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(54) TORQUE TOOL CONTROL ARRANGMENT

(57) The invention relates to a control system of a torque tool (1) provided for tightening and unscrewing of screw connections with adjustable torque. The system has a controller (3) of an electric motor (2) of the torque tool (1), and comprises a sensor (6) measuring the torque. The sensor (6) is configured to measure torsional deformations of a reduction gear (5) component of the torque tool (1) transferring the torque. Moreover, the sensor (6) is coupled with the controller (3), and the controller is configured to correct the output control signal to the electric motor (2) on the basis of the signal from the sensor (6) of the measured actual torque. The application also refers to a method of controlling the torque tool (1).

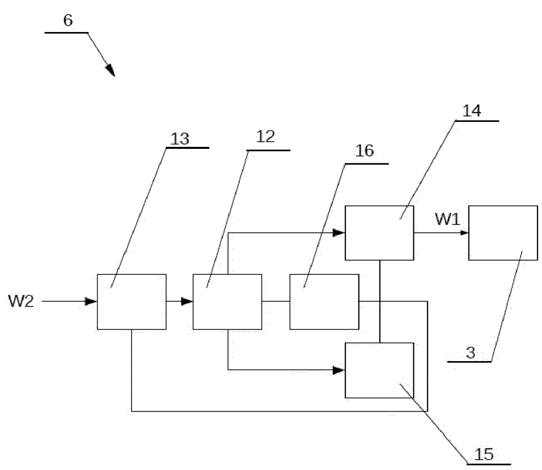

Fig. 5

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Description

Subject of the invention

[0001] The subject of the invention is a control system of a torque tool, in particular a digitally controlled high-torque electric tool, intended for tightening and unscrewing screw connections, in particular in steel constructions, machines, chemical reactors, distillation columns, and other similar constructions and devices.

State of the art

[0002] Electric torque tools are used to tighten or unscrew screw connections with adjustable and controllable torque. In general, such an electric tool comprises an electric motor controlled by a control unit and a gearbox coupled with a reduction gear, as well as a reaction arm and a working cap. When the torque tool is operating, it is important to accurately determine the torque at which a particular screw connection is being tightened. The commonly used electromechanical torque tools use current measurements in order to determine the torque for tightening the screw. The disadvantage of that method is the existence of errors connected with difficult to overcome phenomena which occur in the mechanical elements of the torque tool during tightening.

[0003] Moreover, US 2013/0205955 presented an electromechanical torque device, which used a torque sensor.

Aim of the invention

[0004] The purpose of the invention is to develop a system and a method of controlling an electric torque tool that would allow tightening and unscrewing of screw connections with high accuracy and torque recurrence of the tightening and unscrewing. Another purpose of the invention is to develop a system that would allow direct measurement and control over the actual torque applied to the screw connection.

Idea of the invention

[0005] According to the preamble of claim 1, the torque tool control system is characterized in that the torque sensor is configured to measure torsional deformations of an element of a reduction gear transferring the torque, and further the sensor is coupled with a controller, which controller is configured to correct the output control signal to the electric motor on the basis of the signal from the sensor measuring the actual torque.

[0006] It is appropriate to have the sensor coupled with the controller wirelessly, preferably via radio waves.

[0007] In particular, the sensor is in a form of a module put on the reduction gear, which module is coupled with the elements of the reduction gear transferring the torque, and the measuring component of the sensor is fixed on a measuring sleeve seated in a movable way on the sensor shackle.

[0008] In another possible execution, the measuring component of the sensor is located on the body of the reduction gear, while the electronic circuit of the sensor is integrated with the reduction gear.

[0009] The most advantageous form for the measuring component of the sensor is in form of a strain gauge.

[0010] The system can have a single control loop with regulator R that is configured to control the electric motor when the measured torque has values lower than the threshold value in order to maintain the motor speed running the gearbox at the set speed. Moreover, the control system includes a cascade regulation system with regulator R1, regulator R2, and regulator R3, which are configured to control the motor when the measured torque assumes values between the threshold value and the set value, whereas regulator R3 is configured to monotonically decrease the difference between the set torque and the measured torque, regulator R2 is configured to decrease the rate at which the torque increases proportionally to the difference between the measured torque and the set torque, while regulator R1 is configured to decrease the motor speed according to the signal from regulator R2.

