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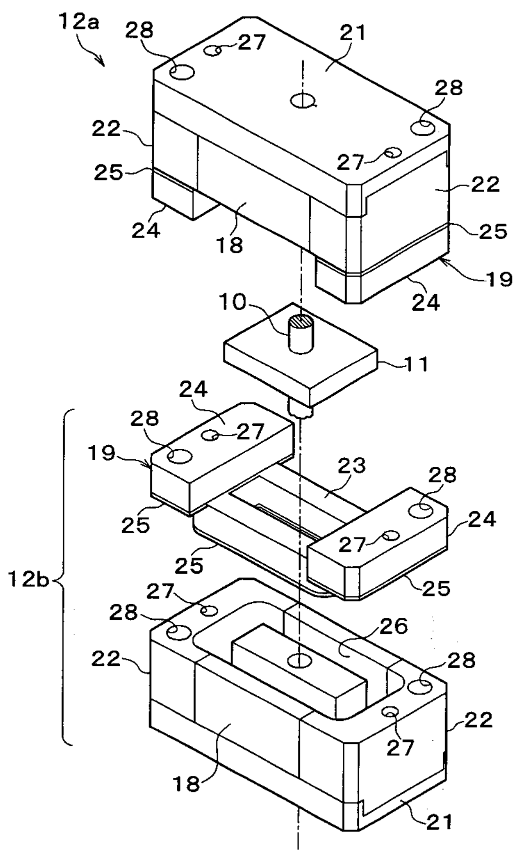
(54) **Electromagnetic actuator**

(57) An electromagnetic actuator (7) includes a pair of core assemblies (12a, 12b) and a spacer (24). The armature (11) is provided between the pair of core assemblies (12a, 12b). The spacer (24) is formed by molding to be integral with a coil (20) provided in electromagnets (30a, 30b) of the core assemblies (12a, 12b) and is located between the electromagnets (30a, 30b). And relative positions of the pair of electromagnets (30a and 30b) to each other are determined by the spacer (24). A space to allow the armature to reciprocate is secured between the core assemblies (12a, 12b) by the spacer (24).

FIG. 2



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Description

BACKGROUND OF THE INVENTION

1. Field of Invention

[0001] The invention relates to an electromagnetic actuator.

2. Description of Related Art

[0002] It has been suggested that an electromagnetic actuator can be used to open and close intake and exhaust valves in an internal combustion engine.

[0003] Conventionally, the electromagnetic actuator includes an armature, which moves integrally with a valve body, and a pair of core assemblies (electromagnets), between which the armature is provided. These core assemblies provide a coil and a core that retains the coil. These core assemblies exert an electromagnetic attraction on the armature as an electromagnet. When the pair of core assemblies alternatively exert the electromagnetic attraction on the armature, the armature reciprocates so that the electromagnetic actuator is driven and the intake and exhaust valves in an internal combustion engine are opened and closed.

[0004] In the above-described electromagnetic actuator, it is necessary that a space be secured for the armature to reciprocate between the pair of core assemblies. Therefore, it is conceivable that a spacer is used to secure the space for the armature to reciprocate like an electromagnetic actuator according to a Laid-Open Japanese patent Publication No. JP 11-260638.

[0005] FIG. 4 is a side cross-sectional view showing the arrangement of the spacer and the core assemblies of the electromagnetic actuator according to JP-A-11-260638. The conventional structure shown in Fig. 4 illustrates the space required for the armature to move by the spacer.

[0006] As shown in FIG. 4, a pair of core assemblies 102 are provided on both sides of the moving directions of an armature 101 (e.g., as shown by the up and down direction in FIG. 4). A horizontal hole 103 is formed and extends along the width direction of each core assembly 102 (e.g., as shown by the right and left direction in FIG. 4). Spacers 104 are provided on both sides of the pair of core assemblies 102 along the width direction. At each location corresponding to one of the horizontal holes 103, a pin hole 105 is provided in the spacer 104. A constant distance between the pair of core assemblies 102 is maintained by the spacers 104. Pins 106 are inserted into the pin holes 105 aligned with the horizontal holes 103 to ensure the constant distance.

