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(54) **COMPACT IMPACT TOOL**

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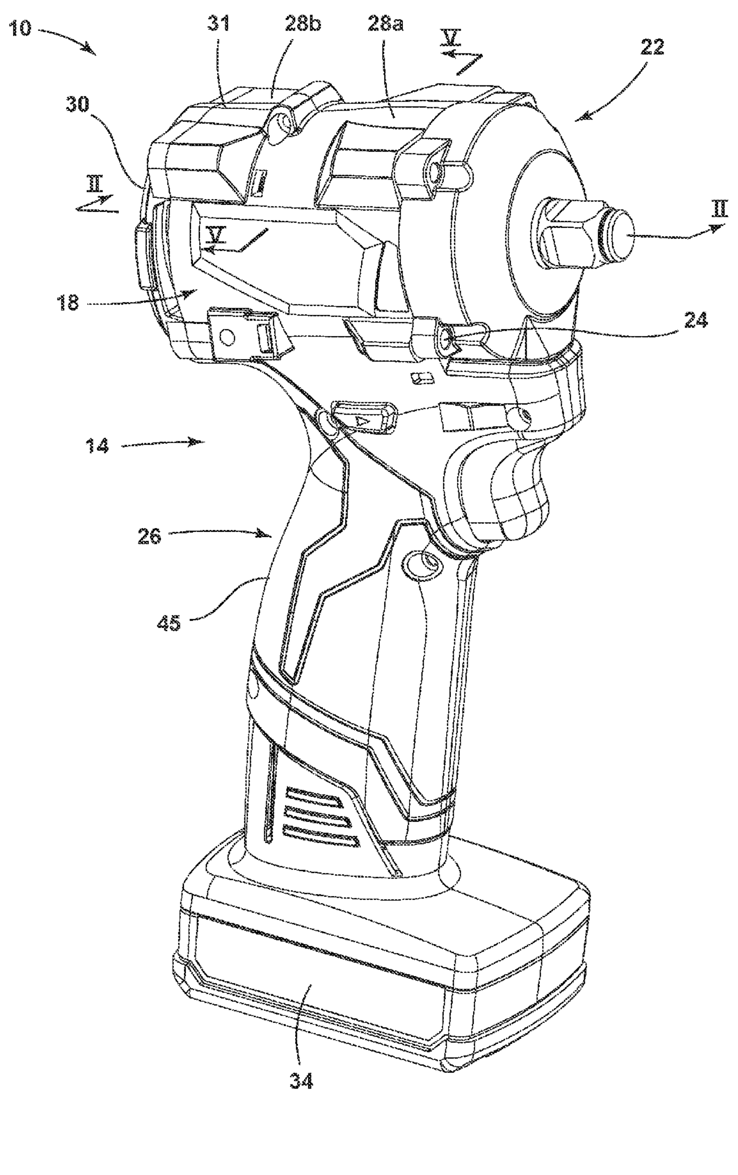
CPC ***B25B 21/02*** (2013.01)

(57) **ABSTRACT**

A power tool includes a first housing portion and a second housing portion, a motor directly mounted between the housing portions with an output shaft defining an axis, and a gear assembly supported within the housing and including a ring gear directly supported by the housing portions, a pinion gear coupled for co-rotation with the output shaft, and planet gears meshed with the pinion gear and the ring gear. The power tool also includes a drive assembly operably coupled to the gear assembly with a camshaft, an anvil, a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil, and a spring biasing the hammer towards the anvil. The ring gear includes lugs engaged with the first housing portion and the second housing portion to rotationally constrain the ring gear.



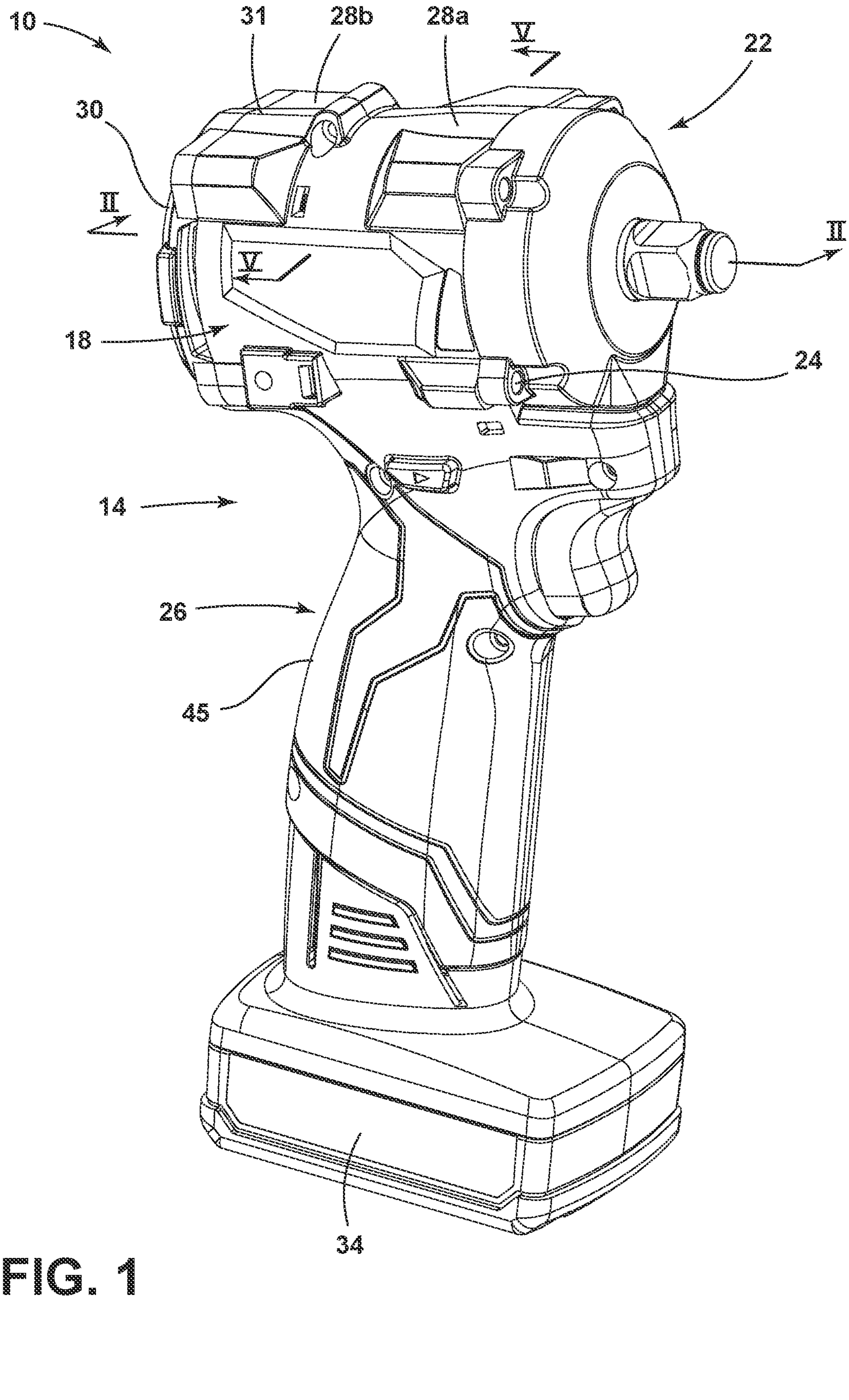
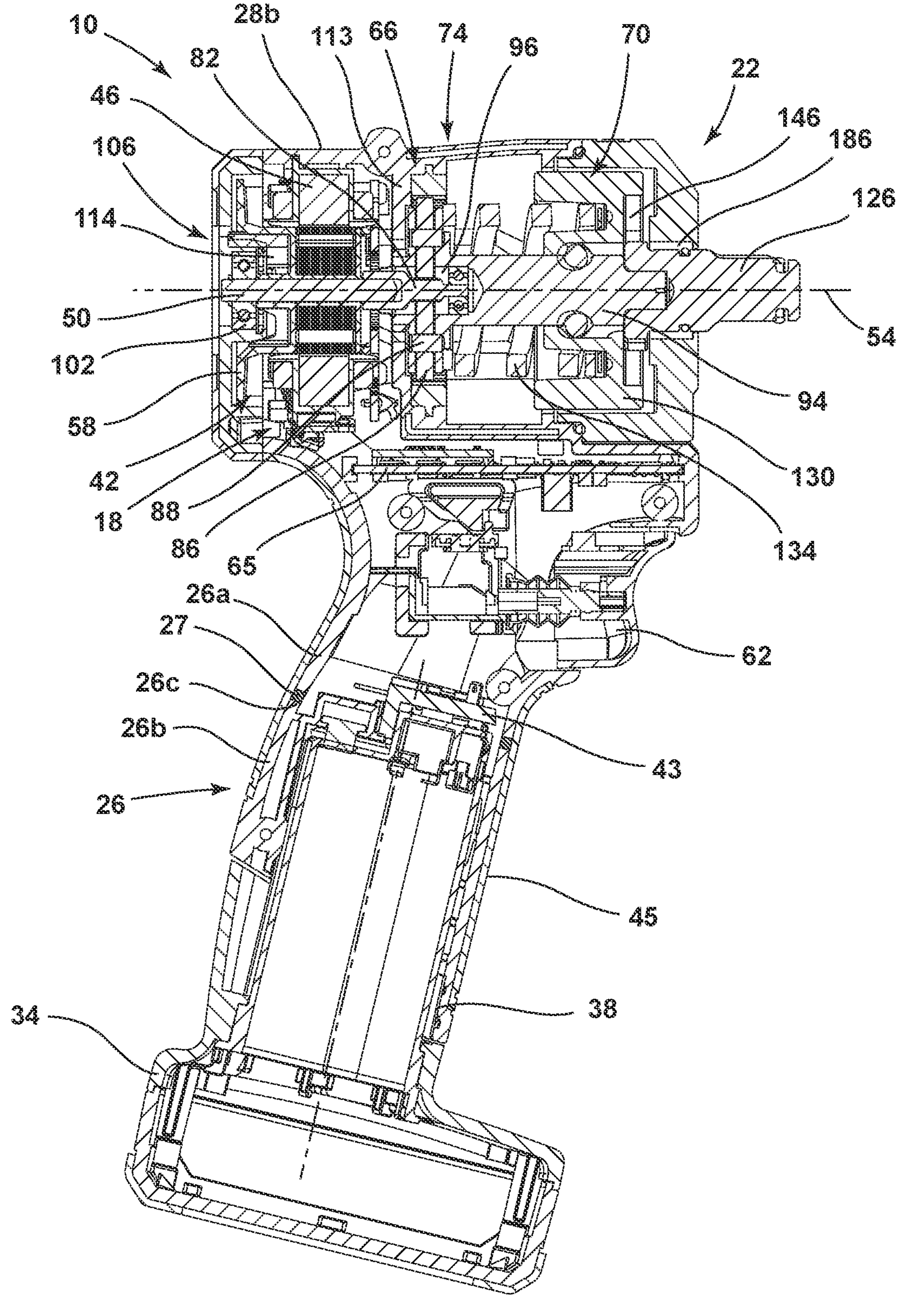


