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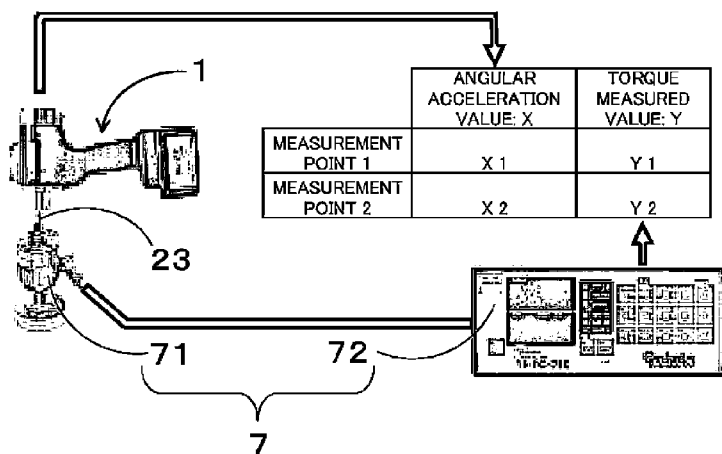
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(54) Title: IMPACT TIGHTENING TOOL



(57) Abstract: An impact tightening tool (1), including a rotating part (2), angular acceleration detection means (3), torque value calculation means (4), and a storage section (5), wherein: the rotating part (2) includes a rotary power source (21), an impact tightening generation mechanism (22), and an output shaft (23); the angular acceleration detection means (3) is configured to detect an angular acceleration value of the rotary power source (21); the torque value calculation means (4) is configured to calculate an actual torque approximate value of the output shaft (23) by using an approximation formula stored in the storage section (5); and the approximation formula stored in the storage section (5) is a formula which correlates an angular acceleration value detected by the angular acceleration detection means (3) at the time of torque transmission to a screw with an actual torque value of the output shaft (23) at the time of torque transmission to the screw, and is a formula based on a torque measured value of the output shaft (23) measured before the torque transmission to the screw.

Description

Title of Invention: IMPACT TIGHTENING TOOL

Technical Field

[0001] The present invention relates to an impact tightening tool to be used for tightening a screw.

Background Art

[0002] Screws are used for fastening parts together. A screw will loosen if the tightening torque is insufficient and, on the contrary, excessive torque may cause failure of the screw.

Therefore, when tightening a screw, it is essential to perform a tightening operation with a proper torque.

Summary of Invention

Technical Problem

[0003] Nowadays, impact tightening tools which perform tightening of a screw with successive blows are widely used. Upon use of an impact tightening tool, tightening operation is performed such that when a preset tightening torque (proper tightening torque) is reached, the torque transmission to the screw is stopped, thereby maintaining a proper tightening torque.

Implementations of the stopping of torque transmission to the screw may be exemplified by such as one in which a rotary power source (for example, a motor) of the impact tightening tool is stopped or broken, and one in which the torque transmission from the drive source to the screw is disengaged.

Impact tightening tools of this type have been already disclosed in Japanese Patent Laid-Open No. 61-4676 and Japanese Patent No. 4560268. (Patent Literature 1, Patent Literature 2)

[0004] In the technique according to Patent Literature 1, the tightening torque of the tool is determined by acquiring a twist amount (strain amount) of a power transmission shaft with a strain gauge provided in the power transmission shaft, and the motor is stopped when the tightening torque reaches a preset value.

This is convenient for tightening a screw with a proper torque. However, since the operation to paste a strain gauge onto the power transmission shaft is very delicate, it requires skilled work and poses high cost. Moreover, since it requires associated parts, a problem exists in that the tool as a whole increases in size, as well as in weight.

[0005] In the technique according to Patent Literature 2, the tightening torque of the tool is calculated from the inertia of the rotating part including a motor, and the angular acceleration value obtained based on the position sensor information owned by the

driving side of the impact tightening generation mechanism. According to the technique of Patent Literature 2, the output shaft becomes not to include a strain gauge so that the impact tightening tool becomes reduced in size and weight.

However, in actual impact tightening, there exist various losses such as deflection and internal loss in each transmission part due to pulsed tightening torque, and losses caused by the internal inertia of the transmission part itself, and backlashes in joint portions, and thus the technique according to Patent Literature 2 has a problem in that such losses are not taken into consideration.

