

Referring to FIG. 18 (above), a modeled structure (i.e., *an object*) is being built on substrate 3710. EX1003, ¶106; E.g., EX1004, [0295] ("multilayered" structure), [0324] ("four different layers"), [0088], [0093], [0316], [0427]. Warren describes that the vibrating force sensing "enables the dispenser to seek and find contact with a surface, maintain contact of a desirable intensity, accurate to a precision of micronewtons of force." *Id.*, [0316], [0375], [0301-316]. A POSITA

EX 1004 ¶ [0316]

'381 EX 1003 ¶ 95

'381 Pet. pp. 20-27 / '381 Reply p. 6-7

71. As a *fourth* reason, a POSITA would have recognized the benefits of providing an instance of the through-nozzle dispenser with vibrating force sensor capabilities. As Warren explains, "for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and surface where deposition is desired." EX1004, [0286]. "Improper prediction of the intensity of this

'381 EX 1003 ¶ 71

'381 Pet. pp. 13-14

Warren's Expresses a Desire for Accurately Determining Intensity of Contact Force

Warren provides express motivation for detecting the contact force. Warren begins by stating plainly that “for proper deposition some knowledge is required of the intensity of the contact force between the dispenser tip and the surface where deposition is desired.” EX1004 ¶[0285]; Petition 15; EX1003 ¶71. Warren

'381 Reply pp. 6-7
EX 1004 ¶ [0285]
'381 Pet. pp. 13-14

And as discussed above, Warren compares a detected contact force intensity with a desired value for determining whether to reposition the dispenser/substrate, the force intensity being a magnitude component of the force vector quantity measured in Newtons. *E.g.*, EX1004 ¶¶[0313]-[0316] (micronewton precision).

'381 Reply pp. 6-7
EX 1004 ¶¶ [0313]-[0316]
'381 Pet. pp. 26-27

Contact Force Was Readily Calculable from ΔA

of force values from the sensor signals was routine at the time. Indeed, specific conversion operations to calculate the contact force were well-known. *See e.g.*, Matsumiya (EX1012) at [0120-121] (“scanning measuring force”) and [0128-129] (“touch detecting measuring force”) and Igasaki (EX1017) at FIG. 4. Calculating contact force from a sensor intended to produce a signal proportional to contact force was rudimentary engineering and commonplace long before 2012 and would have led to many advantages in a control system designed to “maintain a desired contact

'381 EX 1003 ¶ 95

'381 Pet. pp. 22-24

Obviousness of Calculating Force Is Corroborated

The sensors discussed above are routinely used to measure force and the calculation of force values from the sensor signals was routine at the time. Indeed, specific conversion operations to calculate the contact force were well-known. *See e.g.*, **Matsumiya (EX1012)** at [0120-121] (“scanning measuring force”) and [0128-129] (“touch detecting measuring force”) and **Igasaki (EX1017)** at FIG. 4. Calculating contact force from a sensor intended to produce a signal proportional to contact force was rudimentary engineering and commonplace long before 2012 and would have

'381 EX 1003 ¶ 95
'381 Pet. pp. 22-24

Also contrary to PO's arguments, the evidence shows that calculating contact force from ΔA was common at that time. For example, **Igasaki describes a vibrating force sensor that determines the contact force.** *E.g.*, EX1017 ¶¶ [0006]-[0007] (“135 [μ N] is obtained as measurement force F”). **Matsumiya likewise teaches calculating a “measuring force based on the change in the vibration level.”** EX1012 ¶¶ [0034], [0078]; Petition, 23.

'381 Reply p. 9
EX 1012 ¶¶ [0034], [0078]

Contact Force Was Readily Calculable from ΔA

95. Thus, in my opinion, a POSITA would have known, or found it obvious, that Warren's controller calculates the contact force based on the feedback signal using proportionality and other commonly used sensor conditioning math functions. The sensors discussed above are routinely used to measure force and the calculation of force values from the sensor signals was routine at the time. Indeed, specific conversion operations to calculate the contact force were well-known. See e.g., Matsumiya (EX1012) at [0120-121] ("scanning measuring force") and [0128-129] ("touch detecting measuring force") and Igasaki (EX1017) at FIG. 4. Calculating

'381 EX 1003 ¶ 95

'381 Pet. pp. 22-24

PO Failed to Prove Non-enablement

PO's extended discussion of Young's Modulus and frequency selection to suggest that it is infeasible to calculate force from Warren's vibrating force sensor is a red herring, particularly given Warren's express teaching that the contact force is "proportional" to ΔA and the necessity to compare the "desired force" to the force measured by the vibrating force sensor. "Prior art disclosures are presumed enabling." *Agilent*, 139 F.4th at 1327; *Apple*, 861 F. App'x at 449-50; *Amgen*, 314 F.3d at 1355. The patentee's burden requires evidence that "undue experimentation," *In re Wands*, 858 F.2d at 737, was necessary to practice even "a single embodiment," *In re Morsa*, 803 F.3d 1377, *Raytheon*, 993 F.3d at 1380. Patent Owner fails to surmount this high hurdle.

'381 Reply p. 8

PO's Arguments Support the Obviousness of Calculating Contact Force from ΔA

Even still, PO's infeasibility arguments support, rather than detract from, feasibility. POR, 32 (citing EX2024, FIG. 4.1). PO's own evidence demonstrates that the properties that it says are relevant to calculating force, such as Young's Modulus, were well-known for a wide variety of materials. EX2024, 6-8 (showing Young's Modulus displayed in three different styles of graphical representation to show how material properties can be displayed); EX1042, 80:2-81:6 (can look up modulus for commonly printed materials). A POSITA would simply look up those properties, which reinforces Dr. Wolfe's testimony that "[c]alculating contact force from...a signal proportional to contact force was rudimentary engineering, commonplace and typical long before 2012." EX1003, ¶95; Petition, 23. Warren

'381 Reply pp. 8-9

'381 EX 2024 6-8

'381 EX 1042 80:2-81:6

PO's Expert Testified that Force Is Obtainable Empirically

Warren so teaches. EX2027 ¶0185. Moreover, PO's arguments assume calculating force from first principle calculations, wholly ignoring that the proportionality could be established by measurement and calibration. *See, e.g.*, EX1042, 102:7-103-11 (testifying a force-frequency relationship is obtainable experimentally); 100:13-104:14.

'381 Reply pp. 8-9

'381 EX 1042 102:7-103:11, 100:13-104:14

PO's Expert Testified that Force Is Obtainable from Frequency Through Experimentation

2	And that amount of force is then related because the gap
3	is related to the frequency, so you can have a direct
4	relationship between frequency and load.
5	Q. Okay. How do you -- how do you determine that
6	relationship?
7	A. Experimentally.
8	Q. Okay. So would that be like applying a known
9	force and monitoring the displacement or the re -- the
10	frequency change?
11	A. Correct.
12	Q. Okay. And then based on that, you would know
13	how that particular system reacts; is that right?
14	A. Yes, you would know what force is being
15	applied to on the nozzle.

EX 1042 102:7-103:11
'381 Reply p. 9

PO's Expert Testified that Modulus Is Not Required to Determine Force

3	So you push on the nozzle. You have a force
4	that you know that changes the gap, and so you can
5	relate the force to the change in gap. Or the change in
6	gap changes the frequency. So you apply a force, and
7	you see what the frequency is. You apply another force;
8	you see what the frequency is.
9	And you have now a direct relationship between
10	frequency and force without having to compute any moduli
11	or anything for the system.

*EX 1042 102:7-103:11
'381 Reply p. 9*

PO's Expert Testified that Young's Modulus Is Readily Obtainable

7 Q. So we talked about the modulus for solids.
8 Is that referred to as Young's modulus?
9 A. For some of them, yes. So Young's modulus or
10 elastic modulus is for elastic materials; and, yeah, you
11 can -- there is a modulus or an elastic modulus.
12 Young's modulus is equivalent to that, yes.
13 Q. Okay. And, again, that's something that would
14 have been taught in that kind of more junior level
15 mechanical engineering class?
16 A. Probably sophomore.

EX 1042 70:13-16

13 Q. So the standard -- maybe more standard
14 polymers kind of have that information more readily
15 accessible; is that right?
16 A. More standard polymers have it more
17 accessible. Yeah. Exactly.

EX 1042 77:13-17

14 Q. Okay. So the modulus for some materials are
15 maybe static, but they would vary from material to
16 material; is that right?
17 A. Yes. For elastic materials, correct.
18 Q. And that's something that a practitioner could
19 look up and find what that modulus is for the specific
20 material?
21 A. Yeah, if you have steel or if you have
22 aluminum or those known materials, yeah, they could read
23 it off a handbook or some other system. If you have a
24 new alloy or something you develop, then you need to
25 measure the standard form of measurement.

EX 1042 75:14-25

6 Q. Okay. So the modulus is calculated from
7 empirical tests; is that right?
8 A. Not from tests. From stress/strain tests. I
9 mean, they are all -- they are not really empirical.
10 There is science behind it, so it's not really
11 empirical, so...
12 Q. Okay. But it's from, I guess, physical
13 testing, right?
14 A. Yes.

EX 1042 78:6-14 fr.com | 81

Obviousness of Calculating Force Is Corroborated by Warren

61. The system of claim 54, wherein the position controller varies the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate to obtain a desired force of contact accurate to a precision of micronewtons of force.

EX 1004 Claim 61

72. The method of claim 65, wherein the step of varying varies the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate to obtain a desired force of contact accurate to a precision of micronewtons of force.

EX 1004 Claim 72

'698 Patent Ground 1A Warren Renders Claim 2 Obvious

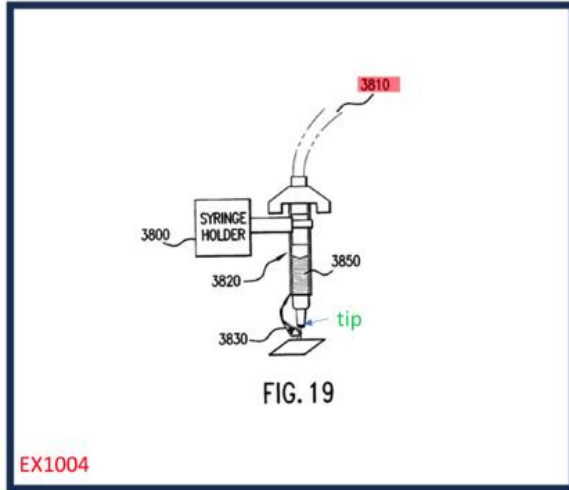
FISH.

Warren Teaches an Extruder -- Undisputed

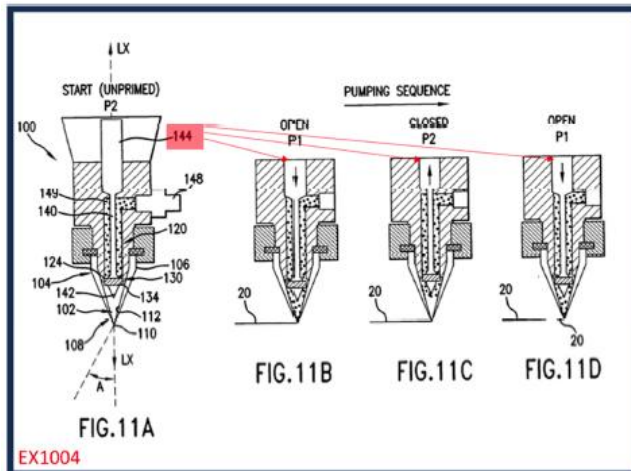
'698 Patent Claim 2

2. The method of claim 1, wherein the fabrication tool includes an extruder.

Warren's Capillary Vibro-sensor and Through-Nozzle Dispenser Are Extruders



'698 EX 1003 ¶ 48
'698 Pet. pp. 10-11



'698 EX 1003 ¶ 49
'698 Pet. pp. 11-12

95. The capillary vibro-sensor dispensing unit is *an extruder* because it “forces, e.g., fluid or paste, in a reservoir 3850 through the tip 3840 of a syringe using air pressure applied from a source 3810.” EX1004, [0295], [0299], FIGS 18-20A, 20B.

96. The through-nozzle dispenser is likewise *an extruder* because it features a “positive-displacement/suck-back pump system,” where “the pump 148 powers a simple process of applying positive pressure to a material in a reservoir 149, and the flow of material is controlled by adjusting the open position P1 and closed position P2 of the valve 130.” EX1004, [0232]; *see also generally* [0230-0252], FIGS. 11A-12B. The “valve 130 includes a linear-actuated piston 140..., the

'698 EX 1003 ¶¶ 95-96
'698 Pet. pp. 23-25

PO Recognizes that Warren Teaches an Extruder

First, Warren already discloses his solution for avoiding damage to the extruder tip by using vibration sensing. *See, e.g.* EX1004, [0293-95] (following curved irregular or curved surfaces by varying the position of the dispenser and

'698 POR p. 44

PO Does Not Offer Technical Arguments for Claim 2

D. Ground 1A Does Not Render Claims 2-6, 8-15 Unpatentable

Because claims 2-6 and 8-15 depend from claim 1, for at least the reasons provided above for claim 1, Ground 1A does not render claims 2-6 and 8-15 obvious. *See* EX2027, ¶192.

