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ALGORITHM FOR INDEPENDENT DETECTION OF PROBE BLOCKAGES

Abstract

A blockage detection system for detecting aircraft probe blockages includes a processor, a communication device, and computer-readable memory. The computer-readable memory encoded with instructions that, when executed by the processor, cause the system to execute a blockage detection algorithm. The processor receives a static pressure and an impact pressure from one or more aircraft probes. The processor converts the static pressure and the impact pressure to a correlating variable, via the blockage detection algorithm. The processor evaluates the correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage. The processor outputs a blockage indicator, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage. The processor is further able to determine if the blockage has cleared by reference to an external comparative pressure measurement.

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Background/Summary

BACKGROUND

[0001] Aircraft can contain several air data probes for measuring parameters such as static and impact pressure. While measuring such parameters, air data probes are susceptible to various failure modes which can cause erroneous data readings or loss of air data readings altogether. One such failure mode is a probe blockage condition that can occur due to conditions such as icing, excessive moisture, volcanic ash, sand/dirt, insect nesting, and/or other such conditions. The erroneous nature or loss of such readings can have downstream impacts on systems within the aircraft that consume such readings. Therefore, it is desirable to have a system which indicates when such air data probes are in a failure mode, such that consuming systems do not rely on the erroneous readings.

SUMMARY

[0002] A blockage detection system for detecting aircraft probe blockages includes a processor. The system further includes a communication device operably connected to the processor. The system further includes computer-readable memory operably connected to the processor, the computer-readable memory encoded with instructions that, when executed by the processor, cause the system to perform the following steps. The system receives a static pressure and an impact pressure from one or more aircraft probes. The system converts the static pressure and the impact pressure to a correlating variable, via a blockage detection algorithm. The system evaluates the correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage. The system outputs a blockage indicator, via the communication device, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage.

[0003] A method for detecting aircraft probe blockages includes receiving a static pressure and an impact pressure from one or more aircraft probes. The method further includes converting the static pressure and the impact pressure to a correlating variable, via a blockage detection algorithm. The method further includes evaluating the correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage. The method further includes outputting a blockage indicator, via the communication device, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] FIG. **1** is a diagram of a system for detecting a blockage on a probe.

[0005] FIG. **2**A is a schematic diagram of an air data system architecture including an algorithm for detecting probe blockage.

[0006] FIG. **2**B is a schematic diagram of an alternative air data system architecture including the algorithm for detecting probe blockages.

[0007] FIG. **3** is an example graph depicting a correlating variable response indicative of a blockage condition.

[0008] FIG. **4** is a flowchart depicting a method for detecting a blockage within a probe.

DETAILED DESCRIPTION

[0009] The techniques of this disclosure utilize an algorithm housed within an air data computer to determine whether a pressure probe is experiencing a blockage. The system operates by applying a blockage detection algorithm. The blockage detection algorithm receives the static pressure and the impact pressure measured by, for example, a pitot-static probe, and converts such measured values to a single correlating variable. The system then evaluates the correlating variable to determine if it exceeds a threshold indicative of a blockage condition. The techniques of this disclosure do not rely on external sources to determine a blockage condition, and instead use probe measurements from the probe being evaluated to detect a blockage. Upon detecting a blockage, the system can conduct further analysis, using measurements received from one or more additional external probes, to determine whether the blockage has cleared.

[0010] FIG. **1** is a diagram of system **100** for detecting a blockage on a probe. System **100** includes aircraft probe(s) **102**, blockage detection system **104**, and consuming systems **106**. Blockage detection system **104** includes processor **108**, communication device **110**, and computer readable memory **112**. Computer readable memory includes a plurality of executable modules including data receiving module **114**, correlating variable module **116**, evaluation module **118**, blockage indication module **120**, and blockage clearance module **122**.

[0011] Processor **108**, in some examples, is configured to implement functionality and/or process instructions for execution within system **100**. For instance, processor **108** can be capable of processing instructions stored in computer-readable memory **112**. Examples of processor **108** can include any one or more of a microprocessor, a controller, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or other equivalent discrete or integrated logic circuitry.

[0012] Computer-readable memory **112**, in some examples, is described as computer-readable storage media. In some examples, a computer-readable storage medium includes a non-transitory medium. The term “non-transitory” indicates that the storage medium is not embodied in a carrier wave or a propagated signal. In certain examples, a non-transitory storage medium stores data that, over time, changes (e.g., in RAM or cache). In some examples, computer-readable memory **112** is a temporary memory, meaning that a primary purpose of computer-readable memory **112** is not long-term storage. Computer-readable memory **112**, in some examples, is described as volatile memory, meaning that computer-readable memory **112** does not maintain stored contents when electrical power to computer-readable memory **112** is removed. Examples of volatile memories can include random access memories (RAM), dynamic random access memories (DRAM), static random access memories (SRAM), and other forms of volatile memories. In some examples, computer-readable memory **112** is used to store program instructions for execution by processor **108**. Computer-readable memory **112**, in one example, is used by software or applications to temporarily store information during program execution.