FIG. 1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28b
82
113
66
74
96
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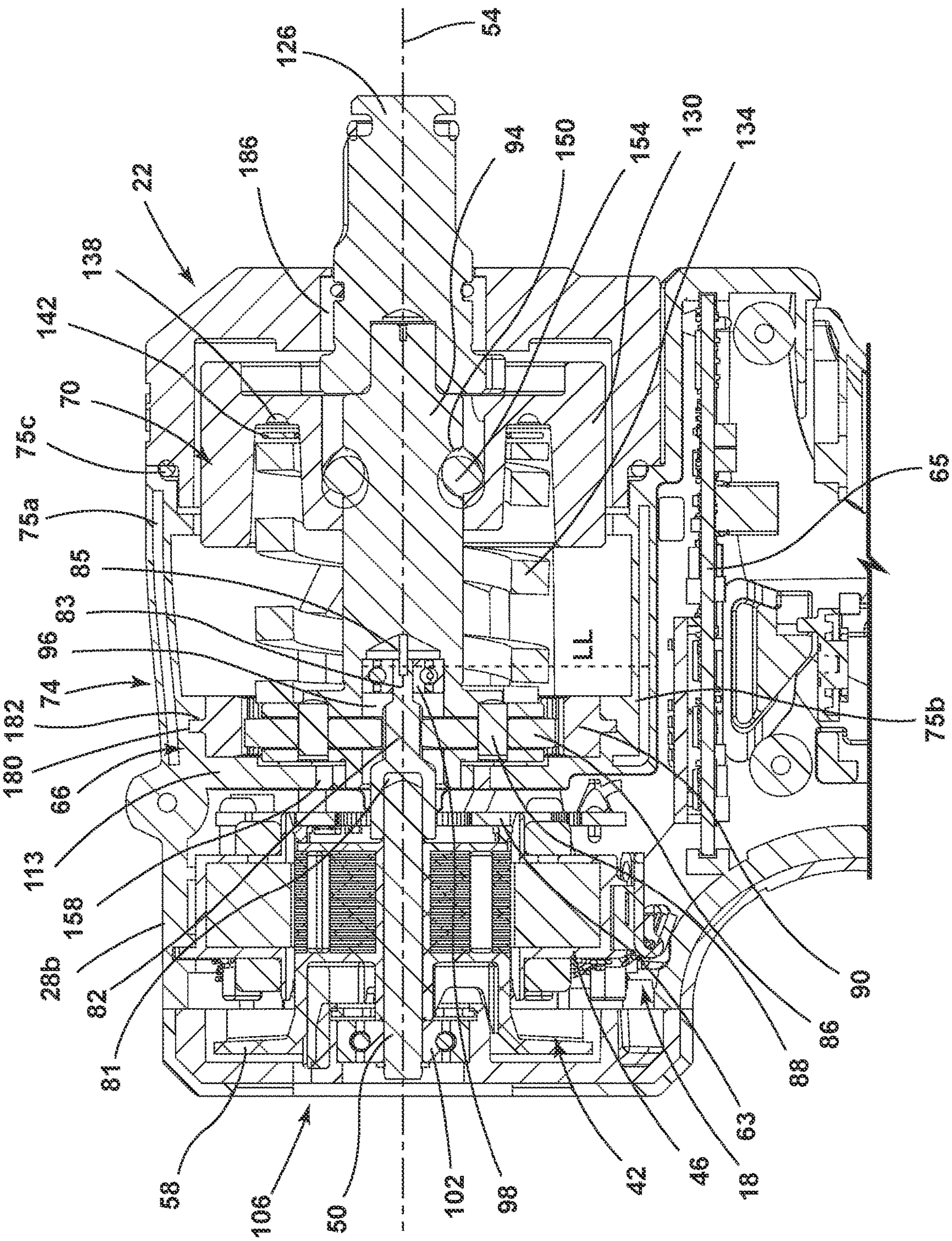
22
46
146
186
106
126
114
50
54
102
94
58
42
130
18
88
86
65
134
26a
62
27
26c
43
26b
26
45
34
38

FIG. 2



54
126
22
186
94
150
154
130
134
138
142
70
75c
75a
85
83
96
74
182
180
66
113
158
28b
82
81
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106
50
102
98
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88
86
90
75b
65
L.L.

FIG. 3

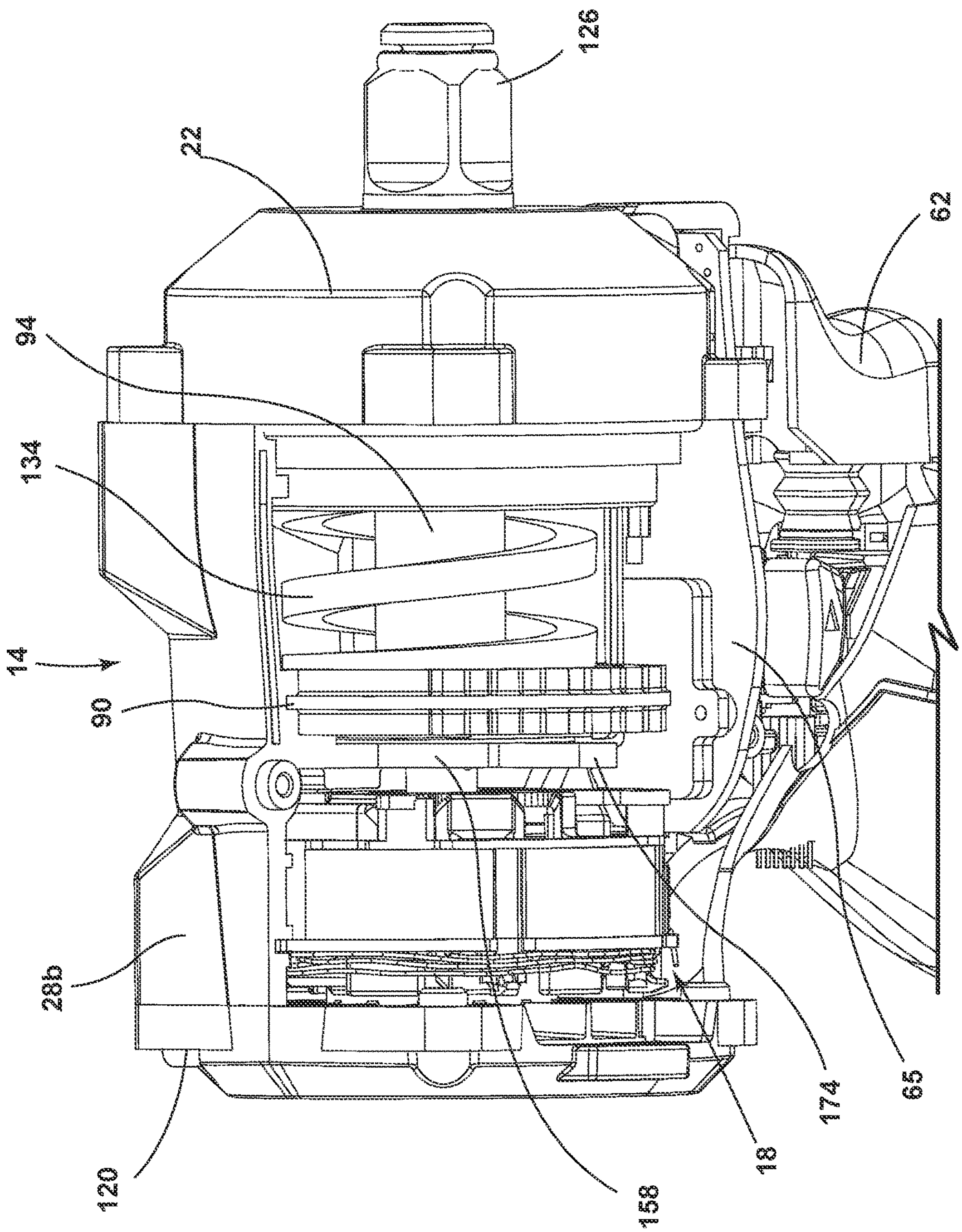

FIG. 4

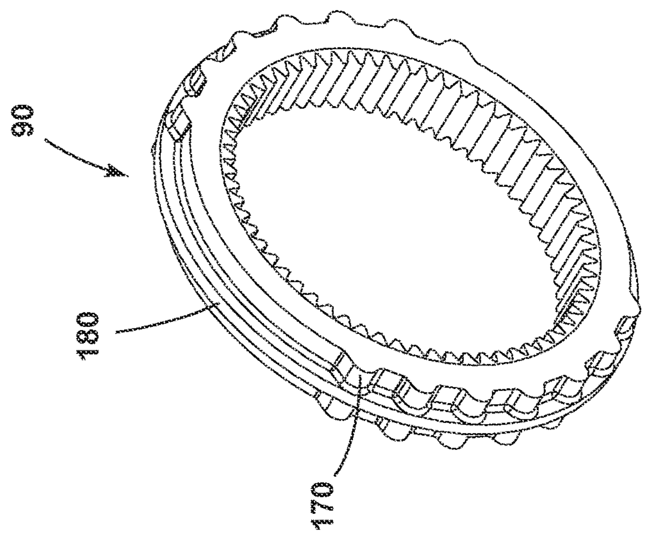
90
180
170

FIG. 6

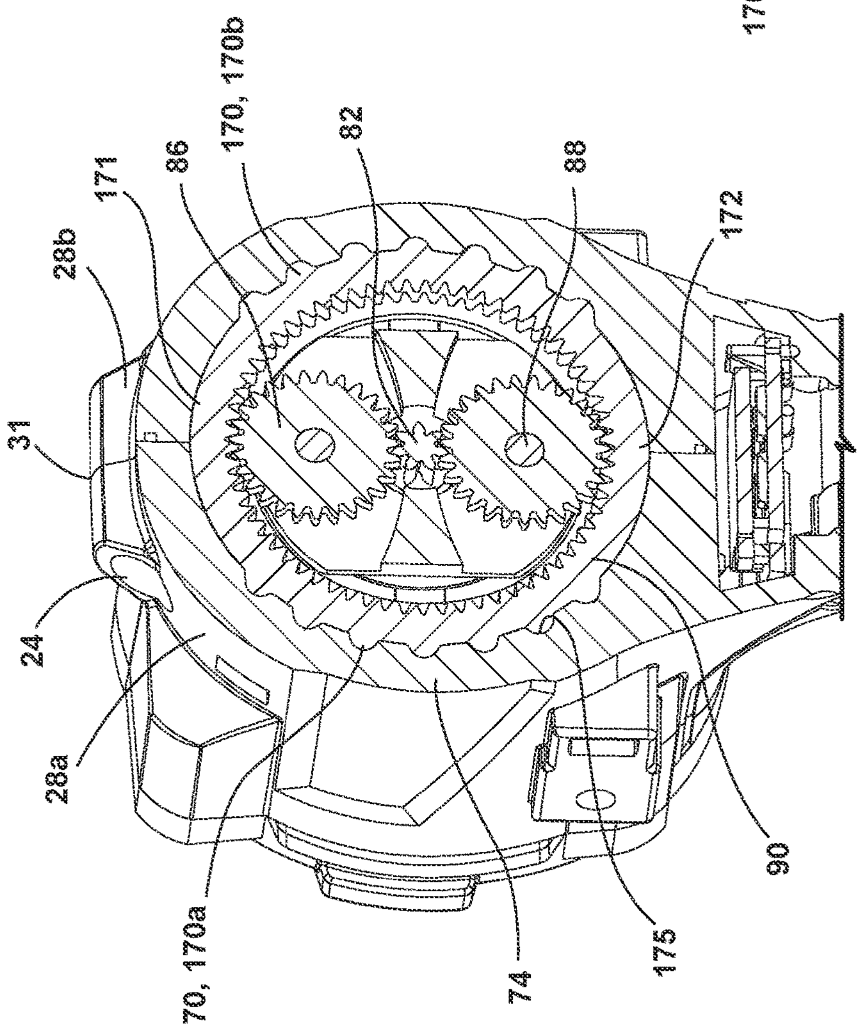
31
28b
171
86
170, 170b
82
88
172
24
28a
170, 170a
74
175
90

