US012385265B2

(12) **United States Patent**
Pickering et al.

(10) **Patent No.: US 12,385,265 B2**
(45) **Date of Patent: Aug. 12, 2025**

(54) **BLOCK TRANSFER APPARATUS AND IMPROVED CLAMPING ASSEMBLY FOR USE THEREWITH**

(71) Applicant: **FASTBRICK IP PTY LTD**, High Wycombe (AU)

(72) Inventors: **Samuel Thomas Pickering**, Kalamunda (AU); **David James Newcombe**, Cottesloe (AU); **Rudolf Hans Hauri**, City Beach (AU)

(73) Assignee: **FASTBRICK IP PTY LTD**, High Wycombe (AU)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 13 days.

(21) Appl. No.: **17/920,335**

(22) PCT Filed: **Apr. 22, 2021**

(86) PCT No.: **PCT/AU2021/050361**
§ 371 (c)(1),
(2) Date: **Oct. 20, 2022**

(87) PCT Pub. No.: **WO2021/212176**
PCT Pub. Date: **Oct. 28, 2021**

(65) **Prior Publication Data**

US 2023/0167650 A1 Jun. 1, 2023

(30) **Foreign Application Priority Data**

Apr. 22, 2020 (AU) 2020901272

(51) **Int. Cl.**
E04G 21/22 (2006.01)
B25J 9/16 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***E04G 21/22*** (2013.01); ***B25J 9/1694*** (2013.01); ***B25J 11/00*** (2013.01); ***B25J 13/089*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B25J 9/1694; B25J 11/00; B25J 13/089; B25J 15/0033; B25J 15/0253;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

428,096 A 5/1890 Hathaway
1,411,172 A 3/1922 Kaye
(Continued)

FOREIGN PATENT DOCUMENTS

AU 645640 B2 1/1994
CH 673498 A 3/1990
(Continued)

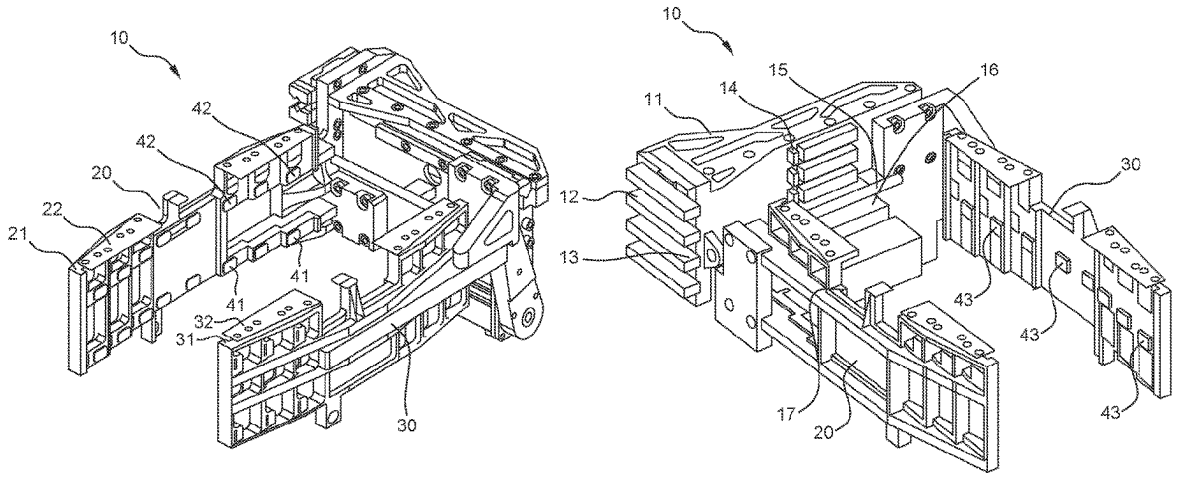
OTHER PUBLICATIONS

Examination report dated Sep. 30, 2023 on Australian Patent Application No. AU2018348785.
(Continued)

Primary Examiner — Saul Rodriguez
Assistant Examiner — Brendan P Tighe
(74) *Attorney, Agent, or Firm* — Perkins Coie LLP

(57) **ABSTRACT**

A block transfer apparatus for transferring a block between an upstream and downstream clamps of a block delivery system. The apparatus includes: a frame pivotally mounted to a support; a clamping assembly mounted to the frame and linearly extendable relative thereto, and including a pair of gripper jaws for clamping opposing sides of the block. The apparatus receives a block in the gripper jaws in an approximate position; rotates to a drop position and releases the block allowing it to self-datum onto first and second
(Continued)



orthogonal datum surfaces. The apparatus re-clamps the block after the drop by applying a clamping force to opposing sides of the block to register the block against a third datum surface to thereby datum the position of the block with respect to the clamping assembly; and presents the block clamped in the datumed position for transfer to the downstream clamp.

16 Claims, 24 Drawing Sheets

(51) **Int. Cl.**

B25J 11/00	(2006.01)
B25J 13/08	(2006.01)
B25J 15/00	(2006.01)
B25J 15/02	(2006.01)

(52) **U.S. Cl.**
CPC ***B25J 15/0033*** (2013.01); ***B25J 15/0253*** (2013.01)

(58) **Field of Classification Search**
CPC B65G 47/248; B65G 47/252; B65G 47/84; B65G 47/842; B65G 47/847; B65G 47/904; E04G 21/22
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,633,192	A		6/1927	Reagan
1,829,435	A		10/1931	Barnhart
2,599,552	A		6/1952	Harney
3,438,171	A		4/1969	Demarest
3,746,570	A		7/1973	McIntosh
3,757,484	A		9/1973	Williamson et al.
3,790,428	A		2/1974	Lingl
3,791,559	A		2/1974	Foye
3,834,973	A		9/1974	Kummerow
RE28,305	E		1/1975	Williamson et al.
3,930,929	A		1/1976	Lingl
3,950,914	A		4/1976	Lowen
4,033,463	A		7/1977	Cervin
4,067,766	A		1/1978	Larger
4,106,259	A		8/1978	Taylor-smith
4,221,258	A		9/1980	Richard
4,245,451	A		1/1981	Taylor-smith
4,303,363	A		12/1981	Cervin
4,523,100	A		6/1985	Payne
4,635,985	A		1/1987	Rooke
4,708,562	A		11/1987	Melan et al.
4,714,339	A		12/1987	Lau
4,758,036	A		7/1988	Legille et al.
4,765,789	A		8/1988	Lonardi et al.
4,786,227	A	*	11/1988	Kremer F27D 1/1621 266/281
4,790,651	A		12/1988	Brown et al.
4,827,689	A		5/1989	Lonardi et al.
4,829,737	A		5/1989	Anliker
4,852,237	A		8/1989	Tradt et al.
4,911,595	A		3/1990	Kirchen et al.
4,945,493	A		7/1990	Huang et al.
4,952,772	A		8/1990	Zana
4,954,762	A		9/1990	Miyake et al.
4,969,789	A		11/1990	Searle
5,004,844	A		4/1991	Van Leeuwen et al.
5,013,986	A		5/1991	Gauggel
5,018,923	A	*	5/1991	Melan E04G 21/22 414/744.5
5,049,797	A		9/1991	Phillips
5,080,415	A		1/1992	Bjornson
5,193,723	A		3/1993	Everett et al.
5,196,900	A		3/1993	Pettersen
5,284,000	A		2/1994	Milne et al.
5,321,353	A		6/1994	Furness
5,403,140	A		4/1995	Carmichael et al.
5,413,454	A		5/1995	Movsesian
5,419,669	A		5/1995	Kremer et al.
5,420,489	A		5/1995	Hansen et al.
5,469,531	A		11/1995	Faure et al.
5,497,061	A		3/1996	Nonaka et al.
5,523,663	A		6/1996	Tsuge et al.
5,527,145	A		6/1996	Duncan
5,557,397	A		9/1996	Hyde et al.
5,581,975	A		12/1996	Trebbi
5,737,500	A		4/1998	Seraji et al.
5,743,374	A	*	4/1998	Monsees B65H 1/30 414/349
5,838,882	A		11/1998	Gan et al.
5,895,690	A		4/1999	Greisel
6,018,923	A		2/2000	Wendt
6,049,377	A		4/2000	Lau et al.
6,101,455	A		8/2000	Davis
6,112,955	A		9/2000	Lang
6,134,507	A		10/2000	Markey, Jr. et al.
6,166,809	A		12/2000	Pettersen et al.
6,166,811	A		12/2000	Long et al.
6,172,754	B1		1/2001	Niebuhr
6,213,309	B1		4/2001	Dadisho
6,285,959	B1		9/2001	Greer
6,310,644	B1		10/2001	Keightley
6,330,503	B1		12/2001	Sharp et al.
6,370,837	B1		4/2002	Mcmahon et al.
6,427,122	B1		7/2002	Lin
6,429,016	B1		8/2002	Mcneil
6,512,993	B2		1/2003	Kacyra et al.
6,516,272	B2		2/2003	Lin
6,584,378	B1		6/2003	Anfindsen
6,611,141	B1		8/2003	Schulz
6,618,496	B1		9/2003	Tassakos et al.
6,628,322	B1		9/2003	Cerruti
6,643,002	B2		11/2003	Drake, Jr.
6,664,529	B2		12/2003	Pack et al.
6,681,145	B1		1/2004	Greenwood et al.
6,683,694	B2		1/2004	Cornil
6,704,619	B1		3/2004	Coleman et al.
6,741,364	B2		5/2004	Lange et al.
6,825,937	B1		11/2004	Gebauer et al.
6,850,946	B1		2/2005	Rappaport et al.
6,859,729	B2		2/2005	Breakfield et al.
6,864,966	B2		3/2005	Giger
6,868,847	B2		3/2005	Ainedter et al.
6,873,880	B2		3/2005	Hooke et al.
6,917,893	B2		7/2005	Dietsch et al.
6,935,036	B2		8/2005	Barber et al.
6,957,496	B2		10/2005	Raab et al.
6,965,843	B2		11/2005	Hobden et al.
6,970,802	B2		11/2005	Ban et al.
6,996,912	B2		2/2006	Raab et al.
7,050,930	B2		5/2006	Hobden et al.
7,051,450	B2		5/2006	Barber et al.
7,069,664	B2		7/2006	Barber et al.
7,107,144	B2		9/2006	Capozzi et al.
7,111,437	B2		9/2006	Ainedter
7,130,034	B2		10/2006	Barvosa-carter et al.
7,142,981	B2		11/2006	Hablani
7,145,647	B2		12/2006	Suphellen et al.
7,153,454	B2		12/2006	Khoshnevis
7,174,651	B2		2/2007	Barber et al.
7,230,689	B2		6/2007	Lau
7,246,030	B2		7/2007	Raab et al.
7,269,910	B2		9/2007	Raab et al.
7,347,311	B2		3/2008	Rudge
7,519,493	B2		4/2009	Atwell et al.
7,551,121	B1		6/2009	Oconnell et al.
7,564,538	B2		7/2009	Sakimura et al.
7,570,371	B1		8/2009	Storm
7,576,836	B2		8/2009	Bridges
7,576,847	B2		8/2009	Bridges
7,591,078	B2		9/2009	Crampton
7,639,347	B2		12/2009	Eaton
7,693,325	B2		4/2010	Pulla et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

7,701,587 B2 4/2010 Shioda et al.
7,743,586 B2 6/2010 Hancock
7,774,159 B2 8/2010 Cheng et al.
7,800,758 B1 9/2010 Bridges et al.
7,804,602 B2 9/2010 Raab
RE42,055 E 1/2011 Raab et al.
RE42,082 E 2/2011 Raab et al.
7,881,896 B2 2/2011 Atwell et al.
7,967,549 B2 6/2011 Geist et al.
7,993,289 B2 8/2011 Quistgaard et al.
8,036,452 B2 10/2011 Pettersson et al.
8,054,451 B2 11/2011 Karazi et al.
8,060,344 B2 11/2011 Stathis
8,145,446 B2 3/2012 Atwell et al.
8,166,727 B2 5/2012 Pivac et al.
8,169,604 B2 5/2012 Braghiroli et al.
8,185,240 B2 5/2012 Williams et al.
8,229,208 B2 7/2012 Pulla et al.
8,233,153 B2 7/2012 Knuettel
8,244,030 B2 8/2012 Pettersson et al.
8,248,620 B2 8/2012 Wicks et al.
8,269,984 B2 9/2012 Hinderling et al.
8,327,555 B2 12/2012 Champ
8,337,407 B2 12/2012 Quistgaard et al.
8,345,926 B2 1/2013 Clark et al.
8,346,392 B2 1/2013 Walser et al.
8,405,716 B2 3/2013 Yu et al.
8,467,072 B2 6/2013 Cramer et al.
8,537,372 B2 9/2013 Siercks et al.
8,537,376 B2 9/2013 Day et al.
8,558,992 B2 10/2013 Steffey
8,593,648 B2 11/2013 Cramer et al.
8,595,948 B2 12/2013 Raab et al.
8,606,399 B2 12/2013 Williams et al.
8,634,950 B2 1/2014 Simonetti et al.
8,644,964 B2 2/2014 Hendron et al.
8,668,074 B2 3/2014 Davidson
8,670,114 B2 3/2014 Bridges et al.
8,677,643 B2 3/2014 Bridges et al.
8,792,709 B2 7/2014 Pulla et al.
8,803,055 B2 8/2014 Lau et al.
8,812,155 B2 8/2014 Brethe
8,825,208 B1 * 9/2014 Benson E04F 21/02 700/247
8,832,954 B2 9/2014 Atwell et al.
8,848,203 B2 9/2014 Bridges et al.
8,875,409 B2 11/2014 Kretschmer et al.
8,898,919 B2 12/2014 Bridges et al.
8,902,408 B2 12/2014 Bridges
8,913,814 B2 12/2014 Gandyra
8,931,182 B2 1/2015 Raab et al.
8,942,940 B2 1/2015 York
8,965,571 B2 2/2015 Peters et al.
8,996,244 B2 3/2015 Summer et al.
8,997,362 B2 4/2015 Briggs et al.
9,020,240 B2 4/2015 Pettersson et al.
9,028,908 B1 5/2015 DeTar
9,033,998 B1 5/2015 Schaible et al.
RE45,565 E 6/2015 Bridges et al.
9,046,360 B2 6/2015 Atwell et al.
9,074,381 B1 7/2015 Drew
9,109,877 B2 8/2015 Thierman
9,146,315 B2 9/2015 Bosse et al.
9,151,830 B2 10/2015 Bridges
9,163,922 B2 10/2015 Bridges et al.
9,170,096 B2 10/2015 Fowler et al.
9,188,430 B2 11/2015 Atwell et al.
9,207,309 B2 12/2015 Bridges
9,223,025 B2 12/2015 Debrunner et al.
9,229,108 B2 1/2016 Debrunner et al.
9,266,238 B2 2/2016 Huettenhofer
9,267,784 B2 2/2016 Atwell et al.
9,278,448 B2 3/2016 Freeman
9,279,661 B2 3/2016 Tateno et al.
9,303,988 B2 4/2016 Tani
9,353,519 B2 5/2016 Williams
9,354,051 B2 5/2016 Dunne et al.
9,358,688 B2 6/2016 Drew
9,367,741 B2 6/2016 Le Marec
9,377,301 B2 6/2016 Neier et al.
9,383,200 B2 7/2016 Hulm et al.
9,395,174 B2 7/2016 Bridges
9,405,293 B2 8/2016 Meuleau
9,423,282 B2 8/2016 Moy
9,437,005 B2 9/2016 Tateno et al.
9,443,308 B2 9/2016 Pettersson et al.
9,452,533 B2 9/2016 Calkins et al.
9,454,818 B2 9/2016 Cramer
9,476,695 B2 10/2016 Becker et al.
9,481,007 B2 11/2016 Rzonca
9,482,524 B2 11/2016 Metzler et al.
9,482,525 B2 11/2016 Bridges
9,482,746 B2 11/2016 Bridges
9,494,686 B2 11/2016 Maryfield et al.
9,513,100 B2 12/2016 Raab et al.
9,536,163 B2 1/2017 Veeser et al.
9,541,371 B2 1/2017 Pettersson et al.
9,561,019 B2 2/2017 Mihailescu et al.
9,607,239 B2 3/2017 Bridges et al.
9,618,620 B2 4/2017 Zweigle et al.
9,658,061 B2 5/2017 Wilson et al.
9,671,221 B2 6/2017 Ruhland et al.
9,679,385 B2 6/2017 Suzuki et al.
9,686,532 B2 6/2017 Tohme
9,708,079 B2 7/2017 Desjardien et al.
9,715,730 B2 7/2017 Suzuki
9,720,087 B2 8/2017 Christen et al.
9,734,609 B2 8/2017 Pulla et al.
9,739,595 B2 8/2017 Lau
9,746,308 B2 8/2017 Gong
9,757,859 B1 9/2017 Kolb et al.
9,768,837 B2 9/2017 Charvat et al.
9,772,173 B2 9/2017 Atwell et al.
9,803,969 B2 10/2017 Gong
9,816,813 B2 11/2017 Lettau et al.
9,829,305 B2 11/2017 Gong
9,835,717 B2 12/2017 Bosse et al.
9,844,792 B2 12/2017 Pettersson et al.
9,879,976 B2 1/2018 Bridges et al.
9,897,442 B2 2/2018 Pettersson et al.
9,903,939 B2 2/2018 Charvat et al.
9,909,855 B2 3/2018 Becker et al.
9,915,733 B2 3/2018 Fried et al.
9,921,046 B2 3/2018 Gong
9,958,268 B2 5/2018 Ohtomo et al.
9,958,545 B2 5/2018 Eichenholz et al.
9,964,398 B2 5/2018 Becker et al.
9,964,402 B2 5/2018 Tohme et al.
9,967,545 B2 5/2018 Tohme
9,989,353 B2 6/2018 Bartmann et al.
10,012,732 B2 7/2018 Eichenholz et al.
10,030,972 B2 7/2018 Iseli et al.
10,041,793 B2 8/2018 Metzler et al.
10,054,422 B2 8/2018 Böckem et al.
10,058,394 B2 8/2018 Johnson et al.
10,073,162 B2 9/2018 Charvat et al.
10,074,889 B2 9/2018 Charvat et al.
10,082,521 B2 9/2018 Atlas et al.
10,090,944 B1 10/2018 Charvat et al.
10,094,909 B2 10/2018 Charvat et al.
10,126,415 B2 11/2018 Becker et al.
10,189,176 B2 1/2019 Williams
10,220,511 B2 3/2019 Linnell et al.
10,240,949 B2 3/2019 Peters et al.
10,315,904 B2 6/2019 Landler
10,635,758 B2 * 4/2020 Pivac B25J 9/1651
10,865,578 B2 12/2020 Pivac et al.
10,876,308 B2 12/2020 Pivac et al.
11,106,836 B2 8/2021 Pivac et al.
11,401,115 B2 8/2022 Pivac et al.
2002/0030145 A1 3/2002 Lang
2002/0176603 A1 11/2002 Bauer et al.
2003/0048459 A1 3/2003 Gooch
2003/0090682 A1 5/2003 Gooch et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2003/0120377 A1 6/2003 Hooke et al.
2003/0206285 A1 11/2003 Lau
2004/0078137 A1 4/2004 Breakfield et al.
2004/0093119 A1 5/2004 Gunnarsson et al.
2004/0200947 A1 10/2004 Lau
2005/0007450 A1 1/2005 Hill et al.
2005/0057745 A1 3/2005 Bontje
2005/0060092 A1 3/2005 Hablani
2005/0086901 A1 4/2005 Chisholm
2005/0131619 A1 6/2005 Rappaport et al.
2005/0196484 A1 9/2005 Khoshnevis
2005/0252118 A1 11/2005 Matsufuji
2006/0167587 A1 7/2006 Read
2006/0215179 A1 9/2006 Mcmurtry et al.
2007/0024870 A1 2/2007 Girard et al.
2007/0229802 A1 10/2007 Lau
2007/0284215 A1 12/2007 Rudge
2008/0030855 A1 2/2008 Lau
2008/0189046 A1 8/2008 Eliasson et al.
2009/0038258 A1 2/2009 Pivac et al.
2009/0074979 A1 3/2009 Krogedal et al.
2010/0025349 A1 2/2010 Khoshnevis
2010/0138185 A1 6/2010 Kang
2010/0274390 A1 10/2010 Walser et al.
2010/0281822 A1 11/2010 Murray
2011/0066393 A1 3/2011 Groll et al.
2011/0153524 A1 6/2011 Schnackel
2011/0208347 A1 8/2011 Otake et al.
2012/0038074 A1 2/2012 Khoshnevis
2012/0099096 A1 4/2012 Bridges et al.
2012/0136524 A1 5/2012 Everett et al.
2012/0265391 A1 10/2012 Letsky
2012/0277898 A1 11/2012 Kawai et al.
2013/0028478 A1 1/2013 St-pierre et al.
2013/0068061 A1 3/2013 Yoon
2013/0103192 A1 4/2013 Huettenhofer
2013/0104407 A1 5/2013 Lee
2013/0222816 A1 8/2013 Briggs et al.
2013/0250285 A1 9/2013 Bridges et al.
2013/0286196 A1 10/2013 Atwell
2014/0002608 A1 1/2014 Atwell et al.
2014/0067121 A1 3/2014 Brooks et al.
2014/0076923 A1 3/2014 Clark
2014/0176677 A1 6/2014 Valkenburg et al.
2014/0192187 A1 7/2014 Atwell et al.
2014/0309960 A1 10/2014 Vennegeerts et al.
2014/0343727 A1 11/2014 Calkins et al.
2014/0348388 A1 11/2014 Metzler et al.
2014/0366481 A1 12/2014 Benson
2015/0082740 A1 3/2015 Peters et al.
2015/0100066 A1 4/2015 Kostrzewski et al.
2015/0134303 A1 5/2015 Chang et al.
2015/0153720 A1 6/2015 Pettersson et al.
2015/0158181 A1 6/2015 Kawamura et al.
2015/0241203 A1 8/2015 Jordil et al.
2015/0258694 A1 9/2015 Hand et al.
2015/0276402 A1 10/2015 Grsser et al.
2015/0280829 A1 10/2015 Breuer
2015/0293596 A1 10/2015 Krausen et al.
2015/0309175 A1 10/2015 Hinderling et al.
2015/0314890 A1 11/2015 Desjardien et al.
2015/0352721 A1 12/2015 Wicks et al.
2015/0355310 A1 12/2015 Gong et al.
2015/0367509 A1 12/2015 Georgeson
2015/0371082 A1 12/2015 Csaszar et al.
2015/0377606 A1 12/2015 Thielemans
2016/0005185 A1 1/2016 Geissler
2016/0093099 A1 3/2016 Bridges
2016/0153786 A1 6/2016 Liu et al.
2016/0187130 A1 6/2016 Metzler et al.
2016/0187470 A1 6/2016 Becker et al.
2016/0223364 A1 8/2016 Peters et al.
2016/0242744 A1 8/2016 Mihailescu et al.
2016/0263767 A1 9/2016 Williams
2016/0274237 A1 9/2016 Stutz
2016/0282107 A1 9/2016 Roland et al.
2016/0282110 A1 9/2016 Vagman et al.
2016/0282179 A1 9/2016 Nazemi et al.
2016/0288331 A1 10/2016 Sivich et al.
2016/0313114 A1 10/2016 Tohme et al.
2016/0327383 A1 11/2016 Becker et al.
2016/0340873 A1 11/2016 Eidenberger et al.
2016/0341041 A1 11/2016 Puura et al.
2016/0349746 A1 12/2016 Grau
2016/0363436 A1 12/2016 Clark et al.
2016/0363659 A1 12/2016 Mindell et al.
2016/0363663 A1 12/2016 Mindell et al.
2016/0363664 A1 12/2016 Mindell et al.
2016/0364869 A1 12/2016 Siercks et al.
2016/0364874 A1 12/2016 Tohme et al.
2017/0066157 A1 3/2017 Peters et al.
2017/0067739 A1 3/2017 Siercks et al.
2017/0082436 A1 3/2017 Siercks et al.
2017/0091922 A1 3/2017 Siercks et al.
2017/0091923 A1 3/2017 Siercks et al.
2017/0108528 A1 4/2017 Atlas et al.
2017/0122733 A1 5/2017 Brown
2017/0122736 A1 5/2017 Dold et al.
2017/0166399 A1 6/2017 Stubbs
2017/0173796 A1 6/2017 Kim et al.
2017/0176572 A1 6/2017 Charvat et al.
2017/0179570 A1 6/2017 Charvat
2017/0179603 A1 6/2017 Charvat et al.
2017/0191822 A1 7/2017 Becker et al.
2017/0227355 A1 8/2017 Pettersson et al.
2017/0236299 A1 8/2017 Valkenburg et al.
2017/0254102 A1 9/2017 Peters et al.
2017/0269203 A1 9/2017 Trishaun
2017/0307757 A1 10/2017 Hinderling et al.
2017/0314909 A1 11/2017 Dang
2017/0314918 A1 11/2017 Shah
2017/0333137 A1 11/2017 Roessler
2017/0343336 A1 11/2017 Lettau
2018/0003493 A1 1/2018 Bernhard et al.
2018/0017384 A1 1/2018 Siercks et al.
2018/0023935 A1 1/2018 Atwell et al.
2018/0038684 A1 2/2018 Fröhlich et al.
2018/0046096 A1 2/2018 Shibazaki
2018/0052233 A1 2/2018 Frank et al.
2018/0108178 A1 4/2018 Murugappan et al.
2018/0121571 A1 5/2018 Tiwari et al.
2018/0149469 A1 5/2018 Becker et al.
2018/0156601 A1 6/2018 Pontai
2018/0170719 A1 6/2018 Tasch et al.
2018/0180416 A1 6/2018 Edelman et al.
2018/0202796 A1 7/2018 Ziegenbein
2018/0209156 A1 7/2018 Pettersson
2018/0239010 A1 8/2018 Mindell et al.
2018/0300433 A1 10/2018 Maxam et al.
2019/0026401 A1 1/2019 Benjamin et al.
2019/0032348 A1 1/2019 Parkes
2019/0184555 A1 6/2019 Linnell et al.
2019/0224846 A1 7/2019 Pivac et al.
2019/0251210 A1 8/2019 Pivac et al.
2019/0316369 A1* 10/2019 Pivac E04G 21/22
2020/0173777 A1 6/2020 Pivac et al.
2020/0206923 A1 7/2020 Pivac et al.
2020/0206924 A1 7/2020 Pivac et al.
2020/0215688 A1 7/2020 Pivac et al.
2020/0215692 A1 7/2020 Pivac et al.
2020/0215693 A1 7/2020 Pivac et al.
2021/0016437 A1 1/2021 Pivac et al.
2021/0016438 A1 1/2021 Pivac et al.
2021/0080582 A1 3/2021 Pivac et al.
2021/0291362 A1 9/2021 Pivac et al.
2021/0370509 A1 12/2021 Pivac et al.
2021/0379775 A1 12/2021 Pivac et al.
2022/0058300 A1 2/2022 Pivac et al.
2024/0328180 A1 10/2024 Pickering