[0013] Computer-readable memory **112**, in some examples, also includes one or more computer-readable storage media. Computer-readable memory **112** is configured to store larger amounts of information than volatile memory. Computer-readable memory **112** is further configured for long-term storage of information. In some examples, computer-readable memory **112** includes non-volatile storage elements. Examples of such non-volatile storage elements include, but are not limited to, magnetic hard discs, optical discs, flash memories, or forms of electrically programmable memories (EPROM) or electrically erasable and programmable (EEPROM) memories.

[0014] Processor **108**, communication device **110**, and computer-readable memory **112** are interconnected within blockage detection system **104**. Communication device **110** is operably connected to aircraft probe(s) **102**. Communication device **110** is also operably connected to consuming system(s) **106**. Blockage detection system **104** can be housed within a vehicle management computer, or within any other area with suitable computing power within the aircraft. In the depiction of system **100**, blockage detection system **104** is depicted as external to aircraft probe(s) **102**. It is understood, however, that in some embodiments (e.g., FIG. **2**A), blockage detection system can be housed within aircraft probe(s) **102** when aircraft probe(s) **102** include, for example, one or more pitot-static probes comprising an air data computer.

[0015] In operation, computer-readable memory **112** is encoded with instructions that are executed by processor **108**. Computer-readable memory **112** includes data receiving module **114**. Data receiving module **114** includes one or more programs containing instructions to receive data from aircraft probe(s) **102** at blockage detection system **104**. Upon execution of data receiving module **114**, data (i.e., transmitted from aircraft probe(s) **102**) is received and processed at blockage detection system **104** via communication device **110**. Aircraft probe(s) can include various aircraft pressure sensors including, but not limited to, a pitot-static probe, a pitot-static probe having an in-built computing system, and/or separate pitot probe(s) and static pressure port(s). Blockage detection system **104** thus receives at least a static pressure measurement and an impact pressure measurement from aircraft probe(s) **102**. In some embodiments, blockage detection system **104** can also receive at least a static pressure measurement and total pressure measurement from aircraft probe(s) **102**, thereby making the impact pressure measurement derivable from the received parameters. In some embodiments, blockage detection system **104** can receive an impact pressure measurement and a total pressure measurement from aircraft probe(s) **102**, thereby making the static pressure derivable.
[0016] Data receiving module **114** can be executed manually or at automated intervals. In one embodiment, blockage detection system **104** executes data receiving module **114** on a timed basis, wherein data transmitted from aircraft probe(s) **102** to blockage detection system **104** via communication device **110** and is collected or otherwise sampled on a predetermined sampling interval by blockage detection system **104** via execution of data receiving module **114**.
[0017] Computer readable memory **112** further includes correlating variable module **116**. Correlating variable module **116** includes one or more programs containing instructions to convert the received static pressure measurement and the received impact pressure measurement into a single correlating variable. Upon execution of correlating variable module **116**, processor **108** uses a blockage detection algorithm to compute the correlating variable from the static pressure measurement and the impact pressure measurement. In some embodiments, the correlating variable is calculated, in part, by dividing the static pressure by the impact pressure. In some embodiments, the correlating variable is calculated, in part, by evaluating the derivative of the static pressure divided by the impact pressure with respect to time. In some embodiments, the correlating variable is further processed by converting the derivative of the static pressure divided by the impact pressure with respect to time into the frequency domain via power spectrum estimations. By analyzing the variable in the frequency domain, the blockage detection algorithm can process the signal to remove nuisance or noise data. Nuisance or noise data can be determined by examining flight test data and/or flight simulation data. In further embodiments, an additional differentiation can be added after the power spectrum estimations. Such an embodiment allows for effective removal of nuisance or noise data while the aircraft is on the ground.
[0018] Computer readable memory **112** further includes evaluation module **118**. Evaluation module **118** includes one or more programs containing instructions to evaluate whether a blockage condition exists within the probe being evaluated. Upon execution of evaluation module **118**, processor **108** uses predefined thresholds within the blockage detection algorithm to evaluate whether a blockage exists within the probe being evaluated. In some embodiments, processor **108** determines that a blockage exists if the correlating variable exceeds a threshold indicative of a blockage. The threshold indicative of the blockage can be determined, for example, by evaluating flight test data and/or flight simulation data. Further, the threshold indicative of the blockage can be specific to an architecture of the aircraft on which the probe is mounted. The threshold indicative of the blockage can additionally or alternatively be specific to the mounting location of the probe on the aircraft.
[0019] Computer readable memory **112** further includes blockage indication module **120**. Blockage indication module **120** includes one or more programs containing instructions to output a blockage indicator upon a determination by processor **108** that a blockage exists. Upon execution of