'698 EX 1003 ¶ 124

'698 Pet. pp. 31-32

'698 Reply pp. 11-12

'698 Patent Ground 1A Warren Renders Claim 9 Obvious

FISH.

Warren Renders Claim 9 Obvious

'698 Patent Dependent Claims

2. The method of claim 1, wherein the fabrication tool includes an extruder.



9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.

Warren Controls Material Dispensing Rate

supra claims 1-2, Warren's processor provides instances of control signal to drive components of the material dispensing system including a linear actuator, which "controls the material dispensing rate." *Id.*, [0243] (explaining "the motion of the piston 140 transfers a momentum to the material and causes the material to flow at a specific flow rate"), [0239] (discussing "valve position control ... to control the amount of material dispensed per second"), [0234], [0255], FIGS. 11A-11C, and 12A-12B. In the context of Warren's "force feedback control" that "enables the

'698 EX 1003 ¶ 120
'698 Pet. p. 31

12A-12B. In the context of Warren's "force feedback control" that "enables the dispenser to seek and find contact with a surface," dispense on "conformal surfaces," and identify "trouble spots" having "too much material," a POSITA would have known that the linear actuator regulates the dispensing rate of material from the dispenser to control the amount of material fed to the nozzle tip per second (i.e., *feed rate of build material extruded by the extruder*) so that Warren's dispenser "maintains contact of a desirable intensity." *Id.* [0316], [0234] ("flow characteristic upon leaving the tip orifice 110"); *supra* claim 3.

'698 EX 1003 ¶ 120
'698 Pet. p. 31

Warren Teaches a Linear Actuator to Control Feed Rate

[0243] In this embodiment, the linear actuator 144 controls the material dispensing rate and improves start and stop characteristics by controlling the position of the valve piston 140 and speed of displacement. During the initial valve opening, the motion of the piston 140 transfers a momentum to the material and causes the material to flow at a specific flow rate. This transfer of momentum primes the material in the tip chamber 102, so that the material flowing through the valve 130 will have the same flow velocity, thereby leading to a smooth dispensing start. In conditions where the displacement is too fast, the material may be ejected without any control, which may lead to poor start characteristics (e.g., splashing, puddle formation, and voids). In conditions where the displacement is too slow, the material may be dispensed with some control, but may not have a steady-state flow characteristic upon leaving the tip orifice 110, which can lead to inconsistent volumes and inaccurate starting times. Through precise rate control of the piston opening, the initiation of material flow followed by valve opening can be smooth, seamless, and very reproducible.

EX 1004 ¶ [0243]

'698 EX 1003 ¶ 120

'698 Pet. p. 31

Claim 9 Does Not Link Feed Rate to Contact Force

EX1001, cl.1. Claim 9 merely recites that the control signal “includes” a signal to change the feed rate, without linking this signal back to the contact force. That is, the control signal of claim 1 can include other signals that are not in response to the contact force—in this case the feed rate. Generally, Warren’s control signal controls both the feed rate and the xyz motion of the dispenser based on contact force, as discussed in the Petition. *E.g.*, Petition, 25-26, 31; EX1004 ¶¶[0243], [0239], [0234], [0255]; EX1003 ¶¶119-121.

'698 Reply pp. 9-10

Warren's Claims Prove Obviousness of a Sensor with the Through-Nozzle Extruder

54. A system for controlling the position of at least one element of a dispensing system including at least one dispenser and at least one substrate, the system comprising:

a vibration imparting device for imparting vibration of a particular amplitude to the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate;

a detector for detecting a change in the amplitude of vibration of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate upon contact with each other; and

a position controller for varying the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate based on the detected change in amplitude of vibration to obtain a desired force of contact between the at least one dispenser and the at least one substrate.

EX 1004 Claim 54
'698 Reply p. 2

59. The system of claim 54, wherein the at least one dispenser includes at least one of a through-nozzle, a needle valve, a capillary pen, or a quill pen.

70. The method of claim 65, wherein the at least one dispenser includes at least one of a through-nozzle, a needle valve, a capillary pen, or a quill pen.

EX 1004 Claims 59 and 70
'698 Reply p. 2

'698 Patent Ground 1A Warren Renders Claim 10 Obvious

FISH.

Warren Renders Detecting a Planarity Obvious

'698 Patent Claim 10

2. The method of claim 1, wherein the fabrication tool includes an extruder.



10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.

Warren Teaches Continuously Detecting a Z-height of the Substrate

124. As Warren explains, control based on continuously detecting contact force “allows for dispensing to be accomplished onto conformal surfaces as the force feedback control continuously corrects for dispensing structure’s z-height position as the height of the substrate surfaces changes.” EX1004, [0316]. [0293]. As I have explained above under Element [1.b], Warren describes its force sensing mechanism at e.g., [0301-0304] and FIG. 22A.

'698 EX 1003 ¶ 124

'698 Petition pp. 31-32

'698 Reply pp. 11-12

Obvious From Warren to Detect Planarity

Detecting Planarity Before Printing

126. A POSITA would have found it obvious to apply Warren's force sensing to determine surface planarity as part of a calibration procedure before printing an object. Indeed, a POSITA would have been motivated by known benefits and advantages of the calibration procedure including, e.g., obtaining "spatial relationship between the extrusion tip and the substrate prior to building" in order to "build accurate error-free models." See e.g., EX1007 ("Dunn"), [0006], [0052-54].

'698 EX 1003 ¶ 126

'698 Pet. pp. 31-32

'698 Reply pp. 11-12

Petitioner's Mapping Does Not Implicate a Claim Construction

10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.

EX 1001, claim 10

Note that the claims do not require a determination of a level or measurement of planarity. The claims only require that planarity be detected. Warren satisfies claim

'698 Reply p. 11

Patent Owner Did Not Advance a Construction of Claim 10

IV. CLAIM CONSTRUCTION

For the purposes of this Response, Patent Owner submits that the Board does not need to construe any claim terms in any particular way to conclude that the challenged claims are not unpatentable. *See Wellman, Inc. v. Eastman Chem.*

POR pp. 8-9

10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.

EX 1001, claim 10

Supra Section VII.E. Warren also does not teach making a number of contact force measurements that collectively form the basis for detecting planarity. Rather,

POR p. 91

Rebuttal – Warren Claims Mapping the Surface

Second, Warren does not teach detecting planarity before printing. Petitioner and its expert resort to hindsight bias to assert it would be obvious to apply “Warren’s force sensing to determine surface planarity as part of a calibration procedure.” *See* Pet. at 33 (EX1003, ¶¶126-27). Warren does not teach any calibration procedure involving his vibration sensing solution. *See generally*

’698 POR p. 39

detecting planarity. EX2027, ¶216. That is, what Warren detects is for a given point and not across a surface for a plane. *See* POR, 39.

’698 Sur-reply p. 11

63. The system of claim 54, wherein the system controls the position of at least one element of the dispensing system for mapping the surface of the at least one substrate, prior to dispensing.

74. The method of claim 65, wherein one or more of the steps are performed for mapping the surface of the substrate, prior to dispensing.

EX 1004 claims 63, 74

'698 Patent Ground 1B Warren + Eshed Renders Claim 9 Obvious

FISH.

Warren-Eshed Combination Renders Claim 9 Obvious

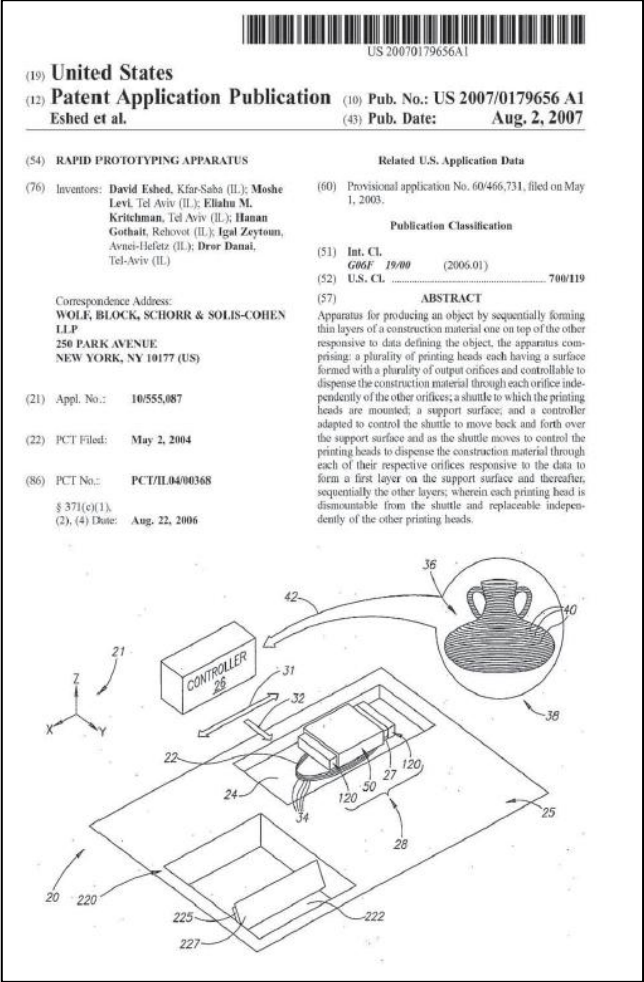
'698 Patent Dependent Claims

2. The method of claim 1, wherein the fabrication tool includes an extruder.



9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.

Overview of Eshed – 698 EX 1008



EX 1008, Face

FIELD OF THE INVENTION

[0002] The present invention relates to apparatus, hereinafter “rapid production apparatus”, for producing a 3-dimensional object by sequentially forming thin layers of material one on top of the other, responsive to data defining the object.

EX 1008 ¶ [0002]

[0180] Optionally, in accordance with an embodiment of the invention, an RPA comprises a collision detection system for detecting if and when the RPA's shuttle collides with an obstacle. Upon occurrence of a collision, controller 26 optionally stops production of an object and generates an alarm to alert a user that a collision has occurred and that his or her intervention is require.

EX 1008 ¶ [0180]

Obvious to Combine Warren and Eshed

146. In my opinion, a POSITA would have been motivated to safeguard operation of the three-dimensional printer by comparing the current contact force and the expected contact force, as taught in Warren, and stopping production when

'698 EX 1003 ¶¶ 146-147
'698 Pet. pp. 38-40

147. First, a POSITA would have known the desirability of preventing further damage to the extruder tip and the build structure being constructed. Here, once a collision has occurred, continuing the build can cause further damage to both. Second, a POSITA would have been prompted by operational efficiency—once a collision has occurred, the build structure can be damaged beyond repair. Hence, there is no point to continue the build, as it may not result in a usable ETC. Third, Warren already suggests “destruction of the dispenser or the substrate as the tip crashes into the substrate material,” (EX1004, [0285]), which would have prompted a POSITA to look for complementary teachings from references like Eshed that explain what to do in those scenarios--i.e., shut the system down and output an error message.

Patent Owner Does Not Address Collisions

First, Warren already discloses his solution for avoiding damage to the extruder tip by using vibration sensing. *See, e.g.* EX1004, [0293-95] (following curved irregular or curved surfaces by varying the position of the dispenser and using vibration sensing). As such, a POSITA would not have desired to prevent

'698 POR p. 44

incorporation. POR, 44-45; Petition, 38-40. Notably, the Response asserted that Warren already avoids damage and thus “a POSITA would not have desired to prevent further damage” by looking to Eshed. POR, 44; EX2027; ¶¶230-231.

'698 Sur-reply p. 12

Petitioner Did Not Argue Bodily Incorporation

collisions. *See, e.g.*, EX1008, ¶¶[0181-182]. There is no teaching in Warren of how to adapt his vibration sensing teachings to Eshed's accelerometer or audio detection systems. EX2027, ¶233. Nor would a POSITA have understood such a

'698 POR p. 45

VII. GROUND 1B RENDERS 3, 7, AND 9 UNPATENTABLE

The Petition is not advancing bodily incorporation of Eshed's system into Warren's. Instead, Eshed's teachings about stopping production when a fabrication error, such as a collision, is detected enhance the combination. Petition, 37-42; EX1008 ¶[0171]; EX1003 ¶¶144-157. Dr. Wolfe explained that a POSITA would have considered destruction of the dispenser or substrate to constitute a fabrication error such that production should be terminated. EX1003 ¶¶144-145. Thus, a POSITA would have found it obvious to detect a fabrication error and terminate the build based on collisions determined from the contact force comparison technique taught by Warren. EX1003 ¶¶144-145.