FOREIGN PATENT DOCUMENTS

CN 2730976 Y 10/2005
CN 2902981 Y 5/2007

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

CN	2923903	Y	7/2007
CN	101100903	A	1/2008
CN	201184054	Y	1/2009
CN	101360873	B	2/2009
CN	101476883	A	7/2009
CN	100557169	C	11/2009
CN	101694130	A	4/2010
CN	201972413	U	9/2011
CN	102359282	A	2/2012
CN	202248944	U	5/2012
CN	202292752	U	7/2012
CN	102995911	A	3/2013
CN	202925913	U	5/2013
CN	103363902	A	10/2013
CN	103698769	A	4/2014
CN	203701626	U	7/2014
CN	104141391	B2	11/2014
CN	104153591	A	11/2014
CN	104493810	A	4/2015
CN	204295678	U	4/2015
CN	104612411	A	5/2015
CN	204311767	U	5/2015
CN	103774859	B	11/2015
CN	103753586	B	12/2015
CN	105113373	A	12/2015
CN	105178616	A	12/2015
CN	105257008	B	1/2016
CN	105544998	A	5/2016
CN	205290958	U	6/2016
CN	104806028	B	11/2016
CN	205668271	U	11/2016
CN	205840368	U	12/2016
CN	205990775	U	3/2017
CN	206185879	U	5/2017
CN	206189878	U	5/2017
CN	105089274	B	6/2017
CN	105064699	B	7/2017
CN	107217859	A	9/2017
CN	107237483	A	10/2017
CN	107357294	A	11/2017
CN	107605167	A	1/2018
CN	206838382	U	1/2018
CN	206844687	U	1/2018
CN	107654077	A	2/2018
CN	107675891	A	2/2018
CN	107740591	A	2/2018
CN	106088632	B	3/2018
CN	107762165	A	3/2018
CN	207063553	U	3/2018
CN	106088631	B	5/2018
CN	107975245	A	5/2018
CN	108061551	A	5/2018
CN	108222527	A	6/2018
CN	108301628	A	7/2018
CN	108331362	A	7/2018
CN	106150109	B	8/2018
CN	108396977	A	8/2018
CN	108457479	A	8/2018
CN	108708560	A	10/2018
CN	208023979	U	10/2018
CN	106881711	A	4/2019
CN	107083845	A	6/2019
CN	108016585	B	7/2019
CN	209701519	U	11/2019
DE	3430915	C2	3/1986
DE	4038260	C2	6/1991
DE	4207384	A1	9/1993
DE	19509809	A1	10/1995
DE	4417928	A1	11/1995
DE	29601535	U1	5/1997
DE	19600006	A1	7/1997
DE	19603234	C2	9/1997
DE	19743717	C2	4/1999
DE	19849720	A1	5/2000
DE	10230021	C1	7/2003
DE	102006030130	B3	9/2007
DE	102009018070	A1	10/2010
DE	102009042014	A1	3/2011
DE	202012100646	U1	6/2013
DE	102013019869	A1	5/2015
EP	190076	A1	8/1986
EP	370682	A2	5/1990
EP	456020	A1	1/1995
EP	493020	B1	4/1995
EP	495525	B1	4/1995
EP	836664	B1	1/1999
EP	674069	B1	12/1999
EP	1918478	A2	5/2008
EP	2112291	A1	10/2009
EP	2219528	A1	8/2010
EP	2249997	A1	11/2010
EP	2353801	A2	8/2011
EP	2199719	B1	10/2014
EP	3084719	A1	10/2016
ES	2296556	A1	4/2008
FR	2230825	A1	12/1974
FR	2524522	A1	10/1983
GB	119331	A	10/1918
GB	2198105	A	5/1923
GB	673472	A	6/1952
GB	682010	A	11/1952
GB	839253	A	6/1960
GB	1067604	A	5/1967
GB	1465068	A	2/1977
GB	2268536	A	1/1994
GB	125079		12/2001
GB	2422400	A	7/2006
JP	64006719	A	1/1989
JP	H07101509	A	11/1999
JP	2000127077	A	5/2000
JP	2005283600	A	10/2005
JP	4294990	B2	4/2009
JP	2009521630	A	6/2009
JP	5508895	B2	3/2014
LU	87054	A1	6/1989
LU	87381	A1	6/1990
LU	88144	A1	4/1994
RU	85392	U1	8/2009
WO	9702397	A1	1/1997
WO	2001076830	A1	10/2001
WO	2004020760	A1	3/2004
WO	2004083540	A3	9/2004
WO	2005014240	A1	2/2005
WO	2005017550	A2	2/2005
WO	2005070657	A1	8/2005
WO	2004011734	A1	11/2005
WO	2006111827	A1	10/2006
WO	2007076581	A1	7/2007
WO	2008124713	A2	10/2008
WO	2009026641	A1	3/2009
WO	2009026642	A1	3/2009
WO	2009044002	A1	4/2009
WO	2010020457	A1	2/2010
WO	2011077006	A2	6/2011
WO	2013088154	A1	6/2013
WO	2013134559	A1	9/2013
WO	2017162630	A1	9/2017
WO	2018009978	A1	1/2018
WO	2018009980	A1	1/2018
WO	2018009985	A1	1/2018
WO	2018009986	A1	1/2018
WO	WO-2018009981	A1 *	1/2018 ..... B25J 13/089
WO	2018052469	A3	4/2018
WO	2018099323	A1	6/2018
WO	2019006511	A1	1/2019
WO	2019014701	A1	1/2019
WO	2019014702	A1	1/2019
WO	2019014705	A1	1/2019
WO	2019014706	A1	1/2019
WO	2019014707	A1	1/2019
WO	2019033165	A1	2/2019
WO	2019033166	A1	2/2019
WO	2019033170	A1	2/2019
WO	2019068128	A1	4/2019

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

WO	2019071313	A1	4/2019
WO	2020014737	A1	1/2020
WO	2020047574	A1	3/2020
WO	2020136563	A2	7/2020
WO	2020210863	A1	10/2020

OTHER PUBLICATIONS

Examination report dated Sep. 30, 2023 on UAE Patent Application No. P60005242020.

Examination report issued Mar. 31, 2023 on Saudi Arabian Patent Application No. 522440994.

Boston Dynamics: "Introducing Spot (previously SpotMini)", Jun. 28, 2016, YouTube video, 1 page (screenshot of video); video retrieved at <https://www.youtube.com/watch?v=tf7IEVTDjng>.

Delgado, R. et al.: "Development and Control of an Omnidirectional Mobile Robot on an EtherCAT Network", International Journal of Applied Engineering Research, vol. 11, No. 21, 2016, pp. 10586-10592, XP055574484 *.

Dorfler, K. et al.: "Mobile Robotic Brickwork ', Automation of a Discrete Robotic Fabrication Process Using an Autonomous Mobile Robot Robotic Fabrication in Architecture", Art and Design 2016, Feb. 4, 2016 (Feb. 4, 2016), pp. 204-217, XP055567451 *.

Egerstedt, M. et al.: "Control of Mobile Platforms using a Virtual Vehicle Approach", IEEE Transactions on Automatic Control, vol. 46, No. 11, Nov. 2001 (Nov. 1, 2001), XP055567515 *.

Examination Report mailed Apr. 18, 2021 in GCC Patent Application No. 2018-35644, 5 pages.

Examination Report mailed Apr. 30, 2021 in GCC Patent Application No. 2018-35643, 3 pages.

Examination Report mailed Jun. 29, 2021 for India Patent Application No. 201927004006, 6 pages.

Examination Report mailed Sep. 30, 2021 for Australian Patent Application No. 2017295316, 3 pages.

Extended European Search Report mailed Jun. 4, 2021 for European Patent Application No. 18865644.1, 7 pages.

Extended European Search Report mailed Mar. 16, 2021 for European Patent Application No. 18834565.6, 19 pages.

Extended European Search Report mailed Mar. 17, 2021 for European Patent Application No. 18835861.8, 12 pages.

Extended European Search Report mailed Mar. 18, 2021 for European Patent Application No. 18834673.8, 14 pages.

Extended European Search Report mailed Mar. 18, 2021 for European Patent Application No. 18834893.2, 12 pages.

Extended European Search Report mailed Mar. 18, 2021 for European Patent Application No. 18835737.0, 10 pages.

Extended European Search Report mailed Mar. 30, 2021 for European Patent Application No. 18845794.9, 13 pages.

Extended European Search Report mailed Mar. 5, 2021 for European Patent Application No. 18828425.1, 7 pages.

Fastbrick Robotics, Fastbrick Robotics: Hadrian 105 First Look Revealed, Nov. 16, 2015 (Nov. 16, 2015), XP054978174, Retrieved from the Internet <URL:https://www.youtube.com/watch?v=7Zw7qHxMtrY> [retrieved on Nov. 16, 2015] *.

Fastbrick Robotics: Hadrian 105 Demonstrative Model Animation, Jun. 29, 2015 (Jun. 29, 2015), XP054979424, Retrieved from the Internet <URL:https://www.youtube.com/watch?v=Rebqcsb61gY> [retrieved on Mar. 7, 2018] *.

Fastbrick Robotics: Hadrian 105 Time Lapse, Fastbrick Robotics Time Lapse, May 22, 2016 (May 22, 2016), XP054978173, Retrieved from the Internet <URL:https://www.youtube.com/watch?v=4YcrO8ONcfY> [retrieved on May 22, 2016] *.

Fastbrick Robotics: Hadrian X Digital Construction System, published on Sep. 21, 2016 <URL: https://www.youtube.com/watch?v=5bW1vuCgEaA >.

Feng, C. et al.: "Vision Guided Autonomous Robotic Assembly and as-built Scanning on Unstructured Construction Sites", Automation in Construction, vol. 59, Nov. 2015 (Nov. 1, 2015), pp. 128-138, XP055567454 *.

Gander H et al: "Application of a floating point digital signal processor to a dynamic robot measurement system", Instrumentation and Measurement Technology Conference, 1994. IMTC/94. Conference Proceedings. 10th Anniversary. Advanced Technologies in I & M., 1994 IEEE Hamamatsu, Japan May 10-12, 1994, New York, NY, USA, IEEE, May 10, 1994 (May 10, 1994), pp. 372-375, XP010121924, DOI: 10.1109/IMTC.1994.352046, ISBN: 978-0-7803-1880-9, *whole document*.

Gao, X. et al.: "Complete Solution Classification for the Perspective-Three-Point Problem", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 25, No. 8, Aug. 2003 (Aug. 1, 2003), pp. 930-943, XP011099374 *.

Garrido, S. et al., "FM2: A real-time fast marching sensor based motion planner", Advanced Intelliget Mechatronics, 2007 IEEE/ASME International Conference on, IEEE, PI, Sep. 1, 2007 (Sep. 1, 2007), pp. 1-6.

Giftthaler, M. et al., "Efficient Kinematic Planning for Mobile Manipulators with Non-holonomic Constraints Using Optimal Control", 2017 IEEE International Conference on Robotics and Automation (ICRA), Singapore, May 29-Jun. 3, 2017.

Heintze, H., "Design and Control of a Hydraulically Actuated Industrial Brick Laying Robot," 264 pages.

Heintze, J. et al., "Controlled hydraulics for a direct drive brick laying robot," Automation in Construction 5 (1996), pp. 23-29.

Helm, V. et al.: "Mobile Robotic Fabrication on Construction Sites: dimRob", IEEE /RSJ International Conference on Intelligent Robots and Systems, Oct. 7, 2012 (Oct. 7, 2012), Vilamoura, Portugal, pp. 4335-4341, XP032287463 *.

http://www.new-technologies.org/ECT/Other/brickrob.htm. "Emerging Construction Technologies." Dec. 1, 2006.

Huang, S. et al., "Applying High-Speed Vision Sensing to an Industrial Robot for High-Performance Position Regulation under Uncertainties," Sensors, 2016, 16, 1195, 15 pages.

International Search Report and Written Opinion for International Application No. PCT/AU2021/050732; Date of Mailing: Sep. 21, 2021; 10 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2017/050731; Date of Mailing: Jan. 15, 2019; 5 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2017/050738; Date of Mailing: Jan. 15, 2019; 13 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2017/050739; Date of Mailing: Jan. 15, 2019; 6 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2018/050733; Date of Mailing: Jan. 21, 2020; 6 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2018/050734; Date of Mailing: Jan. 21, 2020; 9 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2018/050737; Date of Mailing: Jan. 21, 2020; 6 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2018/050739; Date of Mailing: Jan. 21, 2020; 6 pages.

International Preliminary Report on Patentability for International Application No. PCT/AU2018/050740; Date of Mailing: Jan. 21, 2020; 6 pages.

International Search Report and Written Opinion for International Application No. PCT/AU2017/050730; Date of Mailing: Aug. 23, 2017; 17 pages.

International Search Report and Written Opinion for International Application No. PCT/AU2017/050731; Date of Mailing: Aug. 31, 2017; 8 pages.

International Search Report and Written Opinion for International Application No. PCT/AU2017/050738; Date of Mailing: Oct. 17, 2017; 19 pages.

International Search Report and Written Opinion for International Application No. PCT/AU2017/050739; Date of Mailing: Sep. 28, 2017; 9 pages.

(56) **References Cited**

OTHER PUBLICATIONS

International Search Report and Written Opinion for International Patent Application No. PCT/AU19/50742; Date of Mailing Sep. 23, 2019; 5 pages.
International Search Report and Written Opinion for International Patent Application No. PCT/AU19/50743; Date of Mailing mailed Oct. 1, 2019; 10 pages.
International Search Report and Written Opinion for International Patent Application No. PCT/AU20/50367; Date of Mailing Jun. 29, 2020; 15 pages.
International Search Report and Written Opinion for International Patent Application No. PCT/AU20/50368; Date of Mailing Jun. 25, 2020; 11 pages.
Kazemi, M. et al.: "Path Planning for Image-based Control of Wheeled Mobile Manipulators", 2012 IEEE /RSJ International Conference on Intelligent Robots and Systems, Oct. 7, 2012 (Oct. 7, 2012), Vilamoura, Portugal, XP055567470 *.
Kleinigger, M. et al.: "Application of 6-DOF sensing for robotic disturbance compensation", Automation Science and Engineering (CASE), 2010 IEEE Conference on, IEEE, Piscataway, NJ, USA, Aug. 21, 2010 (Aug. 21, 2010, pp. 344-349, XP031762876, ISBN: 978-1-4244-5477-1, *abstract*, *sections 1 to 3*.
Kleinkes, M. et al.: "Laser Tracker and 6DoF measurement strategies in industrial robot applications", CMSC 2011: Coordinate Metrology System Conference, Jul. 25, 2011 (Jul. 25, 2011), XP055456272 *.
Koren et al.: "End-effector guidance of robot arms", CIRP Annals—Manufacturing Technology, vol. 36, No. 1, 1987, pp. 289-292, XP055456270 *.
Kwon, S. et al., "On the Coarse/Fine Dual-Stage Manipulators with Robust Perturbation Compensator," IEEE, May 21-26, 2001, pp. 121-126.
Kyle in CMSC: Charlotte-Concord, Jul. 21-25, 2008.
Latteur, et al., "Drone-Based Additive Manufacturing of Architectural Structures," IASS Symposium 2015, Amsterdam, The Netherlands; Aug. 17-20, 2015; 12 pages.
Lippiello, V. et al.: "Position-Based Visual Servoing in Industrial Multirobot Cells Using a Hybrid Camera Configuration", IEEE Transactions on Robotics, vol. 23, No. 1, Feb. 2007 (Feb. 1, 2007), XP011163518 *.
Liu, Z. et al.: "EtherCAT Based Robot Modular Joint Controller", Proceeding of the 2015 IEEE International Conference on Information and Automation, Aug. 2015 (Aug. 1, 2015), Lijiang, China, pp. 1708-1713, XP033222650 *.
Mercedes-Benz: "Mercedes-Benz "Chicken" Magic Body Control TV commercial", YouTube, Sep. 23, 2013, 1 page. Retrevied from the internet: <https://www.youtube.com/watch?v+nLwML2PagbY>.
Notice of Acceptance of Patent Application received for priority Australian Patent Application No. 2017294796, mailed May 15, 2019 (158 pages).
Office Action mailed Apr. 21, 2021 in Japanese Patent Application No. 2019-523148, 4 pages.
Office Action mailed Aug. 20, 2021 for Japanese Patent Application No. 2019-523147, 3 pages.
Office Action mailed Jul. 5, 2021 for Japanese Patent Application No. 2019-523145, 4 pages.
Office Action mailed May 24, 2021 for Chinese Patent Application No. 201880067520.0, 8 pages.
Office Action mailed Sep. 3, 2021 for Chinese Patent Application No. 201780056460.8, 9 pages.
Partial Supplementary European Search Report mailed Apr. 14, 2020 in European Patent Application No. 17826696.1, 10 pages.
Pless, R.: "Using Many Cameras as One", IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Jun. 18, 2003 (Jun. 18, 2003), Madison , WI, USA, pp. 1-7, XP055564465 *.
Posada et al.: "High accurate robotic drilling with external sensor and compliance model-based compensation", Robotics and Automation (ICRA), 2016 IEEE International Conference, May 16, 2016 (May 16, 2016), pp. 3901-3907, XP032908649 *.
Pritschow, G. et al., "A Mobile Robot for On-Site Construction of Masonry," Inst. Of Control Tech. for Machine Tools and Manuf. Units, pp. 1701-1707.
Pritschow, G. et al., "Application Specific Realisation of a Mobile Robot for On-Site Construction of Masonry," Automation and Robotics in Construction XI, 1994, pp. 95-102.
Pritschow, G. et al., "Configurable Control System of a Mobile Robot for ON-Site Construction of Masonry," Inst. Of Control Technology for Machine Tools and Manuf. Units, pp. 85-92.
Pritschow, G. et al., "Technological aspects in the development of a mobile bricklaying robot," Automation in Construction 5 (1996), pp. 3-13.
Riegl Laser Measurement Systems. "Long Range & High Accuracy 3D Terrestrial Laser Scanner System—LMS-Z420i." pp. 1-4.
Salcudean, S. et al., "On the Control of Redundant Coarse-Fine Manipulators," IEEE, pp. 1834-1840.
Sandy, T. et al.: "Autonomous Repositioning and Localization of an In Situ Fabricator", 2016 IEEE International Conference on Robotics and Automation (ICRA), May 16, 2016 (May 16, 2016), pp. 2852-2858, XP055567467 *.
Siciliano, B. et al., "Robotics—chapters 2-4" Robotics, Dec. 31, 2009 (Dec. 31, 2009), Springer London, London, pp. 39-189.
Skibniewski, M.J., "Current Status of Construction Automation and Robotics in the United States of America," The 9th International Symposium on Automation and Robotics in Construction, Jun. 3-5, 1992, 8 pages.
Trimble ATS. "Advanced Tracking Sensor (ATS) with target recognition capability for stakeless machine control survey applications." pp. 1-4.
Vincze, M. et al., "A Laser Tracking System to Measure Position and Orientation of Robot End Effectors Under Motion," The International Journal of Robotics Research, vol. 13, No. 4, Aug. 1994, pp. 305-314.
Warszawski, A. et al., "Implementation of Robotics in Building: Current Status and Future Prospects," Journal of Construction Engineering and Management, Jan./Feb. 1998, 124(1), pp. 31-41.
Willmann, J. et al.: "Robotic Timber Construction—Expanding Additive Fabrication to New Dimensions", Automation in Construction, vol. 61, 2016, pp. 16-23, XP029310896 *.
Xu, H. et al.: "Uncalibrated Visual Servoing of Mobile Manipulators with an Eye-to-hand Camera", Proceedings of the 2016 IEEE International Conference on Robotics and Biomimetics, Dec. 3, 2016 (Dec. 3, 2016), Qingdao, China, pp. 2145-2150, XP033071767 *.
Yu, S.N. et al., "Feasibility verification of brick-laying robot using manipulation trajectory and the laying pattern optimization," Dept. of Mech. Eng., Automation in Construction (2009), pp. 644-655.
Zaki, T., "Parametric modeling of Blackwall assemblies for automated generation of shop drawings and detailed estimates using BIM", Master's Thesis, May 23, 2016, pp. 1-151.
Examination report dated Sep. 13, 2022 on Chinese Patent Application No. 201880066756.2, 11 pages.
IPRP dated Jan. 10, 2023 on International Patent Application No. PCT/AU2021/050732, 5 pages.
Examination Report dated Jul. 4, 2024 on European Patent Application No. 21837579.8.
International Preliminary Report on Patentability received for counterpart International Application No. PCT/AU2023/050325, mailed Oct. 31, 2024, 6 pages.
International Preliminary Report on Patentability received in International Patent Application No. PCT/AU2021/050361, mailed Oct. 25, 2022.

* cited by examiner

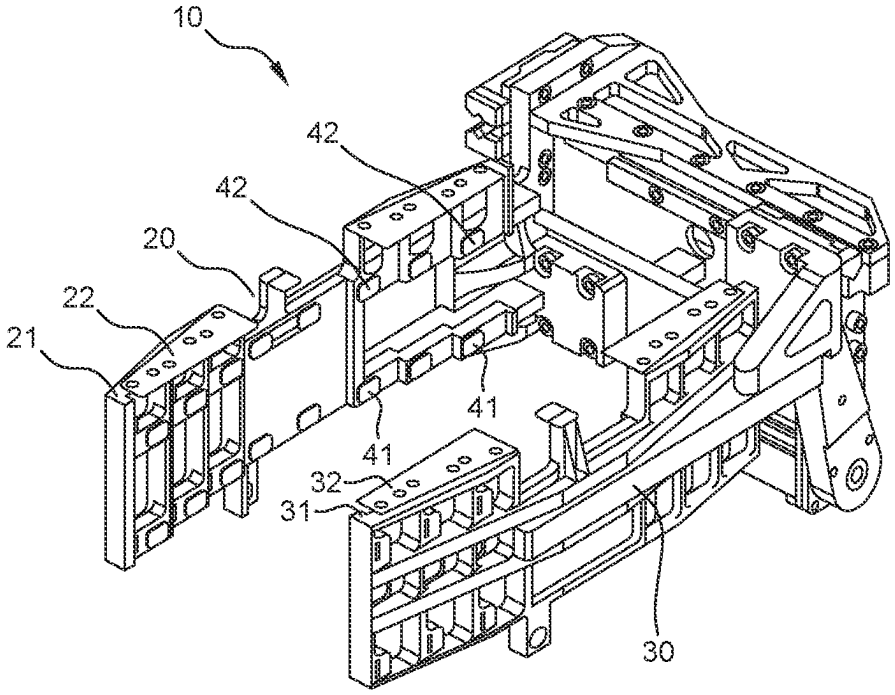


Fig. 1A

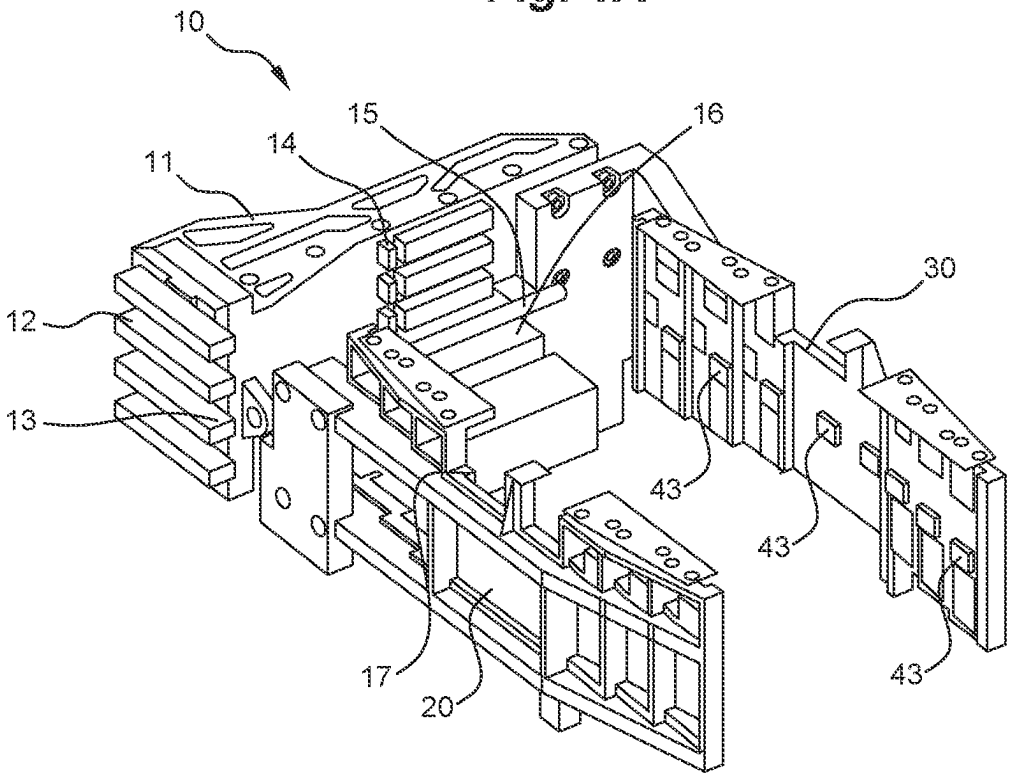


Fig. 1B

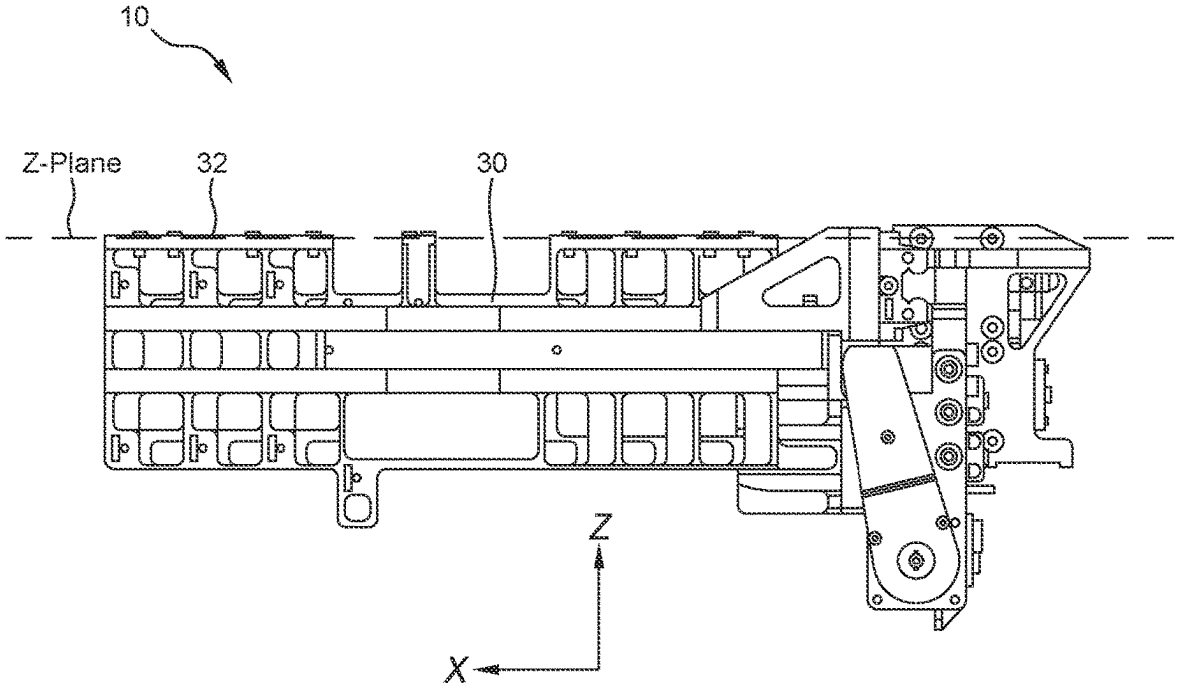

10
Z-Plane
32
30
Z
X

Fig. 1C

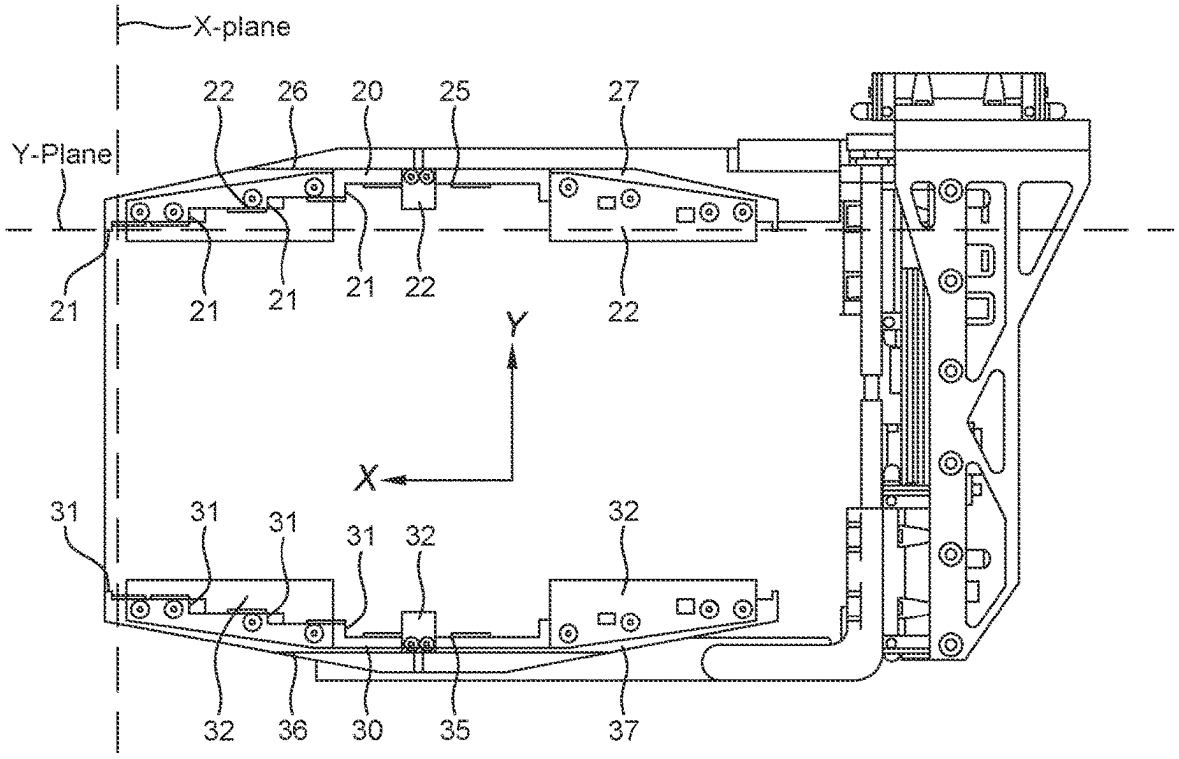

X-plane
Y-Plane
22
26
20
25
27
21
21
21
21
22
22
Y
X
31
31
31
31
32
32
32
36
30
35
37