blockage indication module **120**, processor **108** transmits a blockage indicator via communication device **106** to consuming system(s) **106**. Additionally or alternatively, communication device **106** can send the blockage indicator to an aircraft avionics system including a vehicle management computer. The vehicle management computer can then direct the blockage indicator to one or more downstream consuming systems.

[0020] Computer readable memory **112** further includes blockage clearance module **122**. Blockage clearance module **124** includes one or more programs containing instructions to determine if the blockage has cleared via the blockage detection algorithm. Upon execution of blockage clearance module **124**, processor **108** receives a pressure measurement from an external aircraft probe via communication device **110**. In some embodiments, the external aircraft probe is a static pressure port and/or a pitot pressure tube. In some embodiments the external aircraft probe is mounted on an opposite side of the aircraft as compared to the position of aircraft probe(s) **102**.

[0021] Upon receiving the pressure measurement from the external aircraft probe, processor **108** determines if the blockage has cleared by evaluating whether the rate of change the pressure measurements of aircraft probe(s) **102** indicates a clearance, and whether the pressure measurement from the external aircraft probe is consistent with the measurements from aircraft probe(s) **102**. The rate of change of the pressure measurements of aircraft probe(s) **102** can indicate a clearance when the rate of change shows a spike, as the measurement goes from a blocked condition (i.e., no change in pressure) to a clear condition (i.e., sharp change from blocked measurement to the true pressure measurement). The pressure measurement from the external aircraft probe can be used as an additional confirmation that the blockage has cleared. In some embodiments, the pressure measurement from the external aircraft probe is the sole indicator that the blockage has been cleared. Once the blockage has been cleared, processor **108** can output a blockage clearance indicator via communication device **110** to the vehicle management computer and/or consuming system(s) **106**.

[0022] System **100** provides various advantages. Primarily, system **100** allows for detection of probe blockages without comparing measured and/or calculated parameters across channels and without the need for external sensors. Rather, system **100** relies on the measured static and impact pressures from the pitot-static probe, or from distinct pitot probes and static ports, to determine whether a pitot probe is experiencing a blockage. Further, system **100** does not require additional hardware to implement the blockage detection algorithm. Rather, existing hardware including one or more processors within a pitot-static probe or within a vehicle management computer. This allows for an unchanged weight and cost of manufacturing for the aircraft. Additionally, system **100** is customizable for use on a variety of aircraft with different sensor mounting configurations and flight envelopes. Because flight test data and/or simulation data can be used to calculate thresholds indicative of a blockage, system **100** is applicable across a variety of aircraft applications.

[0023] Additionally, system **100** provides the advantage of being effective during flight and while the aircraft is grounded. As described, power spectrum estimations can be used within the blockage detection algorithm to remove nuisance or noise data from the correlating variable. Further, as described, an additional differentiation added after the power spectrum estimations allows for the blockage detection algorithm to have enhanced efficacy in removing noise or nuisance data that can arise while the aircraft is on the ground. Thus, the accuracy of the correlating variable is enhanced by such an embodiment.

[0024] FIG. **2** is a schematic diagram of air data system architecture **200** including the algorithm for detecting a probe blockage. Air data system architecture **200** includes multi-function probe **202**, multi-function probe **204**, vehicle management computer **206**, and consuming systems **208**. Multi-function probe **202** includes pitot pressure tube **210**, static pressure port **212**, and computing device **214**. Multi-function probe **204** includes pitot pressure tube **216**, static pressure port **218**, and computing device **220**. Multi-function probe **202** is operably connected to multi-function probe

204. Multi-function probe **202** and multi-function probe **204** are operably connected to vehicle management computer **206**. The connection of multi-function probe **202** and multi-function probe **204** to vehicle management computer **206** can be a digital connection or a pneumatic connection. Vehicle management computer **206** is connected to consuming systems **208**.

