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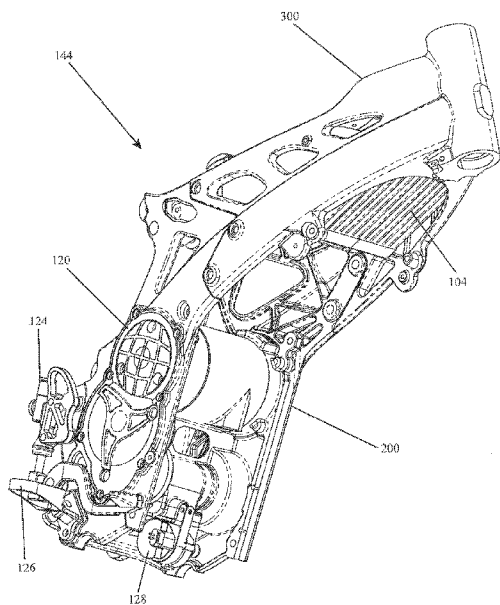
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(54) Title: INTEGRATED CAST MOTORCYCLE CHASSIS AND MOTOR HOUSING

Fig. 3



(57) Abstract: This invention comprises a frame for an electric mo-  
torcycle. Electric motorcycles have vastly different component re-  
quirements compared to internal combustion engine motorcycles,  
and, therefore, require a radical redesign of the frame in order to  
maximize the efficiency of the system.



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## Integrated Cast Motorcycle Chassis and Motor Housing

### Field

5 The invention relates to vehicles, and, more particularly to electric motorcycle frames.

### Background

Recent advances in electric vehicle technology have resulted vehicles that have comparable performance characteristics compared to internal combustion engine vehicles.

10 Unfortunately, one key component, the battery, remains stubbornly expensive, resulting in costly electric cars. One cannot possibly justify the price of a new electric car compared to a similarly equipment gasoline or diesel model. If, instead, one develops the lightest possible vehicle, the electric equation just might make sense.

The lightest practical vehicle is either a motocross bike, a street legal equivalent, the 15 enduro, or it's fully street focused version, the supermoto. Such bikes often weigh a little over 100 kg. By minimizing weight, the battery requirements are minimized, and, consequently, the price as well.

Several companies have seen the light and jumped into the fray. Unfortunately, their efforts have come up short. Many save the expense of designing a new chassis from scratch, 20 and, instead, shoehorn an electric motor and battery pack in a frame that was originally designed for and internal combustion engine. The results have been mediocre, underpowered bikes with limited range and questionable handling.

The published US patent application 2011/0036657 A1 by Bland et al. (subsequently referred to as Bland) assigned to Brammo Inc. discloses a straight electric motorcycle chassis 25 that comprises two sides that enclose the headstock and allow attachment of batteries from above and below. Bland places the motor at the axis of the drive sprocket, with no transmission, subsequently requiring a big, heavy electric motor to generate enough torque. The motor is also fully stressed, resulting in high maintenance costs related to motor repair or replacement. In addition, the batteries are insufficient for a reasonable top speed and range.

30 Zero Motorcycles, from Scotts Valley, California, manufactures an electric motorcycle frame using a combination of tubular and hydroformed aluminum pieces that are welded together. The myriad disadvantages of welded aluminum frames are discussed in the description, below. Like the teachings of Bland, the Zero batteries are insufficient for a reasonable top speed and range.

KTM of Austria and Quantya of Switzerland both employ welded bent steel tube perimeter frames, which can be heavy.

All of the electric motorcycle manufacturers discussed above use air cooled electric motors. Compared to liquid cooled electric motors, air cooled electric motors have lower peak power outputs and vastly lower continuous power outputs.

Given growing consumer demand for high performance, low cost electric vehicles, there is a need for a new electric motorcycle developed around a new type of chassis.

### Summary

The current invention relates to a vehicle frame, or chassis, and its manufacture. In one embodiment the frame comprises two cast aluminum structures that can be bolted together. The frame structures can each be cast in one piece and finish machined with one fixturing. The frame casting can include an integral motor housing that may be fully stressed and act as a torsion tube.

15

### Brief description of drawings

Fig. 1 shows a motorcycle.

Fig. 2 shows motorcycle parts that attach to a motorcycle frame.

Fig. 3 shows motorcycle parts that attach to a motorcycle frame.

20 Fig. 4 shows a rear part of a motorcycle frame.

Fig. 5 shows a rear part of a motorcycle frame.

Fig. 6 shows a rear part of a motorcycle frame.

Fig. 7 shows a rear part of a motorcycle frame.

Fig. 8 shows a front part of a motorcycle frame.

25 Fig. 9 shows a front part of a motorcycle frame.

### Description

Fig. 1 shows a motorcycle 100. The motorcycle 100 shown is an off road or motocross bike. Motorcycles 100 comprise motocross bikes, road bikes, three wheeled bikes, and four wheeled bikes. Any three or four wheeled vehicle where the rider straddles the seat 114 of the vehicle is considered a motorcycle. Scooters are also considered motorcycles. The motorcycle 100 shown in Fig. 1 comprises an electric motorcycle, and, therefore has an electric motor and a battery box 112.

Fig. 2 shows motorcycle parts that attach to a motorcycle frame 144. Shown are a

shroud 102, also known as a fairing, a seat 114, a rear subframe 116, a rear shock 140, a swing arm 138, a rear suspension linkage 130, a skid plate 142, a battery box 112, a motor cover 122, a sprocket 136, and a fork 134. Also shown are the frame structure 200 and the second frame structure 300.

5 Fig. 3 shows motorcycle parts that attach to a motorcycle frame 144. Shown are a radiator 104, a water pump 128, a footpeg 126, a rear master cylinder 124, and a gear cover 120. Also shown are the frame structure 200 and the second frame structure 300.

A frame 144 for a motorcycle can be made as a single piece or several pieces that are attached together. The example frame 144 shown in Figs. 2-3 is a two piece frame 144  
10 comprising the frame structure 200, also known as a rear bulkhead, and the second frame structure 300, also known as a front bulkhead. The two piece frame 144 design allows the frame structure 200 and the second frame structure 300 to each be cast as a single piece, finish machined in one fixture, and attached together.

Using only one fixture per structure reduces time required for machining and  
15 increases accuracy of the machined surfaces. Milling machines large enough for a single structure can be cost prohibitive. Utilizing two structures, rather than a single structure, reduces the size of milling machine required to complete the operation, reducing capital costs. In addition, separating the structure into two pieces can allow machine access to additional areas of the casting, allowing more features to be integrated and reducing the complexity of  
20 fixturing and machining. Casting a single frame unit may also be quite complicated and more costly than two smaller frame castings.

