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Method and Apparatus for Detecting Performance of an APU Fuel Assembly

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Abstract

The present invention relates to a method for detecting performance of an APU fuel assembly, comprising: obtaining APU messages at multiple time points within a time period; obtaining running parameters of the APU fuel assembly according to the APU messages, the running parameters at least comprising starting time STA; calculating average value AVG and deviation index δ of the starting time STA within said time period; determining whether performance of the APU fuel assembly is in the stable phase, decline phase, or failure phase according to the deviation index δ.

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METHOD AND APPARATUS FOR DETECTING PERFORMANCE OF AN APU FUEL ASSEMBLY

Field of the Invention

The present invention relates to a method and apparatus for detecting performance of an Airbone Auxiliary Power Unit, APU, fuel assembly of an aircraft. For example, the invention relates to a method and an apparatus for detecting performance of an aircraft component, in particular to a method and an apparatus for detecting performance of an APU fuel assembly.

Background of the Invention

Airborne Auxiliary Power Unit, abbreviated as APU, is a small turbine engine mounted on the tail of an aircraft. Its main function is to supply power and gas sources, with a few APUs capable of providing additive thrust to the aircraft. Specifically, before taking off from the ground, an aircraft may do not need to rely on ground power and gas source vehicles to start the aircraft as its main engine may be started via power supply from the APU. While on the ground, the APU also supplies power and compressed air to ensure lighting and air-conditioning in the cabin and cockpit. During take-off of an aircraft, the APU can serve as a backup power source. After the aircraft is landed, lighting and air-conditioning of the aircraft are still powered by the APU. The functions of APU determine that its stability directly affects flight cost and quality of service of the aircraft.

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APU fuel assembly is an important component of APU. Once the fuel assembly fails, it will directly cause the APU unable to start, and thus cause grounding of the aircraft. Currently, there is not any effective way to maintain the APU fuel assembly except for breakdown maintenance, which inevitably causes aircraft delay and increases of maintenance costs.

It is generally desirable to overcome or ameliorate one or more of the above described difficulties, or to at least provide a useful alternative.

Summary of the Invention

According to the present invention, there is provided a method for detecting performance of an Airbone Auxiliary Power Unit, APU, fuel assembly of an aircraft, comprising:

obtaining APU messages at multiple time points within a time period;

obtaining running parameters of the APU fuel assembly according to the APU messages, the running parameters at least comprising starting times STA of the APU;

calculating an average value AVG and a standard deviation of the starting times STA within said time period; and

determining whether performance of the APU fuel assembly is in a stable phase, a decline phase or a failure phase according to the standard deviation,

wherein the determining whether performance of the APU fuel assembly is in a stable phase, a decline phase or a failure phase according to the standard deviation comprises:

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in response to the standard deviation within said time period being smaller than a decline threshold value, determining that performance of the APU fuel assembly is in the stable phase;

in response to the standard deviation within said time period being larger than the decline threshold value and smaller than a failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and

in response to the standard deviation within said time period being larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

According to the present invention, there is also provided an apparatus for detecting performance of an Airbone Auxiliary Power Unit, APU, fuel assembly of an aircraft comprises:

a message acquisition unit, which obtains APU messages at multiple time points in a time period;

a message parsing unit, which parses out running parameters of the APU fuel assembly according to the APU messages, the running parameters at least comprising starting times STA of the APU; and

a performance detection unit, which determines whether performance of the APU fuel assembly is in a stable phase, a decline phase, or a failure phasebased on a calculated average and a standard deviation of the starting times within said time period, wherein the performance detection unit is further used for:

in response to the standard deviation within said time period being smaller than a decline threshold value, determining that performance of the APU fuel assembly is in the stable phase;

in response to the standard deviation within said time period being larger than the decline threshold value and smaller than a failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and

in response to the standard deviation within said time period being larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

According to the present invention, there is also provided an apparatus for detecting performance of an Airbone Auxiliary Power Unit, APU, fuel assembly of an aircraft comprises:

a processor; and

a storage coupled to the processor, which stores computer readable instructions;

the computer readable instructions run on the processor to execute the following steps:

obtaining APU messages at multiple time points in a time period;

parsing out running parameters of the APU fuel assembly according to the messages, the running parameters at least comprising starting times STA; and

determining whether performance of the APU fuel assembly is in a stable phase, a decline phase, or a failure phase according to the standard deviation,

wherein the determining whether performance of the APU fuel assembly

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is in a stable phase, a decline phase, or a failure phase according to the standard deviation comprises:

in response to the standard deviation within said time period being smaller than a decline threshold value, determining that performance of the APU fuel assembly is in the stable phase;

in response to the standard deviation within said time period being larger than the decline threshold value and smaller than a failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and

in response to the standard deviation within said time period being larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

For the above technical problem in prior art, there is provided, according to one preferred embodiment of the present invention, a method for detecting an APU fuel assembly of an aircraft, comprising: obtaining APU messages at multiple time points within a time period; obtaining running parameters of the APU fuel assembly according to the APU messages, the running parameters at least comprising starting time STA; calculating average value AVG and deviation index δ of the starting time STA within said time period; and determining whether performance of the APU fuel assembly is in the stable phase, decline phase or failure phase according to the deviation index δ.

For the method as described above, wherein the step of determining whether performance of the APU fuel assembly is in the stable phase, decline phase, or failure phase comprises: in response to that the deviation index δ is smaller than the decline threshold value, determining that performance of the APU fuel assembly is in the stable phase; in response to that the deviation index δ is larger than the decline threshold value and smaller than the failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and in response to that the deviation index δ is larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

The method as described above further comprises: determining the deviation index when the APU fuel assembly is in the stable phase; wherein, the decline threshold value is about 2 times of the deviation index in the stable phase, and the failure threshold value is about 3-4 times of the stable deviation index.

For the method as described above, wherein the time period is about 2-4 days.

For the method as described above, wherein about 5-10 APU messages are obtained within the time period.

The method as described above further comprises: determining starting time STA_{next} obtained according to a next APU-related message; in response to that STA_{next} is larger than AVG+nδ or smaller than AVG-nδ, determining whether STA_{next+1} obtained according to a next APU-related message is larger than

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$AVG+n\delta$ or smaller than $AVG-n\delta$; and in response to that the number of times for starting time STA obtained according to APU-related message continuously larger than $AVG+n\delta$ or continuously smaller than $AVG-n\delta$ exceeds the preset warning number Z, sending out warnings; wherein, n is 2-5; Z is 3-5.

