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(54) Title: VALVE REMAINING LIFE ESTIMATION METHOD AND SYSTEM THEREOF

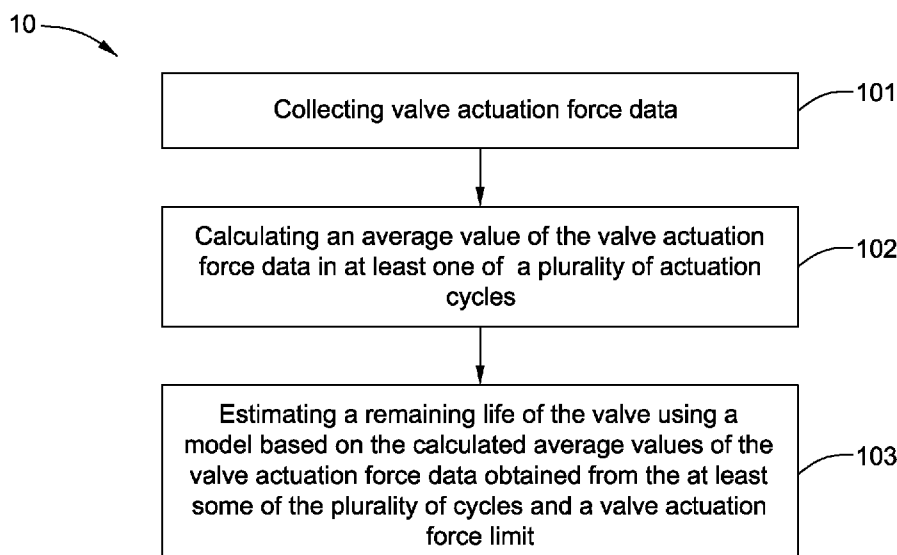


FIG. 1

(57) Abstract: A method of estimating a remaining life of a valve is disclosed, comprising steps of collecting valve actuation force data; calculating an average value of the valve actuation force data in at least one of a plurality of actuation cycles; estimating a remaining life of the valve using a model based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit. A valve controller (20, 21) of estimating a remaining life of a valve is also disclosed.

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VALVE REMAINING LIFE ESTIMATION METHOD AND SYSTEM THEREOF

BACKGROUND

[0001] This disclosure relates generally to a valve monitoring technique, and more particularly to valve remaining life estimation.

[0002] A valve used to control the flow of a fluid, such as gases, liquids, fluidized solids, or slurries, by varying the size of the flow passage as directed by a signal from a controller. The valve includes air-operated valves and motor-operated valves. Air-operated valves use a compressed air to produce an actuation pressure against a piston or diaphragm to operate a valve. Motor-operated valves use electrical power to produce an actuation torque against a piston or diaphragm to operate a valve.

[0003] Smart instrumentations, e.g. smart valve, flow meter, pressure and temperature sensors are widely used in the industrial power plant, the data from these smart instrumentations are transferred by the digital field bus (e.g. Foundation Field bus) to the plant control systems. Smart valve includes internal sensors that reflect operating conditions of the valve. The internal sensors could provide measurements, such as piston/diaphragm position, chamber internal pressure/motor actuation torque, controller temperatures, etc.

[0004] The way for the smart valve life time estimation is now mostly based on travel cycle and travel accumulation signals, which are obtained based on the valve travel position sensor. With more device information is available in the digital bus, there is a need to fully leverage this information to enhance the device operation reliability and easing the power plant maintenance scheduling process in real time.

BRIEF DESCRIPTION

[0005] In one embodiment, the present disclosure provides a method of estimating a remaining life of a valve, comprising steps of collecting valve actuation force data; calculating an average value of the valve actuation force data in at least one of a plurality of actuation cycles; estimating a remaining life of the valve using a model

based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit. The present disclosure also provides a system of estimating a remaining life of a valve.

In another embodiment, the present disclosure provides a valve controller of estimating a remaining life of a valve, comprising a data storage, collecting and storing valve actuation force data; a calculating unit, calculating an average value of the valve actuation force data in at least one of a plurality of actuation cycles; an estimation unit, estimating a remaining life of the valve using a model based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit.

DRAWINGS

[0006] These and other features, aspects, and advantages of the present disclosure will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

[0007] Fig. 1 is a flow chart of a method of estimating a remaining life of a valve in accordance with an embodiment of the present disclosure;

[0008] Fig. 2 is an illustrative view showing a relationship between the valve position and the valve actuation pressure.

[0009] Fig. 3 is an illustrative view of a method of estimating a remaining life of a valve in accordance with an embodiment of the present disclosure;

[0010] Fig. 4 is an illustrative view of a method of estimating a remaining life of a valve in accordance with another embodiment of the present disclosure;

[0011] Fig. 5 is a flow chart of a method of estimating a remaining life of a valve in accordance with another embodiment of the present disclosure;

[0012] Fig. 6 is a block diagram of a system of estimating a remaining life of a valve in accordance with an embodiment of the present disclosure;

[0013] Fig. 7 is a block diagram of a system of estimating a remaining life of a valve in accordance with another embodiment of the present disclosure.

DETAILED DESCRIPTION

[0014] Embodiments of the present disclosure will be described herein below with reference to the accompanying drawings. In the following description, well-known functions or constructions are not described in detail to avoid obscuring the disclosure in unnecessary detail.