Warren-Eshed Renders Claim 9 Obvious

156. Each and every element of claims 1, and 2 is obvious as explained above. In the Warren-Eshed Combination, a POSITA would have understood or found it obvious that when “[u]pon occurrence of a collision, controller...stops production of the object” the controller would stop the feed of material as part of stopping production. Thus, creating a control signal to stop production based on the measured contact force indicating a fabrication error, e.g., collision, provides the claimed *control signal that includes a signal...to change a feed rate of build material extruded by the extruder.*

'698 EX 1003 ¶ 156
'698 Pet. pp. 37-38
'698 Reply p. 12

Patent Owner Does Not Dispute Eshed's Teachings

For claims 3 and 9, Petitioner asserts creating a control signal to stop production based on the measured contact force indicating a fabrication error. *See* Pet. 40-41, 41-42. However, as discussed above for claim 5, Warren does not teach measuring a contact force. *Supra* Section VI.F (claims 5 and 6 for Ground 1A (Warren)); *see also* EX1004, ¶¶[0289], [0313], [0305], [0316]; EX2027, ¶¶240, 206-211 (explaining that Warren teaches looking for a change in amplitude that indicates the desired contact force). Thus, stopping production cannot be based on the measured contact force as Petitioner asserts for claims 3 and 9.

'698 POR p. 46

incorporation. POR, 44-45; Petition, 38-40. Notably, the Response asserted that Warren already avoids damage and thus “a POSITA would not have desired to prevent further damage” by looking to Eshed. POR, 44; EX2027; ¶¶230-231. Petitioner merely repeats Dr. Wolfe’s conclusory assertions without addressing this deficiency in the combination.

'698 Sur-reply p. 12

'381 Patent Ground 1A Warren Renders Claim 11 Obvious

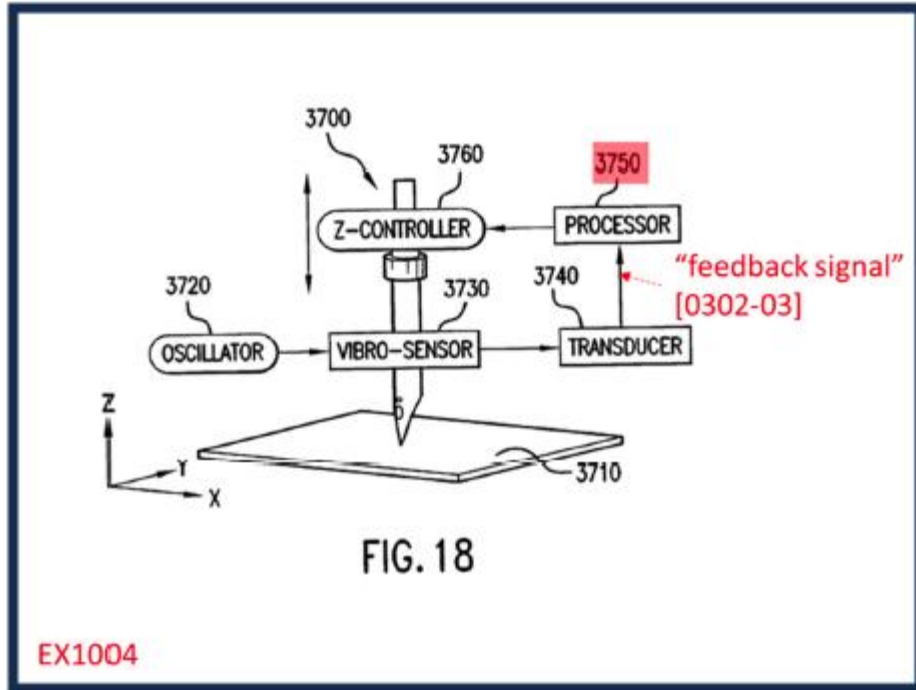
FISH.

'381 Patent Claim 11

'381 Patent Dependent Claims

11. The three-dimensional printer of claim 1, further comprising:
one or more actuators mechanically coupled to the fabrication tool, and
a control circuit in data communication with the one or more actuators and the one or more sensors, the control circuit configured to control the one or more actuators to achieve a specified contact force between the one or more sensors and the separate structure.

Warren Renders Claim 11 Obvious

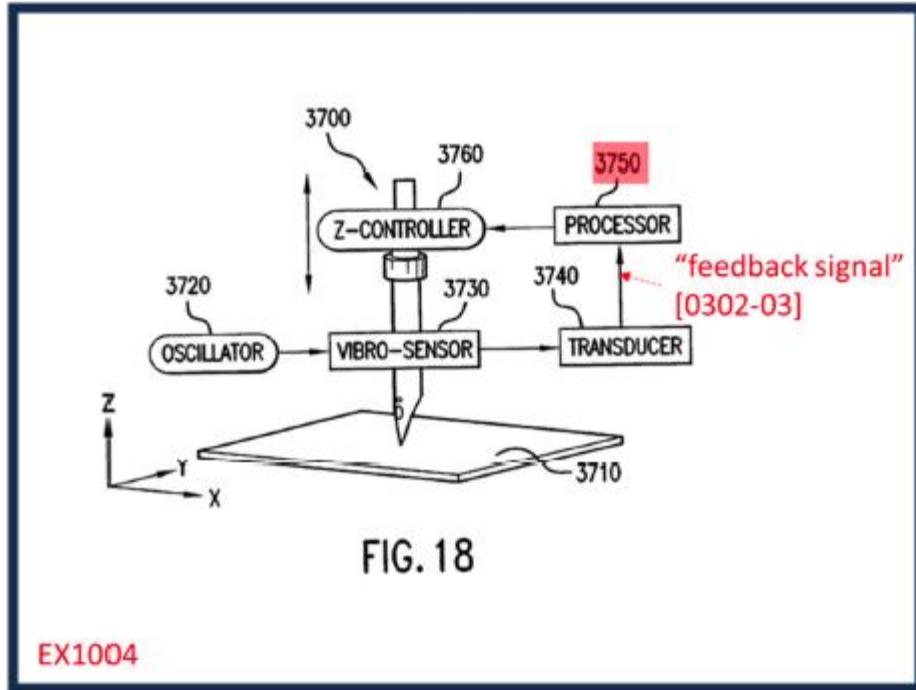


'381 EX 1003 ¶ 126
'381 Pet. p. 31

126. Warren makes clear that its feedback signal is used by “a z-controller processor 3750 to *control* the z positioning of the dispenser 3700 via a z-controller step motor 3760” (i.e., *the one or more actuators*) so as “to maintain a desire force contact [i.e., *a specified contact force*] between the dispenser 3700 [where *the one or more sensors* are located] and the substrate 3710 [included by *the separate structure*]”). *Id.*, [0302].

'381 EX 1003 ¶¶ 123-127
'381 Pet. pp. 22-23, 30-33

Warren Repeatedly Calls for Maintaining a Desired Contact Force



'381 EX 1003 ¶ 126
'381 Pet. p. 31

126. Warren makes clear that its feedback signal is used by “a z-controller processor 3750 to *control* the z positioning of the dispenser 3700 via a z-controller step motor 3760” (i.e., *the one or more actuators*) so as “to maintain a desire force contact [i.e., *a specified contact force*] between the dispenser 3700 [where *the one or more sensors* are located] and the substrate 3710 [included by *the separate structure*]”). *Id.*, [0302].

'381 EX 1003 ¶¶ 123-127
'381 Pet. pp. 31-33

Warren Repeatedly Calls for Determining Contact Force and Maintaining a Desired Contact Force

Warren also explains it is significant “to determine the intensity of contact force between elements” to further Warren’s objective “to maintain a desired contact force between the dispenser and the substrate” and prevent their “destruction.” EX1004, [0286-287], [0313-0316], FIG. 22A. A POSITA would have known, or found it obvious, that Warren’s controller calculates the contact force based on the feedback signal using the proportionality. EX1003, ¶94 (noting the well-known conversion); *E.g.*, EX1012, [0120-121] (“scanning measuring force”), [0128-129] (“touch detecting measuring force”), and EX1017, FIG. 4. Calculating contact force

’381 Pet. p. 23

’381 EX 1003 ¶ 94

force). Warren teaches that “a determination is made whether the contact force is that which is desired.” Warren ¶[0313]. If so, the process may stop; if the contact force is not as desired, “the position(s) of the dispenser and/or substrate are varied.” Warren ¶[0313]; EX1003 ¶¶122-128. Thus, in Warren, the control of the dispenser/substrate achieves a specified (“desired”) contact force. EX1003 ¶¶122-128.

’381 Reply pp. 11-12

Warren Compares Calculated Force with a Desired Force

is detected. This change in amplitude is proportional to the force of contact between the dispenser and the substrate. At step 4106, a determination is made whether the contact force is that which is desired, based on the detected change in amplitude. If the contact force is that which is desired, the process may stop, or this step may be repeated to ensure the contact force remains as desired. If at step 4106 it is determined that the contact force is not as desired, the position(s) of the dispenser and/or the substrate are varied at step 4108, causing a change in the amplitude of vibration.

EX 1004 ¶ [0313]

'381 Pet. pp.

'381 Reply p. 11-12

'381 EX 1003 ¶¶ 131-132

C. Ground 1A Renders Claim 11 Unpatentable

Warren compares the calculated contact force intensity to a desired value when determining whether or not to reposition the dispenser or substrate. *E.g.*, Warren ¶¶[0313]-[0316] (discussing comparing calculated force with a desired force). Warren teaches that “a determination is made whether the contact force is that which is desired.” Warren ¶[0313]. If so, the process may stop; if the contact force is not as desired, “the position(s) of the dispenser and/or substrate are varied.” Warren ¶[0313]; EX1003 ¶¶122-128. Thus, in Warren, the control of the dispenser/substrate achieves a specified (“desired”) contact force. EX1003 ¶¶122-128.

'381 Reply pp. 11-12

381 EX 1003 ¶¶ 131-132

Rebuttal – Warren Controls the Dispenser to Obtain a Desired Contact Force in MicroNewtons

61. The system of claim 54, wherein the position controller varies the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate to obtain a desired force of contact accurate to a precision of micronewtons of force.

72. The method of claim 65, wherein the step of varying varies the position of the at least one dispenser, the at least one substrate, or both the at least one dispenser and the at least one substrate to obtain a desired force of contact accurate to a precision of micronewtons of force.

EX 1004 Claims 61, 72

Calderon + RepRap Grounds

'698 Grounds 2A & 2B

'381 Grounds 2A & 2B

FISH.

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

Calderon + RepRap Application to the '698 Claims

Claim 1		Slide
[1pre]	A method comprising:	Undisputed
[1a]	identifying build instructions for fabricating an object;	
[1b]	initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;	
[1c]	detecting the current contact force based on a sensor signal from the one or more sensors; and	
[1d]	creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.	

Calderon + RepRap Application to the '381 Claims

Claim 1		Slide
[1pre]	1. A three-dimensional printer comprising:	Undisputed
[1a]	a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;	Undisputed
[1b]	one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and	
[1c]	a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.	

EX 1009, front page

fr.com | 119

EX 1010, p. 1

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

EX 1010, p. 13

'698 EX 1003 ¶ 52/'381 EX 1003 ¶ 63
'698 Pet. pp. 46-47/'381 Pet. pp. 46-48

RepRap is a Printed Publication

FISH.