Fig. 1D

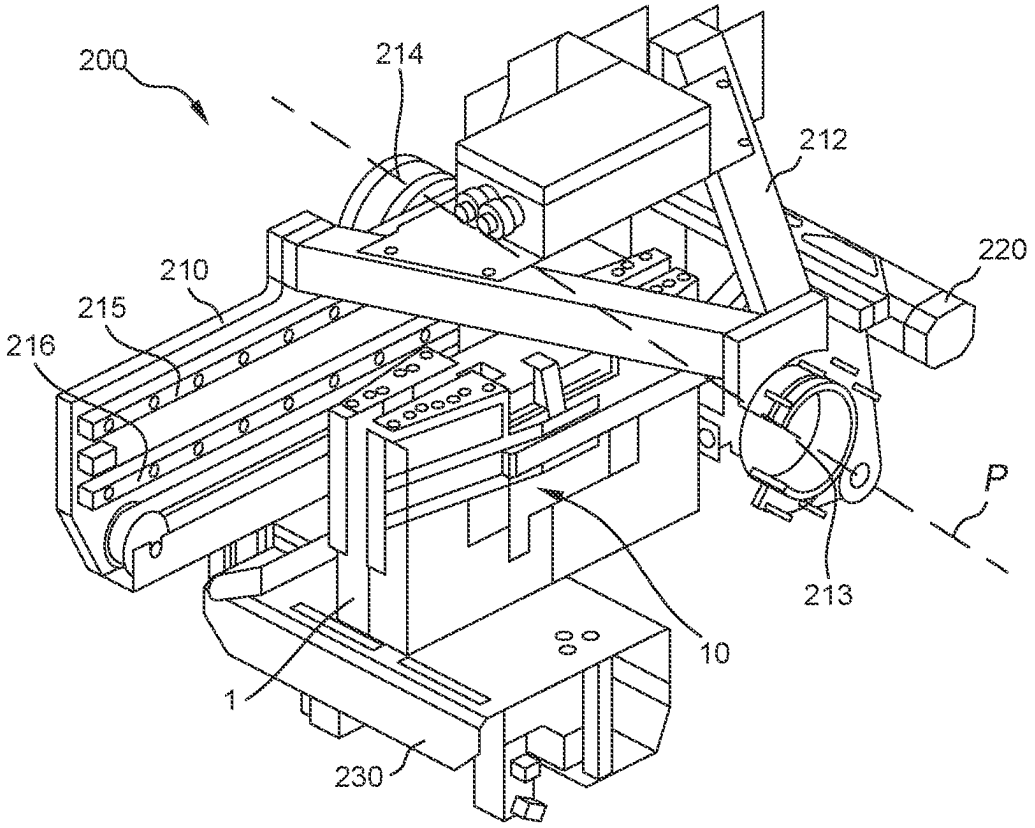


Fig. 2

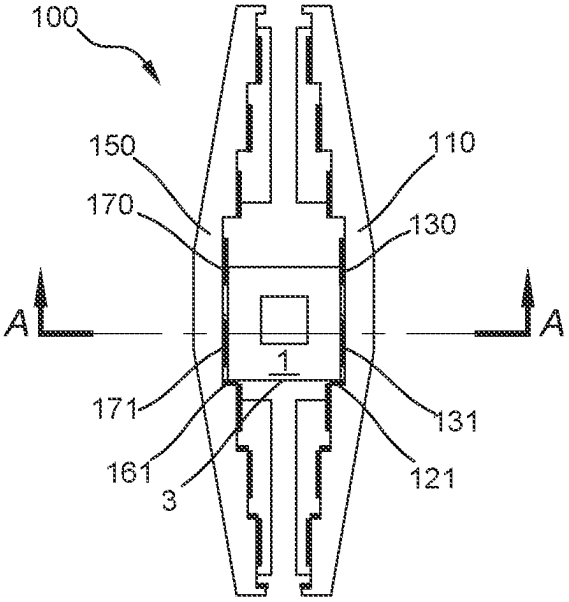


Fig. 3A

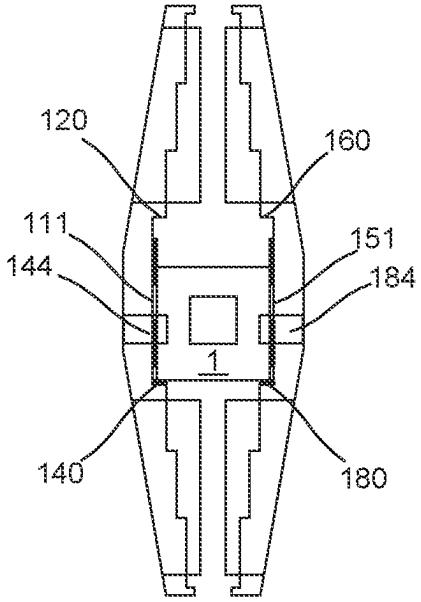


Fig. 3B

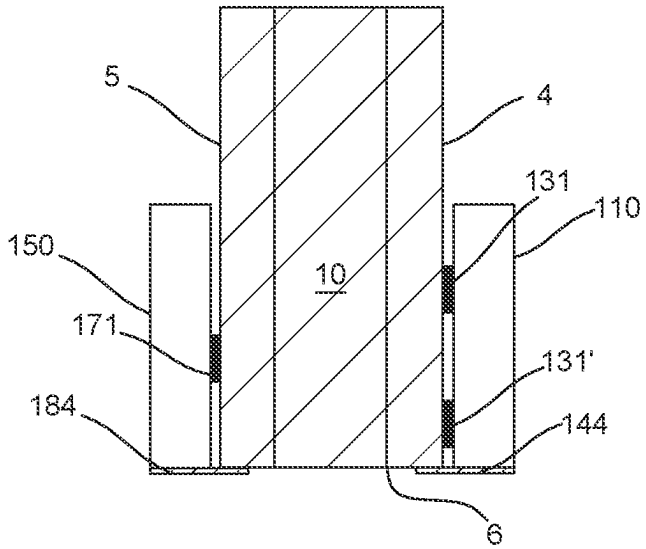


Fig. 3C

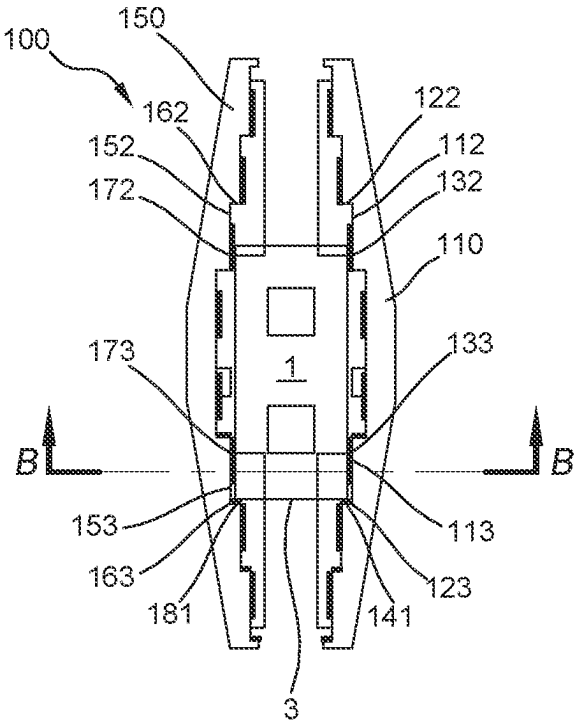


Fig. 4A

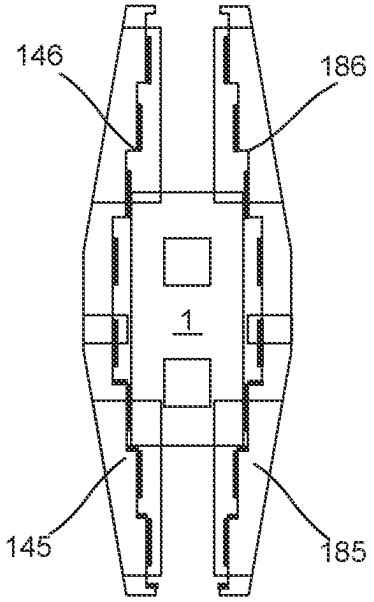


Fig. 4B

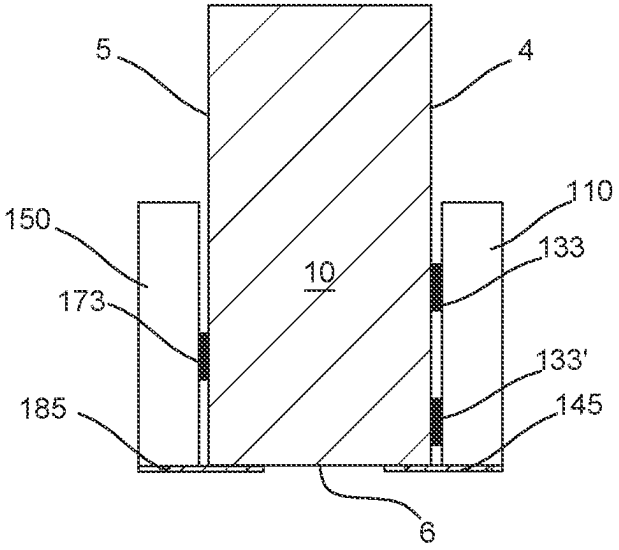


Fig. 4C

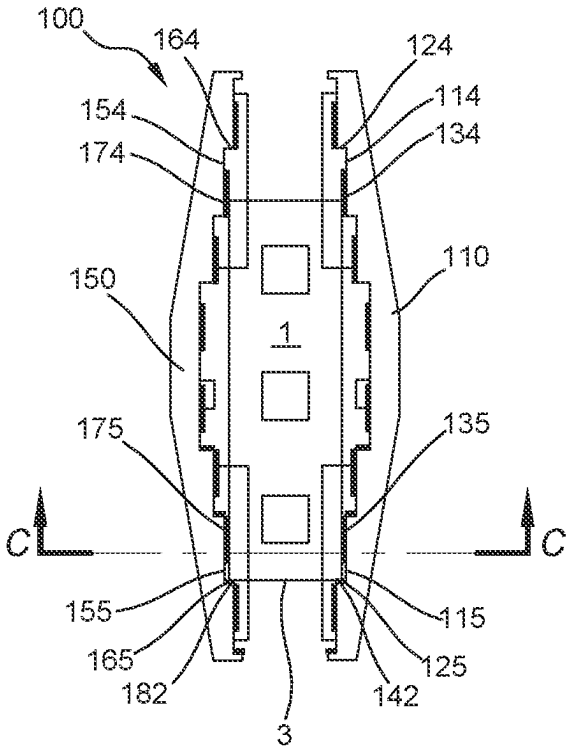


Fig. 5A

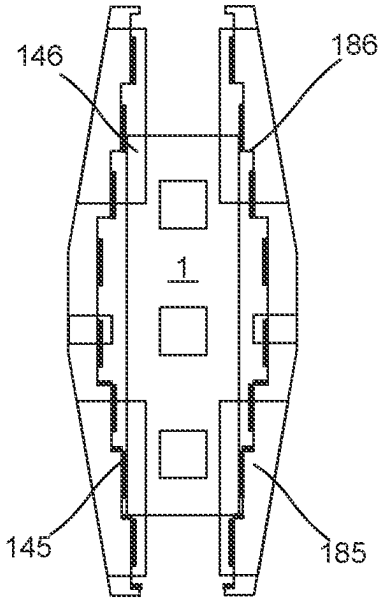


Fig. 5B

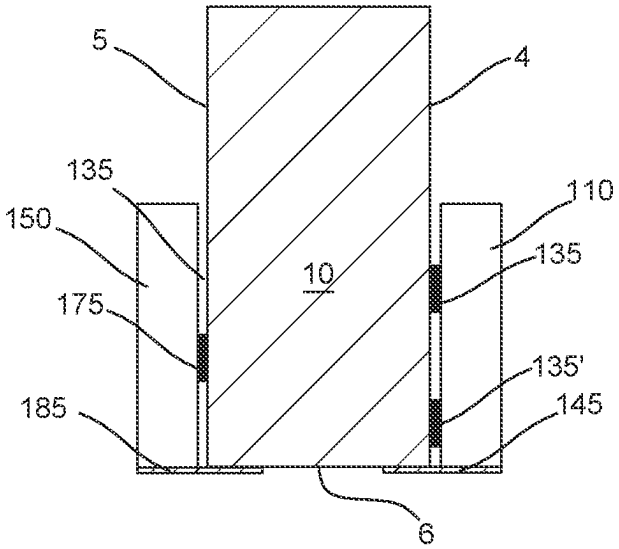


Fig. 5C

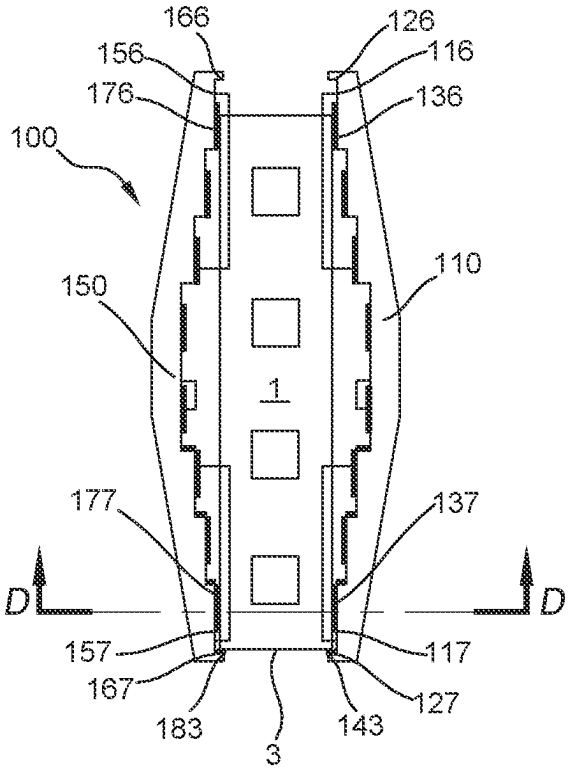


Fig. 6A

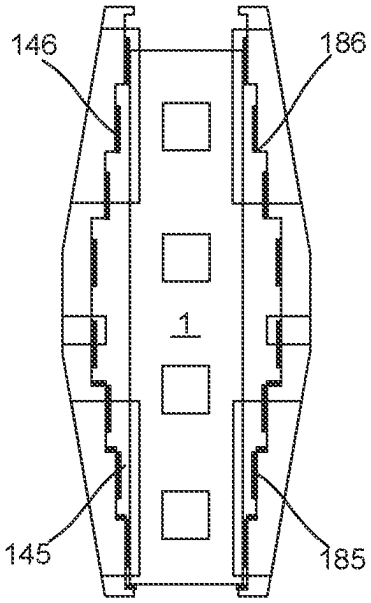


Fig. 6B

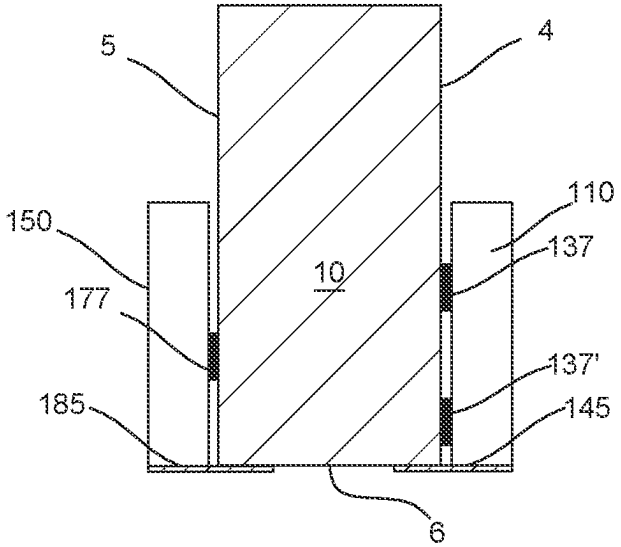


Fig. 6C

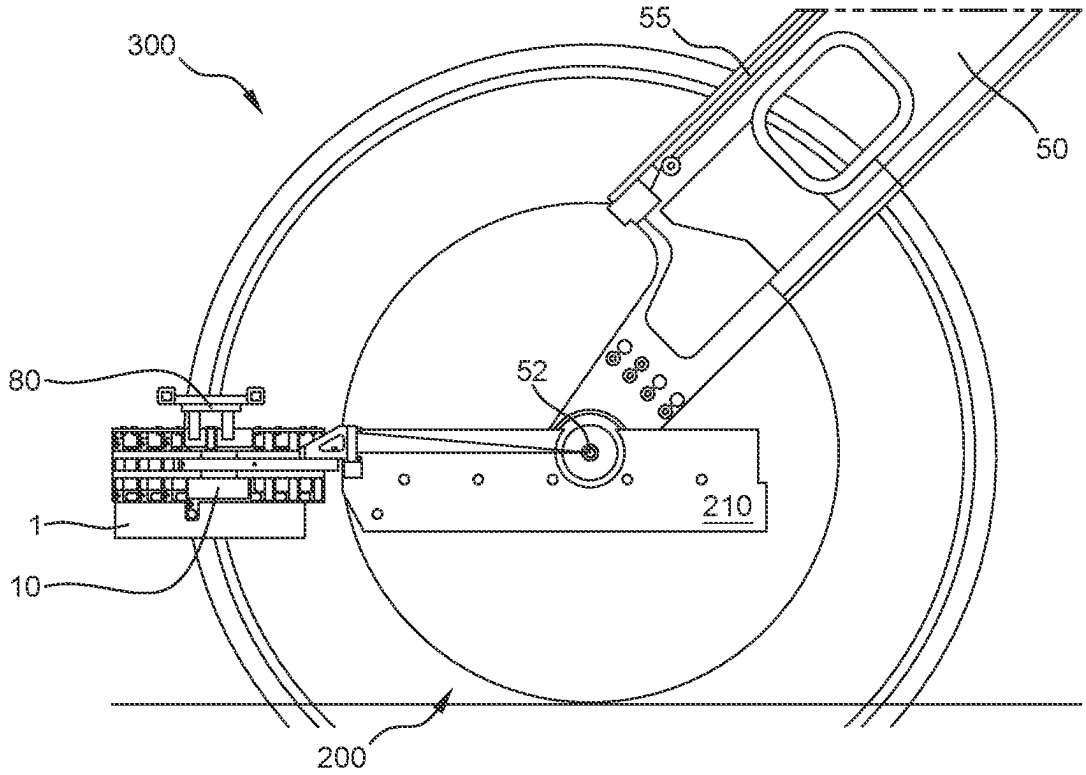


Fig. 7A

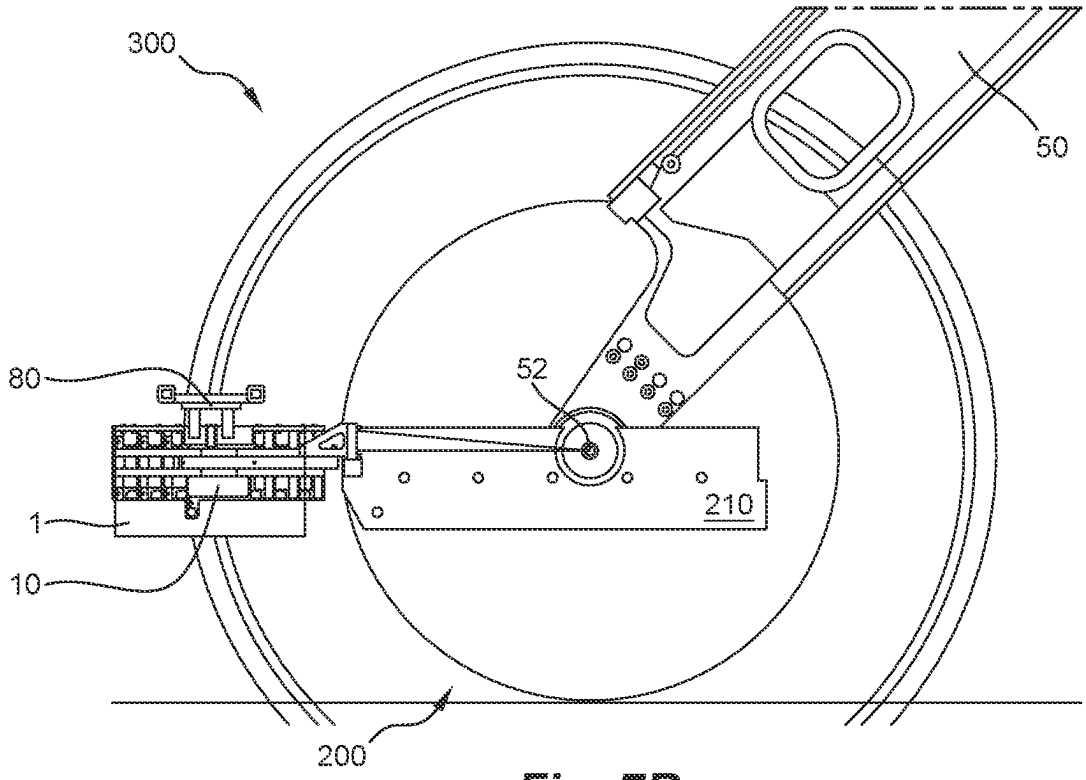


Fig. 7B

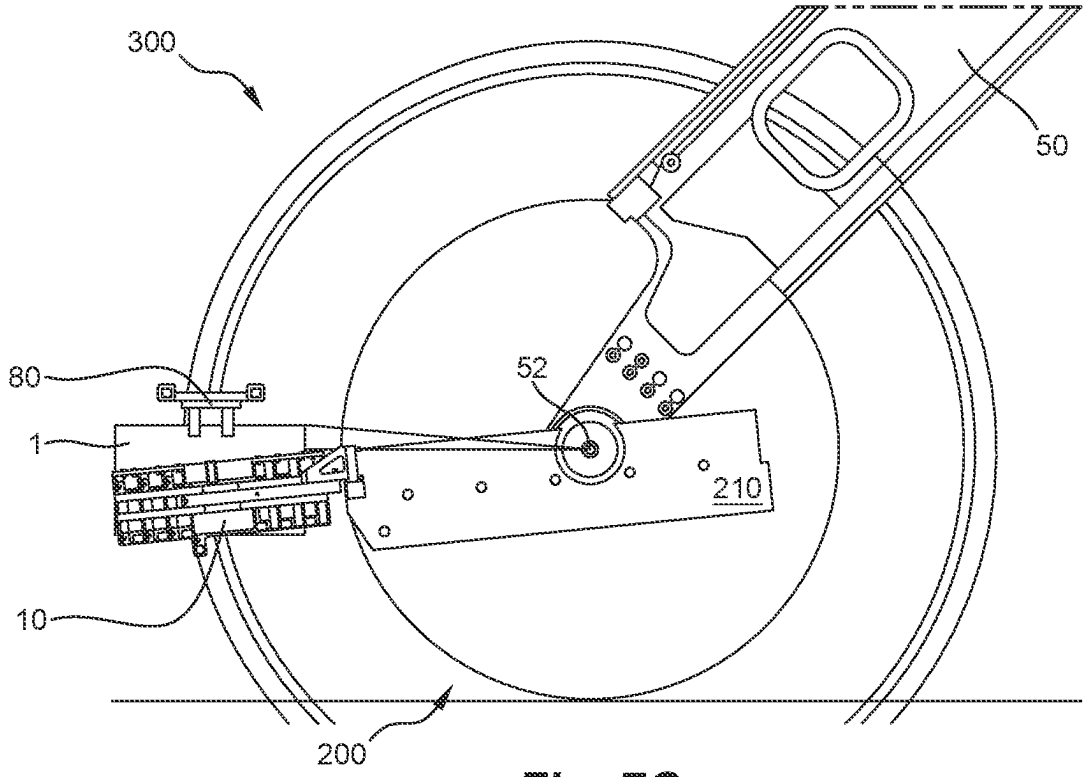


Fig. 7C

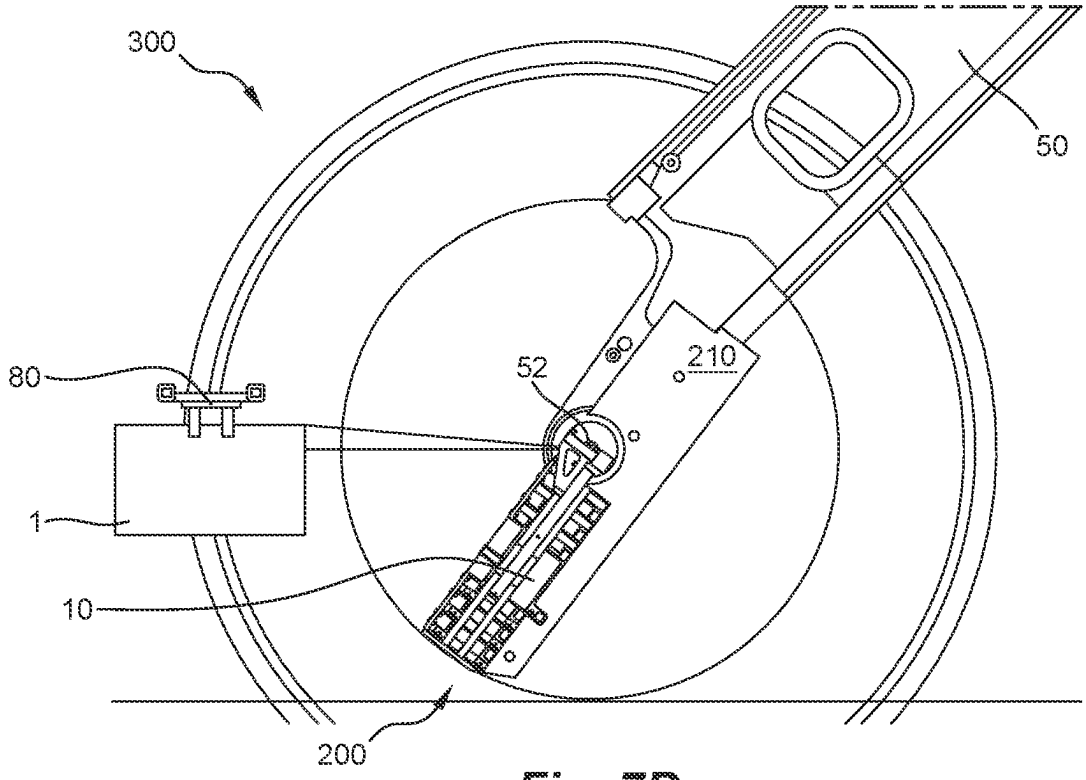


Fig. 7D

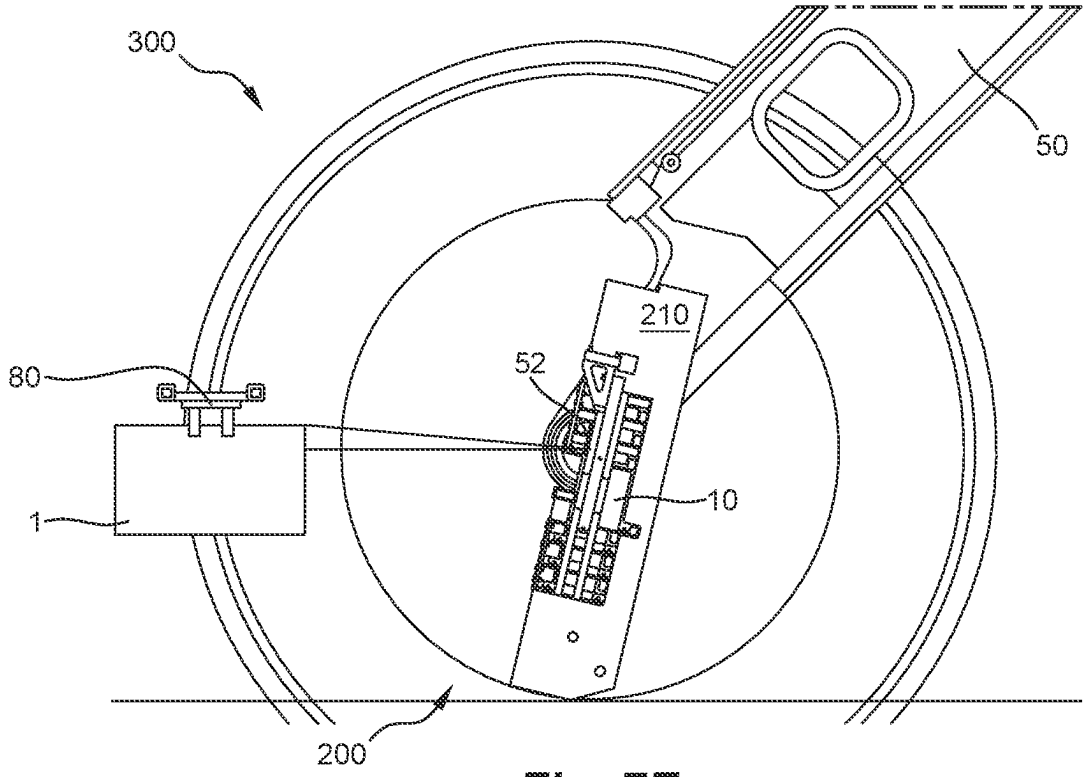


Fig. 7E

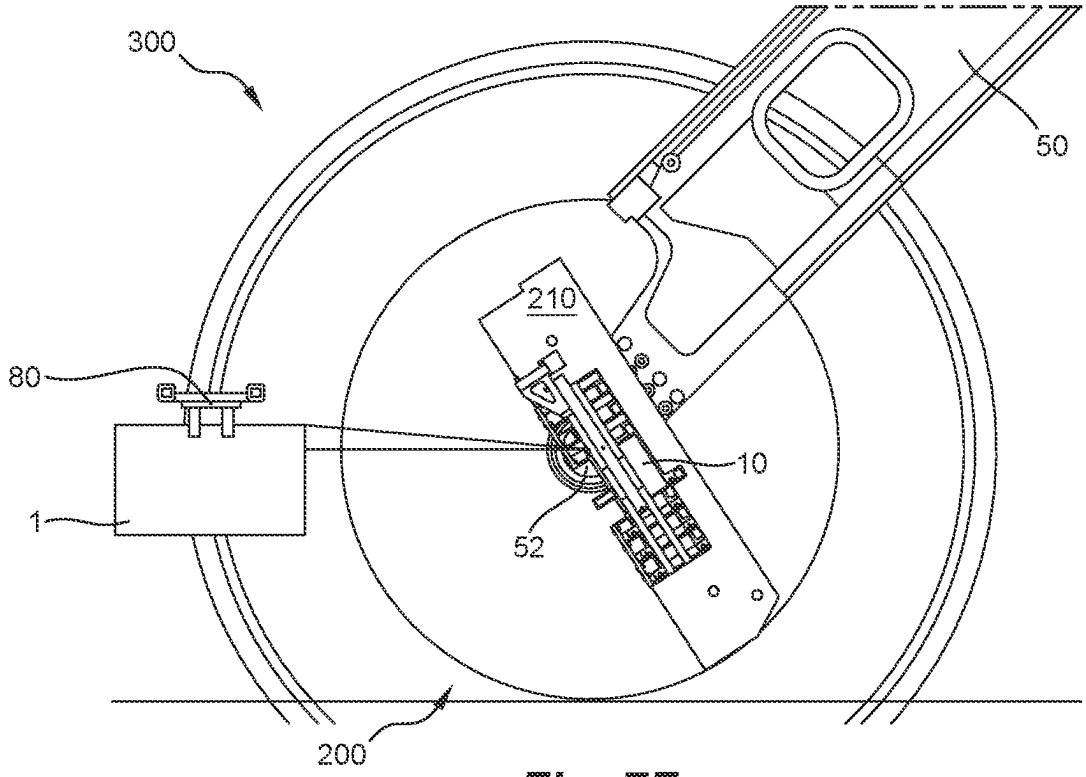


Fig. 7F

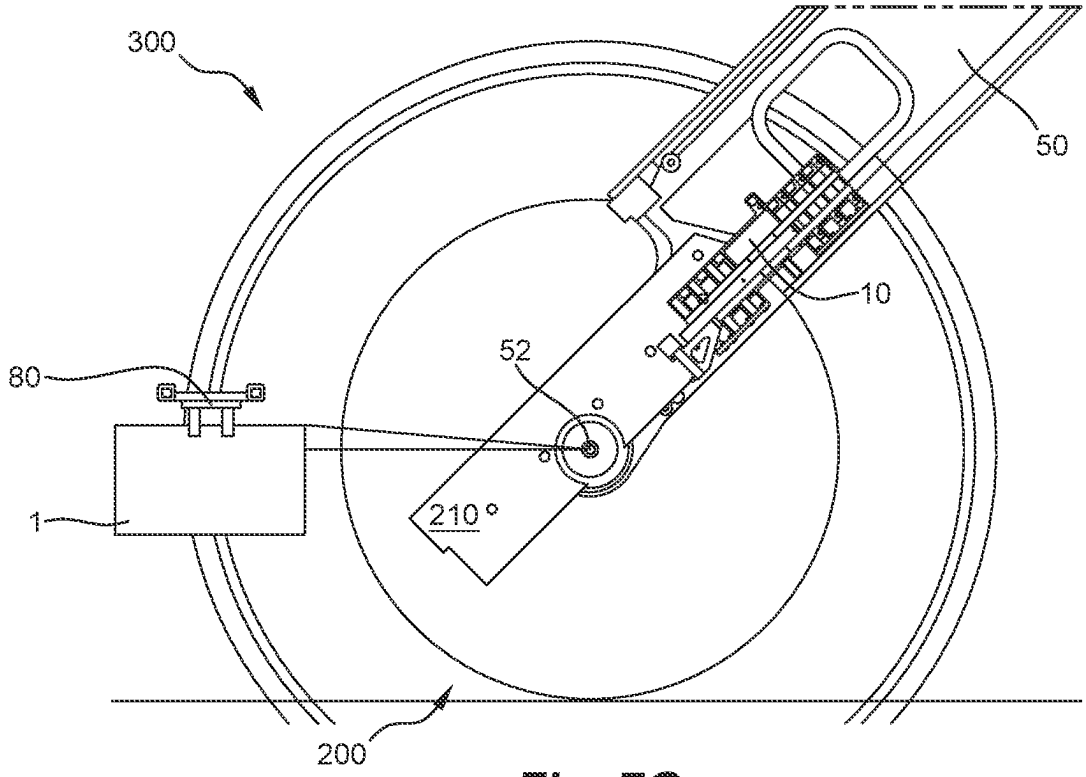


Fig. 7G

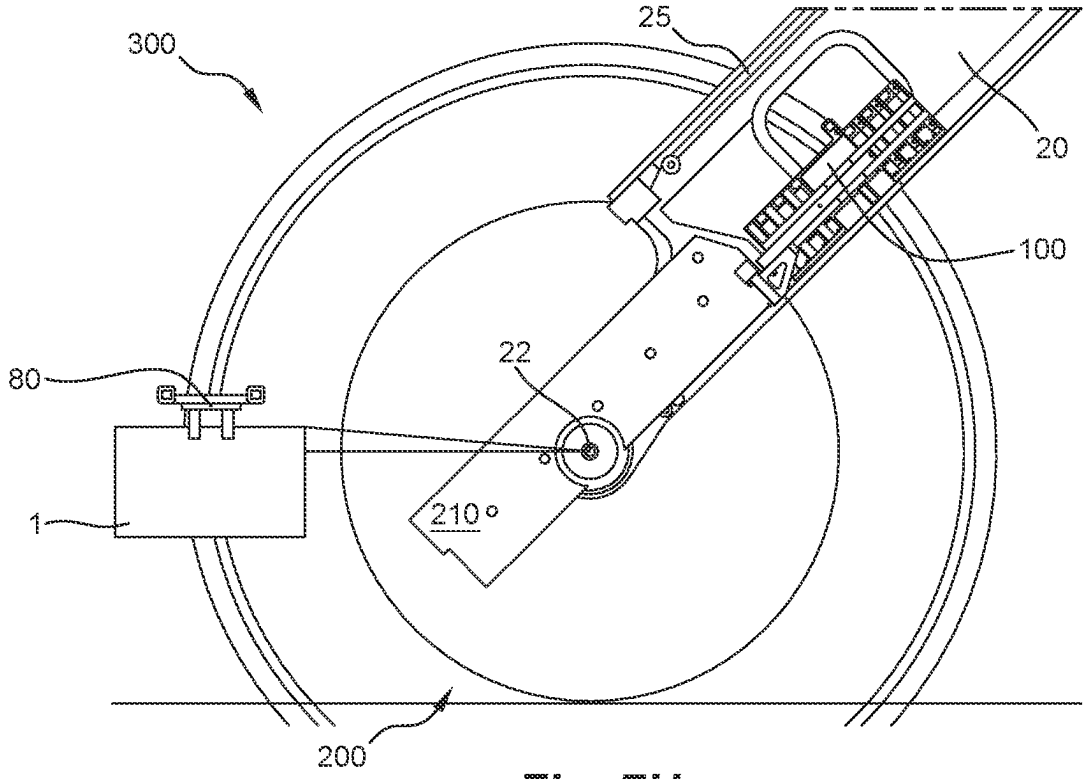


Fig. 7H

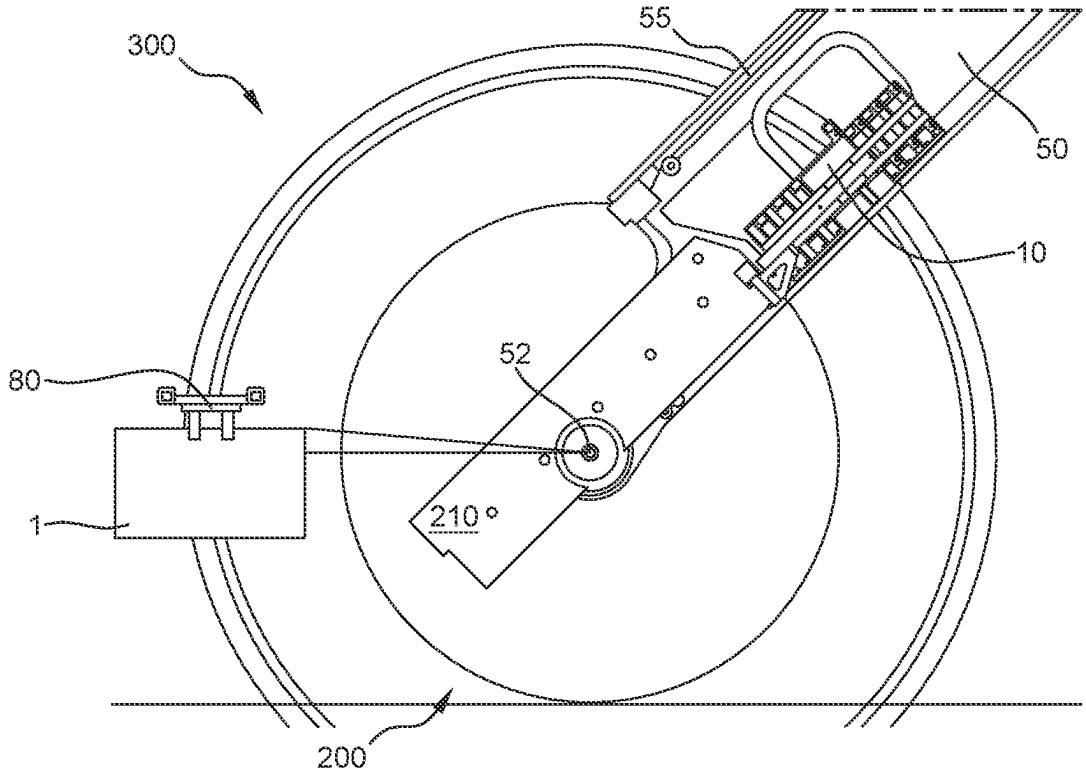


Fig. 7I

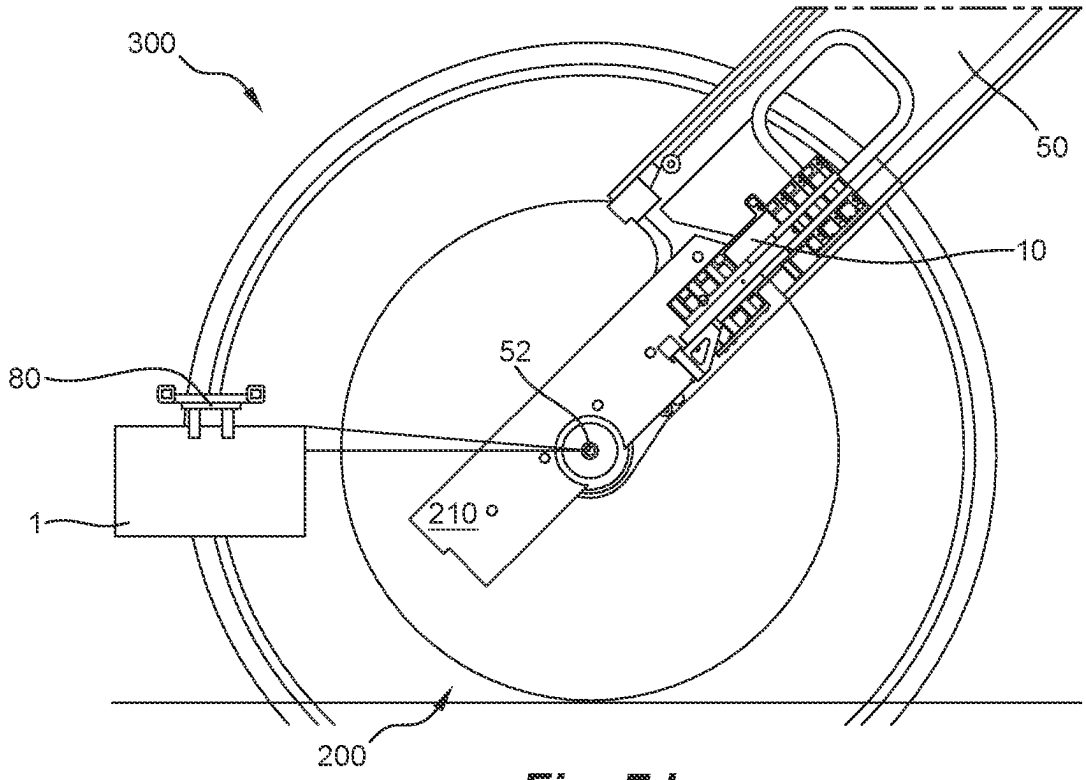


Fig. 7J

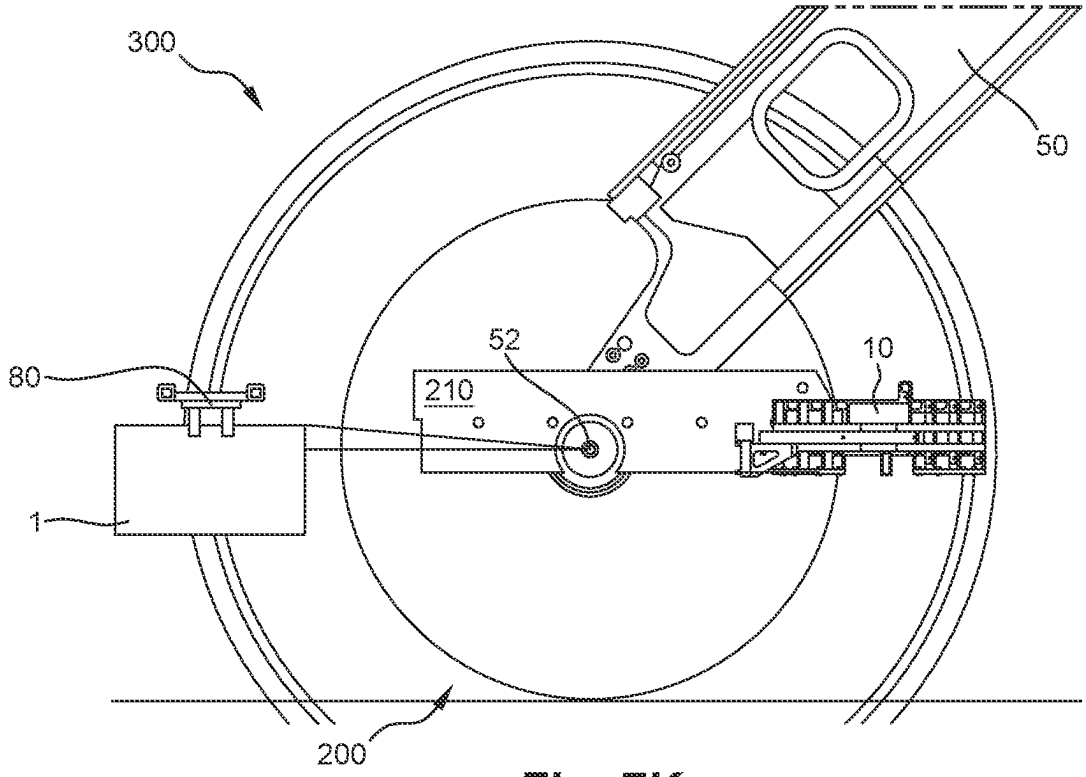


Fig. 7K

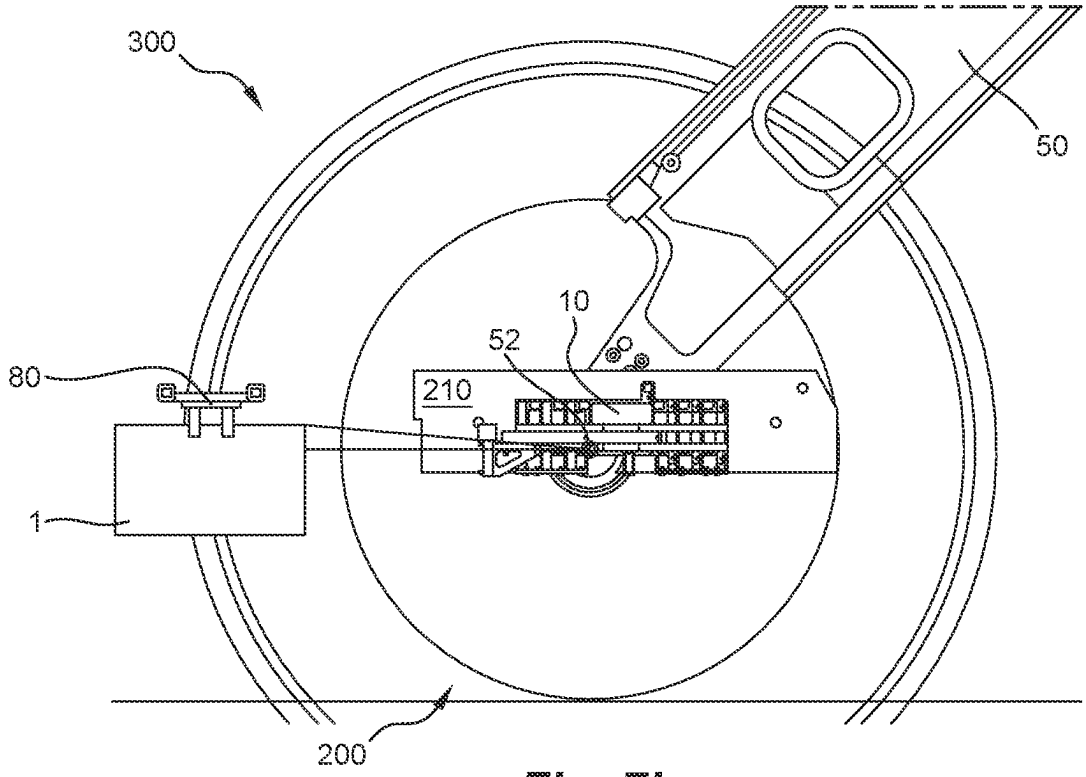


Fig. 7L

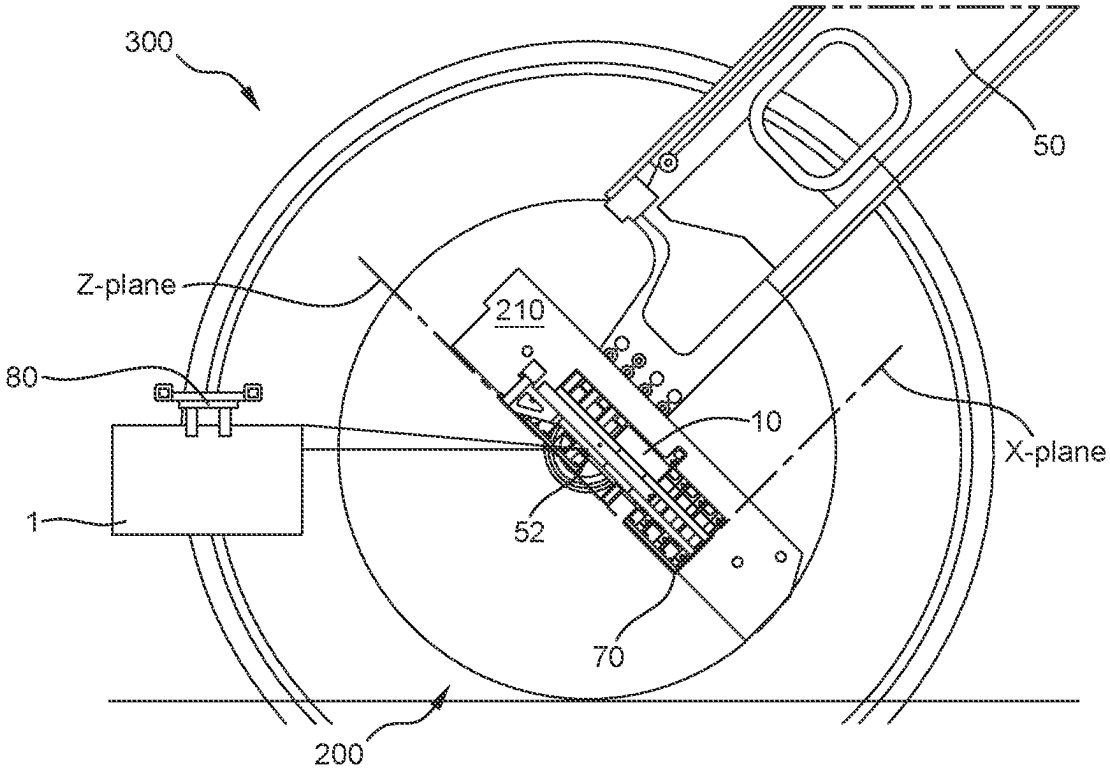

300
50
Z-plane
210
80
10
X-plane
1
52
70
200

Fig. 7M

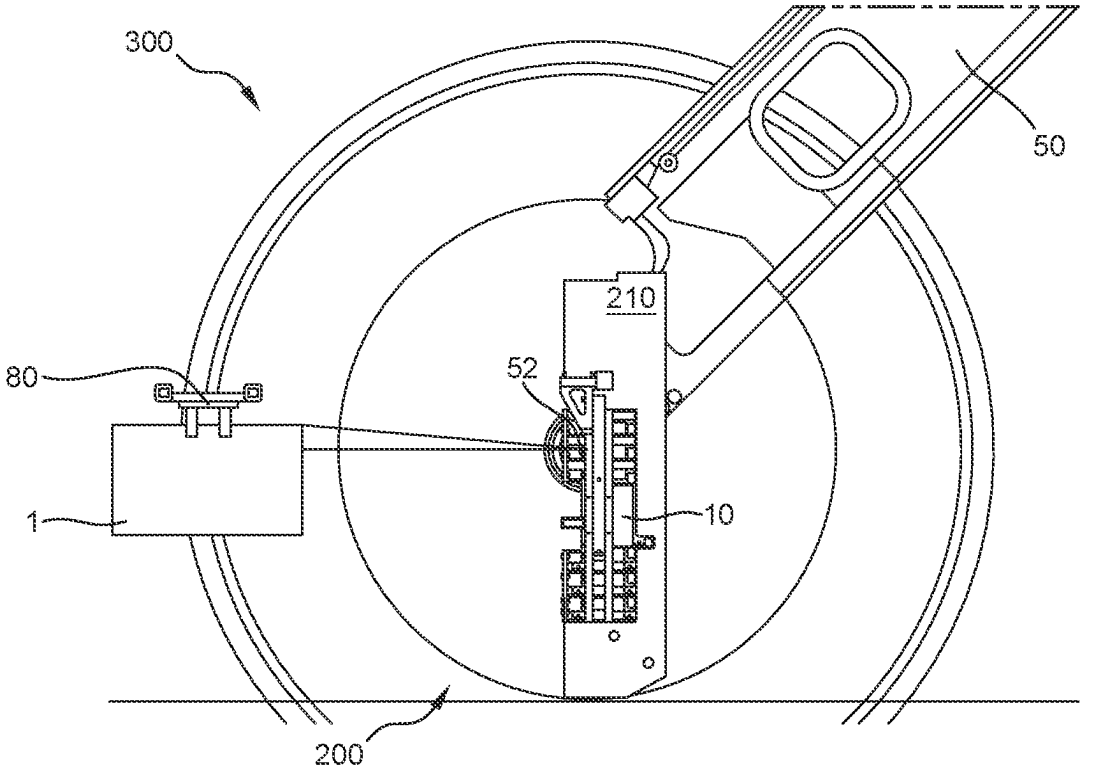

300
50
210
80
52
1
10
200

Fig. 7N

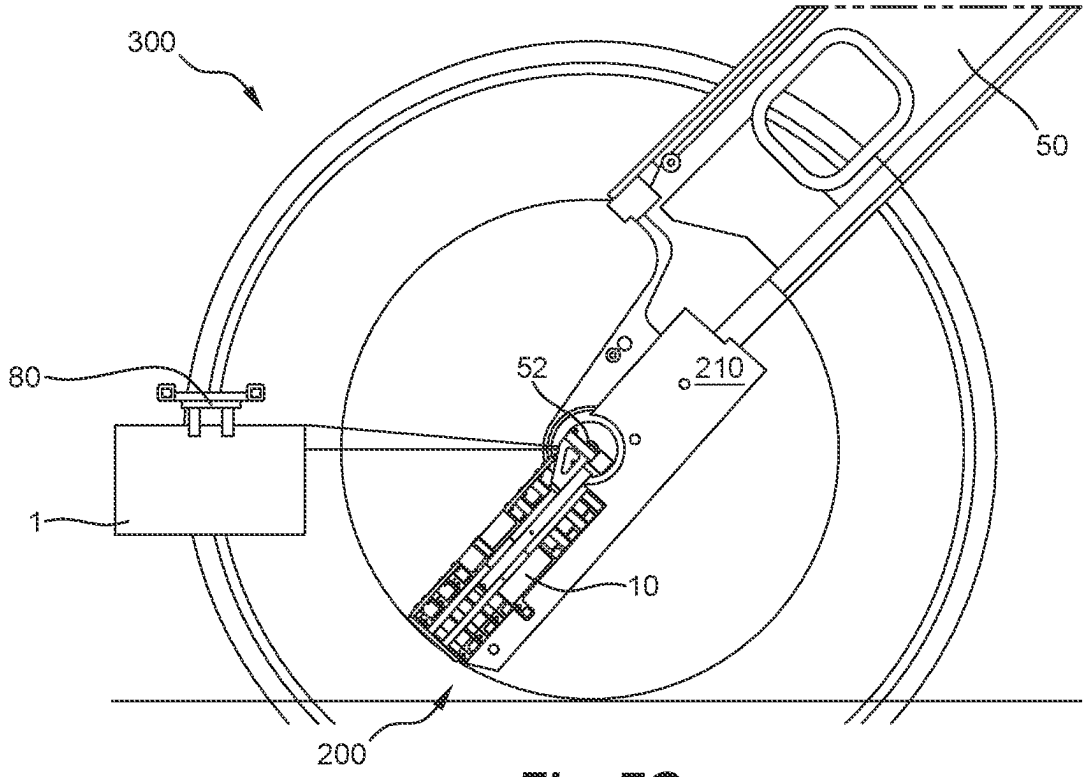


Fig. 7O

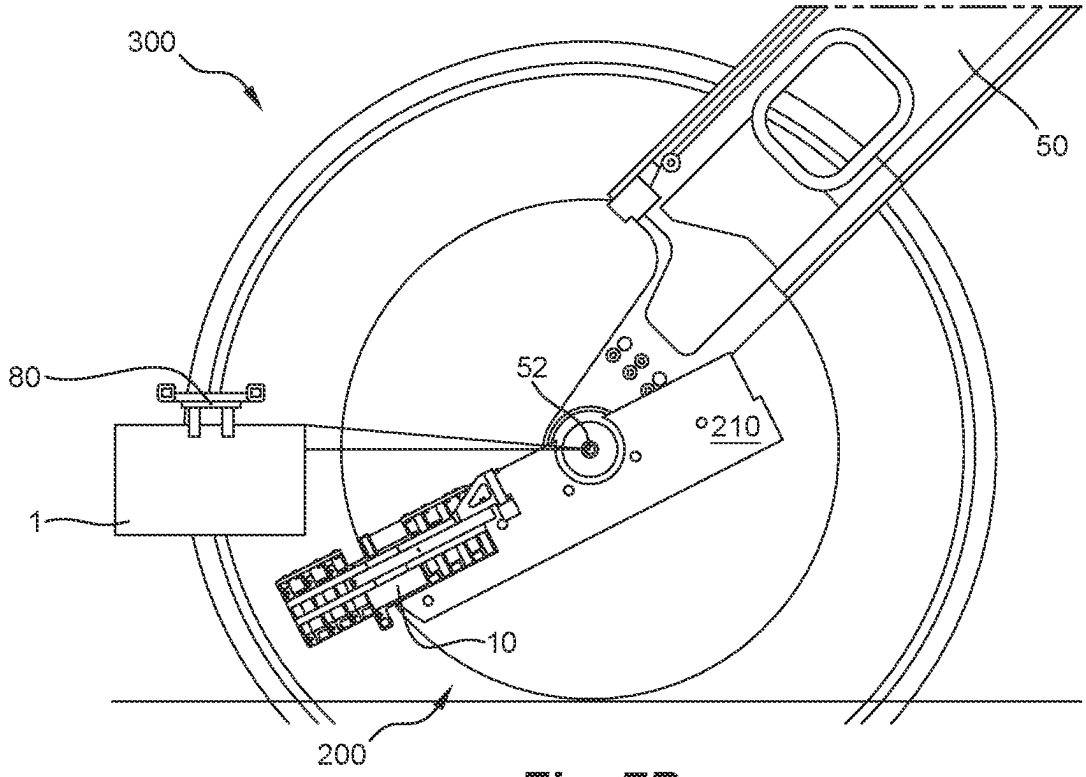


Fig. 7P

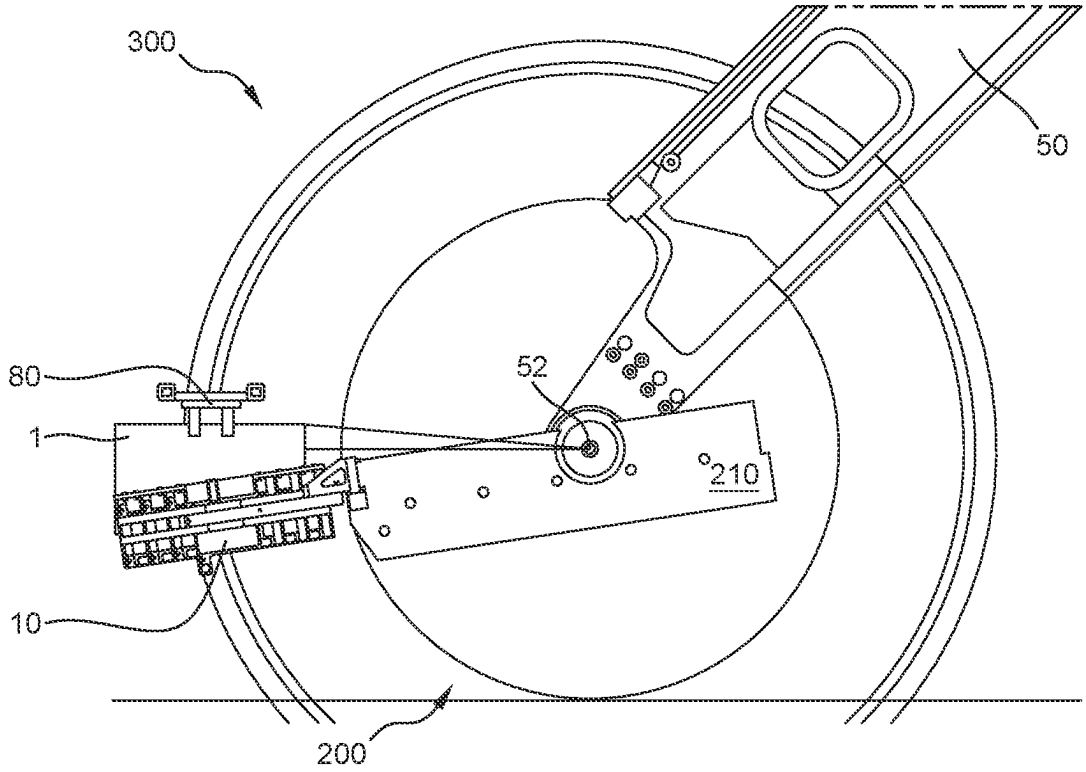


Fig. 7Q

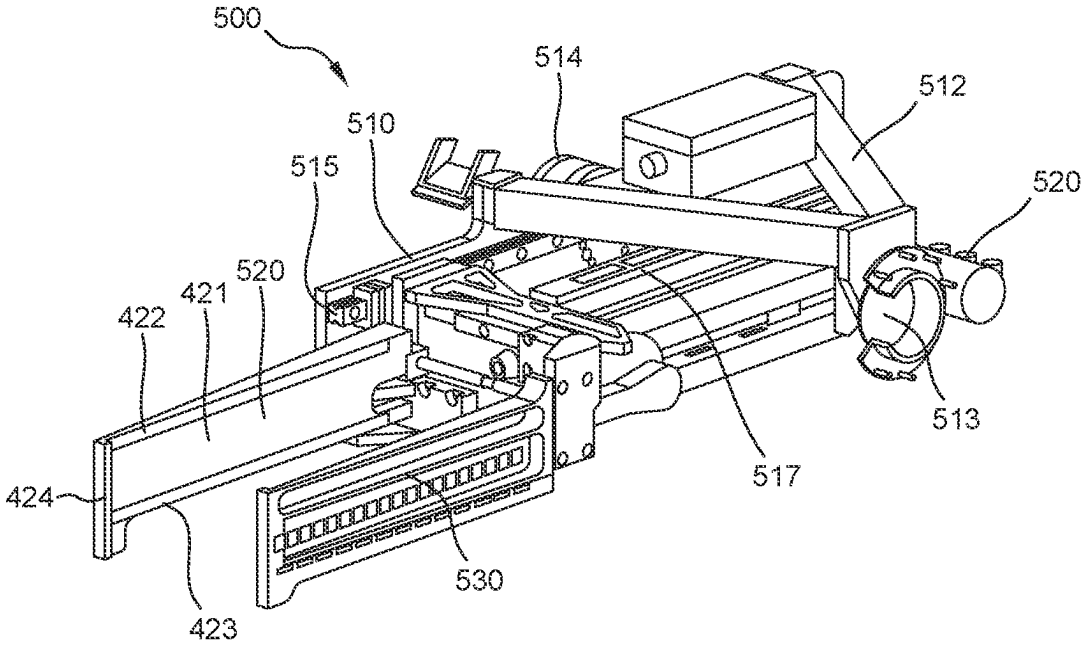

500
514
512
510
515
520
520
421
422
513
517
424
530
423

Fig. 8A

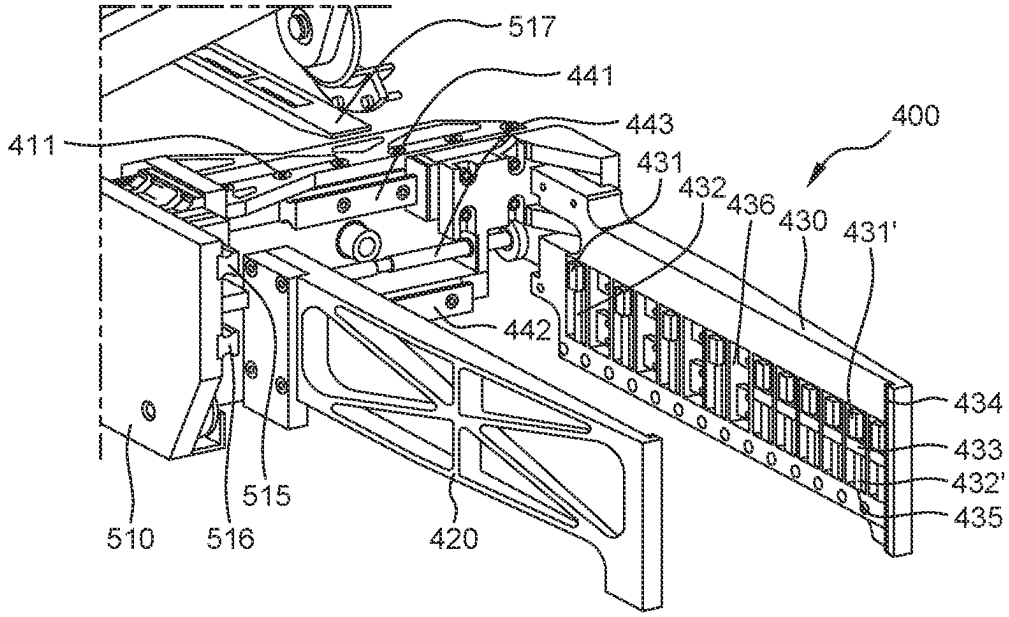

517
441
443
400
411
431
432
436
430
431'
442
434
433
432'
435
515
510
516
420

Fig. 8B

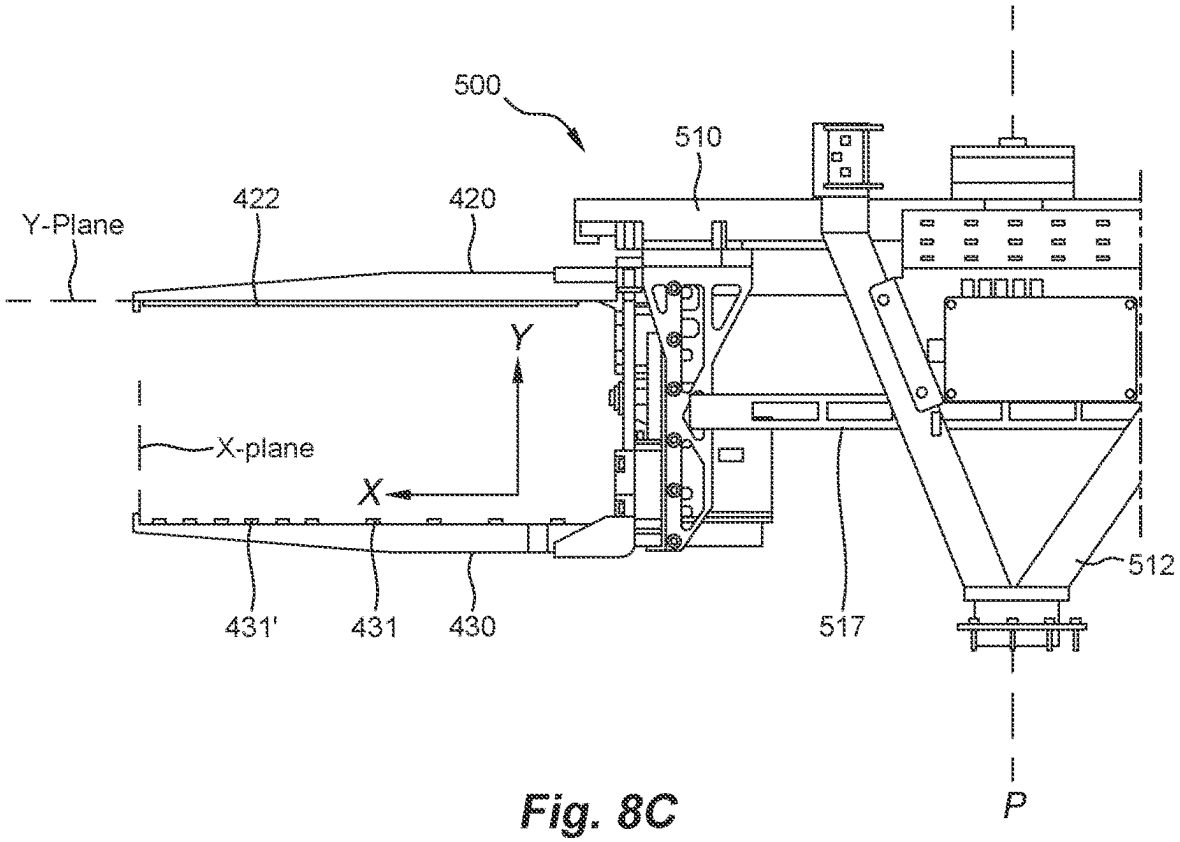

500
510
422
420
Y-Plane
Y
X-plane
X
512
431'
431
430
517
P

Fig. 8C

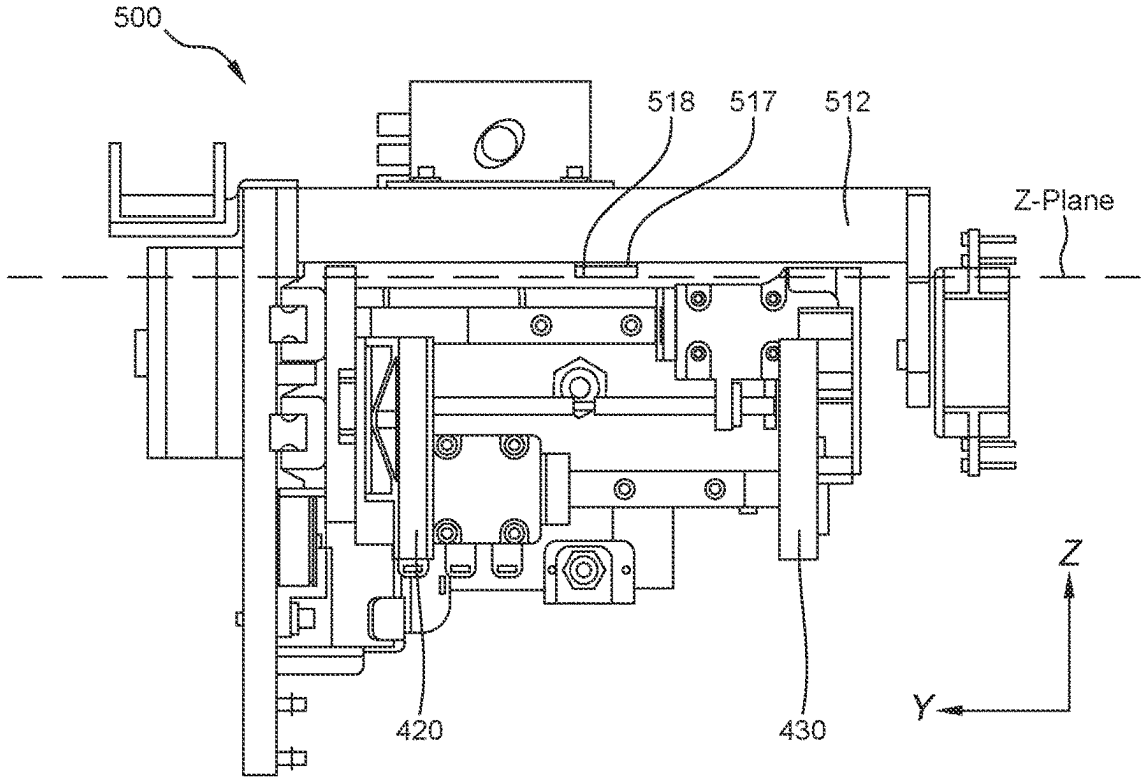

500
518
517
512
Z-Plane
Z
Y
420
430

Fig. 8D

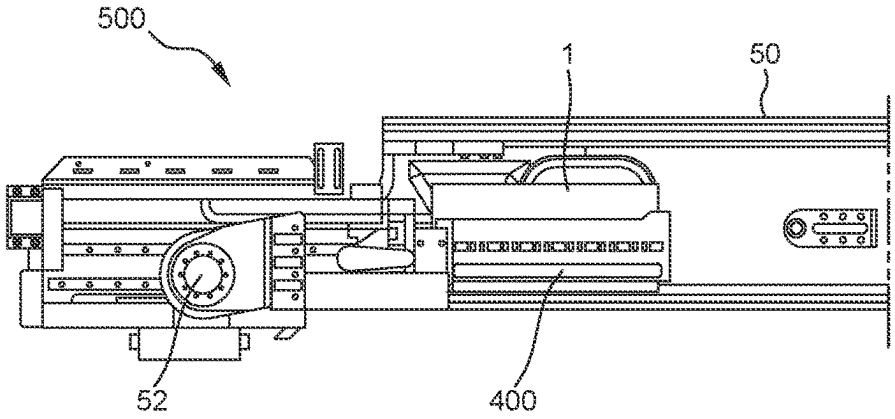


Fig. 9A

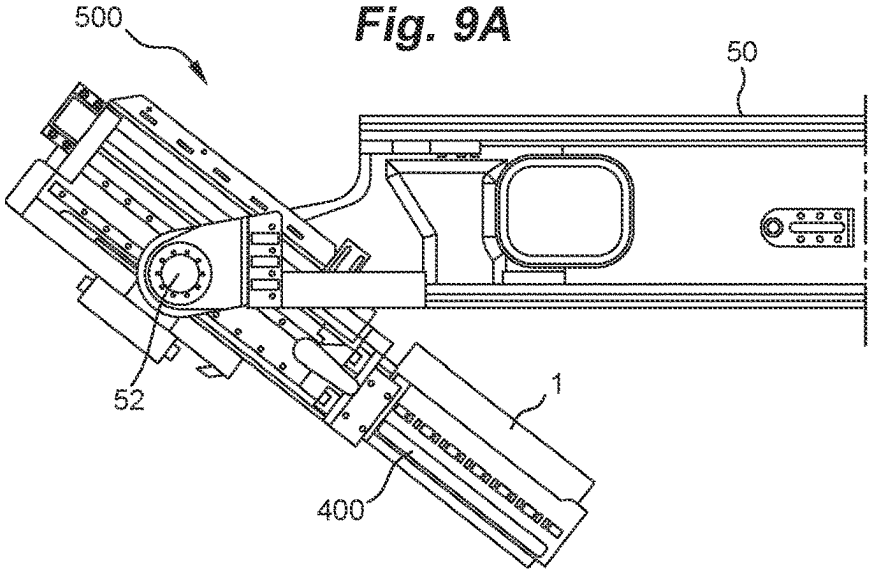


Fig. 9B

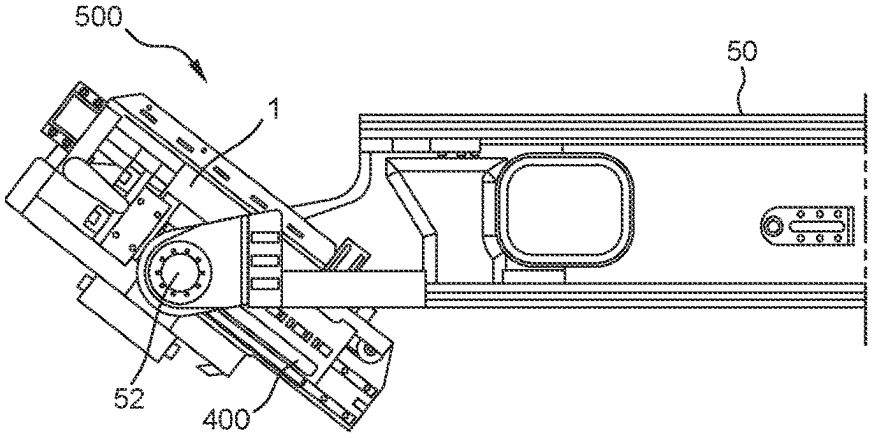


Fig. 9C

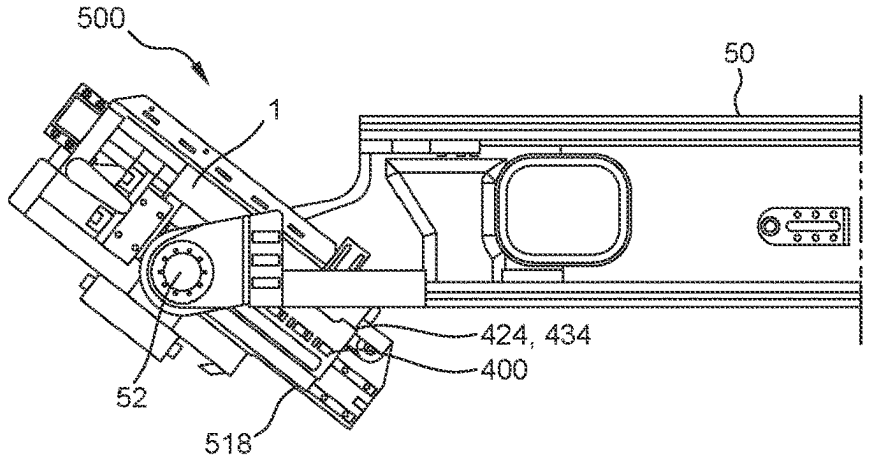


Fig. 9D

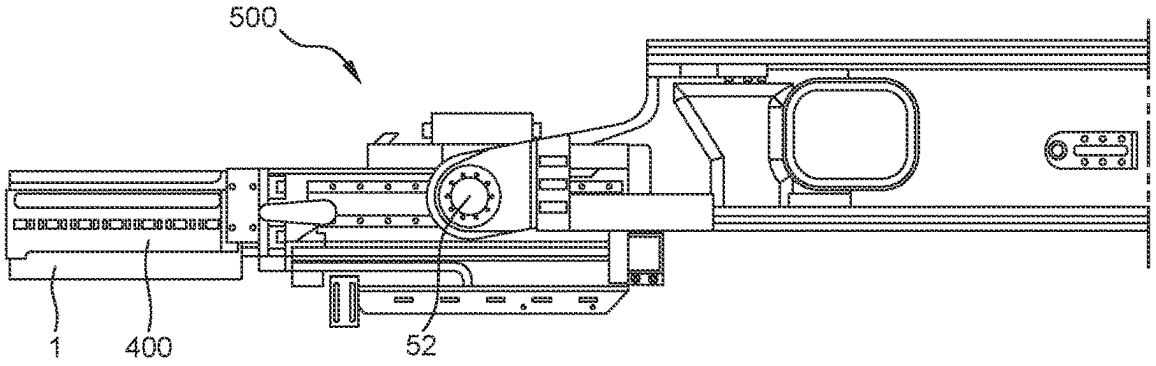


Fig. 9E

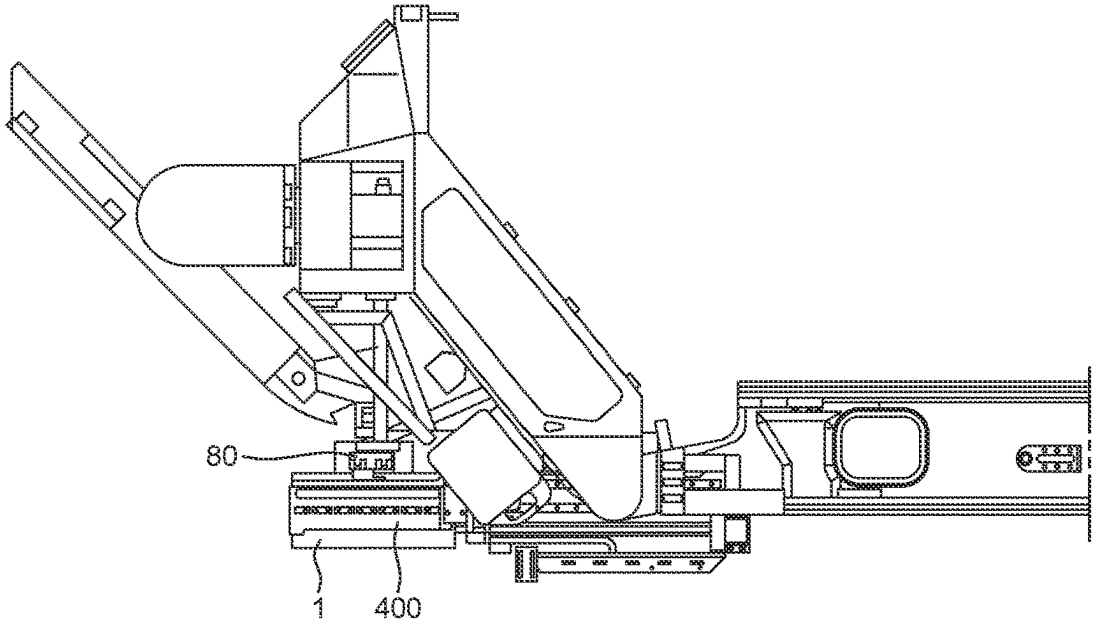


Fig. 9F

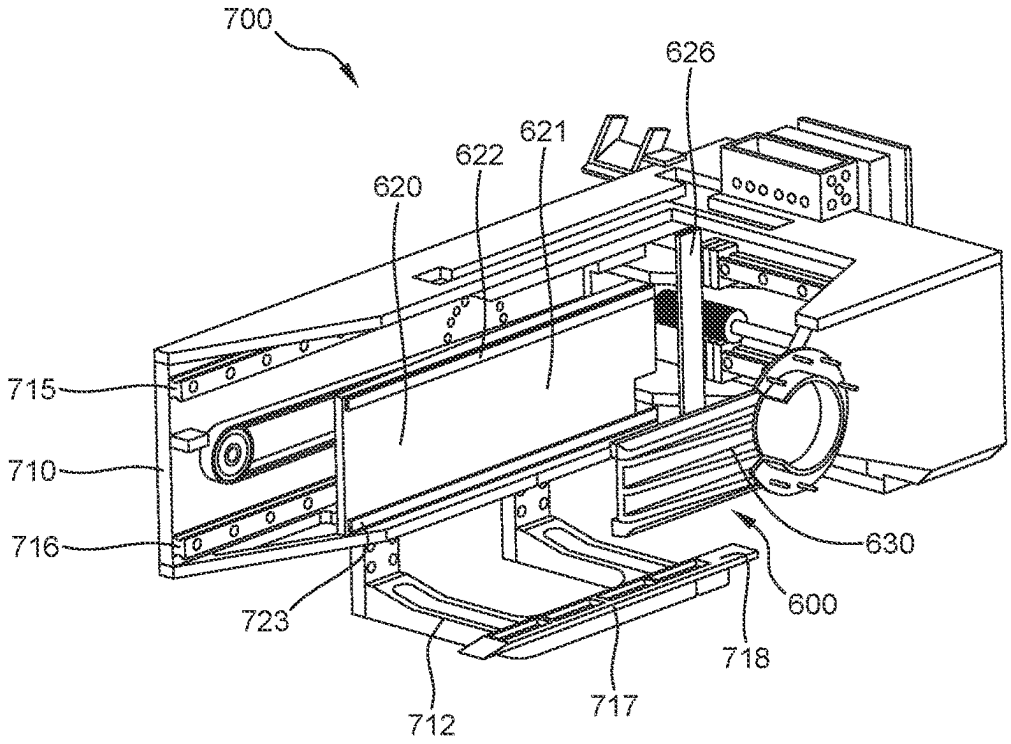


Fig. 10A

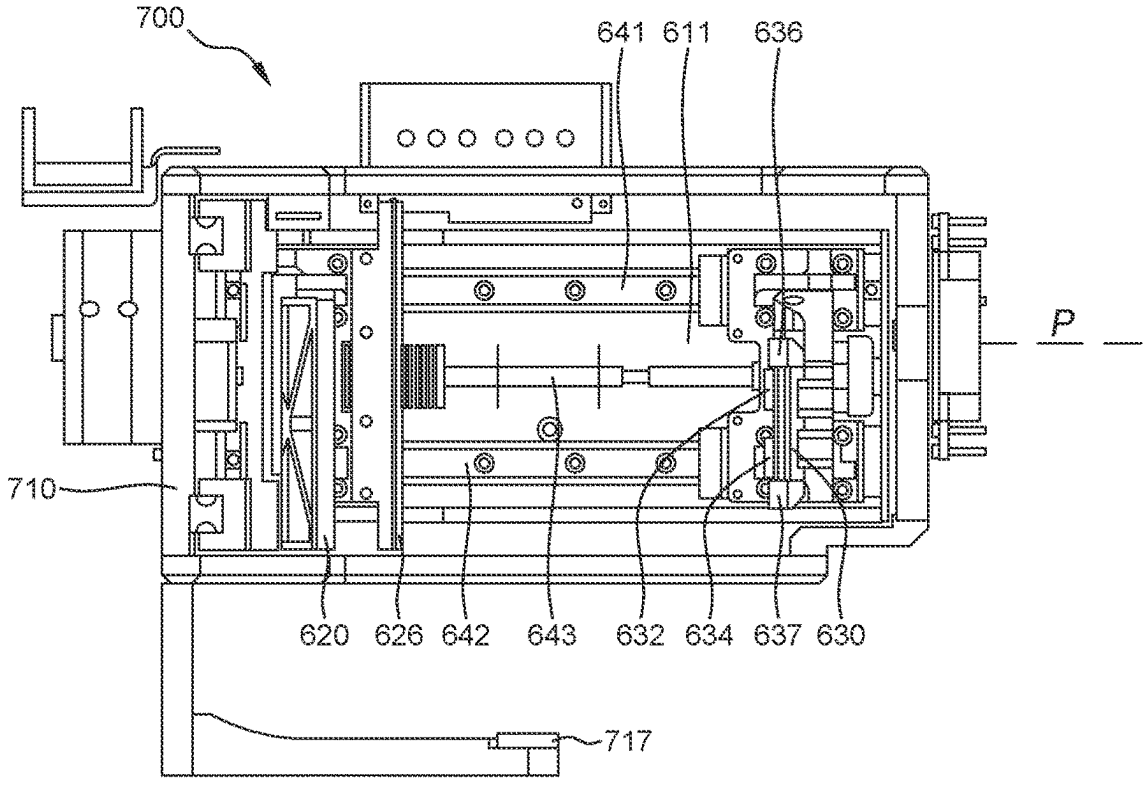


Fig. 10B

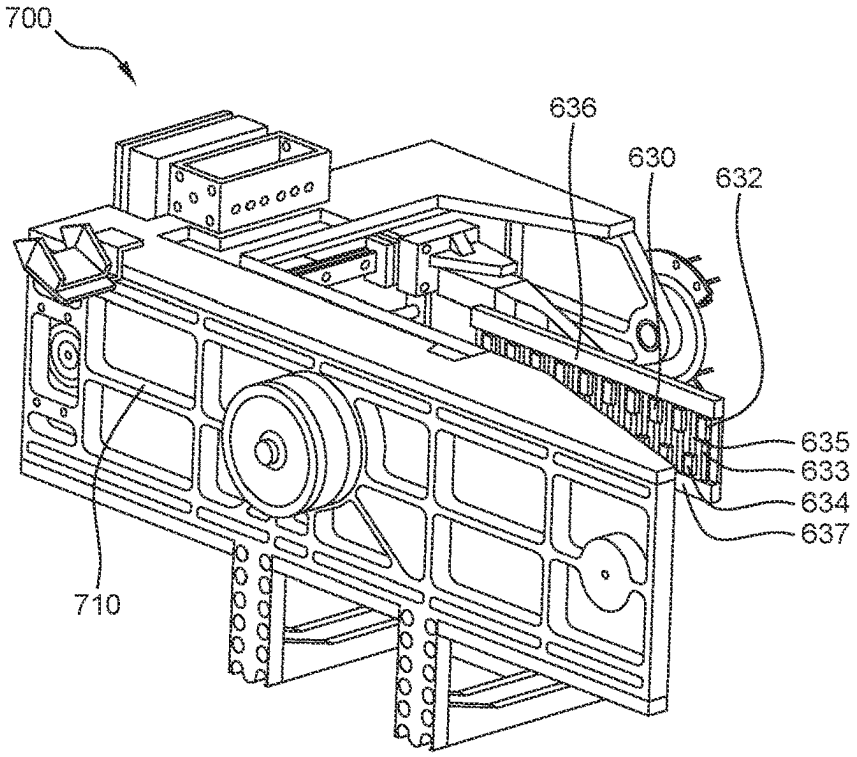


Fig. 10C

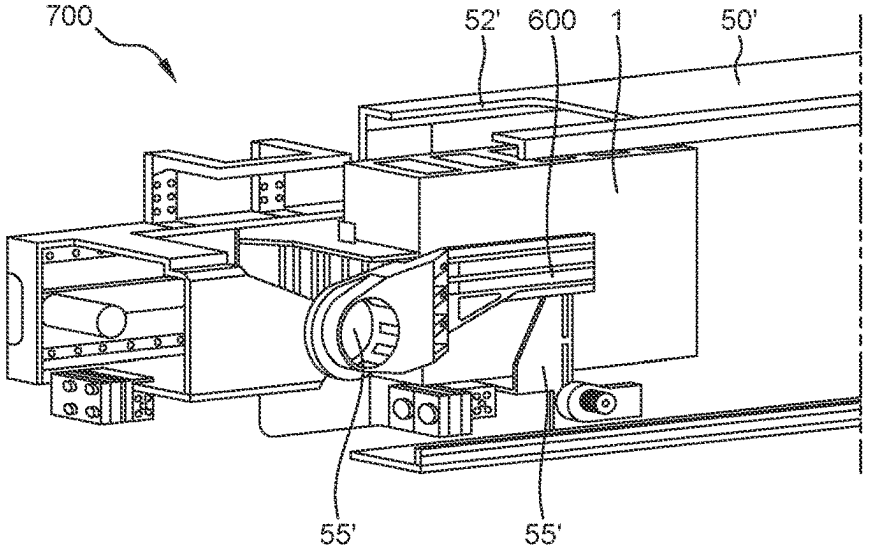


Fig. 11A

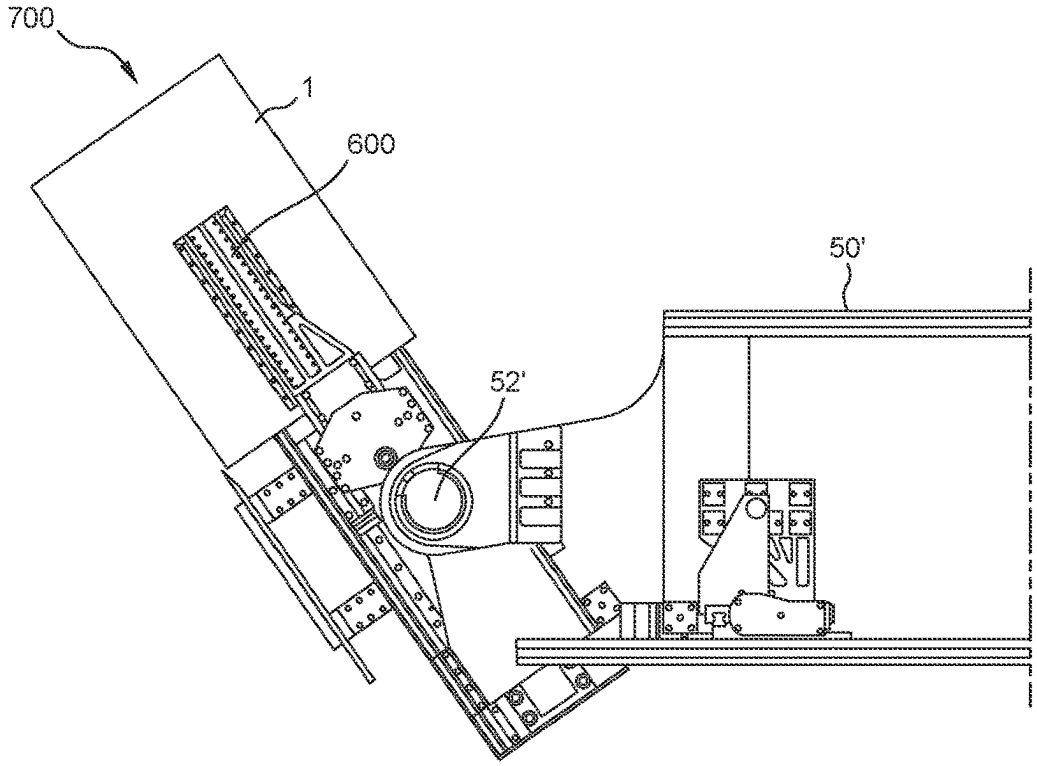


Fig. 11B

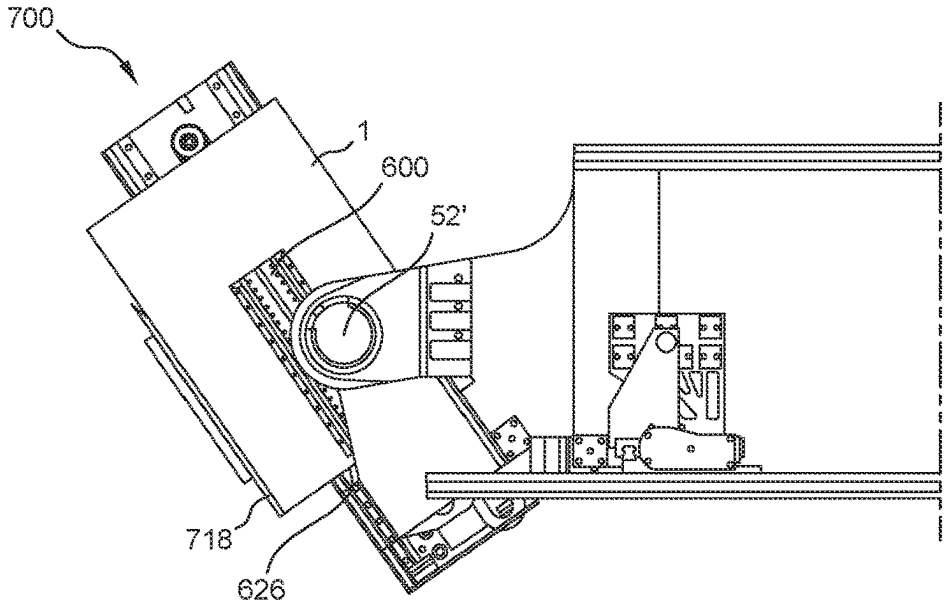


Fig. 11C

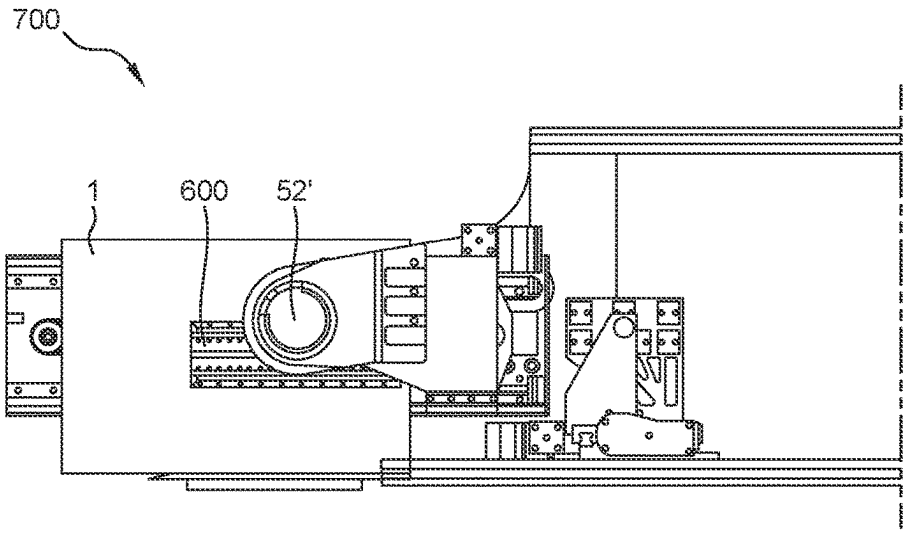


Fig. 11D

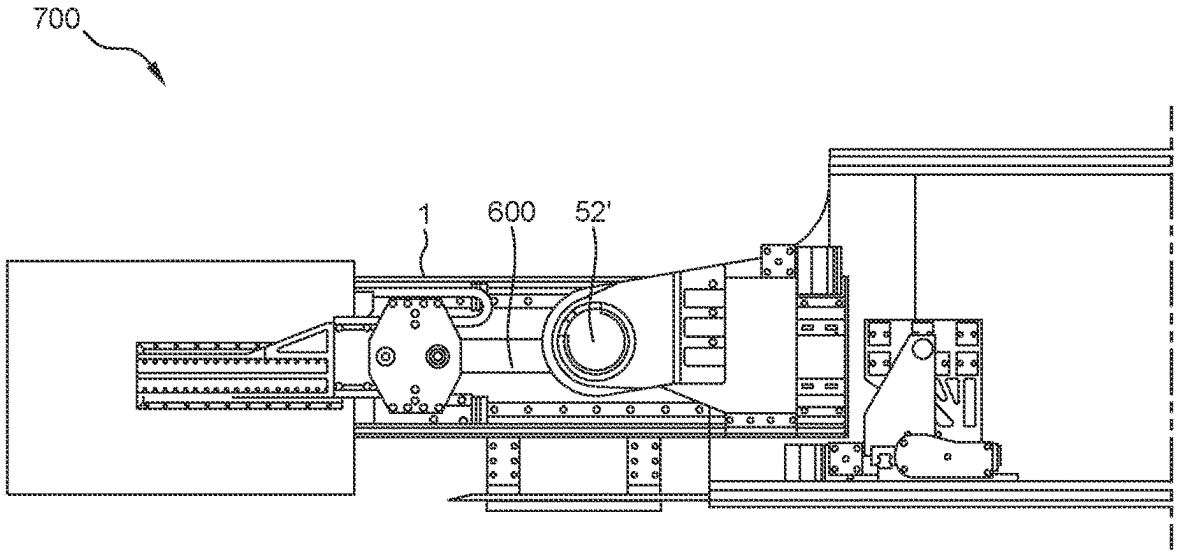


Fig. 11E

BLOCK TRANSFER APPARATUS AND IMPROVED CLAMPING ASSEMBLY FOR USE THEREWITH

CROSS-REFERENCE TO RELATED APPLICATIONS

The present application is a United States national phase entry of International Application No. PCT/AU2021/050361 titled "BLOCK TRANSFER APPARATUS AND IMPROVED CLAMPING ASSEMBLY FOR USE THEREWITH" and filed on April 22, 2022, which claims priority from Australian Provisional Application No. 2020901272 titled "BLOCK TRANSFER APPARATUS AND IMPROVED CLAMPING ASSEMBLY FOR USE THEREWITH" and filed on 22 Apr. 2020, the contents of which are hereby incorporated by reference in their entireties.

