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(54) **TURBOMACHINE COMPRISING A MEANS OF UNCOUPLING A FAN**

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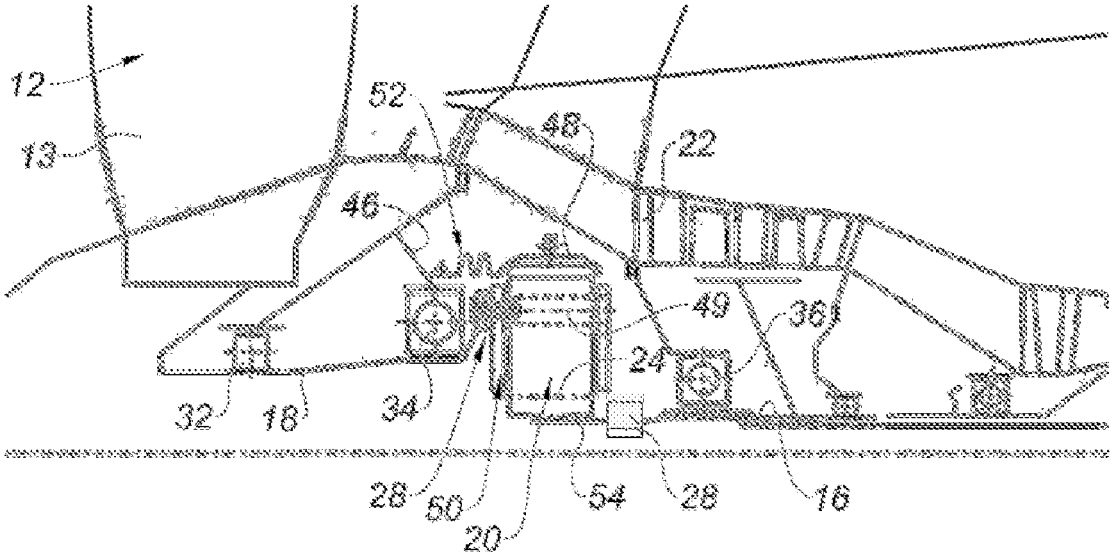
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(57) **ABSTRACT**

A turbojet engine includes a fan shaft driven by a turbine shaft via a device for reducing the speed of rotation. The engine includes an uncoupling device interposed between the reduction device and the turbine shaft. The uncoupling device is configured to uncouple the reduction device and the turbine shaft in response to the exceeding of a determined resistant torque exerted by the reduction device on the turbine shaft.