[0006] For example, actual tightening torque (actual torque) in an impact tightening tool can be represented as follows.

$$T(t) = J \cdot \omega''(t) + M_t(t) - e(t)$$

$$\omega = \text{OMEGA}, e = \text{EPSILON}$$

where,

$T(t)$: Actual torque with which the output shaft tightens a screw,

$J \cdot \omega''(t)$: Torque generated by the acceleration of the rotating part,

$M_t(t)$: Torque generated by the motor, and

$e(t)$: Various loss torques that occur in the transmission system.

Based on the above described formula, the impact tightening tool according to Patent Literature 2 does not take into account $e(t)$.

Because of this, measure values of torque of the impact tightening tool according to Patent Literature 2 tended to be larger than actual torque values since various loss torques that occur in the transmission system $e(t)$ are not taken into account. As a result of that, the impact tightening tool according to Patent Literature 2 has a problem in that the tightening operation is automatically stopped before a proper tightening torque is reached (the timing of automatic stopping is too early).

Solution to Problem

[0007] Accordingly, it is an object of the present invention to provide an impact tightening tool whereby the tool can be stopped at a proper torque by using torque calculation means which takes into account the loss caused by actual impact tightening, without expensive strain gauges provided in the output shaft, thereby enabling improved tightening.

[0008] In order to achieve the above described object, the present invention has used the following means.

(The invention according to claim 1)

The invention according to claim 1 is an impact tightening tool, including a rotating part, angular acceleration detection means, torque value calculation means, and a storage section, wherein: the rotating part includes a rotary power source, an impact

tightening generation mechanism, and an output shaft; the angular acceleration detection means is configured to detect an angular acceleration value of the rotary power source; the torque value calculation means is configured to calculate an actual torque approximate value of the output shaft by using an approximation formula stored in the storage section; and the approximation formula stored in the storage section is a formula which correlates an angular acceleration value detected by the angular acceleration detection means at the time of torque transmission to a screw with an actual torque value of the output shaft at the time of torque transmission to the screw, and is a formula based on a torque measured value of the output shaft measured before the torque transmission to the screw.

[0009] (The invention according to claim 2)

The invention according to claim 2 is the impact tightening tool according to claim 1, wherein the formula based on the torque measured value is derived by substituting an angular acceleration value of the rotary power source measured before the torque transmission to the screw and a torque measured value of the output shaft measured by a torque tester before the torque transmission to the screw into the correlated formula.

(The invention according to claim 3)

The invention according to claim 3 is an impact tightening tool, including a rotating part, angular acceleration detection means, torque value calculation means, a storage section, and approximation formula derivation means, wherein: the rotating part includes a rotary power source, an impact tightening generation mechanism, and an output shaft; the angular acceleration detection means is configured to detect an angular acceleration value of the rotary power source; the torque value calculation means is configured to calculate an actual torque approximate value of the output shaft by using an approximation formula derived by the approximation formula derivation means; the storage section stores an angular acceleration value of the rotary power source measured before torque transmission to a screw, and a torque measured value of the output shaft measured by a torque tester before the torque transmission to the screw; and the approximation formula derivation means is configured to derive a formula based on the torque measured value of the output shaft measured before the torque transmission to the screw by substituting the angular acceleration value and the torque measured value stored in the storage section into a formula which correlates the angular acceleration value detected by the angular acceleration detection means at the time of torque transmission to the screw with the actual torque value of the output shaft at the time of torque transmission to the screw.

Advantageous Effects of Invention

[0010] Owing to the above described configuration, the impact tightening tool of the present

invention has become an impact tightening tool which enables the calculation of an actual torque approximate value which takes into account the loss caused by actual impact tightening, without an expensive strain gauge provided on the output shaft, thus enabling improved tightening. As a result, it is possible to provide a compact, light and inexpensive impact tightening tool.

Brief Description of Drawings

- [0011] [fig.1]Fig. 1 shows a partial cross-sectional view and a general side view of an impact tightening tool.
- [fig.2]Fig. 2 is a conceptual diagram of an impact tightening tool performing the measurement of a torque measured value before the torque transmission to a screw.
- [fig.3]Fig. 3 is a conceptual diagram of an impact tightening tool at the time of torque transmission to a screw.
- [fig.4]Fig. 4 is a conceptual diagram showing the measurement of a torque measured value by using a torque tester.
- [fig.5]Fig. 5 is a graph comparing a tightening torque indicated in the conventional art with an actual tightening torque.

