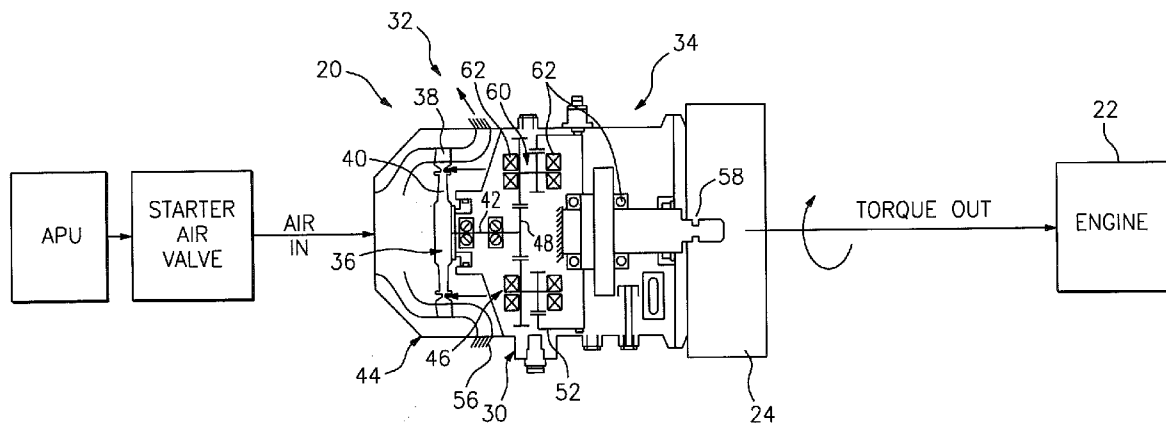




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(19) **United States**(12) **Patent Application Publication**
Kalkovich et al.(10) **Pub. No.: US 2014/0178175 A1**(43) **Pub. Date: Jun. 26, 2014**(54) **AIR TURBINE STARTER MONITOR SYSTEM**(22) Filed: **Dec. 21, 2012**(71) Applicant: **UNITED TECHNOLOGIES CORPORATION**, Hartford, CT (US)**Publication Classification**(72) Inventors: **Dean W. Kalkovich**, Cobalt, CT (US);
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Bobby Allen, Manchester, CT (US)(51) **Int. Cl.**
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CPC **F04D 15/0094** (2013.01)
USPC **415/1; 415/118**(73) Assignee: **UNITED TECHNOLOGIES CORPORATION**, Hartford, CT (US)(57) **ABSTRACT**(21) Appl. No.: **13/725,222**

A method of monitoring a rotational system includes identifying a non-nominal spool-down profile.