For the method as described above, in response to that starting time STA obtained according to APU-related message is smaller than $AVG+n\delta$ and larger than $AVG-n\delta$, recalculating average value AVG and deviation index δ of the starting time STA.

For the method as described above, in response to that the number of times for starting time STA obtained according to APU-related message continuously larger than $AVG+n\delta$ or smaller than $AVG-n\delta$ exceeds the preset warning number Z, recalculating average value AVG and deviation index δ of the starting time STA.

For the method as described above, wherein the deviation index δ is standard deviation.

For the method as described above, wherein the n is 2 or 3, and Z is 3.

The method as described above further comprises: determining that the APU starter works in normal condition.

The method as described above further comprises: determining that other parameters of APU keep normal, the other parameters comprising but not limited to: APU exhaust gas temperature EGT, bleed air pressure PT, angle of inlet guide vane IGV and APU turbine efficiency NPA.

According to another preferred embodiment of the present invention, there is provided an apparatus for detecting performance of an APU fuel assembly of an aircraft, comprising: message acquisition unit, which obtains APU messages in a time period; message parsing unit, which parses out the required running data of APU fuel assembly; and performance detection unit, which determines whether performance of the APU fuel assembly is in the stable phase, decline phase, serious decline phase, or failure phase according to the running data of the fuel assembly.

According to still another preferred embodiment of the present invention, there is provided an apparatus for detecting performance of an APU fuel assembly of an aircraft, comprising a processor; and a storage connected to the processor, which stores computer readable codes; the computer readable codes run on the processor to execute the following steps: obtaining APU messages in one time period; parsing out running parameters of the APU fuel assembly according to the message, the running parameters comprising starting time STA; and determining whether performance of the APU fuel assembly is in the stable phase, decline phase, serious decline phase or failure phase.

Brief Description of the Drawings

Preferred embodiments of the present invention are hereafter described, by way of non-limiting example only, with reference to the accompanying drawings, in which:

Fig.1 is a schematic of the structure of an aircraft APU;

Fig.2 is a schematic of the structure of an aircraft APU fuel assembly;

Fig.3 is a chart showing a curve reflecting changes of performance of an APU fuel assembly;

Fig.4 is a statistic tendency diagram of data of starting time of an APU fuel assembly;

Fig.5 is an example of A13 message of Airbus;

Fig.6 is a flow chart illustrating a method for detecting performance of an APU fuel assembly; and

Fig.7 is a flow chart illustrating a method for detecting performance of an APU fuel assembly.

<u>Detailed Description of Preferred Embodiments of the Invention</u>

In order to give a clearer picture of the purposes, technical solutions and merits of embodiments of the present invention, technical solutions in the embodiments of the present invention will be fully described below, taken in conjunction with the accompanying drawings in the embodiments of the present invention. Apparently, the illustrated embodiments are only a part of the embodiments instead of all the embodiments of the present invention. Based on the embodiments in the present invention, all other embodiments a person will ordinary skill in the art achieved without any creative effort shall fall within the protection scope of the present invention.

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In the following detailed description, reference may be made to each figure, which forms a part of the present application to illustrate specific embodiments of the present application. In the drawings, similar symbols in different figures identify substantially the same components. With the following detailed description of each specific embodiment of the present application, a person with related knowledge and ordinary skill in the art shall be able to performance the technical solution of the present application. It shall be appreciated that other embodiments may be utilized or changes may be made to the structure, logic or electrical property of embodiments of the present application.

Fig.1 is a schematic illustrating the structure of an aircraft APU according to one embodiment of the present invention. As shown in the figure, the aircraft APU mainly comprises a power portion 100, a load portion 200, and an accessory portion 300. Wherein, the power portion 100 mainly comprises a power compressor 110, a turbine assembly 120, and an exhaust assembly 130 and so forth. The load portion 200 mainly comprises a load compressor 210; the accessory portion 300 mainly comprises an accessory gearbox 310, a starter 320, and an electric generator 330 and so forth. The power compressor 110 is utilized to supply gases at high pressure to be burnt in the combustion chamber. APU fuel assembly supplies fuel oil to the combustion chamber. Gas of high temperature and high pressure generated in the combustion chamber via the burning of fuel oil moves and rotates the turbine assembly 120. Input air flow from the air inlet diverges into two streams, with one entering the power compressor 110 and turbine assembly

120 mainly for rotating the APU and then flowing out via the exhaust assembly 130, while another stream entering the load compressor 210 to be pressurized by the load compressor to generate a compressed air exclusively for the use of an aircraft. At the entrance of the airflow, there is provided with a flow regulating valve (inlet guide vane) to regulate the opening degree of the valve (vane) in a real-time manner according to compressed air needed by an aircraft so as to control air flow into the load compressor.

When the APU is started, the starting system obtains power from the direct current system of the aircraft, supplies a direct current voltage of 28 V to the battery bus (BAT BUS), and the direct current voltage is further supplied to the starter via a contactor. The starter rotates and accelerates the APU rotor to a rotational speed such that the fuel and ignition system may work, and then ignites the fuel oil to further accelerate the APU. When the rotational speed reaches 35% to 60% of the normal rotational speed of APU, the starter is shut down while the APU continues to accelerate to a normal working rotational speed. For example, for APU of APS3200, when the rotational speed reaches 55% of the normal rotational speed of APU, the starter is shut off; while for APU of GTCP131-9A, when the rotational speed reaches 50% of normal rotational speed of APU, the starter is shut off.

Inventors of the present application found that performance of APU fuel assembly directly affects the starting time of APU. When performance of the APU fuel assembly deteriorates, oil supply to the combustion chamber is not enough, and it takes more time for the APU to accelerate to the normal working rotational speed. As service time of the fuel assembly increases, its efficiency will decrease gradually and oil supply efficiency will also decrease accordingly. When oil supply efficiency of the fuel assembly decreases to a certain degree, the APU can not accelerate to the normal working rotational speed, namely, failure of fuel assembly occurs.

