Method and system for protecting a turbomachine and/or operator in the event of overspeed of a turbomachine in a test bench

Technical field

[0001] The present invention relates to a method for protecting a turbomachine and/or an operator in the event of overspeed of a turbomachine in a test bench. The present invention also relates to a protection system for the implementation of such a method.

Prior art

[0002] Conducting tests on a turbomachine, especially in the aeronautical field, is a complex task that requires special attention for the safety of personnel and the preservation of equipment. These tests are designed to evaluate the performance and reliability of the turbomachine in controlled environments that mimic real-world operating conditions. However, these tests present significant risks due to the nature of turbomachines and the complexity of the control systems.

[0003] Technical incidents that may occur during these tests are often related to operating errors or failures of the control software, which can cause the turbomachine to accelerate unexpectedly beyond pre-established safety limits. Such accelerations can have serious consequences, including serious injuries to on-site personnel and/or total destruction of the device under test if maximum tolerated speeds are exceeded.

[0004] The test bench operator is responsible for the shutdown of the turbomachine in the event of technical incidents. This is not reliable enough.

Summary of the invention

[0005] In the context of the present invention, the test bench comprises a control system for controlling the turbomachine during a test and an acquisition system for collecting operating parameters of the turbomachine during the test.

[0006] One of the aims of the present invention is to provide a method for protecting a turbomachine and/or an operator in case of overspeed of the turbomachine during a test bench test, with a better level of safety.

[0007] To this end, the invention provides a method for protecting a turbomachine and an operator in the event of overspeed of said turbomachine in a test bench, the protection method comprising the following steps:

a. providing an autonomous speed limiting system for limiting the speed of said turbomachine, said autonomous limiting system being independent of said control system and said acquisition system;

b. monitoring the speed of the turbomachine using said autonomous system;

c. when said operator is present at the test bench, shutting down the turbomachine by the autonomous system when the speed of the turbomachine is higher than a first threshold;

d. when the speed of the turbomachine is higher than a second threshold above said first threshold, shutting down the turbomachine by the autonomous system.

[0008] In general, the responsiveness of a human operator to trigger an emergency stop is limited. Often, the reaction time exceeds two seconds, which is high considering the speed at which a turbomachine can go from idle to full speed. For some turbomachine, the time to reach maximum power from a low speed state, known as a "snap" by a person skilled in the art, is around 3 seconds.

[0009] Advantageously, the method according to the invention allows a rapid and autonomous intervention, as soon as a critical speed threshold is detected. The first threshold is established primarily to protect the operator. This level of safety is designed to intervene before the situation becomes dangerous for the individuals present at the test bench. The goal is to prevent injury or physical damage by acting quickly and effectively at the first indication of abnormal acceleration. The second threshold, for its part, focuses on the protection of the turbomachine itself. This level is set to prevent property damage that may result from prolonged operation in abnormal or hazardous conditions. Therefore, the present invention provides a double threshold protection system, designed to ensure optimal safety of the

operator and the turbomachine during bench tests. Unlike conventional solutions that apply a single cut-off in the event of overspeed without taking into account the presence of the operator, the double threshold approach allows for a gradual reaction adapted to the severity of the speeding. The first threshold is set to intervene as soon as an operator is detected in the test area and the turbomachine reaches a critical speed. This level of protection acts preventively, stopping the machine immediately before the situation becomes dangerous for the operator. This approach eliminates the risk of a late operator reaction and helps to avoid accidents in the event of a sudden overspeed. The second threshold is set to intervene independently of the presence of an operator, when the speed of the turbomachine exceeds the second threshold. This protection acts as an ultimate barrier to prevent mechanical or structural damage to the turbomachine. Thanks to this double-threshold architecture, the invention ensures a rapid intervention adapted to the different levels of risk, while guaranteeing the safe operation of the test bench.

[0010] The method according to the invention has other advantages. The method can easily be implemented into existing control and security systems, improving safety measures without requiring major changes to the existing infrastructure.