[0007] If the pins 106 are inserted into the pin holes 105 and the horizontal holes 103 inaccurately, relative positions between the pair of core assemblies 102 deviate from appropriate positions. For example, the relative positions deviate in the reciprocating directions of the armature 101. As a result, an appropriate size of space for the armature 101 to move between the core assemblies 102 cannot be maintained and maximum displacement of the armature 101 will deviate from appropriate values. If the armature 101 contacts one of the core assemblies 102 as the armature 101 reciprocates, an impact generated from the contact is translated among the horizontal hole 103, the pin holes 105, and the pin 106. Therefore, if the pin 106 is inserted into the pin holes 105 and the horizontal hole 103 inaccurately, a contact force between the armature 101 and one of the core assemblies 102 deviates in the reciprocating direction of the armature 101 due to the impact. As a result, there is a great chance that the relative position of the core assemblies 102, with respect to a neutral position of the armature 101, will deviate from the appropriate values by many degrees.

[0008] Furthermore, in addition to requiring spacers 104, the pin 106 must be inserted into each core assembly 102 in order to secure the space for the armature 101 to move by inserting the pin 106 into the horizontal hole 103 and the pin holes 105. As a result, an increase in the number of components is necessary.

SUMMARY OF THE INVENTION

[0009] It is an object of the invention to provide an electromagnetic actuator to prevent a deviation of the relative positions of a pair of electromagnets with respect to a neutral position of an armature from an appropriate position and to change a maximum displacement of the armature without increasing the number of components parts.

[0010] A first aspect of the invention relates to an electromagnetic actuator. The electromagnetic actuator reciprocates an armature between a pair of electromagnets by an electromagnetic attraction. The pair of electromagnets is provided in both sides of the moving path direction of the armature with a coil being provided inside the pair of electromagnets. In the electromagnetic actuator described above, a spacer is formed by molding to be integral with a coil and is located between the pair of electromagnets. The spacer secures a space for the armature to reciprocate.

[0011] According to the above-described structure of the electromagnetic actuator, the spacer, which determines relative positions of a pair of the electromagnets to the neutral position of the armature, does not deviate in the reciprocating directions of the armature since the spacer is located between the electromagnets. The spacer is formed by molding to be integral with the coil, so that the number of components is not increased. Therefore, deviation of the relative position of the pair of core assemblies to the neutral position of the armature from the appropriate position and to change a maximum displacement of the armature can be prevented without increasing the number of components.

[0012] Furthermore, the electromagnetic actuator may have more than one spacer.

[0013] According to the above-described structure, plural spacers are located between the pair of electromagnets. Therefore, the relative positions of the electromagnets to the neutral position of the armature can be determined by each spacer appropriately. Then the maximum displacement of the armature can be maintained within appropriate values with certainty.

[0014] Furthermore, the spacers may be located on opposite sides of the armature as viewed in a direction perpendicular to the moving direction of the armature.

[0015] According to the above-described structure, the spacer are located on opposite sides of the armature as viewed in a direction perpendicular to the moving direction of the armature. Therefore, the relative positions of the electromagnets to the neutral position of the armature can be determined by each spacer appropriately. Then the maximum displacement of the armature can be maintained within the appropriate values with certainty.

[0016] Furthermore, a noise absorbing material may be provided between a first surface defined by at least one of the spacer and the coil opposite to a side adjacent to the armature and a second surface defined matingly opposite to the first surface.

[0017] The noise absorbing material may be provided on at least one of the spacer and the coil.

[0018] According to the above-described structure, level of contact noise caused by contacting the armature with the electromagnets as the armature reciprocates can be lowered by the noise absorbing material.