Changes of performance of an APU fuel assembly follow certain rules: during the early and middle phases of the use of a fuel assembly, performance of the fuel assembly is relative stable, while during the later phase, its performance will deteriorate until breakdown. As the service time increases, the decline index continues to increase as performance of the APU fuel assembly declines gradually. When the decline index of the performance of the APU fuel assembly is relatively stable, its performance is in the stable phase; when the decline of performance of the APU fuel assembly accelerates, it performance enters the decline phase; when the decline index exceeds a certain threshold value, performance of the APU fuel assembly enters the failure phase during which malfunction might occur at any time. After the APU fuel assembly enters the failure phase, it will not only affect the use of APU and have adverse effect on quality of service and flight safety, but also cause unplanned maintenance and flight delay and grounding.

Performance of an aircraft APU fuel assembly FCU is mainly represented by starting time of APU. Fig. 2 is a statistical tendency diagram reflecting changes of data of the APU starting time caused by changes of performance of the APU fuel assembly. As shown in Fig. 2, when the fuel assembly is in the stable phase, starting time of the APU changes in a very small scope, however when the APU fuel assembly is in the decline phase, starting time of

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the APU leaps upwardly and disperses until the APU cannot be started due to malfunction. In addition, as can be seen from Fig. 2, the time from the entry into the decline phase to the occurrence of malfunction is very short. Therefore, the detection of decline phase of a fuel assembly becomes extremely important.

In prior art, there is no means for detecting whether performance of an APU fuel assembly is in a decline phase. However, some embodiments of the present invention may realize such detection. The detection of decline phase has the following merits: when an APU fuel assembly is in the decline phase, the probability of malfunction remains very low. If the aircraft is maintained at this time, flight safety and quality of service can be guaranteed. At that time, the airline company may arrange inspection and maintenance of the aircraft at an appropriate time so as to avoid unplanned maintenance and reduce flight delay. Meanwhile, excessive costs for maintenance at regular interval can be avoided.

Multiple methods can be utilized to obtain the running parameter STA (starting time). For example, the above data can be obtained from data stored in the black box FDR or Quick Access Recorder (QAR) of an aircraft.

The above data can also be obtained from the data system provided by the aircraft manufacturer, and real-time detection on the ground can be realized. For example, running data of an aircraft can be monitored in a real-time manner via both Aircraft Condition Monitoring System (ACMS) of Airbus and Aircraft Heath Monitor (AHM) system of Boeing. Besides, when certain trigger condition is met, a message containing a series of data information can be generated automatically.

According to one embodiment of the present invention, APU-related running data can be obtained via an aircraft data system (such as ACMS or AHM systems) and be embodied in the related generated message. Such message information can be transmitted to the ground via the Aircraft Communication Addressing and Reporting System (ACARS) and further be distributed to servers of different airline companies. According to one embodiment of the present invention, the APU message may also be transmitted via the communication apparatus or system of Aviation Telecommunication Network (ATN).

In fact, for existing flight data system, monitoring the performance of APU is an already-included item, and thus a corresponding APU message can be generated automatically and transmitted to the ground via ACARS or ATN. However, those data monitored are not utilized for detecting the decline phase of performance of APU. For example, the A13 message of Airbus (namely, APU MES/IDLE REPORT) or the APU message of Boeing is an example of such APU message. In the following embodiment, the A13 message of Airbus is illustrated as an example. APU message of Boeing is processed in a similar way.

Fig. 3 illustrates an example of A13 message of Airbus. As shown in the figure, the A13 message mainly contains the following 4 parts of information: the header, the APU history information, the running parameters for starting

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the aircraft engine and the APU starting parameters.

The header is composed of CC section and C1 section, mainly including information such as flight information, leg in which the message is generated, bleed valve status, total air temperature (i.e., external temperature). The APU history information is comprised of E1 section including APU serial number, service time and circulation and so forth. The running parameters for starting an aircraft engine is comprised of N1 to S3 sections; wherein N1 and S1 indicate the running status when the first aircraft engine is started; N2 and S2 indicate the running status when the second aircraft engine is started; N3 and S3 is the status after all engines are started and the APU is idling; wherein data relating to performance of the fuel assembly is starting time STA.

As can be seen from Fig. 3, starting time STA, the APU running parameter, is included in the existing A13 message. Therefore, detection of performance of the APU fuel assembly of the present invention can be realized by utilizing data obtained in this message.

Fig. 4 is a flow chart illustrating a method for detecting performance of an APU fuel assembly according to one embodiment of the present invention. As shown in this figure, in method 400 for detecting performance of the APU fuel assembly, in step 410, starting time STA of an APU fuel assembly at a certain time point is obtained.

According to one embodiment of the present invention, information needed

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in step 410 can be obtained from an APU message such as the A13 message. For example, the A13 message of the running of an aircraft APU can be remotely obtained in a real-time manner from SITA (Société Internationale de Télécommunications Aéronautiques) network control center and ADCC (Aviation Data Communication Corporation) network control center, and the obtained A13 message of APU running status can be decoded via a message decoder so as to obtain the required running information of the fuel assembly of the Aircraft APU.

In step 420, the previous M starting times STAs are obtained, and their average value AVG and standard deviation δ are calculated. According one embodiment of the present invention, the value of M may be 5-10.

In step 430, determine whether the standard deviation δ calculated in step 420 exceeds the failure threshold value. If yes, then output failure warning.

If the determination in step 430 is NO, then go to step 440, and determine whether the standard deviation δ calculated in step 420 exceeds the decline disperse threshold value. If yes, then output decline warning. Otherwise, return to step 410, and continue to obtain starting time STA of APU at a next time point.

According to one embodiment of the present invention, at first, fluctuation of the APU fuel assembly of a certain type in the stable phase is analyzed based on historical or experience data, and other threshold values are further determined based on the fluctuation in the stable phase. For example, according to one embodiment of the present invention, the decline threshold value is 2 times of the fluctuation in the stable phase, and the failure threshold value is 3 to 4 times of the fluctuation in the stable phase.