FIG. 5

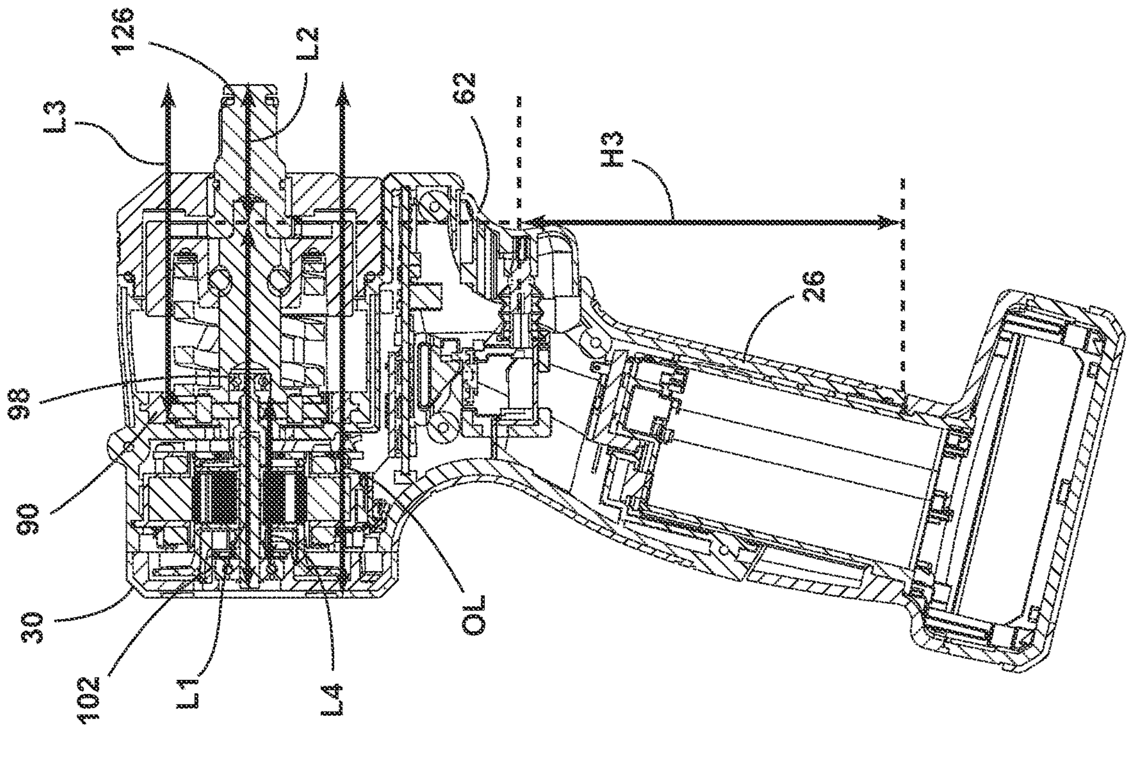

FIG. 7

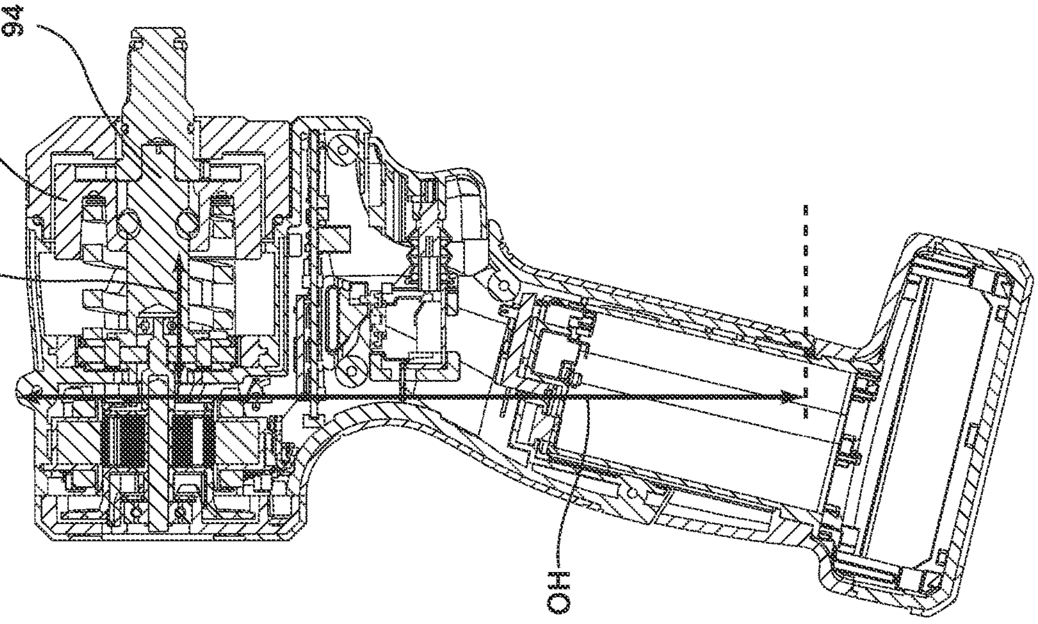

FIG. 8

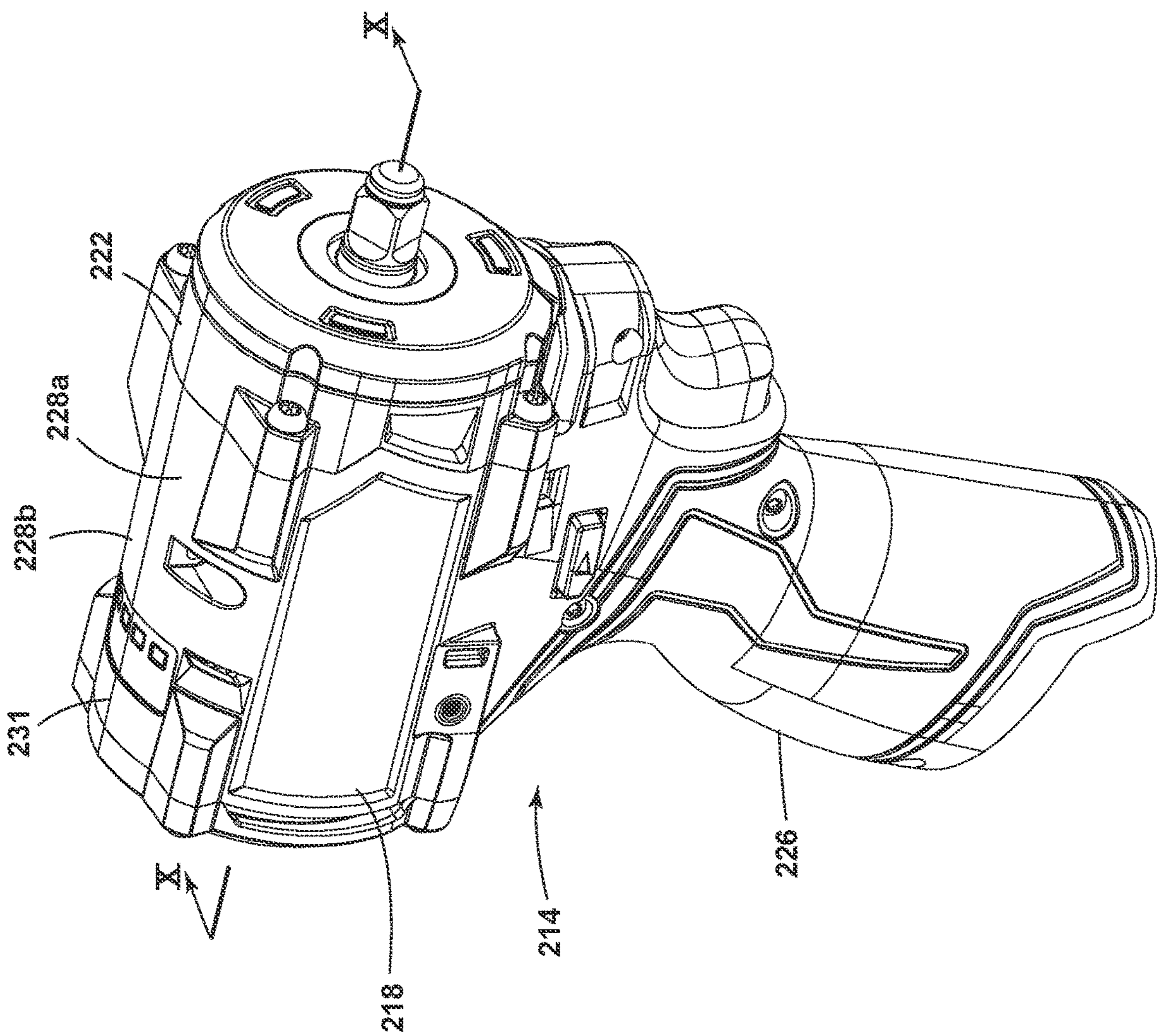

FIG. 9

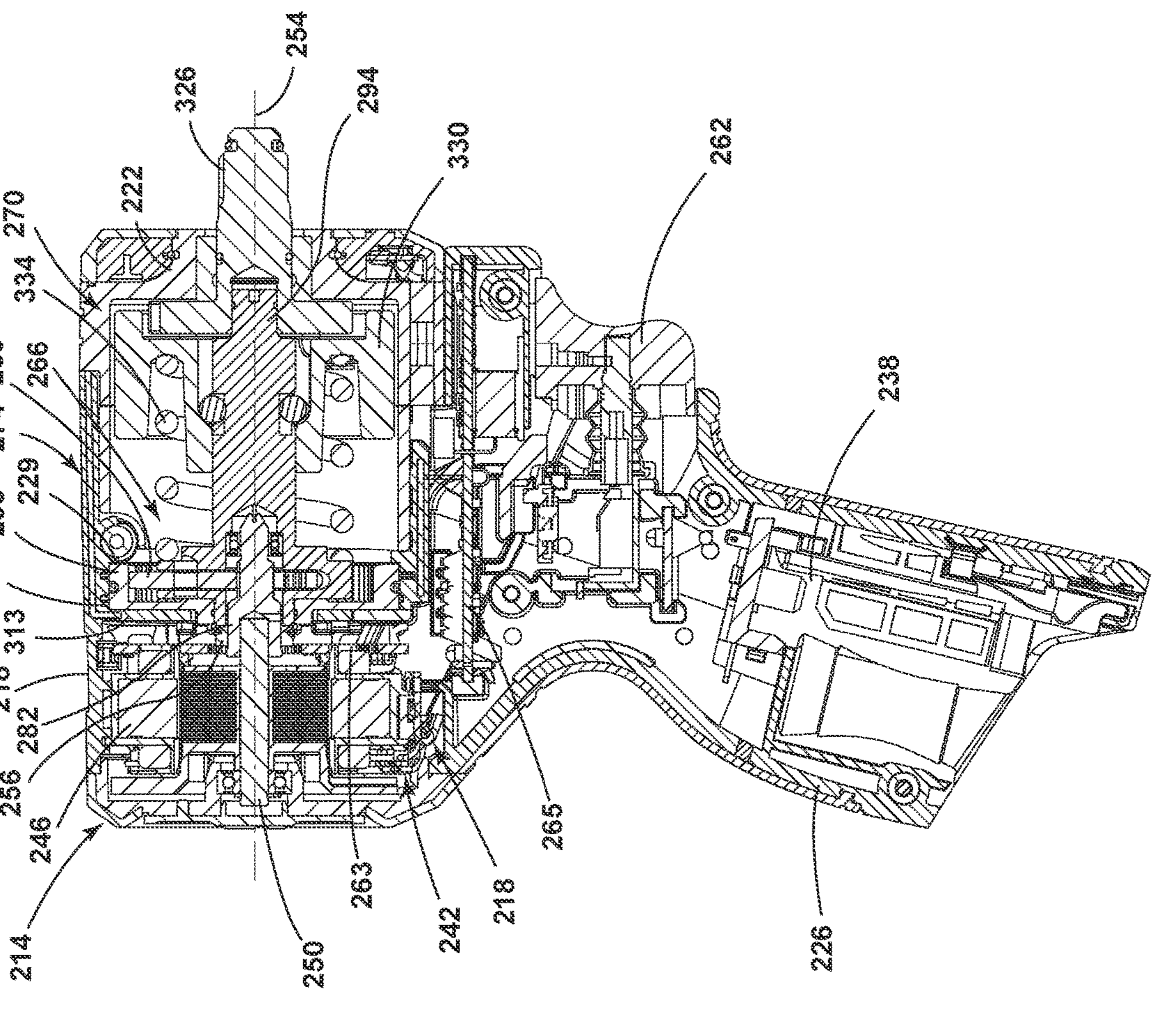
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FIG. 10