Description of Embodiments

- [0012] Hereafter, the impact tightening tool will be described in conjunction with an embodiment shown in each drawing.

Example 1

- [0013] 1. General configuration of impact tightening tool 1

Fig. 1 shows a partial cross-sectional view and a general side view of an impact tightening tool 1. Fig. 2 is a conceptual diagram of an impact tightening tool performing the measurement of a torque measured value before the torque transmission to a screw. Fig. 3 is a conceptual diagram of an impact tightening tool at the time of torque transmission to a screw. Fig. 4 is a conceptual diagram showing the measurement of a torque measured value by using a torque tester. Formula 1 shows an example of the formula for calculating an actual torque approximate value T , represented by a first-order equation.

The impact tightening tool 1, which includes a rotating part 2, angular acceleration detection means 3, torque value calculation means 4, and a storage section 5, is configured to tighten a screw with a preset torque value and include control means 13 for stopping tightening at a preset torque value. The impact tightening tool 1 may also include approximation formula derivation means 6.

The impact tightening tool 1 may include a trigger 11 for performing rotating operation of the rotating part 2, as well as a rotational direction designating lever 12 for designating the rotational direction. To be specific, such impact tightening tool 1 being

used is referred to such as an impulse wrench and an impact wrench.

The impact tightening tool 1 includes at least a calibration mode and a tightening mode. The calibration mode is a mode in which storing operation into the storage section 5 is performed, and the tightening mode is a mode in which a screw is tightened with a preset torque.

[0014] 2. Rotating part 2

The rotating part 2 rotates upon pulling of the trigger 11, and stops upon releasing of the trigger 11.

The rotating part 2 includes a rotary power source 21, an impact tightening generation mechanism 22, and an output shaft 23.

The rotary power source 21 may utilize an electric motor, an air motor, and the like. The output shaft 23 may be provided with a socket 8 at its front end.

[0015] 3. Control of impact tightening tool 1

When tightening a screw with a preset torque value using the impact tightening tool 1, the following control is performed. Since the tightening torque of a screw increases as it is tightened, the impact tightening tool 1 calculates a current, actual torque approximate value T by using an approximation formula stored in the storage section 5 while tightening the screw. When the above described actual torque approximate value T reaches a preset torque value, the control means 13 stops the rotary power source 21 thereby terminating tightening. Alternatively, upon the preset torque value being reached, the control means 13 signals the operator with such as sound and light to release the trigger 11. The confirmation that the preset torque value is reached is performed when the actual torque approximate value T exceeds the preset torque value.

[0016] 4. Angular acceleration detection means 3

The angular acceleration detection means 3 is configured to detect an angular acceleration value X of the rotary power source 21.

The angular acceleration detection means 3 is made up at least of a rotor 31, a sensor 32, and differentiation means 33, as shown in Fig. 2. The rotor 31 is connected to the above described rotary power source 21 so as to rotate in tandem. The sensor 32 detects a rotational angle θ of the rotor 31. The differentiation means 33 differentiates the detected rotational angle θ twice to detect an angular acceleration. That is, differentiating rotational angle θ with respect to time t will result in angular velocity ω , and further differentiating angular velocity ω with respect to time t will result in angular acceleration. This value of angular acceleration is an angular acceleration value X .

The differentiation means 33 for detecting the angular acceleration value X may utilize an arithmetic processing unit to be described later.

[0017] 5. Torque value calculation means 4

The torque value calculation means 4 is configured to calculate an actual torque approximate value T of the output shaft 23 from the angular acceleration value X by using an approximation formula stored in the storage section 5. The approximation formula is a formula which correlates the angular acceleration value X detected by the angular acceleration detection means 3 at the time of torque transmission to the screw with the actual torque value of the output shaft 23 at the time of torque transmission to the screw. In an implementation in which the impact tightening tool 1 is provided with an arithmetic processing unit, the arithmetic processing unit may be used as the torque value calculation means 4 to calculate an actual torque approximate value T. Moreover, a calculation circuit corresponding to the above described approximation formula may be made up in place of the arithmetic processing unit, to be used as the torque value calculation means 4.

