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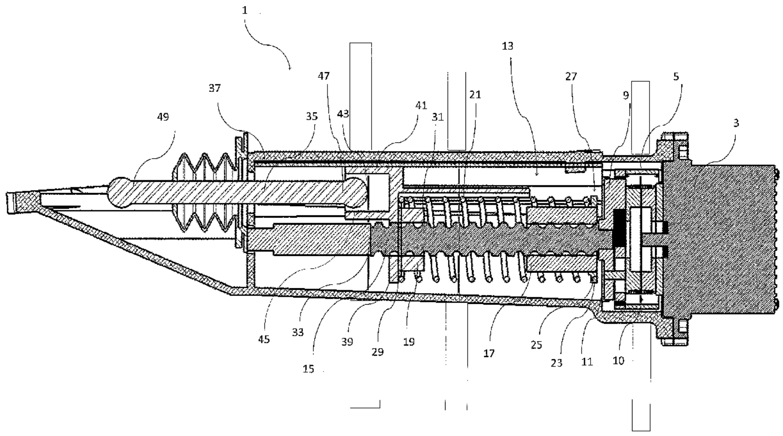
(54) Title: CLUTCH ACTUATOR FOR A VEHICLE

Fig. 1



(57) Abstract: The present invention relates to a clutch actuator for a combustion engine, comprising -a motor for generating a motor torque -transmission means for transforming said motor torque into a force for generating a operating movement able to act on a clutch operating mechanism to operate a clutch, and -a brake able to generate a braking force for braking said means, wherein the braking force able to be generated by said brake is less than the maximum force for generating a operating movement. The invention also relates to a vehicle comprising a clutch actuator and a method and software for failsafe operation of a clutch actuator.

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CLUTCH ACTUATOR FOR A VEHICLE

TECHNICAL FIELD

The present invention relates to a clutch actuator for a vehicle, a vehicle having such a clutch actuator and to a method and software for failsafe operation of such a clutch actuator.

BACKGROUND

Within many fields, such as for instance combustion engines, a clutch is needed to allow the transmission to engage and disengage from the engine, thereby enabling gear shifts as well as smooth starting. The driver generates a signal that an activation of the clutch is desired, often through pushing a pedal in a vehicle with manual transmission or moving the shift lever in a vehicle with automatic transmission, and this signal, sometimes together with a signal from the transmission controller software for automatic shifting, is used by a clutch actuator to activate the clutch itself.

Clutch actuators may be of different types, for instance hydraulic or electric. They are necessary for the reliable operation of the vehicle and must be sturdy and reliable to ensure a safe operation and avoid accidents. If they break or suffer power failure, there must be a failsafe operating mode that allows the engine to remain connected to the transmission so that the vehicle can be driven to another location thereby avoiding blocking other traffic.

Electric clutch actuators are generally driven by a small electric motor and are reliable and suitable for manual as well as automatic transmission. The motor drives a transmission means, which transmits the clutch operating force from an actuator to the clutch operating mechanism, for example a push rod acting on the clutch release bearing operating arm, in a forward or a backward direction and this operating movement allows a disengagement or engagement of the clutch. Generally, a clutch operating mechanism that is in contact with the clutch itself can act with a linear force against the transmission means, so that the motor only needs to deliver torque to drive the transmission means in the forward direction, and a brake is supplied to prevent the clutch operating mechanism from pushing the transmission means in the backward direction when the motor does not deliver a torque. However, in the event of a power loss that prevents the electric motor from operating the clutch in the backwards direction it may be locked in the disengaged position and prevent the vehicle from being driven. Also, during normal operation the motor will suffer excessive wear due to heat generation and may break for this reason.

There is a need for improved clutch actuators that reduce the wear on the components and also have a failsafe mode to ensure that the vehicle can be operated even in the event of a power failure.

SUMMARY

The object of the present invention is to eliminate or at least to minimize the problems described above. This is achieved through a clutch actuator according to the appended independent claim. Thanks to the invention, a clutch actuator that allows for reduced wear of the motor as well as a failsafe operation is achieved.

Many additional benefits and advantages of the invention will become readily apparent to the person skilled in the art in view of the detailed description below.

FIGURES

The invention will now be described in more detail with reference to the appended drawings, wherein

Fig. 1 discloses a cross-sectional view of an actuator for operating a vehicle clutch according to a preferred embodiment of the present invention;

Fig. 2 discloses an exploded view of the actuator of Fig. 1;

Fig. 3 discloses a cross-sectional view of a first end of the actuator of Fig. 1;

Fig. 4 discloses a schematic cross-sectional view of a the actuator of Fig. 1 in an installation position;

Fig. 5 discloses a schematic cross-sectional view of the actuator of Fig. 1 in a first operation position;

Fig. 6 discloses a schematic cross-sectional view of the actuator of Fig. 1 in a second operation position;

Fig. 7 discloses a schematic cross-sectional view of the actuator of Fig. 1 in a third operation position;

Fig. 8a discloses a perspective view of an alternative embodiment of the brake of the actuator according to the invention;

Fig. 8b discloses an exploded view of the alternative embodiment of Fig. 8a;

Fig. 9 discloses schematically method steps for normal operation of the actuator of Fig. 1;

Fig. 10 discloses schematically method steps for failsafe operation of the actuator of Fig. 1; and

Fig. 11 discloses a diagram relating motor torque to pushrod position for the actuator according to the invention.

DETAILED DESCRIPTION

Fig. 1 and 2 show an actuator 1 for operating a vehicle clutch according to a preferred embodiment of the present invention, said actuator 1 comprising a torque producing motor 3 connected by a motor output 5 to and driving a reduction gear 9, which can be for example, as shown here, a planetary gear. A brake means such as return brake 10 is connected to the reduction gear and thereby to the motor as will be described in detail further below. An output shaft 11 of the reduction gear 9 is connected to clutch operating force transmission means (called “transmission means” for brevity in the following) in the form of an actuator 13 with a stationary support, arranged for transforming the torque from motor 3 into a force (F_{motor}) sufficiently high enough to generate a operating movement able to act on a clutch operating mechanism in order to operate the clutch release mechanism throughout the range of the clutch movement. Thus the minimum force able to be generated by the motor (F_{motor} min) must be greater than the maximum force (F_{clutch} max) generated by the clutch release mechanism which opposes it during operation of the clutch. This force generated by the clutch release mechanism generally varies slightly during the clutch release and re-engagement movements due to the changes in geometry of the clutch operating components. The transmission means 13 are illustrated here as a ball screw 15, the rotation of which can drive a movable body, e.g. ball nut 17 linearly along it, and the operating movement able to act on the clutch operating mechanism is therefore a linear operating movement. It is to be noted, however, that rotary operating movement or other operating movements may also be used in a similar way as the linear operating movement described herein with reference to this preferred embodiment.

A clutch preload plunger 19 is also mounted on the ball screw 15 and is able to translate freely along the ball screw 15. A helical preload spring 21 with an inner diameter between the coils which is greater than the outer diameter of the ball nut is mounted concentrically around the ball screw and ball nut. In this embodiment of the invention the proximal end 23 of the preload spring 21 is attached by a spring holder 25 to or near the proximal end 27 of the ball nut and the distal end 29 of the preload spring is attached to or pushes on the proximal end surface 31 of the preload plunger, thereby exerting a force on the preload plunger which pushes the preload plunger towards the distal end 33 of the ball screw.

The transmission means could alternatively comprise other components for translating a rotary operating movement into a linear operating movement, such as a lead screw or a roller screw for example. The adaptations required to alter the preferred embodiment to use such alternatives will be readily apparent to the person skilled in the art.

Other arrangements of the preload spring are also conceivable, for example it may have an inner diameter and an outer diameter which both are less than the diameter of the ball nut and in this case it can be positioned between the distal end of the ball nut and the proximal end of the preload plunger. In this case it must be collapsed completely in order for the high clutch disengaging force to be transmitted from the ball nut to the preload plunger.