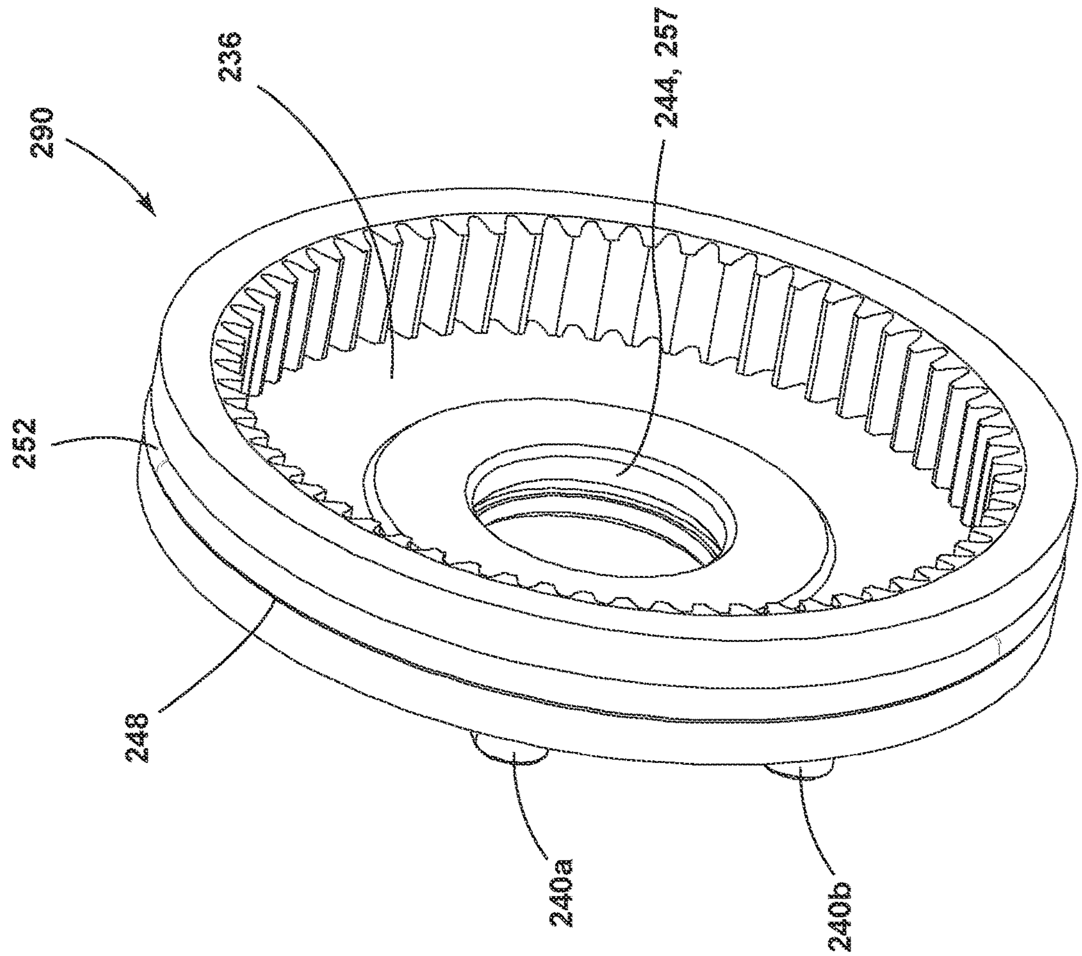

FIG. 11

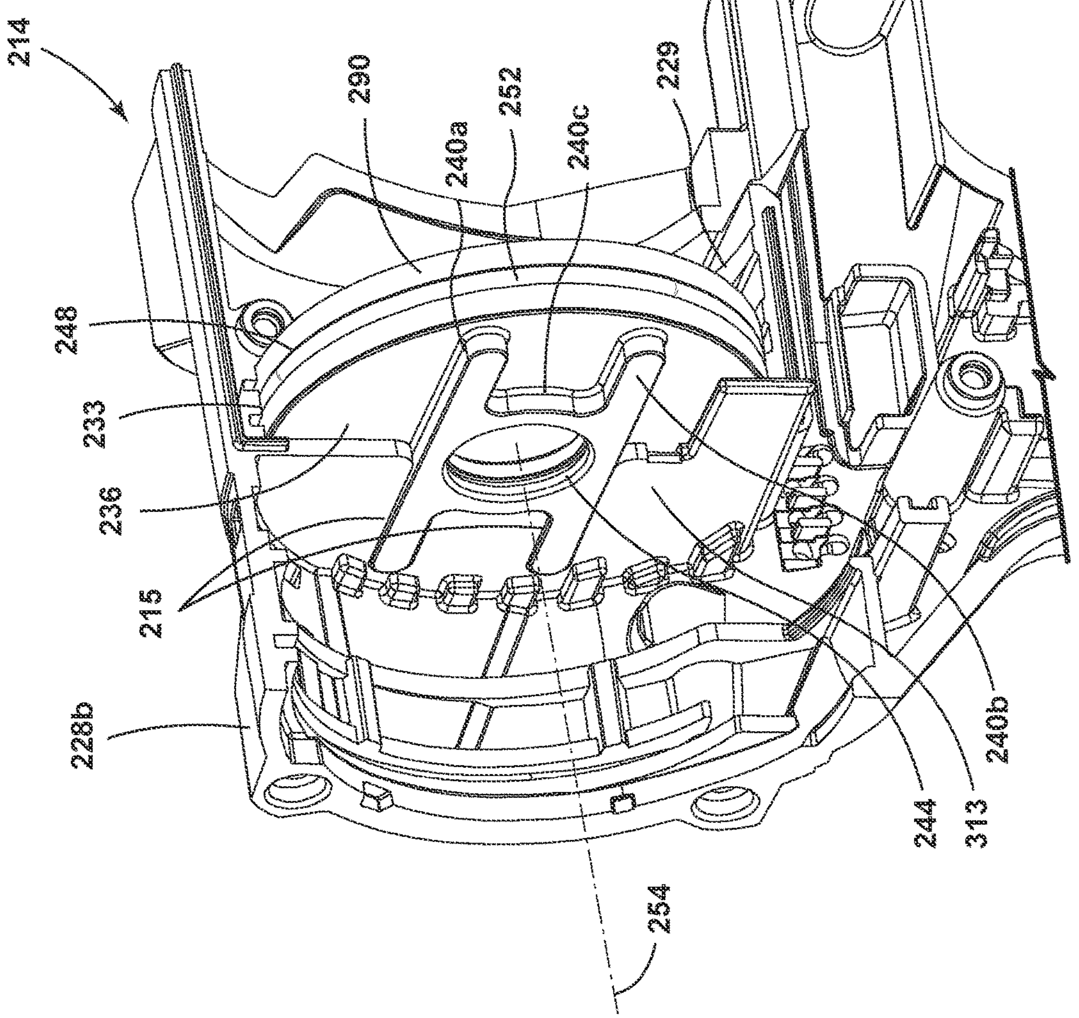

FIG. 12

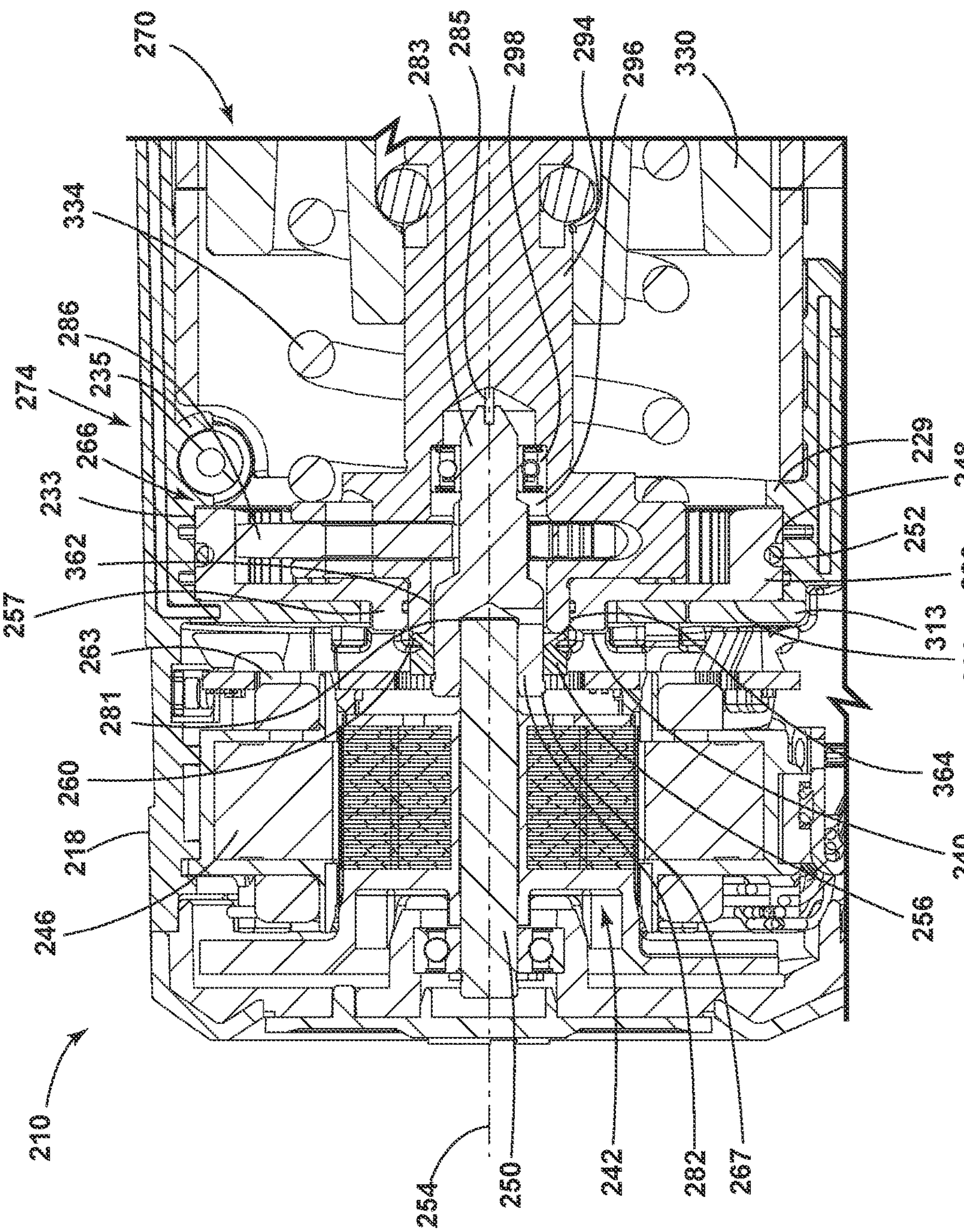
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FIG. 13

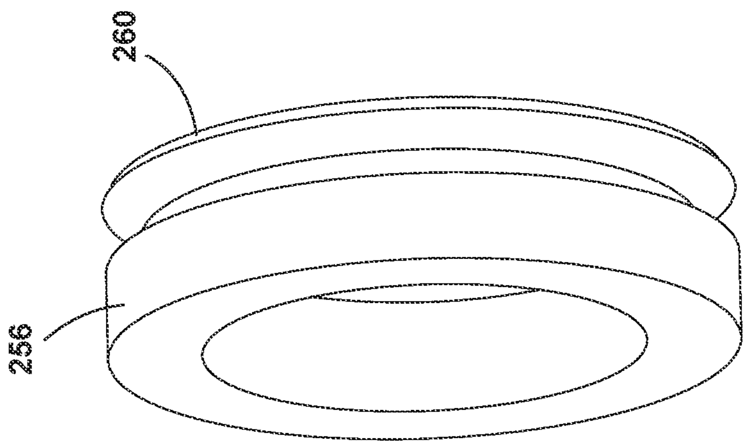

FIG. 14

COMPACT IMPACT TOOL

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to co-pending U.S. Provisional Patent Application No. 63/352,671, filed Jun. 16, 2022, the entire contents of which are incorporated by reference herein.