[0019] The noise absorbing material may contain foam metal.

[0020] According to the above-described structure, the level of contact noise caused by contacting the armature with the electromagnets as the armature reciprocates can be lowered by the noise absorbing material containing foam metal.

[0021] The surface of the armature may be hardened, for example, by colliding high-speed metal particles with the surface of the armature. Therefore, anti abrasion of the armature can be improved by surface-hardening treatment described above.

[0022] The electromagnetic actuator may be provided in an internal combustion engine to drive a valve body of an intake valve or an exhaust valve.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of exemplary embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1 is a cross-sectional view of an electromagnetically driven valve applied by an electromagnetic actuator according to an exemplary embodiment of the invention;

FIG. 2 is an exploded perspective view which shows an interior structure of the electromagnetic actuator;

FIG. 3 is a schematic view of a modified embodiment of a shape of a coil unit according to the exemplary embodiment; and

FIG. 4 is a side cross-sectional view illustrating a structure for securing a space for an electromagnetic actuator to move with a spacer.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0024] The following is an explanation of an exemplary embodiment of the invention applying an electromagnetic actuator to an electromagnetically driven valve as an intake valve or an exhaust valve in an internal combustion engine.

[0025] FIG. 1 shows an electromagnetically driven valve 1 having a valve body 4 which opens and closes a port 3 connected to a combustion chamber 2, a valve shaft 6 which projects from the valve body 4 and is reciprocatingly supported by a cylinder head 5 . An electromagnetic actuator 7 reciprocates the valve shaft 6. The port 3 is opened and closed when the valve body 4 seats to and moves away from a valve seat 3a as the valve shaft 6 reciprocates.

[0026] A lower retainer 8 is provided at an opposite end to the valve body 4 side end of the valve shaft 6. A lower spring 9 is compressed and provided between the lower retainer 8 and the cylinder head 5. The valve body 4 and the valve shaft 6 are biased in the direction of closing the valve (e.g., upwardly as shown in FIG. 1) by the lower spring 9.

[0027] The electromagnetic actuator 7 includes an armature shaft 10 which is provided along the same axis as the valve shaft 6, an armature 11 which is plate-shaped and contains a material with high magnetic permeability, and a pair of core assemblies 12a and 12b which are provided on both sides of a thickness direction of the armature 11. The armature 11 is fixed at approximately the center of the armature shaft 10. An upper cap 14 is provided on top of the core assembly 12a. An adjustment bolt 29 is screwed into and out of the upper cap 14 to adjust a neutral position of the armature 11. Furthermore, the upper cap 14 and the pair of core assemblies 12a and 12b are fixed by pins 15, which extends parallel to the armature shaft 10, and a bolt 16. The upper cap 14 and the pair of core assemblies 12a and 12b are located at orthogonal angles to the armature shaft 10.

[0028] The armature shaft 10 penetrates through the pair of core assemblies 12a and 12b. One end (e.g., the lower end as shown in FIG. 1) of the armature shaft 10 is contacted with the lower retainer 8 side end of the valve shaft 6. An upper retainer 13 is fixed on the other end of the armature shaft 10. An upper spring 17 is compressed and provided between the upper retainer 13 and the upper cap 14. The armature shaft 10 is biased on the side of the valve shaft 6 by the upper spring 17. The valve shaft 6 and the valve body 4 are biased in the direction of opening the valve (e.g., downwardly as shown in FIG. 1) by the biased armature 10.