A typical 3-axis milling machine setup involves clamping the workpiece in a vise where only one face is exposed for cutting at a time. A 4-axis mill setup clamps the workpiece in a rotary fixture. This allows the machine to work on virtually all faces of the  
25 workpiece that are perpendicular to the axis of rotation. Thus, by using a 4-axis milling machine, such as a horizontal milling machine with a rotary axis for the workpiece fixture, one can finish machine all of the features, or interface areas, within the tolerance specification for the frame structure 200 and the second frame structure 300 listed below and seen in Figs. 4-9 with one fixturing per piece, each saving considerable time and expense.

30 In one embodiment, the frame 144 may be manufactured by casting both the frame structure 200 and the second frame structure 300 each as a single casting from 206 aluminum alloy. The frame structure 200 and the second frame structure 300 castings are then separately mounted in respective fixtures and features are finish machined in at least one working plane. 206 aluminum has some corrosion issues, so conversion coating, a process

including an acid dip and passivation, followed by priming and painting would resolve those issues. Other suitable casting aluminum alloys include 201, 204, 356, and 357. In another embodiment, a one piece frame may be manufactured by casting the frame 144 as a single casting with most or all of the features and mounting points included in Figs. 2-8 and then  
5 finish machined. In yet another embodiment, the frame structure 200 may be cast and finish machined as described above, while the second frame structure 300 may be fabricated in another manner, such as milled from billet aluminum or created by welding two or more parts together. Welding allows one to build a trellis frame structure out of steel, titanium, or aluminum or to build a twin spar aluminum frame structure commonly used for motorcycles.  
10 Alternatively, the second frame structure 300 may be built out of a composite material such as carbon fiber.

The embodiment of the frame 144 shown in Fig. 3 with the frame structure 200 and the second frame structure 300 comprises a weldless design. Welding frame components can take a considerable amount of time to accurately fixture and weld together. Welding adds  
15 expense due to inconsistencies in weld quality that require a safety margin or more robust and heavy structure to compensate for these inconsistencies. Welding can also result in stress build up and distortion in a structure requiring secondary heat treatment and straightening.

Fig. 4 shows a rear part of a motorcycle frame 144. The frame structure 200 includes frame mounts 202, a gear cover mount 206, rear subframe mounts 208, linkage mounts 210,  
20 rear master cylinder mounts 212, battery bolt holes 214, skid plate mounts 216, footpeg mounts 218, a rear brake lever mount 220, shroud mounts 222, a bottom coolant port 238, an oil sump 232, a right side 240, a motor housing 244, an output shaft housing 246, a vent hole 248, and a shock mount bolt hole 254.

Fig. 5 shows a rear part of a motorcycle frame 144. The frame structure 200 includes  
25 shock mounts 204, a motor cover mount 224, a pass through hole 226, swing arm mounts 228, a top coolant port 230, a left side 242, a motor housing 244, an output shaft housing 246, a vent hole 248, and a structural rib 250.

The left and right sides 242, 240 shown in Figs. 4, 5 are a type of side structure that connects the motor housing 244, which may act as a torsion tube, to mounting points for  
30 other components or to other frame features. The sides 242, 240 are shown as part of a single casting, but may also be a welded trellis structure or a composite structure. It is also possible to use only one side structure in the middle of the frame to connect the motor housing 244 to other features and mounting points.

Fig. 6 shows a rear part of a motorcycle frame 144. The frame structure 200 includes

an oil sump 232, a drain plug port 234, a bottom coolant port 238, a motor housing 244, an output shaft housing 246, structural ribs 250, and battery box mounts 252.

Fig. 7 shows a rear part of a motorcycle frame 144. The frame structure 200 includes a pass through hole 226, a motor housing 244, and an output shaft housing 246.

5 The left side 242 and right side 240 of the frame structure 200 flank the motor housing 244 and output shaft housing 246. The housings 244, 246 may extend beyond the external wall of the sides 240, 242, or the housings 244, 246 may be contained by the sides 240, 242. Alternately, one or more sides may be connected to the middle of the housings 244, 246. The housings 244, 246 may be fully stressed and may act as torsion tubes to add rigidity  
10 to the frame structure 200. Cylinders are the best structure to use for a torsion tube due to its polar moment of inertia, but other shapes can be used if appropriate. The motor housing 244 be designed to receive a motor, preferably a liquid cooled electric motor. The housing 244 may have a top coolant port 230 and a bottom coolant port 238 to allow the circulation of a coolant between the motor housing 244 and the motor.

15 When the motor housing 244 is used as an outer water jacket for containing coolant between itself and the motor, the motor can be contained by an inner water jacket. In this case, the motor and the inner water jacket are not required to be stressed members, while the motor housing 244 may be fully stressed.

A motor cover 122 may be attached to a motor cover mount 224 on the frame  
20 structure 200 in order to seal the motor from the elements. Likewise, a gear cover 120 may be attached to a gear cover mount 206 in order to seal the motor and/or gear reduction assembly from the elements. A shroud 102 or fairing may be attached to shroud mounts 216, 304. A seat 114 may be attached to seat plate mounts 324 via a seat clip and to the rear subframe 116. The rear subframe 116 may be attached to rear subframe mounts 208. A rear  
25 shock 140 may be attached to shock mounts 204. A swing arm 138 may be attached to swing arm mounts 228. Rear suspension linkages 130 may be attached to linkage mounts 210.

A skid plate 142 may be attached to skid plate mounts 216 in order to protect the a battery box 112. A battery box 112 may be attached to battery box mounts 252 and secured with bolts passing through the battery bolt holes 214. Any feature that generally aids in the  
30 attachment of the battery box 112 to the frame 144 may be generally referred to as a battery box mount. The battery box 112 may be a semi stressed member when attached to the frame structure 200, thereby adding rigidity to the frame 144 when attached while being removable without compromising the structural integrity of the frame 144 or having the rest of the motorcycle 100 lay in pieces when the battery box 112 is removed, as would be the case if

the battery box 112 where fully stressed. A sprocket 136 may drive a chain to drive the rear wheel and may also be attached to an output shaft that is housed in the output shaft housing 246.

5 One or more pass through holes 226, or openings, may be used to allow passage of hoses and wires. Adding a pass through hole 226 on the motor housing 244, as seen in Fig. 7, allows the wires that power the motor to be routed internally in the frame 144, a more attractive and safer solution than routing power wires externally. An o-ring or equivalent seal between the motor housing 244 and the motor can prevent coolant from entering the chamber where the power wires connect to the motor. A rubber gasket or equivalent is preferably set  
10 in the pass through hole 226 to form a seal between the motor housing 244 and the wires and to provide strain relief.

