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(54) **FUEL PUMP**

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(57) **ABSTRACT**

An engaging hole-of an impeller, which receives a shaft, is formed by an impeller first planar surface, which is contactable with a shaft first planar surface, an impeller second planar surface, which is contactable with a shaft second planar surface, and an impeller first curves surface-and an impeller second curved surface, which connect between the shaft first planar surface-and the shaft second planar surface. A first groove and a second groove, which are communicated with the engaging hole, are formed in the impeller first curved surface and the impeller second curved surface, respectively. When the shaft first planar surface contacts the impeller first planar surface upon rotation of the shaft in one direction, the first groove is deformed by an applied force. Thereby, the shaft second planar surface and the impeller second planar surface contact with each other.

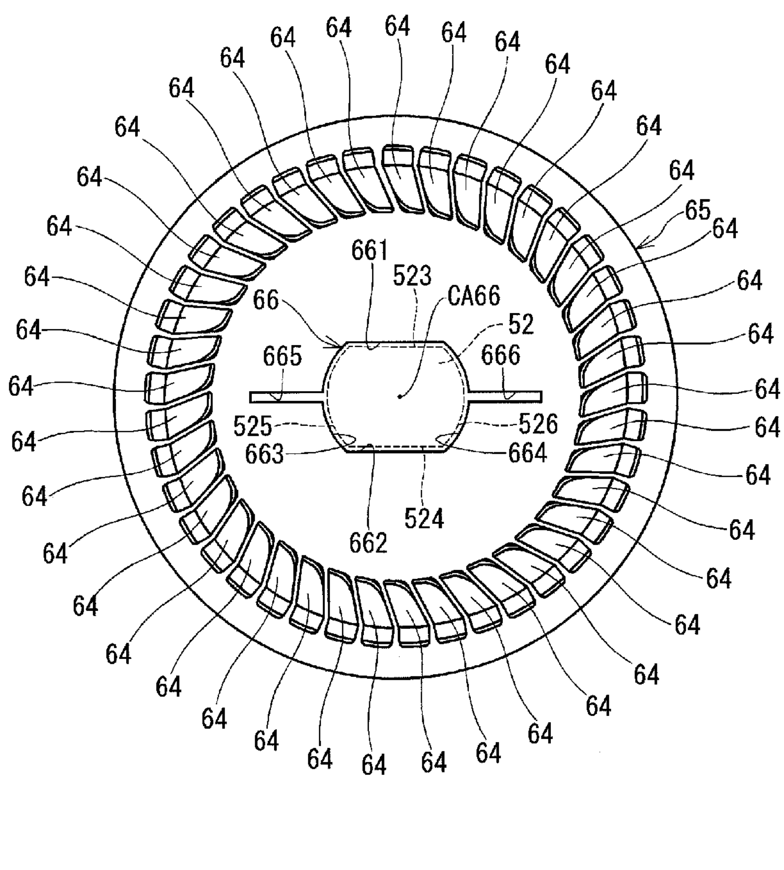
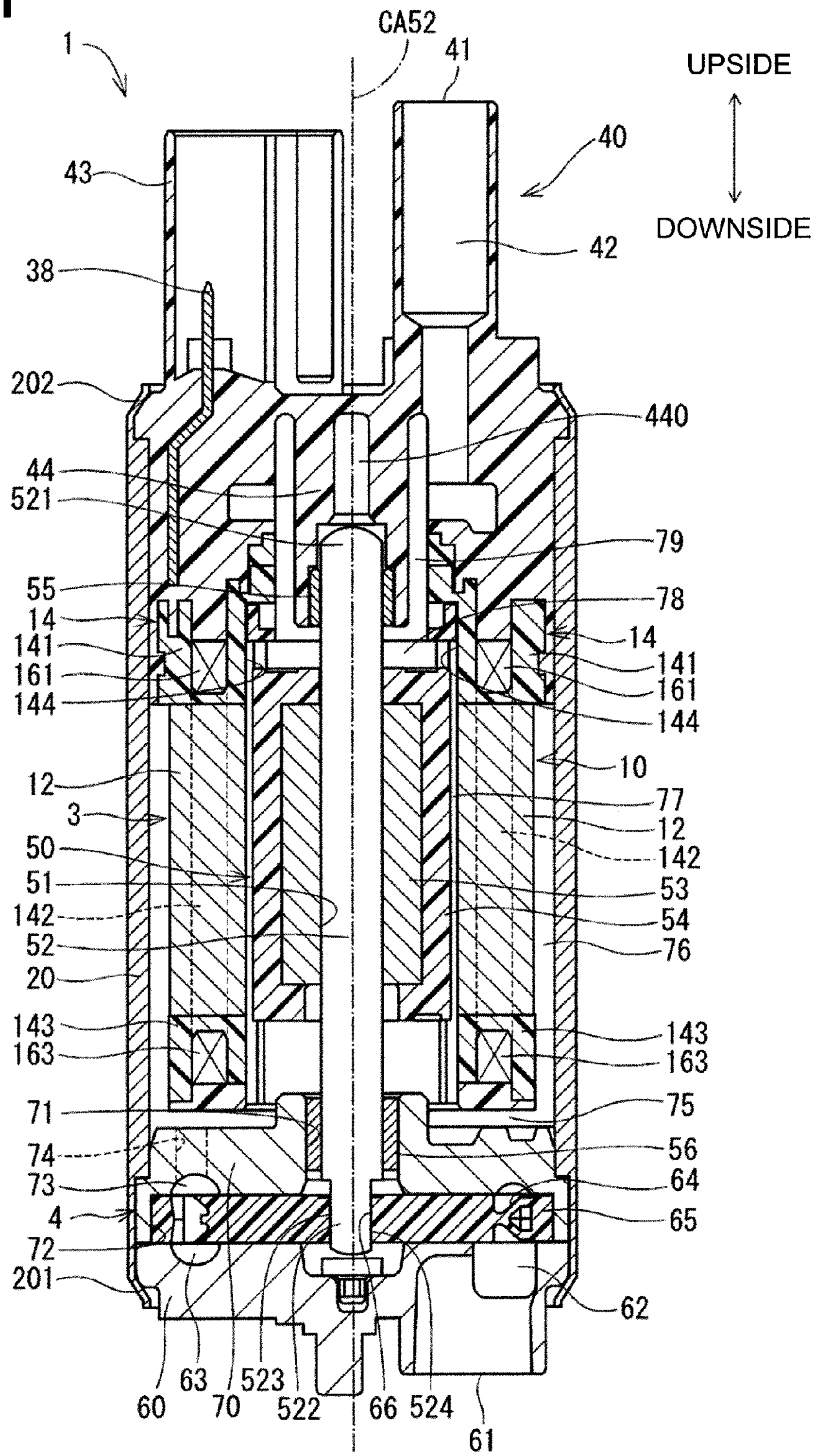


FIG. 1



1
CA52
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38
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521
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55
78
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20
143
163
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201
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70
523
522
66
524
61

FIG. 2

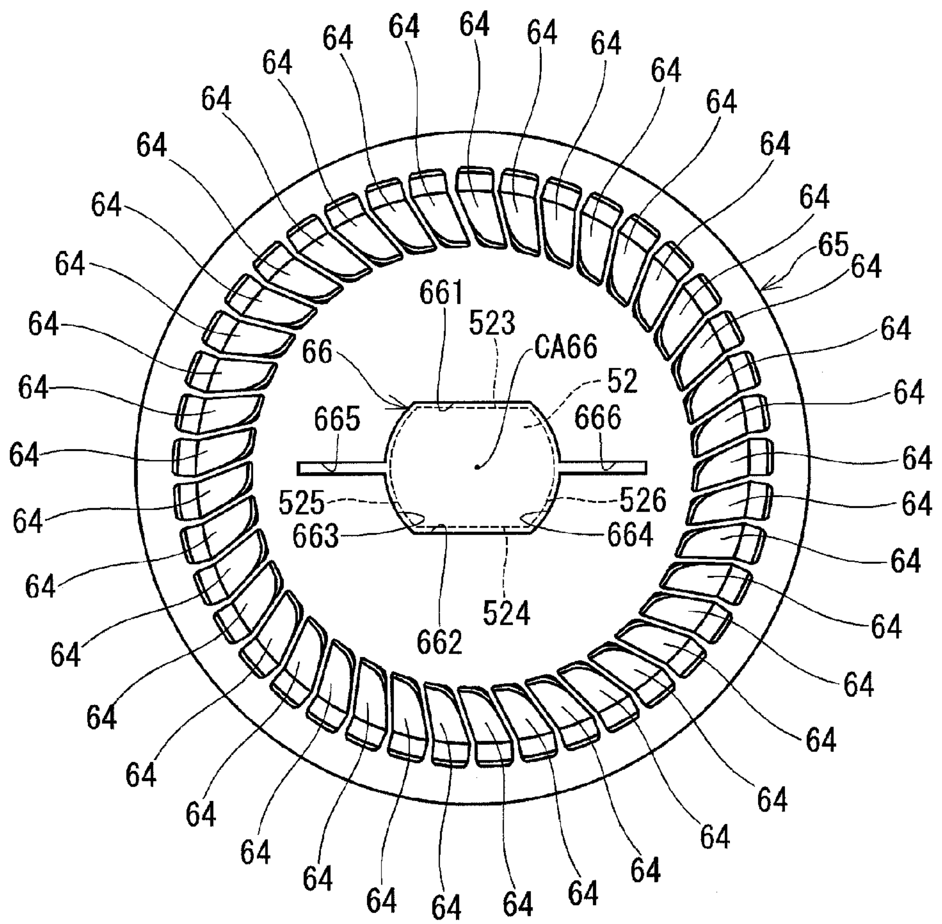


FIG. 3(a)