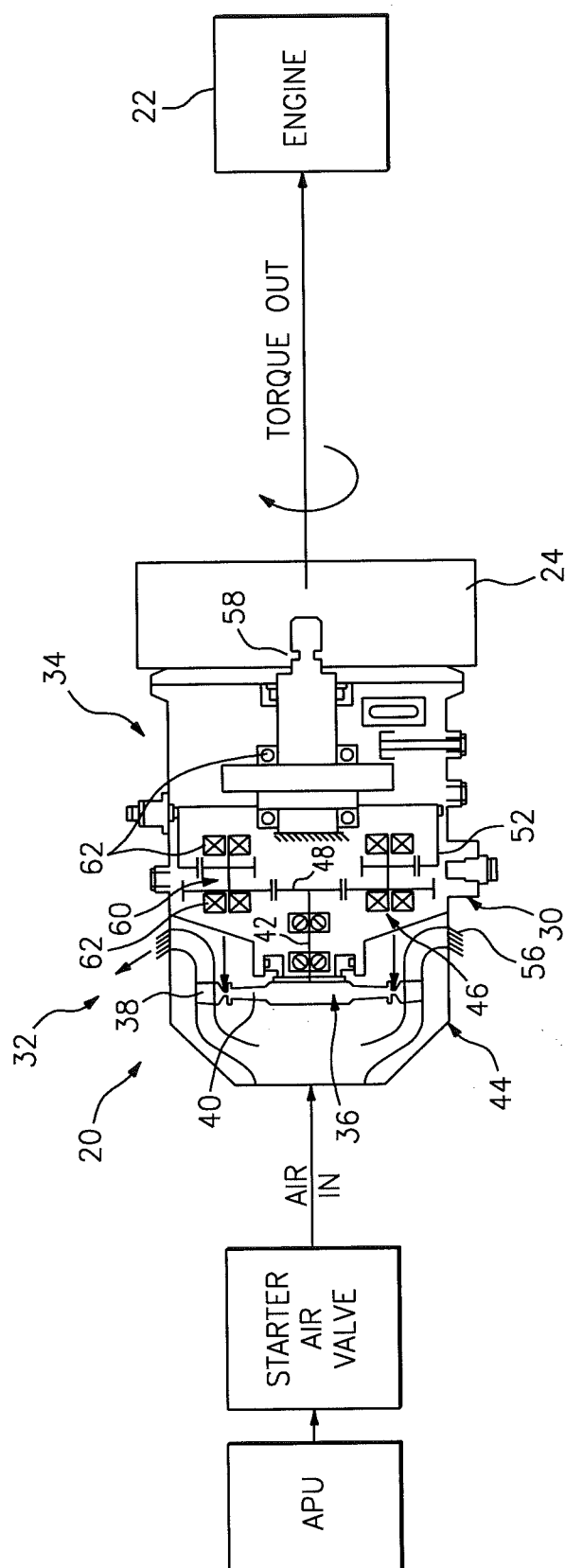


FIG. 1