[0011] As a result, the expression "shut down" in the context of this document is used preferably, in the sense that the autonomous speed limiting system does not act directly on the physical elements of the turbomachine. Instead, the autonomous system sends a signal or command to an existing system for controlling the shutdown of the turbomachine. This shutdown control system can be, for example, the Emergency Shutdown System (ESD), which is known to the person skilled in the art. Thus, the command of the autonomous system serves as an input for the turbomachine emergency shutdown system.

The use of the verb "to comprise" and its variants and conjugations in this document in no way precludes the presence of elements other than those mentioned. Similarly, the use in this document of the indefinite article "a", "an", or the definite article "the" to introduce an element does not exclude the presence of a plurality of these elements.

The terms "first", "second", "third", etc. are used in this document exclusively to differentiate between different elements, without implying any order between these elements.

[0012] In a possible embodiment, the first threshold corresponds to a speed value when the turbomachine is in idle speed. The idle speed as known to the person skilled in the art, refers to the minimum operational state of the turbomachine, where it runs at the lowest possible speed while remaining active and functional. The choice of this speed as the threshold for automatic shutdown offers increased safety to the personnel present in the vicinity of the turbomachine during the tests. For example, on a CFM56-5B turbomachine, this first threshold is preferably between 1000 rpm and 1200 rpm.

[0013] In one possible embodiment, the second threshold corresponds to a speed value when the turbomachine is in a maximum permissible speed. This is intended to establish a final safety barrier before the turbomachine reaches speeds that can lead to catastrophic failures. The maximum permissible speed, as known to the person skilled in the art, is defined as the maximum speed at which the turbomachine can operate without suffering irreversible damage. The second threshold is therefore set just below the design limits of the turbomachine. For example, on the CFM56-5B turbomachine, this second threshold is preferably between 5000 rpm and 5200 rpm.

[0014] In an embodiment**,** the maximum permissible speed comes from a manufacturer of the turbomachine**.** Indeed, manufacturers determine this threshold after a series of tests and analyses, taking into account the design characteristics, the materials used, the optimal operating conditions and the safety margins necessary to ensure a reliable and safe operation. The advantage of relying on the maximum permissible speed specified by the manufacturer lies in its accuracy and its reliability.

[0015] In an embodiment, the shutdown is imposed at step c. in a time interval of less than 10 ms, once the speed of the turbomachine is higher than the first threshold. Advantageously, this allows for rapid intervention to effectively prevent the human risks associated with overspeed of the turbomachine.

[0016] In an embodiment, the shutdown is imposed at step d. in a time interval of less than 10 ms, once the speed of the turbomachine is higher than the second threshold. Advantageously, this allows a quick reaction in the event of exceeding an even more critical speed than that considered in step c.

[0017] In one embodiment, the method according to the invention also includes a step of shutting down the turbomachine in the event of an interruption of the power supplying the autonomous speed limiting system. Indeed, the autonomous speed limiting system, being generally supplied with electricity, which allows it to monitor the speed of the turbomachine and react to threshold exceedances. However, reliance on electricity also introduces the risk of power failure that can compromise its functionality. This embodiment then makes it possible to add an additional layer of safety to manage cases of electrical failure or other incidents that may affect the normal operation of the autonomous system.

[0018] In one embodiment, the autonomous speed limiting system comprises a housing with on-board electronics capable of shutting down the turbomachine in both cases corresponding to steps c. and d. Advantageously, the housing is compact integrating all the necessary components to monitor the speed of the turbomachine and execute shutdown commands. Advantageously, the on-board electronics are designed to operate autonomously, to continuously monitor the speed of the turbomachine and decide whether to stop it if the predefined thresholds are exceeded.

[0019] The invention further provides an autonomous speed limiting system suitable for use in a test bench for testing a turbomachine and comprising:

- a housing comprising:
  - electronic components for receiving information relating to the speed of a turbomachine;
  - a non-volatile memory for storing a first and a second threshold of a speed of the turbomachine;
  - a microcontroller for generating a shutdown command for shutting down the turbomachine on the basis of information relating to a speed

of the turbomachine and on the basis of the first and second thresholds;

- connecting means for sending said shutdown command for shutting down the turbomachine from the housing;

the autonomous speed limiting system being independent of any control and acquisition systems of the test bench.