[0029] A core 18 which contains a material with high magnetic permeability and a coil unit 19 retained by the core 18 are provided in the pair of core assemblies 12a and 12b. A coil 20 is embedded in the coil unit 19. The core assemblies 12a and 12b work as an electromagnet by conducting electricity to the coil 20 and exert electromagnetic attraction on the armature 11. In this connection, the core 18, a core block 22, and a coil part 23 (mentioned later) as an electromagnet according to the exemplary embodiment. Therefore, the core 18, a core block 22, and the coil part 23 are called electromagnets 30a and 30b according to the exemplary embodiment. The electromagnet 30a is side of the core assembly 12a and the electromagnet 30b is side of the core assembly 12b. As the armature shaft 10 and the armature 11 reciprocate in the direction along the axis of the valve shaft 6, the valve body 4 opens and closes by controlling electricity conduction to the two coils 20 located on both sides of the core assemblies 12a and 12b and by alternately exerting electromagnetic attraction from the core assemblies 12a and 12b on the armature 11.

[0030] The surface of the armature 11 is treated to improve anti-abrasion. In other words, anti-abrasion improvement of the surface of the armature 11 is carried out by colliding metal particles with the surface of the armature 11 at a high speed by air to increase the hardness of the surface. Therefore, when the armature 11 comes into contact with the core assemblies 12a and 12b, and as the armature 11 reciprocates, abrasion of the armature 11 can be restrained.

[0031] FIG. 2 is an exploded perspective view which shows an interior structure of an electromagnetic actuator 7. The core assemblies 12a and 12b are arranged symmetrically from the armature 11. The two core assemblies 12a and 12b are identical except for their arrangement and working timing such that only the core assembly 12b is referred to hereafter.

[0032] As shown in FIG. 2, in addition to the core 18 and the coil unit 19, the core assembly 12b includes a core plate 21 with which the core 18 contacts, and a pair of core blocks 22. The pair of core blocks 22 contact the core plate 21 and is provided in a way such that the core 18 is located between the core blocks 22.

[0033] The coil unit 19 having an annular shape includes a coil part 23 into which the coil 20 (e.g., shown in FIG. 1) is embedded, and a pair of spacers 24 which is formed integrally with the coil part 23 at the outer margins of and on top of the coil part 23 (e.g., as shown in FIG. 2). The coil part 23 is molded out of a thermoplastic resin to be integral with the coil 20. The spacers 24 are also molded out of thermoplastic to be integral with the coil 20. On a side opposite to the armature 11 (the underside of the coil part 23 and the spacers 24, e.g., as shown in FIG. 2), the coil unit 19 has a noise absorbing material 25 attached, which is a sheet-shape and contains a foam metal such as a foam cast iron.

[0034] A retaining groove 26 with an annular shape, which houses the coil part 23, is formed in the core 18 and the core blocks 22. The coil unit 19 is matingly fixed on the core 18 and the core blocks 22 by inserting the coil part 23 into the retaining groove 26. The spacers 24 are located above the core blocks 22 as shown in FIG. 2. The noise absorbing material 25 attached on the coil unit 19 is located between two groups. One group comprises the coil part 23 and the spacers 24. The other group comprises the core 18 and the core blocks 22.

[0035] Pin holes 27, through which pins 15 penetrate, and bolt holes 28 into which bolts 16 are screwed, are formed in the spacers 24, core blocks 22, and the core plate 21. The pins 15 and the bolts 16 are shown in FIG. 1. The core assemblies 12a and 12b are fixed to meet at least the following two requirements. The first requirement is that the armature 11 is arranged between the core assemblies 12a and 12b. The second requirement is that the spacers 24 on both sides of the core assembly 12a and 12b are contacted together. This arrangement is fixed by tightening the bolts 16 screwed into the bolt holes 28 after inserting the pins 15 into the pin holes 27.

[0036] As described above, when the core assemblies 12a and 12b are fixed, the spacers 24 are located on both sides of the armature 11 (along the moving path of the armature shaft 10) and between the electromagnet 30a of the core assembly 12a and the electromagnet 30b of the core assembly 12b. The relative position of the electromagnets 30a and 30b to the neutral position of the armature 11 is determined by the spacers 24. A space 11a for the armature 11 to reciprocate between the core assemblies 12a and 12b is secured. Maximum displacement of the armature 11 is determined in proportion to the length of moving direction of the armature 11 in the space 11a.