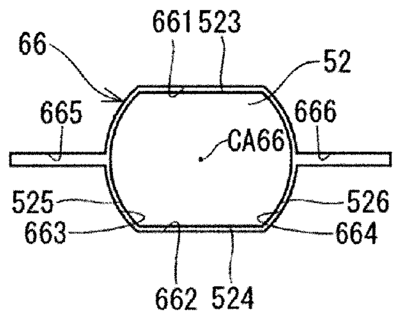


FIG. 3(b)

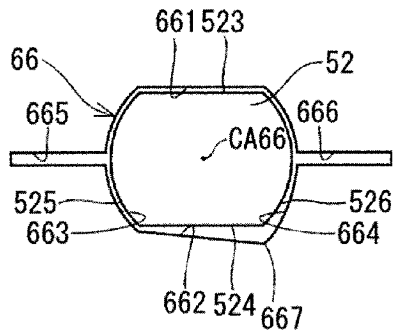


FIG. 3(c)

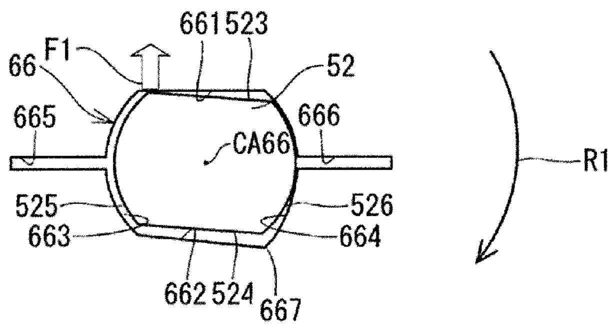


FIG. 3(d)

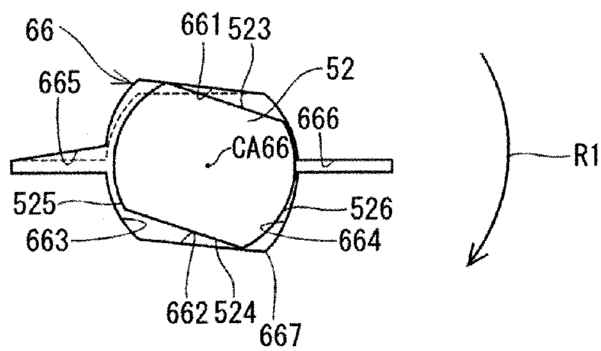
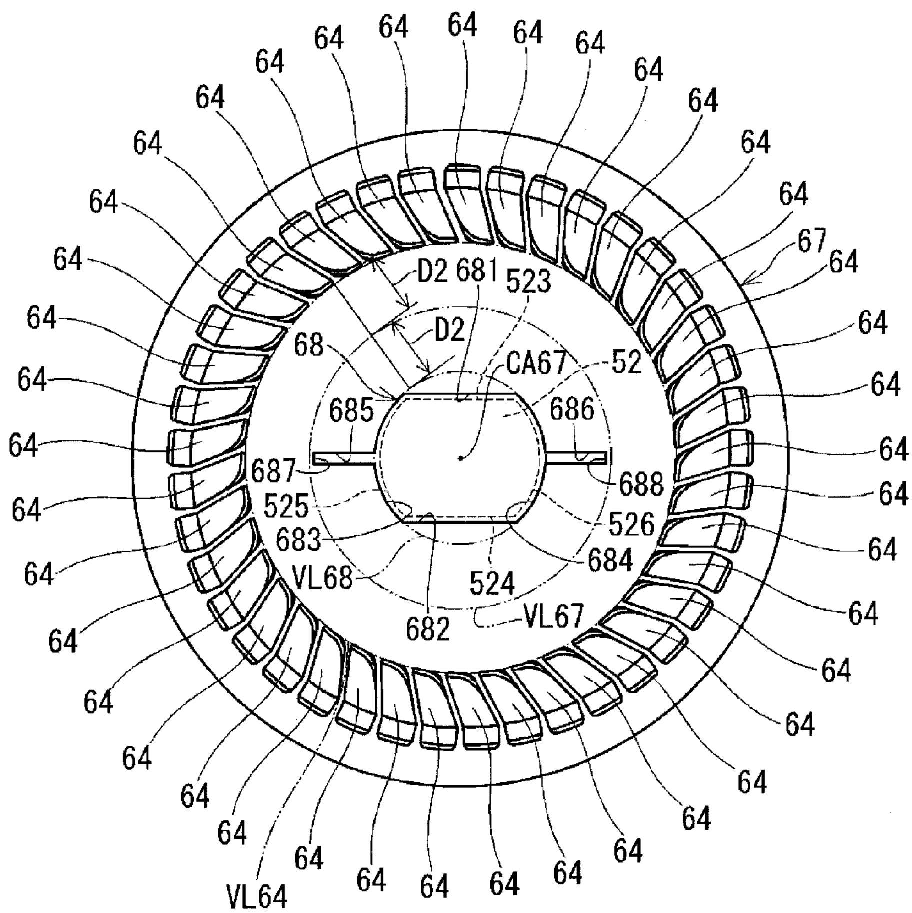


FIG. 4


64
67
D2
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523
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VL68
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VL67
VL64