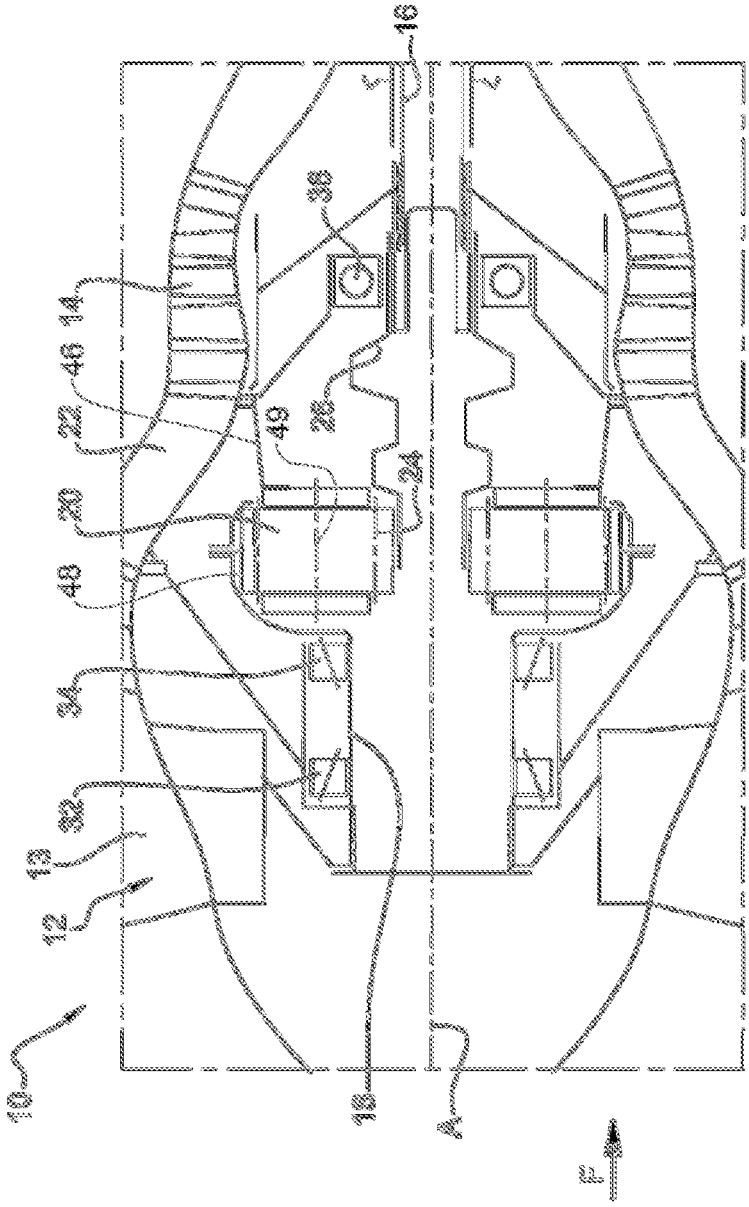


Fig. 1

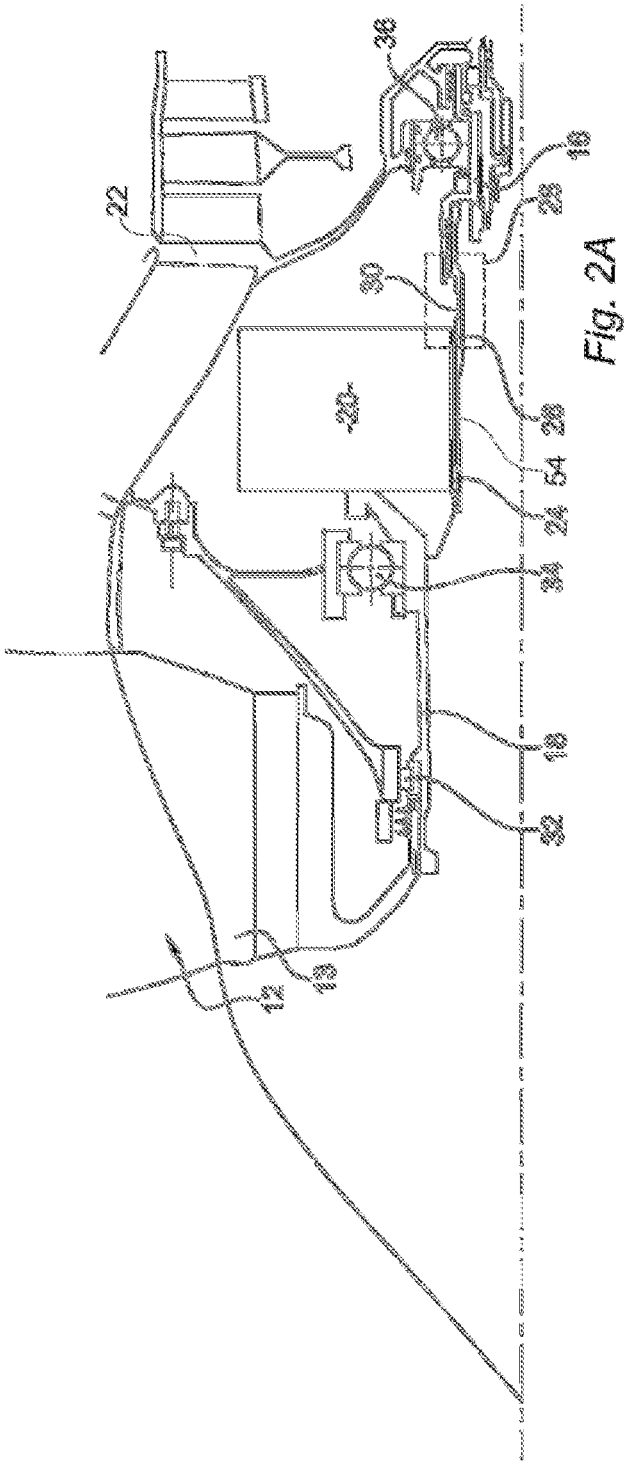


Fig. 2A

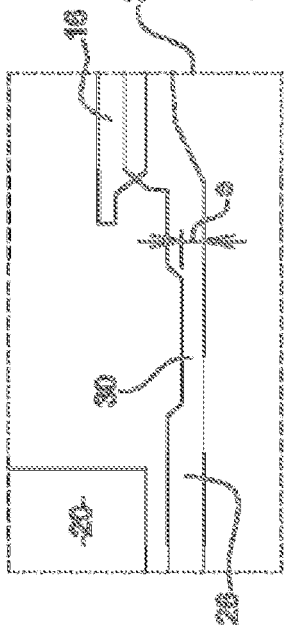