[0037] According to the exemplary embodiment described above, the following characteristics can be obtained. The spacers 24, for determining the relative positions of the electromagnets 30a and 30b to the neutral position of the armature 11, are located between the electromagnets 30a and 30b. Therefore, the spacers 24 do not deviate in the reciprocating direction of the armature 11 (e.g., in the direction of the axis of the armature shaft 10). The spacers 24 are formed by molding to be integral with the coils 20 as the coil unit 19. Therefore, the number of components of the electromagnetic actuator 7 are few and is not increased. Furthermore, deviation of the relative position of the electromagnets 30a and 30b from the neutral position of the armature 11 from an appropriate position can be prevented. Change in the maximum displacement of the armature 11 accompanied by the above-mentioned deviation can also be prevented.

[0038] The spacers 24 are located on opposite sides of the armature 11 as viewed in a direction perpendicular to the moving direction of the armature 11. Because of the above-described relation of the positions among the spacers 24 and the armature 11, the spacers 24 are located between the electromagnets 30a and 30b. Both electromagnets 30a and 30b are located along the axis of the armature shaft 10. Therefore, the position of the electromagnets 30a and 30b relative to the neutral position of the armature 11 can be determined by the spacers 24 appropriately and the maximum displacement of the armature 11 can be maintained within an appropriate value with greater certainty.

[0039] The level of contact noise caused by contacting the armature 11 with the core assemblies 12a and 12b, as the armature 11 reciprocates, can be lowered by the noise absorbing materials 25 located between the two groups of components. As mentioned before, one group comprises the coil part 23 and the spacers 24. The other group comprises the core 18 and the core blocks 22.

[0040] The exemplary embodiment may be modified as follows.

[0041] According to the exemplary embodiment, two of the spacers 24 are provided at each coil unit 19. On the other hand, as shown in FIG. 3, for example, each spacer 24 may be provided at each coil unit 19. And the two coil units 19 may be installed in the electromagnetic actuator in the way that spacers 24 of coil units 19 are located on opposite sides of the armature 11 as viewed in a direction perpendicular to the moving direction of the armature 11.

[0042] According to the exemplary embodiment, the noise absorbing material 25 is attached to the coil part 23 and the spacers 24 on the side opposite to the armature 11 (e.g., the under-side of the coil part 23 and the spacers 24 as shown in FIG. 2). In the alternative, the noise absorbing material 25 may be attached either on the coil part 23 or the spacers 24.

[0043] The noise absorbing material 25 is optional and can be omitted to reduce the number of components. The electromagnetic actuator 7 may be applied to structures other than an engine valve.

[0044] While the invention has been described with reference to the exemplary embodiments thereof, it is to be understood that the invention is not limited to the exemplary embodiments or constructions. To the contrary, the invention is intended to cover various modifications and equivalent arrangements. In addition, while the various elements of the exemplary embodiments are shown in various combinations and configurations, which are exemplary, other combinations and configurations, including more, less or only a single element, are also within the spirit and scope of the invention.

[0045] An electromagnetic actuator (7) includes a pair of core assemblies (12a, 12b) and a spacer (24). The armature (11) is provided between the pair of core assemblies (12a, 12b). The spacer (24) is formed by molding to be integral with a coil (20) provided in electromagnets (30a, 30b) of the core assemblies (12a, 12b) and is located between the electromagnets (30a, 30b). And relative positions of the pair of electromagnets (30a and 30b) to each other are determined by the spacer (24). A space to allow the armature to reciprocate is secured between the core assemblies (12a, 12b) by the spacer (24).

Selected Figure: FIG. 2

Claims

1. An electromagnetic actuator including a pair of electromagnets (30a, 30b) being provided on opposite sides of the armature (11) reciprocating between the pair of electromagnets (30a, 30b) by electromagnetic attraction with a coil (20) being provided inside each the electromagnet (30a, 30b), **characterized in that** a spacer (24), that secures a space for the armature (11) to reciprocate, is formed by molding to be integral with the coil (20) and is located between the pair of electromagnets (30a, 30b).