Such method for utilizing data keeping updated in a certain time period to analyze changes of trend is referred to as “moving window method”. The size of the moving window, namely the number M of the points included in the calculation, depends on a number of factors, such as time interval between different measurements and control strategy and so forth. The smaller the moving window is, the easier the volatility of data will be affected by normal fluctuation, and thus various misinformation will occur, which will affect the technical effect of the present invention. If the moving window is overlarge, although the changes of trends will be reflected more accurately, the timeliness of the present invention will be reduced and warning information cannot be delivered in a timely manner. Therefore, the size of the moving window plays an important role in the present invention. According to one embodiment of the present invention, the value of M is around 5 on the condition that 2 to 3 points are measured in each day. According to another embodiment of the present invention, the value of M is around 10 on the condition that the number of points measured in each day is less than or equals to 2.

According to one embodiment of the present invention, in order to reduce false alarm and improve accuracy, the performance of an APU fuel assembly is determined to be in the decline phase only if two consecutive decline warnings occurred; while performance of the APU fuel assembly is determined to be in the failure phase only when more than 2 consecutive failure warnings occurred.

Fig. 5 is a flow chart illustrating a method for detecting performance of an APU fuel assembly according to another embodiment of the present invention. As shown in this figure, in the method 500 for detecting performance of the APU fuel assembly, similar to the embodiment illustrated in Fig. 4, in step 510, starting time STA of an APU fuel assembly of an aircraft at a certain service time point is obtained.

In step 520, M starting times STAs before the current time point which is the sum of high value counter and low value counter are obtained and their average value AVG and standard deviation δ are calculated. The reason for calculating average value and standard deviation of a certain number of previous points is to set a range of fluctuation for the judgment of a next point, however it is necessary to eliminate values that might be noise. According to the following description, high value counter is utilized to count deviation points higher out of the preset range, and the low value counter is utiliezed to count deviation points lower out of the preset range. When the number of deviation points that consecutively occurred does not reach the warning number, those deviation points will not be included into the sample for calculation of average value and standard deviation. According to one embodiment of the present invention, the value of M may be 5-10.

In step 530, compare whether the standard deviation δ calculated in step 520 exceeds the failure threshold value. If yes, then output failure warning.

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When the judgment in step 530 is NO, then go to step 540, compare whether the standard deviation δ calculated in step 520 exceeds the decline threshold value. If yes, then output decline warning.

When the judgment in step 540 is NO, then go to step 550, the counter returns to zero. This is because the counting of deviation points is interupted according to the previous judgment, and it is necessary to return the counter to zero so as to recount the number of consecutive deviation points. The counter of this type may be realized via various software and hardware means.

In step 560, determine whether APU starting time STA of a next time point is larger than AVG+nδ or smaller than AVG-nδ. Wherein, the value of n depends on control strategy. When the value of n is relatively high, the control on breakpoint is relatively loose, which may reduce misinformation but have the risk of missing the failure; while when the value of n is relatively low, the control on breakpoint is relatively strict, which may prevent report failure but may have warnings with high frequency. Generally speaking, the value of n is between 2 to 5. According to one embodiment of the present invention, the value of n is 3.

The following description is about the STA value is higher than the preset range and only the high value counter is used. In case the STA value is lower than the preset range, the situation is similar. When the judgment in step 560 is YES, then add 1 to the high value counter. In step 570, determine whether the number on the counter equals to the preset warning number. When the determination is NO, return to step 550. When the determination is YES, it means that some consecutive APU starting times STA, the number of which reaches the preset warning number, exceed the preset normal range of fluctuation, then send out warning of upward jumping. Since a single jump might be resulted from various causes, it is required that the warning is output only if the number of jumps consecutively exceeds a certain amount so as to avoid misinformation. The value of preset warning number is related to the control strategy, its value is 3 to 5 in general.

When the judgement in step 560 is No, return to step 510. It means that the starting time STA is within the normal range and no warning is necessary. In step 580, the counter is returned to zero. This is because when the number of consecutive deviation points reaches the preset warning number, the occurrence of deviation point is not accidental and shall not be eliminated as noise. To return the counter to zero at this time, those deviation points will be retained when recycled to step 520 so as to be included into the reference sample. Then, return to step 510 after this step ends.

According to one embodiment of the present invention, information needed in step 510 may be obtained in a way similar to that in step 410.

Fig. 6 is an example of changes of performance of an APU fuel assembly according to one embodiment of the present invention. At the position marked by solid line in the figure, the APU fuel assembly is replaced. As shown in Fig. 6, before the replacement of the APU fuel assembly, the starting time STA increases, and standard deviation of STA also increases (namely, STA starts to disperse). If using the method descried above, one will find that the increase of STA deviation index such as standard deviation will soon trigger the warning that performance of the APU fuel assembly deteriorates into decline phase.

Meanwhile, it shall also be noted that other parameters of APU except for the starting time STA keep normal, the said other parameters comprise but are not limited to: APU exhaust gas temperature EGT, bleed air pressure PT, angle of inlet guide vane IGV and APU turbine efficiency. This is an important feature of the failure of APU fuel assembly.

It shall also be noted that manifestation of failure of the APU starter is also similar to the above. Therefore, it shall be distinguished from the failure of an APU starter: at first, although failure of APU starter may also causes increase of standard deviation of starting time STA, namely, STA dispersion, when the performance of APU fuel assembly deteriorates, the speed of deterioration of starting time STA is slow and standard deviation of STA increases and keeps at a certain level, and this phenomenon may last for over 100 hours per 50 number of start-ups; however, for the failure of starter, it may only last for at most 30 to 40 hours per 10 to 15 number of start-ups.

Besides, although when performance of the APU fuel assembly deteriorates, other parameters except for STA keep good, NPA and EGTP will also deteriorate gradually and approach their threshold value due to unsteady

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supply of oil. This feature may also facilitate the judgment of failure of an APU fuel assembly.

Fig. 7 is a schematic of the structure of an apparatus for detecting performance of an APU fuel assembly according to one embodiment of the present invention. As shown in Fig. 7, the apparatus for detecting performance of an APU fuel assembly comprises: message acquisition unit 701, which obtains APU-related messages within a time period; message parsing unit 702, which parses out the required running data of the APU fuel assembly; and performance detection unit 703, which determines whether performance of the APU fuel assembly is in the stable phase, decline phase or failure phase according to the running data of the fuel assembly.

According to one embodiment of the present invention, an apparatus for detecting performance of an APU fuel assembly of an aircraft comprises: a processor; and a storage coupled to the processor, wherein the storage stores computer readable instructions; the computer readable instructions run on the processor so as to execute the following steps: obtaining APU-related messages in a time period; parsing out running parameters of the APU fuel assembly according to the messages, the running parameters comprise starting time STA; determining whether performance of the APU fuel assembly is in a stable phase, decline phase, or failure phase.