[0025] In operation, multi-function probe **202** and multi-function probe **204** are mounted on an external surface of an aircraft. In some embodiments, multi-function probe **202** and multi-function probe **204** are mounted on opposite sides of the aircraft. Multi-function probe **202** is configured to sense an impact pressure via pitot pressure tube **210**. Multi-function probe **202** is also configured to sense a static pressure via static pressure port **212**. Upon sensing the static pressure and the impact pressure, computing device **214** can implement the blockage detection algorithm, as described above with respect to system **100**, in order to determine if a blockage exists within pitot pressure tube **210**.

[0026] Multi-function probe **204** is configured analogously to multi-function probe **202**. Multi-function probe **204** is configured to sense an impact pressure via pitot pressure tube **216**. Multi-function probe **204** is also configured to sense a static pressure via static pressure port **218**. Upon sensing the static pressure and the impact pressure, computing device **220** can implement the blockage detection algorithm, as described above with respect to system **100**, in order to determine if a blockage exists within pitot pressure tube **216**.

[0027] While it is understood that the blockage detection algorithm is implemented analogously within both multi-function probe **202** and multi-function probe **204**, an example scenario discussing the operation of the algorithm on multi-function probe **202** is described herein. The blockage detection algorithm can run on computing device **214** of multi-function probe **202**. Computing device **214** can include a processor (e.g., processor **108**), a communication device (e.g., communication device **110**), computer readable memory (e.g., computer readable memory **112**). The computer readable memory can include instructions for executing the blockage detection algorithm, and the processor can execute such instructions in order to determine if a blockage exists, and if an existing blockage has been cleared.

[0028] In operation, multi-function probe **202** measures data based upon the impact pressure measured by pitot pressure tube **210** and static pressure port **212**. Computing device **214** then processes the received static pressure measurement and the received impact pressure measurement into a single correlating variable via execution of the blockage detection algorithm. As described, the correlating variable can be calculated, in part, by dividing the static pressure by the impact pressure and evaluating the derivative of the static pressure divided by the impact pressure with respect to time. The correlating variable can be further processed by converting the derivative of the static pressure divided by the impact pressure with respect to time into the frequency domain via power spectrum estimations. By analyzing the variable in the frequency domain, the blockage detection algorithm can process the signal to remove nuisance or noise data.

[0029] Computing device **214** evaluates, via the blockage detection algorithm, whether a blockage condition exists within pitot pressure tube **210** based upon whether the correlating variable exceeds a threshold indicative of a blockage. The threshold indicative of the blockage can be determined, for example, by evaluating flight test data, flight simulation data, or any combination thereof. Further, the threshold indicative of the blockage can be specific to an architecture of the aircraft on which the probe is mounted and/or can be specific to the mounting location of the probe on the aircraft.

[0030] Computing device **214** outputs a blockage indicator upon determining that a blockage exists. Computing device can transmit a blockage indicator to vehicle management computer **206**. Vehicle management computer **206** can transmit the blockage indicator to consuming systems **208**.

[0031] Computing device **214** evaluates whether the blockage has been cleared via the blockage detection algorithm. Computing device **214** receives a pressure measurement from an external aircraft probe, such as multi-function probe **204**. In other embodiments, the external aircraft probe can be a static pressure port, a pitot pressure tube, or a pitot-static pressure sensor (e.g., without a computing device). In some embodiments the external aircraft probe is mounted on an opposite side of the aircraft as compared to the position of multi-function probe **202**.

[0032] Upon receiving the pressure measurement from the external aircraft probe, processor **108** determines if the blockage has cleared by evaluating whether the rate of change the pressure measurements of multi-function probe **202** indicates a clearance, and whether the pressure measurement from the external aircraft probe is consistent with the measurements from multi-function probe **202**. In some embodiments, processor **108** determines if the blockage has been cleared by only considering whether the pressure measurement from the external aircraft probe is consistent with the measurements from multi-function probe **202**. Once the blockage has been cleared, processor **108** can output a blockage clearance indicator via computing device **214** to vehicle management computer **206**. Vehicle management computer **206** can transmit the blockage clearance indicator to consuming systems **208**.

[0033] Multi-function probe **204** can operate analogously to multi-function probe **202**. Thus, in the case that multi-function probe **204** experiences a blockage, multi-function probe **202** can be used as the external aircraft probe to indicate when the blockage is cleared. In some embodiments, one multi-function probe, such as multi-function probe **202**, is mounted on the aircraft and is connected to a static port, a pitot tube, and/or a pitot-static sensor that does not have an in-built processor, and such a connection is used to indicate when the blockage is cleared.