RepRap Had 1,000 Monthly POSITA Users Thread Was Found by POSITA

Contributions from 9 different participants, many not involved in initial Genetic Algorithms discussion

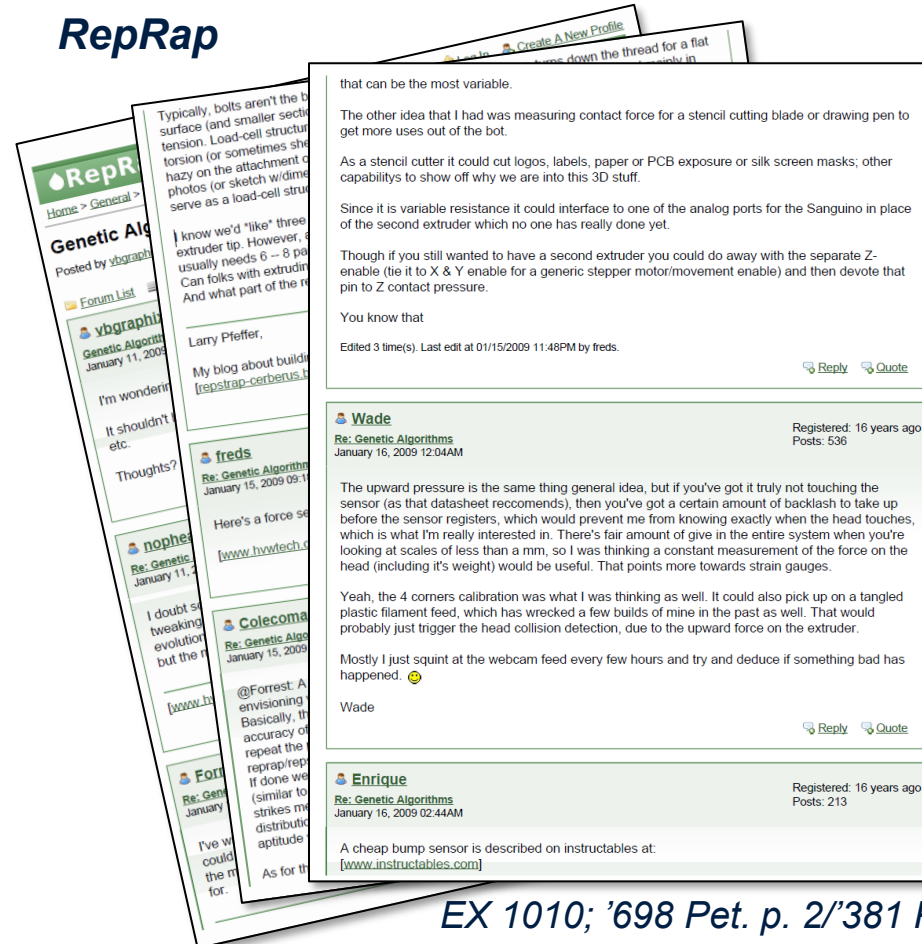
DECLARATION OF ADRIAN BOWYER

4. Persons interested in 3D printing and rapid prototyping, both professionals and hobbyists, would have been aware of RepRap.org. RepRap.org hosts public forums in which community members can discuss topics relevant to the RepRap Project, and the 3D printing and rapid prototyping community, or anyone who visited the site, would have also known of the forums. From the origination of the project onward, the RepRap Project and the site, including the forums, were often discussed in various print and web media and on social media. I, and the others involved in the project, actively worked to raise awareness of the project and site in the 3D printing community and beyond, because we believed that the project would benefit from active involvement by many interested persons. During my time as an administrator, RepRap.org had around 1,000 regular monthly users with many more users occasionally visiting or interacting with the website and public forums. Professionals, hobbyists and others would have known to, and did, visit the forums to interact with like-minded persons. The forums allowed (and still allow) people to pose questions, provide helpful suggestions, update others on new developments, and generally share knowledge and information regarding development of RepRap machines and 3D printing in general.

EX 1014 ¶ 4; '698 Pet. p. 2/'381 Pet. p. 2

FISH.

RepRap



*EX 1010; '698 Pet. p. 2/'381 Pet. p. 2
'698 Reply pp. 26-27;/381 Reply pp. 27-28*

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

fr.com | 122

RepRap Forum Was Cited By '698/'381 Inventors

(12) United States Patent Kemperle et al.		(10) Patent No.: US 9,168,698 B2
		(45) Date of Patent: Oct. 27, 2015
(54) THREE-DIMENSIONAL PRINTER WITH FORCE DETECTION	47/0866 (2013.01); B29C 2947/9258 (2013.01); B29C 2947/92704 (2013.01)	
(71) Applicant: MakerBot Industries, LLC , Brooklyn, NY (US)	(58) Field of Classification Search	
(72) Inventors: Aljosa Kemperle , Brooklyn, NY (US); Filipp Gelman , Staten Island, NY (US); Peter Joseph Schmehl , New York, NY (US)	CPC B29C 67/0055; B29K 2995/0073 USPC 264/129, 176.1, 40.1, 40.7, 308, 113, 264/401, 497; 425/145, 150, 375, 112, 113, 425/174.4, 185, 186; 700/118, 119, 120; 226/8, 24, 26, 42, 43, 45 See application file for complete search history.	
(73) Assignee: MakerBot Industries, LLC , Brooklyn, NY (US)	(56) References Cited	
(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 101 days.	U.S. PATENT DOCUMENTS 5,303,141 A 4/1994 Batchelder et al. 6,129,872 A * 10/2000 Jang 264/75 6,629,011 B1 9/2003 Calderon et al. 7,625,198 B2 * 12/2009 Lipson et al. 425/174	
(21) Appl. No.: 14/065,516	OTHER PUBLICATIONS	
(22) Filed: Oct. 29, 2013	"Touch Sensor and Automated Calibration", by Assargadon— http://forums.reprap.org/read.php?1,8028 , NPL-81, Jan. 4, 2008, 14 pages.	
(65) Prior Publication Data	"HydraRaptor", http://hydraraptor.blogspot.com/2011/04/auto-z-probe.html , NPL-80, Apr. 4, 2011, 12 pages.	
US 2014/0117575 A1 May 1, 2014	"Automated Bed Leveling With Our 3D Printer", by Brian Benchoff— http://hackaday.com/2012/04/23/automated-bed-leveling-with-our-3d-printer/ , NPL-79, Apr. 23, 2012, 5 pages.	
Related U.S. Application Data	* cited by examiner	
(60) Provisional application No. 61/719,874, filed on Oct. 29, 2012.	<i>Primary Examiner</i> — Joseph S Del Sole <i>Assistant Examiner</i> — Thukhanh T Nguyen	
(51) Int. Cl.	(74) <i>Attorney, Agent, or Firm</i> — Strategic Patents, P.C.	
B29C 41/22 (2006.01)	(57) ABSTRACT	
B29C 41/52 (2006.01)	An extruder or other tool head of a three-dimensional printer is instrumented to detect contact force against the extruder, such as by a build platform or an object being fabricated. The tool head may also be instrumented to detect deflection forces and the like acting on the tool that might indicate an operating error. The resulting feedback data can be used in a variety of ways to control operation of the three-dimensional printer during fabrication or diagnostics.	
B29C 67/00 (2006.01)		
B29C 47/92 (2006.01)		
B29C 47/08 (2006.01)		
B29C 47/02 (2006.01)		
B29C 47/00 (2006.01)		
(52) U.S. Cl.	15 Claims, 5 Drawing Sheets	
CPC B29C 67/0055 (2013.01); B29C 47/025 (2013.01); B29C 47/0822 (2013.01); B29C 47/92 (2013.01); B29C 67/0051 (2013.01); B29C 67/0088 (2013.01); B29C 47/0002 (2013.01); B29C 47/0864 (2013.01); B29C		

'698 EX 1001, front page
'698 Pet. p. 2

(12) United States Patent Kemperle et al.		(10) Patent No.: US 10,556,381 B2
		(45) Date of Patent: Feb. 11, 2020
(54) THREE-DIMENSIONAL PRINTER WITH FORCE DETECTION	48/265 (2019.02); B29C 48/266 (2019.02); B29C 2948/9258 (2019.02); B29C 2948/92704 (2019.02);	
(71) Applicant: MakerBot Industries, LLC , Brooklyn, NY (US)	(Continued)	
(72) Inventors: Aljosa Kemperle , Brooklyn, NY (US); Filipp Gelman , Staten Island, NY (US); Peter Joseph Schmehl , Brooklyn, NY (US)	(58) Field of Classification Search	
(73) Assignee: MakerBot Industries, LLC , Brooklyn, NY (US)	CPC B29C 43/08; B29C 43/58; B29C 43/5808; B29C 43/5816; B29C 43/5833; B29C 43/5875; B29C 64/20; B29C 64/393; B33Y 40/00; B33Y 50/00; B33Y 50/02 USPC 425/143, 170-171, 78, 344-345; 700/197, 206; 141/71, 74, 78 See application file for complete search history.	
(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1002 days.	(56) References Cited	
(21) Appl. No.: 14/922,267	U.S. PATENT DOCUMENTS 5,303,141 A 4/1994 Batchelder et al. 6,129,872 A 10/2000 Jang (Continued)	
(22) Filed: Oct. 26, 2015	OTHER PUBLICATIONS	
(65) Prior Publication Data	"Touch Sensor and Automated Calibration", by Assargadon— http://forums.reprap.org/read.php?1,8028 , Jan. 4, 2008, 14 pages.	
US 2016/0039150 A1 Feb. 11, 2016	(Continued)	
Related U.S. Application Data	<i>Primary Examiner</i> — Joseph S Del Sole <i>Assistant Examiner</i> — Thu Khanh T Nguyen	
(63) Continuation of application No. 14/065,516, filed on Oct. 29, 2013, now Pat. No. 9,168,698.	(74) <i>Attorney, Agent, or Firm</i> — Strategic Patents, P.C.	
(51) Int. Cl.	(57) ABSTRACT	
B29C 41/22 (2006.01)	An extruder or other tool head of a three-dimensional printer is instrumented to detect contact force against the extruder, such as by a build platform or an object being fabricated. The tool head may also be instrumented to detect deflection forces and the like acting on the tool that might indicate an operating error. The resulting feedback data can be used in a variety of ways to control operation of the three-dimensional printer during fabrication or diagnostics.	
B29C 41/52 (2006.01)		
(52) U.S. Cl.	16 Claims, 5 Drawing Sheets	
CPC B29C 64/205 (2017.08); B29C 48/154 (2019.02); B29C 48/92 (2019.02); B29C 64/106 (2017.08); B29C 64/209 (2017.08); B29C 64/386 (2017.08); B29C 64/40 (2017.08); B33Y 30/00 (2014.12); B33Y 50/02 (2014.12); B29C 48/02 (2019.02); B29C		

'381 EX 1001, front page
'381 Pet. p. 2

Relevant Posts Public in 2009

DECLARATION OF ADRIAN BOWYER

5. The forms were intentionally accessible to the public. No login was required to view these forums. Registered users can start, or “post,” forum discussion threads and other registered users can post to those discussion threads. The forum software automatically appends a header to each post. The header includes the poster’s user name, the thread title and the date and time the post was made. That date and time is persistent, remaining in the header of the post and unchangeable as long as the post is accessible on the site. All timings are registered in Eastern Standard Time, five hours behind Coordinated Universal Time (UTC). A user can edit his or her own post, but the original header remains unchanged. Instead, when a post is edited, the forum software appends information at the bottom of the post including a label indicating that the post was edited and the date and time the post was edited. If a post has been edited more

<https://reprap.org/forum/read.php?1,20208,page=1> and confirmed that it matches Exhibit A. The first eight posts in this thread have been publicly available, in the form they appear in Exhibit A, since January 11, 2009. The last post in this thread has been publicly available, in the form it appears in Exhibit A, since January 15, 2009. Interested members of the public would have been able to locate the discussion thread by clicking through to the relevant forum or through keyword searching based on the relevant terms that appear in this thread. In the relevant time, we had many regular readers who would have seen, and likely read, the discussion thread when it was posted and as additional posts were added.

FISH.

EX 1014 ¶ 5 and 7
'698 Pet. p. 2/'381 Pet. p. 2

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

RepRap

 **Wade**
Re: Genetic Algorithms
January 14, 2009 04:10PM
Registered: 16 years ago
Posts: 536

Hm, I don't look forward to trying to code up a vision system from scratch....

but, an accelerometer on the write head might be useful. Keep an eye on the RMS power of the vibration the head experiences; that might be able to detect the next time I have an all-night long series of head collisions due to a bad programming job.

A strain gauge on the extruder mount would do that as well, and it could do a few other things as well, like finding the bed height automatically. Could take some time though.

Wade

 Reply  Quote

 **Wade**
Re: Genetic Algorithms
January 16, 2009 12:04AM
Registered: 16 years ago
Posts: 536

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's weight) would be useful. That points more towards strain gauges.

Yeah, the 4 corners calibration was what I was thinking as well. It could also pick up on a tangled plastic filament feed, which has wrecked a few builds of mine in the past as well. That would probably just trigger the head collision detection, due to the upward force on the extruder.

Mostly I just squint at the webcam feed every few hours and try and deduce if something bad has happened. 😊

Wade

 Reply  Quote

EX 1010 p. 13, 20
'698 Pet. pp. 46-47/'381 Pet. pp. 45-46

POSITA Could Navigate to Forums in 2009

DECLARATION OF ADRIAN BOWYER

a header to each post. The header includes the poster's user name, the thread title and the date and time the post was made. That date and time is persistent, remaining in the header of the post and unchangeable as long as the post is accessible on the site. All timings are registered in Eastern Standard Time, five hours behind Coordinated Universal Time (UTC). A user can edit

EX 1014 ¶ 5
'698 Pet. p. 2/381 Pet. p. 2

and confirmed that the records match Exhibits B1 to B4. Together, Exhibits B1 to B4 demonstrate an example of how one would navigate from RepRap.org to a post in a forum that would have contained the thread from Exhibit A. As annotated below, a user can click the "User

EX 1014 ¶ 8
'698 Pet. p. 2/381 Pet. p. 2

thread. By automatically promoting active threads, interested users and members of the public had multiple opportunities to see, read and potentially post to each discussion thread. Although Exhibit B-3 shows the Mechanics forum, the forum software works the same for the other forums. Thus, they are similarly organized.