FIELD OF THE INVENTION

[0002] The present invention relates to power tools, and more particularly to rotary impact tools, such as impact wrenches.

BACKGROUND OF THE INVENTION

[0003] Rotary impact tools are typically utilized to provide a striking rotational force, or intermittent applications of torque, to a tool element or workpiece (e.g., a fastener) to either tighten or loosen the fastener.

SUMMARY OF THE INVENTION

[0004] The present invention provides, in one aspect, a power tool including a housing having a first housing portion and a second housing portion coupled to the first housing portion, a motor directly mounted within the housing between the first and second housing portions and including an output shaft, the output shaft defining an axis, a gear assembly supported within the housing and operably coupled to the motor, the gear assembly including a ring gear directly supported by the first and second housing portions, a pinion gear coupled for co-rotation with the output shaft, and a plurality of planet gears meshed with the pinion gear and the ring gear. The power tool also includes a drive assembly operably coupled to the gear assembly, the drive assembly including a camshaft, an anvil, a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil in response to rotation of the camshaft, and a spring biasing the hammer towards the anvil. The ring gear includes a plurality of lugs engaged with the first housing portion and the second housing portion to rotationally constrain the ring gear.

[0005] The present disclosure provides, in another aspect, a power tool including a housing having a motor housing portion and a handle portion extending from the motor housing portion, the motor housing portion and the handle portion defined by cooperating first and second clamshell halves coupled together along a parting plane, a motor supported within the motor housing portion and including an output shaft, the output shaft defining an axis, and a gear assembly supported within the housing and operably coupled to the motor, the gear assembly including a ring gear directly supported by the first and second clamshell halves, a pinion gear coupled for co-rotation with the output shaft, and a plurality of planet gears meshed with the pinion gear and the ring gear. The power tool also includes a drive assembly operably coupled to the gear assembly, the drive assembly including a camshaft, an anvil, a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil in response to rotation of the camshaft, and a spring biasing the hammer towards the anvil. The ring gear includes a plurality of lugs engaged with the first and second clamshell halves to rotationally constrain the ring gear, and the plurality of lugs is arranged such that all resultant force vectors on the first and second clamshell halves due to torque on the ring gear are oriented at an angle between 0 degrees and 45 degrees relative to the parting plane.

[0006] The present disclosure provides, in another aspect, a power tool including a housing having a first housing portion and a second housing portion coupled to the first housing portion, a motor directly mounted within the housing between the first and second housing portions and including an output shaft, the output shaft defining an axis, a gear assembly supported within the housing and operably coupled to the motor, the gear assembly including a ring gear and a pinion gear coupled to the output shaft, and a drive assembly operably coupled to the gear assembly, the drive assembly including a camshaft, an anvil, and a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil in response to rotation of the camshaft. The camshaft includes a bore through which an extension of the pinion gear extends. A pinion seal is supported on the pinion gear, the pinion seal including a flange configured to seal at least one selected from a group consisting of a first interface between the pinion gear and the camshaft and a second interface between the camshaft and the ring gear.

[0007] Other features and aspects of the disclosure will become apparent by consideration of the following detailed description and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. **1** is a perspective view of a power tool according to an embodiment of the invention.

[0009] FIG. **2** is a cross-sectional view of the power tool of FIG. **1**, taken along line **2-2** in FIG. **1**.

[0010] FIG. **3** is a magnified view of a portion of the cross-sectional view of FIG. **2**.

[0011] FIG. **4** is a perspective view of a portion of the power tool of FIG. **1**, with a housing portion of the power tool hidden.

[0012] FIG. **5** is a cross-sectional tool of a portion of the power tool of FIG. **1**, taken along line **5-5** in FIG. **1**.

[0013] FIG. **6** is a perspective view of a ring gear of a gear assembly of the power tool of FIG. **1**.

[0014] FIGS. **7** and **8** are dimensioned views of the power tool of FIG. **1**, illustrating certain dimensions associated with the power tool in some embodiments.

[0015] FIG. **9** is a perspective view of a power tool according to an embodiment of the invention.

[0016] FIG. **10** is a cross-sectional view of the power tool of FIG. **9**, taken along line **10-10** in FIG. **9**.

[0017] FIG. **11** is a perspective view of a ring gear of a gear assembly of the power tool of FIG. **9**.

[0018] FIG. **12** is a perspective view of a portion of the power tool of FIG. **9**, with portions of the power tool hidden.

[0019] FIG. **13** is a magnified view of a portion of the cross-sectional view of FIG. **10**.

[0020] FIG. **14** is a perspective view of a sealing member of the power tool of FIG. **9**.

[0021] Before any embodiments of the invention are explained in detail, it is to be understood that the invention is not limited in its application to the details of construction and the arrangement of components set forth in the following description or illustrated in the following drawings. The invention is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting.

DETAILED DESCRIPTION

[0022] The present disclosure provides, among other things, embodiments of an impact wrench including combinations of components and dimensions that provide the impact wrench with a very compact overall size but still enable the impact wrench to deliver a large amount of torque to a desired fastening application. For example, in some embodiments, the impact wrench includes a ring gear with a circumferential projection, and the ring gear is directly supported by a clamshell housing of the impact wrench without requiring any additional supports in front of the ring gear. This advantageously reduces the length required for supporting the ring gear. In some embodiments, the impact wrench includes a bearing for supporting a pinion gear coupled to an output shaft of the motor. The bearing is received within a bore of a camshaft at a location in front of the ring gear and associated planet gears. This arrangement also contributes to length reduction. In some embodiments, the impact wrench may include a vibration isolating connection incorporated into a handle of the impact wrench, to reduce the transmission of vibration to a battery pack supported on the handle.

[0023] FIG. **1** illustrates an embodiment of a power tool in the form of a rotary impact tool, and, more specifically, an impact wrench **10**. The impact wrench **10** includes a housing **14** with a motor housing portion **18**, an impact case or front housing portion **22** coupled to the motor housing portion **18** (e.g., by a plurality of fasteners **24**), and a handle portion **26** extending downwardly from the motor housing portion **18**. In the illustrated embodiment, the handle portion **26** and the motor housing portion **18** are defined by a first clamshell half **28***a* and a cooperating second clamshell half **28***b* (i.e., a first housing portion and a second housing portion).

[0024] The illustrated housing **14** also includes an end cap **30** coupled to the motor housing portion **18** opposite the front housing portion **22**. The first and second housing portions **28***a*, **28***b* can be coupled (e.g., fastened) together at an interface or seam **31**. In the illustrated embodiment, the end cap **30** is continuous and may be pressed or fitted over a rear end of the clamshell halves **28***a*, **28***b*. In other words, the end cap **30** may not include two halves such that the end cap **30** may extend over the seam **31**. The end cap **30** is coupled to the motor housing portion **18** by a plurality of fasteners **120** (FIG. **4**). In yet other embodiments, the impact wrench **10** may not include a separate end cap, such that the clamshell halves **28***a*, **28***b* instead define the rear end of the motor housing portion **18**.

[0025] Referring to FIGS. **1** and **2**, the impact wrench **10** includes a battery **34** removably coupled to a battery receptacle **38**, which in the illustrated embodiment, includes a cavity extending into the handle portion **26**. A motor **42** is supported within the motor housing portion **18** and receives power from the battery **34** via connections, pads, and/or battery terminals **43** in the battery receptacle **38** when the battery **34** is coupled to the battery receptacle **38**. In the illustrated embodiment, the handle portion **26** of the clamshell halves **28***a*, **28***b* can be covered or surrounded by a grip portion **45**, which may be overmolded on the handle portion **26**.

[0026] The battery **34** may be a power tool battery pack generally used to supply power to a power tool, such as an electric drill, an electric saw, and the like (e.g., a 12 volt rechargeable battery pack, such as an M12 REDLITHIUM battery pack sold by Milwaukee Electric Tool Corporation). The battery **34** may include lithium ion (Li-ion) cells. The 12 volt nominal output voltage of the battery **34** provides an optimal balance between weight/size and power in the illustrated impact wrench **10**; however, batteries with other nominal voltages may be used in other embodiments.

[0027] Referring to FIG. **2**, in the illustrated embodiment, the handle portion **26** includes an upper portion **26***a* extending from the motor housing portion **18** and a lower portion **26***b* movably coupled to the upper portion **26***a* via a vibration isolating connection **26***c*. The vibration isolating connection **26***c* includes a damping element **27**, which may be made of a vibration damping material, such as an elastomeric material. In some embodiments, the damping element **27** may be generally ring-shaped. In the illustrated embodiment, the damping element **27** is received in a gap between the upper and lower portions **26***a*, **26***b* and covered by the overmolded grip portion **45**. In yet other embodiments, the damping element **27** may be integrally formed as a single piece with the overmolded grip portion **45** (i.e. during the grip overmolding process).

[0028] The damping element **27** at least partially mechanically isolates the lower portion **26***b* of the handle portion **26** from the upper portion **26***a* and thereby inhibits transmission of vibration from the upper portion **26***a* to the lower portion **26***b*. The battery **34** is coupled to and supported by the lower portion **26***b*. As such, the vibration isolating connection **26***c*, including the damping element **27**, is configured to isolate the battery **34** from vibrations produced during operation of the impact wrench **10**.

[0029] Now referring to FIGS. **2** and **3**, in the illustrated embodiment, the motor **42** is a brushless direct current ("BLDC") motor with a stator **46** and a rotor with an output shaft **50** that is rotatable about an axis **54** relative to the stator **46**. The brushless motor **42** preferably has a nominal diameter of 50 millimeters, or more than 50 millimeters in other embodiments. In yet other embodiments, other types of motors may be used. A fan **58** is coupled to the output shaft **50** behind the motor **42** to generate airflow. The impact wrench **10** also includes a switch **62** (e.g., a trigger switch; FIG. **2**) supported by the housing **14** that selectively connects the motor **42** (e.g., via suitable control circuitry provided on one or more printed circuit board assemblies ("PCBAs") and the battery **34** electrically, to provide DC power to the motor **42**. In other embodiments, the impact wrench **10** may include a power cord for electrically connecting the switch **62** and the motor **42** to a source of AC power. As a further alternative, the impact wrench **10** may be configured to operate using a different power source (e.g., a pneumatic or hydraulic power source, etc.).