[0011] The method of controlling a torque tool is characterized in that the torsional deformations of the reduction gear element in the torque tool that transfers the torque is measured, while the signal from a sensor of the actual measurement of the torque is sent to the controller. Next, on the basis of that measurement signal, there the output signal from the controller to the electric motor running the torque tool is corrected.

[0012] In the simplest embodiment, the signal from the sensor is sent to the controller wirelessly, preferably via radio waves.

[0013] In one of the most advantageous embodiments, torsional deformations of the reduction gear element that transfers the torque is measured with the use of a strain gauge.

[0014] It is justified to cease the tightening process when the measured torque has the value equal to the set torque.

[0015] In the case in which the measured torque assumes values lower than the threshold value, the motor is controlled in a single control loop, in which regulator R maintains the motor speed running the reduction gear at the set value of speed. When the measured torque assumes values between the threshold value and the set value, the motor is controlled with a cascade regulation system, in which regulator R3 monotonically decreases the difference between the set torque and the measured torque, while regulator R2 decreases the rate at which the torque increases proportionally to the difference between the measured torque and the set torque, while regulator R1 decreases the motor speed according to the signal from regulator R2.

Advantageous effects of the invention

[0016] The invention allows to direct measurement of the torque applied to a screw connection and allows to compare the measured torque with the torque set by the operator in the controller of the motor that runs the torque tool. It provides the possibility of making corrections by adjusting the signal which controls the motor. As a result, higher accuracy of tightening and unscrewing of screw connections has been achieved and additionally the possibility of determining, with high accuracy, the torque at which screw connections were tightened is provided. Moreover, a significantly higher recurrence of torques is provided than in the case of conventional solutions. It has been also possible to significantly decrease the cases in which screw connection ae tighten with exceeded torque in comparison to the currently used torque tools. The sensor measures torsional deformations of the element transferring the torque and, based on that, calculates the applied torque. The sensor can be fixed permanently in the gearbox, in other words it can be integrated with it or, as an alternative, form a separate component fixed at the end of the gearbox in form of a cap.

Description of drawings and embodiments

[0017] The invention is presented in more details in the attached drawings, which represent:

Fig. 1 - a schematic plan of a torque tool divided into individual main components;
Fig. 2 - a schematic section through the element of the reduction gear with the torque measuring component fixed directly on the body of the gear;
Fig. 3 - a schematic plan of the torque tool divided into individual main components in a different execution;
Fig. 4 - a schematic section through a part of the sensor with the torque measuring component mounted on the measuring sleeve;
Fig. 5 - a block diagram of the torque sensor;
Fig. 6 - a block diagram of the single control loop;
Fig. 7 - a block diagram of the cascade control loop;
Fig. 8 - a chart with the run function of the torque during tightening with regard to the threshold value of the torque and value of the set torque.

[0018] An electric torque tool 1 (Fig. 1) is provided for tightening and unscrewing of screw connections with adjustable torque and it has a motor 2 with a control system comprising a control unit - a digital controller 3. The motor 2 is connected with a gearbox 4, preferably by using a rotary joint, which provides full rotation of the body of the gearbox 4 against the body of the motor 2. In turn, the gearbox 4 is coupled with a reduction gear 5. The change of gears in the gearbox is executed with a manual gear lever that is not presented in the drawing.

[0019] The control system of the torque tool 1 comprises a torque measuring sensor 6, which is configured to measure the torsional deformations of an element of the reduction gear 5 of the torque tool 1 transferring the torque. Moreover, the sensor 6 is coupled with the controller 3, which is configured to correct the output control signal to the electric motor 2 on the basis of the signal from the sensor 6 of the actual torque. In particular, the sensor 6 is coupled with the controller 3 wirelessly, for example by using radio waves. What is more, the torque tool 1 comprises a resistance arm 7 and cap pin 8, in other words a working component through which the torque is transferred to a screw connection.

[0020] In the embodiment presented in Fig. 1, the sensor 6 is integrated with the reduction gear 5, which means that both its measuring component 6A as well as an electronic circuit of the sensor 6 are located within the reduction gear 5. In particular, Fig. 2 presents that the measuring component 6A of the sensor 6 is located on a body 10 of the reduction gear 5. In that embodiment, the sensor 6 with the measuring component 6A measures the value of torsional deformations of the body 10 of the reduction gear 5 and the torque is transferred to the body 10 through gear wheels of the reduction gear 5 from a shackle 9 of the reduction gear 5. The shackle 9 is connected with the cap pin 8, onto which a cap is put the size of which depends on the size of the screw component. On the other side, the same torque as in the body 10 of the reduction gear 5 is transferred to the resistance arm 7. A different embodiment, not presented in the drawing, is also possible, for example the measuring component 6A can be seated directly on the shackle 9.