EX 1014 ¶ 10
'698 Pet. p. 2/381 Pet. p. 2



RepRap

The Wayback Machine - <https://web.archive.org/web/20081216112729/http://www.reprap.org:80/bin/view/Main/...>

RepRap "Wealth without money..." Jump:

RepRap Home
What can it make?
One page description
Future Plans
Main Blog

Documentation
Make your own RepRap
Using your RepRap
Software
Obtaining Parts
RepStrap machines
Videos / Movies

Community
User Forums
Builder's Wiki
Builder's Blog
Object Library
The People
World RepRap map
Related Sites

Background
Press
Philosophy
Acknowledgments
T-shirts, mugs etc.
GPL Licence

Support this project

Edit Attach Printable Main.WebHome: r1.161 - 12 Dec 2008 - 16:12 - [AdrianBowyer](#) [topic end](#)

RepRap machine makes beer! See the main and builders' blogs for more news.

[Sale of replicated machine](#)

Wade Bortz writes: Thanks to all the awesome work of the entire [RepRap](#) team, I sold my first set of second generation [RepRap](#) parts today, for the grand sum of one case of Upper Canada Dark Ale! Here's the shot - the proud new owners of the [RepRap](#) parts are (left to right) Liav Koren and Michael Bartosik, of Toronto, Ontario, Canada. I'm on the right, proudly clutching my well earned case of beer!
30 November 2008

"Think of RepRap as a China on your desktop."
- Chris DiBona, Open Source Programs Manager, Google Inc., 8 April 2008.

"The promise of advanced fabrication technology that can copy itself is a truly remarkable concept with far reaching implications."
- Sir James Dyson, 17 April 2007.

"[RepRap] has been called the invention that will bring down global capitalism, start a second industrial revolution and save the environment..."
- The front page of [The Guardian](#), November 25, 2006.

Exhibit B-1 to EX 1014 (as annotated ¶ 8)
'698 Pet. p. 2/381 Pet. p. 2
'698 Reply p. 28/381 Reply p. 29

Entire Text of Forums Were Keyword Searchable

Patent Owner declined to depose RepRap founder and forum moderator Dr. Bowyer. Dr. Bowyer's testimony is undisputed.

DECLARATION OF ADRIAN BOWYER

thread identifies the forum that it was posted into. Additionally, the forums were (and still are) fully keyword searchable, allowing users to search for and readily identify relevant discussion threads. The search functionality allowed users to search for posts based on the author, the headings and the content of the posts.

*EX 1014 ¶ 6; '698 Pet. p. 2/'381 Pet. p. 2
'698 Reply p. 26/'381 Reply p. 27*

since January 11, 2009. The last post in this thread has been publicly available, in the form it appears in Exhibit A, since January 15, 2009. Interested members of the public would have been able to locate the discussion thread by clicking through to the relevant forum or through keyword searching based on the relevant terms that appear in this thread. In the relevant time, we had many regular readers who would have seen, and likely read, the discussion thread when it was posted and as additional posts were added.

*EX 1014 ¶ 7; '698 Pet. p. 2/'381 Pet. p. 2
'698 Reply p. 26/'381 Reply p. 27*

RepRap

The Wayback Machine - <https://web.archive.org/web/20081018071513/http://forums.reprap.org/search.php?14>

RepRap RepRap : Mechanics : Reprap Forums

Discuss any sort of mechanical stuff here: positioning systems, gears, extruding methods, etc.

Goto: Forum List · Message List · New Topic · Log In · Back to RepRap

Search Messages	Search Authors
Search	Search
Search All Forums ▾	Search All Forums ▾
Last 30 Days ▾ All Words ▾	Last 30 Days ▾

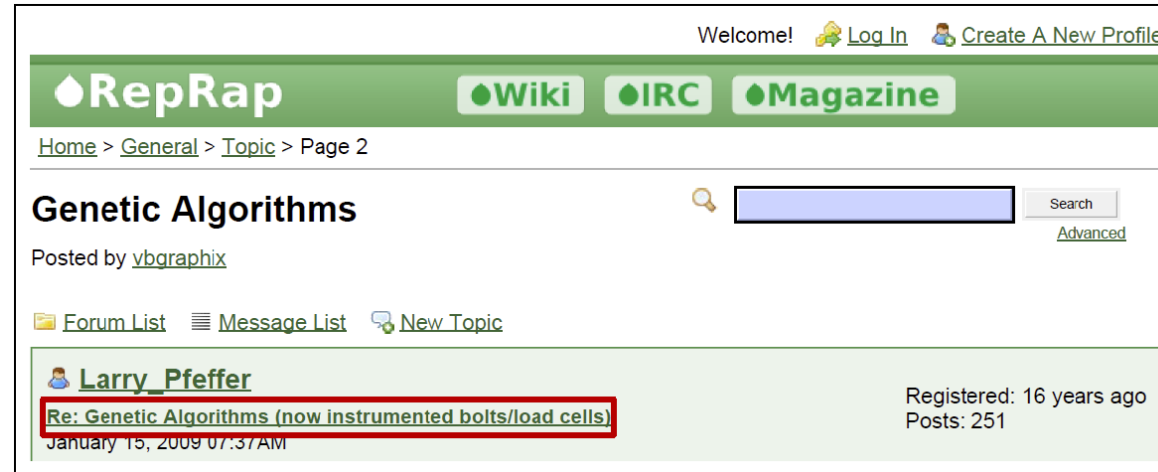
EX 1014 ¶ 11; '698 Pet. p. 2/'381 Pet. p. 2

the search button, the user will see the search interface of Exhibit 4. As shown below, a user can click the search button and then search all forums or specific forums based on keywords and author's user name. This search function was available to registered users and unregistered users alike. The forum software automatically indexed, for searching, the entire text of the posts and user names contemporaneously with the postings. Thus, a post to a forum would be searchable

EX 1014 ¶ 11; '698 Pet. p. 2/'381 Pet. p. 2

RepRap Thread Titles

RepRap



RepRap

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[Wiki](#) [IRC](#) [Magazine](#)

[Home](#) > [General](#) > [Topic](#) > Page 2

Genetic Algorithms

Posted by [vbgraphix](#)

[Forum List](#) [Message List](#) [New Topic](#)

[Larry_Pfeffer](#) Registered: 16 years ago
Posts: 251

Re: Genetic Algorithms (now instrumented bolts/load cells)
January 15, 2009 07:37 AM

EX 1010 p. 16

'698 Reply p. 27/381 Reply p. 28

Motivation to Combine Calderon & RepRap

FISH.

Calderon – Monitors Contact of Tip Two Ways

Calderon et al.

the nozzle tip contacts the substrate. Contact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means and the controller 116 electrically records the z-axis position of platform 134 at the time contact is detected. In an apparatus that uses servo drive motors, contact with the substrate 128 can be detected by simply monitoring a change in the servo drive current without need for any special purpose sensing means.

“sensing means”

“In an apparatus that uses servo drive motors... monitoring a change in the servo drive current”

*EX 1009 10:1-8; '698 Pet. p. 49/ '381 Pet. p. 48
'698 Reply p. 14/'381 Reply p. 14*

Calderon – “Sensing Means” Are Broadly Disclosed

Calderon et al.

Sensing techniques that do not necessarily involve the use of a plunging means can also be used in practice of the method of the present invention. Any manner of sensing a surface at selected coordinates to detect the corresponding z-axis coordinate may be used in practice of the invention. Suitable sensing means include but are not limited to, visible imaging devices, tactile detection devices and pneumatic detection devices. Examples of such devices are shown and discussed in Batchelder, et. al. U.S. Pat. No. 5,303,141 (see col.8, line 39 through col. 10, line 61), which is hereby incorporated by reference herein.

*EX 1009 6:62-7:5; '698 Pet. pp. 44-45/'381 Pet. p. 44
'698 Reply p. 14/'381 Reply p. 15*

“Any manner of sensing...may be used”

“sensing means include but are not limited to”

DECLARATION OF ANDREW WOLFE

sensing means.”) *Id.* A POSITA would have understood that while Calderon included examples that do not rely on a separate sensor, Calderon also included examples that incorporate many kinds of conventional sensors. The POSITA would have understood that Calderon was suggesting that the mechanism for force measurement can include any known sensing mechanism using a conventional sensor such as a strain gauge, which was known as “a common sensor.” EX1001, 9:1-2.

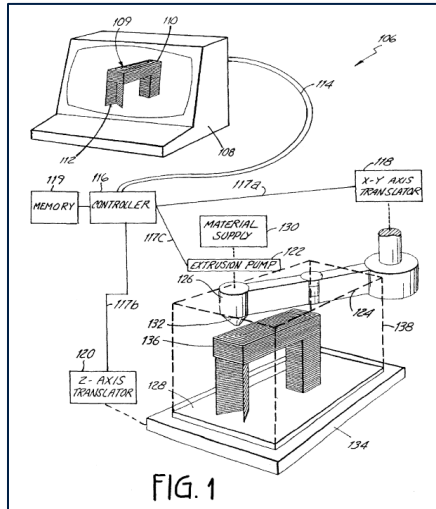
'698 EX 1003 ¶ 61/ '381 EX 1003 ¶ 60; '698 Pet. p. 45/ '381 Pet. p. 45

'698 Calderon + RepRap Combination

The combination is not limited to Calderon's servo drive embodiment.

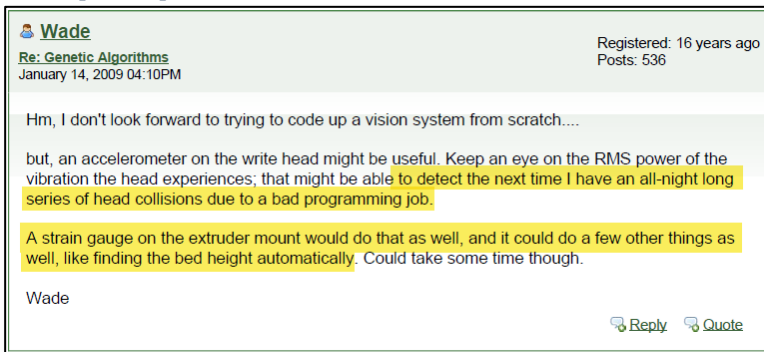
PETITION FOR INTER PARTES REVIEW

Calderon et al.



EX 1003 FIG. 1
'698 Pet. p. 43

RepRap



EX 1010 p. 13
Pet. p. 59-60

In view of the synergistic and complementary disclosures, a POSITA would have been motivated to implement collision detection after initialization, for example, using one or more strain gauges on the extrusion head mount, as suggested by RepRap20208, rather than Calderon's suggestion of "monitoring a change in the servo drive current" to enable collision detection as well as to provide "a sensing means," as called for by Calderon to monitor "contact between the tip of the nozzle 132 and the substrate 128." EX1010, 13-14; EX1009, 9:63-10:23; EX1003, ¶¶158-160. The collision detection in the Calderon-RepRap20208 Combination would follow RepRap20208's suggestion to "have the machine shut down" upon collision to avoid damage to the machine. EX1010, 19; EX1003, ¶160.

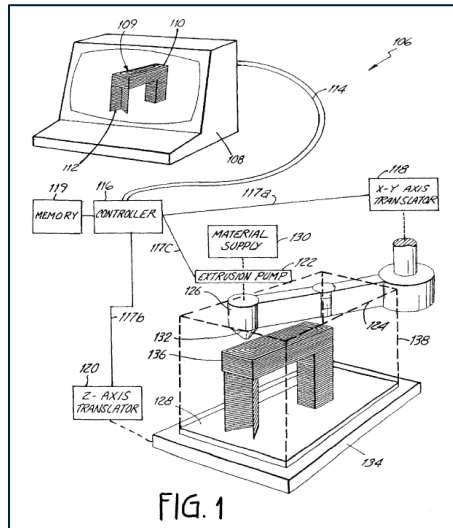
'698 Pet. p. 49

A POSITA would have been motivated to apply one or more strain gauges from RepRap20208 to Calderon's three-dimensional printer so that the printer of the Calderon-RepRap20208 Combination is equipped with one or more strain gauges located on the extruder mount, where Calderon's extrusion head 126 mounts to the arm 124, to sense a contact force between nozzle 132, and substrate 128. EX1003, ¶161. The visual aid below demonstrates an exemplary three-dimensional printer embraced by the Calderon-RepRap20208 Combination where the strain gauge example of RepRap20208 is applied to Calderon's "sensing means."³ *Id.*

'381 Calderon + RepRap Combination

The combination is not limited to Calderon's servo drive embodiment.

Calderon et al.



EX 1003 FIG. 1
'381 Pet. p. 42

PETITION FOR INTER PARTES REVIEW

A POSITA would have found it obvious to use one or more strain gauges on the extrusion head mount, as suggested by RepRap20208, to provide Calderon's "sensing means," to monitor "contact between the tip of the nozzle 132 and the substrate 128." EX1010, 13-14; EX1009, 9:63-10:23; EX1003, ¶¶156-158. In view of the synergistic and complementary disclosures, a POSITA would have been motivated to (i) apply strain gauges as in RepRap20208, rather than relying on Calderon's suggestion of "monitoring a change in the servo drive current," and (ii) calculate the contact force based on measurements from the strain gauge. *Id.*, ¶158.