One or more vent holes 248, 308 allow air to flow through the radiator 104 and to exit the frame 144. One or more structural ribs 250 may be added to the frame structure 200 to increase rigidity.

15 An oil sump 232 may be placed in the output shaft housing 246 to provide lubrication for a gear reduction. The oil sump 232 can be drained via a drain plug port 234. An oil level sight and oil fill port may be integrated into the gear cover 120. A water pump 128 may be attached to a water pump mount 236, the water pump 128 circulating a coolant to the motor and optionally to the motor control unit and the battery.

20 Fig. 8 shows a front part of a motorcycle frame 144. The second frame structure 300 includes frame mounts 302, shroud mounts 304, a headstock structure 306, vent holes 308, a right side 310, a structural rib 314, battery box mounts 316, skid plate mounts 318, steering stop mounts 320, radiator mounts 322, seat plate mounts 324, and a mounting plane 326. The headstock structure 306 is designed for receiving a fork 134. The headstock structure 306  
25 may be a tube as shown in Fig. 8 or any other structure that holds upper and lower bearings that receive a fork 134. A box construction type headstock structure 306 may be used to allow greater airflow through the front of the motorcycle 100.

Fig. 9 shows a front part of a motorcycle frame 144. The second frame structure 300 includes frame mounts 302, shroud mounts 304, a headstock structure 306, a left side 312, a  
30 structural rib 314, battery box mounts 316, skid plate mounts 318, steering stop mounts 320, radiator mounts 322, seat plate mounts 324, and an access hole 328. The headstock structure 306 may receive a fork 134. The left and right sides 312, 310 are attached to the headstock structure 306. A structural rib 314 attaches to the left and right sides 312, 310, aids in structural rigidity, and helps keep the left and right sides 312, 310 in place during the casting

and finish machining process. The seat plate mounts 324 may receive a plate or clip that receives the seat 114. The access hole 328 can allow access to the radiator fill cap. The battery box mounts 316 may receive a battery box 112. The skid plate mounts 318 may receive a skid plate 142. The steering stop mounts 320 may receive steering stops. The radiator mounts 322 may receive a radiator 104.

In addition to having the ability to cool the motor with a coolant, the frame 144 itself can act as a heat sink. Aluminum is a very good heat conductor, and the shape of the frame structure 200 allows excess heat to travel from the motor housing 244 to the left and right sides 242, 240 of the frame structure 200 where the heat may be dissipated via air convection, conduction to attached parts, or radiation.

The left and right sides 242, 240 of the frame structure 200 as shown in Figs. 4-7 comprise a perimeter frame construction to allow for the connection of parts including the rear swingarm 138, rear suspension linkage 130, rear shock 140, rear subframe 116, and fork 134. Alternate constructions include a trellis frame construction and a composite frame construction.

#### Reference Numerals

	100	motorcycle
	102	shroud
20	104	radiator
	106	steering dampener
	108	steering stop
	110	skid plate
	112	battery box
25	114	seat
	116	rear subframe
	118	shock
	120	gear cover
	122	motor cover
30	124	rear master cylinder
	126	foot peg
	128	water pump
	130	rear suspension linkage
	134	fork

	136	sprocket
	138	swing arm
	140	shock
	142	skid plate
5	144	frame
	200	frame structure
	202	frame mount
	204	shock mount
	206	gear cover mount
10	208	rear subframe mount
	210	linkage mount
	212	rear master cylinder mount
	214	battery bolt hole
	216	skid plate mount
15	218	footpeg mount
	220	rear brake lever mount
	222	shroud mount
	224	motor cover mount
	226	pass through hole
20	228	swing arm mount
	230	top coolant port
	232	oil sump
	234	drain plug port
	236	water pump mount
25	238	bottom coolant port
	240	right side
	242	left side
	244	motor housing
	246	output shaft housing
30	248	vent hole
	250	structural rib
	252	battery box mount
	254	shock mount bolt hole
	300	second frame structure

- 302 frame mount
- 304 shroud mount
- 306 headstock tube
- 308 vent hole
- 5 310 right side
- 312 left side
- 314 structural rib
- 316 battery box mount
- 318 skid plate mount
- 10 320 steering stop mount
- 322 radiator mount
- 324 seat plate mount
- 326 mounting plane
- 328 access hole

15

## Claims

What is claimed is:

- 5 1. A frame for an electric vehicle, the frame comprising:  
a fully stressed torsion tube for housing an electric motor;  
means for connecting a front suspension; and  
means for connecting a rear suspension.
- 10 2. A frame of claim 1, further comprising:  
means for connecting a rear subframe.
- 15 3. An electric motorcycle frame, the frame comprising:  
a first frame structure, the first frame structure comprising:  
a first torsion tube; and  
at least one mount for attaching additional components,  
where the first torsion tube is fully stressed.
- 20 4. The frame of claim 3, where the first frame structure further comprises:  
at least one side structure,  
where the at least one side structure connects the at least one mount to the first torsion  
tube.
- 25 5. The frame of claim 3, where the first frame structure further comprises:  
at least one structural rib.
6. The frame of claim 3, where the first torsion tube includes at least one port for a  
coolant flow.
- 30 7. The frame of claim 3, where the first torsion tube is designed to receive an electric  
motor.
8. The frame of claim 7, where the first torsion tube acts as an outside water jacket for  
containing a coolant that circulates between the first torsion tube and the motor.

9. The frame of claim 7, where the first frame structure comprises a heat sink for the motor.

5 10. The frame of claim 7, where the first torsion tube has an opening for passing through electric wires to power the electric motor.

11. The frame of claim 3, where the first frame structure further comprises:  
a second torsion tube.

10 12. The frame of claim 11,  
where the second torsion tube comprises an output shaft housing, and  
where the second torsion tube is fully stressed.

15 13. The frame of claim 3, where the at least one mount comprises:  
at least one swing arm pivot mount.

20 14. The frame of claim 13, where the first frame structure further comprises:  
an oil sump,  
where the oil sump reinforces the at least one swing arm pivot mount.

25 15. The frame of claim 3, where the at least one mount comprises:  
at least one mount for a battery box,  
where the battery box is a semi stressed member when attached to the first frame  
structure.

30 16. The frame of claim 3, where the first frame structure further comprises:  
a headstock structure for receiving a motorcycle fork.