BACKGROUND OF THE INVENTION

The present invention relates to a block transfer apparatus and improved clamping assembly for use therewith. In one particular example, the block transfer apparatus and clamping assembly is suitable for use by a robotic block laying machine.

DESCRIPTION OF THE PRIOR ART

The reference in this specification to any prior publication (or information derived from it), or to any matter which is known, is not, and should not be taken as an acknowledgment or admission or any form of suggestion that the prior publication (or information derived from it) or known matter forms part of the common general knowledge in the field of endeavour to which this specification relates.

Autonomous and semi-autonomous industrial robotic equipment is increasingly being used in outside work environments such as on construction sites, building sites, mining sites, and industrial sites. For example, WO 2007/076581 describes an automated brick laying system for constructing a building from a plurality of bricks comprising a robot provided with a brick laying and adhesive applying head, a measuring system, and a controller that provides control data to the robot to lay the bricks at predetermined locations. The measuring system measures in real time the position of the head and produces position data for the controller. The controller produces control data on the basis of a comparison between the position data and a predetermined or pre-programmed position of the head to lay a brick at a predetermined position for the building under construction. The controller can control the robot to construct the building in a course by course manner where the bricks are laid sequentially at their respective predetermined positions and where a complete course of bricks for the entire building is laid prior to laying of the bricks for the next course.

In one example of a robotic construction robot developed by the applicant there is provided a telescoping articulated boom that is mounted on a truck, and a conveying system that transports bricks along the boom to an end effector known as the layhead, which lays the bricks at predetermined locations. When the brick arrives at the layhead via the boom, it is clamped while adhesive is applied and then it is rotated 180 degrees and presented for pickup by a robot arm that places the brick at a desired location, preferably with sub-mm accuracy. When a brick is laid, it is assumed that the brick is held in a certain pose with respect to the robot arm. In order for the robot arm to place a brick at the desired location, it must pick up the brick in the correct location from the clamp.

One problem is that the exact location of the brick with respect to the clamp in the layhead is not accurately known. It may be translated or rotated slightly away from an ideal pickup location of the robot arm. A camera-based vision system may be used to determine the exact 6 DOF location of the brick in space. However, this is a challenging task, as there are spatial constraints at the layhead to place cameras and sensors (without affecting the required functionality) and processing must be performed quickly (e.g. less than 2 seconds) to ensure rapid bricklaying. Further this task is made more difficult due to the varied range of outdoor conditions the robot is required to operate in—this includes temperatures ranging from 0-50° C., rain, dust, wind as well as full daylight, twilight and dark night lighting conditions. This places significant demands on the vision system for determining the location of the brick to enable precise placement of the brick.