The preload plunger is preferably provided with a longitudinally extending guide arm 35 which is offset from, and parallel with, the central longitudinal axis of the preload plunger and which can cooperate with an optional housing 37 which can at least partially surround the actuator to protect it from dust and other contamination. The guide rail is arranged parallel to the central longitudinal axis of the ball screw in order to ensure that the preload plunger is maintained parallel to the ball screw as it moves along it. The distal end surface 39 of the preload plunger further comprises a clutch pushrod receiving cup 41 with an open end 43. The cup is offset from the central axis of the preload plunger which reduces the overall length of the actuator. The open end faces away from the preload plunger and the interior of the clutch pushrod receiving cup is provided with gripping means 45 for gripping the proximal end 47 of a clutch operating mechanism 49, here in the form of a clutch pushrod 49. Preferably the gripping means and the proximal end of the clutch pushrod are arranged to allow angular movement of the pushrod, for example as a ball on the end of the pushrod and a corresponding socket in the cup. During use the distal end 57 of the pushrod is intended to be pressed in contact with the release bearing operating arm of a clutch with a continuous preload force which is generated by the preload spring.

The clutch operating mechanism 49 is thus arranged to perform a linear movement in a distal direction for disengaging and a proximal direction for engaging the clutch of the vehicle, and the movement is performed in response to a linear operating movement of the transmission means 13, driven by the motor 3. The brake 10 is arranged to generate a braking force (F_{brake}) for braking the transmission means 13, i.e. in this embodiment the ball screw 15 and ball nut 17, and to prevent a rotary movement that can be translated into a linear movement of the ball nut 17.

The brake 10 is preferably a one-way brake that is able to brake the transmission means 13 to halt or to slow a movement in a proximal direction but is not able to brake a movement in the distal direction. Generally, the motor 3 can be arranged to provide torque for generating an operating movement in both the proximal and the distal direction, while the clutch operating mechanism 49 provides a clutch force (F_{clutch}) in a proximal direction that must be counteracted by the motor 3 to create the operating movement of the clutch operating mechanism 49 in the distal direction. Thus, when the clutch has been dis-engaged and the motor 3 is no longer providing a torque to generate the operating movement in the distal direction, the transmission means 13 are pushed back in the proximal direction by the clutch operating mechanism 49, and the brake 10 may then serve to brake this proximal movement to smoothly engage the clutch. In the preferred embodiment the brake 10 is a wrap spring brake. Such a brake acts on a shaft when a spring which is wrapped around the shaft is tighten onto it (this tightening can be achieved by moving the ends of the spring relative to each other in order to cause the coils of the spring to tighten). The maximum braking force (F_{brake} max) that can be generated by the brake 10 is less than the minimum force (F_{motor} min) for generating a linear operating movement that can be obtained from the motor 3. Thereby, the brake 10 is unable to lock the transmission means 13 and prevent an operating movement when the motor 3 is operated to generate a torque. The maximum braking force is also preferably smaller than the minimum clutch force (F_{clutch} min) applied by the clutch via the clutch operating mechanism 49, so that the clutch operating mechanism 49 can push the transmission means 13 in the proximal direction when the motor 3 does not deliver a torque to overcome this. Thus F_{motor} min > F_{clutch} max > F_{clutch} min >F_{brake} max. In the cases when the clutch force F_{clutch} is substantially constant then F_{clutch} max is the same as F_{clutch} min and therefore F_{motor} min > F_{clutch} > F_{brake} max. In this way the brake 10 is able to slow movement in the proximal direction (which re-engages the clutch) but is not able to prevent it.

Fig. 3 discloses the proximal end of the clutch actuator 1 with the motor 3 connected via an output 5 to the reduction gear 9. The motor 3 is also attached to the housing 37, and to the brake 10 by a shaft 51 that extends through a brake disk 52 and a proximal part 53 of the brake 10. The brake 10 is in this preferred embodiment in the form of a wrap spring brake with a brake spring 55 surrounding the proximal part 53 and a distal part 54 that is connected to the transmission means 13, in this embodiment to the ball screw 15 in order to be able to brake said ball screw 15 when the brake 10 is activated. Fig. 3 also discloses the ball nut 17 and the preload spring 21 mounted on the proximal end of the ball nut 17.

The operation of the clutch actuator 1, and in particular of the brake 10, will now be described in more detail with reference to Figs. 4-7, where the clutch actuator 1 is shown schematically in different operation positions.

Fig. 4 discloses an installation position where the ball nut 17 is located in a proximal position adjacent to the reduction gears 9. Via the motor output 5 and reduction gear 9, the transmission means 13 in the form of the ball screw 15 and ball nut 17 may be operated so that a rotation of the ball screw 15 results in a linear movement of the ball nut 17 in the distal direction towards the plunger 19.

In the first operation position shown in Fig. 5, the ball nut 17 has been moved in the distal direction and is situated at a distance d from the plunger 19. This is the position where the clutch is engaged and the clutch actuator 1 is not being operated to disengage it. Thanks to the nearness of the ball nut 17 to the plunger 19, the operation to disengage the clutch can be performed quickly by moving the ball nut 17 only a small distance. In this position, the motor is stopped and the brake 10 activated to hold the transmission means 13 in the position shown in the Figure.

Fig. 6 discloses a second operation position where the clutch actuator 1 is operated to disengage the clutch. The motor 3 now delivers a torque to the transmission means 13 and the ball screw 15 is rotated so that the ball nut 17 moves linearly in the distal direction and abuts the plunger 19.

In this position, the brake 10 is not active and the ball nut 17 pushes against the plunger 19 with a force that must be larger than the clutch force in order to move the plunger 19 in the distal direction.

Fig. 7 shows a third operational position, where the ball nut 17 has continued the movement in the distal direction and pushed the plunger 19 and push rod that together form the clutch operating mechanism 49 to the position where the clutch is disengaged.

The clutch actuator 1 is held in the third operating position until the clutch is again to be engaged. The motor 3 then ceases to act on the transmission means 13 to hold the ball nut 17 in position, and once the force with which the ball nut 17 presses against the plunger becomes smaller than the clutch force, the clutch operating mechanism 49 is able to push the ball nut 17 in the proximal direction and thereby cause a rotation of the ball screw 15 in the other direction. The brake 10 can be activated to brake this rotation and allow the ball nut 17 to reach the first operation position in a controlled manner, and thanks to the dimensioning of the brake 10 where the maximum brake force is smaller than the clutch force, the brake 10 is not able to completely prevent the movement of the ball nut 17. Thanks to the use of the brake 10 rather than using the motor 3 for driving the ball nut 17 to the first operational position, energy can be saved and the torque from the ball screw 15 during the movement of the ball nut 17 in the proximal direction is transformed into heat at the brake 10 rather than in the motor 3. This is advantageous in reducing the wear on the motor 3 and thereby prolonging its life.

The brake 10 can be activated by a control unit (not shown) that serves to control the operation of the clutch actuator 1 but can also be activated automatically by a linear force or a torque in the backward direction, said force or torque acting on the clutch actuator 1 by the clutch operating mechanism 49. It may also be activated by a torque in the backward direction at the reduction gear. The brake 10 would then be activated each time the clutch actuator 1 is operated to engage the clutch and serves to decrease the velocity of the transmission means 13 in the backward direction.

The backward direction is defined as the direction of rotation that generates a linear movement of the transmission means in the proximal direction, i.e. away from the clutch operating mechanism 49.

The clutch actuator 1 according to the present invention is also especially advantageous in the event of a loss of power of the motor 3, since the interaction between the clutch operating mechanism 49, the transmission means 13 and the brake 10 allow for a failsafe operation of the clutch actuator 1.