FIG. 5

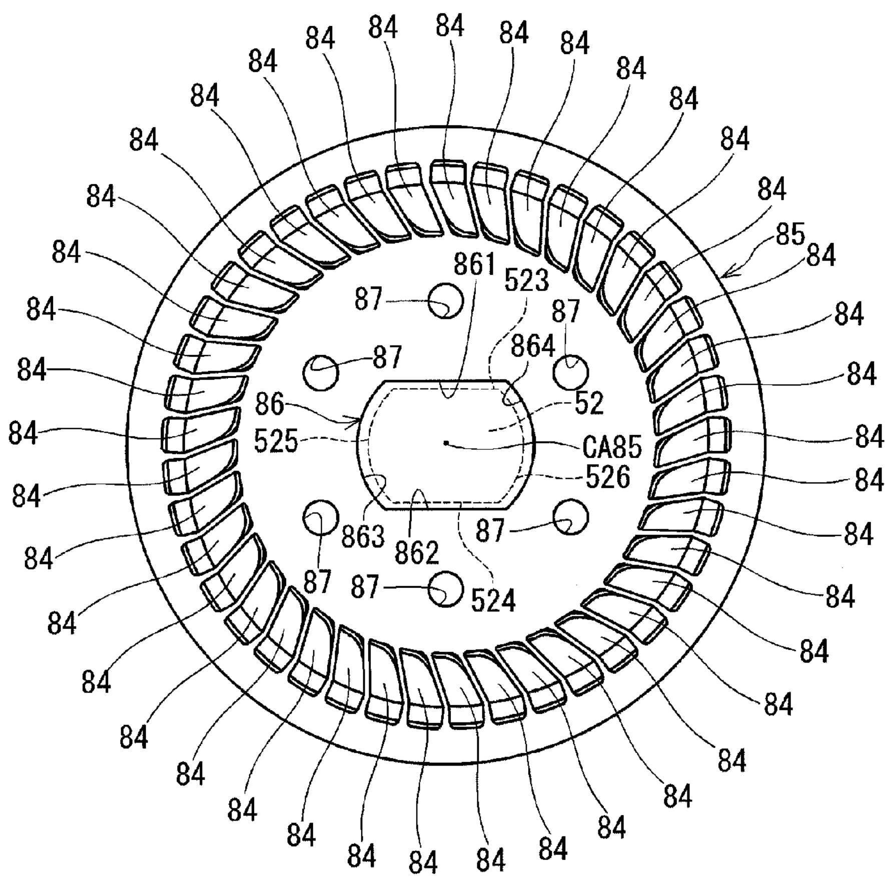


FIG. 6

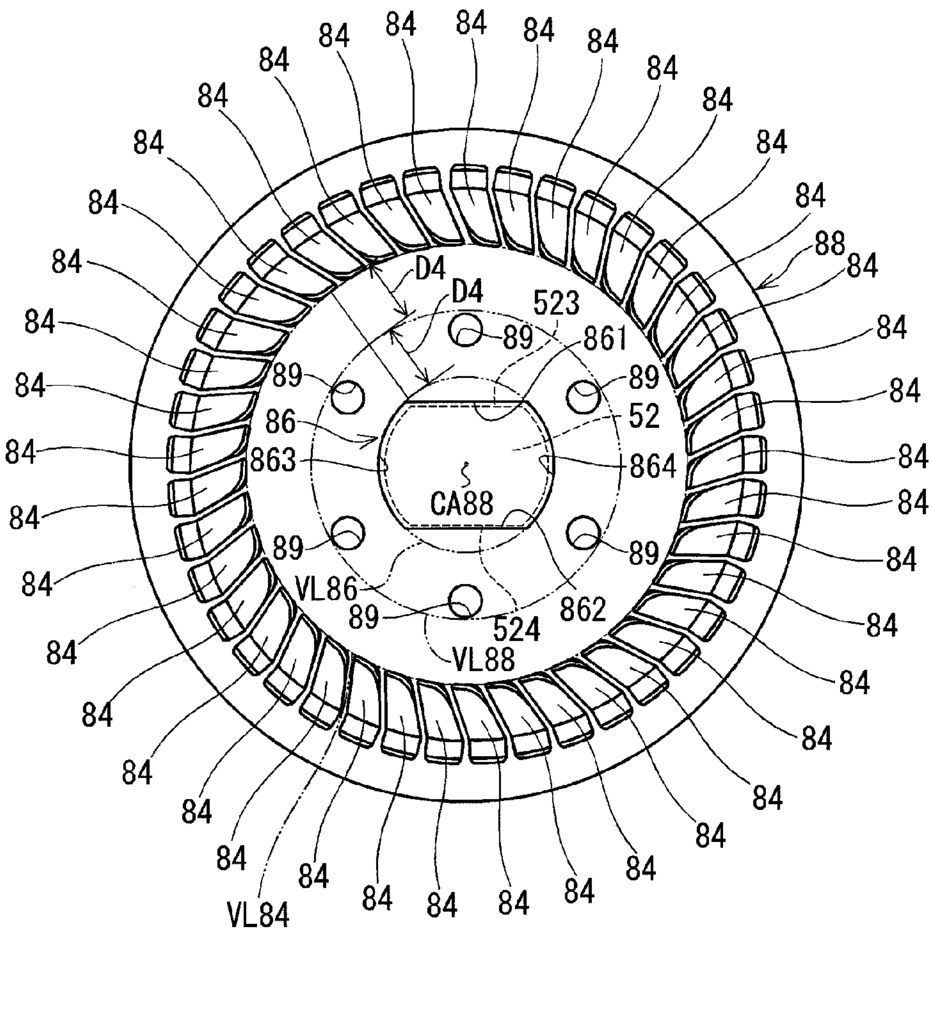
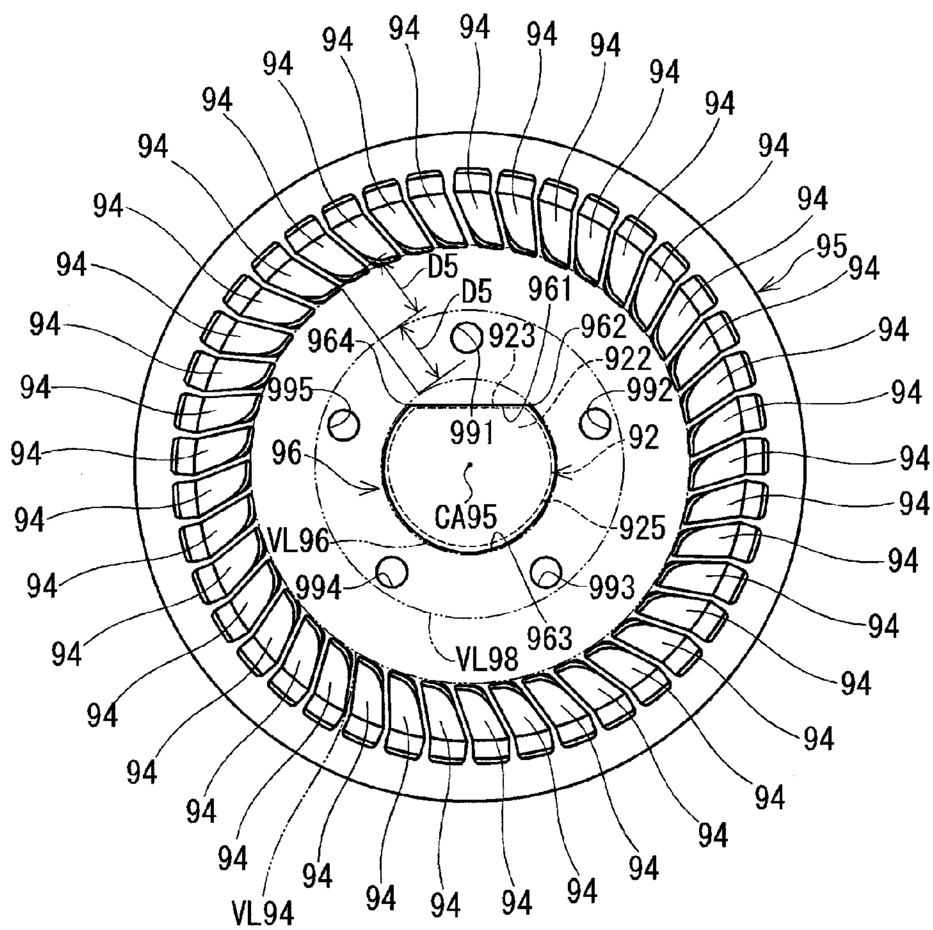


FIG. 7



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VL96
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VL98
VL94

FUEL PUMP

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is based on and incorporates herein by reference Japanese Patent Application No. 2013-196615 filed on Sep. 24, 2013 and Japanese Patent Application No. 2014-095859 filed on May 7, 2014.

TECHNICAL FIELD

[0002] The present disclosure relates to a fuel pump.

BACKGROUND ART

[0003] There is known a fuel pump that includes an impeller, which is rotatable in a pump chamber, and a motor, which generates a drive force to rotate the impeller. The fuel pump pumps fuel of a fuel tank to an internal combustion engine through rotation of the impeller. The patent literature **1** recites a fuel pump that includes an impeller. The impeller includes an engaging hole, which has a cross section of a D-shape and receives a shaft of an electric motor, and a hole, which receives a weight that corrects weight distribution of the impeller.

[0004] In a case of the fuel pump, which uses a brushless motor as the motor, the shaft is rotatable in two opposite directions, i.e., a normal direction, which is a rotational direction at the time of pressurizing the fuel with the impeller, and a reverse direction, which is a rotational direction at the time of sensing a rotational position of the rotor relative to the stator. A manufacturing tolerance exists in a size of the engaging hole of the impeller. Therefore, a gap is formed between an inner wall of the impeller, which forms the engaging hole, and a side wall of one end portion of the shaft, which is received in the engaging hole. When the operational state of the brushless motor is changed from one state, in which the one end portion of the shaft is rotatable in one of the normal direction and the reverse direction, to another state, in which the one end portion of the shaft is rotatable in the other one of the normal direction and the reverse direction, the shaft is rotated in the engaging hole, so that a rotational torque of the shaft, which is rotated with an accelerating force of a some degree, is applied to a contact surface of the engaging hole. Therefore, a damage of the impeller may possibly occur.

[0005] Furthermore, there is known another type of fuel pump, in which both of the cross section of the engaging hole and the cross-section of the one end portion of the shaft have an I-shape, so that two contact surfaces of the one end portion of the shaft simultaneously contact two contact surfaces of an inner wall of the engaging hole of the impeller. However, in the case of the impeller, which is molded through the injection molding, it is difficult to form the impeller such that the two contact surfaces of the impeller can simultaneously contact the two contact surfaces of the shaft. Therefore, at the time of contacting the shaft against the impeller, only one of the two contact surfaces of the shaft may possibly contact the impeller to possibly cause the damage of the impeller.

CITATION LIST

Patent Literature(s)

Patent Literature 1: JPH11-082208A

SUMMARY OF THE INVENTION

[0006] It is an objective of the present disclosure to provide a fuel pump, which can effectively limit a damage of an impeller.