Fig. 2B

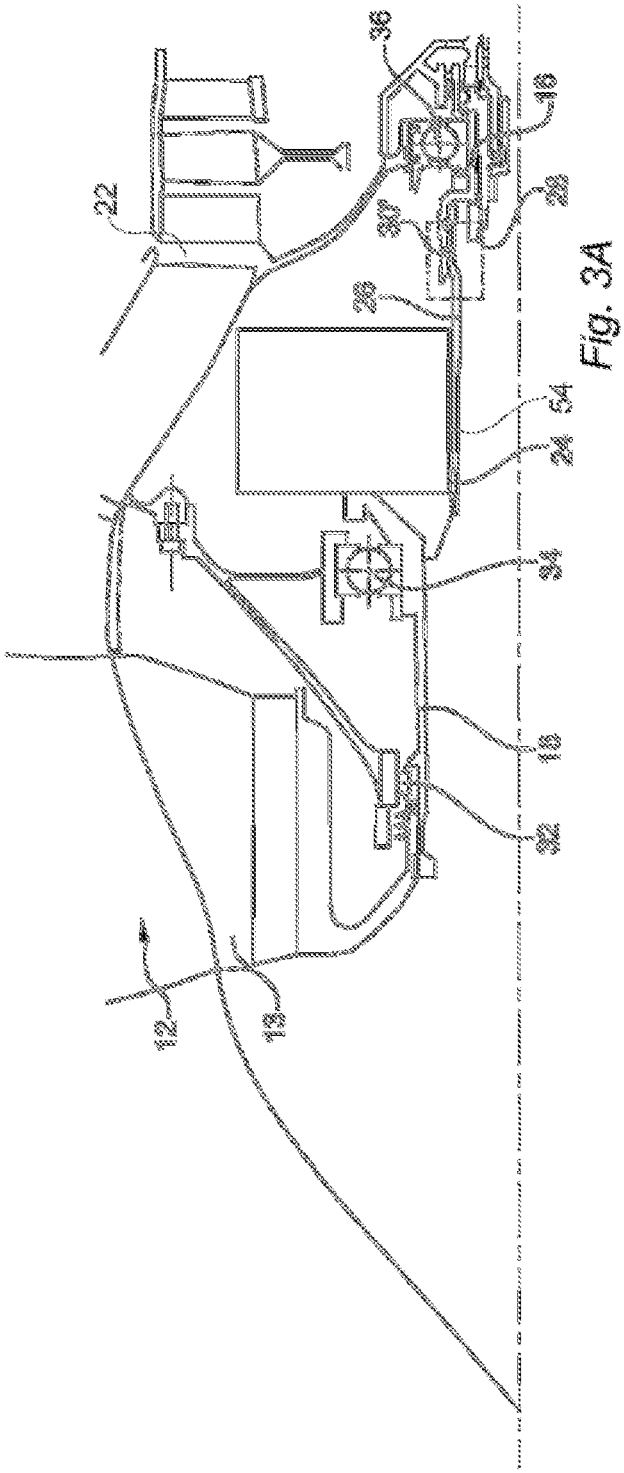


Fig. 3A

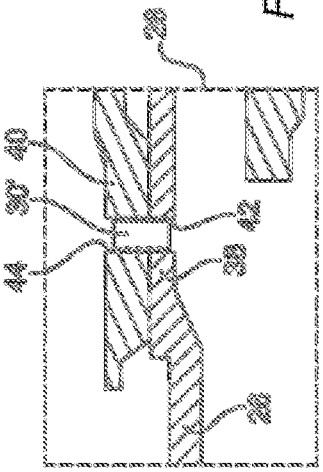


Fig. 3B

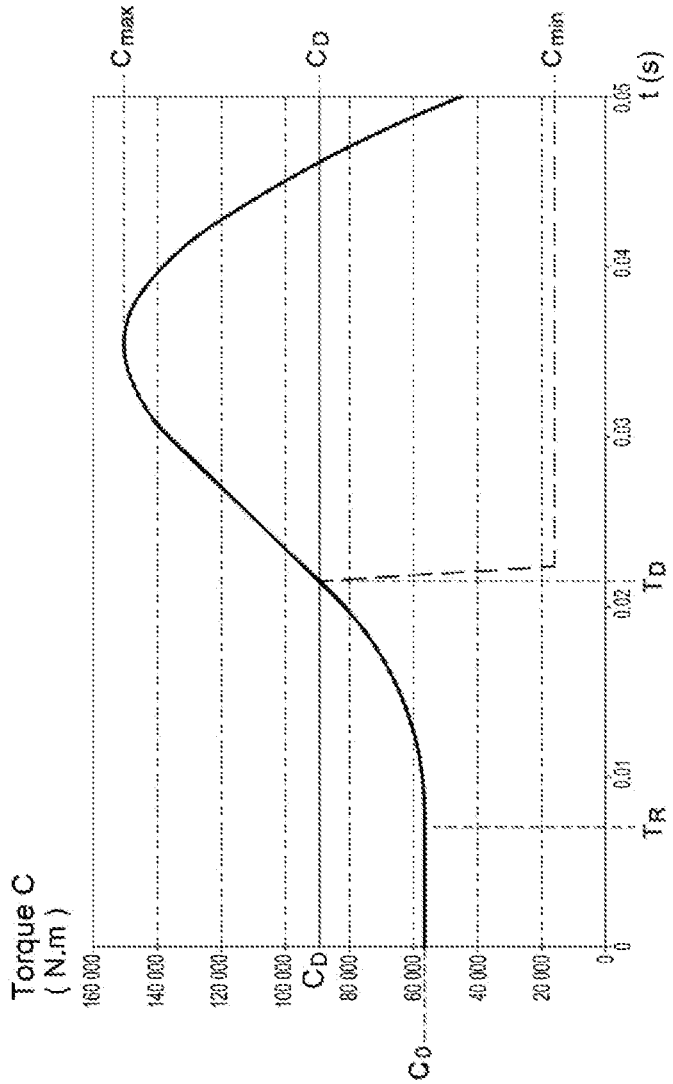

Torque C
(N.m)
160 000
140 000
120 000
100 000
80 000
60 000
40 000
20 000
0
C max
C D
C min
C 0
0
0.01
0.02
0.03
0.04
0.05
t (s)
T R
T D