17. The frame of claim 3, where the first frame structure comprises aluminum.

18. The frame of claim 3, where the first frame structure comprises magnesium.

19. The frame of claim 3, where the first frame structure is cast as a single casting.

20. The frame of claim 3, further comprising:  
a second frame structure,  
where the second frame structure attaches to the first structure, and  
where the second frame structure includes a headstock structure for receiving a  
5 motorcycle fork.
21. The frame of claim 20, where the second frame structure is cast as a single casting.
22. The frame of claim 21, where the second frame structure includes at least one  
10 structural rib.
23. The frame of claim 20, where the second frame structure is fabricated.
24. A method of manufacturing an aluminum frame for an electric motorcycle,  
15 the frame comprising:  
a first cast structure, the first cast structure comprising:  
at least one side structure; and  
a motor housing,  
where the motor housing is attached to the at least one side structure,  
20 and  
where the motor housing is fully stressed,  
the method comprising:  
casting the first cast structure as a single piece; and  
machining motor housing and the at least one side structure of the first cast structure  
25 such that interface areas with other parts are within tolerance specifications.
25. A method of claim 24, where the machining is accomplished with two or fewer  
machining fixtures.
- 30 26. A method of claim 25, where the machining is accomplished with a single  
machining fixture.
27. An aluminum frame for an electric motorcycle, the frame comprising:  
a first frame structure, the first frame structure comprising:

a first side;  
a second side;  
a cylindrical motor housing;  
a cylindrical output shaft housing;  
5 at least one structural rib;  
a first swing arm pivot;  
a second swing arm pivot; and  
an oil sump,  
where the output shaft housing is flanked by the first and second sides,  
10 where the output shaft housing is fully stressed.  
where the motor housing is flanked by the first and second sides,  
where the motor housing is a fully stressed torsion tube,  
where the motor housing includes a first port and a second port for a coolant  
flow,  
15 where the motor housing acts as an outside water jacket for containing a  
coolant that circulates between the motor housing and an electric motor,  
where the motor housing and frame comprise a heat sink for the electric motor,  
where the motor housing has an opening for passing through electric wires to  
power the electric motor,  
20 where the electric motor, without the motor housing, is not stressed,  
where the oil sump reinforces the first and second swing arm pivots,  
where the at least on structural rib is flanked by the first and second sides,  
where a battery box is a semi stressed member when attached to the first  
frame structure, and  
25 where the first frame structure is cast as a single casting; and  
a second frame structure, the second frame structure comprising:  
a first side;  
a second side;  
30 at least one structural rib; and  
a headstock structure,  
where the at least on structural rib is flanked by the first and second sides,  
where the headstock structure is connected to the first and second sides,  
where the second frame structure attaches to the first frame structure,

where the headstock structure receives a motorcycle fork,  
where the second frame structure is cast as a single casting,

where the first and second frame structures are weldless, and

- 5 where the first and second frame structures are machined to have features comprising:
- at least one shroud mount;
  - at least one radiator mount;
  - at least one steering dampener mount;
  - at least one steering stop mount;
  - 10 at least one skid plate mount;
  - at least one battery box mount;
  - at least one rear subframe mount;
  - at least one shock mount;
  - at least one gear cover mount;
  - 15 at least one motor cover mount;
  - at least one rear master cylinder mount;
  - at least one foot peg mount;
  - at least one rear suspension linkage mount;
  - at least one water pump mount;
  - 20 at least one brake mount; and
  - a drain plug port for the oil sump.