[0020] Advantageously, the autonomous speed limiting system minimizes the risk of accidents, thus protecting equipment and personnel, by acting autonomously to stop the turbomachine when overspeed is detected. In addition, its compact design including a housing, with connecting means for sending stop commands, ensures high reliability with minimal maintenance. In addition, thanks to the microcontroller, the autonomous system is able to quickly process speed information and generate a real-time shutdown command. This ability to react instantly to exceedances of established thresholds ensures that actions are taken well before the situation becomes critical.

Non-volatile memory, on the other hand, offers the possibility of storing and modifying these speed thresholds while allowing great flexibility, adapted to the specificities of each turbomachine and to the test conditions.

[0021] In a particular embodiment, the connecting means comprise electrical cables allowing for wiring between the housing and the turbomachine. Advantageously, electrical cables provide a physical and direct connection, which reduces the risk of disruption or interference that could affect wireless means of communication.

[0022] In one possible embodiment, the microcontroller is configured to shut down the turbomachine in the event of an interruption of the power supplying the housing. Indeed, the housing includes electronic components, such as the microcontroller, non-volatile memory, and other circuits necessary for data processing, speed threshold detection, and the generation of stop commands. These components require an electrical power source to function properly. However, under certain circumstances, the power supply may be unstable and may be interrupted. In this embodiment, the fact that the microcontroller is configured to shut down the turbomachine in the event of a power supply interruption to the housing adds an

additional layer of safety to the autonomous speed limiting system. This feature ensures that, even in the event that the system itself is compromised by a loss of power, the turbomachine is automatically shut down to prevent any potential hazards.

[0023] The inventors also propose a protection system for implementing a method by any of the above-mentioned embodiments, comprising:

- a first sensor to detect a presence of the operator in a given area;
- a second sensor to measure the speed of the turbomachine;
- an autonomous speed limiting system according to any of the three above-mentioned embodiments.

Brief description of the Figures

[0026] Other features and advantages of the present invention will become apparent from the following detailed description, for the understanding of which reference is made to the annexed figures, among which:

- Figure 1 illustrates a schematic representation of the steps of the method according to the invention;
- Figure 2 illustrates a schematic representation of a system for the implementation of the method according to the invention;
- Figure 3 shows a view of an operator in a given area of the test bench.

[0027] The drawings of the figures are not to scale. Similar elements are generally denoted by similar references in the figures. In the scope of this document, the same or similar elements may have the same references. Furthermore, the presence of reference numbers or letters in the drawings may not be considered as limiting, even when these numbers or letters are indicated in the claims.

Detailed description of some embodiments of the invention

[0028] This part presents a detailed description of certain embodiments of the present invention. The latter is described with particular embodiments and references to figures but the invention is not limited by them. In particular, the drawings and figures described below are only schematic and are not limiting.

[0029] Figure 1 illustrates a schematic representation of the steps of the method for protecting a turbomachine and an operator in the event of overspeed of the turbomachine in a test bench. The test bench includes a control system to control the turbomachine during a test and an acquisition system to collect operating parameters of the turbomachine during the test. The method according to the invention comprises a step a. consisting in providing an autonomous speed limiting system for limiting the speed of the turbomachine. The autonomous limiting system is independent of the control system and the acquisition system of the turbomachine. A step b. of the method consists of monitoring the speed of the turbomachine using the autonomous system. A step c. of the method consists, when the operator is present at the level of the test bench, shutting down the turbomachine by the autonomous system when its speed is higher than a first threshold. A step d. of the method consists in shutting down the turbomachine by the autonomous system, when the speed of the turbomachine is higher than a second threshold above the first threshold. Preferably, the first threshold corresponds to a speed value when the turbomachine is in idle mode. Preferably, the second threshold corresponds to a speed value when the turbomachine is in a maximum permissible speed. The maximum permissible speed is preferably coming from a manufacturer of the turbomachine. For example, on a CFM56-5B turbomachine, the first threshold is preferentially set at 1150 rpm (Ground Idle) and the second threshold is preferentially set at 5100 rpm. Preferably, the protection method according to the invention also includes a step (not shown) of shutdown the turbomachine in the event of a power supply interruption of the autonomous speed limiting system.