[0034] Air data system architecture **200** is a schematic representation of how the blockage detection algorithm can be used within an aircraft architecture, and thus exhibits the same advantages as those described with respect to system **100**. Furthermore, air data system architecture **200** is advantageous because all the computing for the blockage detection algorithm is done within a pitot-static probe having an in-built processor (e.g., multi-function probe **202** and/or multi-function probe **204**). As such, no external processing is required and thus the multi-function probe is able to self-identify as to when a blockage occurs.

[0035] FIG. **2**B is a schematic diagram of air data system architecture **250** including the algorithm for detecting probe blockages. Air data system architecture **250** is an alternative embodiment to air data system architecture **200** as depicted in FIG. **2**A. Air data system architecture **250** includes vehicle management computer **256**, consuming systems **258**, first side pitot probe **262**, first side static port **264**, second side pitot probe **266**, second side static port **268**, air data module **270**, air data module **272**, and air data module **274**. Vehicle management computer **256** includes computing device **260**.

[0036] First side pitot probe **262** is operably connected to air data module **274**. Air data module **274** is operably connected to vehicle management computer **256**. First side static port **264** is operably connected to air data module **274** and to second side static port **268**. Air data module **274** is operably connected to vehicle management computer **256**. Second side pitot probe **266** is operably connected to air data module **272**. Air data module **272** is operably connected to vehicle management computer **256**. Vehicle management computer **256** is operably connected to consuming systems **258**.

[0037] In operation, first side pitot probe **262** and first side static port **264** collect pressure measurements from a first side of the aircraft. First side pitot probe **262** and first side static port **264** can be housed within a single pitot-static probe. Alternatively, first side pitot probe **262** and first side static port **264** can be spaced apart along the first side of the aircraft. Similarly, second side pitot probe **266** and second side static port **268** collect pressure measurements from a second side of the aircraft. Second side pitot probe **266** and second side static port **268** can be housed within a single pitot-static probe. Alternatively, second side pitot probe **266** and second side static port **268** can be spaced apart along the second side of the aircraft.

[0038] First side pitot probe **262** can transmit a measured impact pressure to air data module **270**. Air data module **270** converts the pneumatic impact pressure into numerical information which can be sent along a data bus to vehicle management computer **256**. Second side pitot probe **266** can transmit a measured impact pressure to air data module **272**. First side static port **264** and second side static port **268** can transmit first side static pressure data and second side static pressure data respectively to vehicle management computer **256** via air data module **274**. In some embodiments, the connection between any or all of first side pitot probe **262**, first side static port **264**, second side pitot probe **266**, and second side static port **268** and vehicle management computer **256** is digital and hence no numerical conversion within a pneumatic connection is required.

[0039] Upon receiving the pressure measurements, vehicle management computer can execute the blockage detection algorithm housed within computing device **260**. The blockage detection algorithm is executed as described above with respect to system **200**. While it is understood that the blocking detection algorithm can be used on both the first side pitot probe **262** and the second side pitot probe **266**, it is described with respect to the first side pitot probe **262** herein.

[0040] Computing device **260** generates a single correlating variable from the impact pressure and static pressure measurement received from first side pitot probe **262** and first side static port **264**, respectively. Computing device **260** evaluates, via the blockage detection algorithm, whether a blockage condition exists within first side pitot probe **262** based upon whether the correlating variable exceeds a threshold indicative of a blockage. Computing device **260** can output a blockage indicator to consuming systems **258** upon detecting the blockage. Computing device **260** can then evaluate whether the blockage has cleared by evaluating whether the pressure measurement from an external aircraft probe is consistent with the measurements from pitot-static probe **102**, and by evaluating the rate of change of the correlating variable. In the depicted embodiment, the external aircraft probe is second side static port **268**. In other embodiments, additional external probes can be used to determine whether the blockage has cleared. Upon determining that the blockage has cleared, computing device **260** can output a clearance indicator to consuming systems **258**.

[0041] Air data system architecture **250** is an additional embodiment of air data system architecture **200**, depicting the blockage detection algorithm housed within vehicle management computer **256**. As such, it provides many of the same advantages. Further, the depictions of architectures **200** and **250** demonstrate that the blockage detection algorithm can be implemented with or without pitot-static probes with in-built processing power, wherein in either architecture, no additional hardware is required.

[0042] FIG. **3** is an example graph **300** depicting a correlating variable response indicative of a blockage condition. Graph **300** depicts the correlating variable as a function of time. As described, the correlating variable can be indicative of the rate of change of the static pressure divided by the impact pressure as measured by a pitot-static probe, or a separate pitot probe and static port.