Fig. 4

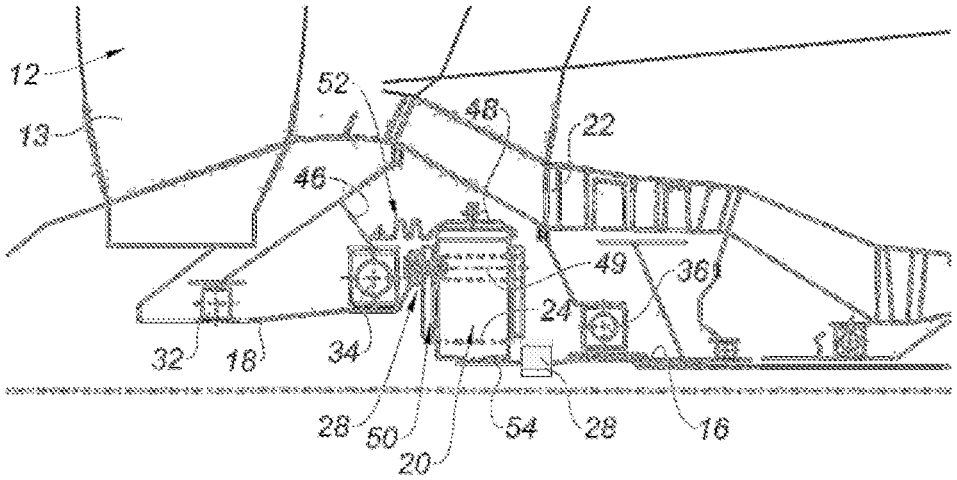


Fig. 5

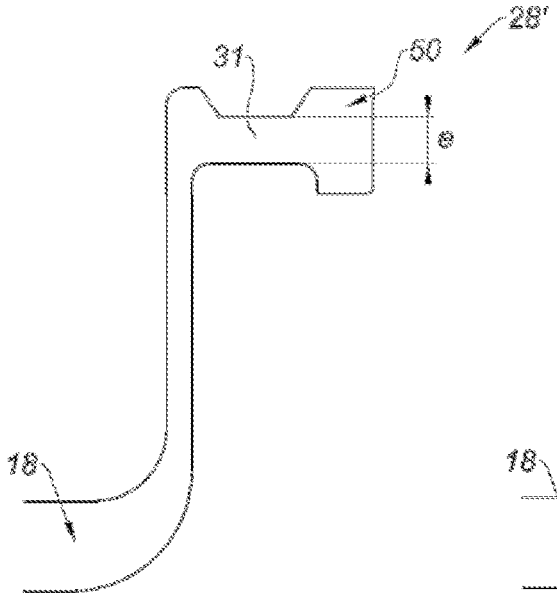


Fig. 6

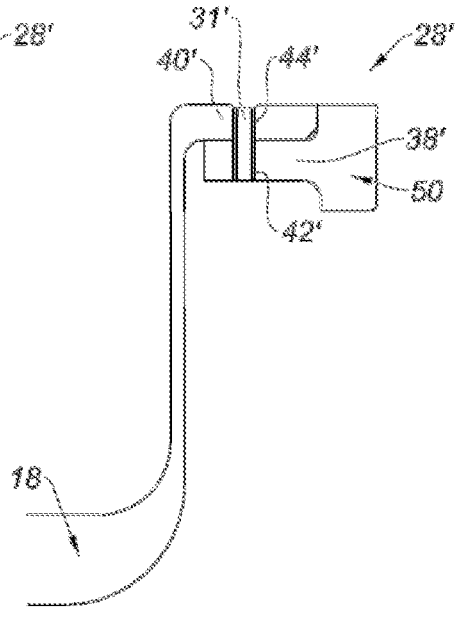


Fig. 7

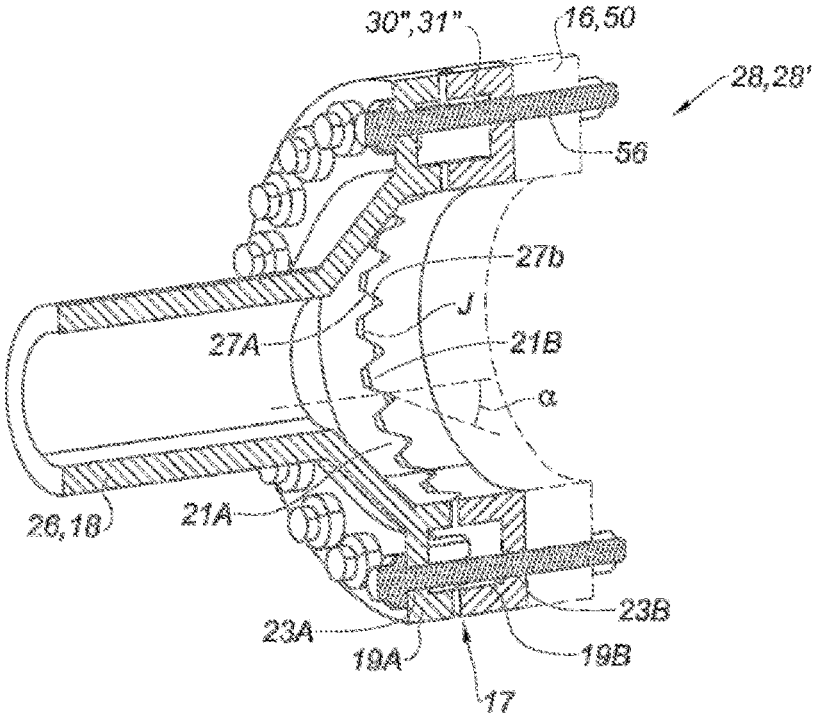


Fig. 8A

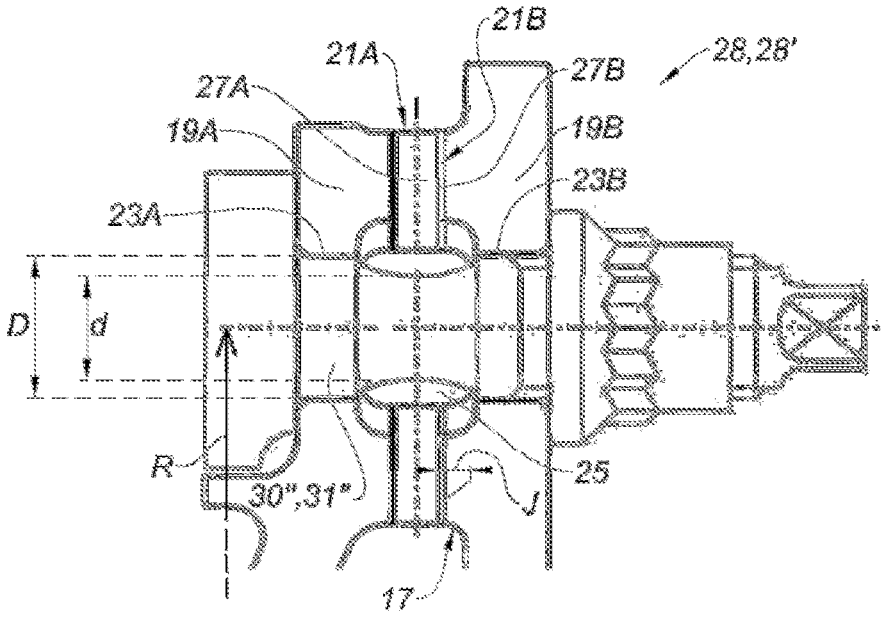

21B
21A
28,28'
27B
27A
19B
19A
23B
23A
D
d
R
30",31"
25
J
17

Fig. 8B