[0007] According to the present disclosure, there is provided a fuel pump, which includes a pump case, a stator, a rotor, a shaft and an impeller. The pump case includes a suction port, through which fuel is drawn into the pump case, and a discharge port, through which the fuel is discharged from the pump case. A plurality of windings is wound around the stator, which is configured into a tubular form, and the stator is received in the pump case. The rotor is rotatably placed on a radially inner side of the stator. The shaft is coaxial with the rotor and rotates integrally with the rotor. The impeller includes an engaging hole, which receives one end portion of the shaft. When the impeller is rotated integrally with the shaft, the impeller pressurizes the fuel drawn through the suction port and discharges the pressurized fuel through the discharge port. The one end portion of the shaft includes at least one shaft side contact surface that is contactable with the impeller. The engaging hole includes at least one impeller side contact surface, which opposes the at least one shaft side contact surface and is contactable with the at least one shaft side contact surface. The impeller includes at least one deformation enabling space that is deformed when the at least one shaft side contact surface and the at least one impeller side contact surface contact with each other.

[0008] In the fuel pump of the present disclosure, the shaft and the impeller are formed such that the shaft and the impeller integrally rotate while the shaft side contact surface and the impeller side contact surface contact with each other. When the impeller is rotated integrally with the shaft, the shaft side contact surface and the impeller side contact surface may possibly contact with each other in an incorrect state depending on the processing accuracy of the engaging hole and/or the position of the shaft relative to the engaging hole. In the impeller of the fuel pump of the present disclosure, when the shaft side contact surface and the impeller side contact surface contact with each other, the deformable space is deformed by a force, which is applied from the shaft to the impeller. When the deformable space is deformed, the resiliently deformable amount of the impeller is increased. Therefore, the shape of the engaging hole is changed, and the shaft side contact surface correctly contacts the impeller side contact surface. As discussed above, in the fuel pump of the present disclosure, the shaft side contact surface and the impeller side contact surface can correctly contact with each other through the deformation of the deformation enabling space without being influenced by the processing accuracy of the engaging hole and/or the position of the shaft relative to the engaging hole. Thus, the surface pressure, which is applied to the impeller at the time of rotating the shaft, becomes small, and the damage of the impeller can be effectively limited.

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. **1** is a cross-sectional view of a fuel pump according to a first embodiment of the present disclosure.

[0010] FIG. **2** is a top view of an impeller of the fuel pump of the first embodiment.

[0011] FIGS. **3**(*a*) to **3**(*d*) are schematic diagrams for describing an operation of the fuel pump according to the first embodiment.

[0012] FIG. **4** is a top view of an impeller of a fuel pump according to a second embodiment of the present disclosure.

[0013] FIG. **5** is a top view of an impeller of a fuel pump according to a third embodiment of the present disclosure.

[0014] FIG. **6** is a top view of an impeller of a fuel pump according to a fourth embodiment of the present disclosure.

[0015] FIG. **7** is a top view of an impeller of a fuel pump according to a fifth embodiment of the present disclosure.

DESCRIPTION OF EMBODIMENTS

[0016] Various embodiments of the present disclosure will be described with reference to the accompanying drawings.

First Embodiment

[0017] A fuel pump according to a first embodiment of the present disclosure will be described with reference to FIGS. **1** to **3**(*d*).

[0018] The fuel pump **1** includes a motor device **3**, a pump device **4**, a housing **20**, a pump cover **60** and a cover end **40**. In the fuel pump **1**, the motor device **3** and the pump device **4** are received in a space, which is formed by the housing **20**, the pump cover **60** and the cover end **40**. The fuel pump **1** draws fuel from a fuel tank (not shown) through a suction port **61**, which is indicated in a lower side of FIG. **1**, and discharges the fuel toward an internal combustion engine through a discharge port **41**, which is indicated in an upper side in FIG. **1**. In FIG. **1**, the upper side will be referred to as "the upside", and the lower side will be referred to as "the downside." The housing **20**, the pump cover **60** and the cover end **40** serve as a pump case of the present disclosure.

[0019] The housing **20** is configured into a cylindrical tubular form and is made of metal (e.g., iron). The pump cover **60** and the cover end **40** are installed to two end portions **201**, **202**, respectively, of the housing **20**.

[0020] The pump cover **60** closes the end portion **201** of the housing **20**, at which the suction port **61** is located. A peripheral edge part of the end portion **201** of the housing **20** is inwardly swaged, so that the pump cover **60** is fixed at the inside of the housing **20**. Thereby, removal of the pump cover **60** from the housing **20** in the axial direction of the fuel pump **1** is limited. The pump cover **60** includes the suction port **61**, which opens toward the downside. An intake passage **62** is formed in an inside of the suction port **61** to extend through the pump cover **60** in a direction (axial direction) of a rotational axis CA**52** of a shaft **52**. A groove **63**, which is connected to the intake passage **62**, is formed in a surface of the pump cover **60**, which is located on a side where the pump device **4** is placed.

[0021] The cover end **40** is made of resin and closes the end portion **202** of the housing **20**, at which the discharge port **41** is located. A peripheral edge part of the end portion **202** of the housing **20** is swaged, so that the cover end **40** is fixed in the inside of the housing **20**. Therefore, the removal of the cover end **40** from the housing **20** in the axial direction of the fuel pump **1** is limited. The cover end **40** includes the discharge port **41**, which opens toward the upside. A discharge passage **42** is formed in an inside of the discharge port **41** to extend through the cover end **40** in the direction of the rotational axis CA**52** of the shaft **52**. An electric connector portion **43**, which receives three connecting terminals **38** to receive an electric power from an outside, is formed in an end portion of the cover end **40**, which is located on a side that is opposite from the side where the discharge passage **42** is formed.

[0022] A bearing receiving portion **44**, which is configured into a generally tubular form, is formed in an inside of the cover end **40**, which is placed in the inside of the housing **20**. The bearing receiving portion **44** includes a receiving space **440** that is formed in an inside of the bearing receiving portion **44** to receive an end portion **521** of the shaft **52** and a bearing **55**. The bearing **55** rotatably supports the end portion **521** of the shaft **52**.

[0023] The motor device **3** generates a rotational torque through use of a magnetic field that is generated when the electric power is supplied to the motor device **3**. The motor device **3** includes a stator **10**, a rotor **50** and the shaft **52**. The motor device **3** of the fuel pump **1** of the first embodiment is a brushless motor that senses a position of the rotor **50** relative to the stator **10** through sensing of rotation of the shaft **52**.

[0024] The stator **10** is configured into a cylindrical tubular form and is received at a radially outer side location in the inside of housing **20**. The stator **10** includes six cores **12**, six bobbins, six windings and the three connecting terminals. The stator **10** is integrally formed through resin molding of these components.

[0025] Each core **12** is formed by stacking a plurality of plates, which are made of a magnetic material (e.g., iron). The cores **12** are arranged one after another in a circumferential direction to radially oppose a magnet **54** of the rotor **50**.

[0026] The bobbins **14** are made of a resin material. At the time of manufacturing, the cores **12** are inserted into and integrated with the bobbins **14**, respectively. Each bobbin **14** includes an upper end portion **141**, an insert portion **142** and a lower end portion **143**. The upper end portion **141** is formed on the discharge port **41** side. Each core **12** is inserted into the insert portion **142** of the corresponding bobbin **14**. The lower end portion **143** is formed on the suction port **61** side.

[0027] Each of the windings is, for example, a copper wire that has an outer surface coated with a dielectric film. Each winding is wound around the corresponding bobbin **14**, into which the core **12** is inserted, to form one coil. Each winding includes an upper end winding portion **161**, an insert winding portion (not shown) and a lower end winding portion **163**. The upper end winding portion **161** is wound around the upper end portion **141** of the corresponding bobbin **14**. The insert winding portion is wound around the insert portion **142** of the bobbin **14**. The lower end winding portion **163** is wound around the lower end portion **143** of the bobbin **14**. The windings are electrically connected to the connecting terminals **38** received in the electric connector portion **43**.

[0028] Each connecting terminal **38** extends through the cover end **40** and is fixed to the upper end portion **141** of the corresponding bobbin **14**. In the fuel pump **1** of the first embodiment, the number of the connecting terminals **38** is three, and these connecting terminals **38** receive the three-phase electric power from an electric power source device (not shown).

[0029] The rotor **50** is rotatably received on the inner side of the stator **10**. The rotor **50** includes the magnet **54**, which is placed to surround an iron core **53**. The magnet **54** is magnetized to have N-poles and S-poles, which are alternately arranged one after another in the circumferential direction. In the first embodiment, the number of pole pairs of the N-pole and the S-pole is two, so that the total number of the poles is four.

[0030] The shaft **52** is securely press fitted into a shaft hole **51** of the rotor **50**, which extends along a central axis of the rotor **50**, and the shaft **52** is rotated integrally with the rotor **50**. An end portion **522** of the shaft **52**, which serves as one end portion of the shaft **52** of the present disclosure and is located on the suction port **61** side, is connected to the pump device **4**.