[0043] As depicted in graph **300**, the correlating variable can indicate a characteristic spike when a blockage occurs. Point **302** is indicative of a point where the correlating variable has exceeded the threshold indicative of a blockage and a blockage indicator is output (e.g., to consuming systems **106** of FIG. **1**). The depicted threshold can be determined based on flight test data or flight simulation data and can be specific to the aircraft architecture and mounting locations of the probes.

[0044] In graph **300**, point **304** depicts the point at which the blockage clearance signal is output (e.g., to consuming systems **106**). As described with respect to FIGS. **1** and **2**A-B, the clearance indicator can be output based upon a pressure received from an external sensor, such as a static pressure port mounted on an opposite side of the aircraft as compared to the probe being evaluated for a blockage. While the stabilization of the correlating variable value may be indicative of a blockage clearance, the external sensor data can function as a confirmation that the blockage is cleared. Because the correlating variable value is based on a rate of change, a stabilization, such as in region **306**, can erroneously indicate a clearance when a clearance has not yet occurred.

[0045] Graph **300** also includes event start indicator **308** and event end indicator **310**. Indicators **308** and **310** are intended to illustrate an example in which a probe can become blocked, and the resulting response of the correlating variable. In one example, event start indicator **308** is indicative of a pitot probe heater fault. In such an example, a heater within a pitot probe, which is designed to alleviate icing conditions to keep the pitot probe clear, is faulty. As depicted, the correlating variable value spikes shortly after such a fault, indicating that the probe is blocked due to ice accumulation. Event end indicator **310** can indicate a point in time at which the pitot probe heater fault is fixed, and the heater is once again functional. As depicted, the correlating variable value then stabilizes shortly after event end indicator **310**, indicating that the rate of change of the pressure quotient (i.e., static pressure divided by impact pressure) is no longer fluctuating significantly.

[0046] The depiction of graph **300** is intended to show the analysis of the correlating variable with respect to time resulting in a blockage indicator. Graph **300** allows for data of a single variable resulting from the probe to be analyzed in order to determine if a blockage exists. Thus, graph **300** illustrates the benefits of system **100**, particularly that system **100** is capable of determining probe blockages without need for reference to external parameters or sensors.

[0047] FIG. **4** depicts method **400**, which is a method flowchart for detecting a blockage within a probe. In the description of method **400**, reference will be made to the component numbers of system **100** for clarity.

[0048] Method **400** begins at step **402**, wherein blockage detection system **104** receives a static pressure measurement and an impact pressure measurement from aircraft probe(s) **102** via communication device **110**. As described, aircraft probe(s) **102** can be a pitot-static probe (e.g., with or without in-built processing power), a pitot probe and static port spaced apart, or any other probe configuration for measuring static and impact pressure.

[0049] At step **404**, processor **108** converts the static pressure and the impact pressure into a correlating variable via the blockage detection algorithm. The correlating variable can be indicative of a rate of change of the static pressure divided by the impact pressure. The correlating variable can be further processed by converting the derivative of the static pressure divided by the impact pressure with respect to time into the frequency domain via power spectrum estimations, then removing nuisance or noise data.

[0050] At decision step **406**, processor **108** evaluates the correlating variable to determine whether the value exceeds a threshold indicative of a blockage. The threshold indicative of a blockage can be based upon the aircraft configuration and/or the mounting location of the sensors on the aircraft. If the value of the correlating variable does not exceed the threshold indicative of a blockage, method **400** returns to step **402**, wherein the static and impact pressure are again received from aircraft probe(s) **102**. If the value of the correlating variable does exceed the threshold indicative of a blockage, method **400** proceeds to step **408**.

[0051] At step **408**, processor **108** outputs a blockage indicator, via communication device **110**, to a receiving system, such as consuming systems **106** and/or a vehicle management computer.

[0052] At step **410**, blockage detection system **104** receives a static pressure measurement and an impact pressure measurement from aircraft probe(s) **102** via communication device **110**. At step **412**, processor **108** converts the static pressure and the impact pressure into a correlating variable via the blockage detection algorithm.

[0053] At step **414**, processor **108** receives an external comparative pressure, via communication device **110**. The external comparative pressure is measured by an additional probe external to aircraft probe(s) **102**. In the example of FIG. **2**A, wherein multi-function probe **202** is the probe experiencing the blockage, multi-function probe **204** can be the additional external probe. In some embodiments, the external comparative pressure is measured by a probe mounted on the opposite side of the aircraft as compared to the probe experiencing the blockage. In some embodiments, the external comparative pressure is a static pressure, measured by a static pressure port.