[0030] In the illustrated embodiment, a first PCBA **63** is provided adjacent a front end of the motor **42** (FIG. **3**). The illustrated first PCBA **63** includes one or more Hall-Effect sensors, which provide feedback for controlling the motor **42**. A second PCBA **65** is positioned within the handle portion **26** (adjacent a top end of the handle portion **26**) and generally between the switch **62** and the motor **42**. The second PCBA **65** is in electrical communication with the motor **42**, the switch **62**, and the battery receptacle **38**. In the illustrated embodiment, the second PCBA **65** includes a plurality of semi-conductor switching elements (e.g., MOSFETs, IGBTs, or the like) that control and distribute power to windings in the stator **46** in order to cause rotation of the rotor and output shaft **50**. The second PCBA **65** may also include one or more microprocessors, machine-readable, non-transitory memory elements, and other electrical or electronic elements for providing operational control to the impact wrench **10**. In some embodiments, the first PCBA **63** may be omitted, and the motor **42** may be configured for sensorless control via the second PCBA **65**.

[0031] In the illustrated embodiment, as best shown in FIG. **5**, the clamshell halves **28***a*, **28***b* are positioned to at least partially overlap one another at the seam **31**, and the grip portion **45** is shaped to surround the mated clamshell halves **28***a*, **28***b*. Fasteners (e.g., fasteners **24**) may be threaded, pinned, inserted, etc. into each of the clamshell halves **28***a*, **28***b* to further secure the housing **14** of the handle portion **26** in a closed or generally sealed position.

[0032] Referring now to FIGS. **2** and **3**, the impact wrench **10** further includes a gear assembly **66** driven by the output shaft **50** and an impact mechanism **70** coupled to an output of the gear assembly **66**. The impact mechanism **70** may also be referred to herein as a drive assembly **70**. The gear assembly **66** may be configured in any of a number of different ways to provide a speed reduction between the output shaft **50** and an input of the drive assembly **70**. The gear assembly **66** is at least partially housed within the housing **14**, and specifically within a gear housing portion **74** of the housing defined by the clamshell halves **28***a*, **28***b* in the illustrated embodiment. That is, the impact wrench **10** does not include a separate gear case positioned within the housing **14** for supporting the gear assembly **66**. Instead, the gear assembly **66**—and particularly a ring gear **90** of the gear assembly **66**—is directly supported by the clamshell halves **28***a*, **28***b*. This may advantageously reduce the size, weight, and/or manufacturing cost associated with the impact wrench **10**. However, in alternate embodiments, the ring gear **90** may be supported within a separate gear case within the housing **14**.

[0033] In the illustrated embodiment, the motor housing **18** and handle portion **26** include a rigid polymer or plastic material and the front housing portion **22** is metal. In some embodiments, the gear housing portion **74** may include additional and/or differently composed material (e.g., stronger) to support the gear assembly **66**. As will be described in greater detail below, the configurations of the gear assembly **66** and gear housing portion **74** of the impact wrench **10** described herein advantageously reduces an overall size of the impact wrench **10**.

[0034] Referring to FIG. **3**, the gear housing portion **74** may contain lubricant, such as grease or oil, that assists in smooth operation of the impact wrench **10** by minimizing friction between movable components. The impact wrench **10** includes a plurality of sealing elements **75***a*, **75***b*, **75***c*, which inhibit the lubricant from leaking out of the gear housing portion **74**. In the illustrated embodiment, first and second elongated sealing elements **75***a*, are positioned within walls of the clamshell halves **28***a*, **28***b* such that the elongated sealing elements **75***a*, **75***b* generally extend along and seal upper and lower sides of the gear housing portion **74**. A third sealing element **75***c*, which is an annular sealing element such as an o-ring, forms a seal between the clamshell halves **28***a*, **28***b* and the front housing portion **22**.

[0035] As illustrated in FIGS. **3** and **5**, the gear assembly **66** includes a pinion gear **82** coupled to the output shaft **50** of the motor **42**, a plurality of planet gears **86** meshed with the pinion gear **82**, and a ring gear **90** meshed with the planet gears **86** and rotationally fixed within the housing **14** (specifically, within the gear housing portion **74**). A rearward facing side of the ring gear **90** is seated against a dividing wall **113** formed by the clamshell halves **28***a*, **28***b* (FIG. **3**). The dividing wall **113** separates the interior of the gear housing portion **74** from the motor **42**. The illustrated pinion gear **82** includes a recess **81** that receives the output shaft **50** and an extension **83**. The output shaft **50** may be press fit into the recess **81**, or the output shaft **50** and the recess **81** may include cooperating spline patterns or other suitable geometries for coupling the pinion gear **82** for co-rotation with the output shaft **50**. In other embodiments, the pinion gear **82** may be integrally formed as a single piece with the output shaft **50**.

[0036] Referring to FIG. **5**, the illustrated ring gear **90** includes a plurality of lugs **170**. In the illustrated embodiment, the lugs **170** of the ring gear **90** fit within grooves **175** formed by the clamshell halves **28***a*, **28***b* to support and constrain the ring gear **90** in a rotational direction. As shown in FIG. **5**, the lugs **170** include a first set of lugs **170***a* and a second set of lugs **170***b* extending from opposite lateral sides of the ring gear **90**. The lugs **170** are positioned such that the first set of lugs **170***a* is received by grooves **175** of the first clamshell half **28***a*, and the second set of lugs **170***b* is received by grooves **175** of the second clamshell half **28***b*. The illustrated ring gear **90** includes upper and lower regions **171**, **172** without any lugs **170**. Each of the upper and lower regions **171**, **172** may span between about 25 degrees and about 60 degrees of the circumference of the ring gear **90**. Because the lugs **170** are positioned only along the lateral sides of the ring gear **90**, reaction forces experienced by the housing **14** due to torque on the ring gear **90** during operation of the impact wrench **10** have resultant force vectors oriented in a generally vertical direction (i.e., generally parallel to the parting plane of the clamshell halves **28***a*, **28***b*.) For example, the lugs **170** may transmit reaction forces with resultant force vectors oriented at angles between 0 and 45 degrees relative to the parting plane in some embodiments. In some embodiments, the lugs **170** may transmit reaction forces with resultant force vectors oriented at angles between 0 and 30 degrees relative to the parting plane. This reduces separation of the clamshell halves **28***a*, **28***b* due the reaction forces.

[0037] With reference to FIG. **3**, the planet gears **86** are coupled, via pins **88**, to a camshaft **94** of the drive assembly **70** such that the camshaft **94** acts as a planet carrier. Accordingly, rotation of the output shaft **50** rotates the planet gears **86**, which then advance along the inner circumference of the ring gear **90** and thereby rotates the camshaft **94**. In the illustrated embodiment, the camshaft **94** includes a bore **96** extending partially through the camshaft **94** along the axis **54**. The bore **96** is shaped to accommodate and/or receive at least a portion of the pinion gear **82**. In the illustrated embodiment, the bore **96** extends only partially through the length of the camshaft **94**; however, the bore **96** may extend through the entire length of the camshaft **94**, to reduce the weight of the camshaft **94**, in other embodiments.

[0038] With reference to FIG. **6**, the ring gear **90** of the impact wrench **10** includes a rib **180** extending around a circumference of the ring gear **90**. The gear housing portion

74 includes a recess **182** (FIG. **3**) disposed around an interior circumference of the gear housing portion **74**. The rib **180** of the ring gear **90** is disposed within the recess **182** of the gear housing portion **74** such that the ring gear **90** is axially constrained with respect to the gear housing portion **74**. By axially constraining the ring gear **90** with a feature along a circumference of the ring gear **90**, an overall length OL (FIG. **9**) of the impact wrench **10** is reduced compared to typical impact-type power tools, in which the ring gear may be axially secured using a mechanism that is disposed past a front face of the ring gear (i.e., axially toward the anvil). In such typical impact-type power tools, such securing features may reduce the available space to accommodate rearward travel of the hammer, thus requiring an increase in the overall tool length to accommodate hammer travel.

[0039] Referring to FIGS. **2** and **3**, the output shaft **50** is rotatably supported by a first or forward bearing **98** and a second or rear bearing **102**. The pinion gear **82**, coupled to the output shaft **50**, extends through an opening in the dividing wall **113**. The impact wrench **10** includes a hub or bearing retainer **106**, which may be at least partially integrally formed with the end cap **30** in some embodiments, and which secures the rear bearing **102** both axially (e.g., against forces transmitted along the axis **54**) and radially (i.e., against forces transmitted in a radial direction of the output shaft **50**). In the illustrated embodiment, the fan **58** includes a recess **114** and the bearing retainer **106** extends into the recess **114** such that at least a portion of the bearing retainer **106** and at least a portion of the rear bearing **102** overlap the fan **58** along the axis **54** (FIG. **2**). This overlapping arrangement advantageously reduces the axial length of the impact wrench **10**.

[0040] With continued reference to FIGS. **2** and **3**, the forward bearing **98** is axially recessed within the bore **96** of the camshaft **94** and supports the extension **83** of the pinion gear **82**. An alignment pin **85** is axially recessed within the extension **83** and is configured to align the pinion gear **82** with the bore **96** of the camshaft **94** and the forward bearing **98** (e.g., during assembly of the impact wrench **10**). The forward bearing **98** is coupled to and supported by the camshaft **94** (e.g., at an outer race of the forward bearing **98**), such that at least a portion of the forward bearing **98** is located axially in front of ring gear **90** and the planet gears **86**, and the forward bearing **98** is axially aligned with a portion of a spring **134**, described in greater detail below. In this manner, the housing **14**, spring **134**, camshaft **94**, forward bearing **98**, and the extension **83** of the pinion gear **82** each overlap along the axis **54**. In other words, at least one plane LL (FIG. **3**) can be drawn in a radially outward direction from the extension **83** of the pinion gear **82** that intersects the housing **14**, spring **134**, camshaft **94**, and forward bearing **98**.

[0041] The drive assembly **70** of the impact wrench **10** will now be described with reference to FIG. **3**. The drive assembly **70** includes an anvil **126**, extending from the front housing portion **22**, to which a tool element (e.g., a socket, not shown) can be coupled for performing work on a workpiece (e.g., a fastener). The drive assembly **70** is configured to convert the constant rotational force or torque provided by the gear assembly **66** to a striking rotational force or intermittent applications of torque to the anvil **126** when the reaction torque on the anvil **126** (e.g., due to engagement between the tool element and a fastener being worked upon) exceeds a certain threshold. In the illustrated embodiment of the impact wrench **10**, the drive assembly **70** includes the camshaft **94**, a hammer **130** supported on and axially slidable relative to the camshaft **94**, and the anvil **126**. Stated another way, the hammer **130** is configured to reciprocate axially along the camshaft **94** and impart periodic rotational impacts to the anvil **126** in response to rotation of the camshaft **94**.

[0042] The drive assembly **70** further includes a spring **134** that biases the hammer **130** toward the front of the impact wrench **10**. In other words, the spring **134** biases the hammer **130** in an axial direction toward the anvil **126**, along the axis **54**. A thrust bearing **138** and a thrust washer **142** are positioned between the spring **134** and the hammer **130**. The thrust bearing **138** and the thrust washer **142** allow for the spring **134** and the camshaft **94** to continue to rotate relative to the hammer **130** after each impact strike when lugs **146** on the hammer **130** engage with corresponding anvil lugs (not shown) and rotation of the hammer **130** momentarily stops or reverses. The camshaft **94** includes cam grooves **150** in which corresponding cam balls **154** are received. The cam balls **154** are in driving engagement with the hammer **130** and movement of the cam balls **154** within the cam grooves **150** allows for relative axial movement of the hammer **130** along the camshaft **94** when the hammer lugs **146** and the anvil lugs are engaged and the camshaft **94** continues to rotate. The axial movement of the hammer **130** compresses the spring **134**, which then releases its stored energy to propel the hammer **130** forward and rotate the hammer **130** once the hammer lugs **146** clear the anvil lugs.