**Fig. 1**

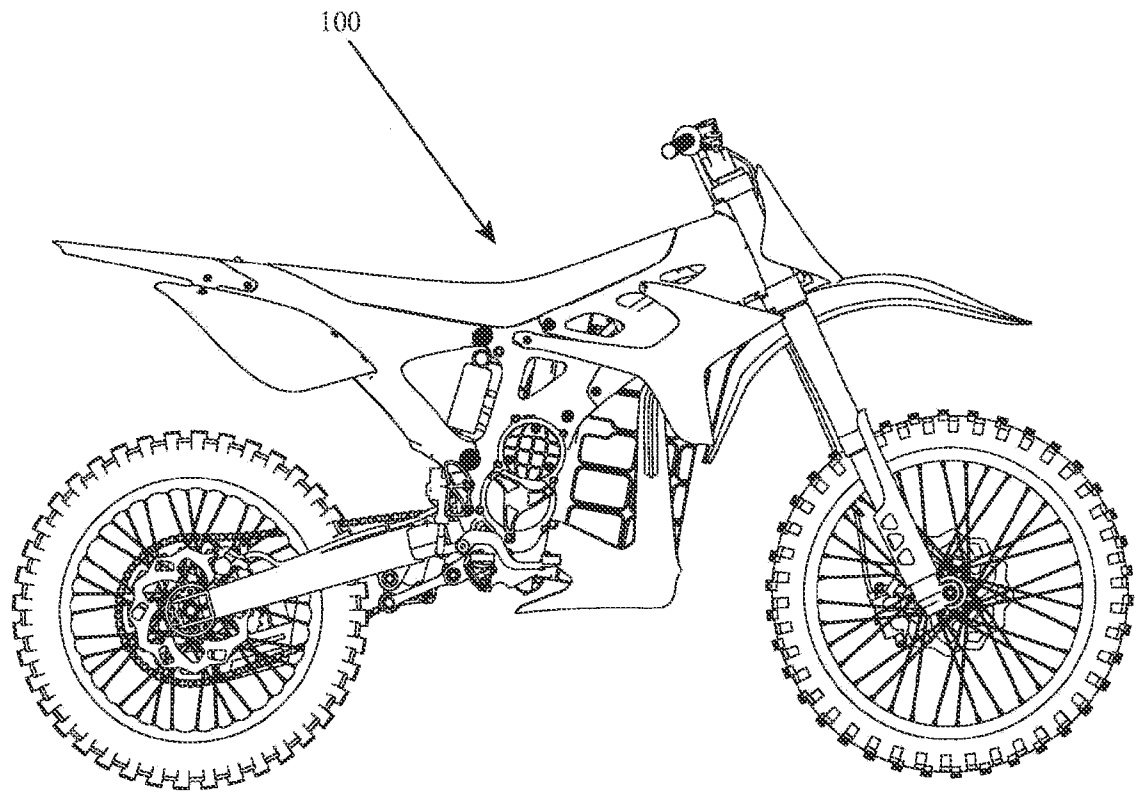


Fig. 2

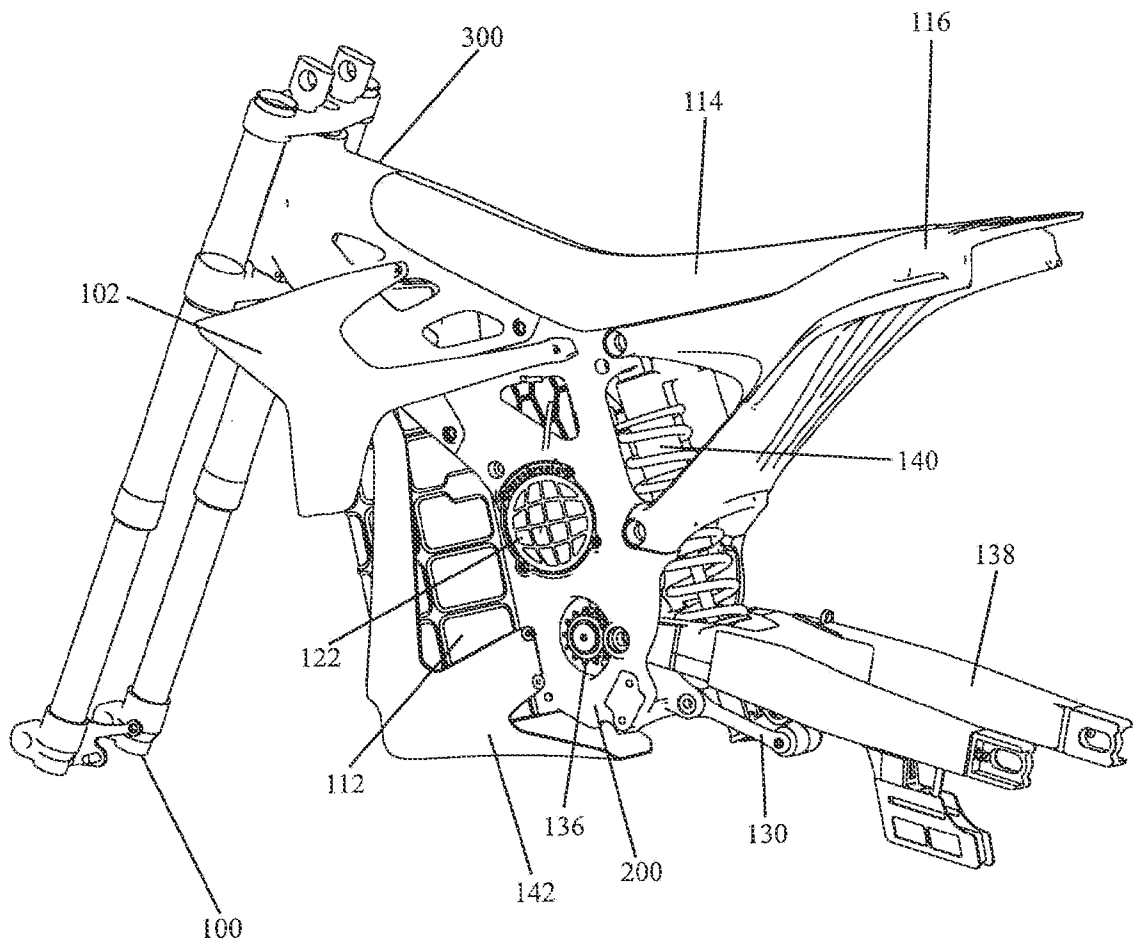