2. The electromagnetic actuator according to claim 1, wherein the electromagnetic actuator has at least two of the spacers (24).

3. The electromagnetic actuator according to claim 2, wherein the spacers (24) are located on opposite sides of the armature (11) as viewed in a direction perpendicular to the moving direction of the armature (11).

4. The electromagnetic actuator according any one of claims 1 to 3, wherein a noise absorbing material (25) is provided between a first surface defined by at least one of the spacer (24) and the coil (20) opposite to a side adjacent to the armature (34) and a second surface defined matingly opposite to the first surface.

5. The electromagnetic actuator according claim 4, wherein the noise absorbing material (25) is provided on at least one of the spacer (24) and the coil (20).

6. The electromagnetic actuator according to claim 4 or claim 5, wherein the noise absorbing material (25) comprises a foam metal.

7. The electromagnetic actuator according to any one of claims 1 to 6, wherein a surface of the armature (11) is hardened by a surface-hardening treatment.

8. The electromagnetic actuator according any one of claims 1 to 7, wherein the electromagnetic actuator is provided in an internal combustion engine to drive a valve body of an intake valve.

9. The electromagnetic actuator according any one of claims 1 to 7, wherein the electromagnetic actuator is provided in an internal combustion engine to drive a valve body (4) of an exhaust valve.

FIG. 1

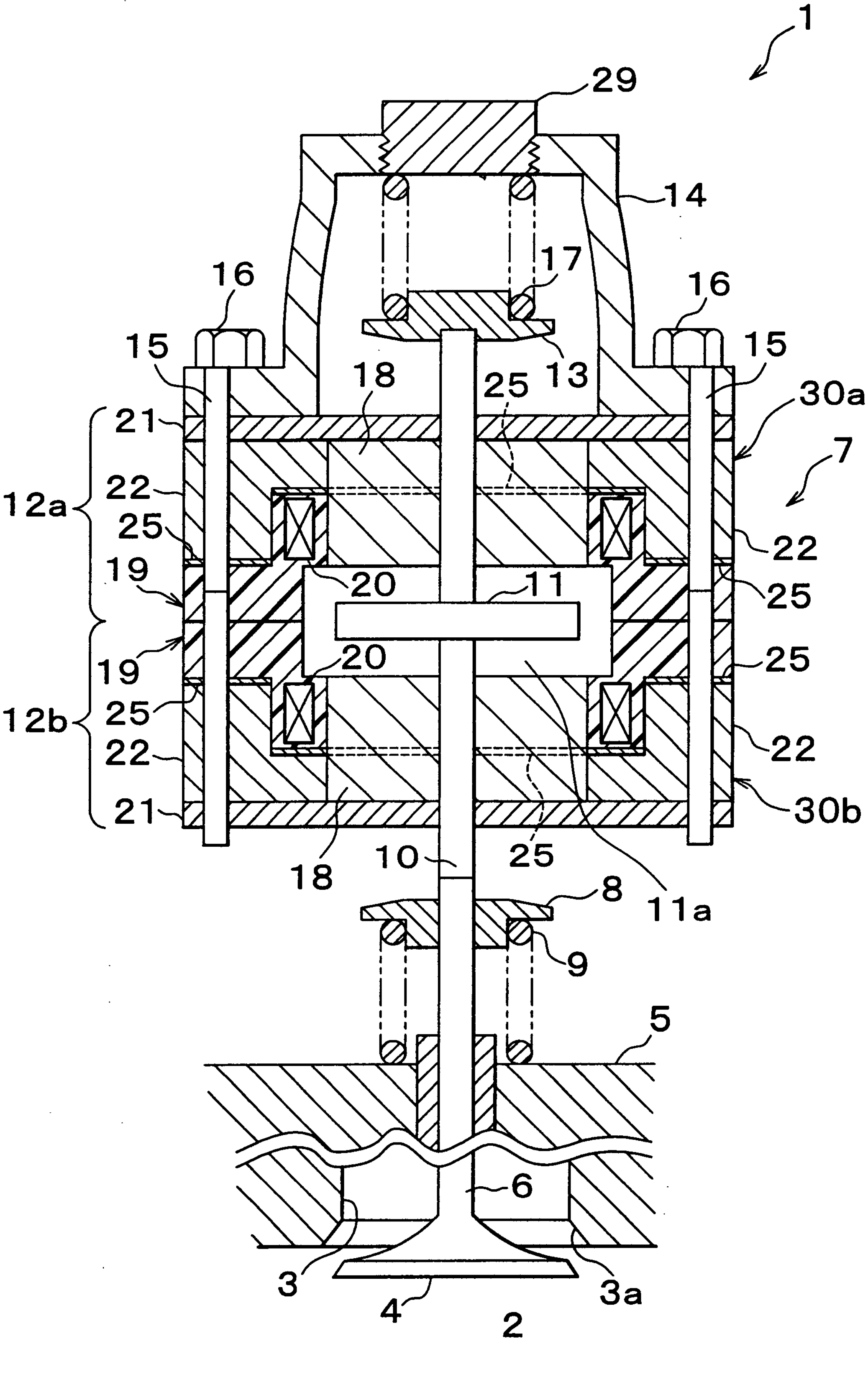
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FIG. 2