[0030] Figure 2 illustrates a schematic representation of a protection system 40 for the implementation of the method according to the invention. As shown in Figure 2, the autonomous speed limiting system 5 consists of a housing 3. The housing 3, offers optimal protection against dust and moisture, thus ensuring the optimal functioning of the electronic components it houses.

[0031] The housing 3 includes electronic components 16 designed to receive information relating to the speed of a turbomachine. They include, preferably,

amplifiers and signal conditioners. These ensure the adjustment and filtering of the incoming signals so that their amplitude and format are adapted to the processing. This is provided by a microcontroller 11 which is capable of generating a command for shutting down the turbomachine, based on the received speed data and on predefined thresholds stored in a non-volatile memory 10.

[0032] The non-volatile memory 10 can, for example, take the form of an EEPROM (Electrically-erasable programmable read-only memory). This allows data, such as speed thresholds for the turbomachine to be shut down, to be stored even in the event of a power failure. Thanks to its ability to be electrically reprogrammed, the memory 10 allows for thresholds to be updated as needed, without requiring the complete replacement of the autonomous speed limiting system 5.

[0033] Preferably, the microcontroller 11 does not intervene directly on the physical components of the turbomachine. The microcontroller 11 preferably transmits a signal or command to an existing system for controlling the shutdown of the turbomachine, such as the Emergency Shutdown System (ESD), which is well known to the person skilled in the art. The command coming from the microcontroller 11 then serves as an input to the emergency shutdown system for controlling the shutdown of the turbomachine, adding an extra layer of safety without requiring major modifications to the main control system for controlling the turbomachine.

[0034] The microcontroller 11 can, for example, be an AVR microcontroller from Atmel, programmed to analyze the input signals, compare this data to the thresholds stored in the memory 10, and generate shutdown commands if necessary.

[0035] Preferably, the microcontroller 11, the non-volatile memory 10, and the electronic components dedicated to receiving speed information are integrated on a printed circuit board (PCB). This integration aims to create a compact, robust and easy-to-install system.

[0036] The housing 3 is usually powered by a standard power source of the installation. Preferably, the microcontroller 11 is configured to initiate a shutdown of the turbomachine in the event of an interruption of the power supplying the housing

3, adding additional protection. This feature is possible, for example, thanks to a power supply interruption detector circuit, designed to deactivate the microcontroller 11 immediately when the supply voltage falls below a critical threshold, without the need for the use of a battery-type backup device. By design, if the microcontroller is inactivated, the protection is still active (safe logic).

[0037] The connection between the housing 3 and the turbomachine is established by connecting means 9 to send the shutdown command of the turbomachine from the housing 3. These connecting means 9 are, preferably, in the form of electrical cables for a direct wiring. This ensures efficient and immediate transmission of shut down commands.

[0038] Finally, the protection system 40 also includes a first 12 and a second 13 sensors. The first sensor 12 is responsible for detecting the presence of the operator in a given area of the test bench. This sensor 12 can be, for example, a binary sensor at the access door to the test bench. The sensor activates a signal that is sent to the autonomous speed limiting system 5. A binary or On/Off sensor is known to a person skilled in the art.

[0039] The second sensor 13 is responsible for measuring the speed of the turbomachine. An example of a sensor 13 is the Hall effect sensor, which is used for an accurate, real-time measurement of the rotational speed of the turbomachine, or the original sensor mounted on the turbomachine.

[0040] These sensors, through their functionality and their integration into the autonomous speed limiting system 5, make it possible to provide essential data to the microcontroller 11 for fast and efficient decision-making, thus guaranteeing optimal safety at the test bench level.

[0041] Figure 3 shows a view of an operator 22 present in a given area of the test bench 7. In the test bench 7, there is preferably a central area where a turbomachine 15 is tested equipped with various instruments to test its performance. The test bench 7 is equipped, for example, with side walkways. These walkways, designed for safety and accessibility, allow an operator to closely monitor the test operations while easily moving along the test bench 7. They are equipped, for example, with

guardrails to prevent accidental falls and ensure the safety of the operator during testing.