Deterioration of performance of fuel assembly is not too fast, general over 100 hours. According to previous troubleshooting rules and orders, it is difficult to spot breakdown of fuel assembly and capture any failure phenomenon. It often takes several times of replacements of other components to determine failure of fuel assembly FCU. With the present invention, maintenance staff may rapidly locate decline of performance of APU fuel assembly, which may avoid several times of replacements of other components, reduce overstock of aviation materials, and save enough time to prepare a standby component. It is very important for ensuring on-schedule operation of an aircraft. Meanwhile, it will help to control inventory more accurately, or even realize zero inventory.

The above embodiments are only described for illustrating the present invention, and do not mean to limit the present invention. A person with ordinary skill in relevant art may make various changes and variations without departing from the scope of the present invention. Therefore, all equivalent technical solutions shall also fall within the disclosure of the present invention.

Throughout this specification and the claims which follow, unless the context requires otherwise, the word “comprise”, and variations such as “comprises” and “comprising”, will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

Claims Defining the Invention

1. A method for detecting performance of an Airbone Auxiliary Power Unit, APU, fuel assembly of an aircraft, comprising:

obtaining APU messages at multiple time points within a time period;

obtaining running parameters of the APU fuel assembly according to the APU messages, the running parameters at least comprising starting times STA of the APU;

calculating an average value AVG and a standard deviation of the starting times STA within said time period; and

determining whether performance of the APU fuel assembly is in a stable phase, a decline phase or a failure phase according to the standard deviation, wherein the determining whether performance of the APU fuel assembly is in a stable phase, a decline phase or a failure phase according to the standard deviation comprises:

in response to the standard deviation within said time period being smaller than a decline threshold value, determining that performance of the APU fuel assembly is in the stable phase;

in response to the standard deviation within said time period being larger than the decline threshold value and smaller than a failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and

in response to the standard deviation within said time period being larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

2. The method of Claim 1 , wherein:

the decline threshold value is 2 times of the standard deviation when the APU fuel assembly is in the stable phase, and the failure threshold value is 3-4 times of the standard deviation when the APU fuel assembly is in the stable phase.

3. The method of Claim 1, wherein the time period is 2-4 days.

4. The method of Claim 1, wherein 5-10 APU messages are obtained within said time period.

5. The method of Claim 1 further comprises: determining starting times STA_{next} obtained according to a next APU-related message;

in response to STA_{next} being larger than AVG+nδ or smaller than VG-nδ, determining whether STA_{next+1} obtained according to a next APU-related message is larger than AVG+nδ or smaller than AVG-nδ; and

in response to the number of times for starting times STA obtained according to APU-related message continuously larger than AVG+nδ or continuously smaller than AVG-nδ exceeding the preset warning number Z, sending out warnings;

wherein, δ is the standard deviation, AVG is the average value, n is 2-5; and Z is

3-5.

6. The method of Claim 5, in response to starting times STA obtained according to APU-related message being smaller than AVG+nδ and larger than AVG-nδ, recalculating average value AVG and standard deviation of the starting times STA.

7. The method of Claim 5, in response to the number of times for starting times STA obtained according to APU-related message continuously larger than AVG+nδ or continuously smaller than AVG-nδ exceeding the preset warning number Z, recalculating average value AVG and standard deviation of the starting times STA.

8. The method of any one of Claims 5-7, wherein n is 2 or 3, and Z is 3.

9. The method of Claim 1 further comprises: determining that the APU starter works in normal condition.

10. The method of Claim 1 further comprises: determining that other parameters of APU keep normal, the other parameters comprising but not limited to: APU exhaust gas temperature EGT, bleed air pressure PT, angle of inlet guide vane IGV and APU turbine efficiency NPA.

11. An apparatus for detecting performance of an Airbone Auxiliary Power Unit,

APU, fuel assembly of an aircraft comprises:

a message acquisition unit, which obtains APU messages at multiple time points in a time period;

a message parsing unit, which parses out running parameters of the APU fuel assembly according to the APU messages, the running parameters at least comprising starting times STA of the APU; and

a performance detection unit, which determines whether performance of the APU fuel assembly is in a stable phase, a decline phase, or a failure phase based on a calculated average and a standard deviation of the starting times within said time period, wherein the performance detection unit is further used for:

in response to the standard deviation within said time period being smaller than a decline threshold value, determining that performance of the APU fuel assembly is in the stable phase;

in response to the standard deviation within said time period being larger than the decline threshold value and smaller than a failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and

in response to the standard deviation within said time period being larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

12. An apparatus for detecting performance of an Airbone Auxiliary Power Unit,

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APU, fuel assembly of an aircraft comprises:

a processor; and

a storage coupled to the processor, which stores computer readable instructions; the computer readable instructions run on the processor to execute the following steps:

obtaining APU messages at multiple time points in a time period;

parsing out running parameters of the APU fuel assembly according to the messages, the running parameters at least comprising starting times STA; and

determining whether performance of the APU fuel assembly is in a stable phase, a decline phase, or a failure phase according to the standard deviation, wherein the determining whether performance of the APU fuel assembly is in a stable phase, a decline phase, or a failure phase according to the standard deviation comprises:

in response to the standard deviation within said time period being smaller than a decline threshold value, determining that performance of the APU fuel assembly is in the stable phase;

in response to the standard deviation within said time period being larger than the decline threshold value and smaller than a failure threshold value, determining that performance of the APU fuel assembly is in the decline phase; and

in response to the standard deviation within said time period being larger than the failure threshold value, determining that performance of the APU fuel assembly is in the failure phase.