This is achieved by the actuator performing a controlled proximal movement of the ball nut 17, the movement being driven by the return force generated by the clutch operating mechanism 49 and being slowed by the brake 10 (which is too weak to totally resist this force but which is strong enough to prevent a dangerously rapid movement of the ball nut which would result in an abrupt re-engagement of the clutch) so that the clutch is engaged and the vehicle can be driven to a secure place for maintenance or repair after an actuator power loss or motor failure has occurred.

The relationship between the clutch force, motor torque and pitch of the ball screw are given by

Torsion = clutch force * pitch/2π,

which determines the torque given by the clutch force acting on the transmission means; and the relationship between the movement of the ball nut, the clutch force and the friction is given by

$Torsion_{\mu}$ = clutch force * μr

where μ is the friction factor and r is the median contact radius on the brake disk.

Also provided are software for controlling the normal and failsafe operation of the clutch actuator 1. The software can be stored and executed by a control unit with storage means, such as are generally known in the art. Furthermore, the software is able to detect and control the position of the transmission means in order to operate the clutch actuator. The invention also comprises a vehicle having a clutch actuator as defined above, wherein the vehicle comprises a clutch with a clutch operating mechanism that is able to act on the transmission means with a clutch force, said clutch force being smaller than the force for generating a linear operating movement which can be generated by the motor. Preferably, the clutch force is larger than the maximum braking force, so that the benefits and advantages described above are achieved.

Fig. 8a is an example of a generic spring brake and 8b shows an embodiment of the brake of the actuator according to the invention which uses a suitably adapted spring brake. Most of the components are identical to the preferred embodiment described above, but, instead of the wrap spring brake, the brake comprises a helical spring 56 mounted around the ball screw 15 of the transmission means and covered by a sleeve 57. The helical spring 56 acts as a one-way brake and provides a braking torque when the transmission means rotate in the backwards direction, i.e. towards engaging the clutch (and thus generates a linear movement in the proximal direction away from said clutch operating mechanism), in a similar way as the preferred embodiment described above and also delivers a braking torque in a failsafe mode. The braking torque is achieved through an unraveling of the helical spring 56 that arises when the ball screw 15 is rotated in the opposite direction from the motor output 5 and thereby amplifies the motor torque when used as a brake.

It is to be noted that the alternative embodiment is in many ways similar to the other embodiments described herein and that features of the different embodiments may be combined with each other within the scope of the claims.

Fig. 9 discloses the normal operation of the clutch actuator 1 where in a first step 101 the transmission means 13 are moved from the installation position to the third operation position via the first and second operation positions to disengage the clutch. In a second step 102, the ball nut 17 is held in position by the motor 3 delivering a torque that is transformed to a force equal to the clutch force so that the ball nut 17 is held stably against the plunger 19 of the clutch operating mechanism 49. In a third step 103 the motor 3 stops and the brake 10 is activated so that the ball nut 17 is pushed in a proximal direction at a controlled speed. In a fourth step 104 the ball nut 17 has reached the first operation position and is held stably.

Fig. 10 discloses the failsafe operation of the clutch actuator 1, where in a first failsafe step 201 a power loss at the motor 3 is detected. If the clutch actuator 1 is currently operated to disengage the clutch, a power loss will immediately result in the clutch force pushing the transmission means 13 in the proximal direction so that the ball nut 17 is rotated around the ball screw 15 in the backwards direction.

The purpose of the failsafe operation is to slow the speed of the transmission means so that the clutch can be engaged through a controlled operation without the risk of damage or wear to the motor. This is achieved by engaging the brake and short circuiting the motor so that the speed of transmission means of the clutch actuator is reduced.

In a second failsafe step 202, it may also be determined whether a decrease of velocity of the transmission means 13 is actually necessary to prevent damage to the clutch actuator or heat generation at the motor 3. If it is determined that the velocity should decrease, the velocity is decreased in a third failsafe step 203 by short circuiting to ground and thereby activate the brake torque available in the motor. Since the maximum brake force is not sufficient to completely halt the movement of the transmission means 13, this will result in a decrease of velocity and in a heat generation at the brake 10 rather than in the motor 3. In a fifth failsafe step 205, it is determined whether the transmission means 13 have reached the first operation position where the ball nut 17 is no longer in contact with the plunger 19. If not, the second failsafe step 202 is repeated as above.

When it is determined in the fifth failsafe step 205 that the first operation position has been reached, the failsafe operation is finished in a sixth failsafe step 206.

If in the second failsafe step 202 it is determined that the velocity does not have to be decreased, the operation is continued in a fourth failsafe step 204 where a predetermined time interval is allowed to pass without an activation of the brake 10. After that interval has passed, the operation is moved to the fifth failsafe step as described above.

To further explain the relationship between the torque supplied by the motor 3 and the position of the transmission means 13, Fig. 11 is provided and discloses the motor torque required to move the transmission means to act on the clutch operating mechanism to disengage the clutch. Also shown is the motor torque required in the other direction to engage the clutch, and it is to be noted that considerably less motor torque is required in the proximal direction, i.e. to engage the clutch. In the event of a power loss, the motor is thus used as a generator to power the electronics and allow it to control the speed of engagement.

The scope of the present disclosure is defined by the following claims rather than by the detailed description of the embodiment. It shall be understood that all modifications and embodiments conceived from the meaning and scope of the claims and their equivalents are included in the scope of the present disclosure.

CLAIMS

1. Clutch actuator for a vehicle, comprising

- a motor (3) for generating a motor torque
- transmission means (13) for transforming said motor torque into a force for generating an operating movement able to act on a clutch operating mechanism in order to operate a clutch, and
  a brake (10) able to generate a braking force for braking said transmission means (13), **characterized in** the maximum braking force able to be generated by said brake (10) is less than the minimum force for generating such an operating movement.

2. Clutch actuator according to claim 1, **characterized in** that the transmission means (13) are able to receive a clutch force from the clutch operating mechanism, said clutch force being smaller than the force for generating an operating movement.

3. Clutch actuator according to claim 2, **characterized in** that the clutch force is larger than the maximum braking force.

4. Clutch actuator according to any of claims 1-3, **characterized in** that said transmission means (13) comprise a ball screw arranged to receive said motor torque and a ball nut mounted on said ball screw, and that said operating movement able to act on a clutch operating mechanism is a linear operating movement.

5. Clutch actuator according to any of claims 1-3, **characterized in** that said transmission means (13) comprises a lead screw.

6. Clutch actuator according to any of claims 1-5, **characterized in** that the brake (10) is a one-way brake (10) able to brake (10) the transmission means (13) when it moves in a proximal direction away from said clutch operating mechanism.

7. Clutch actuator according to any of claims 1-6, **characterized in** that the brake (10) is arranged to only be able to brake (10) the transmission means (13) when it moves in a proximal direction away from said clutch operating mechanism.

8. Clutch actuator according to any previous claim, **characterized in** that the brake (10) is a wrap spring brake (10).

9. Clutch actuator according to any previous claim, **characterized in** that the brake (10) is arranged to be activated by a linear force acting on the transmission means (13) in the proximal direction away from said clutch operating mechanism.

10. Clutch actuator according to any previous claims, **characterized in** that the brake (10) is arranged to be activated by a torque that rotates the transmission means (13) in the backwards direction which generates a linear movement in the proximal direction away from said clutch operating mechanism.

11. Clutch actuator according to any previous claims, **characterized in** that the brake (10) is arranged to be activated by a torque in the backwards direction at the reduction gear (9).

12. Vehicle comprising a clutch actuator having a motor (3) for generating a motor torque, transmission means (13) for transforming said motor torque into a force for generating an operating movement able to act on a clutch operating mechanism in order to operate a clutch, and a brake (10) able to generate a braking force for braking said transmission means (13), wherein the maximum braking force able to be generated by said brake (10) is less than the maximum force for generating an operating movement, **characterized in** said vehicle further comprising a clutch having a clutch operating mechanism that is able to act on the transmission means (13) with a clutch force, said clutch force being smaller than the force for generating an operating movement.