'381 Pet. pp. 48-49

RepRap

**Wade**

Re: Genetic Algorithms
January 14, 2009 04:10PM

Registered: 16 years ago
Posts: 536

Hm, I don't look forward to trying to code up a vision system from scratch....

but, an accelerometer on the write head might be useful. Keep an eye on the RMS power of the vibration the head experiences; that might be able to detect the next time I have an all-night long series of head collisions due to a bad programming job.

A strain gauge on the extruder mount would do that as well, and it could do a few other things as well, like finding the bed height automatically. Could take some time though.

Wade

 Reply  Quote

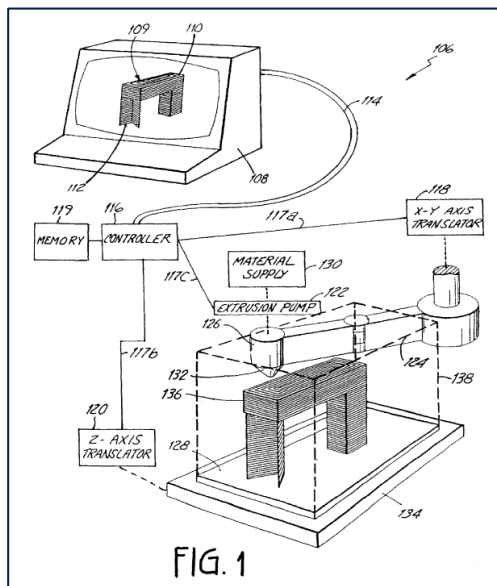
EX 1010 p. 13
Pet. p. 57-58

A POSITA would have been motivated to provide one or more strain gauge on the extrusion head mount, where Calderon's extrusion head 126 mounts to the arm 124, to sense a contact force between nozzle 132 and substrate 128. EX1003, ¶160. The visual aid below demonstrates the Calderon-RepRap20208 Combination where the strain gauge example of RepRap20208 is applied as Calderon's "sensing means."² *Id.*

'381 Pet. p. 49

'381 Calderon + RepRap Combination

Calderon et al.



EX 1003 FIG. 1
'381 Pet. p. 42

RepRap

 **Wade**
Re: Genetic Algorithms
January 16, 2009 12:04AM

Registered: 16 years ago
Posts: 536

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's weight) would be useful. That points more towards strain gauges.

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Mostly I just squint at the webcam feed every few hours and try and deduce if something bad has happened. 😊

Wade

[Reply](#) [Quote](#)

EX 1010 p. 20
'381 Pet. p. 55

PETITION FOR INTER PARTES REVIEW

A POSITA would have been further motivated to calculate the contact force from the strain gauges in the Calderon-RepRap20208 Combination using Calderon's controller 116 or another controller associated with the system. EX1003, ¶169. The following independent reasons, taken separately or collectively, support the motivation.

'381 Pet. pp. 54-55

Furthermore, as discussed above, a POSITA would have configured the Calderon-RepRap20208 Combination to control the contact force to prevent damaging the substrate 128 or the nozzle 132. Thus, a POSITA would have understood, or would have found it obvious, that the controller of the Calderon-RepRap20208 Combination includes a maximum contact pressure, either coded into the software or input by a user, that was related to the compression strengths of the substrate 128 and nozzle 132. EX1003, ¶170-171. Compression strength can be

'381 Pet. p. 55

'698 Calderon + RepRap Many Motivations

- “benefits of collision detection” ('698 Pet. p. 51)
- “real-time collision detection after system initialization” ('698 Pet. pp. 51-52)
- avoid “imprecision caused by slop/backlash” ('698 Pet. pp. 52-53)
- “more accurate and consistent force measurements” by not measuring the “force of resistance to movement” ('698 Pet. pp. 53-54)
- “strain gauge as a convenient, well understood manner of measuring force” with “sufficient precision to control the contact force” so as to “not damage the nozzle on ‘rigid substrates’ and not damage ‘foam substrates’” ('698 Pet. pp. 54-55)
- “strain gauges were commonly known” and a “predictable inclusion” ('698 Pet. pp. 55-56)

'381 Calderon + RepRap Many Motivations

Strain gauge

- avoid “imprecision caused by slop/backlash” ('381 Pet. pp. 50-52)
- “more accurate and consistent force measurements” by not measuring the “force of resistance to movement” ('381 Pet. p. 52)
- “strain gauge as a convenient, well understood manner of measuring force” with “sufficient precision to control the contact force” so as to “not damage the nozzle on ‘rigid substrates’ and not damage ‘foam substrates’” ('381 Pet. p. 53)
- “strain gauges were commonly known” and a “predictable inclusion” ('381 Pet. pp. 53-54)

Calculating force

- Wade’s seeking a “measurement of the force” and a “weight” invites calculating force ('381 Pet. p. 55)
- facilitates comparison between strain and strength of substrate or nozzle ('381 Pet. pp. 55-56)
- facilitate “programming controller to a maximum contact pressure setpoint” (381 Pet. p. 56)

Real-time Collision Detection After Initialization

Calderon et al.

EXAMPLE 4

In the embodiments of any of the above examples, the autoinitialization method of the present invention can further be used to detect whether the built envelope is cleared before the building of a model begins. This becomes of issue in the case of a modeling system wherein the model is built in a location remote from the user, for example, a user interface at processor 108 by which the user instructs that a part be built by an extruder located in another room. If a prior user builds a model but does not remove the model from the machine, instruction from a next user to build a subsequent model could cause the machine to crush the previous model as the machine starts to build the subsequent model. The present invention can be used to prevent such destruction of a previous model. In this example, the machine looks up the x,y,z coordinates of the last features built on the previous model (stored in memory 119), and feels for the presence or absence of those features employing the sensing techniques of the present invention. If a model is detected at the coordinates of the last features, the machine stops the build and alerts the user to clear the build envelope. The machine continues with the z-axis initialization routine when the envelope is cleared.

EX 1009 10:26-47

'698 POR pp. 48-50/'381 POR pp. 46-48

PETITION FOR INTER PARTES REVIEW

EX1010, 19. A POSITA would have been inspired to use the suggested strain gauges on extruder mount for real-time collision detection after system initialization because the feature would have used the same sensor configuration as initialization without requiring more. EX1003, ¶166.

'698 Pet. p. 52/'381 Pet. pp. 70-71

Constant Measurement of Force Collision Detection

 **Wade**

Re: Genetic Algorithms
January 16, 2009 12:04AM

Registered: 16 years ago
Posts: 536

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including its weight) would be useful. That points more towards strain gauges.

EX 1010 p. 20
'698 Pet. p. 51/'381 Pet. p. 71

EX1010, 20. A POSITA would understand Wade's suggestion of constantly measuring the force acting on the extrusion head, including its weight, to be teaching detecting contact by sensing when the weight of the extrusion head carried by the extrusion head mounting is reduced by contact of the nozzle to the substrate. A POSITA would appreciate that this manner of identifying contact would not be

EX 1003 ¶ 169
'698 Pet. p. 53/'381 Pet. p. 51

PETITION FOR INTER PARTES REVIEW

Furthermore, Wade explains "There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including its [sic] weight) would be useful."

EX1010, 20. A POSITA would understand Wade's suggestion of constantly measuring the force acting on the extrusion head, including its weight, to be teaching detecting contact by sensing when the weight of the extrusion head carried by the extrusion head mounting is reduced by contact of the nozzle to the substrate. EX1003, ¶169. A POSITA would appreciate that this manner of identifying contact would not be influenced by slop/backlash, because it is not measuring in force relative to a reaction force affected by slop/backlash. *Id.* A strain gauge on the extrusion mount would allow the weight of the extrusion head to be constantly monitored. *Id.* Thus, a POSITA would seek to use a strain gauge on the extrusion head mounting as a "sensing means" in Calderon to more precisely identify when the nozzle 132 has contacted the substrate 128 without the imprecision caused by slop/backlash. *Id.*

'698 Pet. p. 53/'381 Pet. p. 51

Slop/Backlash Was a Known Problem

RepRap

 **Wade**

Re: Genetic Algorithms
January 16, 2009 12:04AM

Registered: 16 years ago
Posts: 536

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Wade

 Reply  Quote

EX 1010 p. 20
'698 Pet. p. 53/'381 Pet. p. 50

DECLARATION OF ANDREW WOLFE

167. As a *third* reason, the support frame of the extrusion head and the motors and associated drive, including those of Calderon (e.g., arm 124, x-y axis translator 118, z-axis translator 120 and servo drive motors), were known to have “slop/backlash” that would make it difficult to accurately and precisely identify when the nozzle contacted the substrate as is needed for Calderon’s Find-Z program.

EX1010, 20. As Wade described, if “you’ve got a certain amount of backlash to take up before the sensor registers, [it] would prevent [one] from knowing exactly when the head touches.” *Id.* In other words, using the servo drive as a sensing means would have a dampening effect on the force signal due to this “slop/backlash.”

'698 EX 1003 ¶ 167/'381 EX 1003 ¶ 161
'698 Pet. p. 52/'381 Pet. p. 50

Slop/Backlash

DECLARATION OF DR. TIM A. OSSWALD

251. Similarly, Petitioner's assertion that Calderon's solution that monitors the current of the servo drive motors would have "slop/backlash" is deficient. *See* Petition at 52-53 (citing to RepRap20208 (EX1010), 20 and EX1003, ¶¶168-69). Page 20 of RepRap20208 (EX1010) only mentions "backlash" and not "slop" and does not indicate that the concern about backlash "before the sensor registers" relates to Calderon's solution of constantly monitoring the current of the servo drive motors for a change. *See* EX1010 (RepRap20208), 20; *see also* EX1009 (Calderon), 10:5-8. The surrounding context in RepRap20208 indicates that it is referring to some other sensor unrelated to Calderon's solution, such as the IESP-12 force sensor or bump sensor. *See* EX1010 (RepRap20208) at 19 ("That IESP-12 force sensor is priced right at \$7, but I'm a little skittish about the 'estimate' language in the datasheet."), 20 ("measuring contact force for a stencil cutting blade or drawing pen to get more uses out of the bot"), 20 ("if you've got it truly not touching the sensor (as that datasheet recommends [sic]), then you've got a certain amount of backlash to take up before the sensor registers"), 20 ("A cheap bump sensor is described on instructables").

'698 EX 2027 ¶ 251/'381 EX 2027 ¶ 242

'698 POR p. 51/'381 POR p. 48
fr.com | 139

Slop/Backlash Is Solved by the Combination

DECLARATION OF ANDREW WOLFE

168. In contrast, the RepRap's approach of using strain gauge on the extruder mount would not suffer the same degree of "slop/backlash," in part because the strain gauge would measure force from a location closer to the nozzle – at the extrusion head mounting – which would alleviate the issue of "slop/backlash" in Calderon's arm, x-y axis translator or its servo drive.