[0018] 6. Torque measured value of output shaft 23 measured before the torque transmission to a screw and an approximation formula

Fig. 5 is a graph comparing a tightening torque indicated in the conventional art with an actual tightening torque.

Formula 1 is an approximation formula, which is based on a torque measured value Y of the output shaft 23 measured before the torque transmission to the screw.

Math 1

[0019] Equation 1

$$T = \frac{Y_2 - Y_1}{X_2 - X_1} X + \left(Y_1 - \frac{Y_2 - Y_1}{X_2 - X_1} X_1 \right)$$

T : Actual torque approximate value

X : Angular acceleration

Y : Torque measured value

[0020] Description will be made, as an example, on a case in which as a formula based on the torque measured value Y of the output shaft 23 measured before the torque transmission to the screw, an approximation formula of a first-order equation is derived by substituting angular acceleration values (X1, X2) of the rotary power source 21 measured before the torque transmission to the screw, and torque measured values (Y1, Y2) of the output shaft 23 measured by the torque tester 7 before the torque transmission to the screw into Formula 1.

First, as shown in Fig. 4, a torque tester 7 having a torque sensor 71 and a torque indicator 72 is prepared. Next, the impact tightening tool 1 is activated in a pre-

programmed calibration mode. Then, the torque sensor 71 is attached and fixed to the output shaft 23 of the impact tightening tool 1 so that the torque measured value Y of the output shaft 23 is measured by the torque tester 7 (see Fig. 5). When there are two measurement points, it is possible to obtain a torque measured value Y1 when the angular acceleration value is X1, and a torque measured value Y2 when the angular acceleration value is X2.

Then, the angular acceleration values (X1, X2) and the torque measured values (Y1, Y2) are substituted into Formula 1 to derive an approximation formula which is a first-order equation between the angular acceleration value X and the actual torque approximate value T. The derived approximation formula of a first-order equation is stored in the storage section 5, and when the storing operation into the storage section 5 is finished, the impact tightening tool 1 is switched from the calibration mode to a tightening mode. At the time of torque transmission to the screw, an actual torque approximate value T is calculated by using the stored approximation formula of a first-order equation based on the angular acceleration value X detected by the angular acceleration detection means 3 at the time of torque transmission to the screw.

[0021] 7. Implementation in which storage section 5 stores angular acceleration values and torque measured values

Further, the storage section 5 may be configured to store angular acceleration values (X1, X2) of the rotary power source 21 measured before the torque transmission to the screw, and torque measured values (Y1, Y2) of the output shaft 23 measured by the torque tester 7 before the torque transmission to the screw.

When the storage section 5 stores the angular acceleration values (X1, X2) and the torque measured values (Y1, Y2), the impact tightening tool 1 includes approximation formula derivation means 6. In this case as well, when the storing operation into the storage section 5 is finished, the impact tightening tool 1 is switched from the calibration mode to the tightening mode.

Then, the approximation formula derivation means 6 substitutes "the angular acceleration values (X1, X2) and the torque measured values (Y1, Y2) stored in the storage section 5" into the "formula (Formula 1) which correlates the angular acceleration value X detected by the angular acceleration detection means 3 at the time of torque transmission to the screw with the actual torque value of the output shaft 23 at the time of torque transmission to the screw" to derive a "formula (approximation formula of a first-order equation) based on the torque measured value Y of the output shaft 23 measured before the torque transmission to the screw."

Then, at the time of torque transmission to the screw, the torque value calculation means 4 calculates the actual torque approximate value T of the output shaft 23 by using the approximation formula of a first-order equation derived by the approximation

formula derivation means 6 based on the angular acceleration value X detected by the angular acceleration detection means 3 at the time of torque transmission to the screw.

[0022] 8. Data storage of storage section 5

As described so far, the storage section 5 stores data such as "the approximation formula of a first-order equation between the angular acceleration value X and the actual torque approximate value T" or "the angular acceleration values (X1, X2) of the rotary power source 21 measured before the torque transmission to the screw, and the torque measured values (Y1, Y2) of the output shaft 23 measured by the torque tester 7 before the torque transmission to the screw." Examples of the storage section 5 storing these data may include a flash memory.

Then, the impact tightening tool 1 may incorporate a flash memory, and also include an access terminal to the flash memory. The access terminal enables data storage by external electronic devices.