There is thus a need to develop an improved system for clamping a brick or block such that its location with respect to the clamp is known without requiring vision-based processing techniques, or to at least provide a useful alternative to existing systems.

SUMMARY OF THE PRESENT INVENTION

In one broad form, an aspect of the present invention seeks to provide a block transfer apparatus for transferring a block between an upstream clamp of a block delivery system and a downstream clamp of the block delivery system, the block transfer apparatus including:

a) a frame pivotally mounted to a support; and,

b) a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws for clamping opposing sides of the block;

wherein, the block transfer apparatus is configured to:

i) receive a block from the upstream clamp, wherein the block is initially clamped in the gripper jaws in an approximate position;

ii) rotate to a drop position whereby the gripper jaws release the block and allow it to self-datum onto first and second orthogonal datum surfaces to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes;

iii) re-clamp the block after the drop by applying a clamping force to opposing sides of the block so as to register the block against a third datum surface defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly; and,

iv) present the block clamped in the datumed position for transfer to the downstream clamp.

In one embodiment, the first datum surface that registers an end of the block is provided as part of the clamping assembly at one of:

a) a distal end of the gripper jaws; and,

b) a proximal end of the gripper jaws to either the jaw or a jaw support structure.

In one embodiment, the second datum surface that registers a top or bottom surface of the block is at least one of:

a) provided as part of the clamping assembly along an upper lengthwise extending edge of the gripper jaws; and,

b) provided as part of the frame in the form of a lengthwise extending bar or plate mounted to the support that is parallel to the gripper jaws.

In one embodiment, the third datum surface is provided by a first of the two gripper jaws.

In one embodiment, the first gripper jaw has a pair of spaced apart first gripper pads rigidly attached to an inner surface of the jaw.

In one embodiment, the first gripper pads extend lengthwise along the first gripper jaw.

In one embodiment, a second of the two gripper jaws includes a plurality of second gripper pads attached to flexible finger members spaced apart along the length of the jaw that allow the pads to flex laterally and compensate for variations in flatness of the side of the block along its length.

In one embodiment, an at least one row of second gripper pads of the second gripper jaw is located approximately midway between the pair of spaced apart first gripper pads such that when a clamping force is applied to the block it is urged into planar alignment with the third datum surface.

In one embodiment, the gripper jaws are configured to accommodate blocks of varying length.

In one embodiment, the gripper jaws are configured to one of:

a) clamp blocks of varying length at different pre-defined positions along the length of the gripper jaws; and,

