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(54) Title: WHEEL MODULE WITH INTEGRATED ACTIVE SUSPENSION

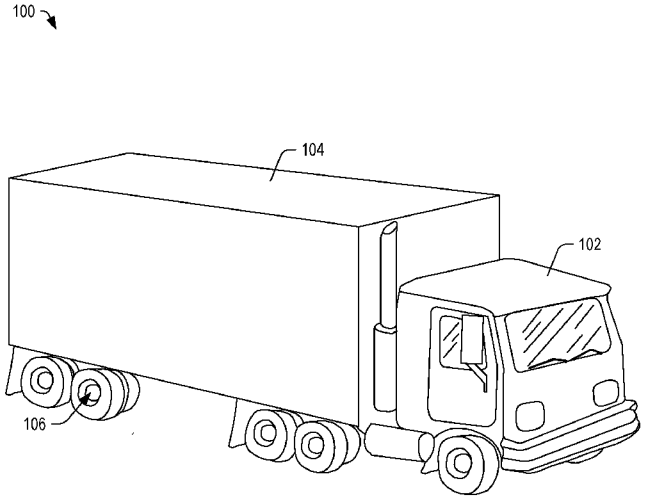

FIG. 1

(57) Abstract: In some embodiments, an apparatus may include a wheel module including a linear actuator, a piston, a drive element, and a coil. The linear actuator may include a stator and a piston configured to fit within the stator. The piston includes a plurality of permanent magnets responsive to coils of the stator to move relative to the stator. The apparatus further includes a drive element threadably coupled to an external surface of the linear actuator. The drive element includes a plurality of permanent magnets responsive to the coils of the stator to move relative to the stator. The apparatus also includes a coil configured to fit over the linear actuator.

[Continued on next page]

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:
07 September 2018 (07.09.2018)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/69161

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B60G 23/00 (2018.01)
CPC - B60G 2206/01, B60G 2600/22, B60G 2600/24

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0252972 A1 (Cox et al.) 07 October 2010 (07.10.2010), entire document, especially fig. 1, 4; para [0009]; para [0015]	1-6
A	US 6,857,625 B2 (Loser et al.) 22 February 2005 (22.02.2005), entire document, especially fig. 1; col. 1, ln 65- col. 2, ln 3; col. 2, ln 15-21	1-6
A	EP 1,484,201 A1 (BOSE CORPORATION) 02 June 2003 (02.06.2003), entire document, especially fig. 1; para [0025]; para [0030]	1-6
A	US 3,603,575 A (Arlasky) 07 September 1971 (07.09.1971), entire document	1-6
A	US 5,803,443 A (Chang) 08 September 1998 (08.09.1998), entire document	1-6
A	US 4,036,335 A (Thompson et al.) 19 July 1977 (19.07.1977), entire document	1-6
A	US 2013/0106038 A1 (Miyamoto et al.) 02 May 2013 (02.05.2013), entire document	1-6
A	EP 1,582,383 A1 (CALZOLARI) 30 March 2005 (30.03.2005), entire document	1-6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 May 2018	31 JUL 2018
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-8300	Authorized officer: Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 17/69161

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Group I: Claims 1-6, directed to an apparatus comprising a wheel module including a linear actuator, a piston, a drive element including a plurality of permanent magnets, and a coil.

Group II: Claim 7-20 directed to a system and method comprising a control circuit, a vehicle with a frame, at least one wheel modules coupled to such frame, and the wheel module including a wheel and at least one suspension spring assembly.

--- See Supplemental Box --

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:
1-6 (Group I)

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

Continuation of Box No. III - Observations where unity of invention is lacking:

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:

SPECIAL TECHNICAL FEATURES

The invention of Group I includes the special technical feature of an apparatus comprising a linear actuator, a piston, a drive element including a plurality of permanent magnets, and a coil, not required by the claims of Group II.

The invention of Group II includes the special technical feature of a system and method comprising a control circuit, a vehicle with a frame, at least one wheel module coupled to such frame, and the wheel module including a wheel and at least one suspension spring assembly, not required by the claims of Group I.

COMMON TECHNICAL FEATURES

Groups I-II share the common technical features of a wheel module. However, this shared technical feature does not represent a contribution over prior art as being anticipated by EP 1,484,201 A1 to BOSE CORPORATION (hereinafter 'BOSE'), which discloses a wheel module (system 10, fig. 1; para [0024-0025]; See - "In an active electromechanical suspension system, power is supplied to an electromechanical suspension to help control vertical accelerations of the sprung mass when the unsprung mass encounters road disturbances. The shock absorber of a common suspension can be replaced by a con trolled force actuator that responds according to commands from a control system.").

As the common technical features were known in the art at the time of the invention, these cannot be considered special technical feature that would otherwise unify the groups.

Therefore, Groups I-II lack unity under PCT Rule 13 because they do not share a same or corresponding special technical feature.