[0031] The end portion **522** of the shaft **52** includes a shaft first planar surface (serving as a shaft side first contact surface or a shaft side contact surface) **523**, which extends in the vertical direction and is formed as a planar surface, and a shaft second planar surface (serving as a shaft side second contact surface or a shaft side contact surface) **524**, which is formed as a planar surface and is generally parallel to the shaft first planar surface **523**. The end portion **522** of the shaft **52** includes a shaft first curved surface **525** and a shaft second curved surface **526**. The shaft first curved surface **525** connects between one side of the shaft first planar surface **523** and one side of the shaft second planar surface **524** and is formed as a curved surface. The shaft second curved surface **526** connects between another side of the shaft first planar surface **523** and another side of the shaft second planar surface **524** and is formed as a curved surface. In this way, a cross section of the end portion **522** of the shaft **52**, which is taken in a direction perpendicular to the rotational axis CA**52** of the shaft **52**, has a generally I-shape.

[0032] The pump device **4** pressurizes the fuel drawn through the suction port **61** and discharges the pressurized fuel into the inside of the housing **20** through use of the rotational torque generated by the motor device **3**. The pump device **4** includes a pump casing **70** and an impeller **65**.

[0033] The pump casing **70** is configured into a generally circular disk form and is placed between the pump cover **60** and the stator **10**. A through-hole **71** is formed in a center portion of the pump casing **70** to extend through the pump casing **70** in a plate thickness direction of the pump casing **70**. A bearing **56** is fitted into the through-hole **71**. The bearing **56** rotatably supports the end portion **522** of the shaft **52**. In this way, the rotor **50** and the shaft **52** are rotatable relative to the cover end **40** and the pump casing **70**.

[0034] In a surface of the pump casing **70**, which is axially placed on the impeller **65** side, a groove **73** is formed at a location that is opposed to the groove **63** of the pump cover **60**. A fuel passage **74**, which extends through the pump casing **70** in the direction of the rotational axis CA**52** of the shaft **52**, is communicated with the groove **73**.

[0035] The impeller **65** is made of resin and is configured into a generally circular disk form. The impeller **65** is received in a pump chamber **72**, which is formed between the pump cover **60** and the pump casing **70**.

[0036] An engaging hole **66** is formed generally in a center of the impeller **65**. A cross section of the engaging hole **66** is configured to have a generally I-shape to correspond with the cross section of the end portion **522** of the shaft **52**. The end portion **522** of the shaft **52** is received in the engaging hole **66**. In this way, the impeller **65** is rotated in the pump chamber **72** by the rotation of the shaft **52**. The details of the shape of the impeller **65** will be described later.

[0037] The impeller **65** includes a plurality of tilt surfaces **64**, which are placed at a location that corresponds to the grooves **63**, **73**. As shown in FIG. **2**, the tilt surfaces **64** are arranged one after another at generally equal intervals in the circumferential direction in a radially outer end part of the impeller **65**.

[0038] In the fuel pump **1** of the first embodiment, when the electric power is supplied to the windings of the motor device **3** through the terminals **38**, the impeller **65** is rotated together with the rotor **50** and the shaft **52**. When the impeller **65** is rotated, the fuel in the fuel tank, which receives the fuel pump **1**, is guided to the groove **63** through the suction port **61**. The fuel, which is guided to the groove **63**, is pressurized through the rotation of the impeller **65** and is guided to the groove **73**. The pressurized fuel is guided to an intermediate chamber **75**, which is formed between the pump casing **70** and the motor device **3**, through the fuel passage **74**. The fuel, which is guided to the intermediate chamber **75**, is conducted through a fuel passage **77**, which is formed between the rotor **50** and the stator **10**, a fuel passage **78**, which is formed between an outer wall of the shaft **52** and inner walls **144** of the bobbins **14**, and a fuel passage **79**, which is formed on a radially outer side of the bearing receiving portion **44**. Furthermore, the fuel, which is guided to the intermediate chamber **75**, is conducted through a fuel passage **76** that is formed between an inner wall of the housing **20** and an outer wall of the stator **10**. The fuel, which flows through the fuel passages **76**, **77**, **78**, **79**, is discharged to the outside of the fuel pump **1** through the discharge passage **42** and the discharge port **41**.

[0039] The fuel pump **1** of the first embodiment has a characteristic feature with respect to a shape of the impeller **65**. Now, the details of the shape of the impeller **65** will be described with reference to FIGS. **2** to **3**(*d*). FIG. **2** is a top view of the impeller **65**. FIGS. **3**(*a*) to **3**(*d*) are schematic diagrams showing a positional relationship between the engaging hole **66** and the shaft **52** at the time of driving the fuel pump **1**. Here, it should be noted that the shape of the engaging hole **66** of FIGS. **3**(*b*) to **3**(*d*) is exaggerated in comparison to the actual shape of the engaging hole **66** for the descriptive purpose.

[0040] The engaging hole **66** of the impeller **65** is formed by an impeller first planar surface (serving as an impeller side first contact surface or an impeller side contact surface) **661**, an impeller second planar surface (serving as an impeller side second contact surface or an impeller side contact surface) **662**, an impeller first curved surface (serving as an engaging hole first forming surface or an engaging hole forming surface) **663** and an impeller second curved surface (serving as an engaging hole second forming surface or an engaging hole forming surface) **664**.

[0041] The impeller first planar surface **661** is a planar surface that is formed to extend in a direction (axial direction) of a central axis CA**66** of the engaging hole **66**. The central axis CA**66** also serves as a central axis of the impeller **65**. The impeller first planar surface **661** is formed at a corresponding location, at which the impeller first planar surface **661** opposes the shaft first planar surface **523**. When the shaft **52** is rotated, the impeller first planar surface **661** is contactable with the shaft first planar surface **523**.

[0042] The impeller second planar surface **662** is a planar surface that is formed to extend in the direction of the central axis CA**66**. The impeller second planar surface **662** is generally parallel to the impeller first planar surface **661**. The impeller second planar surface **662** is formed at a corresponding location, at which the impeller second planar surface **662** opposes the shaft second planar surface **524**. When the shaft **52** is rotated, the impeller second planar surface **662** is contactable with the shaft second planar surface **524**.

[0043] The impeller first curved surface **663** connects between one side of the impeller first planar surface **661**, which is parallel to the central axis CA**66**, and one side of the impeller second planar surface **662**, which is parallel to the central axis CA**66**. A cross section of the impeller first curved surface **663** is generally configured into a shape of an arc, which is centered at the central axis CA**66** and is radially outwardly bulged. A first groove (serving as a deformation enabling space) **665** is formed generally in a center (circumferential center) of the impeller first curved surface **663**.

[0044] The impeller second curved surface **664** connects between another side of the impeller first planar surface **661**, which is parallel to the central axis CA**66**, and another side of the impeller second planar surface **662**, which is parallel to the central axis CA**66**. A cross section of the impeller second curved surface **664** is generally configured into a shape of an arc, which is centered at the central axis CA**66** and is radially outwardly bulged. A second groove (serving as a deformation enabling space) **666** is formed generally in a center (circumferential center) of the impeller second curved surface **664**.

[0045] The first groove **665** is configured into a form of a slit and extends from the impeller first curved surface **663** in the radially outward direction. The first groove **665** is formed to communicate with the engaging hole **66** and extends through the impeller **65** in the direction of the central axis CA**66**.

[0046] The second groove **666** is configured into a form of a slit and extends from the impeller second curved surface **664** in the radially outward direction. The second groove **666** is formed to communicate with the engaging hole **66** and extends through the impeller **65** in the direction of the central axis CA**66**.

[0047] The first groove **665** and the second groove **666** extend in opposite directions, respectively, which are opposite to each other when the first groove **665** and the second groove **666** are viewed from the central axis CA**66**. Furthermore, a radial length of the first groove **665** and a radial length of the second groove **666** are equal to each other.

[0048] Now, the operation and advantages of the fuel pump **1** of the first embodiment will be described with reference to FIGS. **3**(*a*) to **3**(*d*).

[0049] In the fuel pump **1** of the first embodiment, as shown in FIG. **3**(*a*), it is desirable to satisfy the relationship of that when the shaft first planar surface **523** of the shaft **52** and the impeller first planar surface **661** of the engaging hole **66** are placed parallel to each other, the shaft second planar surface **524** of the shaft **52** and the impeller second planar surface **662** of the engaging hole **66** are placed parallel to each other.

[0050] However, in the case of the impeller **65**, which is made of resin and is formed through injection molding, it is difficult to form the impeller **65** in a manner that satisfies the above relationship. Therefore, in some cases, for example, in a state where the shaft first planar surface **523** and the impeller first planar surface **661** are placed parallel to each other, the shaft second planar surface **524** and the impeller second planar surface **662** may not be parallel to each other.