In this way, the impact tightening tool 1 does not need to include an input key which is used in the operation for storing data in the flash memory. This will allow the reduction in size and weight of the impact tightening tool 1.

Further, the flash memory may be a removable small one, such that it may be removable from the interior of the impact tightening tool 1. By doing so, the removed small flash memory can be mounted to an external electronic device to make the flash memory store the above described data. Then, the small flash memory that has stored the above described data is mounted to the impact tightening tool 1.

[0023] 9. Other approximation formulas

The above described approximation formula of torque will not be limited to Formula 1 and a first-order equation between the angular acceleration value X and the actual torque approximate value T, and can be exemplified by linear approximation, polynomial approximation, power approximation, exponential approximation, log approximation, the spline interpolation, and so on. Then, the number of measurement points may be 2 to n points ($[X1, X2, \dots, Xn : Y1, Y2, \dots, Yn]$, where n is an arbitrary number) in correspondence with the approximation formula. Further, the differentiation means 33, the torque value calculation means 4, the storage section 5 and the approximation formula derivation means 6 can be combined and installed in the impact tightening tool 1 as hardware or software so that the actual torque approximate value T can be calculated by using various mathematical algorithms including the above described methods.

[0024] 10. Effect of the impact tightening tool 1 which adopts the above described actual torque approximate value T

As a result of using Formula 1 or the first-order equation between the angular acceleration value X and the actual torque approximate value T, the calculated actual

torque approximate value T becomes close to the torque measured value Y shown in Fig. 5 so that the impact tightening tool 1 enables better torque management.

As a result of obviating the need for a strain gauge which is conventionally needed for good torque management, the impact tightening tool 1 becomes reduced in size and weight, and moreover inexpensive, even though it can obtain a relatively accurate actual torque approximate value T.

Industrial Applicability

[0025] It is assumed that the above described actual torque approximate value T be used for impact tightening tools 1 such as air impact wrenches, air impulse wrenches, power impact wrenches, power impulse wrenches, and so on.

It can also be applied to other tools which provide successive blows.

Reference Signs List

[0026] 1.impact tightening tool
 11.trigger
 12.rotational direction designating lever
 13.control means
 2.rotating part
 21.rotary power source
 22.impact tightening generation mechanism
 23.output shaft
 3 .angular acceleration detection means
 31.rotor
 32.sensor
 33.differentiation means
 4.torque value calculation means
 5.storage section
 6.approximation formula derivation means
 7.torque tester
 71.torque sensor
 72.torque indicator
 8.socket

Citation List

Patent Literature

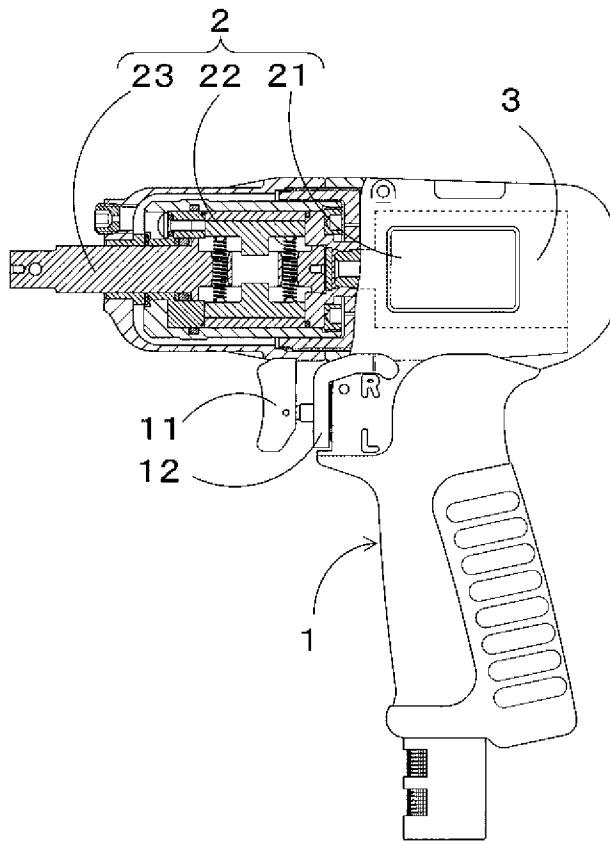
[0027] PTL 1: Japanese Patent Laid-Open No. S61-4676 A
 PTL 2: Patent Literature 2 : Japanese Patent No. 4560268