[0015] Unless defined otherwise, technical and scientific terms used herein have the same meaning as is commonly understood by one of ordinary skill in the art to which this disclosure belongs. The terms “first,” “second,” and the like, as used herein do not denote any order, quantity, or importance, but rather are used to distinguish one element from another. Also, the terms “a” and “an” do not denote a limitation of quantity, but rather denote the presence of at least one of the referenced items. The term “or” is meant to be inclusive and mean either or all of the listed items. The use of “including,” “comprising,” or “having” and variations thereof herein are meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

[0016] Embodiments of the present disclosure may be described herein in terms of functional components and various processing steps. It should be appreciated that such functional components may be realized by any number of hardware, software, and/or firmware components configured to perform the specific functions. For example, an embodiment of the present disclosure may employ various integrated circuit components, e.g., memory elements, digital signal processing elements, logic elements, look-up tables, and the like, which may carry out a variety of functions under the control of one or more microprocessors or other control devices. In addition, embodiments of the present disclosure may be practiced in conjunction with any number of data transmission protocols.

[0017] Referring to Fig. 1 of the drawings, the present disclosure provides a method 10 of estimating a remaining life to stuck of a valve, which comprises steps of

101) collecting valve actuation force data; 102) calculating an average value of the valve actuation force data in at least one of a plurality of cycles; 103) estimating a remaining life of the valve using a model based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit.

[0018] The valve actuation force is the force required during the valve actuation cycle to trigger the movement of a piston of a valve. For an air-operated valve or pneumatic valve or hydraulic valve, the valve actuation force is valve actuation pressure; while for a moto-operated valve, electric hydraulic valve, the valve actuation force is valve actuation torque. Every valve has a life period. As the valve is used (actuated), the life of the valve is reduced. Generally, as the number of valve travel cycles increases, the average value of the valve actuation pressure increases as well due to surface corrosion or dirt accumulation in the valve around the piston areas resulting in more force being required to move the piston (except in embodiments wherein the spring is failing), so that the life of a valve is gradually reducing. The method 10 of estimating a remaining life to stuck of a valve further comprises a step of calculating a standard deviation of the valve actuation force data in a cycle to make sure the average value of the of the valve actuation force data is meaningful.

[0019] As shown in Fig. 2, the actuation pressure of a valve varies in different valve positions during a single valve travel cycle. When the position of a valve increases from 0-100% as shown in horizontal axis, the valve actuation pressure shown in vertical axis increases too. When the valve actuation pressure is within upper and lower pressure limits, the valve is considered “safe.” The upper limit is a limit for classifying the valve as “stuck.” when the valve actuation pressure is beyond the upper limit. The lower limit is a limit for classifying the valve as “spring loosen” when the valve actuation pressure is lower than the lower limit (for the valve has spring). In certain embodiments of the present disclosure, the average value of the valve actuation pressure during a valve travel cycle is calculated.

[0020] As shown in the XY plot in Fig. 3, an example is proposed in to calculate the valve remaining life to stuck based on the valve actuation force. The value in

vertical axis is the average value of the actuation force in one cycle (which could be calculated based on the valve actuation pressure/torque). A model may be built between the cycle and average value of the valve actuation force. For example, FIG. 3 illustrates a regression model based on the historical data to estimate the remaining valve life (in terms of full stuck), which is shown in the dash line section in the XY plot. The regression model shown in solid line indicates the valve stuck trending caused by the valve piston/cylinder surface corrosion or dirt accumulation in these areas. In another embodiment, the model can also be described as first principle model, which can be a transfer function or a set of equations. A more complicated regression model could be built here for more complicated situations, such as quadratic regression model. Although a “stuck” type model is shown in this figure, a similar “spring loosen” type module may additionally be used in the unusual instance where the average value of the actuation force is dropping rather than rising.

[0021] Use an air-operated valve as an example, the valve controller collects the data from actuation pressure sensor, then sends signals to the plant controller via a field bus, and then the valve actuation pressure data collected in all cycles or in some cycles to be further processed. In step 102, the average value of the valve actuation force data in a cycle is calculated to represent the average valve actuation force in that cycle. In step 103, after a model between the number of cycles and the average value of valve actuation force data is built and an actuation force limit is set, and then a remaining life can be estimated based on the trend of the model and the actuation force limit. In one embodiment, an estimation algorithm is provided to estimate the remaining life of a valve, such as rainflow counting. After the remaining life is estimated for the first time, then the remaining life can be updated any time later by incorporating the historical data and fresh data. In one embodiment, the steps 101 to 103 are repeated for an update remaining life estimation result.

[0022] The remaining life can be embodied as remaining life cycles or remaining life time. By the method shown in Fig 2, the remaining life cycles can be estimated. Further, based on the operation cycles and time spent on these cycles, the remaining life time can be estimated responding to the remaining life cycles. A model can be

built between cycles and the time spent on the cycles, and then the remaining life time can be estimated based on the model and the remaining life cycles.