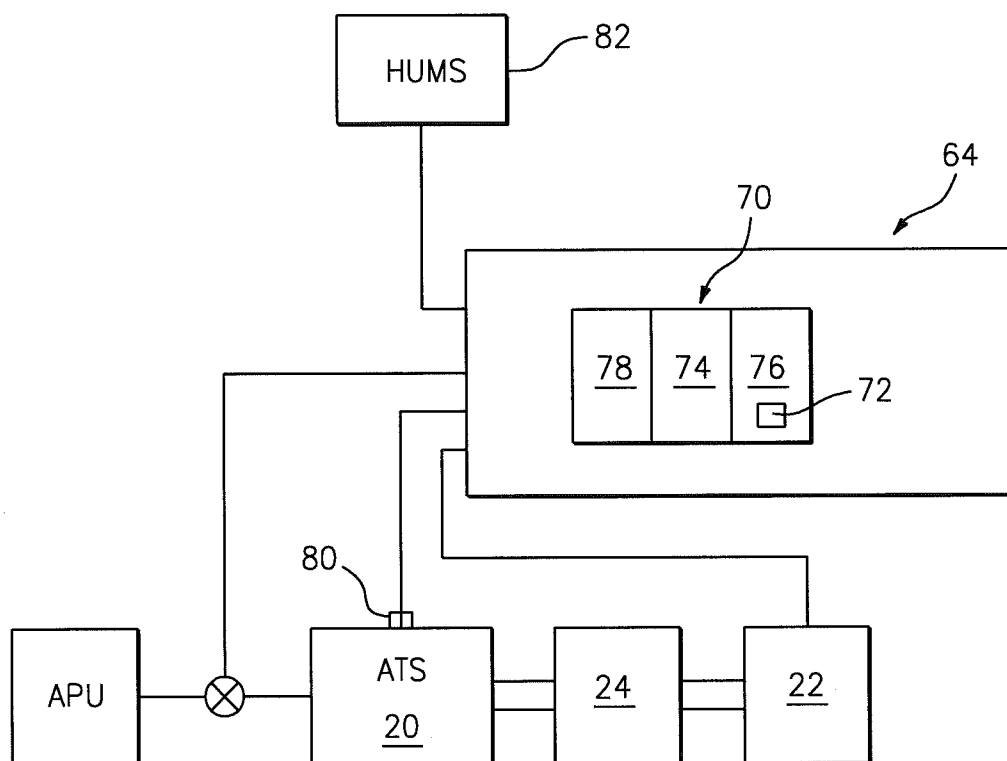
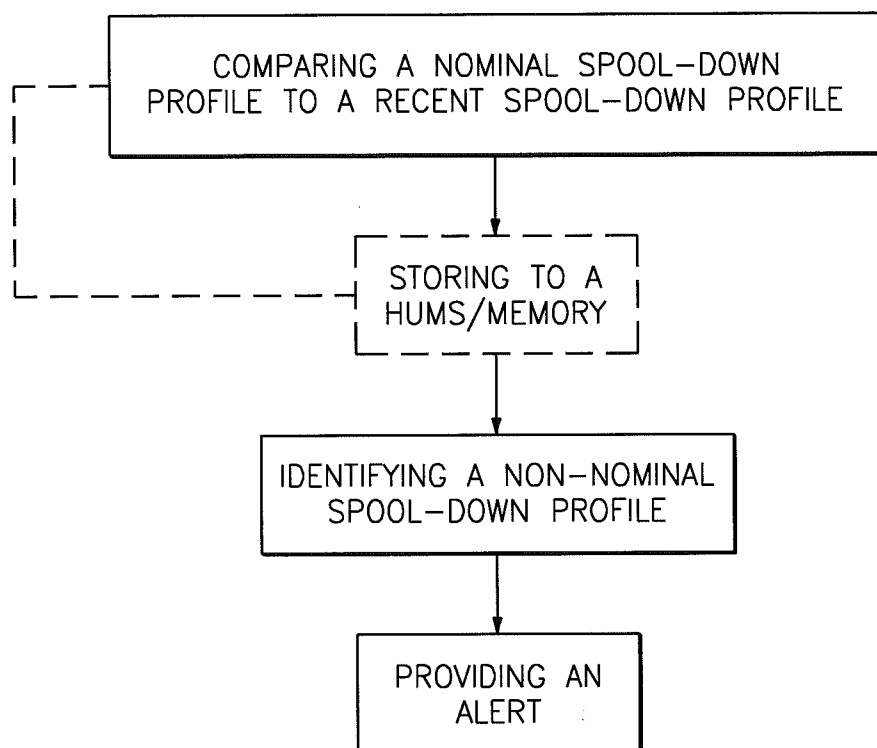