b) clamp blocks of varying length at the same position along the length of the gripper jaws.

In one embodiment, the drop position coincides with the clamping assembly being rotated to a relative angle to the ground of at least one of:

a) between 30 to 60 degrees;

b) between 35 to 55 degrees;

c) between 40 to 50 degrees; and,

d) approximately 45 degrees.

In one embodiment, the support comprises a distal end of a boom used for transferring blocks therealong.

In one embodiment, the upstream clamp forms part of a shuttle for delivering a block along the boom.

In one embodiment, the downstream clamp is an end effector of a robotic block placement arm that is programmed to place blocks during construction of a building structure.

In one embodiment, the block transfer apparatus includes a distance range sensor for use in determining the proximity between the clamping assembly and the block held by the upstream clamp.

In another broad form, an aspect of the present invention seeks to provide a block delivery system for delivering blocks for placement during construction of a building structure, the block delivery system including:

a) a boom for transferring blocks therealong;

b) an upstream clamp forming part of a shuttle that delivers blocks along the boom;

c) a downstream clamp associated with an end effector of a robotic block placement arm that is programmed to place blocks during construction of the building structure; and,

d) a block transfer apparatus for transferring a block between the upstream clamp and the downstream clamp, the block transfer apparatus including:

i) a frame pivotally mounted to a distal end of the boom; and,

ii) a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws for clamping opposing sides of the block;

wherein, the block transfer apparatus is configured to:

(1) receive a block from the upstream clamp, wherein the block is initially clamped in the gripper jaws in an approximate position;

(2) rotate to a drop position whereby the gripper jaws release the block and allow it to self-datum onto first and second orthogonal datum surfaces to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes;

(3) re-clamp the block after the drop by applying a clamping force to opposing sides of the block so as to register the block against a third datum surface defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly; and,

(4) present the block clamped in the datumed position for transfer to the downstream clamp.

In another broad form, an aspect of the present invention seeks to provide a clamping assembly for clamping a block, the clamping assembly including a pair of gripper jaws including datum surfaces in first and second orthogonal planes to locate the block relative thereto, the clamping assembly configured to locate an end and top or bottom face of the block in the first and second orthogonal planes and then apply a clamping force to opposing sides of the block so as to locate the block in a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly.

In one embodiment, the datum surfaces form a V-shaped wedge into which the block is located.

In one embodiment, each gripper jaw includes at least one first datum surface extending at least partially between top and bottom surfaces of the gripper jaw and towards the opposing gripper jaw for locating an end of the block.