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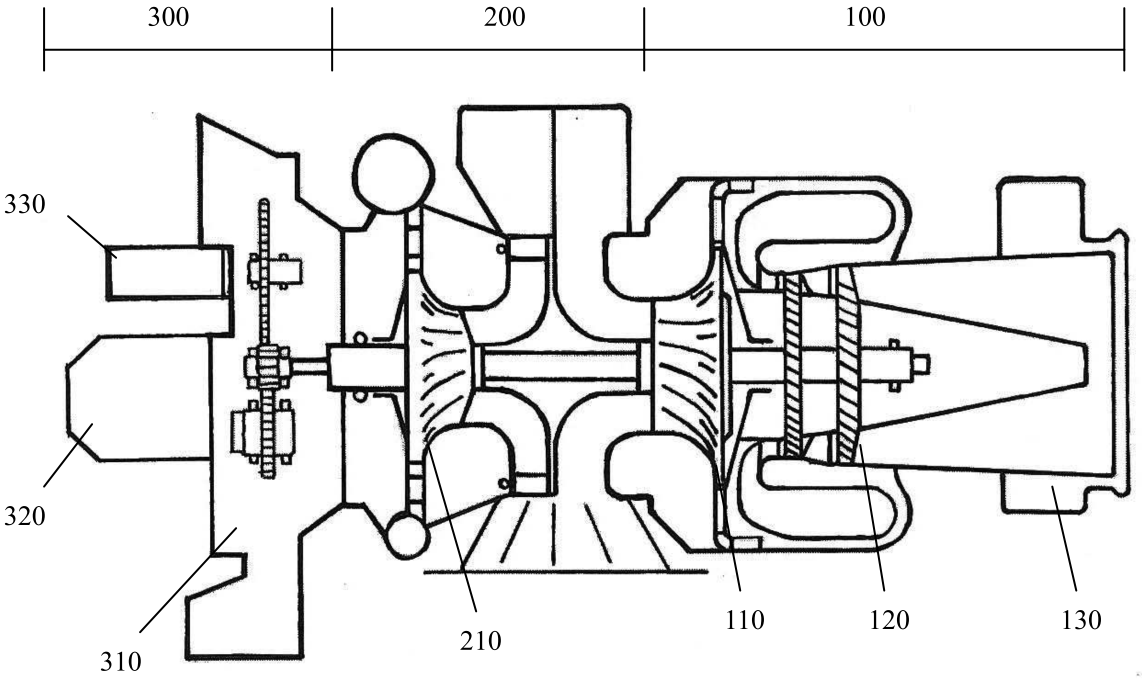

FIG.1

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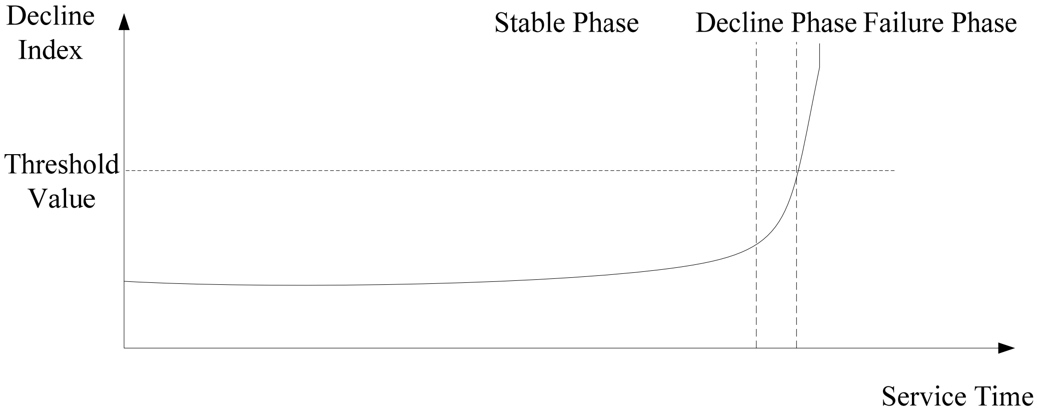

FIG. 2

APU MES/IDLE REPORT <13>

	A/C ID	DATE UTC		FROM	TO	FLT	
	Aircraft No.	UTC Date		Take off	landing	Flight No.	
CC	BXXXX	yyyy-dd-mm xx:xx:xx		-	-	-	
	PH	CNT	CODE	BLEEDSTATUS		APU	
	Leg	Count	Trigger Code	Bleed Valve Status		APU Bleed Valve	
C1	11	76401	4000	16 0000 1 00000 19		1	
	TAT	ALT	CAS	MN	GW	CG	DMU
	Total Temperature	Elevation	Calculate Air Speed	Mach Speed	Total Weight	Center of Gravity	Version
CE	23.3	150	-	-	65600	29.2	I71CA2
	ASN	AHRS	ACYC	PHAD			
	APU Serial No.	APU hour	APU Cycle	APU Performance Adjustment			
E1	2056	18477	16894	4000			
	ESN	ACW1	ACW2	NA	EGTA	IGV	
	Engine Serial No.	Control Word 1	Control Word 2	Rotate Speed	Exhaust Gas Temperature	IGV Location	
N1	011909	00000	0A000	99.7	588	-5	
N2	011473	00000	0A000	99.8	580	-5	
N3	000000	00000	04000	99.8	388	82	
	P2A	LCIT	WB	PT	LCDT	OTA	GLA
	Inlet Pressure	Load Compressor Inlet Temperature	Bleed Air Flow	Bleed Air Pressure	Load Compressor Outlet Temperature	Lubricant Temperature	APU Generator Loading
S1	.956	33	.41	3.99	XXXX	110	38
S2	.952	32	.41	3.99	XXXX	110	27
S3	.96	32	0	1.17	XXXX	107	0
	STA	EGIP	NPA	OTA	ICIT		
	PREVIOUS APU START (APU Starting Parameters)						
	Starting Time	EGT Peak Value	Peak Value EGT Rotational Speed	Lubricant Temperature	Load Compressor Inlet Temperature		
V1	49	808	35	110	32		