[0051] For instance, in some cases, as shown in FIG. **3**(*b*), the engaging hole **66** may be formed such that although the shaft first planar surface **523** and the impeller first planar surface **661** are held parallel to each other, the shaft second planar surface **524** and the impeller second planar surface **662** are not parallel to each other, and an intersection line **667** between the impeller second planar surface **662** and the impeller second curved surface **664** is held further away from the point along the central axis CA**66** of the engaging hole **66**.

[0052] In the case of the engaging hole **66**, which is configured into the shape shown in FIG. **3**(*b*), when the shaft **52** is rotated in a direction R**1** indicated by a solid arrow, the shaft first planar surface **523** and the impeller first planar surface **661** contact with each other, and the shaft second planar surface **524** and the impeller second planar surface **662** are spaced away from each other. The shaft **52** and the impeller **65** are further rotated in the direction R**1** in this state. At this time, a force F**1** is applied between the shaft first planar surface **523** and the impeller first planar surface **661** in a direction that is from the shaft first planar surface **523** to the impeller first planar surface **661**. Because of the applied force F**1**, the impeller **65** is deformed such that the first groove **665** is expanded, as shown in FIG. **3**(*d*). Due to the deformation of the first groove **665**, the shape of the engaging hole **66** is changed such that the shaft second planar surface **524** and the impeller second planar surface **662**, which were previously spaced from each other, now contact with each other. In FIG. **3**(*d*), a dotted line indicates the shape of the engaging hole **66** and the shape of the first groove **665** before the occurrence of the deformation of the first groove **665**.

[0053] Here, it is described that the two planar surfaces of the shaft **52** contact the two planar surfaces of the impeller **65** due to the expansion of the first groove **665**. This phenomenon may also occur in the second groove **666**.

[0054] Now, advantages of the first embodiment will be described.

[0055] (a) In the fuel pump **1** of the first embodiment, when the shaft **52** contacts one of the impeller first planar surface **661** and the impeller second planar surface **662** upon rotation of the shaft **52** in the engaging hole **66**, the first groove **665** or the second groove **666** is deformed to cause the change in the shape of the engaging hole **66**. When the shape of the engaging hole **66** is changed, the other one of the shaft first planar surface **523** and the shaft second planar surface **524**, which does not contact the one of the impeller first planar surface **661** and the impeller second planar surface **662**, contacts the other one of the impeller first planar surface **661** and the impeller second planar surface **662**. Thereby, the two planar surfaces of the shaft **52** contact the inner wall of the engaging hole **66**. In this way, the rotational torque of the shaft **52** is applied to both of the impeller first planar surface **661** and the impeller second planar surface **662**, and thereby the surface pressure of the rotational torque applied to the impeller **65** is reduced. Therefore, the surface pressure, which is applied to the impeller **65**, becomes relatively small, and thereby it is possible to effectively limit the damage of the impeller **65** caused by the rotational torque of the shaft **52**.

[0056] (b) Furthermore, in the fuel pump **1** of the first embodiment, at the time of molding the impeller **65** through the injection molding, it is no longer required to precisely control the parallelism of the impeller first planar surface **661** relative to the shaft first planar surface **523** and the parallelism of the impeller second planar surface **662** relative to the shaft second planar surface **524**. Thereby, the two planar surfaces of the shaft **52** can contact the two planar surfaces of the engaging hole **66** while the number of the manufacturing steps of the fuel pump **1** is reduced. Therefore, the manufacturing costs of the fuel pump **1** can be reduced.

[0057] (c) The first groove **665** and the second groove **666** are formed in the center of the impeller first curved surface **663** and the center of the impeller second curved surface **664**, respectively, which are opposed to each other. The first groove **665** and the second groove **666** extend for the same length in the two opposite directions, respectively, which are opposite to each other when the two opposite directions are viewed from the central axis CA**66**. In this way, when the rotational torque of the shaft **52** is applied to the impeller first planar surface **661** or the impeller second planar surface **662**, the impeller **65** is deformed to the similar shape. Thereby, the concentration of the stress on any particular portion of the impeller **65** can be limited. Thus, it is possible to limit the damage of the impeller **65** caused by the rotational torque of the shaft **52**.

Second Embodiment

[0058] Next, a fuel pump according to a second embodiment of the present disclosure will be described with reference to FIG. **4**. The second embodiment differs from the first embodiment with respect to the shape of the impeller. In the following description, components, which are similar to those of the first embodiment, will be indicated by the same reference numerals and will not be described further.

[0059] FIG. **4** is a top view of an impeller **67** of a fuel pump according to the second embodiment. An engaging hole **68** is formed generally in a center of the impeller **67**. The end portion **522** of the shaft **52** is received in the engaging hole **66**.

[0060] A cross section of the engaging hole **68** is configured to have a generally I-shape to correspond with the cross section of the end portion **522** of the shaft **52**. The engaging hole **68** is formed by an impeller first planar surface (serving as an impeller side first contact surface or an impeller side contact surface) **681**, an impeller second planar surface (serving as an impeller side second contact surface or an impeller side contact surface) **682**, an impeller first curved surface (serving as an engaging hole first forming surface or an engaging hole forming surface) **683** and an impeller second curved surface (serving as an engaging hole second forming surface or an engaging hole forming surface) **684**.

[0061] The impeller first planar surface **681** is formed to extend in a direction of a central axis CA**67** of the engaging hole **68**. The impeller first planar surface **681** is formed at a corresponding location, at which the impeller first planar surface **681** opposes the shaft first planar surface **523**. When the shaft **52** is rotated, the impeller first planar surface **681** is contactable with the shaft first planar surface **523**.

[0062] The impeller second planar surface **682** is a planar surface that is formed to extend in the direction of the central axis CA**67**. The impeller second planar surface **682** is generally parallel to the impeller first planar surface **681**. The impeller second planar surface **682** is formed at a corresponding location, at which the impeller second planar surface **662** opposes the shaft second planar surface **524**. When the shaft **52** is rotated, the impeller second planar surface **682** is contactable with the shaft second planar surface **524**.

[0063] The impeller first curved surface **683** connects between one side of the impeller first planar surface **681**, which is parallel to the central axis CA**67**, and one side of the impeller second planar surface **682**, which is parallel to the central axis CA**67**. A cross section of the impeller first curved surface **683** is configured into a shape of an arc, which is centered at the point along the central axis CA**67** and is radially outwardly bulged. A first groove (serving as a deformation enabling space) **685** is formed generally in a center (circumferential center) of the impeller first curved surface **683**.

[0064] The impeller second curved surface **684** connects between another side of the impeller first planar surface **681**, which is parallel to the central axis CA**67**, and another side of the impeller second planar surface **682**, which is parallel to the central axis CA**67**. A cross section of the impeller second curved surface **684** is configured into a shape of an arc, which is centered at the point along the central axis CA**67** and is radially outwardly bulged. A second groove (serving as a deformation enabling space) **686** is formed generally in a center (circumferential center) of the impeller second curved surface **684**.

[0065] The first groove **685** is configured into a form of a slit and extends from the impeller first curved surface **683** in the radially outward direction. The first groove **685** is formed to communicate with the engaging hole **68** and extends through the impeller **67** in the direction of the central axis CA**67**. The second groove **686** is configured into a form of a slit and extends from the impeller second curved surface **684** in the radially outward direction. The second groove **686** is formed to communicate with the engaging hole **68** and extends through the impeller **67** in the direction of the central axis CA**67**.

[0066] The first groove **685** and the second groove **686** extend in two opposite directions, respectively, which are opposite to each other when the two directions are viewed from the central axis CA**67**. Furthermore, a radial length of the first groove **685** and a radial length of the second groove **686** are equal to each other. Here, it is assumed that an imaginary circle, which is centered at the central axis CA**67** and circumferentially connects radially inner side parts of the tilt surfaces **64** of the impeller **67**, is an imaginary circle VL**64**, and an imaginary circle, which is centered at the central axis CA**67** and extends along the impeller first curved surface **683** and the impeller second curved surface **684**, is an imaginary circular VL**68**. In such a case, a radially outer side wall surface **687** of the first groove **685**, and a radially outer side wall surface **688** of the second groove **686**, are formed on a radially inner side of an intermediate imaginary circle VL**67** that is radially equally spaced (by a distance D2 in FIG. **4**) from both of the imaginary circle VL**64** and the imaginary circle VL**68**, as shown in FIG. **4**.

[0067] In the fuel pump of the second embodiment, the first groove **685** and the second groove **686** are formed on the radially inner side of the intermediate imaginary circle VL**67**. In this way, the impeller **67** can be appropriately deformed by the action of the shaft **52**. Therefore, the fuel pump of the second embodiment achieves the advantages, which are similar to those of the first embodiment. Also, in the fuel pump of the second embodiment, the tolerable amount of deformation is increased in comparison to that of the first embodiment. Thereby, the damage of the impeller **67** caused by the rotational torque of the shaft **52** can be further effectively limited.