Fig. 3

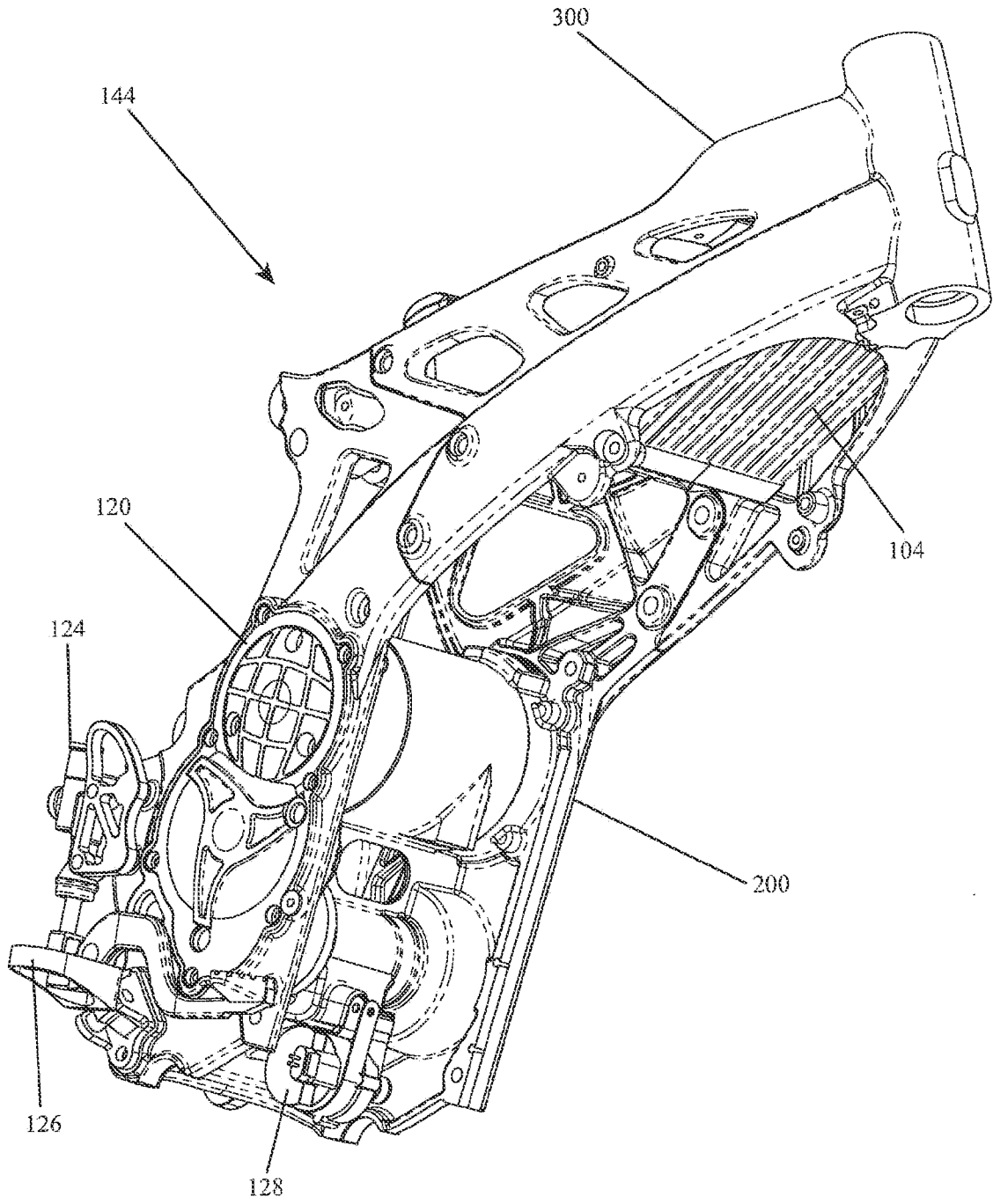


Fig. 4

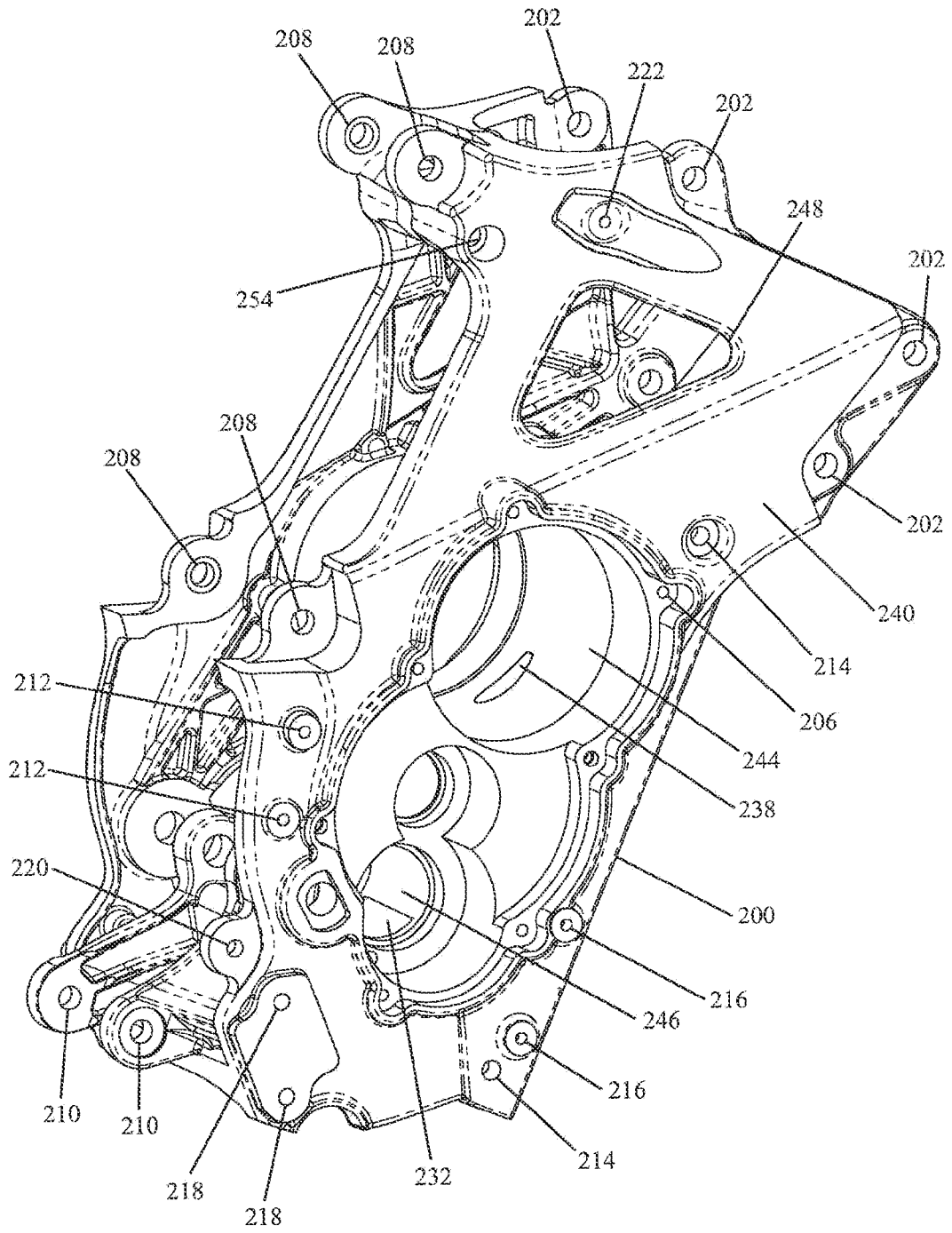