[0021] In another embodiment which is schematically shown in Fig. 3, the sensor 6 of the torque tool 1 is in form of a module attached on the reduction gear 5 and such module constitutes a separate component of the torque tool 1 and its components, especially a shackle 6B and a measuring sleeve 11, are mechanically coupled with components of the reduction gear 5 transferring the torque. In this embodiment, the measuring component 6A of the sensor 6 is fixed on the measuring sleeve 11 seated in a movable way on the shackle 6B of the sensor 6, for example by using a bearing that has not been presented in the drawing, and covered with a body 6C of the sensor 6 to protect the mechanical elements and electronic circuits against damage and external factors.

[0022] With reference to the above-mentioned exemplary embodiments, the most advantageous situation is when the measuring component 6A of the sensor 6 is in a form of a gauge meter, depending on the needs in the deflection compensation system, or in a system without deflection compensation system. It is also possible to apply other known measuring components, for example by using the phenomenon of magnetostriction or the phenomenon of surface acoustic wave SAW.

[0023] In Fig. 5, a block diagram has been presented for the torque measuring sensor 6, in which one may distinguish an electronic circuit 12 that manages the operation of the torque sensor, an electronic measuring system 13, an electronic radio communication system 14, an electronic user interface system 15, and an electronic power supply system 16.

[0024] Fig. 6 shows a single control loop with regulator R, which is configured to control the electric motor 2 when the measured torque assumes values lower than threshold value M_P. Regulator R is configured to maintain speed of the motor 2 running the reduction gear 5 through the gearbox 4 at set speed value V_z. The threshold value M_P should be understood as the empirically set value of the torque that falls within the range of 50% to 90% of set torque M_Z, depending on the absolute value of the torque and the type and technical condition of the screw connection.

[0025] Fig. 7 shows an additional control loop, which means a cascade regulation system with regulator R1, regulator R2, and regulator R3, which are configured to control the motor 2 when the measured torque assumes values between the threshold value M_P and the set value M_Z. In particular, regulator R3 is configured to monotonically decrease the difference between the set torque M_Z and the measured torque M, regulator R2 is configured to decrease rate ΔM at which the torque increases proportionally to the difference between the measured torque M and the set torque M_Z, while regulator R1 is configured to decrease the speed of the motor 2 according to the signal from regulator R2.

[0026] The sensor 6 is used to measure the torsional deformation of the element of the reduction gear 5 transferring the torque and, on that basis, the applied torque is calculated. For that process, a known measurement filtering system, a power supply system, and other electronic circuits helpful in controlling the torque tool are used. The signal from the sensor 6 regarding the actual measurement of the torque is sent to the controller 3 and then, based on that signal, corrections are made in the output signal from the controller 3 to the electric motor 2.

[0027] The operator sets the desired torque on the controller, places the torque tool in a position appropriate for tightening and starts the tightening process. Torque M is measured during the tightening process and the tightening is stopped when the set value is reached.

[0028] In particular, which is shown in Fig. 6 to Fig. 8, the motor 2 is accelerated by providing supply voltage with a value growing linearly or in another way over time, until the motor reaches working speed V. The working speed is determined for a particular type of screw connection and the set tightening torque, while its value is calculated by the control system during configuration of set torque M_z. The regulation system stabilizes the motor speed at the set working speed. The procedure lasts until the torque gain from the initial value exceeds the value calculated by the control system at the stage of configuration of the set torque. The regulation system changes the set value of speed to a value that is proportional to the difference between the temporary gain of torque and the value proportional to the difference between the temporary torque and set torque.