13. Vehicle according to claim 12, **characterized in** that the clutch force is larger than the maximum braking force.

14. Method for failsafe operation of a clutch actuator according to any of claims 1 to 11, **characterized in** the method comprising the steps of

- detecting a power loss at a motor (3) arranged to operate the clutch actuator
- engaging a brake (10) and short circuiting the motor (3) so that the speed of transmission means (13) of the clutch actuator is reduced.

15. Method according to claim 14, **characterized in** the method further comprising the steps of

- a) determining if a decrease of velocity of operating movement of a transmission means (13) for performing an operating movement is necessary and, if so, activating the brake (10) to decrease said velocity
- b) determining if the transmission means (13) have reached a first operation position, and repeating step a) until said first operation position has been reached.

16. Method according to claim 14 or 15, **characterized** by arranging the brake (10) to be activatable by a rotation of the transmission means (13) in the backwards direction.

17. Method according to any of claims 14-16, **characterized in** decreasing the velocity of operating movement of the transmission means (13) is achieved by short circuiting the motor (3) in addition to said activating the brake.

18. Software for performing the steps of a method for failsafe operation of a clutch actuator according to any of claims 1 to 11, said method **characterized by** comprising the steps of

- i) detecting a power loss at a motor (3) arranged to operate the clutch actuator
- ii) determining if a decrease of velocity of operating movement of a transmission means (13) for performing an operating movement is necessary and, if so, activating a brake (10),
- iii) determining if the transmission means (13) have reached a first operation position, and repeating step i) until said first operation position has been reached.

19. Computer storage means arranged to store and execute software for performing the steps of a method for failsafe operation of a clutch actuator according to any of claims 1 to 11, said method **characterized by** comprising the steps of

- i) detecting a power loss at a motor (3) arranged to operate the clutch actuator

- ii) determining if a decrease of velocity of operating movement of a transmission means (13) for performing an operating movement is necessary and, if so, activating a brake (10),
- iii) determining if the transmission means (13) have reached a first operation position, and repeating step i) until said first operation position has been reached.