FIG. 2

*FIG. 3*

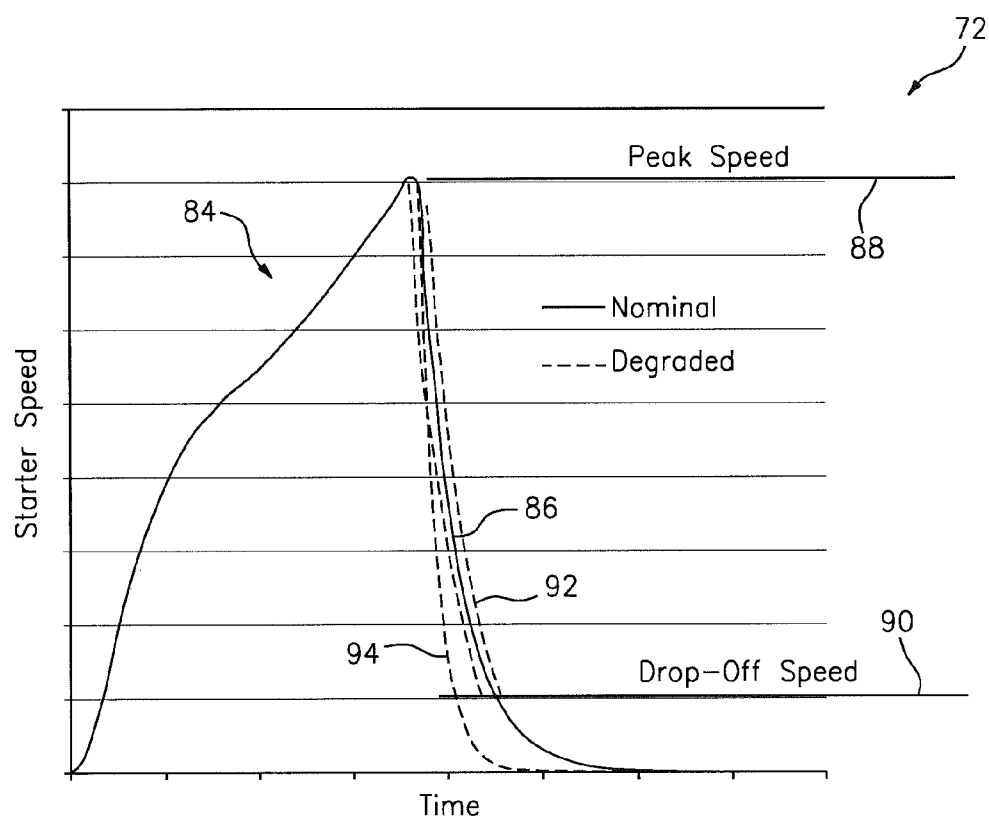


FIG. 4

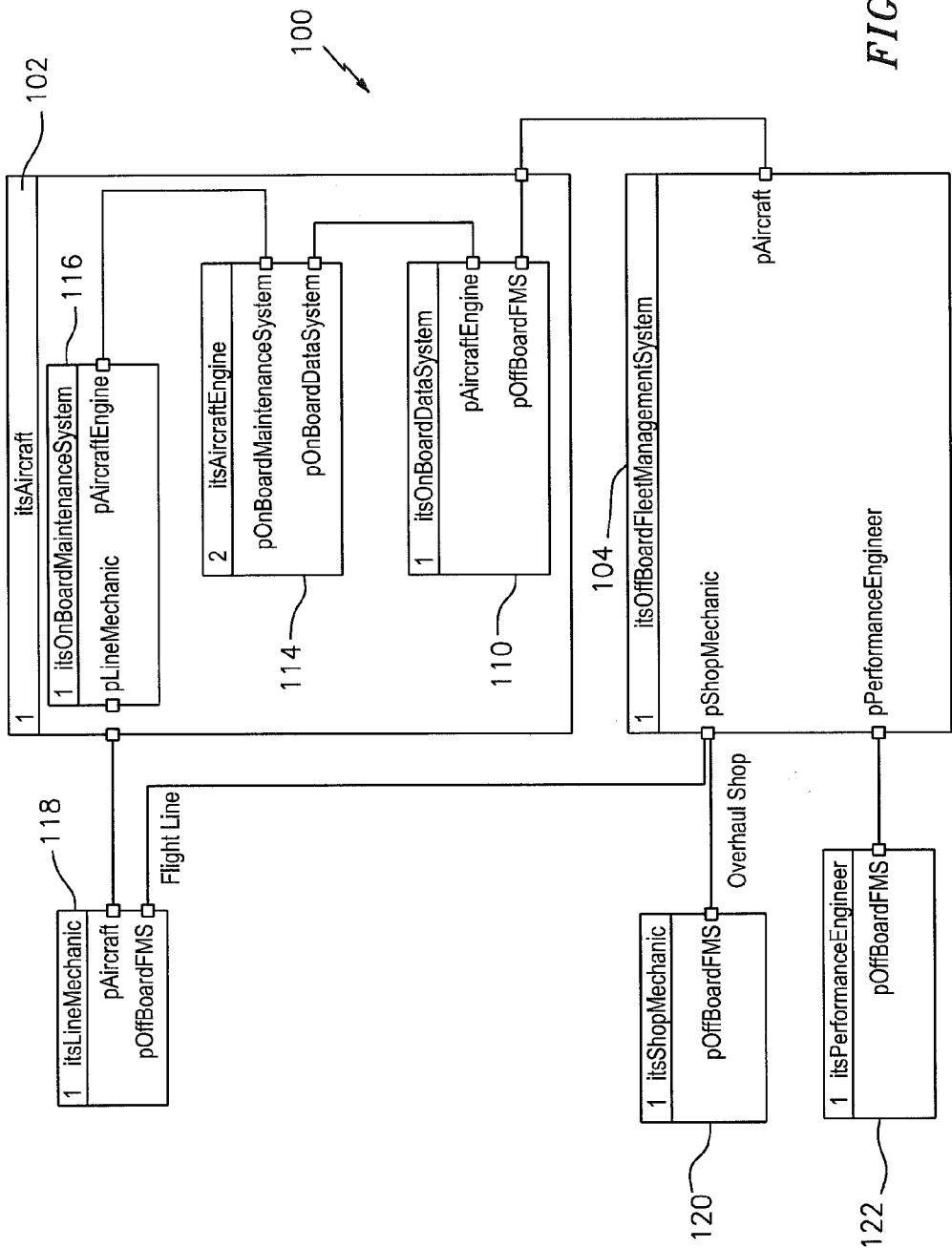


FIG. 5

AIR TURBINE STARTER MONITOR SYSTEM

BACKGROUND

[0001] The present disclosure relates to an air-turbine starter which is operable to start a gas turbine engine, and more particularly to a monitor system therefor.

[0002] Many relatively large gas turbine engines, including turbofan engines, utilize an air turbine starter (ATS) for spool up to ignition. The ATS is typically mounted to an accessory gearbox to drive a spool of the gas turbine engine. Consequently, the ATS is installed in the aircraft at all times even though active operation may occur only for a minute or so at the beginning of each flight cycle, along with occasional operation during engine maintenance activities.

[0003] The ATS generally includes a turbine section coupled to an output section within a housing. The turbine section is coupled to a high-pressure source, such as compressed air from an auxiliary power unit (APU), to drive the output section through a gear system. Thus, when the high-pressure source impinges upon the turbine section, the output section spools-up the gas turbine engine through the accessory gearbox.

SUMMARY

[0004] A method of monitoring a rotational system according to one disclosed non-limiting embodiment of the present disclosure includes identifying a non-nominal spool-down profile.