In one embodiment, the at least one first datum surface is provided by one of:

a) a surface integral with each gripper jaw; and,

b) a plate element mounted to a surface integral with each gripper jaw.

In one embodiment, each gripper jaw includes at least one second datum surface that is parallel to a top or bottom surface of the gripper jaw and projects towards the opposing gripper jaw for locating the top or bottom surface of the block.

In one embodiment, the at least one second datum surface is provided by one of:

a) the top or bottom surface of each gripper jaw; and,

b) plate elements mounted to the top or bottom surfaces of each gripper jaw.

In one embodiment, the at least one second datum surface is discontinuous.

In one embodiment, the gripper jaws are configured to accommodate blocks of varying length.

In one embodiment, the gripper jaws are configured to clamp blocks of varying length at different pre-defined positions along the length of the gripper jaws.

In one embodiment, each gripper jaw includes a plurality of first datum surfaces spaced apart along a lengthwise direction thereof.

In one embodiment, the plurality of spaced apart first datum surfaces are further stepped apart laterally with respect to each gripper jaw so as not to overlap in the lengthwise direction thereof.

In one embodiment, an end of blocks of varying length are each located on one of the plurality of first datum surfaces of each gripper jaw.

In one embodiment, a first of the pair of gripper jaws has a plurality of first gripper pads arranged to define the third plane for locating a side face of the block when clamped.

In one embodiment, a second of the pair of gripper jaws has a plurality of second gripper pads arranged co-linearly in a lengthwise direction thereof such that when a clamping force is applied to the block the plurality of second gripper pads act to urge the block into planar alignment with the third plane defined by the plurality of first gripper pads.

In one embodiment, the plurality of first gripper pads comprise a pair of spaced apart rows of first gripper pads extending in a lengthwise direction of the first gripper jaw and wherein the second gripper pads are located on the second gripper jaw approximately midway between the spaced apart rows of first gripper pads.

In one embodiment, the first and second gripper pads are arranged on stepped surfaces of each gripper jaw so that each different length of block clamped by the assembly is contacted by a different plurality of first and second gripper pads.

In one embodiment, any block clamped by the assembly will be in contact with at least four first gripper pads and at least two second gripper pads when a clamping force is applied.

In one embodiment, the block is allowed to drop into the wedge under gravity to locate onto the datum surfaces defining the first and second orthogonal planes.

In one embodiment, the clamping assembly is pivotable and the drop is performed when the gripper jaws have been pivoted to a relative angle to the ground of at least one of:

a) between 30 to 60 degrees;

b) between 35 to 55 degrees;

c) between 40 to 50 degrees; and,

d) approximately 45 degrees.

In one embodiment, the block is:

a) initially clamped in the gripper jaws in an approximate position;

b) rotated to a drop position whereby the gripper jaws release the block and allow it to drop into the wedge; and,

c) re-clamped when the block is located in the wedge so that the block is located in a datumed position.

In another broad form, an aspect of the present in invention seeks to provide a block transfer apparatus for transferring a block between an upstream clamp of a block delivery system and a downstream clamp of the block delivery system, the block transfer apparatus including:

a) a frame pivotally mounted to a support; and,

b) a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws including datum surfaces in first and second orthogonal planes to locate the block relative thereto, wherein the clamping assembly is configured to at least:

i) receive a block from the upstream clamp, wherein the block is initially clamped in the gripper jaws in an approximate position;

ii) rotate to a drop position whereby the gripper jaws release the block and allow it to drop into a V-shaped wedge formed by the datum surfaces to thereby locate an end and top or bottom face of the block in the first and second orthogonal planes;

iii) re-clamp the block after the drop by applying a clamping force to opposing sides of the block so as to locate the block in a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly.

iv) present the block clamped in the datumed position for transfer to the downstream clamp.

In one embodiment, the support comprises a distal end of a boom used for transferring blocks therealong.

In one embodiment, the upstream clamp forms part of a shuttle for delivering a block along the boom.

In one embodiment, the downstream clamp is an end effector of a robotic block placement arm that is programmed to place blocks during construction of a building structure.

In one embodiment, the block transfer apparatus includes a distance range sensor for use in determining the proximity between the clamping assembly and the block held by the upstream clamp.

In yet a further broad form, an aspect of the present invention seeks to provide a block delivery system for delivering blocks for placement during construction of a building structure, the block delivery system including:

a) a boom for transferring blocks therealong;

b) an upstream clamp forming part of a shuttle that delivers blocks along the boom;

c) a downstream clamp associated with an end effector of a robotic block placement arm that is programmed to place blocks during construction of the building structure; and,

d) a block transfer apparatus for transferring a block between the upstream clamp and the downstream clamp, the block transfer apparatus including:

i) a frame pivotally mounted to a distal end of the boom; and,

ii) a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws including datum surfaces in first and second orthogonal planes to locate the block relative thereto, wherein the clamping assembly is configured to at least:

(1) receive a block from the upstream clamp, wherein the block is initially clamped in the gripper jaws in an approximate position;

(2) rotate to a drop position whereby the gripper jaws release the block and allow it to drop into a V-shaped wedge formed by the datum surfaces to thereby locate an end and top or bottom face of the block in the first and second orthogonal planes;

(3) re-clamp the block after the drop by applying a clamping force to opposing sides of the block so as to locate the block in a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly; and,

(4) present the block clamped in the datumed position for transfer to the downstream clamp.

It will be appreciated that the broad forms of the invention and their respective features can be used in conjunction and/or independently, and reference to separate broad forms is not intended to be limiting.

BRIEF DESCRIPTION OF THE DRAWINGS

Various examples and embodiments of the present invention will now be described with reference to the accompanying drawings, in which:

FIG. **1**A is a perspective view of an example of a clamping assembly;

FIG. 1B is a further perspective view of the clamping assembly of FIG. 1A;

FIG. 1C is a side view of the clamping assembly of FIG. 1A;

FIG. 1D is a top view of the clamping assembly of FIG. 1A;

FIG. 2 is a perspective view of a block transfer apparatus incorporating the clamping assembly of FIGS. 1A to 1D;

FIG. 3A is a schematic bottom view of a clamping assembly shown in use clamping a first block type;

FIG. 3B is a schematic top view of the clamping assembly of FIG. 3A;

FIG. 3C is a sectional view of the clamping assembly taken through section A-A of FIG. 3A;

FIG. 4A is a schematic bottom view of a clamping assembly shown in use clamping a second block type;

FIG. 4B is a schematic top view of the clamping assembly of FIG. 4A;

FIG. 4C is a sectional view of the clamping assembly taken through section B-B of FIG. 4A;

FIG. 5A is a schematic bottom view of a clamping assembly shown in use clamping a third block type;

FIG. 5B is a schematic top view of the clamping assembly of FIG. 5A;

FIG. 5C is a sectional view of the clamping assembly taken through section C-C of FIG. 5A;

FIG. 6A is a schematic bottom view of a clamping assembly shown in use clamping a fourth block type;

FIG. 6B is a schematic top view of the clamping assembly of FIG. 6A;

FIG. 6C is a sectional view of the clamping assembly taken through section D-D of FIG. 6A;

FIGS. 7A to 7Q provide a detailed sequence of schematic views of a block transfer apparatus illustrating controlled movements thereof;

FIG. 8A is a perspective view of a further example of a block transfer apparatus;

FIG. 8B is a further perspective view of the block transfer apparatus of FIG. 8A;

FIG. 8C is a top view of the block transfer apparatus of FIG. 8A;

FIG. 8D is a front view of the block transfer apparatus of FIG. 8A;

FIGS. 9A to 9F provide a detailed sequence of schematic views of the block transfer apparatus of FIG. 8A illustrating controlled movements thereof;

FIG. 10A is a perspective view of a further example of a block transfer apparatus;

FIG. 10B is a front view of the block transfer apparatus of FIG. 10A;

FIG. 10C is a further perspective view of the block transfer apparatus of FIG. 10A; and,

FIGS. 11A to 11E provide a detailed sequence of schematic views of the block transfer apparatus of FIG. 10A illustrating controlled movements thereof.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

An example of a clamping assembly **10** for clamping a block will now be described with references to FIGS. 1A to 1D.

The term "block" used herein is a piece of material, typically in the form of a polyhedron, such as a cuboid having six quadrilateral and more typically substantially rectangular faces. The block is typically made of a hard material and may include openings or recesses, such as cavities or the like. The block is configured to be used in constructing a structure, such as a building or the like and specific example blocks include bricks, besser blocks, concrete masonry units or similar.

In this example, the clamping assembly **10** includes a pair of gripper jaws **20**, **30** including datum surfaces **21**, **31** and **22**, **32** in first and second orthogonal planes to locate the block relative thereto. The clamping assembly **10** is configured to locate an end and top or bottom face of the block in the first and second orthogonal planes and then apply a clamping force to opposing sides of the block so as to locate the block in a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly **10**.

An advantage of the above-described clamping assembly **10** is its ability to provide a reliable and repeatable mechanical datum for the block it is clamping. This is particularly useful in a robotic system in which the clamping assembly may be used to clamp a block and transfer it for pick up by a robotic arm. As the position and orientation of the block is known relative to the clamping assembly, the block may be accurately transferred to the robotic arm and the robotic arm may be programmed to pick up the block from a precise location with respect to the clamping assembly. This enables a further clamp (i.e. end effector) of the robotic arm to pick up a block in the same position every time which is important to ensure that the block is placed accurately at its target destination. The ability to mechanically datum the block in the gripper jaws removes the need for a vision system to image the block in the clamping assembly in order to determine its precise 6 DOF location. By eliminating the need for a camera-based vision system, the robotic block transfer system is made more reliable and efficient.

A number of further features will now be described.

In one example, the datum surfaces form a V-shaped wedge into which the block is located. This corresponds to the intersection of the X and Z planes in FIGS. 1C and 1D. As will be described in further detail below, typically the block is allowed to drop into the wedge under the force of gravity when the clamping assembly is oriented at an acute angle, typically around 45 degrees to the ground.

Typically, each gripper jaw includes at least one first datum surface extending at least partially between top and bottom surfaces of the gripper jaw and towards the opposing gripper jaw for locating an end of the block. The at least one first datum surface is provided by one of a surface integral with each gripper jaw or a plate element mounted to a surface integral with each gripper jaw. In an example configuration, a thin wear plate/strip, for example made from Steel or the like is fixed to the surface integral with each gripper jaw. These strips or inserts can be replaced periodically when the datum surface starts to wear and this obviates the need to replace the entire gripper jaw.

Further, each gripper jaw includes at least one second datum surface that is parallel to a top or bottom surface of the gripper jaw and projects towards the opposing gripper jaw for locating the top or bottom surface of the block. The at least one second datum surface is provided by one of the top or bottom surface of each gripper jaw or plate elements mounted to the top or bottom surfaces of each gripper jaw. It will be appreciated therefore that the datum surfaces could be surfaces machined into the body of each gripper jaw, whilst in other embodiments the datum surfaces may be provided by additional plate elements fixed to surfaces of the gripper jaw.

In one example, the at least one second datum surface is discontinuous. In this regard, the top or bottom surface of

each gripper jaw and/or plate elements fixed thereto may be segmented so as to provide gaps suitable for a gripper of a robotic arm to grip the block whilst it is held by the clamping assembly to effect transfer to the robotic arm. It is to be appreciated that in order to datum the block in the at least one second datum plane contact with one or more surface segments or plate elements may be used. In some examples, depending on the length of block being clamped, more than one surface segment or plate element providing the second datum surface will be in contact with the block whereas for shorter blocks only one surface segment or plate element may contact the block.

The gripper jaws of the clamping assembly may therefore be configured to accommodate blocks of varying length. In one example, the jaws may accommodate one or more of a full-size block of length L, a three-quarter size block of length 0.75 L, a half-size block of length 0.5 L and a quarter-size block of length 0.25 L.

Typically, the gripper jaws are configured to clamp blocks of varying length at different pre-defined positions along the length of the gripper jaws. In this regard, each gripper jaw may include a plurality of first datum surfaces spaced apart along a lengthwise direction thereof. The plurality of spaced apart first datum surfaces are typically further stepped apart laterally with respect to each gripper jaw so as not to overlap in the lengthwise direction thereof. In this arrangement, an end of blocks of varying length are each located on one of the plurality of first datum surfaces of each gripper jaw. Accordingly, when a particular block type is held by the clamping assembly in a datumed configuration, only one of the plurality of first datum surfaces will be in contact with the block.

The clamping method of the gripper jaws will now be described. Typically, a first of the pair of gripper jaws has a plurality of first gripper pads arranged to define the third plane for locating a side face of the block when clamped. The plurality of first gripper pads may be mounted onto an inner face of the first gripper jaw or into recesses formed therein such that the pads protrude slightly past the inner face. In one example, the plurality of first gripper pads comprise a pair of spaced apart rows of first gripper pads extending in a lengthwise direction of the first gripper jaw. In a preferred arrangement, at least four first gripper pads will contact a first side face of the block when clamping. Typically, this comprises two first gripper pads in the first row and two first gripper pads in the second row. This arrangement will provide four points of contact typically whereby the gripper pads in the first and second rows are equally spaced apart in the lengthwise direction.

A second of the pair of gripper jaws typically has a plurality of second gripper pads arranged co-linearly in a lengthwise direction thereof such that when a clamping force is applied to the block the plurality of second gripper pads act to urge the block into planar alignment with the third plane defined by the plurality of first gripper pads. In this regard, the second gripper pads are typically located on the second gripper jaw approximately midway between the spaced apart rows of first gripper pads. In this way, the line of action of the clamping force through the second gripper pads will be midway between the corresponding lines of action of the clamping force through the first gripper pads. This arrangement assists in providing planar alignment in the third plane (i.e. Y-plane) and prevents the block from being angularly misaligned in the jaws.

The first and second gripper pads are arranged on stepped surfaces of each gripper jaw so that each different length of block clamped by the assembly is contacted by a different plurality of first and second gripper pads.

In one example, any block clamped by the assembly will be in contact with at least four first gripper pads and at least two second gripper pads when a clamping force is applied. In other arrangements it may be possible to for a block to be in contact with only three first gripper pads and one second gripper pad.

It is to be understood that when a block is clamped by the above-described clamping assembly it may be held initially in an undatumed and unknown position. In order to datum the block in the jaws, typically the block is allowed to drop into the wedge under gravity to locate onto the datum surfaces defining the first and second orthogonal planes.

In order to effect this drop, typically the clamping assembly is pivotable (either directly or indirectly) and the drop is performed when the gripper jaws have been pivoted to a relative angle to the ground of at least one of: between 30 to 60 degrees; between 35 to 55 degrees; between 40 to 50 degrees; and, approximately 45 degrees. As the jaws must be opened in order to allow the block to drop, the angle is chosen for a particular block type to ensure that the block is not inadvertently dropped out of the clamping assembly.

In operation, in one example, the block is initially clamped in the gripper jaws in an approximate position. It is then rotated to a drop position whereby the gripper jaws release the block and allow it to drop into the wedge. The block is then re-clamped when it is located in the wedge so that the block is then clamped in a datumed position.

In another broad form there is provided a block transfer apparatus for transferring a block between an upstream clamp of a block delivery system and a downstream clamp of the block delivery system. The block transfer apparatus includes a frame pivotally mounted to a support; and, a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws including datum surfaces in first and second orthogonal planes to locate the block relative thereto. The clamping assembly is configured to at least: receive a block from the upstream clamp, wherein the block is initially clamped in the gripper jaws in an approximate position; rotate to a drop position whereby the gripper jaws release the block and allow it to drop into a V-shaped wedge formed by the datum surfaces to thereby locate an end and top or bottom face of the block in the first and second orthogonal planes; re-clamp the block after the drop by applying a clamping force to opposing sides of the block so as to locate the block in a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly. Finally, the block transfer apparatus presents the block clamped in the datumed position for transfer to the downstream clamp.

In one example, the support comprises a distal end of a boom used for transferring blocks therealong and the upstream clamp forms part of a shuttle for delivering a block along the boom.

The downstream clamp may be an end effector of a robotic block placement arm that is programmed to place blocks during construction of a building structure.

In some arrangements, the block transfer apparatus includes a distance range sensor for use in determining the proximity between the clamping assembly and the block held by the upstream clamp. Any suitable distance range sensing technology such as ultrasonic, laser etc may be used. Feedback from the distance sensor can be used to control the block transfer apparatus to pick up the block from the upstream clamp.

In a further broad form, there is provided a block delivery system for delivering blocks for placement during construction of a building structure. The block delivery system includes a boom for transferring blocks therealong; an upstream clamp forming part of a shuttle that delivers blocks along the boom; a downstream clamp associated with an end effector of a robotic block placement arm that is programmed to place blocks during construction of the building structure; and, a block transfer apparatus for transferring a block between the upstream clamp and the downstream clamp, the block transfer apparatus including: a frame pivotally mounted to a distal end of the boom; and, a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws including datum surfaces in first and second orthogonal planes to locate the block relative thereto, wherein the clamping assembly is configured to at least: receive a block from the upstream clamp, wherein the block is initially clamped in the gripper jaws in an approximate position; rotate to a drop position whereby the gripper jaws release the block and allow it to drop into a V-shaped wedge formed by the datum surfaces to thereby locate an end and top or bottom face of the block in the first and second orthogonal planes; re-clamp the block after the drop by applying a clamping force to opposing sides of the block so as to locate the block in a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly; and, present the block clamped in the datumed position for transfer to the downstream clamp.

Referring again to FIGS. **1**A to **1**D, the clamping assembly **10** will be described in further detail. The clamping assembly **10** includes a frame **11** to which the gripper jaws **20**, **30** are slidably mounted onto rails **14**, **16** via bearing blocks or rail guides for linear movement in a lateral direction in order to open and close the jaws. The jaws **20**, **30** are belt driven by a servo motor **17** that turns a lead screw **15** connecting the jaws to thereby move the jaws along the rails **14**, **16** in order to apply and release a clamping force to a block. Further bearing blocks or rail guides **12**, **13** are also mounted to one side of the frame **11** and these guides are engageable onto rails of a block transfer apparatus as will be described in further detail below.

As shown in FIGS. **1**A and **1**B, first gripper jaw **20** includes two rows of spaced apart gripper pads **41**, **42** along the length of the first griper jaw **20**, whilst second gripper jaw **30** includes a single row of spaced apart gripper pads **43** along the length of second gripper jaw **30**. These gripper pads exert a clamping force onto a block when clamped and are arranged so that the gripper pads **43** of the second gripper jaw **30** urge the block into planar alignment in a Y-plane defined by the gripper pads **41**, **42** of the first gripper jaw **20** in contact with the block. In this regard, the single row of gripper pads **43** of the second gripper jaw **30** are typically located approximately midway between the height of the two rows defined respectively by gripper pads **41**, **42** of the first gripper jaw **20**. This arrangement prevents angular misalignment or twisting of the block in the jaws.

Each gripper jaw **20**, **30** of the clamping assembly has a body extending in a lengthwise direction. In plan view, the gripper jaws **20**, **30** each have a central portion **25**, **35** and fore and aft portions **26**, **36** and **27**, **37** that are inwardly tapered from the central portion **25**, **35** towards respective opposing ends of each jaw **20**, **30**. Internally, the body of each gripper jaw has a central recessed portion, from which the body defines a stepped profile in opposing directions towards respective ends of each jaw. The inner face of each jaw therefore defines a number of laterally stepped apart recessed portions, each defining a recessed inner surface and corresponding lip segment as will be described in further detail below with respect to the schematic views shown in FIGS. **3**A to **3**C, **4**A to **4**C, **5**A to **5**C and **6**A to **6**C.

In FIG. **1**D, it is to be noted that the clamping assembly **10** includes a plurality of first datum surfaces **21**, **31** that are stepped apart in a lengthwise direction of the gripper jaws **20**, **30**. Advantageously, this enables the clamping assembly **10** to be able to clamp and datum blocks of varying length which increases its utility. There may also be provided a plurality of second datum surfaces **22**, **32** as shown that have gaps between them suitable for a clamp of a robot to grip the block whilst held by the clamping assembly **10** for transfer thereto.

An example of a block transfer apparatus **200** is provided in FIG. **2**. In this example, the block transfer apparatus **200** includes a lengthwise extending frame or bracket **210** to which the clamping assembly **10** is translatably mounted for linear extension and retraction therealong about rails **215**, **216**. The rail guides **12**, **13** mounted to the frame **11** of the clamping assembly **10** receive the rails **215**, **216** therein and the clamping assembly **10** is belt driven along the rails by servo motor **220**. In use, the block transfer apparatus **200** is pivotally mounted to a support (such as a distal end of a boom) to enable controlled rotation about pivot axis P. In the example shown, the bracket **210** has structural cross bracing support **212** attached thereto and a pivot mount **213** is provided on this support. On the opposing side, a pivot mount **214** which may be in the form of a high precision reduction gearing is provided mounted to the bracket **210**. Mounted beneath the bracket **210** is an adhesive applicator **230** for dispensing construction adhesive onto the block **1**. In use, the block is translated beneath nozzles of the adhesive applicator in order to apply adhesive along a substantial length of the block surface. Further details of operation of the block transfer apparatus **200** are described below with references to FIGS. **7**A to **7**Q.

Referring now to FIGS. **3**A to **3**C, **4**A to **4**C, **5**A to **5**C and **6**A to **6**C, there are shown detailed schematic representations of a clamping assembly **100** for use in clamping various block types in a datumed position. In these figures, the nomenclature of first and second gripper jaws is the opposite of that used with respect to FIGS. **1**A to **1**D.

In the below description, each gripper jaw of the clamping assembly has a body extending in a lengthwise direction. In plan view, the gripper jaws have a central portion and fore and aft portions that are inwardly tapered from the central portion towards respective opposing ends of each jaw. Internally, the body of each gripper jaw has a central recessed portion, from which the body defines a stepped profile in opposing directions towards respective ends of each jaw. The inner face of each jaw therefore defines a number of laterally stepped apart recessed portions, each defining a recessed inner surface and corresponding lip segment.

It is to be understood that at least some of the lips define the plurality of first datum surfaces spaced apart along a lengthwise direction of each jaw and stepped apart laterally so as not to overlap in the lengthwise direction thereof.

In FIGS. **3**A to **3**C, the clamping assembly **100** is shown clamping a quarter-length block **1** having a single core or cavity therethrough, although this is for purposes of illustration only.

In this arrangement, the block **1** is clamped in the central recessed portion of the jaws **110**, **150** between first recessed inner surfaces **111**, **151**. The end face **3** of the block **1** is in

contact with first lip segments **121**, **161** that define first datum surfaces in the X-plane. In this example, first insert wear strips **140**, **180** are fixed onto the corresponding first lip segments **121**, **161** and the block **1** is held in contact with these strips. A top or bottom face **6** of the block **1** is in contact with plate elements **144**, **184** that are fixed to the top surface of respective jaws **110**, **150** proximate the central portion thereof. These plate elements **144**, **184** project inwardly so as to at least partly extend above the central recessed portion of the jaws. The plate elements **144**, **184** define second datum surfaces in the Z-plane and accordingly in the clamped configuration shown, the block **1** is datumed in the X and Z planes.

Respective sides **4** and **5** of the block **1** are clamped respectively by first gripper pads **130**, **131** and **130'**, **131'** that are fixed proximal first recessed inner surface **111** of the first gripper jaw **110** and second gripper pads **170**, **171** that are fixed proximal first recessed inner surface **151** of the second gripper jaw **150**. As shown in FIG. **3**B, the first gripper pads are arranged in spaced apart rows with first gripper pads **130**, **131** being in an upper row and first gripper pads **130'**, **131'** being in a lower row so as to position first gripper pad **130** above first gripper pad **130'** and first gripper pad **131** above first gripper pad **131'**. The second gripper pads **170**, **171** are arranged co-linearly in a single row that is centrally disposed between the two rows of first gripper pads.

In this way, when a clamping force is applied to the block **1**, the plurality of second gripper pads **170**, **171** act to urge the block into planar alignment with a third plane (the Y-plane) defined by the surfaces of the plurality of first gripper pads **130**, **131**, **130'**, **131'**. This arrangement of gripper pads prevents angular misalignment when the block is clamped as side face **4** of the block **1** has four points of contact and side face **5** has two points of contact disposed midway between the opposing points of contact on the other side. As such, in this configuration the position of the block **1** is datumed in the X, Y and Z planes relative to the clamping assembly **100**.

In FIGS. **4**A to **4**C, the clamping assembly **100** is shown clamping a half-length block **1** having a two cores or cavities therethrough, although this is for purposes of illustration only.

In this arrangement, the block **1** is clamped by respective fore and aft portions of each gripper jaw **110**, **150**, between second recessed inner surfaces **112**, **152** in the aft portion and second recessed inner surfaces **113**, **153** in the fore portion. The end face **3** of the block **1** is in contact with second lip segments **123**, **163** that define first datum surfaces in the X-plane. In this example, second insert wear strips **141**, **181** are fixed onto the corresponding second lip segments **123**, **163** and the block **1** is held in contact with these strips. A top or bottom face **6** of the block **1** is in contact with plate elements **145**, **185** that are fixed to the top surface of respective fore portions of the gripper jaws **110**, **150** so as to project inwardly past the second recessed inner surfaces **113**, **153**. In addition, the top or bottom face **6** of the block **1** is also in contact with plate elements **146**, **186** that are fixed to the top surface of respective aft portions of the gripper jaws **110**, **150** so as to project inwardly past the second recessed inner surfaces **112**, **152**. The plate elements **145**, **146**, **184**, **186** define second datum surfaces in the Z-plane and accordingly in the clamped configuration shown, the block **1** is datumed in the X and Z planes.

Side **4** of the block **1** is clamped respectively by first gripper pads **132**, **132'** that are fixed proximal second recessed inner surface **112** of the first gripper jaw **110** and first gripper pads **133**, **133'** that are fixed proximal second recessed inner surface **113** of the first gripper jaw **110**. Side **5** of the block **1** is clamped respectively by second gripper pad **172** that is fixed proximal second recessed inner surface **152** of the second gripper jaw **150**, and second gripper pad **173**, that is fixed proximal second recessed inner surface **153** of the second gripper jaw **150**. The respective first and second gripper pads are arranged substantially as previous described, except spaced apart further in a lengthwise direction of the gripper jaws. As the block **1** is clamped, the plurality of second gripper pads **172**, **173** act to urge the block into planar alignment with a third plane (the Y-plane) defined by the surfaces of the plurality of first gripper pads **132**, **133**, **132'**, **133'**. As such, in this configuration the position of the block **1** is datumed in the X, Y and Z planes relative to the clamping assembly **100**.

In FIGS. **5**A to **5**C, the clamping assembly **100** is shown clamping a three quarter-length block **1** having a three cores or cavities therethrough, although this is for purposes of illustration only.

In this arrangement, the block **1** is clamped by respective fore and aft portions of each gripper jaw **110**, **150**, between third recessed inner surfaces **114**, **154** in the aft portion and third recessed inner surfaces **115**, **155** in the fore portion. The end face **3** of the block **1** is in contact with third lip segments **125**, **165** that define first datum surfaces in the X-plane. In this example, third insert wear strips **142**, **182** are fixed onto the corresponding third lip segments **125**, **165** and the block **1** is held in contact with these strips. A top or bottom face **6** of the block **1** is in contact with plate elements **145**, **185** that are fixed to the top surface of respective fore portions of the gripper jaws **110**, **150** so as to project inwardly past the third recessed inner surfaces **115**, **155**. In addition, the top or bottom face **6** of the block **1** is also in contact with plate elements **146**, **186** that are fixed to the top surface of respective aft portions of the gripper jaws **110**, **150** so as to project inwardly past the third recessed inner surfaces **114**, **154**. The plate elements **145**, **146**, **184**, **186** define second datum surfaces in the Z-plane and accordingly in the clamped configuration shown, the block **1** is datumed in the X and Z planes.