Claims

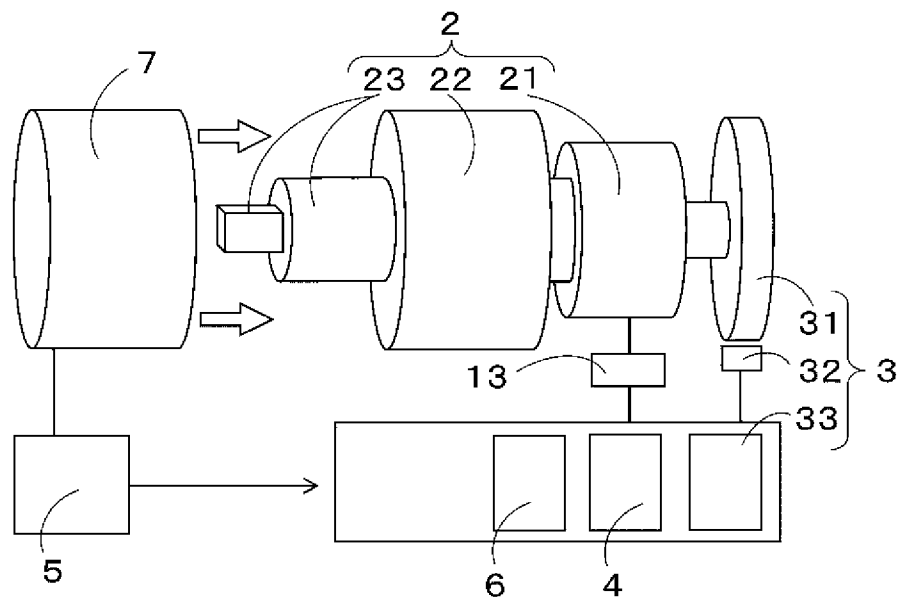
- [Claim 1] An impact tightening tool (1), comprising a rotating part (2), angular acceleration detection means (3), torque value calculation means (4), and a storage section (5), wherein:
the rotating part (2) includes a rotary power source (21), an impact tightening generation mechanism (22), and an output shaft (23);
the angular acceleration detection means (3) is configured to detect an angular acceleration value of the rotary power source (21);
the torque value calculation means (4) is configured to calculate an actual torque approximate value of the output shaft (23) by using an approximation formula stored in the storage section (5); and
the approximation formula stored in the storage section (5) is a formula which correlates an angular acceleration value detected by the angular acceleration detection means (3) at the time of torque transmission to a screw with an actual torque value of the output shaft (23) at the time of torque transmission to the screw, and is a formula based on a torque measured value of the output shaft (23) measured before the torque transmission to the screw.
- [Claim 2] The impact tightening tool according to claim 1, wherein
the formula based on the torque measured value is derived by substituting an angular acceleration value of the rotary power source (21) measured before the torque transmission to the screw and a torque measured value of the output shaft (23) measured by a torque tester (7) before the torque transmission to the screw into the correlated formula.
- [Claim 3] An impact tightening tool (1), comprising a rotating part (2), angular acceleration detection means (3), torque value calculation means (4), a storage section (5), and approximation formula derivation means (6), wherein:
the rotating part (2) includes a rotary power source (21), an impact tightening generation mechanism (22), and an output shaft (23);
the angular acceleration detection means (3) is configured to detect an angular acceleration value of the rotary power source (21);
the torque value calculation means (4) is configured to calculate an actual torque approximate value of the output shaft (23) by using an approximation formula derived by the approximation formula derivation means (6);
the storage section (5) stores an angular acceleration value of the rotary

power source (21) measured before torque transmission to a screw, and a torque measured value of the output shaft (23) measured by a torque tester (7) before the torque transmission to the screw; and the approximation formula derivation means (6) is configured to derive a formula based on the torque measured value of the output shaft (23) measured before the torque transmission to the screw by substituting the angular acceleration value and the torque measured value stored in the storage section (5) into a formula which correlates the angular acceleration value detected by the angular acceleration detection means (3) at the time of torque transmission to the screw with the actual torque value of the output shaft (23) at the time of torque transmission to the screw.