[0005] In a further embodiment of the foregoing embodiment, the method includes providing an alert upon identification of the non-nominal spool-down profile. In the alternative or additionally thereto, the foregoing embodiment includes providing the alert to a Health and Usage Monitoring System (HUMS). In the alternative or additionally thereto, the foregoing embodiment includes providing the alert to an on-board system.

[0006] In a further embodiment of any of the foregoing embodiments, the method includes defining the non-nominal spool-down profile to be outside a tolerance band. In the alternative or additionally thereto, in the foregoing embodiment the tolerance band is determined from a multiple of recent spool-down profiles. In the alternative or additionally thereto, in the foregoing embodiment the tolerance band is predetermined.

[0007] In a further embodiment of any of the foregoing embodiments, the method includes defining the non-nominal spool-down profile to be within a peak speed and a drop-off speed.

[0008] In a further embodiment of any of the foregoing embodiments, the method includes comparing a nominal spool-down profile to a recent spool-down profile. In the alternative or additionally thereto, in the foregoing embodiment the recent spool-down profile is the most recent spool-down profile.

[0009] A method of monitoring an Air Turbine Starter (ATS) according to another disclosed non-limiting embodiment of the present disclosure includes comparing a nominal spool-down profile to a recent spool-down profile and identifying a non-nominal spool-down profile from the comparing.