[0054] At decision step **416**, processor **108** evaluates whether the blockage is cleared based upon the external comparative pressure and based upon prior blockage thresholds. If the blockage is not cleared, method **400** returns to step **408**, wherein an additional static pressure and impact pressure measurement is received for calculation of an updated correlating variable. If the blockage is cleared, method **400** continues to step **418**.

[0055] At step **418**, processor **108** outputs a blockage cleared indicator, via communication device **110**, to consuming systems **106** and/or a vehicle management computer.

[0056] Overall, the techniques of this disclosure provide a system and method for evaluating a blockage within an aircraft probe. The disclosed techniques allow for a probe blockage algorithm to be installed within an existing pitot-static probe or vehicle management computer, thereby relieving the need for any additional hardware to be installed on an aircraft. The techniques of this disclosure are further able to be tailored to the aircraft configuration and probe mounting locations by adjusting the threshold indicative of a probe blockage based upon such factors (e.g., via flight test data or simulation data). The techniques of this disclosure also permit detection of probe blockages without any need for external measured and/or calculated air data parameters across additional channels.

DISCUSSION OF POSSIBLE EMBODIMENTS

[0057] The following are non-exclusive descriptions of possible embodiments of the present invention.

[0058] A blockage detection system for detecting aircraft probe blockages includes a processor. The system further includes a communication device operably connected to the processor. The system further includes computer-readable memory operably connected to the processor, the computer-readable memory encoded with instructions that, when executed by the processor, cause the system to perform the following steps. The system receives a static pressure and an impact pressure from one or more aircraft probes. The system converts the static pressure and the impact pressure to a correlating variable, via a blockage detection algorithm. The system evaluates the correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage. The system outputs a blockage indicator, via the communication device, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage.

[0059] The system of the preceding paragraph can optionally include, additionally and/or alternatively, any one or more of the following features, configurations and/or additional components:

[0060] A further embodiment of the foregoing system, wherein the computer-readable memory is further encoded with instructions that, when executed by the one or more processors, cause the system to receive an external comparative pressure, wherein the external comparative pressure is measured by an additional probe external to the one or more aircraft probes; and evaluate whether the blockage is cleared based upon the external comparative pressure.

[0061] A further embodiment of any of the foregoing systems, wherein the additional probe external to the one or more aircraft probes is a static pressure port mounted on an opposite side of the aircraft from a mounting location of the one or more aircraft probes.

[0062] A further embodiment of any of the foregoing systems, wherein the blockage detection system is housed within the one or more aircraft probes.

[0063] A further embodiment of any of the foregoing systems, wherein the one or more aircraft probes are pitot-static probes, the pitot-static probes comprising an internal air data computer.

[0064] A further embodiment of any of the foregoing systems, wherein the one or more aircraft probes include a pitot tube and a static pressure port, the pitot tube and the static pressure port being spaced apart from each other and mounted on the side of an aircraft.

[0065] A further embodiment of any of the foregoing systems, wherein the one or more aircraft probes include a pitot-static probe comprising a pitot tube and a static port.

[0066] A further embodiment of any of the foregoing systems, wherein the blockage detection system is housed within a vehicle management computer.

[0067] A further embodiment of any of the foregoing systems, wherein the vehicle management computer is digitally connected to the communication device.
[0068] A further embodiment of any of the foregoing systems, wherein the computer-readable memory is further encoded with instructions that, when executed by the one or more processors, cause the system to convert the correlating variable to the frequency domain; and remove, via the blockage detection algorithm, nuisance data, the nuisance data determined by examining flight test data.
[0069] A further embodiment of any of the foregoing systems, wherein the correlating variable is calculated, in part, by dividing the static pressure by the impact pressure.
[0070] A further embodiment of any of the foregoing systems, wherein the correlating variable is calculated, in part, by evaluating the derivative of the static pressure divided by the impact pressure with respect to time.
[0071] A further embodiment of any of the foregoing systems, wherein the correlating variable is calculated, in part, by converting the derivative of the static pressure divided by the impact pressure with respect to time to the frequency domain via power spectrum estimations.
[0072] A further embodiment of any of the foregoing systems, wherein the threshold indicative of the blockage is determined by evaluating flight test data and flight simulation data.
[0073] A further embodiment of any of the foregoing systems, wherein the threshold indicative of the blockage is specific to an architecture of the aircraft and to a mounting location of the one or more aircraft probes.
[0074] A method for detecting aircraft probe blockages includes receiving a static pressure and an impact pressure from one or more aircraft probes. The method further includes converting the static pressure and the impact pressure to a correlating variable, via a blockage detection algorithm. The method further includes evaluating the correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage. The method further includes outputting a blockage indicator, via the communication device, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage.
[0075] A further embodiment of the foregoing method, further including receiving an external comparative pressure, wherein the external comparative pressure is measured by an additional probe external to the one or more aircraft probes. The method further includes evaluating whether the blockage is cleared based upon the external comparative pressure.
[0076] A further embodiment of any of the foregoing methods, wherein the additional probe external to the one or more aircraft probes is a static pressure port mounted on an opposite side of the aircraft from a mounting location of the one or more aircraft probes.
[0077] A further embodiment of any of the foregoing methods, wherein the blockage detection system is housed within the one or more aircraft probes.
[0078] A further embodiment of any of the foregoing methods, wherein the one or more aircraft probes are pitot-static probes, the pitot-static probes comprising an internal air data computer.
[0079] While the invention has been described with reference to an exemplary embodiment(s), it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted for elements thereof without departing from the scope of the invention. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the invention without departing from the essential scope thereof. Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.