[0023] Referring to Fig. 4 of the drawings, there is another way to estimate the remaining life, which is based on a valve travel distance and a valve travel accumulation limit. A valve travel distance is a distance that a piston travels in total. When the piston travels a full cycle each time, the valve travel cycles can also be used to represent the valve travel distance. With the travel distance or travel cycles increase with time, the life is reduced. When the travel cycles or travel distance reaches the valve travel accumulation limit (cycles or distance), the valve should be replaced or repaired. The travel distance or travel cycles are obtained from the valve travel position sensor.

[0024] In one embodiment, by counting the cycles, a second remaining life can be calculated by subtracting the counted cycles from the valve travel accumulation limit (cycles). In another embodiment, by recording the time and the valve travel distance, a second remaining life can be estimated based on the valve travel distance and the valve travel accumulation limit. In the embodiment of FIG. 4, the total travel distance is approximately linear over time, the second remaining life time can be easily estimated based on the slope.

[0025] The remaining life based on distance/cycle number is labeled as second remaining life, and the remaining life of the valve based on valve actuation pressure/torque is labeled as first remaining life in Fig.4. When the estimation of the first remaining life of the valve based on valve actuation pressure/torque differs from the estimation of the second remaining life based on distance/cycle number, in one embodiment the minimum of the two estimations is selected. As described above, both the first and second remaining life can be cycles or time, and cycles and time is interchangeable, so that the minimum of the two estimation can be both cycles or time.

[0026] The method of estimating a remaining life of a valve shown in FIG. 5 includes steps 101-103 from FIG. 1 and further includes steps relating to use of travel distance/cycle number. At step 104) a second remaining life based on a valve travel

accumulation limit and a valve travel distance or a number of travel cycles is estimated, and at step 105) a minimum remaining life between the first remaining life using the model and the second remaining life based on the valve travel accumulation limit and the valve travel distance or a number of valve travel cycles is selected.

[0027] However, the trend of the model may not exist for certain cases, for example, on the very early stage of the life of a valve or a sudden accident occurs on the valve. In one embodiment, the method 11 of estimating a remaining life of a valve further comprises step of 106) determining whether a stuck trend exists, wherein if the stuck trend exists, 107) outputting a final remaining life comprises outputting the minimum remaining life as the remaining life; and if the stuck trend does not exist, 107) outputting a final remaining life comprises outputting the second remaining life based on the valve travel accumulation limit and the valve travel distance or a number of travel cycles.

[0028] In the example of Fig. 2, the stuck trend is an overall escalating trend as shown in the solid line. The stuck trend can be determined by determining whether the average value of the actuation force increases with the number of cycles, the stuck trend can be simply determined based on the model.

[0029] Referring to Fig. 6 of the drawings, a valve controller 20 of estimating a remaining life to stuck of a valve comprises a data storage 201 collecting and storing valve actuation force data from an internal sensor of a valve 100; a calculating unit 202 calculating an average value of the valve actuation force data in at least one of a plurality of cycles; and a first estimation unit 203 estimating a first remaining life of the valve using a model based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit.

[0030] Referring to Fig. 7 of the drawings, in another embodiment a valve controller 21 of estimating a remaining life to stuck of a valve comprises a second estimation unit 204 estimating a second remaining life based on a valve travel accumulation limit and a valve travel distance or a number of valve travel cycles, and

output unit 205 outputting a minimum remaining life between the first remaining life using the model and the second remaining life based on the valve travel distance or the number of valve travel cycles and the travel accumulation limit.

[0031] The valve controller 21 of estimating a remaining life to stuck of a valve may further comprise a determining unit 206 determining whether a stuck trend exists, wherein if the stuck trend exist, the output unit 205 outputs the minimum remaining life, and if the stuck trend does not exist, the output unit 205 outputs the second remaining life based on the valve travel distance or the number of valve travel cycles and the travel accumulation limit.

[0032] While the disclosure has been illustrated and described in typical embodiments, it is not intended to be limited to the details shown, since various modifications and substitutions can be made without departing in any way from the spirit of the present disclosure. As such, further modifications and equivalents of the disclosure herein disclosed may occur to persons skilled in the art using no more than routine experimentation, and all such modifications and equivalents are believed to be within the spirit and scope of the disclosure as defined by the following claims.

WHAT IS CLAIMED IS:

1. A method of estimating a remaining life of a valve, comprising:
 - collecting valve actuation force data;
 - calculating an average value of the valve actuation force data in at least one of a plurality of actuation cycles;
 - estimating a remaining life of the valve using a model based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit.
2. The method of claim 1, comprising:
 - estimating a second remaining life based on a valve travel accumulation limit and a valve travel distance or a number of valve travel cycles, and
 - selecting a minimum remaining life between the remaining life based on the model and the second remaining life based on the valve travel accumulation limit and the valve travel distance or a number of valve travel cycles.
3. The method of claim 2, comprising:
 - determining whether a stuck trend exists;
 - wherein if the stuck trend exists, outputting the minimum remaining life, and
 - if the stuck trend does not exist, outputting the second remaining life based on the valve travel accumulation limit and the valve travel distance or the number of valve travel cycles.
4. The method of claim 1, wherein the model is a regression model.
5. The method of claim 1, wherein the actuation force comprises actuation pressure.
6. The method of claim 1, wherein the actuation force comprises actuation torque.
7. A valve controller of estimating a remaining life of a valve, comprising:
 - a data storage, collecting and storing valve actuation force data;

a calculating unit, calculating an average value of the valve actuation force data in at least one of a plurality of actuation cycles;

a first estimation unit, estimating a first remaining life of the valve using a model based on the calculated average values of the valve actuation force data obtained from the at least some of the plurality of cycles and a valve actuation force limit.