Third Embodiment

[0068] Next, a fuel pump according to a third embodiment of the present disclosure will be described with reference to FIG. **5**. The third embodiment differs from the first embodiment with respect to the shape of the impeller. In the following description, components, which are similar to those of the first embodiment, will be indicated by the same reference numerals and will not be described further.

[0069] In the fuel pump of the third embodiment, the impeller **85** includes a plurality of tilt surfaces **84**, an engaging hole **86** and a plurality of through-holes (serving as deformation enabling spaces) **87**.

[0070] Similar to the tilt surfaces **64** of the first embodiment, the tilt surfaces **84** are formed at the location that corresponds to the grooves **63**, **73**.

[0071] Similar to the engaging hole **66** of the first embodiment, a cross section of the engaging hole **86** is configured to have a generally I-shape to correspond with the cross section of the end portion **522** of the shaft **52**. The engaging hole **86**

is formed by an impeller first planar surface (serving as an impeller side first contact surface or an impeller side contact surface) **861**, which is contactable with the shaft first planar surface **523**, and an impeller second planar surface (serving as an impeller side second contact surface or an impeller side contact surface) **862**, which is contactable with the shaft second planar surface **524**.

[0072] The through-holes **87** extend through the impeller **85** in a direction of a central axis CA**85**. In the fuel pump of the second embodiment, the total number of the through-holes **87** is six, and these through-holes **87** are arranged one after another at equal intervals along an imaginary circle, which is located on a radially outer side of the engaging hole **86** and is centered at a point along the central axis CA**85** of the engaging hole **86**. Each of the through-holes **87** is formed at a corresponding location which is point symmetric to another one of the through-holes **87** about a symmetric point that is a point along the central axis CA**85**.

[0073] In the fuel pump of the third embodiment, when the shaft **52** is rotated in the engaging hole **86** of the impeller **85**, only one of the shaft first planar surface **523** and the shaft second planar surface **524** of the shaft **52** may contact the inner wall of the engaging hole **86** in some cases. In such a case, the shape of the engaging hole **86** is changed due to the deformation of the through-holes **87**, and the other one of the shaft first planar surface **523** and the shaft second planar surface **524** of the shaft **52**, which was not previously in contact with the inner wall of the engaging hole **86**, now contacts the inner wall of the engaging hole **86**. In this way, the fuel pump of the third embodiment can achieve the advantages, which are similar to the advantages discussed in the sections (a) and (b) of the first embodiment, can be achieved. Furthermore, the through-holes **87** are arranged one after another at equal intervals along the imaginary circle, which is centered at the point along the central axis CA**85**, and each of the through-holes **87** is formed at the corresponding location which is point symmetric to another one of the through-holes **87** about the symmetric point that is the point along the central axis CA**85**. In this way, when the rotational torque of the shaft **52** is applied to the impeller first planar surface **861** or the impeller second planar surface **862**, the impeller **85** is deformed to the similar shape. Thereby, the concentration of the stress (force) on any particular portion of the impeller **85** can be limited. Thus, it is possible to limit the damage of the impeller **85** caused by the rotational torque of the shaft **52**.

Fourth Embodiment

[0074] Next, a fuel pump according to a fourth embodiment of the present disclosure will be described with reference to FIG. **6**. The fourth embodiment differs from the third embodiment with respect to the shape of the impeller. In the following description, components, which are similar to those of the third embodiment, will be indicated by the same reference numerals and will not be described further.

[0075] FIG. **6** is a top view of an impeller **88** of a fuel pump according to the fourth embodiment. The impeller **88** includes the tilt surfaces **84**, the engaging hole **86** and a plurality of through-holes (serving as deformation enabling spaces) **89**.

[0076] The through-holes **89** extend through the impeller **88** in the direction of the central axis CA**88**. In the fuel pump of the fourth embodiment, the total number of the through-holes **89** is six, and these through-holes **89** are arranged one after another at equal intervals along an imaginary circle, which is located on a radially outer side of the engaging hole **86** and is centered at a point along the central axis CA**88** of the engaging hole **86**.

[0077] Here, it is assumed that an imaginary circle, which is centered at the central axis CA**88** and circumferentially connects radially inner side parts of the tilt surfaces **84** located at the radially outer side in the impeller **88**, is an imaginary circle VL**84**, and an imaginary circle, which is centered at the central axis CA**88** and extends along the impeller first curved surface (serving as the engaging hole forming surface) **863** and the impeller second curved surface (serving as the engaging hole forming surface) **864** of the engaging hole **86**, is an imaginary circular VL**88**. In such a case, the through-holes **89** are formed on a radially inner side of an intermediate imaginary circle VL**88** that is radially equally spaced (by a distance D4 in FIG. **6**) from both of the imaginary circle VL**84** and the imaginary circle VL**86**, as shown in FIG. **6**.

[0078] In the fuel pump of the fourth embodiment, the through-holes **89** are formed on the radially inner side of the intermediate imaginary circle VL**88**. In this way, the impeller **88** can be appropriately deformed by the action of the shaft **52**. Therefore, the fuel pump of the fourth embodiment achieves the advantages, which are similar to those of the third embodiment. Also, according to the fourth embodiment, the tolerable amount of deformation is increased in comparison to that of the third embodiment. Thereby, the damage of the impeller **88** caused by the rotational torque of the shaft **52** can be further effectively limited.

Fifth Embodiment

[0079] Next, a fuel pump according to a fifth embodiment of the present disclosure will be described with reference to FIG. **7**. In the fifth embodiment, the shape of the end portion of the shaft and the shape of the impeller are different from those of the third embodiment. In the following description, components, which are similar to those of the third embodiment, will be indicated by the same reference numerals and will not be described further.

[0080] FIG. **7** is a top view of an impeller **95** of a fuel pump according to the fifth embodiment. The impeller **95** includes a plurality of tilt surfaces **94**, an engaging hole **96** and a plurality of through-holes (serving as deformation enabling spaces) **991**-**995**.

[0081] The tilt surfaces **94** are formed at a location, which corresponds to the groove **63** formed in the pump cover **60** and the groove **73** formed in the pump casing **70**.

[0082] The cross section of the engaging hole **96** is configured into a generally D-shape to correspond with a cross section of the one end portion **922** of the shaft **92**. The engaging hole **96** is formed by an impeller third planar surface (serving as an impeller side third contact surface or an impeller side contact surface) **961** and an impeller curved surface (serving as an engaging hole forming surface) **963**. The impeller third planar surface **961** is contactable with a shaft third planar surface (serving as a shaft side third contact surface or a shaft side contact surface) **923** formed in the one end portion **922** of the shaft **92**. The impeller curved surface **963** is formed to extend along a shaft third curved surface (serving as a shaft third curved surface or a shaft curved surface) **925**. The shaft third curved surface **925** is an arcuately curved surface and connects between two ends of the shaft third planar surface **923**, which are generally parallel to a central axis CA**95**.

[0083] The through-holes **991-995** extend through the impeller **95** in the direction of the central axis CA**95**. In the fuel pump of the fifth embodiment, the impeller **95** includes the five through-holes **991-995**. The through-holes **991-995** are arranged one after another at equal intervals along an imaginary circle, which is located on the radially outer side of the engaging hole **96** and is centered at the point along the central axis CA**95** of the engaging hole **96**. Furthermore, among the through-holes **991-995** of the impeller **95**, two of them, i.e., the through-holes **992**, **995** are placed adjacent to two points **962**, **964**, respectively, at each of which the impeller third planar surface **961** and the impeller curved surface **963** are connected with each other.

[0084] Here, it is assumed that an imaginary circle, which is centered at the central axis CA**95** and circumferentially connects radially inner side parts of the tilt surfaces **94**, is an imaginary circle VL**94**, and an imaginary circle, which is centered at the central axis CA**95** and extends along the impeller curved surface **963**, is an imaginary circular VL**96**. In such a case, the through-holes **991-995** are formed on a radially inner side of an intermediate imaginary circle VL**98** that is radially equally spaced (by a distance D5 in FIG. **7**) from both of the imaginary circle VL**94** and the imaginary circle VL**96**, as shown in FIG. **7**.

[0085] In the fuel pump of the fifth embodiment, the cross section of the end portion **922** of the shaft **92** has the D-shape, and the cross section of the engaging hole **96** has the D-shape. Here, the total number of the through-holes **991-995** is five, which is the odd number and corresponds to the shape of the engaging hole **96**. In this way, unlike the I-shape of the cross section of the engaging hole, which receives the end portion of the shaft and contacts the end portion of the shaft at the two opposed sides of the engaging hole, even in the case of the engaging hole, which has the cross section that has the D-shape to contact with the end portion of the shaft only at the one side of the engaging hole, the impeller **95** can be deformed such that the shaft third planar surface **923** contacts the impeller third planar surface **961**. Therefore, in the fifth embodiment, the advantages, which are similar to those of the third embodiment, are achieved.