DECLARATION OF ANDREW WOLFE

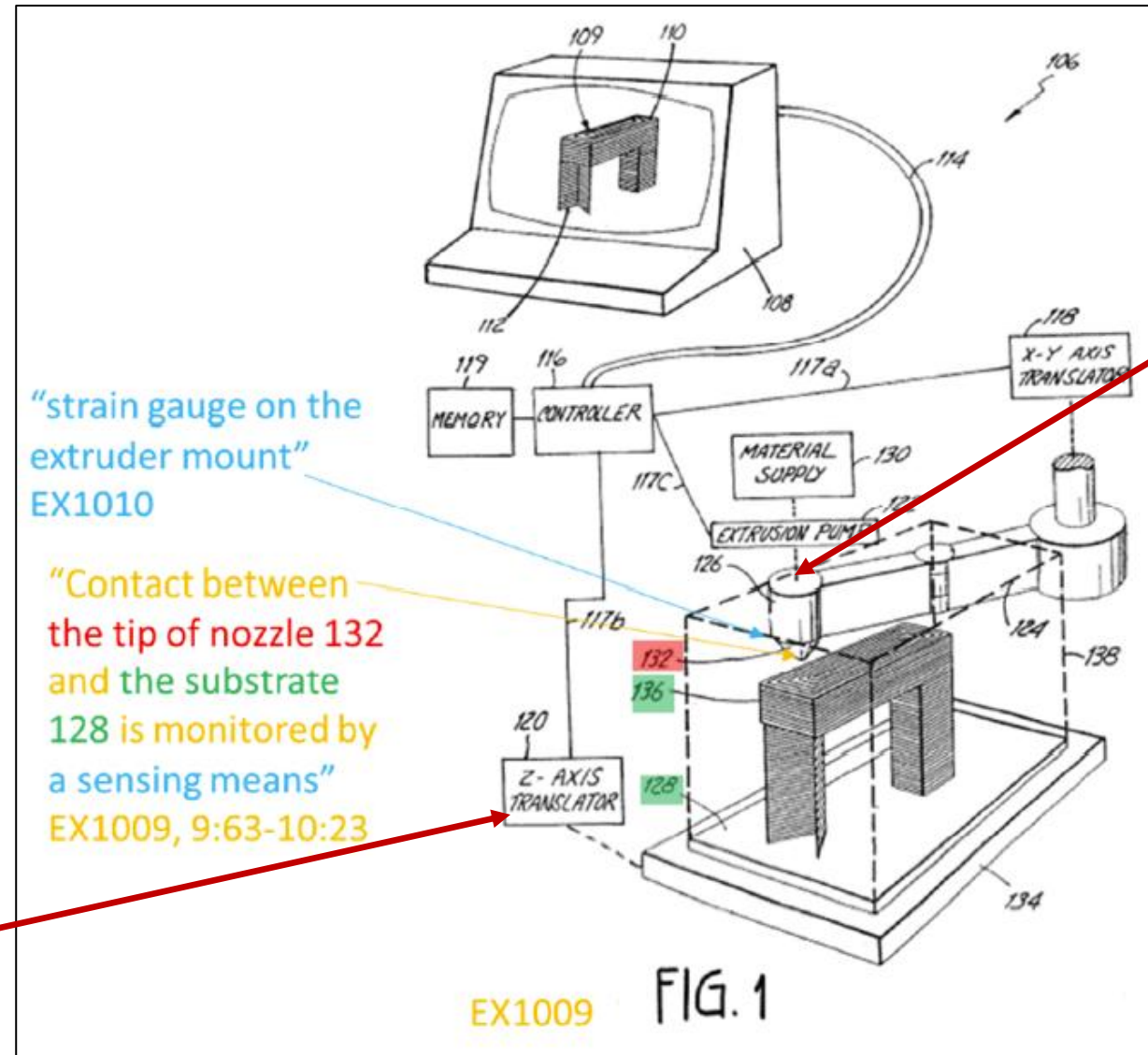
169. Furthermore, Wade explains "There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's [sic] weight) would be useful." EX1010, 20. A POSITA would understand Wade's suggestion of constantly measuring the force acting on the extrusion head, including its weight, to be teaching detecting contact by sensing when the weight of the extrusion head carried by the extrusion head mounting is reduced by contact of the nozzle to the substrate. A POSITA would appreciate that this manner of identifying contact would not be influenced by slop/backlash, because it is not measuring in force relative to a reaction force affected by slop/backlash. A strain gauge on the extrusion mount would allow the weight of the extrusion head to be constantly monitored. Thus, a POSITA would seek to use a strain gauge on the extrusion head mounting as a "sensing means" in Calderon to more precisely identify when the nozzle 132 has contacted the substrate 128 without the imprecision caused by slop/backlash.

*'698 EX 1003 ¶ 168-169/'381 EX 1003 ¶ 162-163
'698 Pet. p. 53/'381 Pet. p. 50*

Slop/Backlash Is Solved by the Combination

EX 1009 FIG. 1 (annotated as in Pet.)

'698 Pet. p. 50/'381 Pet. p. 50



extrusion head

z-axis translator

Servo Drive Current Is Inaccurate, Inconsistent Solved by Combination

DECLARATION OF ANDREW WOLFE

170. As a *fourth* reason, a POSITA would have understood that the “monitoring a change in the servo drive current” measures the force of resistance to movement of the substrate 128 and platform 134 in the Z-axis, not just the contact force between the substrate 128 and nozzle 132. EX1009, 9:63-10:23. The resistance to movement of the substrate 128 and platform 134 can be influenced by other factors like damage, wear or friction (e.g., due to dirt or need of maintenance) in the servo drive motors and drive system, as well as other factors. This resistance to movement can change over time, and so measurements made by “monitoring a change in the servo drive current” are both inaccurate and, over time, inconsistent.

DECLARATION OF ANDREW WOLFE

Id. A POSITA would have appreciated that the force measured by a strain gauge on the extrusion head mount would not be influenced by these other factors, because the extrusion head mount is not in a force chain of components that experience this type of damage, wear or friction. A strain gauge on the extrusion head mount can measure the forces acting on the extrusion head, itself, which during Calderon’s initialization is largely the contact force between the nozzle 132 and substrate 128. *Id.* Thus, a POSITA would seek to implement RepRap20208’s strain gauge on the extrusion head as a “sensing means” in Calderon’s system to produce more accurate and consistent force measurements by which to sense contact of the nozzle 132 to the substrate 128.

'698 EX 1003 ¶ 170/'381 EX 1003 ¶

164

'698 Pet. pp. 53-54/'381 Pet. p. 52

Servo Drive Current

DECLARATION OF DR. TIM A. OSSWALD

253. Petitioner next assertion that a strain gauge would provide “more accurate,” “consistent” force measurement is **guided by hindsight**. *See* Petition at 53-54 (“force of resistance to movement”); EX1003, ¶170. Although Dr. Wolfe provides a citation to Calderon (*see* EX1003, ¶170 *citing to* EX1009 at 9:63-10:23), those portions of Calderon do not support Petitioner’s conclusion that there are problems with constantly monitoring the servo drive current for a change, as Calderon teaches. **In my view, there is no supporting disclosure regarding any problems with Calderon constantly monitoring the servo drive current for a change to a strain gauge.**

*'698 EX 2027 ¶ 253/'381 EX 2027 ¶ 244
'698 POR p. 52/'381 POR p. 49*

RepRap Teaches/Renders Obvious Calculating Contact Force

FISH.

RepRap Taught Calculating Force

RepRap

**Wade**

Registered: 16 years ago
Posts: 536

Re: Genetic Algorithms
January 14, 2009 04:10PM

Hm, I don't look forward to trying to code up a vision system from scratch....

but, an accelerometer on the write head might be useful. Keep an eye on the RMS power of the vibration the head experiences; that might be able to detect the next time I have an all-night long series of head collisions due to a bad programming job.

A strain gauge on the extruder mount would do that as well, and it could do a few other things as well, like finding the bed height automatically. Could take some time though.

Wade

[Reply](#) [Quote](#)

EX 1010 p. 13
'381 Pet. p. 55

DECLARATION OF ANDREW WOLFE

170. A POSITA would have understood RepRap20208 to teach calculating contact force from the strain gauge signal when Wade explains “I was thinking a constant measurement of the force on the head (including it’s [sic] weight) would be useful,” because Wade is indicating he seeks a force “measurement” and a “weight,” not simply a sensor signal. EX1010, 17. This disclosure at least invites a POSITA to use the strain gauge to calculate contact force. As I have discussed above, a

RepRap

**Wade**

Registered: 16 years ago
Posts: 536

Re: Genetic Algorithms
January 16, 2009 12:04AM

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's weight) would be useful. That points more towards strain gauges.

Yeah, the 4 corners calibration was what I was thinking as well. It could also pick up on a tangled plastic filament feed, which has wrecked a few builds of mine in the past as well. That would probably just trigger the head collision detection, due to the upward force on the extruder.

Mostly I just squint at the webcam feed every few hours and try and deduce if something bad has happened. 😊

Wade

[Reply](#) [Quote](#)

EX 1010 p. 20
'381 Pet. p. 55

EX 1003 ¶ 170
'381 Pet. p. 55

Calculating Force From a Strain Gauge Is Rudimentary

DECLARATION OF ANDREW WOLFE

171. A POSITA would have been motivated to program the controller to calculate the contact force at the nozzle 132/substrate 128 interface from the signal output by the strain gauge so that the contact pressure, in turn, could be calculated and be directly comparable to the compression strength of the substrate. *Id.* For example, the strain gauge outputs a signal related to the geometric distortion of the gauge which is caused by forces acting on the gauge. In the most common configuration, these forces represent the deflection of the substrate or surface that the strain gauge is connected to. Knowing the geometry of the extruder mount at this location, one can measure and calculate the stress and force at this location. Thereafter, by knowing the material properties of the nozzle, one could calculate the force exerted on the nozzle through the contact with the substrate. And, knowing the geometry of the nozzle where it contacts the substrate, one could calculate the contact pressure. In fact, RepRap 20208 taught to “measure upwards pressure from a calibration touch down.” EX1010, 19.

*EX 1003 ¶ 171
'381 Pet. p. 55*

DECLARATION OF ANDREW WOLFE

173. In my opinion, a POSITA would have reasonably expected success in calculating, with a controller, the contact force from the strain gauge of the combination. Calculating contact force, and then contact pressure, with a controller from a sensor intended to produce a signal related to force, and particularly a strain gauge, was rudimentary engineering and commonplace long before the '381 patent and 2012. For example, a well-known textbook explains that a strain gauge is commonly used in a Wheatstone configuration. EX1018, 302-304, 284-290. Thus, these calculations would have been predictable to a POSITA, who would have expected it to work.

*EX 1003 ¶ 173
'381 Pet. p. 57*

“strain” → “force” → “contact pressure”

Strain Gauges Were Commonly Used for Force Sensing

DECLARATION OF ANDREW WOLFE

166. As a *fourth* reason, strain gauges were commonly used for force measurement of the type described in Calderon long before the '381 patent. It is rudimentary engineering to convert the signal from a strain gauge to a force measurement. In fact, the '381 patent admits that “[s]train gauges are one common sensor used for such [contact force] measurements.” EX1001, 9:16-24. The predictable inclusion of a strain gauge amounts to nothing more than supplementing Calderon with a strain gauge on the extrusion head mount, which would not have disturbed the other aspects of the system, and would have produced substantially similar functionality to what Calderon described.

*EX 1003 ¶ 166
'381 Pet. pp. 53-54*

ME students use force sensors/strain gauges by “sophomore year, beginning of junior year”

DEPOSITION OF TIM A OSSWALD

Q. Did the students in these classes actually use force sensors in a lab or anything or was it just more theoretical learning?

A. No. That one was more theoretical and showing them the -- giving presentations on that.

But mechanical engineering students do take a measurements course where they do learn about strain gauges and learn about that, so that's a classic mechanical engineering measurements course where they know about those things. So I don't have to teach them. They already have hands-on experience with that.

Q. When do mechanical engineering students usually learn or take that class?

A. Yeah. Probably end of the sophomore year, beginning of the junior year. That's -- even when I took mechanical engineering classes in undergraduate, that's -- the measurements class was done then.

EX 1042 67:24-68:20
'381 Reply p. 21

Calculating Force Facilitates Comparison to Nozzle/Substrate Strength

DECLARATION OF ANDREW WOLFE

not simply a sensor signal. EX1010, 17. This disclosure at least invites a POSITA to use the strain gauge to calculate contact force. As I have discussed above, a POSITA would have configured the 3D printer of the Calderon-RepRap20208 Combination to control the contact force between the nozzle 132 and substrate 128 during initialization to prevent damaging the substrate 128, especially with low compression strength foam substrates, and to prevent damaging the nozzle 132, for example on rigid substrates. Thus, the controller of the Calderon-RepRap20208 Combination would be programmed with a maximum contact pressure, either coded into the software or input by a user, that that was related to the compression strengths of the substrate 128 and nozzle 132. Compression strength is expressed in units of force per unit area, e.g., pounds per square inch (psi) or newtons per square meter (pascals). Yet, the output of a strain gauge in the Calderon-RepRap20208 Combination would be a signal indicative of displacement or strain at the extruder mount, not directly the contact pressure (e.g., at the nozzle/substrate interface).

“control the contact force...to prevent damaging the substrate...[and]nozzle”

“maximum contact pressure...related to compression strengths of the substrate [] and nozzle[]”

“[c]ompression strength is expressed in units of force per unit area,” i.e., pressure

“the output of a strain gauge...[is] displacement or strain

*EX 1003 ¶ 170
'381 Pet. pp. 55-56*

Calculating Force Facilitates Setting Controller Maximum Force

DECLARATION OF ANDREW WOLFE

172. The controller calculating the contact force, and then the contact pressure, would facilitate programming the controller to a maximum contact pressure setpoint related to the compression strength of the substrate and nozzle because the setpoint and the compression strength would be in the same units (force per unit area). Or, if the controller were configured to allow a user to change the setpoint, such as to allow the printer to be adapted to different substrate materials, calculating contact force and contact pressure would facilitate a user's interaction with the controller. The controller's settings values could more readily be set, adjusted or displayed in meaningful (to a user) force-based units rather than in values of strain at the extrusion head mounting. Thus, for example, the Calderon-RepRap20208 Combination would accommodate a variety of substrate materials by enabling a user to input a contact strength limit based on a specification sheet for the substrate material. Moreover, as evidenced by RepRap20208, a POSITA would have perceived the contact sensing in terms of force. EX1010, 17 ("we'd *like* three forces"), 17 ("here's a force sensor"), 20 ("a constant measurement of force"). As such, the strain/deflection measured by the strain gauge would have required a user to know the material properties and geometry of the strain gauge at the mounting in order to make sense of the measured strain.

*EX 1003 ¶ 172
'381 Pet. p. 56*

'698 [1a] Calderon Teaches Identifying Build Instructions

FISH.

'698 Limitation [1a]

1. A method comprising:
identifying build instructions for fabricating an object;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;
detecting the current contact force based on a sensor signal from the one or more sensors; and
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.