[0029] If the value of the tightening torque M is below the threshold torque value M_P, the controlling is performed in accordance with the diagram presented in Fig. 6, where regulator R controls the motor 2 in order to stabilize the difference between the set value V_z and the measured speed V at 0. If the value of the tightening torque is between the value of the threshold torque M_P and the value of the set torque M_Z, the control is performed according to the diagram shown in Fig. 7. The reduction gear 5 is run by the gearbox 4 and the motor 2 that rotates at speed V and generates torque M. The gain of rate ΔM is calculated between measurements. By using regulator R3, the difference between the set torque M_Z and the measured torque M decreases monotonically. Regulator R2 decreases the rate at which torque increases proportionally to the difference between the measured torque M and the set torque M_Z, while regulator R1 decreases the speed of the motor 2 based on the signal from regulator R2.

[0030] List of reference numbers in the drawing:

- 1 - electric torque tool
- 2 - motor
- 3 - digital controller
- 4 - gearbox
- 5 - reduction gear
- 6 - torque sensor
- 6A - measuring component of the torque sensor
- 6B - shackle
- 6C - sensor body
- 7 - resistance arm
- 8 - cap pin
- 9 - shackle of the reduction gear
- 10 - body of the reduction gear
- 11 - measuring sleeve
- 12 - electronic circuit managing the torque sensor
- 13 - electronic measurement system
- 14 - electronic radio communication system
- 15 - electronic user interface system
- 16 - electronic power supply system
- W1 - output signal from the sensor
- W2 - output signal from the measuring component
- R, R1, R2, R3 - regulators
- M - measured torque
- M_Z - set torque
- M_P - threshold value of the torque
- ΔM - gain of the measured torque
- V_Z - set speed
- V - measured speed of the motor

Claims

1. A control system of a torque tool (1) provided for tightening and unscrewing of screw connections with adjustable torque, comprising a controller (3) of an electric motor (2) of the torque tool (1), further comprising a torque sensor (6), **characterized in that**

the torque sensor (6) is configured to measure the torsional deformations of an element of a reduction gear (5) of the torque tool (1) transferring the torque, and moreover the sensor (6) is coupled with the controller (3) which is configured to correct the output control signal to the electric motor (2) based on the signal from the sensor (6) measuring the actual torque.

2. The control system of a torque tool according to claim 1, **characterized in that** the sensor (6) is coupled with the controller (3) wirelessly, preferably by using radio waves.

3. The control system of a torque tool according to claim 1 or 2, **characterized in that** the sensor (6) is in a form of a module put on the reduction gear (5), which is coupled with the elements of the reduction gear (5) transferring the torque, and the measuring component (6A) of the sensor (6) is fixed on a measuring sleeve (11) seated movably on the sensor (6) shackle (6B).

4. The control system of a torque tool according to claim 1 or 2, **characterized in that** the measuring component (6A) of the sensor (6) is located on the body (10) of the reduction gear (5), while the electronic circuit of the sensor (6) is integrated with the reduction gear (5).

5. The control system of a torque tool according to one of the claims 1 - 4, **characterized in that** the measuring component (6A) of the sensor (6) is in the form of a strain gauge.

6. The control system of a torque tool according to one of the claims 1 - 5, **characterized in that** it comprises a single control loop with regulator R that is configured to control the electric motor (2) when the measured torque has values lower than the threshold value (M_P) in order to maintain the motor speed running the gearbox (4) at the set speed (V_z), further comprising a cascade regulation system with regulator R1, regulator R2, and regulator R3, which are configured to control the motor (2) when the measured torque assumes values between the threshold value (M_P) and the set value (M_Z), whereas regulator R3 is configured to monotonically decrease the difference between the set torque (M_Z) and the measured torque (M), regulator R2 is configured to decrease the rate at which the torque increases proportionally to the difference between the measured torque (M) and the set torque (M_Z), and regulator R1 is configured to decrease the motor (2) speed according to the signal from regulator R2.

7. A method of controlling a torque tool provided for tightening and unscrewing screw connections with adjustable torque, in which measurement of the actual torque is performed, **characterized in that** the torsional deformations of a reduction gear (5) element in the torque tool (1) that transfers the torque is measured, while the signal from a sensor (6) of the actual measurement of the torque is sent to a controller (3), and further on the basis of that measurement signal the output signal from the controller (3) to an electric motor (2) running the torque tool (1) is corrected.

8. The method according to claim 7, **characterized in that** the signal from the sensor (6) is sent to the controller (3) wirelessly, preferably via radio waves.

9. The method according to claim 7 or 8, **characterized in that** torsional deformations of the reduction gear (5) element that transfers the torque is measured with the use of an strain gauge.