Claims

1. A blockage detection system for detecting aircraft probe blockages, the system comprising: a processor; a communication device operably connected to the processor; computer-readable memory operably connected to the processor, the computer-readable memory encoded with instructions that, when executed by the processor, cause the system to: receive a static pressure and an impact pressure from one or more aircraft probes; convert the static pressure and the impact pressure to a correlating variable, via a blockage detection algorithm; evaluate the correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage; and output a blockage indicator, via the communication device, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage.
2. The system of claim 1, wherein the computer-readable memory is further encoded with instructions that, when executed by the one or more processors, cause the system to: receive an external comparative pressure, wherein the external comparative pressure is measured by an additional probe external to the one or more aircraft probes; and evaluate whether the blockage is cleared based upon the external comparative pressure.
3. The system of claim 2, wherein the additional probe external to the one or more aircraft probes is a static pressure port mounted on an opposite side of the aircraft from a mounting location of the one or more aircraft probes.
4. The system of claim 1, wherein the blockage detection system is housed within the one or more aircraft probes.
5. The system of claim 4, wherein the one or more aircraft probes are pitot-static probes, the pitot-static probes comprising an internal air data computer.
6. The system of claim 1, wherein the one or more aircraft probes include a pitot tube and a static pressure port, the pitot tube and the static pressure port being spaced apart from each other and mounted on the side of an aircraft.
7. The system of claim 1, wherein the one or more aircraft probes include a pitot-static probe comprising a pitot tube and a static port.
8. The system of claim 1, wherein the blockage detection system is housed within a vehicle management computer.
9. The system of claim 8, wherein the vehicle management computer is digitally connected to the communication device.
10. The system of claim 1, wherein the computer-readable memory is further encoded with instructions that, when executed by the one or more processors, cause the system to: convert the correlating variable to the frequency domain; and remove, via the blockage detection algorithm, nuisance data, the nuisance data determined by examining flight test data.
11. The system of claim 1, wherein the correlating variable is calculated, in part, by dividing the static pressure by the impact pressure.
12. The system of claim 11, wherein the correlating variable is calculated, in part, by evaluating the derivative of the static pressure divided by the impact pressure with respect to time.
13. The system of claim 12, wherein the correlating variable is calculated, in part, by converting the derivative of the static pressure divided by the impact pressure with respect to time to the frequency domain via power spectrum estimations.
14. The system of claim 1, wherein the threshold indicative of the blockage is determined by evaluating flight test data and flight simulation data.
15. The system of claim 1, wherein the threshold indicative of the blockage is specific to an architecture of the aircraft and to a mounting location of the one or more aircraft probes.
16. A method for detecting aircraft probe blockages, the method comprising: receiving a static pressure and an impact pressure from one or more aircraft probes; converting the static pressure and the impact pressure to a correlating variable, via a blockage detection algorithm; evaluating the

correlating variable, via the blockage detection algorithm, to determine if a value of the correlating variable exceeds a threshold indicative of a blockage; and outputting a blockage indicator, via the communication device, to a receiving system in response to the correlating variable exceeding the first threshold indicative of a blockage.

17. The method of claim 16, further comprising: receiving an external comparative pressure, wherein the external comparative pressure is measured by an additional probe external to the one or more aircraft probes; and evaluating whether the blockage is cleared based upon the external comparative pressure.

18. The method of claim 17, wherein the additional probe external to the one or more aircraft probes is a static pressure port mounted on an opposite side of the aircraft from a mounting location of the one or more aircraft probes.

19. The method of claim 16, wherein the blockage detection system is housed within the one or more aircraft probes.

20. The method of claim 19, wherein the one or more aircraft probes are pitot-static probes, the pitot-static probes comprising an internal air data computer.