FIG. 3

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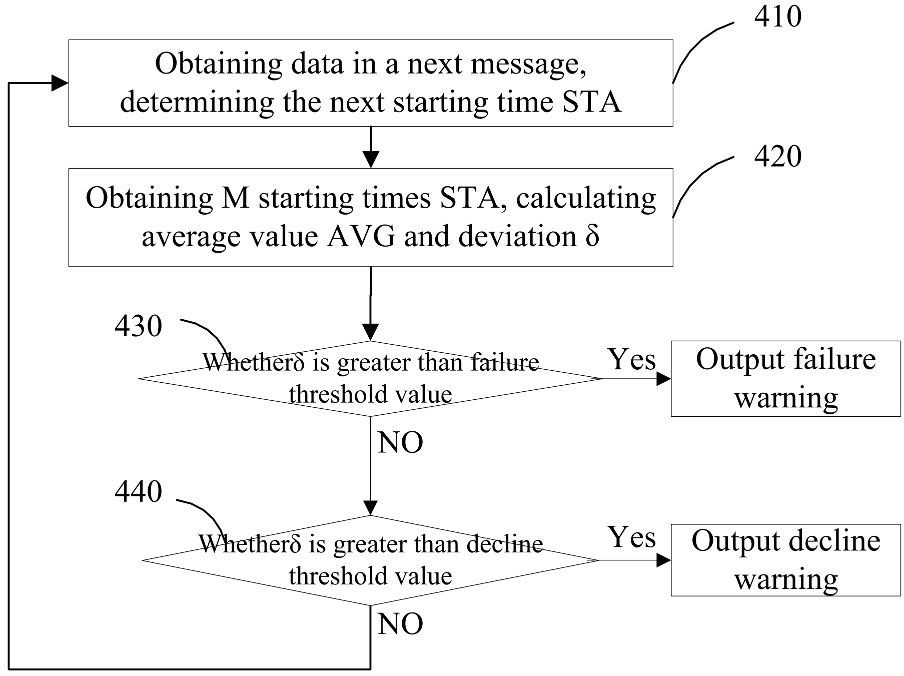

FIG.4

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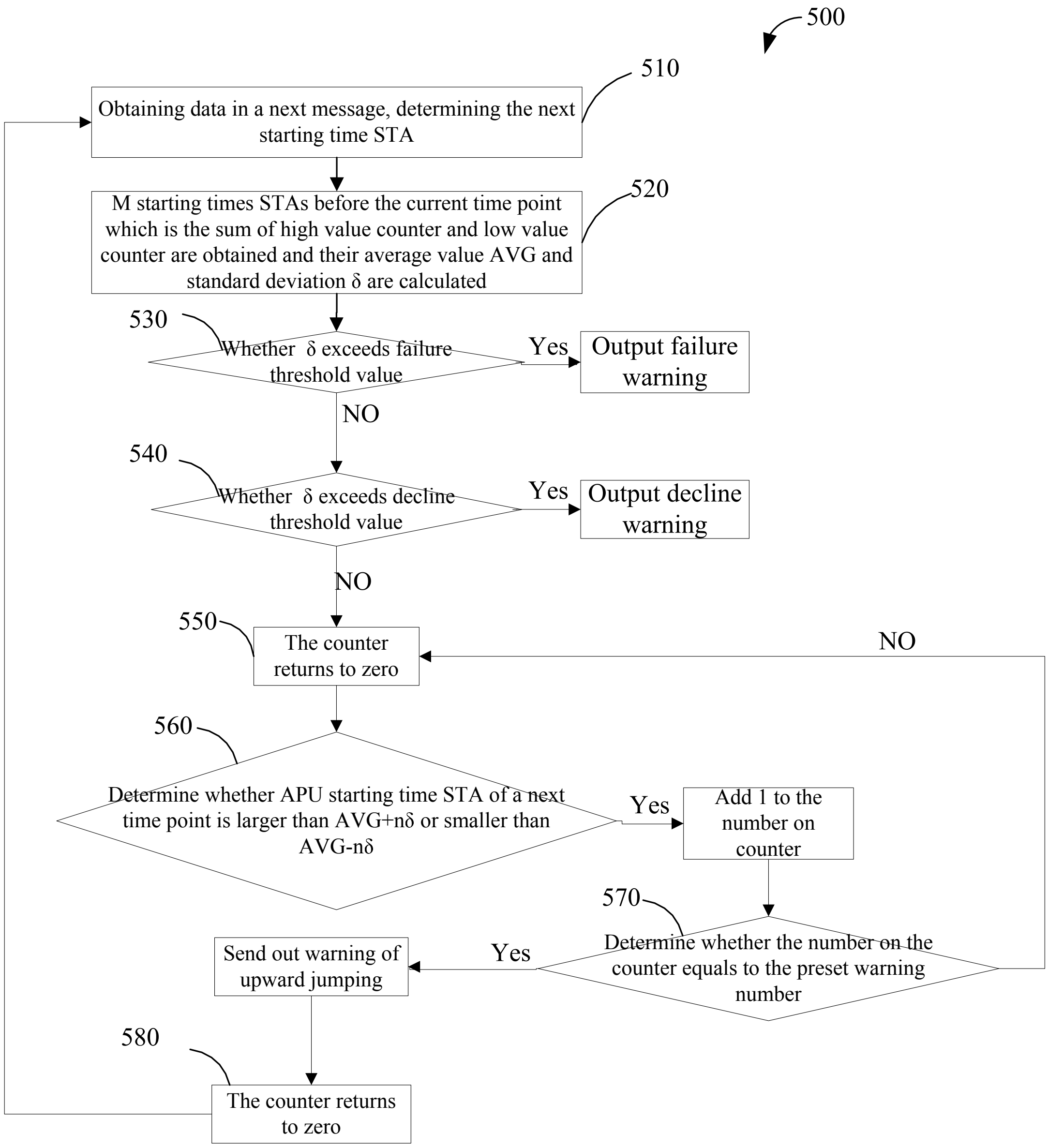