[0042] The operator 22 is, for example, represented standing on one of these walkways. The first sensor 12 is, for example, mounted on the access door of the test bench. The first sensor 12 detects the presence of the operator 22 in the designated area, and sends a signal to the autonomous speed limiting system 5 which stops the turbomachine 15 when its speed exceeds the first threshold. This is preferably a speed value when the turbomachine 15 is in idle mode.

[0043] In summary, the invention relates to a method for protecting a turbomachine 15 and/or an operator 22 in the event of overspeed of a turbomachine 15 in a test bench 7. The invention makes it possible to strengthen the level of security and guarantee an autonomous and rapid intervention, to protect both personnel and equipment.

[0044] The present invention has been described above in relation to specific embodiments, which have a purely illustrative value and should not be considered as limiting. It will be readily apparent to the person skilled in the art that the invention is not limited to the examples illustrated or described above, and that its scope is more broadly defined by the claims hereinafter introduced.

CLAIMS

1. A method for protecting an aircraft turbomachine (15) and/or an operator (22) in the event of overspeed of said turbomachine (15) in a test bench (7), said test bench (7) comprising a control system for controlling the turbomachine (15) during a test and an acquisition system for collecting operating parameters of the turbomachine during said test, the protection method comprising the following steps:

a. providing an autonomous speed limiting system (5) for limiting the speed of said turbomachine (15), said autonomous limiting system (5) being independent of said control system and said acquisition system;

b. monitoring the speed of the turbomachine using said autonomous system (5);

c. when said operator (22) is present at the level of the test bench (7), shutting down the turbomachine (15) by the autonomous system (5) when the speed of the turbomachine is higher than a first threshold;

d. when the speed of the turbomachine (15) is higher than a second threshold higher than said first threshold, shutting down the turbomachine (15) by the autonomous system (5).

2. The method according to claim 1, characterized in that said first threshold corresponds to a speed value when the turbomachine (15) is in an idle speed.

3. The method according to any one of the preceding claims, characterized in that said second threshold corresponds to a speed value when the turbomachine (15) is in a maximum permissible speed.

4. The method according to the preceding claim, characterised in that the maximum permissible speed comes from a manufacturer of the turbomachine (15).

5. The method according to any one of the preceding claims, characterized in that the shutdown is imposed at step c. in a time interval of less than 10 ms, once the speed of the turbomachine (15) is higher than the first threshold.

6. The method according to any one of the preceding claims, characterized in that the shutdown is imposed at step d. in a time interval of less than 10 ms, once the speed of the turbomachine (15) is higher than the second threshold.

7. The method according to any one of the preceding claims, further comprising, a step of shutting down the turbomachine (15) in the event of an interruption of the power supplying said autonomous speed limiting system (5).

8. The method according to any one of the preceding claims, characterized in that the autonomous speed limiting system comprises a housing (3) with on-board electronics capable of shutting down the turbomachine (15) in both cases corresponding to steps c. and d.

9. An autonomous speed limiting system (5) suitable for use in a test bench (7) for testing a turbomachine (15) and comprising:

- a housing (3) comprising:
  - electronic components (16) for receiving information relating to the speed of a turbomachine (15);
  - a non-volatile memory (10) for storing a first and a second threshold of a speed of the turbomachine (15);
  - a microcontroller (11) for generating a shutdown command for shutting down the turbomachine (15) on the basis of information relating to a speed of the turbomachine (15) and on the basis of the first and second thresholds;
- connecting means (9) for sending said shutdown command for shutting down the turbomachine (15) from the housing (3);

said autonomous speed limiting system (5) being independent of any control and acquisition systems of the test bench (7).

10. The autonomous speed limiting system (5) according to the preceding claim, characterized in that the connecting means (9) comprise electrical cables allowing for wiring between the housing (3) and the turbomachine (15).

11. The autonomous speed limiting system (5) according to any one of the two preceding claims, characterized in that the microcontroller (11) is configured to shut down the turbomachine (15) in the event of an interruption of the power supplying said housing (3).

12. A protection system (40) for carrying out a method according to any one of claims 1 to 8 and comprising:

- a first (12) sensor to detect a presence of the operator in a given area;
- a second (13) sensor to measure the speed of the turbomachine;
- an autonomous speed limiting system (5) according to any one of the three preceding claims.