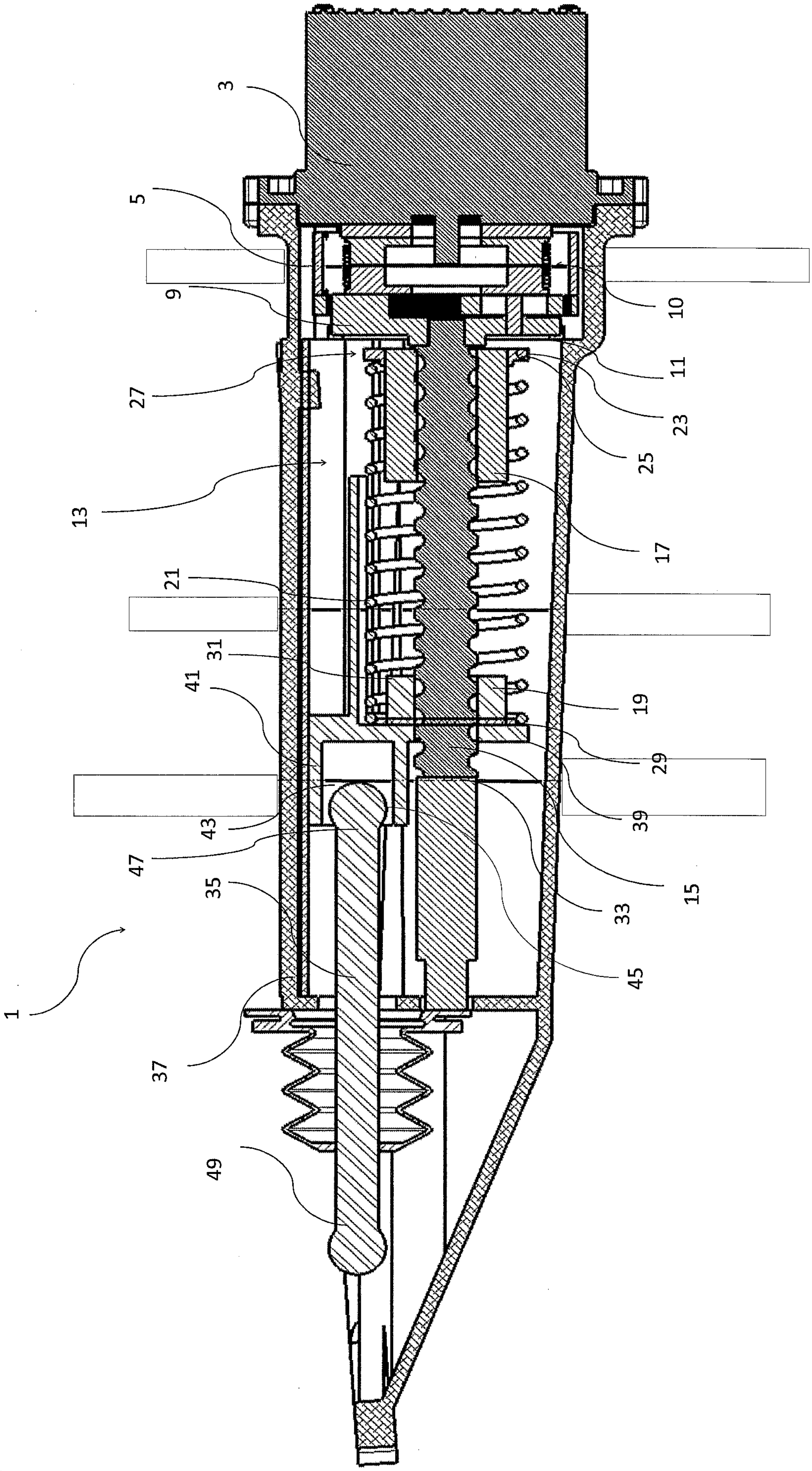


Fig. 1

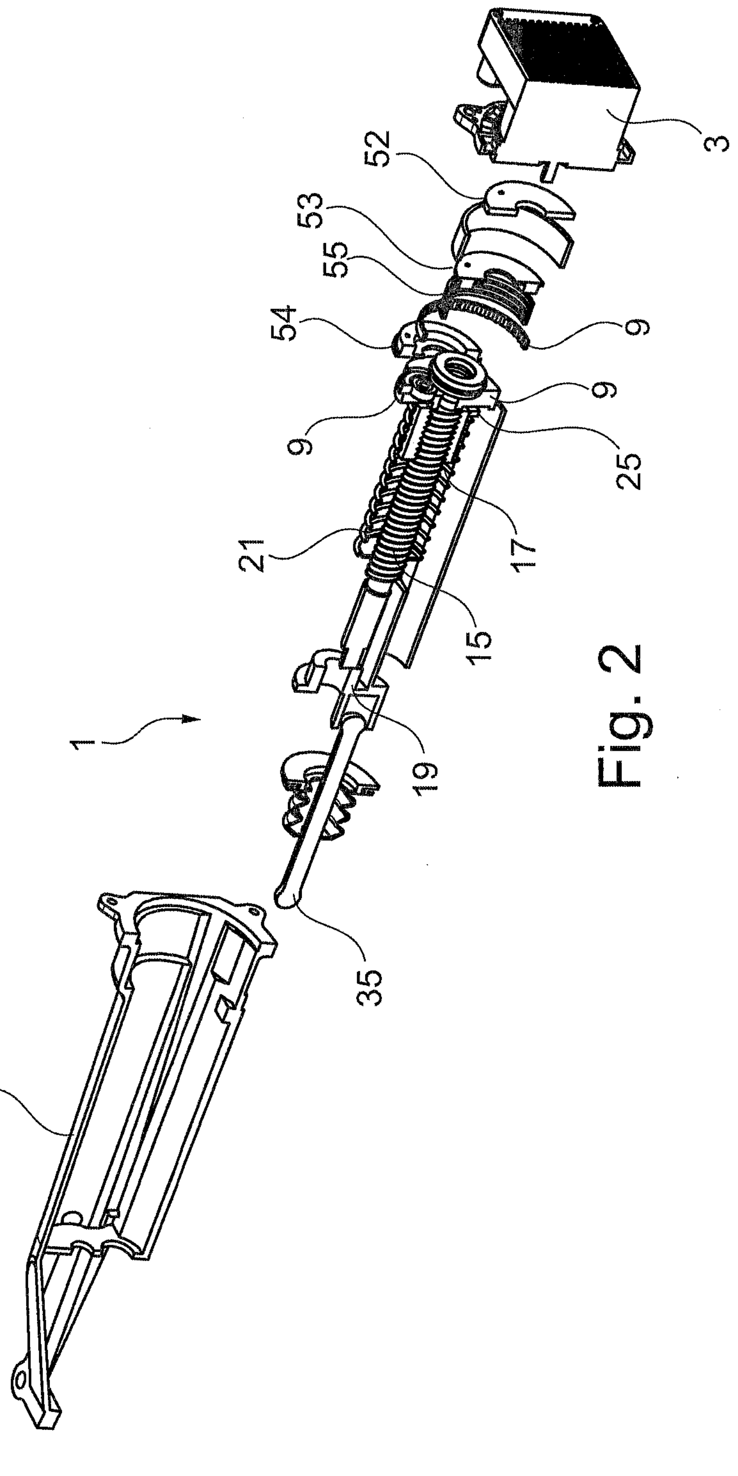


Fig. 2

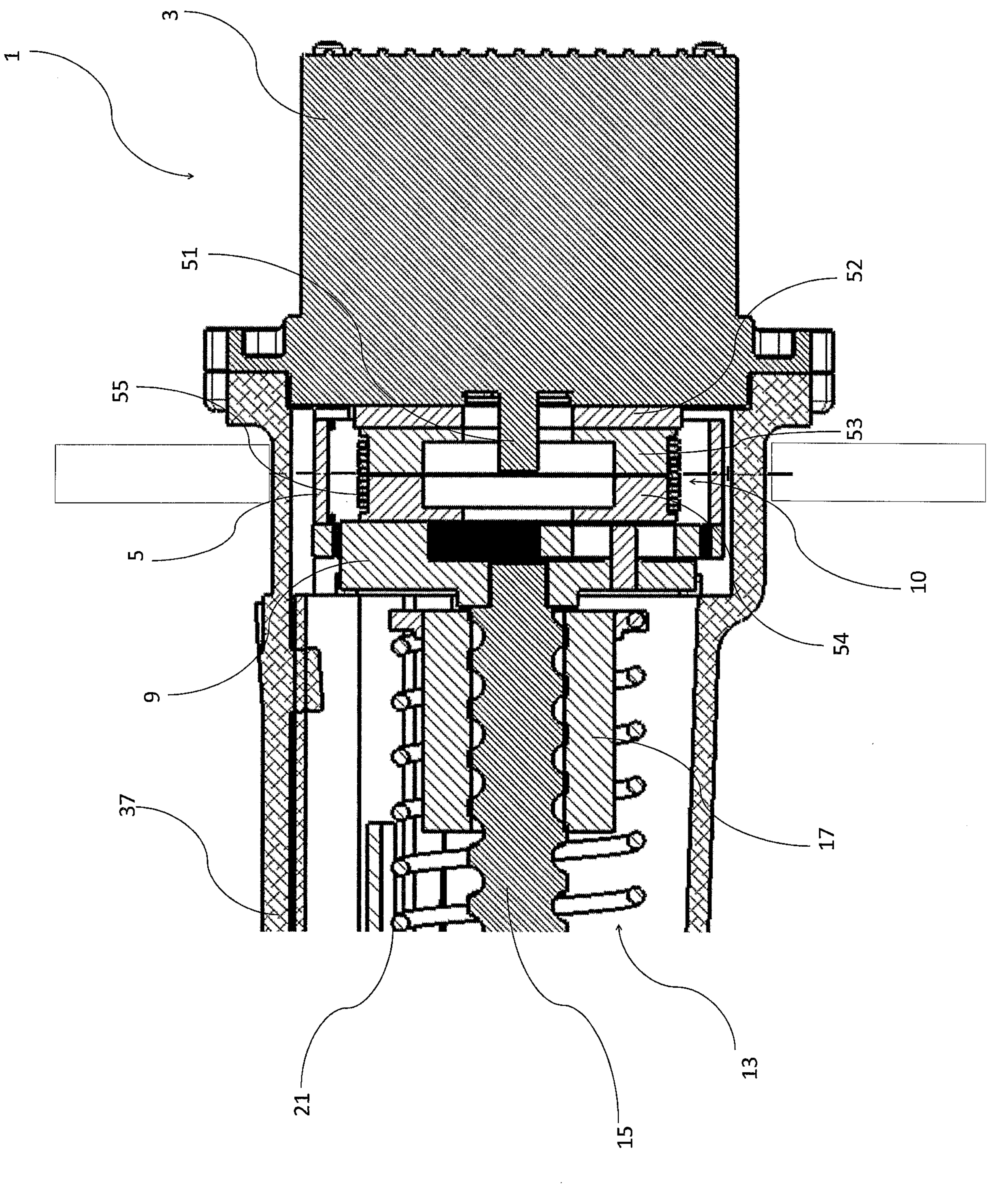


Fig. 3