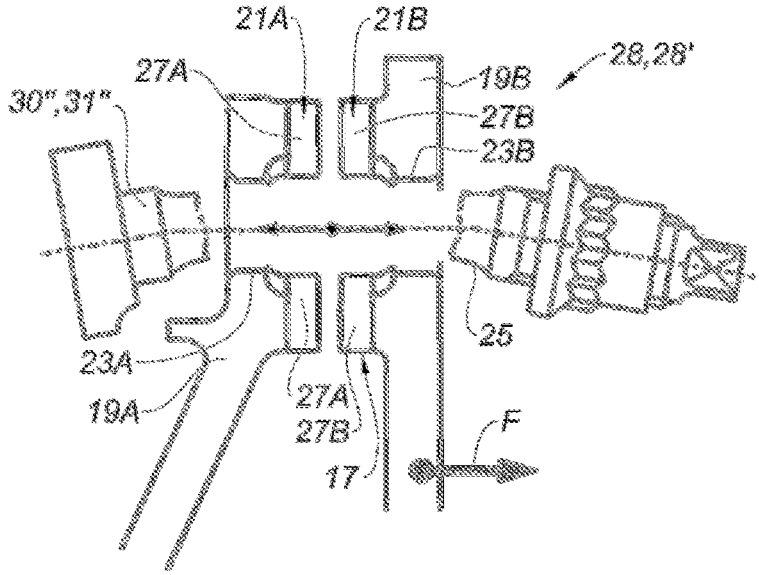

21A
21B
28,28'
27A
19B
30",31"
27B
23B
25
23A
19A
27A
27B
F
17

Fig. 8C

TURBOMACHINE COMPRISING A MEANS OF UNCOUPLING A FAN

[0001] The field of the present invention is that of aeronautical turbomachines and more particularly that of dual flux turbomachines including a reduction device for driving the fan.