8. The valve controller of claim 7, comprising:

a second estimation unit, estimating a second remaining life based on a valve travel accumulation limit and a valve travel distance or a number of valve travel cycles, and

an output unit outputting a minimum remaining life between the first remaining life using the model and the second remaining life based on the valve travel accumulation limit and the valve travel distance or the number of valve travel cycles.

9. The valve controller of claim 8, comprising

a determining unit determining whether a stuck trend exists based on the model,

wherein if the stuck trend exists, the output unit outputs the minimum remaining life, and

if the stuck trend does not exist, the output unit outputs the second remaining life based on the valve travel accumulation limit and the valve travel distance or the number of valve travel cycles.

10. The valve controller of claim 7, wherein the model is a regression model.

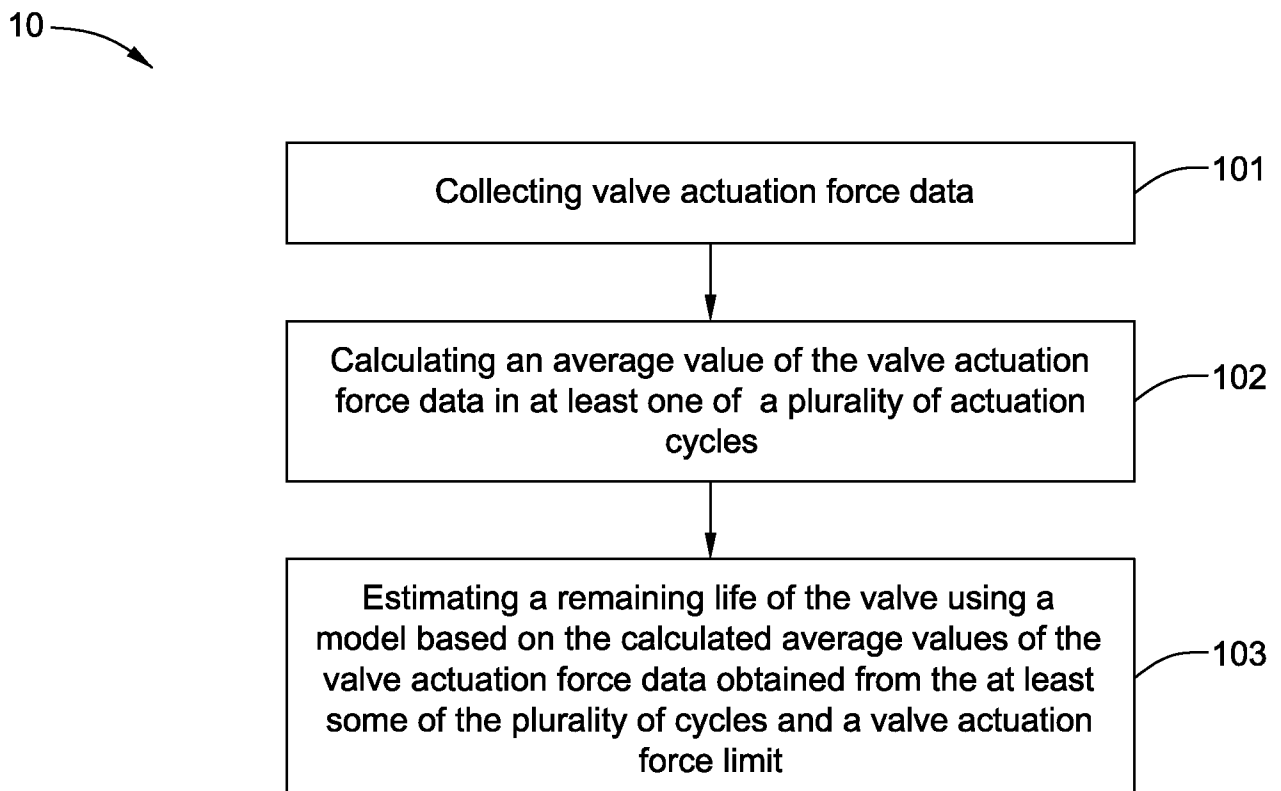


FIG. 1

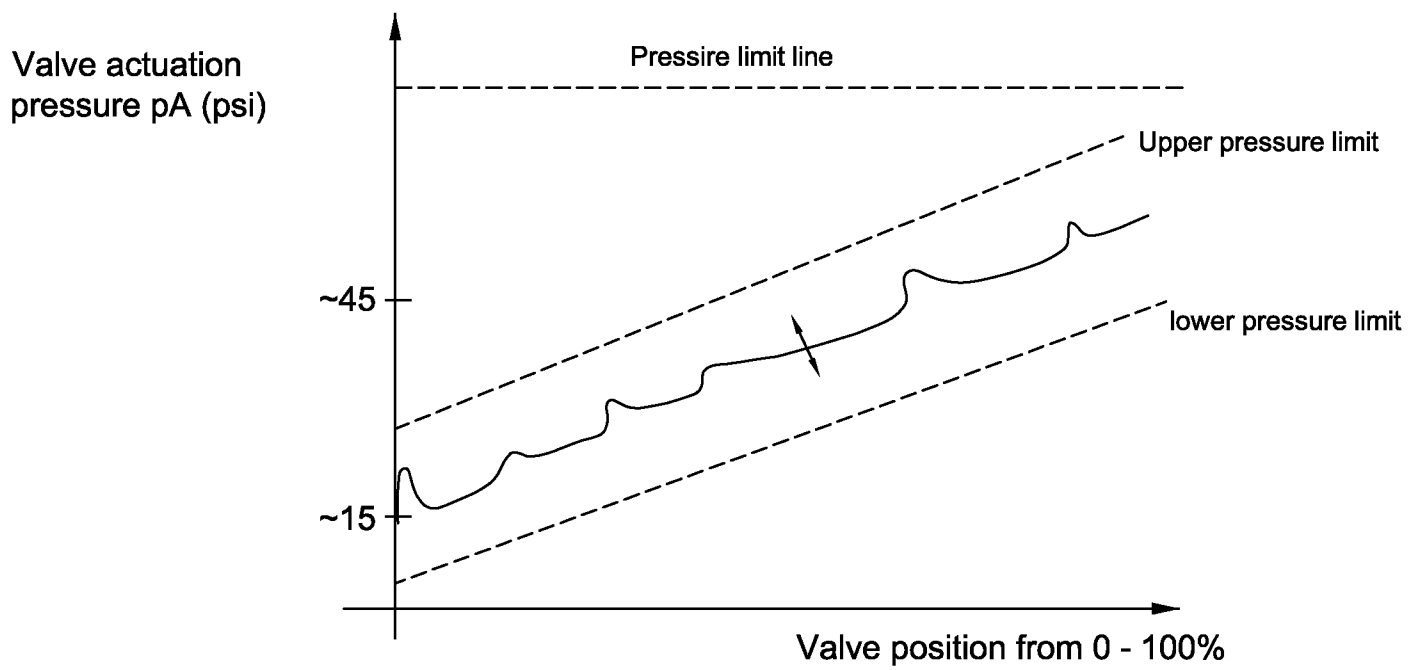


FIG. 2