Fig. 5

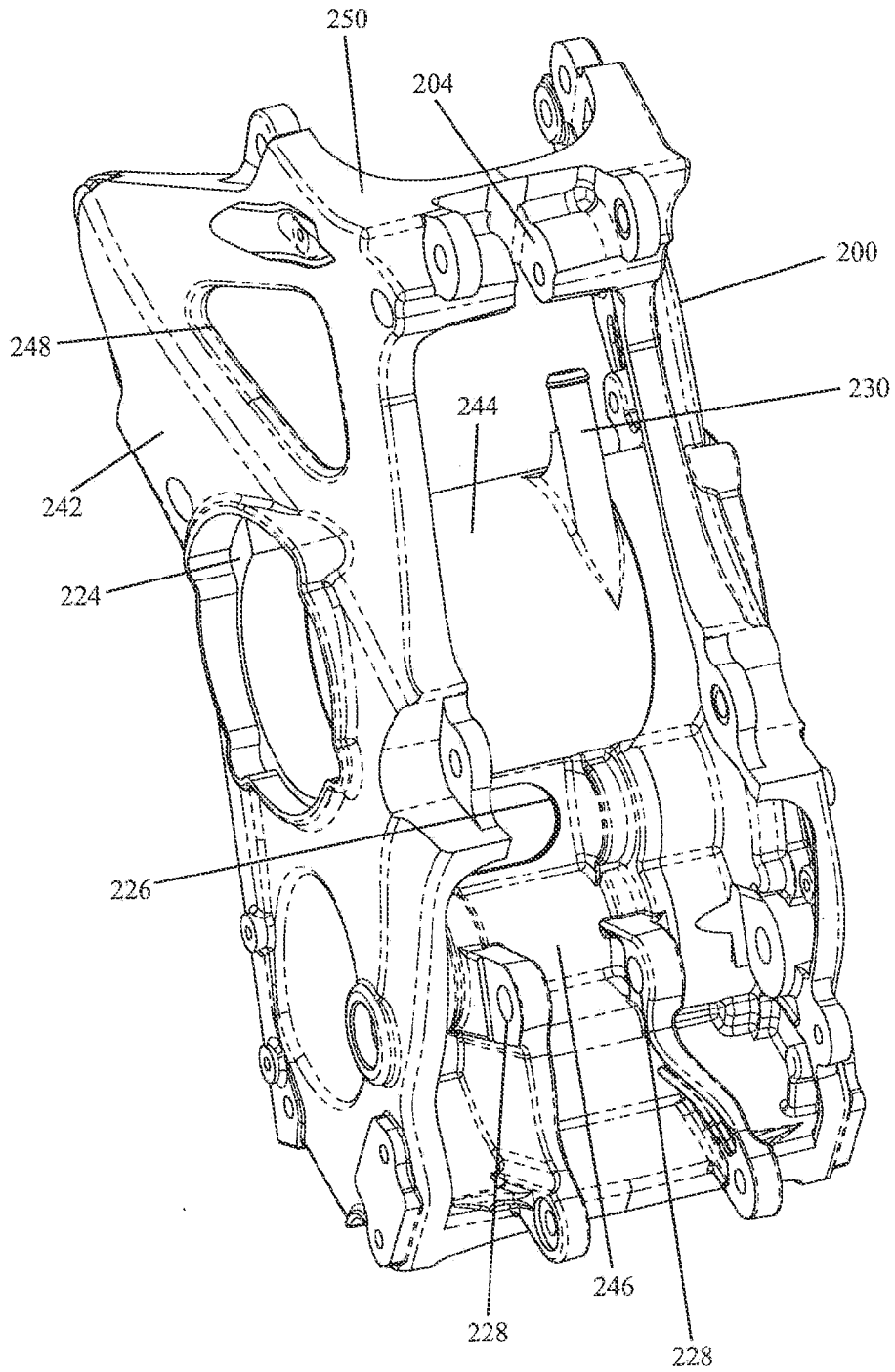
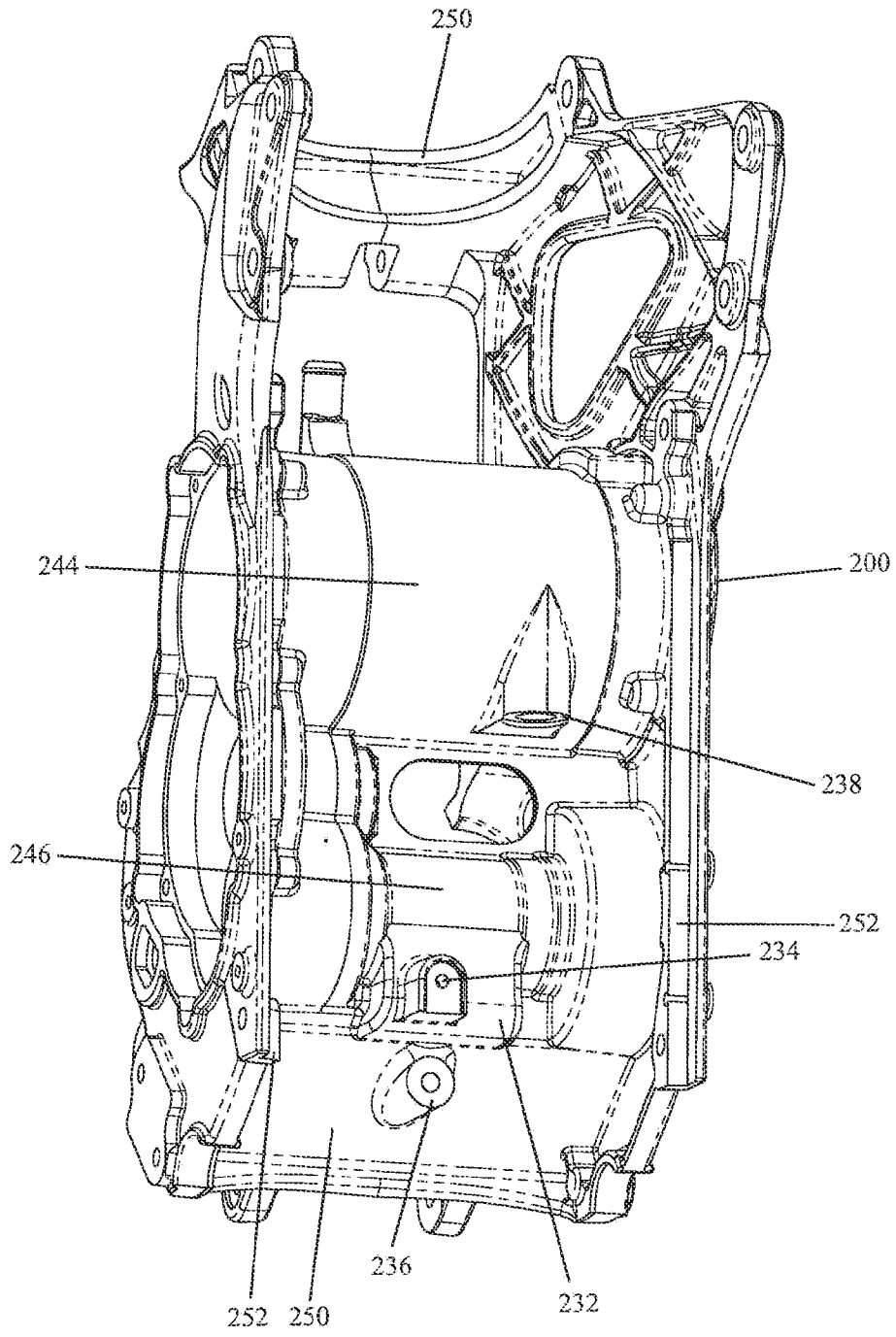