[0002] Conventionally, turbomachines comprise, starting from the upstream side, one or several compressor modules positioned in series, which compress the air sucked up in an air intake. The air is then introduced into a combustion chamber where it is mixed with fuel and burnt. The combustion gases pass through one or several turbine modules which drive the compressor(s) via associated turbine shafts. The gases are finally ejected either into a nozzle for producing a propelling force either on a free turbine in order to produce power which is recovered on a transmission shaft.

[0003] Present dual flow turbomachines with a strong dilution rate includes several compressor stages, notably a low pressure (LP) compressor and a high pressure (HP) compressor, crossed by a primary flow. These low pressure (LP) and high pressure (HP) compressors are each driven by an associated respective low pressure (LP) or high pressure (HP) turbine shaft. Upstream from the low pressure (LP) compressor is positioned a wheel including movable blades or vanes of large dimension, or a fan, which feeds both the primary flow crossing the LP and HP compressors and a cold flow, or secondary flow, which is directly directed towards a cold flow nozzle, a so called secondary nozzle. The fan is driven by the rotation shaft of an LP turbine of the LP body and generally rotates at the same speed as it.

[0004] It may be interesting to have the fan rotate at a rotational speed of less than that of the LP shaft, notably when the latter is of a very large size, with the purpose of better adapting it aerodynamically. For this, a reduction device is positioned between the turbine shaft LP and a fan shaft, which bears the fan. Such a configuration is notably described in patent applications FR 1,251,655 and 1,251,656 filed on Feb. 23, 2012.

[0005] In this configuration, it may occur that the fan loses a blade, for example in the case of ingestion of a foreign body such as a bird. This phenomenon also called "Fan Blade Out" (FBO) causes off-centering of the fan having the consequence of causing a contact of the ends of its blades with the case of the fan. This contact may suddenly slow down the fan even while the reduction device and the turbine shaft are still driven by the LP turbine, which may generate a high torsional torque in the LP turbine shaft and in the reduction device.

[0006] The torsion of the shafts may lead to breakages of the shafts in different points of the turbomachine, as this is taught by document EP-2,048,330-A2.

[0007] Document EP-2,048,330-A2 discloses a turbomachine including a fan shaft and a shaft of a compressor each driven by a turbine shaft via two different coupling paths torqued with the turbine shaft at an intersection laid out at a bearing. The coupling path drives the fan via a reduction device. Both coupling paths are provided so that in the case of an incidental breakage of one of the coupling paths, the turbine remains being charged on the other coupling path in order to avoid excess speeds of the turbine, while a control unit of the turbine may reduce the speed of the turbine. The turbomachine described in this document starts from the fact that a possible mechanical malfunction of the coupling paths may occur, such as for example the one which connects the turbine shaft to the fan. However, this document does not explicitly specify the nature of this malfunction, which may consist or not in a break, but which is in any case incidental and not predictable. In the case of a break of the coupling path, of the turbine shaft with the fan, this incidental break then only occurs when the reduction device has already been subject to significant torques and has already likely been damaged.

[0008] Indeed, such a torsional torque in the case of a blade loss also risks seriously damaging the reduction device, which then may be blocked and make the rotation of the fan impossible. This would have the consequence of suddenly increasing the aerodynamic drag of the engine, making the airplane impossible to pilot.

[0009] In order to find a remedy to this drawback, a solution consists of limiting the torsional torque which may pass through the reduction device and the turbine shaft LP in order to avoid blocking the fan.

[0010] Moreover, the limitation of this torque gives the possibility to avoid any over-dimensioning of the members of the reduction device and of the low pressure turbine shaft, and therefore to lighten the design of the reduction device and of the LP turbine shaft.

[0011] With this purpose, the invention proposes a turbomachine of the type mentioned earlier, characterized in that it includes at least one uncoupling means interposed between the reduction device and the turbine shaft, which is able of uncoupling the reduction device and the turbine shaft in response to exceeding a determined resistant torque exerted by the reduction device on the turbine shaft.