[0043] In some embodiments, the hammer spring **134** is formed from a cylindrical coil and, therefore, possesses a circular cross-section. In other embodiments, such as the illustrated embodiment, the spring **134** of the impact wrench **10** is formed from a rectangular coil and possesses a rectangular cross-section. In some embodiments, the cross-section of the spring **134** may be square. Because a spring formed with a rectangular or square cross-section has a larger cross-sectional area and larger area moment of inertia than a typical coil spring formed with a circular cross-section having an outer diameter equal to a shortest side length of the rectangular or square-cross-section, the spring **134** of the impact wrench **10** may have a larger spring constant than a circular coil spring in a typical impact-type power tool with the same outer diameter and number of active coils. Accordingly, the impact wrench **10** can be built with smaller dimensions than a typical impact-type power tool while storing an equal or greater amount of hammer energy in the spring **134** and thereby providing an equal or larger operating torque. In some embodiments, the spring **134** is made from a chrome silicone spring steel.

[0044] In the illustrated embodiment, with reference to FIGS. **2** and **3**, the impact wrench **10** further includes a bushing **158** supported by the dividing wall **113** and surrounding the camshaft **94**. The illustrated bushing **158** includes a plurality of arms **174** (FIG. **4**). The arms **174** of the bushing **158** fit within grooves (not shown) of the housing **14** to rotationally fix the bushing **158** relative to the housing **14**. In some embodiments, the bushing **158** may include two arms **174** positioned opposite one another to support the bushing **158** within the housing **14**. A second end of the camshaft **94** is supported by the anvil **126**, which is retained in the front housing portion **22** by an anvil bushing **186**.

[0045] Referring now to FIGS. **7** and **8**, dimensions of the impact wrench **10**, according to one example construction, include a first length L**1** defined axially between an end of the end cap **30** and an end of the trigger switch **62**. In the illustrated embodiment, the first length L**1** may be between approximately 79 mm and approximately 90 mm (e.g., 84 mm).

[0046] The impact wrench **10** may include a second length L**2** defined axially between the end of the trigger switch **62** and a tip of the anvil **126**. In the illustrated embodiment, the second length L**2** may be between approximately 27 mm and approximately 35 mm (e.g., 29 mm).

[0047] The impact wrench **10** may further include a third length L**3** defined axially between the tip of the anvil **126** and a first or rear end of the ring gear **90**. In the illustrated embodiment, the third length L**3** may be between approximately 75 mm and approximately 85 mm (e.g., 79 mm).

[0048] The impact wrench **10** may further include a fourth length L**4** defined axially between a rear end of the rear bearing **102** and a rear end of forward bearing **98**. In the illustrated embodiment, the fourth length L**4** may be between approximately 39 mm and approximately 49 mm (e.g., 44 mm).

[0049] The impact wrench **10** may also include a height H**3** defined linearly between a center of a plunger of the trigger switch **62** and a bottom of the handle portion **26**. In the illustrated embodiment, the height may be between approximately 105 mm and approximately 140 mm (e.g., 125 mm).

[0050] As illustrated in FIG. **8**, the impact wrench **10** may also include a fifth length L**5** defined axially between a rear end of the camshaft **94** and a rear end of the hammer **130** when the spring **134** is in an uncompressed or free state/condition. In the illustrated embodiment, the fifth length L**5** may be between approximately 25 mm and approximately 35 mm (e.g., 29 mm).

[0051] The combined dimensions (e.g., L**1**, L**2**, L**3**, L**4**, L**5**, H3, OH) of the illustrated impact wrench **10** are not known in the art such that the impact wrench **10** has advanced ergonomics without sacrificing operation capabilities (e.g., torque transmission, form factor, and the like).

[0052] In some embodiments, as illustrated in FIGS. **7** and **8**, an overall length OL of the impact wrench **10** may be between approximately 106 mm and approximately 125 mm (e.g., 116 mm), and an overall height OH of the impact wrench **10** (not including the battery **34** may be between approximately 200 mm and approximately 235 mm (e.g., 225 mm). In the illustrated embodiment, the overall height OH is 1.6 times greater than the overall length OL.

[0053] The features and dimensions of the impact wrench **10**, as described above, allow the impact wrench **10** to be both compact and lightweight. The impact wrench **10** has a total weight, not including the battery **34**, between 2 and 2.15 pounds in some embodiments, or between 1.9 and 2.15 pounds in some embodiments. Furthermore, the impact wrench **10** is capable of delivering at least 350 ft-lbs. of fastening torque to a workpiece in some embodiments, or at least 500 ft-lbs. of fastening torque in other embodiments. In some embodiments, the impact wrench **10** may be capable of delivering between at least 230 ft-lbs. and 265 ft-lbs. of fastening torque per pound of weight.

[0054] In operation of the impact wrench **10**, an operator depresses the switch **62** to activate the motor **42**, which continuously drives the gear assembly **66** and the camshaft **94** via the output shaft **50**. As the camshaft **94** rotates, the cam balls **154** drive the hammer **130** to co-rotate with the camshaft **94**, and the drive surfaces of hammer lugs **146** to engage, respectively, the driven surfaces of anvil lugs to provide an impact and to rotatably drive the anvil **126** and the tool element. After each impact, the hammer **130** moves or slides rearward along the camshaft **94**, away from the anvil **126**, so that the hammer lugs **146** disengage the anvil lugs.

[0055] As the hammer **130** moves rearward, the cam balls **154** situated in the respective cam grooves **150** in the camshaft **94** move rearward in the cam grooves **150**. The spring **134** stores some of the rearward energy of the hammer **130** to provide a return mechanism for the hammer **130**. After the hammer lugs **146** disengage the respective anvil lugs, the hammer **130** continues to rotate and moves or slides forwardly, toward the anvil **126**, as the spring **134** releases its stored energy, until the drive surfaces of the hammer lugs **146** re-engage the driven surfaces of the anvil lugs to cause another impact.

[0056] FIG. **9** illustrates a power tool in the form of an impact wrench **210** according to another embodiment. The impact wrench **210** is similar in some aspects to the impact wrench **10** described above with reference to FIGS. **1**-**8**, and features of the impact wrench **210** corresponding with features of the impact wrench **10** are given corresponding reference numerals plus '**200**.' The following description focuses primarily on differences between the impact wrench **210** and the impact wrench **10**, and it should be understood that features of the impact wrench **210** and alternatives described herein may be incorporated into the impact wrench **10** where applicable, and vice versa.

[0057] Referring to FIG. **9**, the illustrated impact wrench **210** includes a housing **214** with a motor housing portion **218**, an impact case or front housing portion **222** coupled to the motor housing portion **218**, and a handle portion **226** extending from the motor housing portion **218**. The handle portion **226** and the motor housing portion **218** are defined by a first clamshell half **228*a*** and a cooperating second clamshell half **228*b***, coupled together at an interface or seam **231**.

[0058] With reference to FIG. **10**, a motor **242** (e.g., a BLDC motor) is supported within the motor housing portion **218** and includes a stator **246** and a rotor with an output shaft **250** that is rotatable about an axis **254** relative to the stator **246**. The impact wrench **210** also includes a switch **262** (e.g., a trigger switch; FIG. **10**) supported by the housing **214** that selectively connects the motor **242** (e.g., via suitable control circuitry provided on one or more printed circuit board assemblies ("PCBAs") and a battery (not shown) electrically, to provide DC power to the motor **242**.

[0059] A first PCBA **263** is provided adjacent a front end of the motor **242**. The illustrated first PCBA **263** includes one or more Hall-Effect sensors, which provide feedback for controlling the motor **242**. A second PCBA **265** is positioned within the handle portion **226** (adjacent a top end of the handle portion **226**) and generally between the switch **262** and the motor **242**. The second PCBA **65** is in electrical communication with the motor **242**, the switch **262**, and terminals of a battery receptacle **238** located in the handle portion **226**. In the illustrated embodiment, the second PCBA **265** includes a plurality of semi-conductor switching elements (e.g., MOSFETs, IGBTs, or the like) that control and distribute power to windings in the stator **246** in order to cause rotation of the rotor and output shaft **250**. The second PCBA **265** may also include one or more microprocessors, machine-readable, non-transitory memory elements, and other electrical or electronic elements for providing operational control to the impact wrench **210**. In some embodiments, the first PCBA **263** may be omitted, and the motor **242** may be configured for sensorless control via the second PCBA **265**.

[0060] The impact wrench **210** includes a gear assembly **266** driven by the output shaft **250** and an impact mechanism or drive assembly **270** coupled to an output of the gear assembly **266**. The gear assembly **266** is at least partially housed within a gear housing portion **274** that is defined by the clamshell halves **228***a*, **228***b* and the front housing portion **222**. Thus, like the impact wrench **10**, the impact wrench **210** does not include a separate gear case positioned within the housing **214** for supporting the gear assembly **226**. Instead, the gear assembly **266**—and particularly a ring gear **290** of the gear assembly **266**—is directly supported by the clamshell halves **228***a*, **228***b*. This may allow the ring gear **290** to have a larger diameter within a given size of the housing **14** than if the ring gear **290** were supported within a separate gear case within the housing **14**. In the illustrated embodiment, the ring gear **290** may have an outer diameter that is greater than an inner diameter of the front housing portion **222**.

[0061] Like the impact wrench **10**, the drive assembly of the impact wrench **210** includes a camshaft **294**, an anvil **326**, a hammer **330**, and a hammer spring **334**. With reference to FIG. **13**, the gear assembly **266** includes a pinion gear **282** coupled to the output shaft **250** of the motor **242**, a plurality of planet gears **286** meshed with the pinion gear **282**, and the ring gear **290**, which is meshed with the planet gears **286** and rotationally fixed within the housing **214** (specifically, within the gear housing portion **274**). The ring gear **290** is positioned within a groove **233** bounded in the axial direction by a first wall **313**, which may be referred to as a dividing wall, and a second wall **229**. The first wall **313** and the second wall **229** are each collectively defined by the two clamshell halves **228***a*, **228***b*. The first wall **313** separates the interior of the gear housing portion **274** from the motor **242**. The second wall **229** is generally annular and centered with respect to the rotational axis **254**. In the illustrated embodiment, the second wall **229** includes a portion of a boss **235**, which projects into the gear housing portion **274** and receives a screw (not shown) to couple the clamshell halves **228***a*, **228***b* together.

[0062] As shown in FIGS. **11** and **12**, the ring gear **290** includes a rear wall **236** with lugs **240***a*, **240***b* projecting from the rear wall **236**. The lugs **240***a*, **240***b* are received within correspondingly shaped receptacles **215** in the first wall **313** to prevent rotation of the ring gear **290** relative to the housing **214**. In the illustrated embodiment, the lugs **240***a*, **240***b* are generally linear and extend in a lateral (i.e., horizontal) direction perpendicular to the axis **254** and offset above and below the axis **254**. The lugs **240***a*, **240***b* are interconnected by arcuate webs **240***c* surrounding an aperture **244** extending through the rear wall **236** of the ring gear **290**. In some embodiments, the ring gear **290**, including the lugs **240***a*, **240***b* and webs **240***c* may be integrally formed as a single piece from powdered metal. In other embodiments, the ring gear **290** may be formed in other ways.