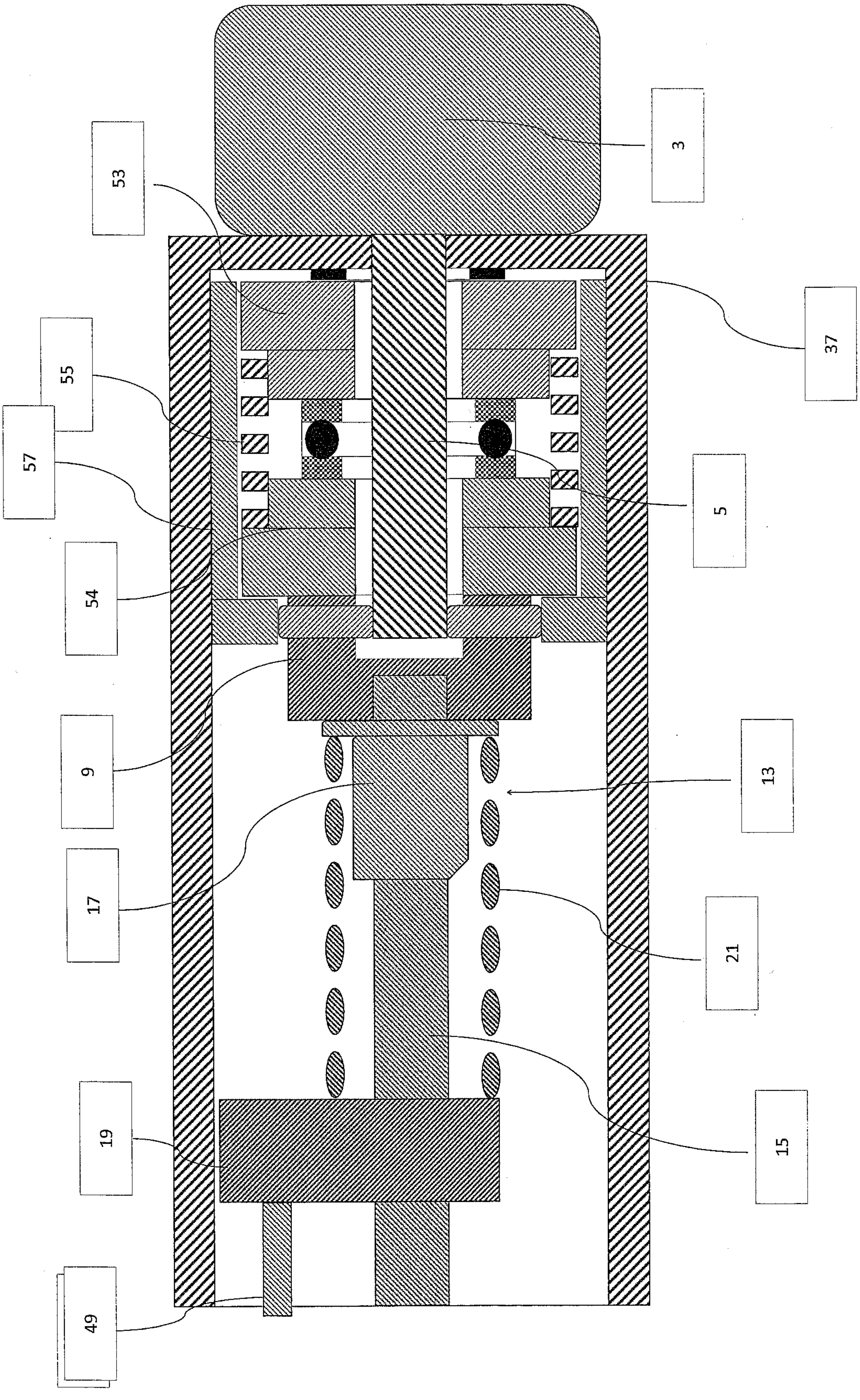


Fig. 4

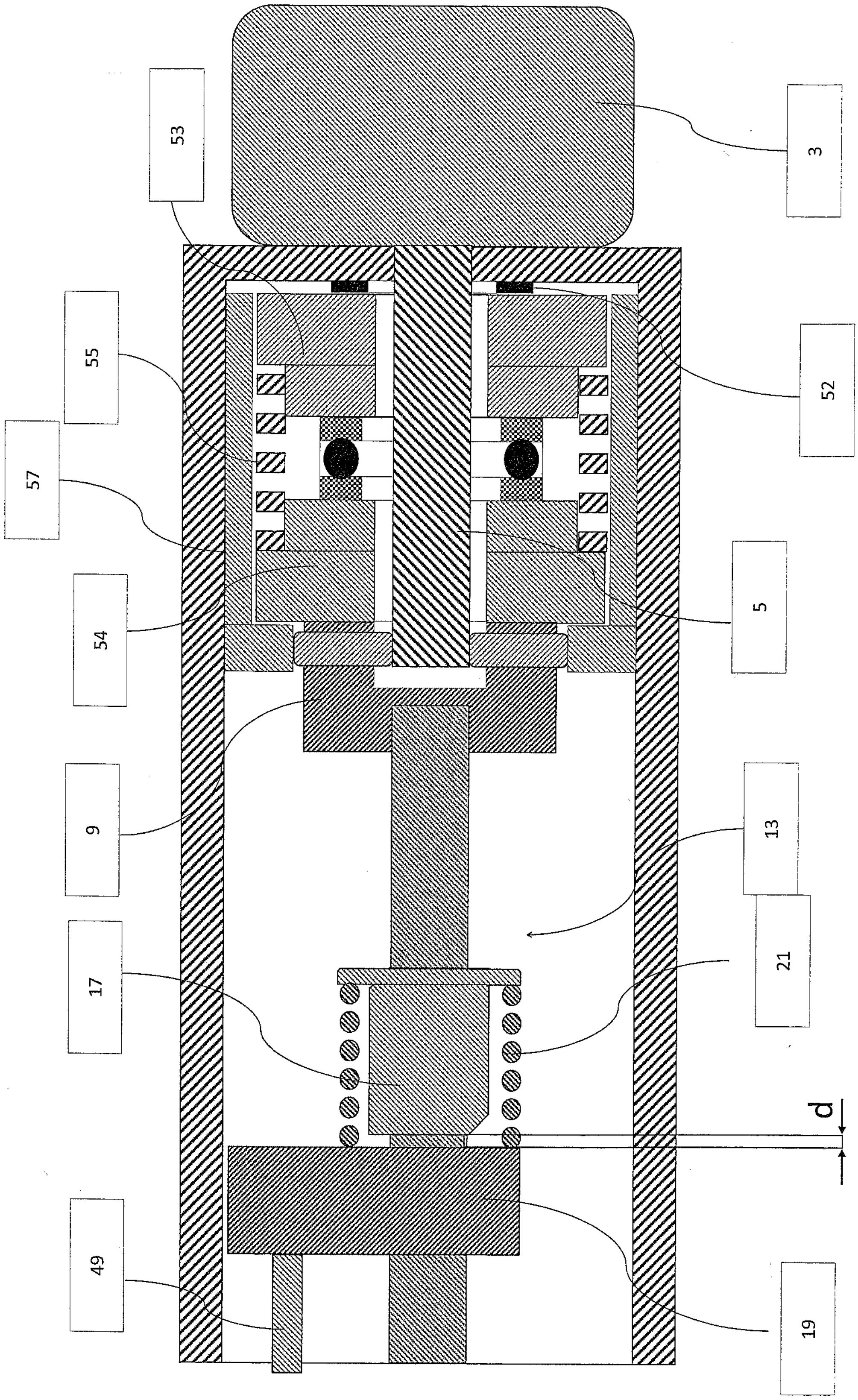


Fig. 5

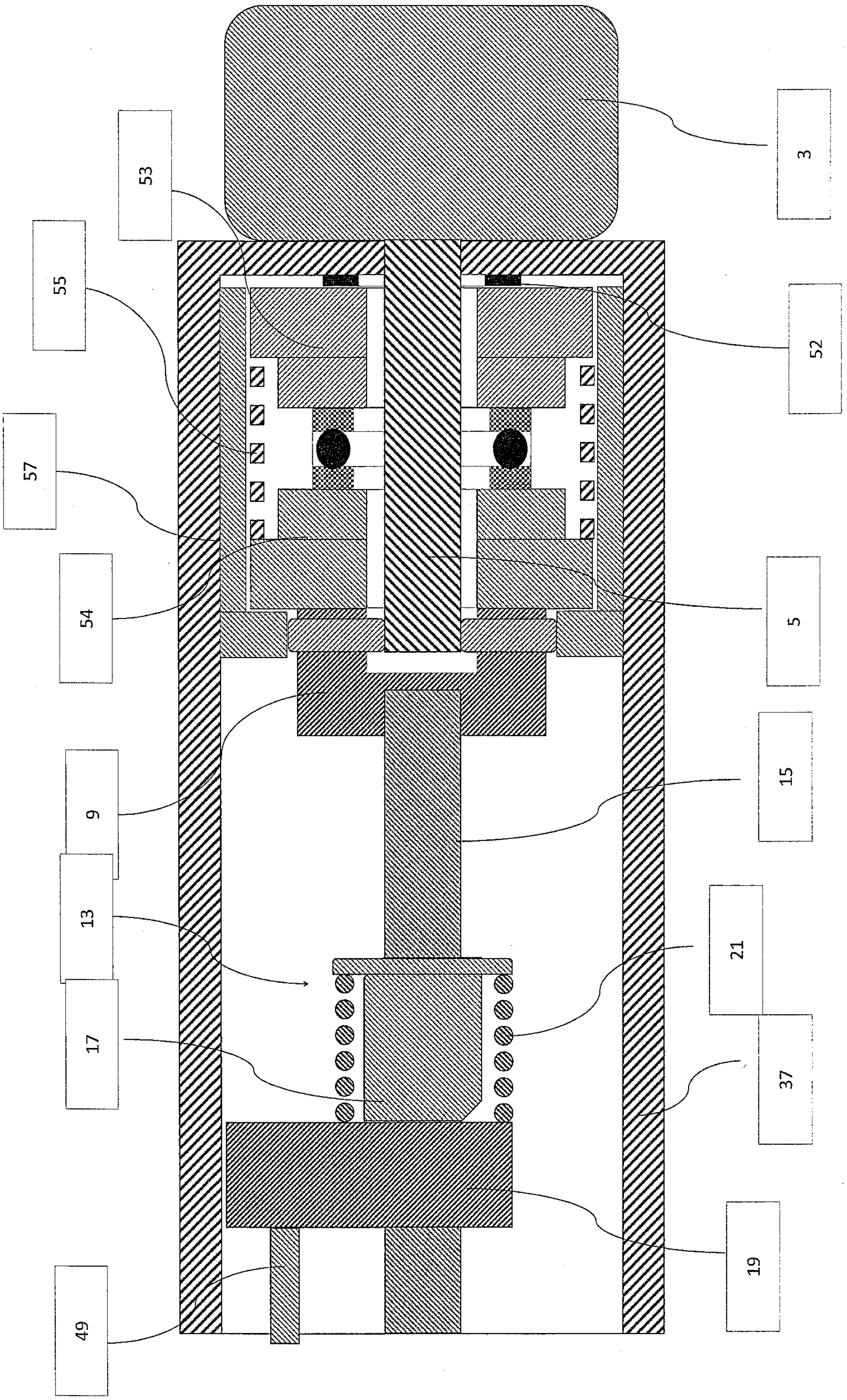


Fig. 6

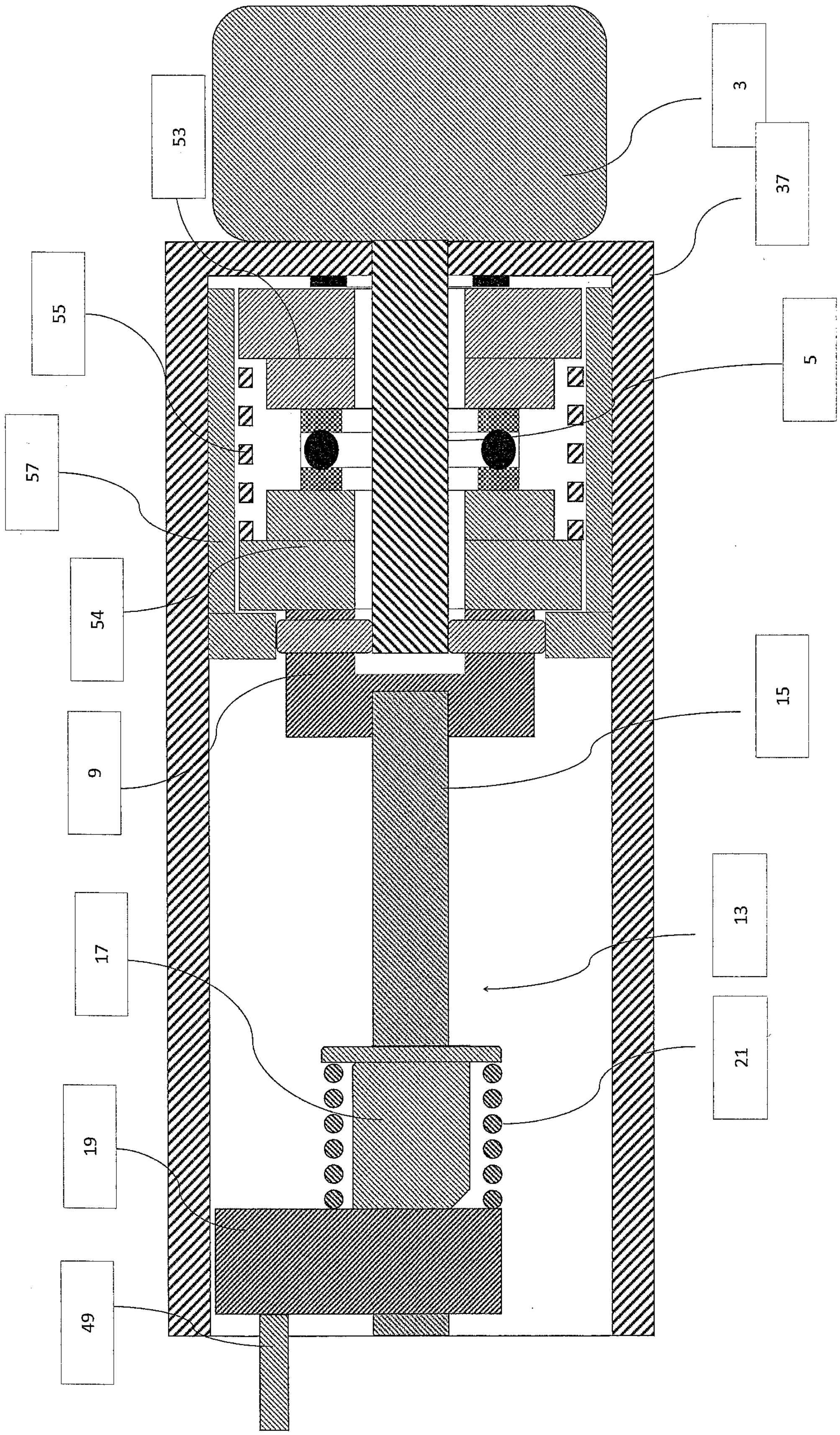