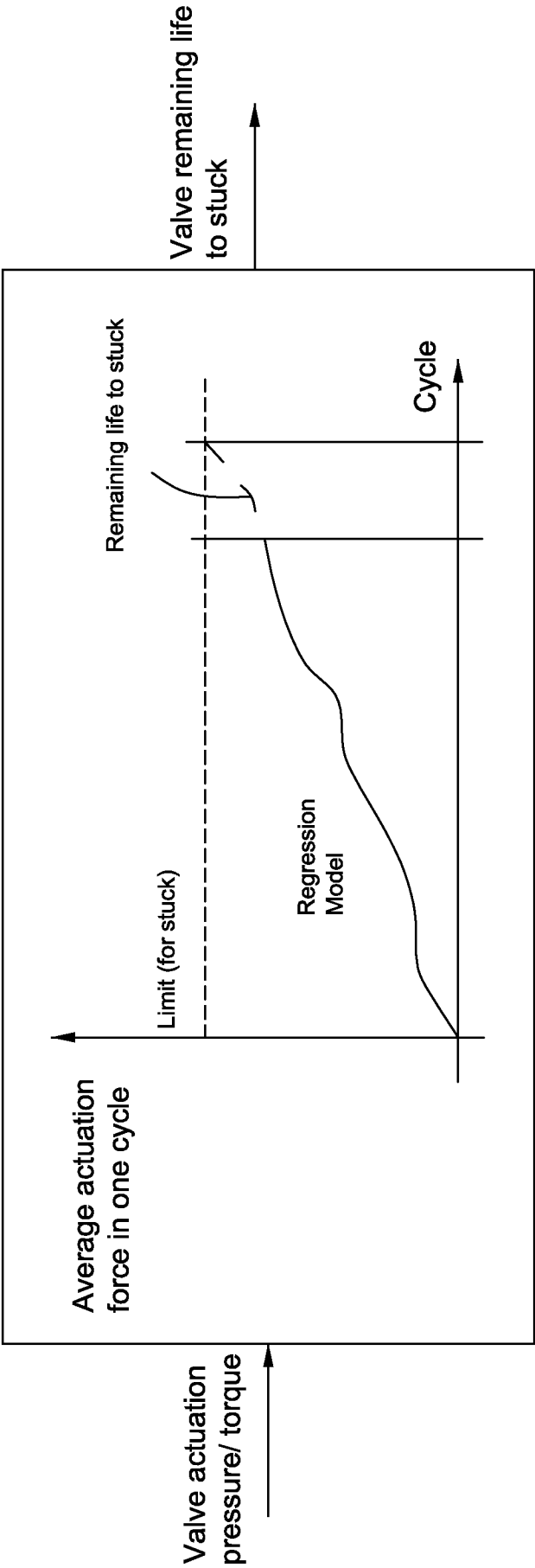


FIG. 3

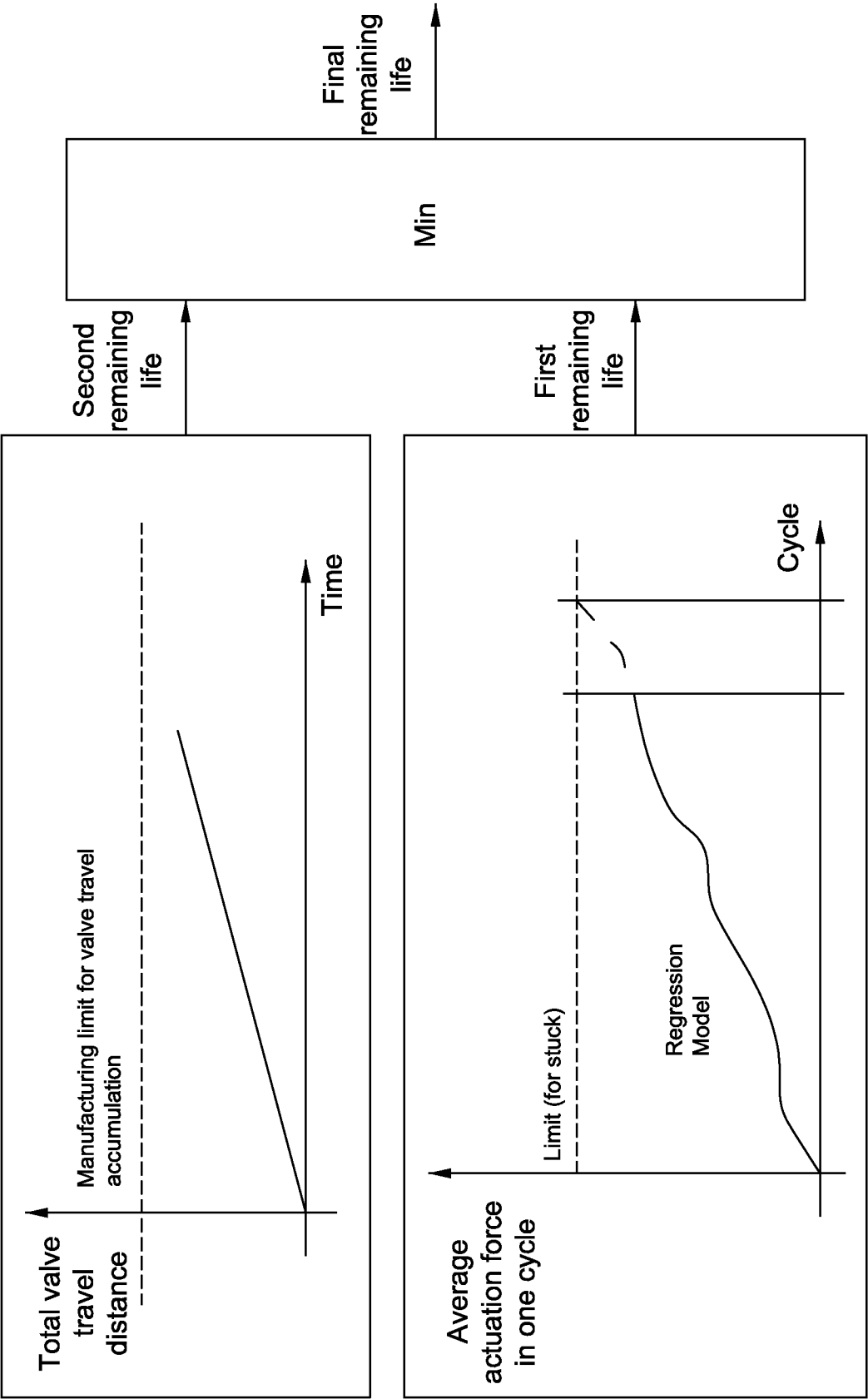


FIG. 4

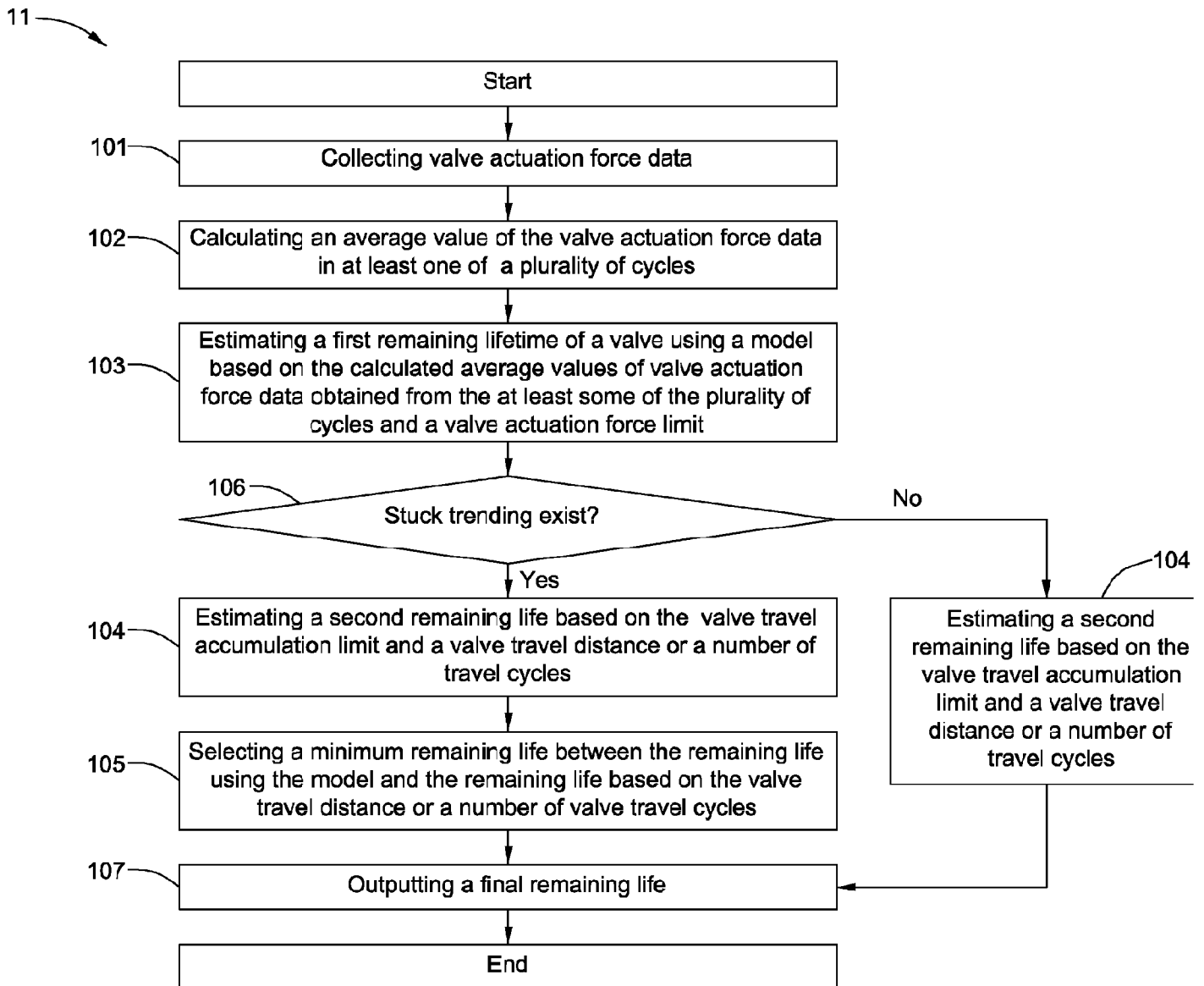


FIG. 5

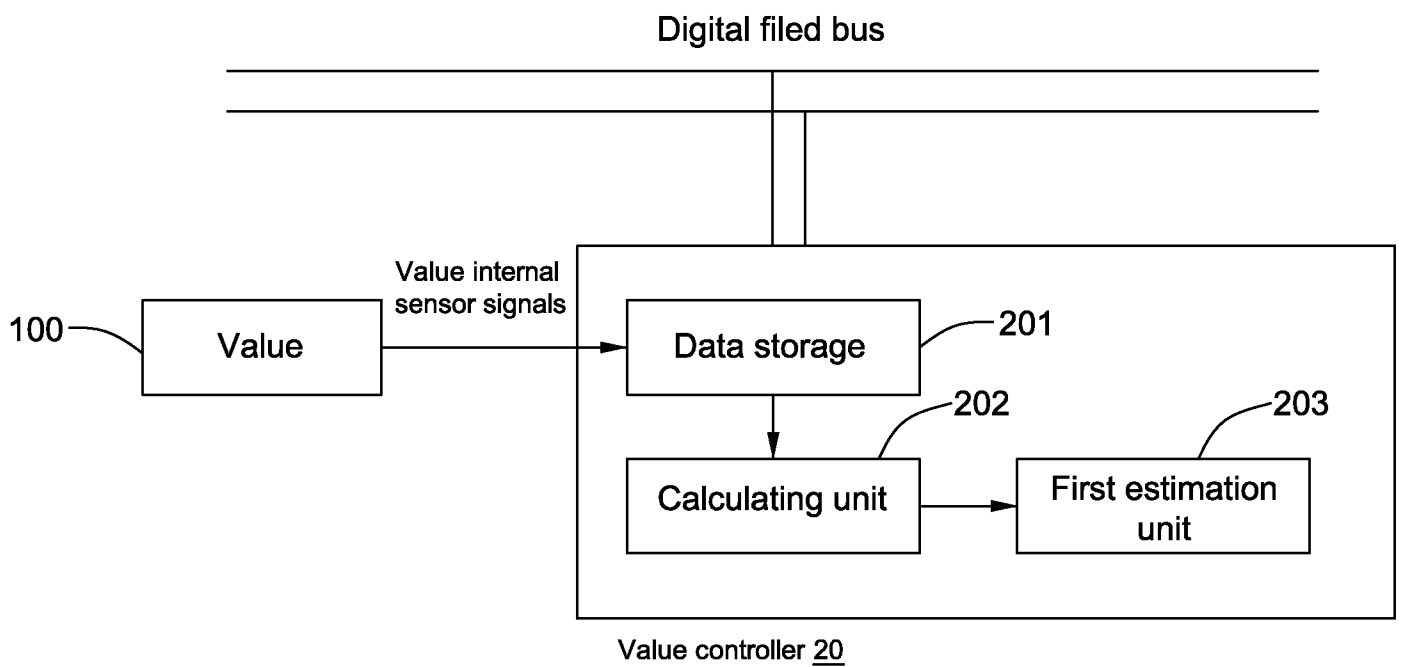


FIG. 6

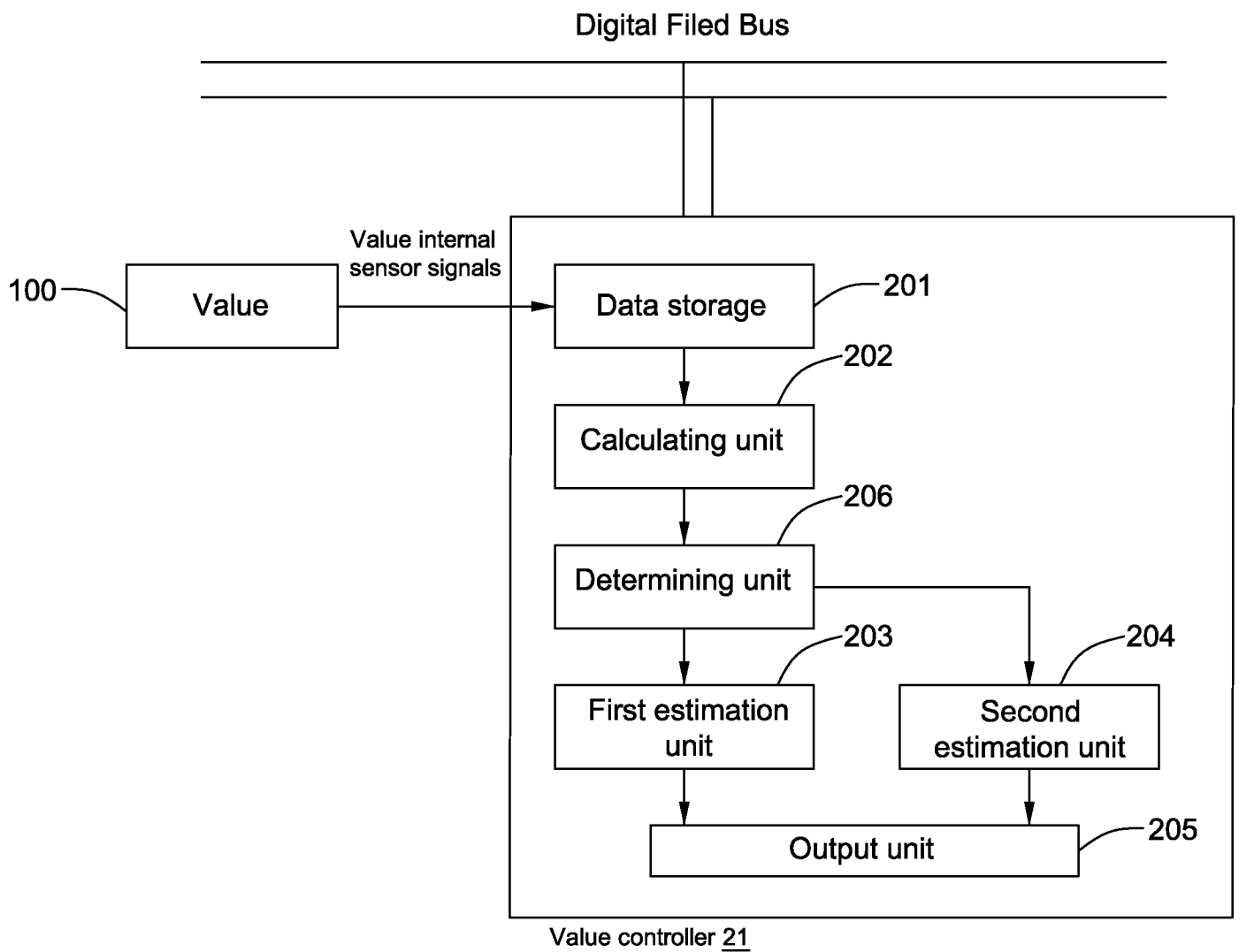


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2017/084549

A. CLASSIFICATION OF SUBJECT MATTER

F16K 37/00(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)

F16K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNABS,CNXTX,DWPI,VEN,CNKI:valve, life, remaining, actuat+, estimating, force, travel, stuck

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2007061424 A1 (NORGREN INC ET AL.) 31 May 2007 (2007-05-31) description, pages 6-11, figures 2-3	1, 4-7, 10
A	JP 58121384 A (MITSUBISHI HEAVY IND LTD) 19 July 1983 (1983-07-19) the whole document	1-10
A	US 4976144 A (FISHER CONTROLS INT) 11 December 1990 (1990-12-11) the whole document	1-10
A	US 4523286 A (HITACHI LTD ET AL.) 11 June 1985 (1985-06-11) the whole document	1-10
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A	JP 61228181 A (TOSHIBA CORP) 11 October 1986 (1986-10-11) the whole document	1-10

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

* Special categories of cited documents:

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Date of the actual completion of the international search

01 February 2018

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06 March 2018

Name and mailing address of the ISA/CN

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INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.

PCT/CN2017/084549

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