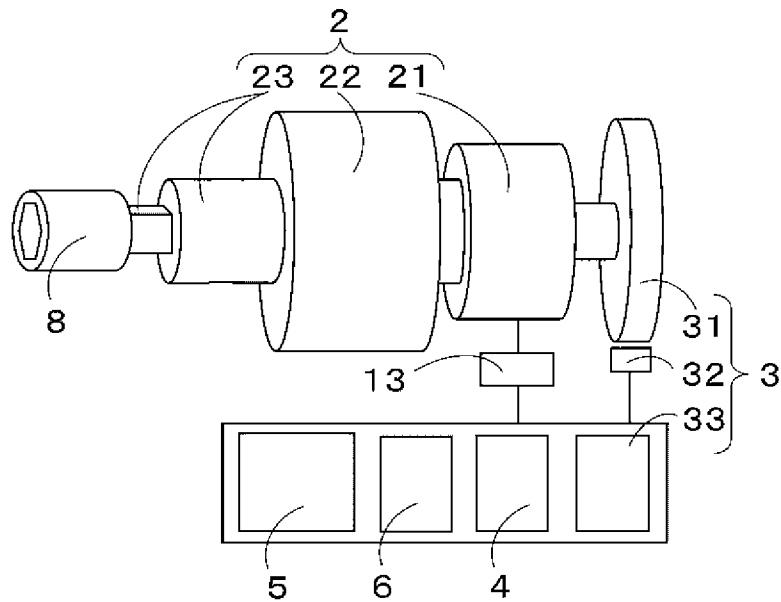
[Fig. 1]



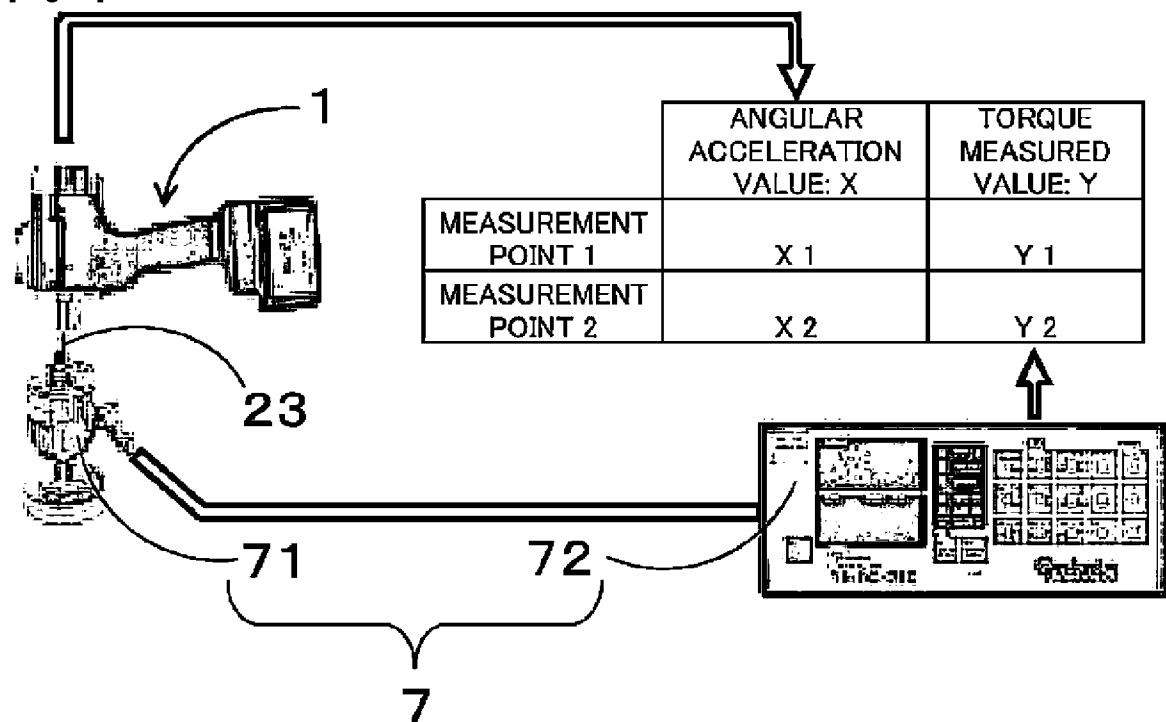
[Fig. 2]