[0010] In a further embodiment of the foregoing embodiment, the method includes defining the nominal spool-down profile to be within a peak speed and a drop-off speed. In the

alternative or additionally thereto, the foregoing embodiment includes defining the nominal spool-down profile to be within a tolerance band. In the alternative or additionally thereto, the in foregoing embodiment the tolerance band is determined from a multiple of recent spool-down profiles. In the alternative or additionally thereto, the in foregoing embodiment the tolerance band is predetermined.

[0011] In a further embodiment of any of the foregoing embodiments, the recent spool-down profile is the most recent spool-down profile.

[0012] A system according to another disclosed non-limiting embodiment of the present disclosure includes a rotational system with a spool-down profile and a controller in communication with said rotational system, said controller operable to identifying a non-nominal spool-down profile.

[0013] In a further embodiment of the foregoing embodiment, the rotational system is an Air Turbine Starter (ATS).

[0014] In a further embodiment of any of the foregoing embodiments, the controller is operable to compare a nominal spool-down profile to a recent spool-down profile.

[0015] In a further embodiment of any of the foregoing embodiments, the recent spool-down profile is a latest spool-down profile.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Various features will become apparent to those skilled in the art from the following detailed description of the disclosed non-limiting embodiment. The drawings that accompany the detailed description can be briefly described as follows:

[0017] FIG. 1 is a general schematic view of an air turbine starter (ATS) used to initiate the rotation of a larger turbine through an accessory gearbox;

[0018] FIG. 2 is a schematic block diagram of a control system for the ATS;

[0019] FIG. 3 is a block diagram of monitoring logic in the control system;

[0020] FIG. 4 is a graphical representation of the monitoring logic; and

[0021] FIG. 5 is a schematic block diagram of a system architecture operable with many diagnostic and health management functions.

DETAILED DESCRIPTION

[0022] FIG. 1 schematically illustrates an exemplary air turbine starter (ATS) 20 used to initiate spool-up of a larger gas turbine engine 22, such as a turbofan engine through an accessory gearbox 24. It should be appreciated that the present application is not limited to use in conjunction with a specific type of rotating machine. Thus, although the present application is, for convenience of explanation, depicted and described as being implemented in an air turbine starter (ATS), it should be appreciated that it can be implemented in numerous other machines which have a spool-down time in which the machine is no longer driving and no longer driven.

[0023] The ATS 20 generally includes a housing assembly 30 that generally includes a turbine section 32 and an output section 34. The turbine section 32 includes a turbine wheel 36 with a plurality of turbine blades 38, a hub 40, and a turbine rotor shaft 42. The turbine blades 38 of the turbine wheel 36 are located downstream of an inlet housing assembly 44 which includes an inlet housing 46 with a nozzle 48. The nozzle 48 includes a plurality of vanes 50 which direct com-

pressed air flow from an inlet **52** through an inlet flowpath **54**. The compressed air flows past the vanes **50**, drives the turbine wheel **36** then is exhausted through an outlet **56**.

[0024] The turbine wheel **36** is driven by the compressed airflow from, for example, an auxiliary power unit (APU) such that the turbine rotor shaft **42** mechanically drives a starter output shaft **58** through a gear system **60** such as a planetary gear system. The turbine rotor shaft **42** starter output unit **58** and the gear system **60** are typically supported upon bearings **62** (illustrated schematically). The ATS **20** thereby transmits relatively high loads through the gear system **60** to convert the pneumatic energy from the compressed air into mechanical energy to, for example, rotate the gas turbine **22** for spool-up.

[0025] With reference to FIG. 2, control system **64** (illustrated schematically) is in electrical communication with the ATS **20**. In one non-limiting embodiment, the control system **64** may be a portion of a flight control computer, a portion of a Full Authority Digital Engine Control (FADEC), a stand-alone unit or other system that may additionally control normal operations of the ATS **20**. The control system **64** generally includes a control module **70** that executes monitoring logic **72** (FIG. 3). The monitoring logic **72** is disclosed in terms of functional block diagrams, and it should be understood by those skilled in the art with the benefit of this disclosure that these functions may be enacted in either dedicated hardware circuitry or programmed software routines capable of execution in a microprocessor based electronics control embodiment.