FIG. 5

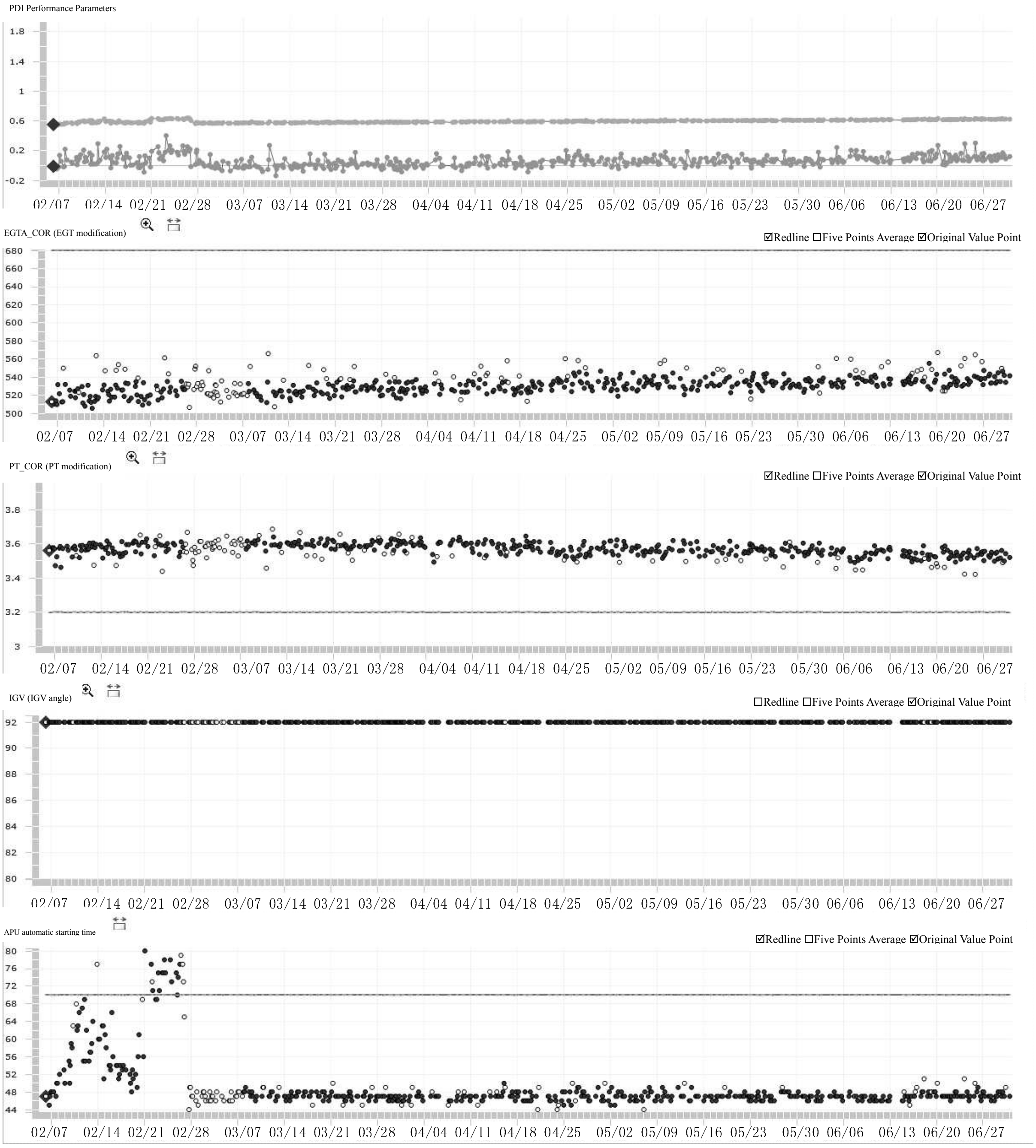
PDI Performance Parameters
1.8
1.4
1
0.6
0.2
-0.2
02/07 02/14 02/21 02/28 03/07 03/14 03/21 03/28 04/04 04/11 04/18 04/25 05/02 05/09 05/16 05/23 05/30 06/06 06/13 06/20 06/27
EGTA_COR (EGT modification)
☑Redline ☐Five Points Average ☑Original Value Point
680
660
640
620
600
580
560
540
520
500
02/07 02/14 02/21 02/28 03/07 03/14 03/21 03/28 04/04 04/11 04/18 04/25 05/02 05/09 05/16 05/23 05/30 06/06 06/13 06/20 06/27
PT_COR (PT modification)
☑Redline ☐Five Points Average ☑Original Value Point
3.8
3.6
3.4
3.2
3
02/07 02/14 02/21 02/28 03/07 03/14 03/21 03/28 04/04 04/11 04/18 04/25 05/02 05/09 05/16 05/23 05/30 06/06 06/13 06/20 06/27
IGV (IGV angle)
☐Redline ☐Five Points Average ☑Original Value Point
92
90
88
86
84
82
80
02/07 02/14 02/21 02/28 03/07 03/14 03/21 03/28 04/04 04/11 04/18 04/25 05/02 05/09 05/16 05/23 05/30 06/06 06/13 06/20 06/27
APU automatic starting time
☑Redline ☐Five Points Average ☑Original Value Point
80
76
72
68
64
60
56
52
48
44
02/07 02/14 02/21 02/28 03/07 03/14 03/21 03/28 04/04 04/11 04/18 04/25 05/02 05/09 05/16 05/23 05/30 06/06 06/13 06/20 06/27

FIG. 6

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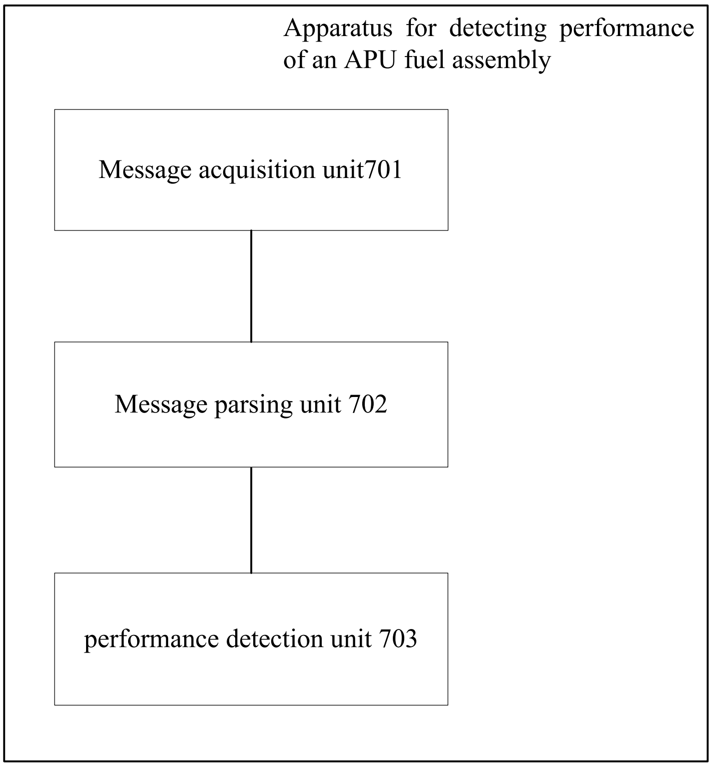

FIG. 7