Side **4** of the block **1** is clamped respectively by first gripper pads **134**, **134'** that are fixed proximal third recessed inner surface **114** of the first gripper jaw **110** and first gripper pads **135**, **135'** that are fixed proximal third recessed inner surface **115** of the first gripper jaw **110**. Side **5** of the block **1** is clamped respectively by second gripper pad **174** that is fixed proximal third recessed inner surface **154** of the second gripper jaw **150**, and second gripper pad **175** that is fixed proximal third recessed inner surface **155** of the second gripper jaw **150**. The respective first and second gripper pads are arranged substantially as previous described, except spaced apart further in a lengthwise direction of the gripper jaws than the previous examples. As the block **1** is clamped, the plurality of second gripper pads **174**, **175** act to urge the block into planar alignment with a third plane (the Y-plane) defined by the surfaces of the plurality of first gripper pads **134**, **135**, **134'**, **135'**. As such, in this configuration the position of the block **1** is datumed in the X, Y and Z planes relative to the clamping assembly **100**.

In FIGS. **6**A to **6**C, the clamping assembly **100** is shown clamping a full-length block **1** having a four cores or cavities therethrough, although this is for purposes of illustration only.

In this arrangement, the block **1** is clamped by respective fore and aft portions of each gripper jaw **110**, **150**, between fourth recessed inner surfaces **116**, **156** in the aft portion and fourth recessed inner surfaces **117**, **157** in the fore portion.

The end face **3** of the block **1** is in contact with fourth lip segments **127**, **167** that define first datum surfaces in the X-plane. In this example, fourth insert wear strips **143**, **183** are fixed onto the corresponding fourth lip segments **127**, **167** and the block **1** is held in contact with these strips. A top or bottom face **6** of the block **1** is in contact with plate elements **145**, **185** that are fixed to the top surface of respective fore portions of the gripper jaws **110**, **150** so as to project inwardly past the fourth recessed inner surfaces **117**, **157**. In addition, the top or bottom face **6** of the block **1** is also in contact with plate elements **146**, **186** that are fixed to the top surface of respective aft portions of the gripper jaws **110**, **150** so as to project inwardly past the fourth recessed inner surfaces **116**, **156**. The plate elements **145**, **146**, **184**, **186** define second datum surfaces in the Z-plane and accordingly in the clamped configuration shown, the block **1** is datumed in the X and Z planes.

Side **4** of the block **1** is clamped respectively by first gripper pads **136**, **136'** that are fixed proximal fourth recessed inner surface **116** of the first gripper jaw **110** and first gripper pads **137**, **137'** that are fixed proximal fourth recessed inner surface **117** of the first gripper jaw **110**. Side **5** of the block **1** is clamped respectively by second gripper pad **176** that is fixed proximal fourth recessed inner surface **156** of the second gripper jaw **150**, and second gripper pad **177** that is fixed proximal fourth recessed inner surface **157** of the second gripper jaw **150**. The respective first and second gripper pads are arranged substantially as previous described, except spaced apart further in a lengthwise direction of the gripper jaws than the previous examples. As the block **1** is clamped, the plurality of second gripper pads **176**, **177** act to urge the block into planar alignment with a third plane (the Y-plane) defined by the surfaces of the plurality of first gripper pads **136**, **137**, **136'**, **137'**. As such, in this configuration the position of the block **1** is datumed in the X, Y and Z planes relative to the clamping assembly **100**.

Referring now to FIGS. **7**A to **7**Q, the controlled operation of the block transfer apparatus **200** shall be described in the context of a block delivery system **300** for delivering blocks for placement during construction of a building structure.

In this example, operation of the block transfer between the downstream and upstream clamps **55**, **80** of the block delivery system **300** via the block transfer apparatus **200** shall be described. In FIG. **7**A, a block **1** is being transferred to the downstream clamp **80** which is a robotic gripper of a robotic block placement arm (not shown). As soon as the downstream clamp **80** has gripped the block **1**, the clamping assembly **10** of the block transfer apparatus **200** may release the block. In this block handover position, the block transfer apparatus **200** is in a horizontal orientation with the clamping assembly **10** fully extended in the longitudinal direction.

In FIG. **7**B, the block transfer apparatus **200** releases the block and begins to rotate away from the downstream clamp **80** about support **52** which is a mount at the distal end of boom **50**, the support **52** defining a rotation or pivot axis about which the block transfer apparatus **200** is able to pivot. In this initial phase of rotation, the clamping assembly **10** remains at full extension.

In FIG. **7**C, as rotation of the block transfer apparatus **200** continues, the clamping assembly **10** begins to retract and move linearly along rails of the frame or bracket **210** of the block transfer apparatus **200**. In FIG. **7**D, retraction of the clamping assembly **10** continues whilst the block transfer apparatus **200** is rotating and in this state the clamping assembly **10** is now retracted sufficiently to be within the envelope of the frame or bracket **210**.

In FIG. **7**E, the clamping assembly **10** is shown fully retracted with respect to frame **210** as the block transfer apparatus **200** approaches a nearly vertical orientation. In FIG. **7**F, the block transfer apparatus **200** has rotated past vertical and the clamping assembly **10** has begun to extend away from its fully retracted position. In this state, the orientation of the clamping assembly **10** has "flipped" over from the initial orientation shown in FIG. **7**A.

The block transfer apparatus **200** continues rotation until the longitudinal axis of the frame **210** is aligned with the lengthwise direction of the boom **50** as shown in FIG. **7**F. In this state, the clamping assembly **10** is nearly fully extended so as to reach into the opening **51** of the distal end of the boom **50**. Typically, there is a recess or cut-out in the underside portion of the distal end of the boom so that the block transfer apparatus **200** can enter the envelope of the boom without any physical clash. Depending on the size of the cut-out, the clamping assembly **10** may be able to reach full extension during rotation. Otherwise, the block transfer apparatus **200** rotates into alignment with the boom **50** first and then extends the clamping assembly **10** into the boom **50**.

As shown in FIG. **7**H, the clamping assembly **10** is then fully extended into a position whereby it clamps a block held by the downstream clamp **55** disposed inside the boom **50**. The downstream clamp **55** typically forms part of a shuttle mechanism that delivers blocks internally through the boom **50**. Once the clamping assembly **10** has clamped the block, the downstream clamp **55** may release its grip of the block. It is to be understood that the position of the block with respect to the gripper jaws of the clamping assembly **10** is not precisely known at this stage.

In FIGS. **7**I and **7**J, the clamping assembly **10** is shown beginning to retract away from its fully extended position whilst the frame **210** remains in alignment with the boom **50**. In FIG. **7**J, the clamping assembly **10** has retracted sufficiently so that it is within the cut-out portion of the underside of the distal end of the boom in a safe position for rotation of the block transfer apparatus **200** to begin.

In FIG. **7**K, the block transfer apparatus **200** is rotated to a horizontal orientation whilst the clamping assembly **10** remains in an extended state (retracted only a sufficient amount to clear the distal end of the boom upon exit thereof). An adhesive applicator (see FIG. **2**A) mounted to the block transfer apparatus **200** then begins dispensing adhesive onto an upper face of the block whilst the clamping assembly **10** retracts the block and thereby translates it linearly beneath nozzles of the adhesive applicator. Once the adhesive dispensing is complete and when the clamping assembly **10** is nearly fully retracted as shown in FIG. **7**L the block transfer apparatus **200** rotates to a drop position in which the block is datumed.

The drop position is shown in FIG. **7**M. In this example, the block transfer apparatus **200** and clamping assembly **10** are oriented at an angle to the ground of approximately 45 degrees. In this position, the clamping assembly **10** releases its clamp of the block and allows it to drop under gravity into the wedge **70** defined by the first and second datum surfaces as previously described which thereby datums the block in the clamping assembly **10** with respect to the X and Z planes as shown. Once the drop has been performed and the block is datumed in these planes, the gripper jaws of the clamping assembly **10** re-clamp the block to thereby locate the block in a third plane orthogonal to both the first and second planes to thereby fully datum the position of the block with respect to the clamping assembly **10**.

After the drop is complete and the block is re-clamped in the gripper jaws, the block transfer apparatus **200** commences further rotation at a safe speed as shown in FIG. **7**N. The block transfer apparatus **200** continues to rotate whilst the clamping assembly **10** is extended to the edge of the frame **210** as shown in FIG. **7**O. Rotation speed is then decreased whilst the clamping assembly **10** continues to extend beyond the frame **210** as shown in FIG. **7**P.

In FIG. **7**Q, the final stage of rotation of the block transfer apparatus **200** and extension of the clamping assembly **10** is completed resulting in the block being held out in a substantially horizontal position for transfer to the upstream clamp **80** as shown in FIG. **7**A. The cycle then repeats as further blocks are transferred by the block delivery system for laying by the robotic placement arm on a construction site in order to construct a building. It is to be noted that in the transfer position shown in FIG. **7**A, the clamping assembly **10** has been flipped 180 degrees from its orientation when adhesive was applied to the block in FIG. **7**L. As such the block is now oriented in the clamping assembly **100** such that the face with adhesive applied is now facing downward ready for laying.

A second example of a block transfer apparatus **500** shall now be described with reference to FIGS. **8**A to **8**D and **9**A to **9**F.

In this example, the block transfer apparatus **500** is for transferring a block **1** between an upstream clamp (not shown) of a block delivery system and a downstream clamp **80** of the block delivery system. The block transfer apparatus **500** includes a frame **510** pivotally mounted to a support and a clamping assembly **400** mounted to the frame **510** and linearly extendable relative thereto, the clamping assembly **400** including a pair of gripper jaws **420**, **430** for clamping opposing sides of the block.

The block transfer apparatus **500** is configured to receive a block **1** from the upstream clamp, wherein the block **1** is initially clamped in the gripper jaws **420**, **430** in an approximate position; rotate to a drop position whereby the gripper jaws **420**, **430** release the block **1** and allow it to self-datum onto first and second orthogonal datum surfaces **424**, **434** and **518** to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes; re-clamp the block **1** after the drop by applying a clamping force to opposing sides of the block so as to register the block **1** against a third datum surface **422**, **423** defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block **1** with respect to the clamping assembly **400**; and, present the block **1** clamped in the datumed position for transfer to the downstream clamp **80**.

In this example, the clamping assembly **400** includes a frame **411** to which the gripper jaws **420**, **430** are slidably mounted onto rails **441**, **442** via bearing blocks or rail guides for linear movement in a lateral direction in order to open and close the jaws. The jaws **420**, **430** may be belt driven by a servo motor that turns a lead screw **443** connecting the jaws to thereby move the jaws along the rails **441**, **442** in order to apply and release a clamping force to a block.

The first gripper jaw **420** includes two rows of spaced apart gripper pads **422**, **423** rigidly mounted to an inner face **421** along the length of the first gripper jaw **420**, whilst the second gripper jaw **430** includes a single row of spaced apart gripper pads **431**, **431'** mounted to a distal end of flexible fingers or battens **432**, **432'** along the length of second gripper jaw **430**. The gripper pads exert a clamping force onto a block when clamped and are arranged so that the gripper pads **431**, **431'** of the second gripper jaw **430** urge the block into planar alignment in a Y-plane defined by the gripper pads **422**, **423** of the first gripper jaw **420** in contact with the block. In this regard, the single row of gripper pads **431**, **431'** of the second gripper jaw **430** are typically located approximately midway between the height of the two rows defined respectively by gripper pads **422**, **423** of the first gripper jaw **420**. This arrangement prevents angular misalignment or twisting of the block in the jaws.

The flexible finger members or battens **432**, **432'** spaced apart along the length of the second gripper jaw **430**, allow the pads **431**, **431'** to flex laterally and compensate for variations in flatness of the side of the block along its length (which may for instance be slightly bowed) as well as any lateral flex in the gripper jaws themselves. This ensures an equal clamping force is applied along the length of the block as each finger will flex to a different degree depending on the variation in flatness. Some of the flexible fingers **432'** are partially restrained by retaining clips **433** that act to pretension the finger members. Each flexible finger is located at its base into a recessed portion **436** of the second gripper jaw **430**.

The block transfer apparatus **500** further includes a lengthwise extending frame **510** to which the clamping assembly **400** is translatably mounted for linear extension and retraction therealong about rails **515**, **516**. Rail guides or bearing blocks mounted to the frame **411** of the clamping assembly **400** receive the rails **515**, **516** therein and the clamping assembly **400** is belt driven along the rails by servo motor **520**. In use, the block transfer apparatus **500** is pivotally mounted to a support (such as a distal end of a boom) to enable controlled rotation about pivot axis P. In the example shown, the frame **510** has structural cross bracing support **512** attached thereto and a pivot mount **513** is provided on this support. On the opposing side, a pivot mount **514** which may be in the form of a high precision reduction gearing is provided mounted to the frame **510**. Additionally, a datum bar or plate **517** is mounted to the structural support **512** so that it extends in a direction parallel to the lengthwise direction of the gripper jaws **420**, **430**. This datum bar **517** is used to datum the top or bottom face of the block as will be described in further detail below. In this example, the distal ends **424**, **434** of the gripper jaws provide datum surfaces which register an end face of the block.

Referring now to FIGS. **9**A to **9**F, the controlled operation of the block transfer apparatus **500** shall be described in the context of a block delivery system for delivering blocks for placement during construction of a building structure.

In this example, operation of the block transfer between the downstream and upstream clamps of the block delivery system via the block transfer apparatus **500** shall be described.

In FIG. **9**A, the block transfer apparatus **500** is shown with its clamping assembly **400** extended out and reaching into a boom **50** to receive a block **1** from a downstream clamp (not shown) such as a shuttle clamp that runs along the boom element **50**. In this example, the clamping assembly **400** has been rotated about axis **52** in a counterclockwise direction through a recess or cut-out in the underside portion of the distal end of the boom so that the block transfer apparatus **500** can enter the envelope of the boom without any physical clash. Depending on the size of the cut-out, the clamping assembly **400** may be able to reach full extension during rotation. Otherwise, the block transfer apparatus **500** rotates into alignment with the boom **50** first and then extends the clamping assembly **400** into the boom **50**. Once the clamping assembly **400** has clamped the block,

the downstream clamp may release its grip of the block. It is to be understood that the position of the block with respect to the gripper jaws of the clamping assembly **400** is not precisely known at this stage.

In FIGS. **9**B and **9**C, the clamping assembly **400** is shown rotating out of the boom in a clockwise direction and starting to retract away from its fully extended position in preparation for the block datuming operation. In FIG. **9**D, when the block transfer apparatus **500** is in the drop position (oriented at an angle to the ground of approximately 45 degrees), the clamping assembly **400** releases its clamp of the block and allows it to drop under gravity so that the block self-datums onto first and second orthogonal datum surfaces (**424**, **434**) and **518** to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes. This datums the blocks with respect to the X and Z planes as depicted in FIGS. **8**C and **8**D. Once the drop has been performed and the block is datumed in these planes, the gripper jaws of the clamping assembly **400** re-clamp the block by applying a clamping force to opposing sides of the block so as to register the block against a third datum surface defining a third plane (Y plane) orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly **400**.

After the drop is complete and the block is re-clamped in the gripper jaws, the block transfer apparatus **500** commences further rotation in a clockwise direction whilst concurrently extending the clamping assembly **400** out in a horizontal disposition as shown in FIG. **9**E. In this example, during extension, the block may be translated over a transfer adhesive applicator to apply adhesive to the bottom surface of the block. In this position, the block is held out for transfer to the upstream clamp **80** (e.g. end effector of robotic block placement arm) as shown in FIG. **9**F from which it is subsequently laid in position.

A third example of a block transfer apparatus **700** shall now be described with reference to FIGS. **10**A to **10**C and **11**A to **11**E.

In this example, the block transfer apparatus **700** is for transferring a block **1** between an upstream clamp of a block delivery system and a downstream clamp of the block delivery system as previously described. The block transfer apparatus **700** includes a frame **710** pivotally mounted to a support and a clamping assembly **600** mounted to the frame **710** and linearly extendable relative thereto, the clamping assembly **600** including a pair of gripper jaws **620**, **630** for clamping opposing sides of the block.

The block transfer apparatus **700** is configured to receive a block **1** from the upstream clamp, wherein the block **1** is initially clamped in the gripper jaws **620**, **630** in an approximate position; rotate to a drop position whereby the gripper jaws **620**, **630** release the block **1** and allow it to self-datum onto first and second orthogonal datum surfaces **626**, **718** to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes; re-clamp the block **1** after the drop by applying a clamping force to opposing sides of the block so as to register the block **1** against a third datum surface **622**, **623** defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block **1** with respect to the clamping assembly **600**; and, present the block **1** clamped in the datumed position for transfer to the downstream clamp.

In this example, the clamping assembly **600** includes a frame **611** to which the gripper jaws **620**, **630** are slidably mounted onto rails **641**, **642** via bearing blocks or rail guides for linear movement in a lateral direction in order to open and close the jaws. The jaws **620**, **630** may be belt driven by a servo motor that turns a lead screw **643** connecting the jaws to thereby move the jaws along the rails **641**, **642** in order to apply and release a clamping force to a block.

The first gripper jaw **620** includes two rows of spaced apart gripper pads **622**, **623** rigidly mounted to an inner face **621** along the length of the first gripper jaw **620**, whilst the second gripper jaw **630** includes two rows of spaced apart gripper pads **632**, **634** mounted to a distal end of flexible fingers or battens **633**,**635** along the length of second gripper jaw **630**. The gripper pads exert a clamping force onto a block when clamped and are arranged so that the gripper pads **632**, **634** of the second gripper jaw **630** urge the block into planar alignment in the third datum plane defined by the gripper pads **622**, **623** of the first gripper jaw **620** in contact with the block. In this regard, the two rows of gripper pads **632**, **634** of the second gripper jaw **630** are close together and are typically located approximately midway between the height of the two rows defined respectively by gripper pads **622**, **623** of the first gripper jaw **420**. This arrangement prevents angular misalignment or twisting of the block in the jaws.

The flexible finger members or battens **633**, **635** spaced apart along the length of the second gripper jaw **430**, allow the pads **634**, **636** to flex laterally and compensate for variations in flatness of the side of the block along its length (which may for instance be slightly bowed). This ensures an equal clamping force is applied along the length of the block as each finger will flex to a different degree depending on the variation in flatness. Each flexible finger is located at its base into a respective upper and lower cap **636**, **637** mounted along respective top and bottom edges of the second gripper jaw **430** so as to pretension the gripper pads. In this arrangement, the gripper pads **432**, **434** alternate in position between the first and second rows.

The block transfer apparatus **700** further includes a lengthwise extending frame **710** to which the clamping assembly **600** is translatably mounted for linear extension and retraction therealong about rails **715**, **716**. Rail guides or bearing blocks mounted to the frame **611** of the clamping assembly **600** receive the rails **715**, **716** therein and the clamping assembly **600** is belt driven along the rails by a servo motor. In use, the block transfer apparatus **700** is pivotally mounted to a support (such as a distal end of a boom) to enable controlled rotation about pivot axis P. In the example shown, the frame **710** has U-shaped support **712** mounted to the frame **710** to which a datum bar or plate **717** is mounted so that it extends in a direction parallel to the lengthwise direction of the gripper jaws **620**, **630**. This datum bar **717** is used to datum the top or bottom face of the block as will be described in further detail below. In this example, a datum bracket **626** is mounted to a proximate end of the support structure of gripper jaw **620** and this bracket provides a datum surface which registers an end face of the block. In other examples, another datum bracket **626** could be installed in a similar manner in association with gripper jaw **630**.

Referring now to FIGS. **11**A to **11**E, the controlled operation of the block transfer apparatus **700** shall be described in the context of a block delivery system for delivering blocks for placement during construction of a building structure.

In this example, operation of the block transfer between the downstream and upstream clamps of the block delivery system via the block transfer apparatus **700** shall be described.

In FIG. **11**A, the block transfer apparatus **700** is shown with its clamping assembly **600** extended out and reaching

into a boom **50'** to receive a block **1** from a downstream clamp **55'** such as a shuttle clamp that runs along the boom element **55'**. In this example, the clamping assembly **600** has been rotated about axis **52'** in a clockwise direction through a recess or cut-out in the topside portion of the distal end of the boom so that the block transfer apparatus **700** can enter the envelope of the boom without any physical clash. Depending on the size of the cut-out, the clamping assembly **600** may be able to reach full extension during rotation. Otherwise, the block transfer apparatus **700** rotates into alignment with the boom **50'** first and then extends the clamping assembly **600** into the boom **50'**. Once the clamping assembly **600** has clamped the block, the downstream clamp **55'** may release its grip of the block. It is to be understood that the position of the block with respect to the gripper jaws of the clamping assembly **600** is not precisely known at this stage.

In FIG. **11**B, the clamping assembly **600** is shown rotating out of the boom in a counter-clockwise direction and starting to retract away from its fully extended position in preparation for the block datuming operation. In FIG. **11**C, when the block transfer apparatus **700** is in the drop position (oriented at an angle to the ground of approximately 45 degrees), the clamping assembly **600** releases its clamp of the block and allows it to drop under gravity so that the block self-datums onto first and second orthogonal datum surfaces **626** and **718** to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes. Once the drop has been performed and the block is datumed in these planes, the gripper jaws of the clamping assembly **600** re-clamp the block by applying a clamping force to opposing sides of the block so as to register the block against a third datum surface defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly **600**.

After the drop is complete and the block is re-clamped in the gripper jaws, the block transfer apparatus **700** commences further rotation in a counter clockwise direction whilst concurrently extending the clamping assembly **600** out in a horizontal disposition as shown in FIGS. **11**D and **11**E. In this example, during extension, the block may be translated over a transfer adhesive applicator to apply adhesive to the bottom surface of the block. In this position, the block is held out for transfer to the upstream clamp (not shown).

In at least one example, the above-described clamping assembly provides a reliable and repeatable means to datum a position of a block being clamped relative thereto. In a robotic system, this enables the clamping assembly or block transfer apparatus to which it may be mounted to present a block for transfer to a robotic arm in a known position and orientation. This mechanical system for self-datuming a block enables confidence in the geometric block position and orientation without requiring a camera-based vision system to image the block in the clamping assembly and determine the pose thereof which has inherent limitations in outdoor operating environments in which vibration, light and inconsistent block geometry can cause issues.

Throughout this specification and claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers or steps but not the exclusion of any other integer or group of integers. As used herein and unless otherwise stated, the term "approximately" means ±20%.

Persons skilled in the art will appreciate that numerous variations and modifications will become apparent. All such variations and modifications which become apparent to persons skilled in the art, should be considered to fall within the spirit and scope that the invention broadly appearing before described.

The invention claimed is:

1. A block transfer apparatus for transferring a block between an upstream clamp of a block delivery system and a downstream clamp of the block delivery system, the block transfer apparatus including:

a frame pivotally mounted to a support; and,

a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws that clamp opposing lateral sides of the block;

wherein, the block transfer apparatus is configured to:

receive a block from the upstream clamp, wherein the opposing lateral sides of the block are initially clamped in the gripper jaws in an approximate position;

rotate to a drop position whereby the gripper jaws release the block and allow it to self-datum onto first and second orthogonal datum surfaces to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes;

re-clamp the block after the drop by applying a clamping force to the opposing lateral sides of the block so as to register the block against a third datum surface defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly; and,

present the block clamped in the datumed position for transfer to the downstream clamp.

2. The block transfer apparatus according to claim **1**, wherein the first datum surface that registers an end of the block is provided as part of the clamping assembly at one of:

a distal end of the gripper jaws; and,

a proximal end of the gripper jaws to either the jaw or a jaw support structure.

3. The block transfer apparatus according to claim **1**, wherein the second datum surface that registers a top or bottom surface of the block is at least one of:

provided as part of the clamping assembly along an upper lengthwise extending edge of the gripper jaws; and,

provided as part of the frame in the form of a lengthwise extending bar or plate mounted to the support that is parallel to the gripper jaws.

4. The block transfer apparatus according to claim **3**, wherein the third datum surface is provided by a first of the two gripper jaws.

5. The block transfer apparatus according to claim **4**, wherein the first gripper jaw has a pair of spaced apart first gripper pads rigidly attached to an inner surface of the jaw.

6. The block transfer apparatus according to claim **5**, wherein the first gripper pads extend lengthwise along the first gripper jaw.

7. The block transfer apparatus according to claim **4**, wherein a second of the two gripper jaws includes a plurality of second gripper pads attached to flexible finger members spaced apart along the length of the jaw that allow the pads to flex laterally and compensate for variations in flatness of the side of the block along its length.

8. The block transfer apparatus according to claim **7**, wherein an at least one row of second gripper pads of the second gripper jaw is located approximately midway between the pair of spaced apart first gripper pads such that when a clamping force is applied to the block it is urged into planar alignment with the third datum surface.

9. The block transfer apparatus according to claim 1, wherein the gripper jaws are configured to accommodate blocks of varying length.

10. The block transfer apparatus according to claim 9, wherein the gripper jaws are configured to one of:

clamp blocks of varying length at different pre-defined positions along the length of the gripper jaws; and,

clamp blocks of varying length at the same position along the length of the gripper jaws.

11. The block transfer apparatus according to claim 1 wherein the drop position coincides with the clamping assembly being rotated to a relative angle to the ground of at least one of:

between 30 to 60 degrees;

between 35 to 55 degrees;

between 40 to 50 degrees; and,

approximately 45 degrees.

12. The block transfer apparatus according to claim 1, wherein the support comprises a distal end of a boom used for transferring blocks therealong.

13. The block transfer apparatus according to claim 1, wherein the upstream clamp forms part of a shuttle for delivering a block along the boom.

14. The block transfer apparatus according to claim 1, wherein the downstream clamp is an end effector of a robotic block placement arm that is programmed to place blocks during construction of a building structure.

15. The block transfer apparatus according to claim 1, wherein the block transfer apparatus includes a distance range sensor for use in determining the proximity between the clamping assembly and the block held by the upstream clamp.

16. A block delivery system for delivering blocks for placement during construction of a building structure, the block delivery system including:

a boom for transferring blocks therealong;

an upstream clamp forming part of a shuttle that delivers blocks along the boom;

a downstream clamp associated with an end effector of a robotic block placement arm that is programmed to place blocks during construction of the building structure; and,

a block transfer apparatus for transferring a block between the upstream clamp and the downstream clamp, the block transfer apparatus including:

a frame pivotally mounted to a distal end of the boom; and,

a clamping assembly mounted to the frame and linearly extendable relative thereto, the clamping assembly including a pair of gripper jaws that clamp opposing lateral sides of the block;

wherein, the block transfer apparatus is configured to:

receive a block from the upstream clamp, wherein the opposing lateral sides of the block are initially clamped in the gripper jaws in an approximate position;

rotate to a drop position whereby the gripper jaws release the block and allow it to self-datum onto first and second orthogonal datum surfaces to thereby register an end and top or bottom face of the block in corresponding first and second orthogonal planes;

re-clamp the block after the drop by applying a clamping force to the opposing lateral sides of the block so as to register the block against a third datum surface defining a third plane orthogonal to both the first and second planes to thereby datum the position of the block with respect to the clamping assembly; and,

present the block clamped in the datumed position for transfer to the downstream clamp.

* * * * *