[0026] The control module **70** typically includes a processor **74**, a memory **76**, and an interface **78**. The processor **74** may include any type of known microprocessor having desired performance characteristics. The memory **76** may include any computer readable medium which stores data and control algorithms such as the logic **74** as described herein. The interface **78** facilitates communication with other components such as a speed sensor **80** that measures a speed of the turbine rotor shaft **42** and other systems such as a Health and Usage Monitoring System (HUMS) **82**. It should be appreciated that various other components such as sensors, actuators and other subsystems may be in communication as well.

[0027] Many ATS **20** failure modes are likely to increase the friction on the rotating components such as the turbine rotor shaft **42**, starter output shaft **58**, gear system **60** and the bearings **62** among others. When the ATS **20** is in spool-up, the ATS **20** is driven by a high pressure air source, and connected to a high moment-of-inertia rotor of the gas turbine engine **22**. Both the air source and rotor dominate the behavior of the ATS **20**. After the ATS **20** has disengaged, however, the accessory gearbox **24** and air source dynamics have minimal, if any, effect upon ATS **20**. The dynamics of the ATS **20** will thereby be impacted to a greater degree by internal friction. Even a marginal increase in ATS **20** friction is likely to predict an impending failure.

[0028] With reference to FIG. 4, the monitoring logic **72** operates to detect developing problems in the ATS **20** that increase internal friction through monitoring of a spool-down profile **84** of the ATS **20**. That is, an increase internal friction will shorten the time for the ATS **20** to spool-down after effectuating an engine start from a nominal spool-down profile **86**.

[0029] In one disclosed non-limiting embodiment, the spool-down profile **84** may be defined between a peak speed **88** and a drop-off speed **90**. The peak speed **88** may be defined

after the ATS **20** has disengaged from the accessory gearbox **24**. The drop-off speed **90** may be defined at a speed somewhere above zero so the speed sensor **80** will not lose fidelity. That is, the drop-off speed **90** is high enough to facilitate reliable and consistent measurement. Monitoring of the ATS **20** spool-down profile **84** may take place during just one start, or over the course of several starts. That is, the recent spool-down profile may be the most recent spool-down profile or a multiple of recent spool-down profiles. The data may be stored in memory **76** (FIG. 2) and/or communicated to the HUMS **82**. The recent spool-down profile or profiles may be utilized to define a tolerance band **92** to minimize false indications. It should be appreciated that the tolerance band may unidirectional, e.g., only a shorter time is encompassed within the tolerance band.

[0030] In one disclosed non-limiting embodiment, the tolerance band **92** may be predetermined or calculated from an average of a multiple of starts. That is, the recent spool-down profile or profiles must differ in comparison to the nominal spool-down profile **86** to identify the recent spool-down profile as a non-nominal spool-down profile **94**. Once a non-nominal spool-down profile **94** is detected, the monitoring logic **72** will provide an alert **94** (FIG. 3). With reference to FIG. 5, the ATS **20** may be part of a system **100** operable with many diagnostic and health management functions. The system **100** generally includes the aircraft **102**, an Off-Board Fleet Management system **104**. The aircraft **102** may include an onboard data system **110** the aircraft propulsion engines **114** and an On-Board Maintenance system **116**, which the airframe includes as a means for the maintainer to query all of the on board intelligent systems (generally located in the cockpit).

[0031] "Actors" may include a line mechanic **118**, a shop mechanic **120**, and a performance engineer **122**. It should be understood that this is merely representative and various other actors and support may alternatively or additionally provided.