[1a] Calderon Teaches Identifying Build Instructions

Calderon

Additive process modeling machines make three-dimensional models by building up a modeling medium, usually in planar layers, based upon design data provided from a computer aided design (CAD) system. A mathematical description of a physical part to be created is split into (usually) planar layers, and those layers are individually shaped and applied to produce the final part. Three-

EX 1009 1:12-18

'698 EX 1003 ¶178-180

'698 Pet. pp. 57-58

Calderon

FIG. 1 shows a generic representation of a extrusion-based layered modeling system **106**, of a type known in the art, with which the present invention may be used. A computer aided design (CAD) program resident in a processor **108** generates a file describing the geometry of a part **109** to be created. A slicing program (shown as resident in processor **108** but which may alternatively be resident in a separate processor) algorithmically subdivides the file into volume elements **110** corresponding to shapes that can be extruded from a nozzle. Additional volume elements **112** are added as necessary to provide mechanical support to a part during its construction. The volume elements are sequentially ordered so that deposited material is supported appropriately.

EX 1009 4:20-33

'698 EX 1003 ¶178-180

'698 Pet. pp. 57-58

'698 [1b]-[1d] / '381 [1b]-[1c] Calderon + RepRap

FISH.

'698 Limitation [1b]-[1d]

1. A method comprising:
identifying build instructions for fabricating an object;
initiating a build using a three-dimensional printer comprising a fabrication tool and one or more sensors mechanically coupled to the fabrication tool, the one or more sensors configured to detect a current contact force between the fabrication tool and a separate structure;
detecting the current contact force based on a sensor signal from the one or more sensors; and
creating a control signal to control at least one component of the three-dimensional printer in response to the current contact force while depositing material during the build.

'381 Limitation [1b]-[1c]

1. A three-dimensional printer comprising:
 - a fabrication tool including an extruder configured to extrude build material to fabricate an object during a build process;
 - one or more sensors mechanically coupled to the extruder, wherein the one or more sensors are collectively operable to sense a contact force between the extruder and a separate structure distinct from the fabrication tool; and
 - a controller configured to receive a signal from the one or more sensors on the extruder and to calculate the contact force between the extruder and the separate structure.

RepRap Determining/Calculating Force

RepRap

 **Wade**
[Re: Genetic Algorithms](#)
January 16, 2009 12:04AM

Registered: 16 years ago
Posts: 536

The upward pressure is the same thing general idea, but if you've got it truly not touching the sensor (as that datasheet recommends), then you've got a certain amount of backlash to take up before the sensor registers, which would prevent me from knowing exactly when the head touches, which is what I'm really interested in. There's fair amount of give in the entire system when you're looking at scales of less than a mm, so I was thinking a constant measurement of the force on the head (including it's weight) would be useful. That points more towards strain gauges.

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Wade

 [Reply](#)  [Quote](#)

EX 1010 p. 20
'698 Pet. 61/'381 Pet. p. 55

DECLARATION OF ANDREW WOLFE

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'698 EX 1003 ¶ 169/'381 EX 1003 ¶ 170
'698 Pet. 53/'381 Pet. p. 55

DECLARATION OF ANDREW WOLFE

EX1010, 20. A POSITA would understand Wade’s suggestion of constantly measuring the force acting on the extrusion head, including its weight, to be teaching detecting contact by sensing when the weight of the extrusion head carried by the extrusion head mounting is reduced by contact of the nozzle to the substrate. A

'691 EX 1003 ¶ 169/'381 EX 1003 ¶ 163
'691 Pet. p. 53/'381 Pet. p. 55

'698 [1d] A Control Signal Is Obvious to Implement Collision Detection

DECLARATION OF ANDREW WOLFE

190. As I have explained above under Sections VII.C-D, X.A, a POSITA would have found it obvious to create the control signal in response to the current contact force (e.g., detected by the strain gauge on the extruder mount, as taught in RepRap20208) while depositing material during the build (e.g., to implement real-time collision detection, as suggested by RepRap20208).

'698 EX 1003 ¶ 190
'698 Pet. p. 62

'698 PETITION FOR INTER PARTES REVIEW

As explained *supra* §§V.C.1-3, a POSITA would have found it obvious to create the control signal *in response to the current contact force* (e.g., detected by the strain gauges on the extruder mount, as taught in RepRap20208) *while depositing material during the build* (e.g., to implement real-time collision detection, as suggested by RepRap20208). EX1003, ¶¶189-190.

'698 Pet. p. 62

DECLARATION OF ANDREW WOLFE

165. As a first reason, a POSITA would have been reminded of the benefits collision detection. As explained by developer Wade: "I'd have the machine shut down and flag me if it [i.e., collision] happens, as opposed to breaking something." EX1010, 19. Developer Wade further explains "a tangled plastic filament feed, which has wrecked a few builds of mine, ... would probably just trigger the head collision detection." *Id.*, 20. A POSITA would have understood that "a collision may be, for example, as a result of dispensed layers being too thick and/or inconsistent in thickness, and/or because of a mechanical malfunction of the dispensing head," or "faulty material dispensing that may occur anywhere in the path" of the extrusion head. EX1005, 18:5-18. A POSITA would have been motivated to shut down the three-dimensional printer upon collision detection to conserve energy, minimize damage, and avoid material waste.

EX 1003 ¶ 165
'698 Pet. p. 51

'698 Claims 2, 9 and 10

FISH.

Calderon + RepRap

698 Patent Dependent Claims

2. The method of claim 1, wherein the fabrication tool includes an extruder.

9. The method of claim 2 wherein the control signal includes a signal to the three-dimensional printer to change a feed rate of build material extruded by the extruder.

10. The method of claim 2 further comprising detecting a planarity of the separate structure based upon a number of contact force measurements across a surface of the separate structure.

Claims 2 and 9 are not separately disputed apart from their features shared with claim 1.

Claim 10 - Calderon Initialization Examples

Calderon

EXAMPLE 1

Referring now to the process flow diagram of FIG. 6, there is described a z-axis initialization routine in accordance with the present invention. The routine is performed

EX 1009 7:6-10

DECLARATION OF ANDREW WOLFE

217. Each and every element of claims 1 and 2 is obvious in light of the Calderon-RepRap20208 Combination as explained above. As I have explained above under Section VII.D, Calderon teaches z-axis initialization “to determine whether the top surface of substrate is approximately parallel to a horizontal, xy-plane.” EX1009, 7:65-8:5 (noting if “substrate top surface does not closely enough approximate a horizontal plane, that result indicates either that the substrate was not mounted flush to platform, or that the substrate has a deformity”) (reference numbers omitted). In Calderon’s Example 3, Calderon describes “positioning the nozzle above pre-selected locations of the substrate” so that “[c]ontact between the tip of nozzle and the substrate is monitored” at these “pre-selected locations.” *Id.*, 9:65-67 (reference numbers omitted).

Calderon

EXAMPLE 3

In an alternative embodiment, the tip of nozzle 132 (shown in FIG. 1) can be used as a plunging means to find z-axis positions of the platform. The initialization routine is performed by positioning the nozzle 132 above pre-selected locations of the substrate and raising the platform 134 until the nozzle tip contacts the substrate. Contact between the tip of nozzle 132 and the substrate 128 is monitored by a sensing means and the controller 116 electrically records the z-axis position of platform 134 at the time contact is detected. In an apparatus that uses servo drive motors, contact with the substrate 128 can be detected by simply monitoring a change in the servo drive current without need for any special purpose sensing means.

EX 1009 9:61-7:8
'698 Pet. pp. 68-69
'698 Reply p. 24

'698 EX 1003 ¶ 217
'698 Pet. pp. 68-60

Calderon Initialization – Planarization/Z-start (Find-Z)

Calderon

Planarization

When a z-axis position has been recorded for each pre-selected x, y location, step (H) is performed. In step (H), a “Find-Z” software program loaded into controller 116 compares the recorded z-axis positions to determine whether the top surface of substrate 146 is approximately parallel to a horizontal, xy-plane. Step (H) is particularly useful for a modeling system that uses a slab substrate. If the result of the comparison shows that the substrate top surface does not closely enough approximate a horizontal plane, that result indicates either that the substrate 146 was not mounted flush to platform 147, or that the substrate 146 has a deformity. In such a case, in a step (I), controller 116 provides a notification to the operator, alerting the operator to reload the substrate 146 onto platform 147 and then repeat the z-axis initialization routine. The notification is preferably by way of a written message on a system display screen (not shown).

*EX 1009 7:62-8:9
'698 Pet. pp. 68-69
'698 Reply p. 24*

Calderon

Z-start (Find-Z)

If the comparison of step (H) shows that the substrate top surface is parallel to the xy-plane, a step (J) is executed, in which the “Find-Z” software, program uses the recorded z-axis positions to calculate a z-start position of platform 147. The Find-Z program uses known, constant system parameters to derive the actual z-axis position of platform 147 at the time of initial contact between substrate 146 and plunger 148 and to thereby determine an appropriate z-start position of platform 147 with respect to the extrusion head nozzle 144. In the case of a foam slab substrate, step (J) can

*EX 1009 8:11-19
'698 Pet. p. 46
'698 Reply p. 24*

Calderon Find-Z

Calderon

The Find-Z program works much the same in the present example as described with respect to Examples, 1 or 2 above. Steps (1) and (3) of the algorithm above can be skipped, however, as the recorded z-positions in the present embodiment are the actual z-axis positions of the platform. In other words, this approach eliminates the variables X and Y.

*EX 1009 10:9-15
'698 POR. pp. 60*

*EX 1009 8:11-37
'698 POR p. 60-61*

Calderon

If the comparison of step (H) shows that the substrate top surface is parallel to the xy-plane, a step (J) is executed, in which the “Find-Z” software, program uses the recorded z-axis positions to calculate a z-start position of platform 147. The Find-Z program uses known, constant system parameters to derive the actual z-axis position of platform 147 at the time of initial contact between substrate 146 and plunger 148 and to thereby determine an appropriate z-start position of platform 147 with respect to the extrusion head nozzle 144. In the case of a foam slab substrate, step (J) can be executed using the following algorithm:

- (1) Subtract the constant value X, representing the pre-determined distance of the sensing location above the actuated position of plunger 148, from each recorded z-axis position. The result of this subtraction is a set of actual z-axis positions of platform 147 at the instant that substrate 146 contacted plunger 148.
- (2) Select the lowest of the actual z-axis positions.
- (3) Add the constant value Y, representing the predetermined distance of the tip of nozzle 144 above the tip 178 of plunger 148, to the selected actual z-axis position. This result of this calculation is the z-axis position at which substrate 146 will contact the tip of nozzle 144.
- (4) Add a constant value Z, representing the desired depth of the tip of nozzle 144 below the top surface of substrate 146, to the result of step (3), to arrive at the z-start position.

'381 Claim 11

FISH.

DEMONSTRATIVE EXHIBIT – NOT EVIDENCE

'381 Patent Claim 11

'381 Patent Dependent Claims

11. The three-dimensional printer of claim 1, further comprising:
one or more actuators mechanically coupled to the fabrication tool, and
a control circuit in data communication with the one or more actuators and the one or more sensors, the control circuit configured to control the one or more actuators to achieve a specified contact force between the one or more sensors and the separate structure.

Maximum to Prevent Damage to Nozzle/Substrate

DECLARATION OF ANDREW WOLFE

206. As I have explained under Sections VII.C&D, X.A and claim 1, controller 116 sends control signals to the z-axis translator (i.e., *controls the one or more actuators*) to achieve a contact force sufficient for measurement but does not exceed a force limit to be damaging (i.e., *a specified contact force*) between the “strain gauge on extruder mount” (i.e., *one or more sensors*) and the modeling platform 134 (i.e., *separate structure*).

'381 EX 1003 ¶ 206
'381 Pet. pp. 67-68

DECLARATION OF ANDREW WOLFE

not simply a sensor signal. EX1010, 17. This disclosure at least invites a POSITA to use the strain gauge to calculate contact force. As I have discussed above, a POSITA would have configured the 3D printer of the Calderon-RepRap20208 Combination to control the contact force between the nozzle 132 and substrate 128 during initialization to prevent damaging the substrate 128, especially with low compression strength foam substrates, and to prevent damaging the nozzle 132, for example on rigid substrates. Thus, the controller of the Calderon-RepRap20208 Combination would be programmed with a maximum contact pressure, either coded into the software or input by a user, that that was related to the compression strengths of the substrate 128 and nozzle 132. Compression strength is expressed in units of force per unit area, e.g., pounds per square inch (psi) or newtons per square meter (pascals). Yet, the output of a strain gauge in the Calderon-RepRap20208 Combination would be a signal indicative of displacement or strain at the extruder mount, not directly the contact pressure (e.g., at the nozzle/substrate interface).

381 EX 1003 ¶ 170
'381 Pet. pp. 67-68

Presenters



Joshua A. Griswold

Principal

griswold@fr.com



Rishi Gupta

Of Counsel

rgupta@fr.com



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