[0063] Because the lugs **240***a*, **240***b* and the receptacles **215** are horizontally oriented, reaction forces on the first wall **313** of the housing **214** due to torque on the ring gear **290** during operation of the impact wrench **210** have resultant force vectors that are oriented in a generally vertical direction (i.e. generally parallel to the parting plane of the clamshell halves **228***a*, **228***b*.) For example, the lugs **240***a*, **240***b* may transmit reaction forces with resultant force vectors oriented at angles between 0 and 45 degrees relative to the parting plane in some embodiments or at angles between 0 and 30 degrees relative to the parting plane in some embodiments. The resultant force vectors therefore do not tend to cause separation of the clamshell halves **228***a*, **228***b*. This maintains the stability of the ring gear **290** and inhibits lubricant from leaking out of the gear housing portion **274**.

[0064] Referring to FIGS. **12**-**13**, the ring gear **290** includes an integrated bushing **257** defining the aperture **244** and rotationally supporting a rear end of the camshaft **294**. The lugs **240***a*, **240***b*, webs **240***c*, and rear wall **236** together define a thickness of the bushing **257**. In other embodiments, the rear end of the camshaft **294** may be supported in other ways, such as by a bearing supported within the aperture **244**.

[0065] Best illustrated in FIG. **11**, the ring gear **290** includes a radial groove **248** on the exterior of the ring gear **290**, which receives a sealing member **252** (i.e., an O-ring). The O-ring **252** serves to inhibit lubrication from the gear housing portion **274** from leaking into the motor housing portion **218**.

[0066] The illustrated pinion gear **282** includes a recess **281** that receives the output shaft **250** and an extension **283**. The output shaft **250** may be press fit into the recess **281**, or the output shaft **250** and the recess **281** may include cooperating spline patterns or other suitable geometries for coupling the pinion gear **82** for co-rotation with the output shaft **50**. In other embodiments, the pinion gear **282** may be integrally formed as a single piece with the output shaft **250**.

[0067] As shown in FIG. **13**, the impact wrench **210** further includes a pinion seal **256**, which in the illustrated embodiment is configured as a V-ring with a resilient flange **260** engageable with rear surfaces of the camshaft **294** and/or ring gear **290**. The pinion seal **256** may be made of a flexible, resilient material, such as an elastomeric material in some embodiments. The illustrated pinion seal **256** is coupled to the pinion gear **282** (e.g., via an interference fit) for co-rotation therewith. In some embodiments, the inner periphery of the pinion seal **256** and the outer periphery of the pinion gear **282** may include cooperating non-circular geometries to couple the pinion seal **256** for co-rotation with the pinion gear **282**. In the illustrated embodiment, the pinion gear **282** includes a shoulder **267** formed adjacent an end of the pinion gear **282** opposite the extension **283**. The shoulder **267** may act as a back stop to prevent axial displacement of the pinion seal **256**.

[0068] The flange **260** is configured to cover and thereby seal a camshaft-pinion interface **362** defined between an outer surface of the pinion gear **282** and an inner surface of the camshaft **294**. Because the pinion gear **282** rotates at a different speed than the camshaft **294**, a small clearance exists along the camshaft-pinion interface **362**. The flange **260** of the pinion seal **256** inhibits lubricant from migrating into the motor housing portion **218** through the camshaft-pinion interface **362**. In some embodiments, the flange **260** may also be configured to cover and thereby seal a camshaft-ring gear interface **364** defined between an outer surface of the camshaft **294** and an inner surface of the bushing **257** of the ring gear **290**. The flange **260** of the pinion seal **256** may therefore also inhibit lubricant from migrating into the motor housing portion **218** through the camshaft-ring gear interface **364**.

[0069] The flange **260** extends at an oblique angle relative to the axis **254**; however, the angle may vary depending on the rotational speed of the motor shaft **250** and pinion gear **282**. In particular, the angle may increase toward 90 degrees when the rotational speed of the motor shaft **250** exceeds a threshold speed, due to centrifugal forces on the flange **260** deforming the resilient material. The threshold speed may correspond with a no-load or idle speed of the motor **242**, during which the hammer **330** does not reciprocate and impart impacts to the anvil **326**. In some embodiments, the threshold speed is 15,000 RPM. In some embodiments, the threshold speed is 17,000 RPM. In some embodiments, the threshold speed is between 15,000 RPM and 30,000 RPM.

[0070] When the flange **260** deforms to increase the angle above the threshold speed, the flange **260** moves away from and out of engagement from the rear end of the camshaft **294** and the rear end of the ring gear **290**. This advantageously reduces friction and wear that could otherwise occur at such high rotational speeds. Furthermore, the inventors have found that lubricant migration along the camshaft-pinion interface **362** and the camshaft-ring gear interface **364** is minimal at speeds above the threshold speed, since, during idle, the hammer **330** does not reciprocate.

[0071] Once load is applied to the motor **242** (e.g., when the anvil **326** engages a fastener offering sufficient resistance), the motor **242** slows the motor shaft **250** to a speed below the threshold speed. The flange **260** resiliently recovers to re-engage with the rear end of the camshaft **294** and/or the rear end of the ring gear **290**. When the hammer **330** proceeds to reciprocate during a fastening operation, which may act like a piston to displace the lubricant, cause localized pressure increases, as well increase the temperature of the lubricant, the pinion seal **256** inhibits the lubricant from entering the motor housing portion **218** via the interfaces **362**, **364**.

[0072] In other embodiments, the seal **260** may be constructed in other ways and from other materials. For example, in some embodiments, the seal **260** may be a radial seal disposed radially between the pinion gear **282** and the interior surface of the camshaft **294**. In such embodiments, the seal **260** may be carried by either the camshaft **294** or the pinion gear **282**. In some embodiments, the seal **260** may include polyurethane. In other embodiments, the seal **260** may include a felt washer. In other embodiments, the seal **260** may include a multi-layer composition, such as a layer of foam, a layer of metal, and another layer of foam or a layer of elastomer.

[0073] Although the disclosure has been described in detail with reference to certain preferred embodiments, variations and modifications exist within the scope and spirit of one or more independent aspects of the disclosure as described. Various features of the disclosure are set forth in the following claims.

What is claimed is:

1. A power tool comprising:

a housing having a first housing portion and a second housing portion coupled to the first housing portion;

a motor directly mounted within the housing between the first and second housing portions and including an output shaft, the output shaft defining an axis;

a gear assembly supported within the housing and operably coupled to the motor, the gear assembly including a ring gear directly supported by the first and second housing portions, a pinion gear coupled for co-rotation with the output shaft, and a plurality of planet gears meshed with the pinion gear and the ring gear; and

a drive assembly operably coupled to the gear assembly, the drive assembly including a camshaft, an anvil, a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil in response to rotation of the camshaft, and a spring biasing the hammer towards the anvil,

wherein the ring gear includes a plurality of lugs engaged with the first housing portion and the second housing portion to rotationally constrain the ring gear.

2. The power tool of claim **1**, wherein the spring has a rectangular cross-section.

3. The power tool of claim **1**, wherein the camshaft includes a bore, wherein the pinion gear is meshed with the planet gears within the bore, wherein the pinion gear includes an extension extending into the bore beyond the planet gears, wherein a bearing is supported within the bore, and wherein the bearing supports the extension of the pinion gear.

4. The power tool of claim **3**, wherein the housing, the spring, the camshaft, the bearing, and the extension overlap along the axis such that a plane perpendicular to the axis intersects the housing, the spring, the camshaft, the bearing, and the extension.

5. The power tool of claim **3**, further comprising an alignment pin received within the extension, the alignment pin configured to centrally align the pinion gear within the bore of the camshaft.

6. The power tool of claim **1**, wherein the ring gear includes a bushing configured to support the camshaft.

7. The power tool of claim **1**, wherein the plurality of lugs projects from a rear wall of the ring gear.

8. The power tool of claim **7**, further comprising a seal disposed about an outer periphery of the ring gear.

9. The power tool of claim **1**, wherein the plurality of lugs projects from an outer periphery of the ring gear.

10. The power tool of claim **9**, further comprising a rib engageable with the first housing portion and the second housing portion to axially secure the ring gear.

11. The power tool of claim **1**, further comprising a pinion seal coupled to the pinion gear for rotation therewith, wherein the pinion seal is configured to seal an interface between the pinion gear and the camshaft.

12. The power tool of claim **11**, wherein the pinion seal is configured to engage a rear end of the camshaft when the output shaft rotates at a speed less than a threshold speed, and wherein the pinion seal is configured to disengage from the rear end of the camshaft when the output shaft rotates at a speed greater than the threshold speed.

13. The power tool of claim **12**, wherein the threshold speed is between 15,000 RPM and RPM.

14. The power tool of claim **1**, wherein the power tool has an overall length measured along the axis from a rear end of the housing to a front end of the anvil between 106 mm and 125 mm, wherein the power tool has an overall height measured perpendicular to the axis between 200 mm and

235 mm, and wherein the power tool is capable of delivering at least 500 foot-pounds of fastening torque to a workpiece through the anvil.

15. A power tool comprising:

a housing having a motor housing portion and a handle portion extending from the motor housing portion, wherein the motor housing portion and the handle portion are defined by cooperating first and second clamshell halves coupled together along a parting plane;

a motor supported within the moto housing portion and including an output shaft, the output shaft defining an axis;

a gear assembly supported within the housing and operably coupled to the motor, the gear assembly including a ring gear directly supported by the first and second clamshell halves, a pinion gear coupled for co-rotation with the output shaft, and a plurality of planet gears meshed with the pinion gear and the ring gear; and

a drive assembly operably coupled to the gear assembly, the drive assembly including a camshaft, an anvil, a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil in response to rotation of the camshaft, and a spring biasing the hammer towards the anvil,

wherein the ring gear includes a plurality of lugs engaged with the first and second clamshell halves to rotationally constrain the ring gear, and wherein the plurality of lugs is arranged such that all resultant force vectors on the first and second clamshell halves due to torque on the ring gear are oriented at an angle between 0 degrees and 45 degrees relative to the parting plane.

16. The power tool of claim **15**, wherein the power tool has an overall length measured along the axis from a rear end of the housing to a front end of the anvil between 106 mm and 125 mm, wherein the power tool has an overall height measured perpendicular to the axis between 200 mm and 235 mm, and wherein the power tool is capable of delivering at least 500 foot-pounds of fastening torque to a workpiece through the anvil.

17. The power tool of claim **15**, wherein the plurality of lugs projects from a rear wall of the ring gear.

18. The power tool of claim **1**, wherein the plurality of lugs projects from an outer periphery of the ring gear.

19. A power tool comprising:

a housing having a first housing portion and a second housing portion coupled to the first housing portion;

a motor directly mounted within the housing between the first and second housing portions and including an output shaft, the output shaft defining an axis;

a gear assembly supported within the housing and operably coupled to the motor, the gear assembly including a ring gear and a pinion gear coupled to the output shaft; and

a drive assembly operably coupled to the gear assembly, the drive assembly including a camshaft, an anvil, and a hammer configured to reciprocate along the camshaft to impart rotational impacts to the anvil in response to rotation of the camshaft, wherein the camshaft includes a bore through which an extension of the pinion gear extends; and

a pinion seal supported on the pinion gear, the pinion seal including a flange configured to seal at least one selected from a group consisting of: a first interface between the pinion gear and the camshaft, and a second interface between the camshaft and the ring gear.

20. The power tool of claim **19**, wherein the pinion seal is configured to engage a rear end of the camshaft when the output shaft rotates at a speed less than a threshold speed, and wherein the pinion seal is configured to disengage from the rear end of the camshaft when the output shaft rotates at a speed greater than the threshold speed, and wherein the threshold speed corresponds with a no-load speed of the motor.

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