10. The method according to one of the claims 7 - 9, **characterized in that** tightening is stopped once the measured torque (M) has the value equal to the set torque (M_z).

11. The method according to one of claims 7 - 9, **characterized in that** in the case in which the measured torque (M) assumes values lower than the threshold value (M_P), the motor (2) is controlled in a single control loop, in which regulator R maintains the motor (2) speed running the reduction gear (5) through a gearbox (4) at the set value of speed (V_Z), and when the measured torque (M) assumes values between the threshold value (M_P) and the set value (M_Z), the motor (2) is controlled with a cascade regulation system, in which regulator R3 monotonically decreases the difference between the set torque (M_Z) and the measured torque (M), while regulator R2 decreases the rate at which the torque increases proportionally to the difference between the measured torque (M) and the set torque (M_Z), while regulator R1 decreases the motor (2) speed according to the signal from regulator R2.

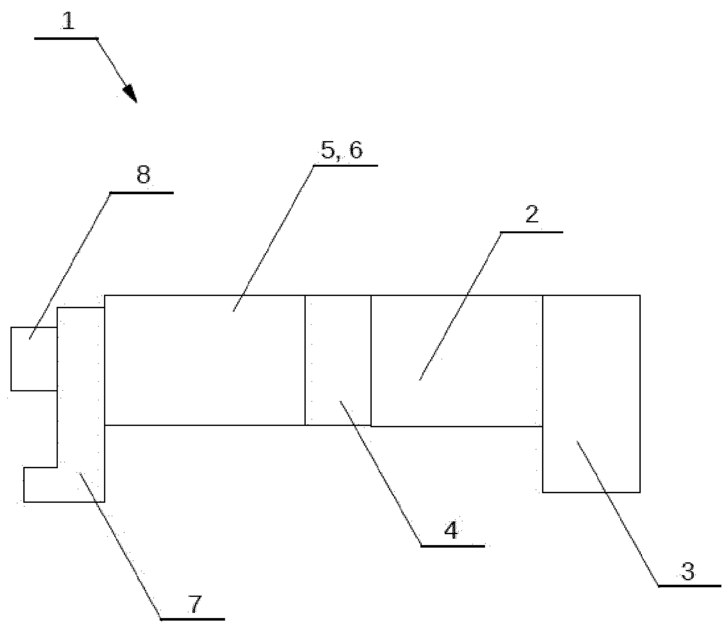

Fig. 1

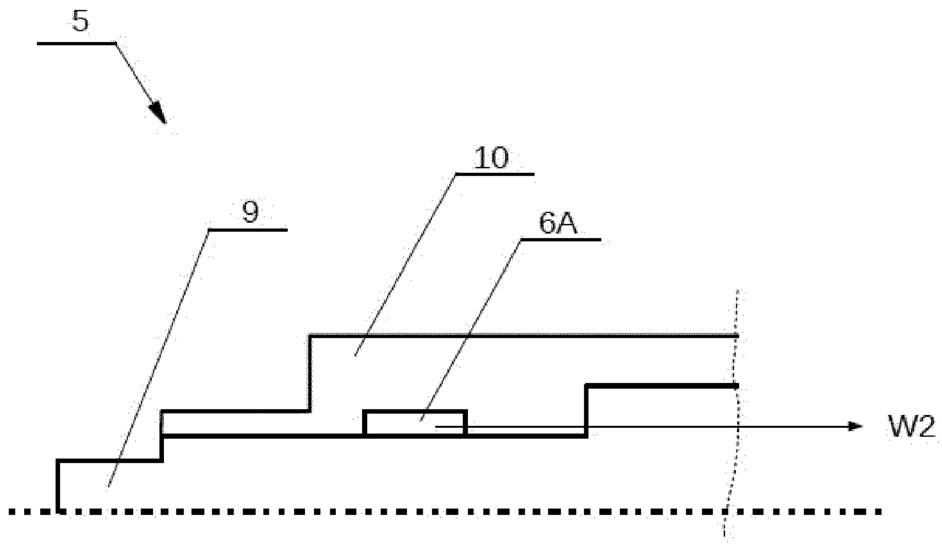