Fig. 7

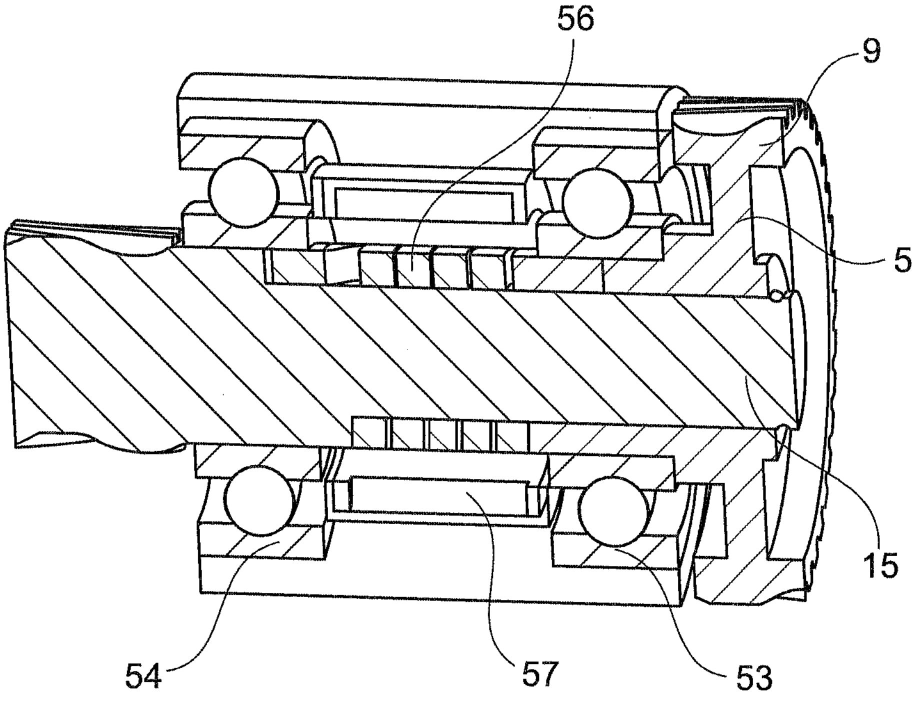


Fig. 8a

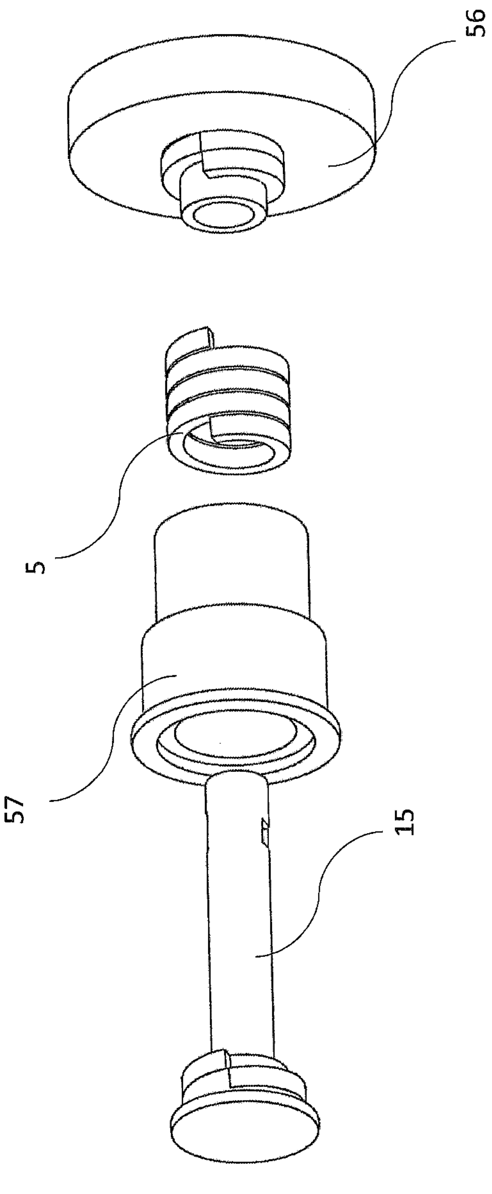
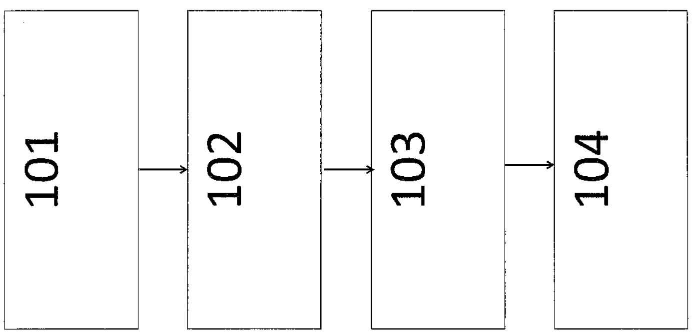