[0032] The Off-Board Fleet Management System **104** format reports and process data received from the aircraft **102**. serve as a portal for internal and external access to the data in a controlled manner. Communication between the aircraft **102** and the Off-Board Fleet Management System is typically with Aircraft Communications Addressing and Reporting System (ACARS) messages, but might be accomplished with Wifi (at the gate) and or cellular telephone.

[0033] The performance engineer **122** can then monitor the trend of the starter wind-down time (over many flights) and notify the line mechanic **118**. That is, the notification need not be a cockpit type alert. Prior techniques focused on detection of a starter failure through failure to start or an extended start cycle which often would result in a last minute flight delay or cancellation. In contrast, the monitoring logic **72** advantageously detects impending failures and facilitates preventative maintenance to thereby avoid flight delay or cancellation. That is, the ATS **20** still operates to start the engine **22** but the non-nominal spool-down profile **94** indicates maintenance or replacement should be scheduled.

[0034] It should be understood that like reference numerals identify corresponding or similar elements throughout the several drawings. It should also be understood that although a particular component arrangement is disclosed in the illustrated embodiment, other arrangements will benefit herefrom.

[0035] Although the different non-limiting embodiments have specific illustrated components, the embodiments of this invention are not limited to those particular combinations. It is possible to use some of the components or features from any of the non-limiting embodiments in combination with features or components from any of the other non-limiting embodiments.

[0036] Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present disclosure.

[0037] The foregoing description is exemplary rather than defined by the limitations within. Various non-limiting embodiments are disclosed herein, however, one of ordinary skill in the art would recognize that various modifications and variations in light of the above teachings will fall within the scope of the appended claims. It is therefore to be understood that within the scope of the appended claims, the disclosure may be practiced other than as specifically described. For that reason the appended claims should be studied to determine true scope and content.

What is claimed is:

1. A method of monitoring a rotational system comprising: identifying a non-nominal spool-down profile.
2. The method as recited in claim 1, further comprising: providing an alert upon identification of the non-nominal spool-down profile.
3. The method as recited in claim 2, further comprising: providing the alert to a Health and Usage Monitoring System (HUMS).
4. The method as recited in claim 2, further comprising: providing the alert to an on-board system.
5. The method as recited in claim 1, further comprising: defining the non-nominal spool-down profile to be outside a tolerance band.
6. The method as recited in claim 5, wherein said tolerance band is determined from a multiple of recent spool-down profiles.
7. The method as recited in claim 5, wherein said tolerance band is predetermined.

8. The method as recited in claim 1, further comprising: defining the non-nominal spool-down profile to be within a peak speed and a drop-off speed.

9. The method as recited in claim 1, further comprising: comparing a nominal spool-down profile to a recent spool-down profile.

10. The method as recited in claim 9, wherein the recent spool-down profile is the most recent spool-down profile.

11. A method of monitoring an Air Turbine Starter (ATS) comprising:

comparing a nominal spool-down profile to a recent spool-down profile; and

identifying a non-nominal spool-down profile from the comparing.

12. The method as recited in claim 11, further comprising: defining the nominal spool-down profile to be within a peak speed and a drop-off speed.

13. The method as recited in claim 12, further comprising: defining the nominal spool-down profile to be within a tolerance band.

14. The method as recited in claim 13, wherein said tolerance band is determined from a multiple of recent spool-down profiles.

15. The method as recited in claim 13, wherein said tolerance band is predetermined.

16. The method as recited in claim 11, wherein the recent spool-down profile is the most recent spool-down profile.

17. A system comprising:

a rotational system with a spool-down profile; and

a controller in communication with said rotational system, said controller operable to identifying a non-nominal spool-down profile

18. The system as recited in claim 16, wherein said rotational system is an Air Turbine Starter (ATS).

19. The system as recited in claim 16, wherein said controller operable to compare a nominal spool-down profile to a recent spool-down profile.

20. The system as recited in claim 16, wherein said recent spool-down profile is a latest spool-down profile.

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