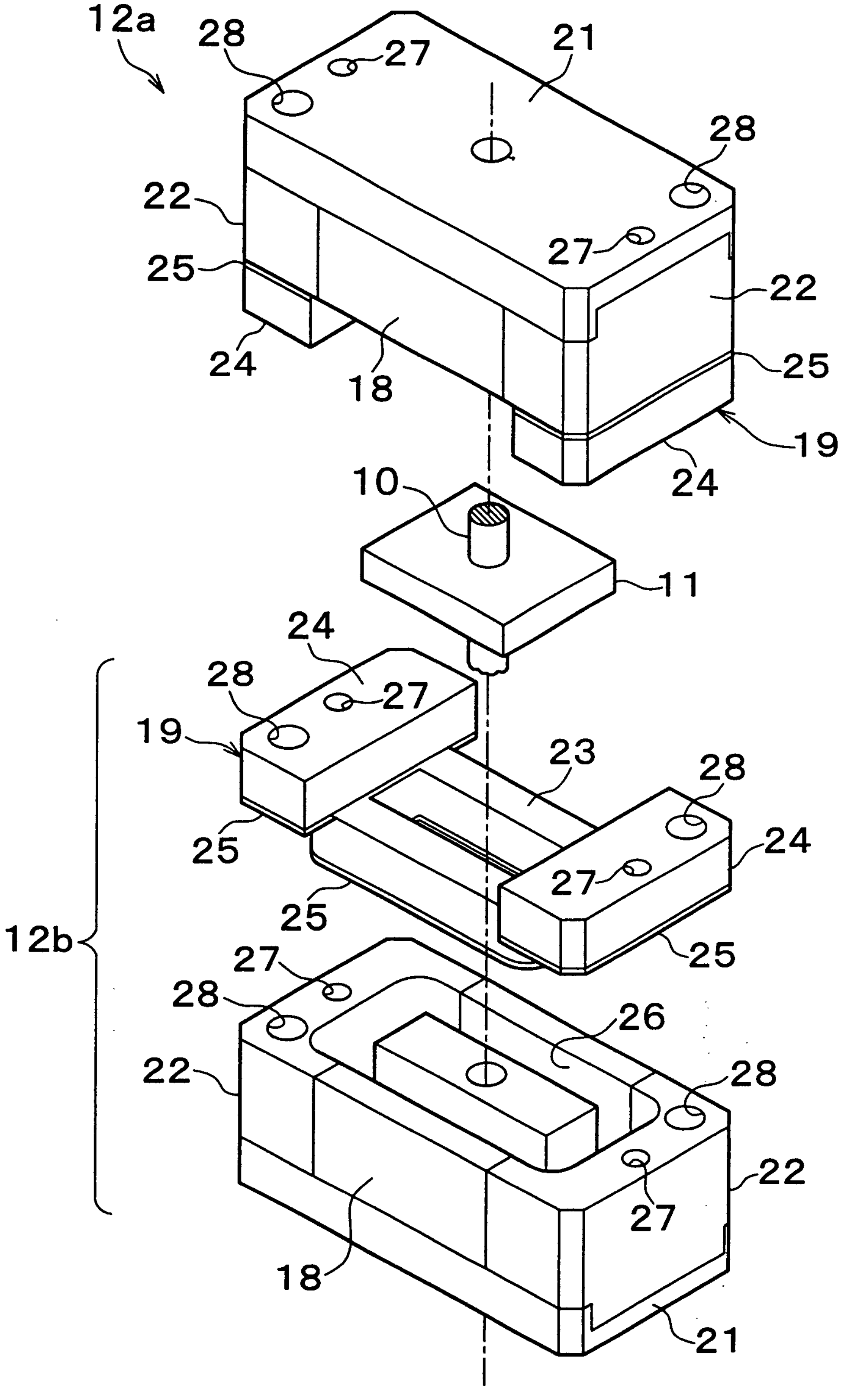
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FIG. 3