Fig. 2

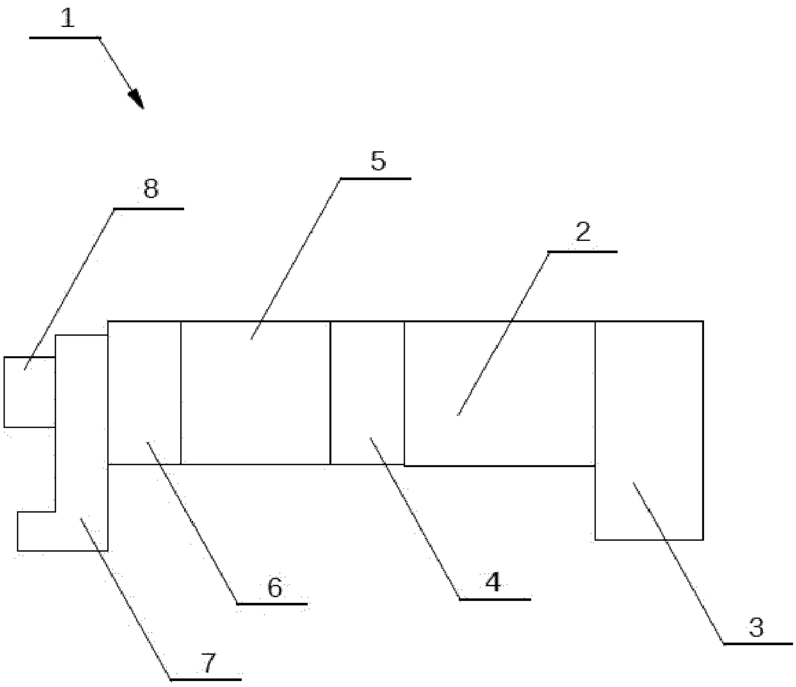

Fig. 3

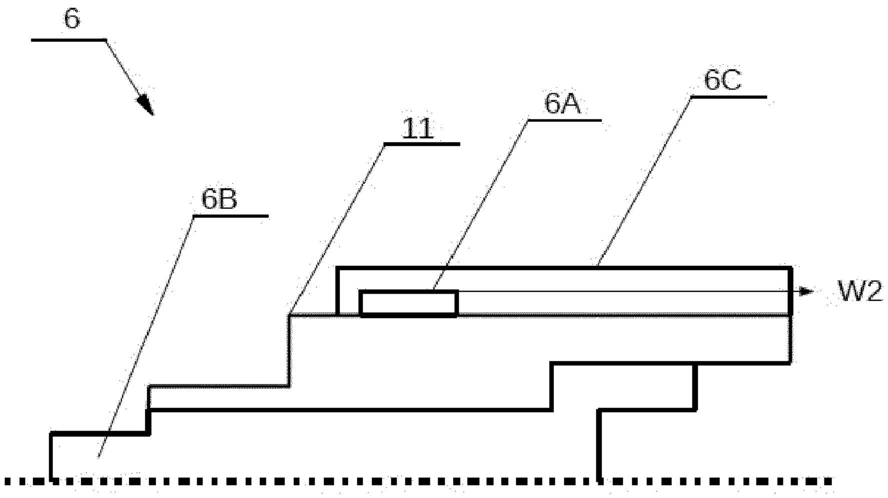

Fig. 4

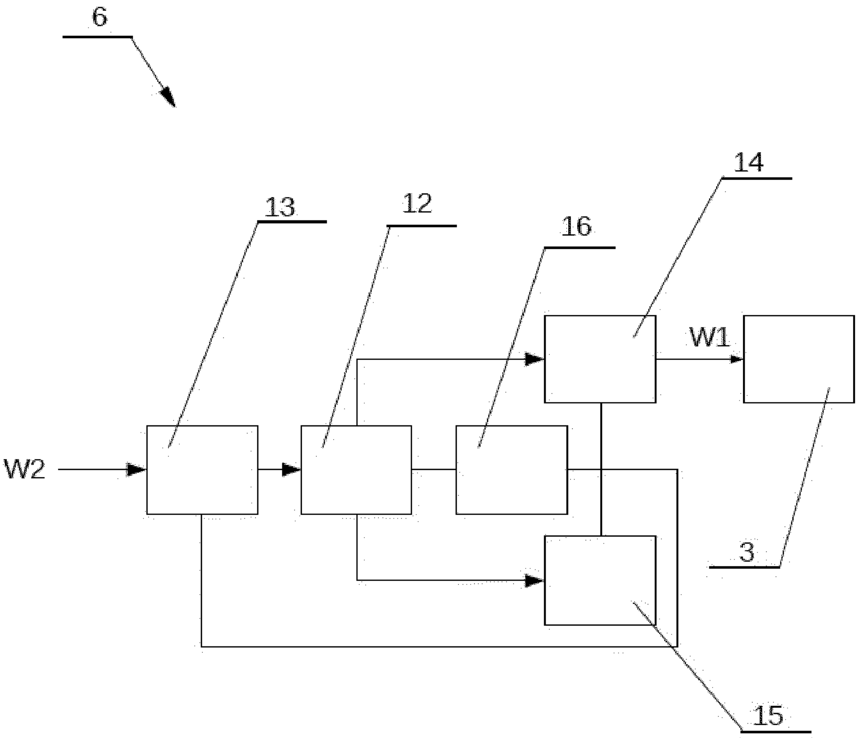

Fig. 5

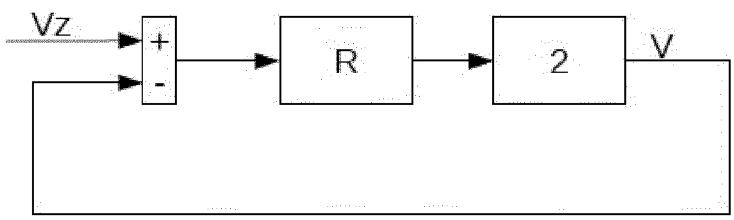

Fig. 6

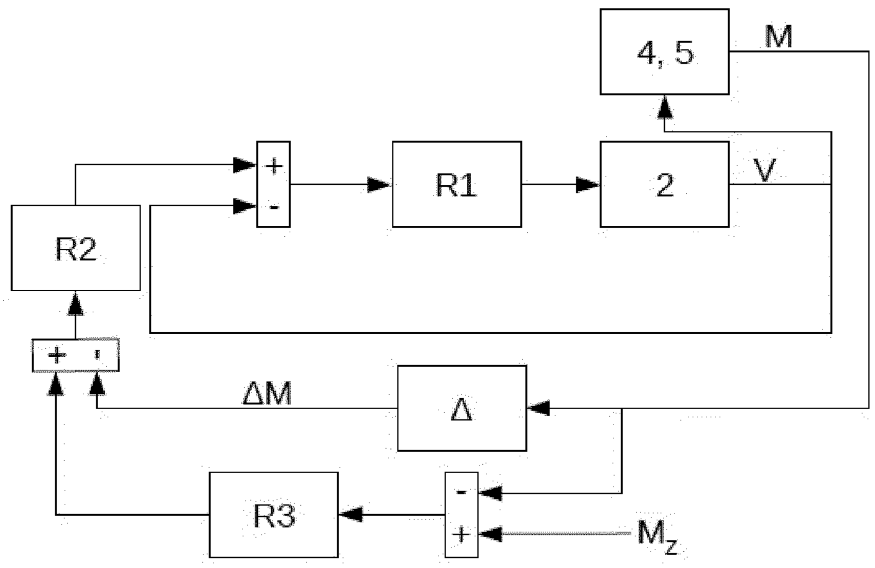

Fig. 7

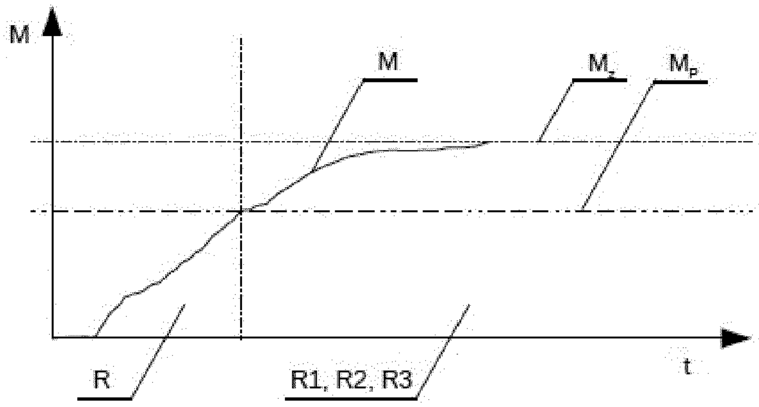

Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 17 18 8780

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
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CATEGORY OF CITED DOCUMENTS

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