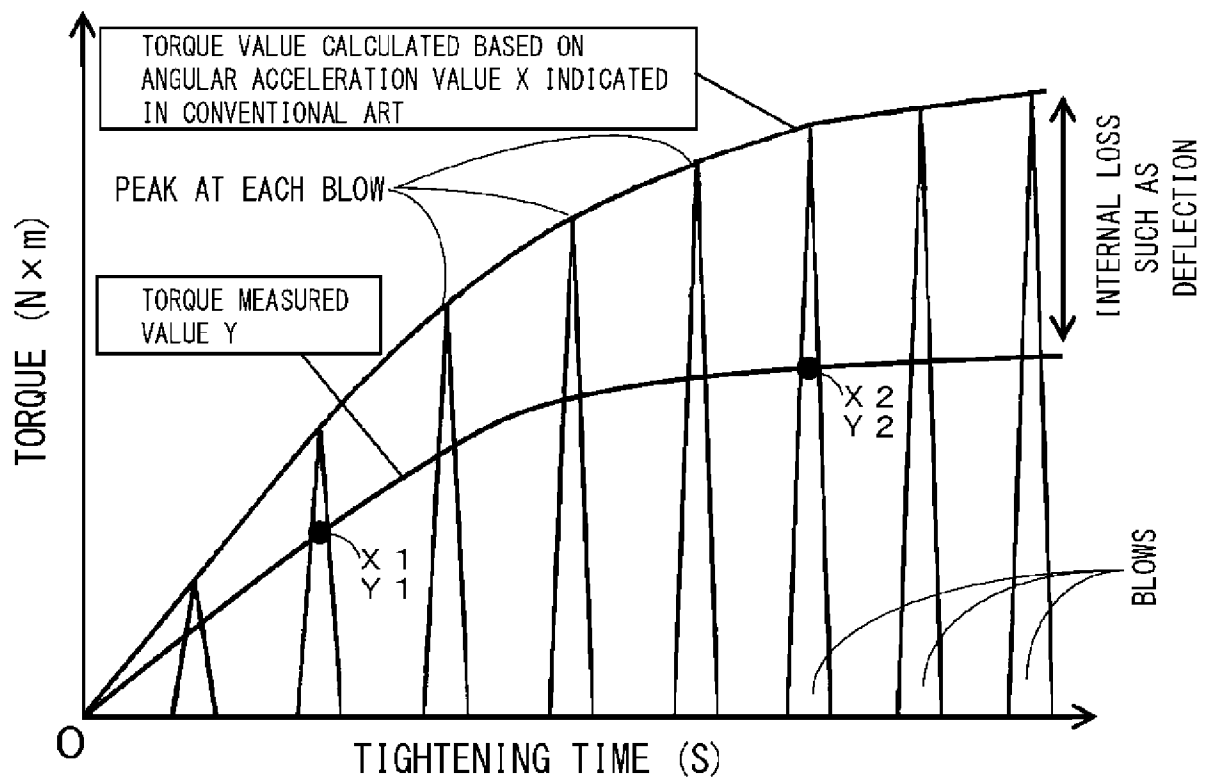
[Fig. 3]



[Fig. 4]



[Fig. 5]



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/003226

A. CLASSIFICATION OF SUBJECT MATTER		
Int.Cl. B25B23/14 (2006.01) i		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED		
Minimum documentation searched (classification system followed by classification symbols)		
Int.Cl. B25B23/14		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Published examined utility model applications of Japan 1922-1996 Published unexamined utility model applications of Japan 1971-2013 Registered utility model specifications of Japan 1996-2013 Published registered utility model applications of Japan 1994-2013		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 04-035878 A (MATSUSHITA ELECTRIC WORKS, LTD.) 1992.02.06, page 2, upper right column, line 1 to page 3, upper right column, line 15; all drawings (No Family)	1-3
A	JP 58-217278 A (REGIE NATIONALE DES USINES RENAULT) 1983.12.17, page 3, lower left column, line 18 to page 5, upper right column, line 4 & US 4488437 A & EP 96620 A1 & FR 2527714 A1	1-3
A	WO 2002/083366 A1 (ATLAS COPCO TOOLS AB), 2002.10.24, the whole document & JP 2004-522604 A & US 2004/0129090 A1	1-3
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
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