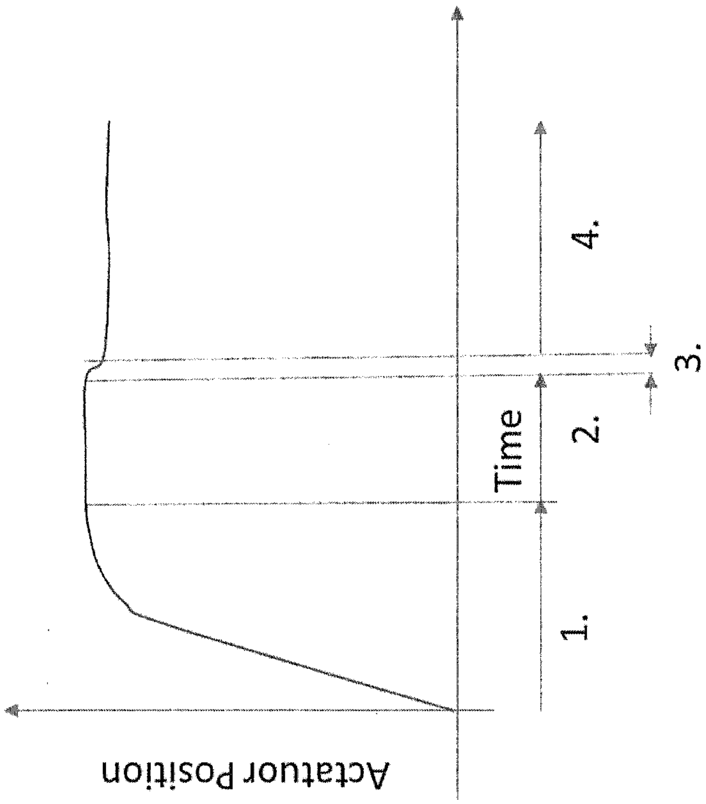


Fig. 8b

Fig. 9





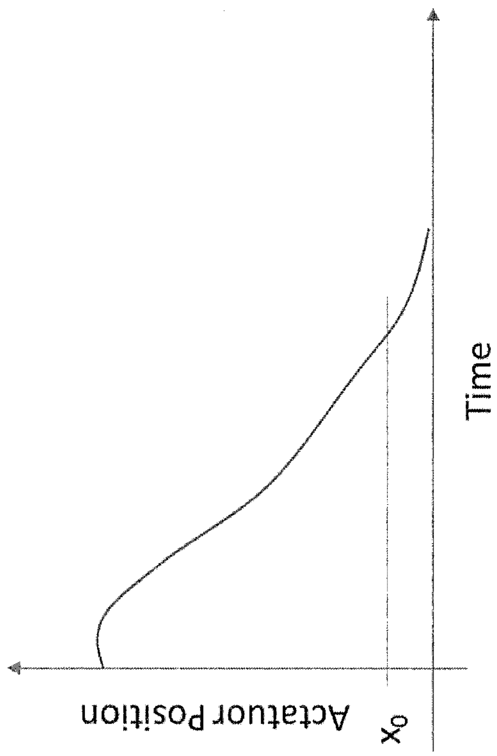


Fig. 10

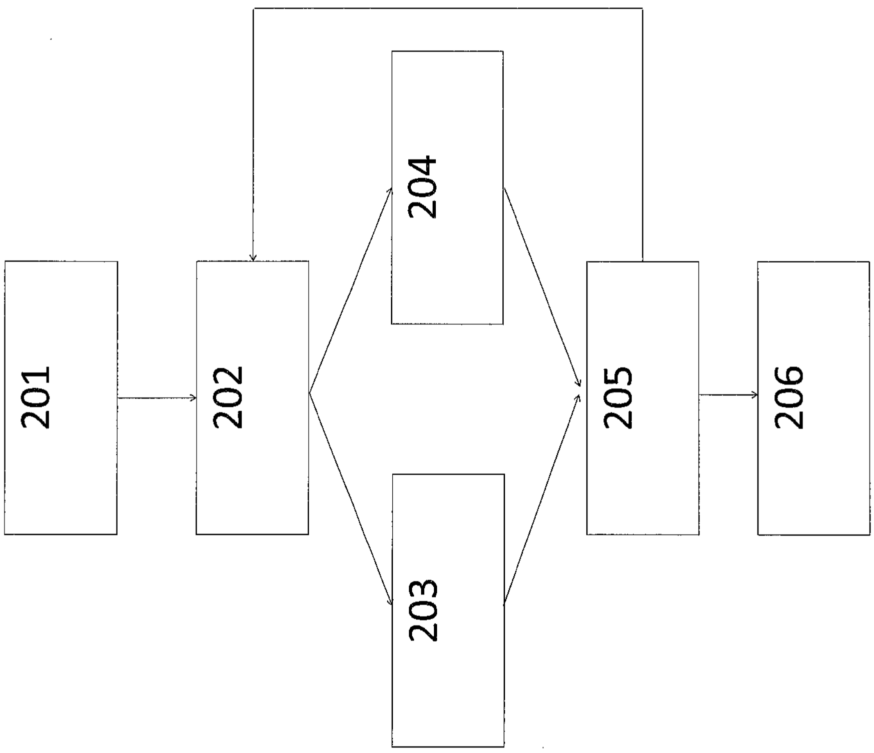


Fig. 11