Fig. 6



**Fig. 7**

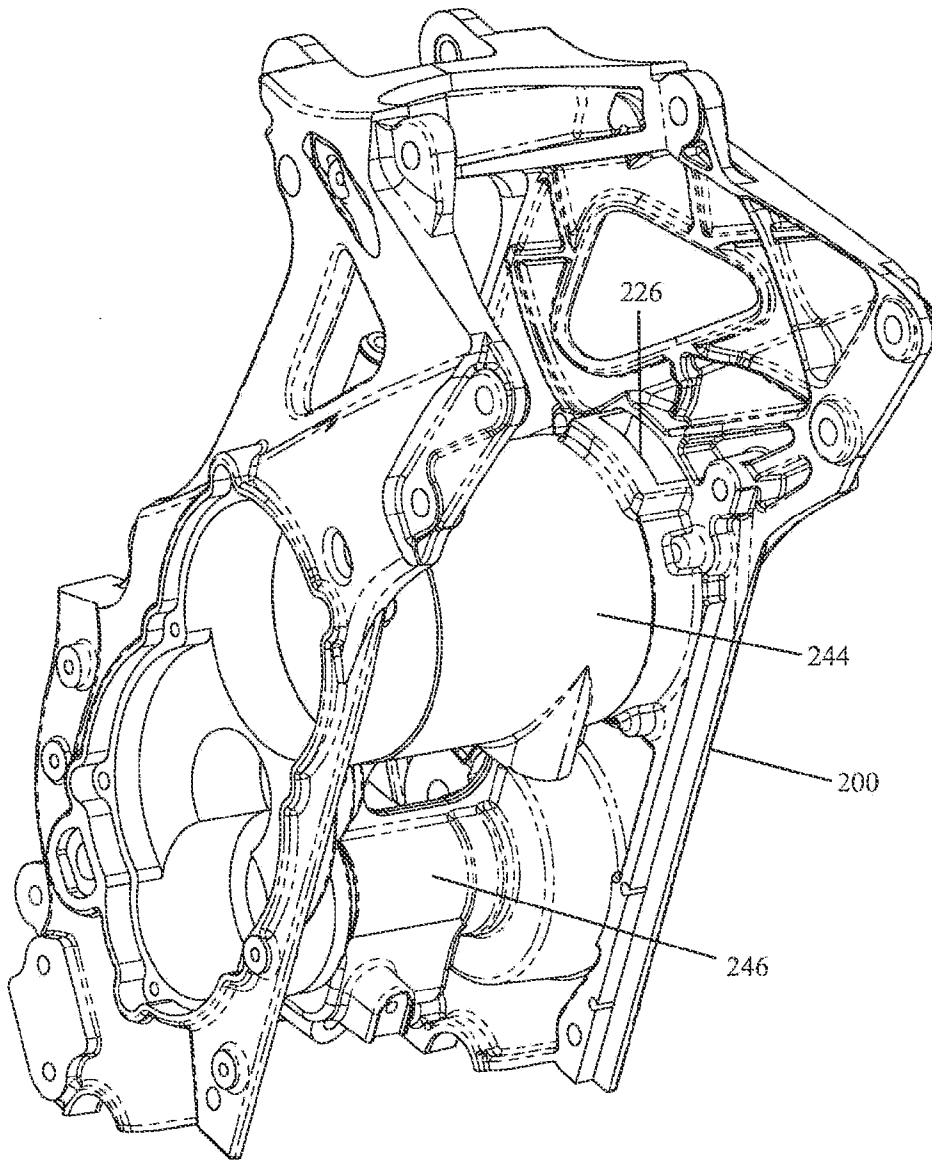


Fig. 8

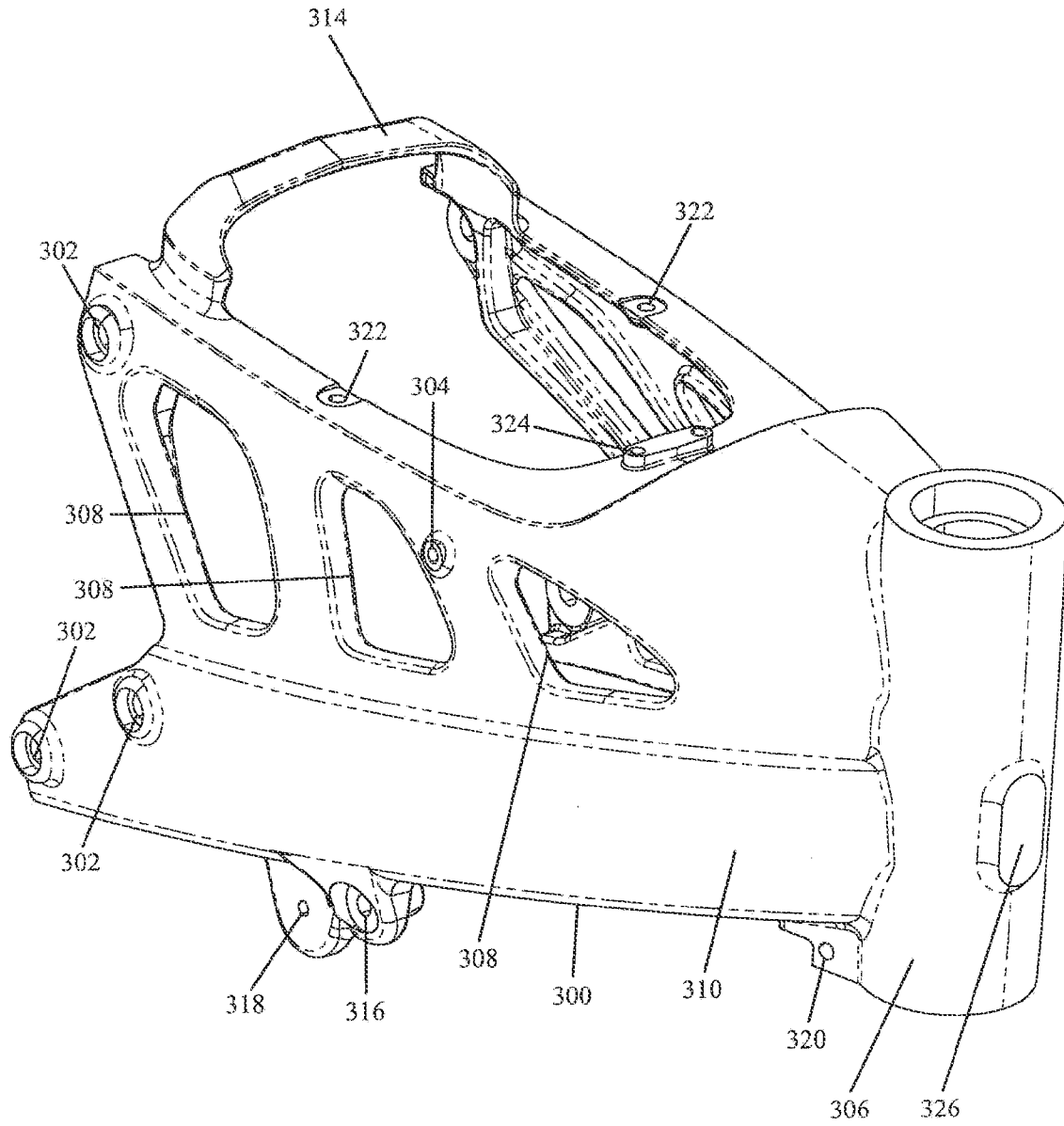


Fig. 9