[0086] Furthermore, in the fuel pump of the fifth embodiment, the through-holes **991-995** are formed on the radially inner side of the intermediate imaginary circle VL**98**. In this way, the impeller **95** can be appropriately deformed by the action of the shaft **52**. As a result, the fuel pump of the fifth embodiment can further effectively limit the damage of the impeller **95** caused by the rotational torque of the shaft **92**.

[0087] Furthermore, in the impeller **95**, the number of the through-holes **991-995** is five, which corresponds to the shape of the engaging hole **96**. In this way, the weight balance of the impeller **95** is kept uniform throughout the impeller **95**, so that occurrence of defects, such as vibrations, at the time of rotation of the impeller **95** can be limited.

Other Embodiments

[0088] (A) In the first and second embodiments, the first groove and the second groove are formed as deformation enabling spaces, respectively. In the third to fifth embodiments, the through-holes are formed as deformation enabling spaces, respectively. However, the shape of the deformation enabling space(s) is not limited to any of these shapes. Specifically, the shape of each deformation enabling space can be any other suitable shape as long as the deformation enabling space is formed in the impeller and can be deformed to increase the resiliently deformable amount of the impeller at the time of occurrence of the contact between the shaft and the impeller.

[0089] (B) In the above embodiments, the shaft first planar surface (serving as the shaft side first contact surface), the shaft second planar surface (serving as the shaft side second contact surface), the impeller first planar surface (serving as the impeller side first contact surface), and the impeller second planar surface (serving as the impeller side second contact surface) are formed as the planar surfaces, respectively. However, it is not necessarily to form these surfaces as the planar surfaces, respectively. Specifically, any one or more of these surfaces may be formed as, for example, a curved surface or any other suitable form as long as the shaft side first contact surface and the impeller side first contact surface are contactable with each other, and the shaft side second contact surface and the impeller side second contact surface are contactable with each other.

[0090] (C) In the above embodiments, the shaft first planar surface (serving as the shaft side first contact surface) and the shaft second planar surface (serving as the shaft side second contact surface) are formed to be generally parallel to each other. Alternatively, the shaft first planar surface and the shaft second planar surface may be formed to be non-parallel to each other.

[0091] (D) In the first and second embodiments, the plurality of deformation enabling spaces is formed in the first and second embodiments. Alternatively, it is possible to provide a single deformation enabling space.

[0092] (E) In the first and second embodiments, the first groove and the second groove are formed in the center of the impeller first curved surface and the center of the impeller second curved surface, respectively. However, the location of the first groove and the location of the second groove should not be limited to these locations.

[0093] (F) In the first and second embodiments, the radial length of the first groove and the radial length of the second groove are equal to each other, and the first groove and the second groove extend to the opposite directions, respectively. However, the relationship between the first groove and the second groove should not be limited to this relationship.

[0094] (G) In the third to fifth embodiments, the through-holes are arranged one after another at equal intervals along the imaginary circle, which is centered at the point along the central axis of the impeller, in the impeller, and each of these through-holes is point-symmetric to another one of these through-holes. However, the locations of the through-holes should not be limited to these locations.

[0095] (H) In the third and fourth embodiments, the total number of the through-holes of the impeller is six. Furthermore, in the fifth embodiment, the total number of the through-holes of the impeller is five. In the case where the cross section of the engaging hole of the impeller is the I-shape, it is desirable that the total number of the through-holes is even number. Furthermore, in the case where the cross section of the engaging hole of the impeller is the D-shape, it is desirable that the total number of the through-holes is odd number. However, the total number of the through-holes is not limited to any of these.

[0096] (I) In the above embodiments, the motor device of the fuel pump is the brushless motor. However, as long as the motor can rotate the shaft in the two directions, i.e., the normal direction and the reverse direction, any other suitable motor, which is other than the brushless motor, may be used.

[0097] The present disclosure is not limited to the above embodiments, and the above embodiments may be modified in various ways within the principle of the present disclosure.

1. A fuel pump comprising:

a pump case that includes a suction port, through which fuel is drawn into the pump case, and a discharge port, through which the fuel is discharged from the pump case;

a stator, around which a plurality of windings is wound, wherein the stator is configured into a tubular form and is received in the pump case;

a rotor that is rotatably placed on a radially inner side of the stator;

a shaft that is coaxial with the rotor and rotates integrally with the rotor; and

an impeller that includes an engaging hole, which receives one end portion of the shaft, wherein:

when the impeller is rotated integrally with the shaft, the impeller pressurizes the fuel drawn through the suction port and discharges the pressurized fuel through the discharge port;

the one end portion of the shaft includes a shaft side first contact surface, which is contactable with the impeller, and a shaft side second contact surface, which is parallel to the shaft side first contact surface and is contactable with the impeller;

the engaging hole includes an impeller side contact surface, which opposes one of the shaft side first contact surface and the shaft side second contact surface and is contactable with the one of the shaft side first contact surface and the shaft side second contact surface; and

the impeller includes at least one deformation enabling space that is deformed when the one of the shaft side first contact surface and the shaft side second contact surface contact the impeller side contact surface.

2. The fuel pump according to claim **1**, wherein:

the impeller side contact surface is an impeller side first contact surface, which opposes the shaft side first contact surface and is contactable with the shaft side first contact surface;

the engaging hole further includes an impeller side second contact surface, which opposes the shaft side second contact surface and is contactable with the shaft side second contact surface;

the at least one deformation enabling space is deformed when the shaft side first contact surface and the impeller side first contact surface contact with each other, or when the shaft side second contact surface and the impeller side second contact surface contact with each other.

3. The fuel pump according to claim **2**, wherein the at least one deformation enabling space is at least one groove that is communicated with the engaging hole.

4. The fuel pump according to claim **3**, wherein:

the engaging hole includes:

an engaging hole first forming surface that connects between one side of the impeller side first contact surface and one side of the impeller side second contact surface; and

an engaging hole second forming surface that connects between another side of the impeller side first contact surface and another side of the impeller side second contact surface; and

the at least one groove includes a first groove, which is formed in the engaging hole first forming surface, and a second groove, which is formed in the engaging hole second forming surface.

5. The fuel pump according to claim **4**, wherein the first groove and the second groove extend in opposite directions, respectively, which are opposite to each other, when the first groove and the second groove are viewed from a central axis of the impeller.

6. The fuel pump according to claim **5**, wherein a radial length of the first groove and a radial length of the second groove are equal to each other.

7. The fuel pump according to claim **5**, wherein:

the first groove is formed in a center of the engaging hole first forming surface; and

the second groove is formed in a center of the engaging hole second forming surface.

8. The fuel pump according to claim **1**, wherein the at least one deformation enabling space is at least one through-hole, which is formed on a radially outer side of the engaging hole and extends through the impeller in an axial direction of a central axis of the impeller.

9. The fuel pump according to claim **8**, wherein:

the impeller side contact surface is an impeller side first contact surface, which opposes the shaft side first contact surface and is contactable with the shaft side first contact surface;

the engaging hole further includes an impeller side second contact surface, which opposes the shaft side second contact surface and is contactable with the shaft side second contact surface;

the at least one through-hole includes a plurality of through-holes, and a total number of the plurality of through-holes is an even number;

the plurality of through-holes is deformed when the shaft side first contact surface and the impeller side first contact surface contact with each other, or when the shaft side second contact surface and the impeller side second contact surface contact with each other; and

each of the plurality of through-holes is formed at a location which is point symmetric to another one of the plurality of through-holes about a symmetric point that is a point along the central axis of the impeller.

10. (canceled)

11. The fuel pump according to claim **8**, wherein the plurality of through-holes is arranged one after another at equal intervals along an imaginary circle, which is centered at the central axis of the impeller.

12. The fuel pump according to claim **1**, wherein:

the impeller includes:

a plurality of tilt surfaces, which are arranged at a radially outer end part of the impeller, wherein the plurality of tilt surfaces pressurize and discharge the fuel through use of rotation of the impeller; and

an engaging hole forming surface that is formed to have a cross section configured into a shape of an arc, which is centered at a central axis of the engaging hole, wherein the engaging hole forming surface is connected to an end of the impeller side contact surface; and

the at least one deformation enabling space is placed on a radially inner side of an intermediate imaginary circle that is placed at a location that is radially equally spaced from both of:

an imaginary circle that is centered at the central axis of the engaging hole and circumferentially connects radially inner side parts of the plurality of tilt surfaces; and

an imaginary circle that is centered at the central axis of the engaging hole and circumferentially connects a radially outer side part of the at least one engaging hole forming surface.

* * * * *