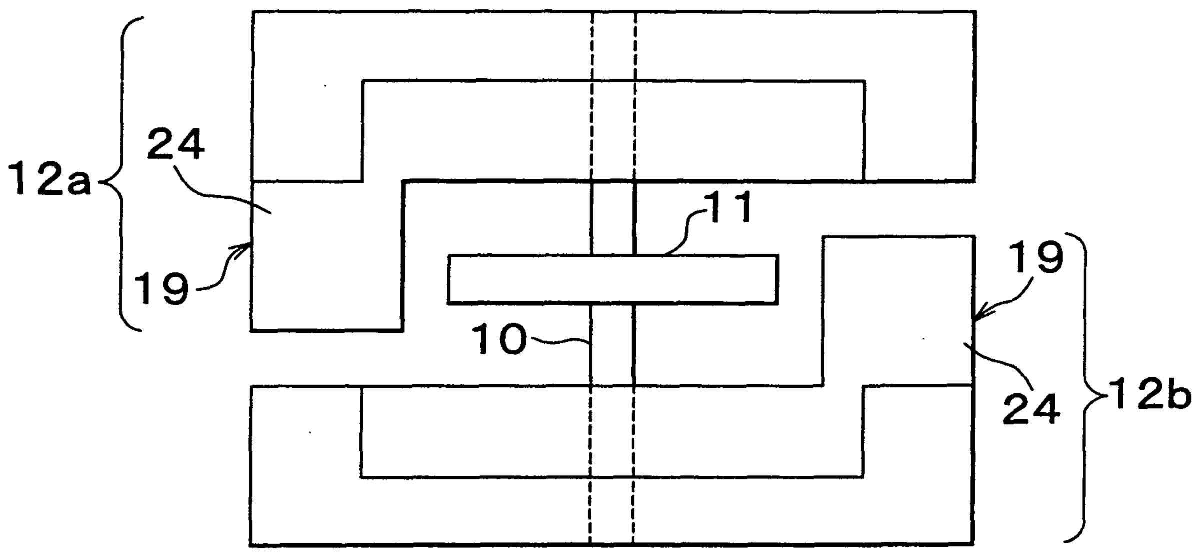

FIG. 4

RELATED ART