[0012] Advantageously, the uncoupling is therefore an event provided as a response to the exceeding of a determined resistant torque exerted by the reduction device on the turbine shaft, i.e. conditioned by the exceeding of this resistant torque.

[0013] According to preferred embodiments of the invention, the uncoupling means includes at least one fuse connecting element which is interposed between the reduction device and the turbine shaft and which is able to be broken when it is subject to a so called uncoupling resistant torque exerted by the device for reducing speed on the turbine shaft.

[0014] According to a first embodiment of the uncoupling means, the fuse element consists of a segment of an input shaft of the reduction device bound to the turbine shaft, said segment being able to be broken when it is subject to a maximum torsional torque corresponding to the uncoupling resistant torque.

[0015] According to a second embodiment of the uncoupling means, an input shaft of the reduction device includes a tubular end segment which is coupled with a complementary tubular end segment of the turbine shaft via at least one radial element able to be broken when it is subject to a shear stress corresponding to the resistant uncoupling torque.

[0016] In this configuration, the radial element includes a pin which is received in a radial orifice of the end segment of the input shaft and in an orifice facing the end segment of the turbine shaft.

[0017] The reduction device can be coupled to the turbine shaft via a coupling with trapezoidal teeth of the curvic type, including two toothed coupling plates meshing with one another and fastened to one another via screws. According to a third embodiment of the uncoupling means, these screws are axial fuse screws forming fuse connecting elements of the uncoupling means.

[0018] In a preferential way of the invention, the fuse connecting element is able to be broken as soon as it is subject to the determined resistant uncoupling torque corresponding to a resistant torque exerted by the fan on the speed reduction device in the case of loss of at least one blade of a fan driven by said fan shaft.

[0019] Moreover, the fuse connecting element is able to be broken as soon as it is subject to a resistant torque which is strictly greater than any torque corresponding to a resistant torque exerted by the fan on the speed reduction device in the case of ingestion of a bird without losing any blade by said fan.

[0020] The fuse connecting element may be associated with a fan including metal blades. In this case, the fuse element is able to be broken as soon as it is subject to an uncoupling torque of 120 to 140% of a normal torque in a maximum speed of the turbomachine.

[0021] Also, the fuse connecting element may be associated with a fan including blades in a composite material. In this case, the melting element is able to be broken as soon as it is subject to an uncoupling torque of 130 to 170% of a normal torque in a maximum speed condition of the turbomachine.

[0022] Finally, in order to avoid run-off of the turbines in the case of uncoupling, the turbomachine according to the invention advantageously includes means for detecting the uncoupling of the reduction device and of the turbine shaft able to control a reduction of speed of the turbine and/or stopping of the turbomachine.

[0023] Preferably, the resistant uncoupling torque is greater than 50,000 N·m, and preferably comprised between 50,000 N·m and 400,000 N·m.

[0024] According to an alternative embodiment of the invention, the turbomachine includes an additional uncoupling means interposed between the reduction device and the fan shaft, which is able to uncouple the reduction device and the fan shaft in response to exceeding a determined resistant torque, called uncoupling torque, exerted by the fan shaft on the reduction device.

[0025] The additional uncoupling means includes at least one fuse connecting element which is interposed between the reduction device and the fan shaft and which is able to be broken when it is subject to the uncoupling resistant torque exerted by the fan shaft on the reduction device.

[0026] According to a first embodiment of this additional uncoupling means, the fuse element consists of a segment of an output shaft of the reduction device bound to the fan shaft, said segment being able to be broken when it is subject to a maximum torsional torque corresponding to the uncoupling resistant torque.

[0027] According to a first embodiment of this additional uncoupling means, an output shaft of the reduction device includes a tubular end segment which is coupled with a complementary tubular end segment of the fan shaft via at least one radial fuse connecting element able to be broken when it is subject to a shear stress corresponding to the resistant uncoupling torque.

[0028] Preferably, the radial element includes a pin which is received in a radial orifice of the end segment of the output shaft and in an orifice facing the end segment of the fan shaft.

[0029] The reduction device can be coupled to the fan shaft via a coupling with trapezoidal teeth of the curvic type, including two toothed coupling plates with trapezoidal axial teeth meshing with one another and fastened to one another via axial screws. According to a third embodiment of this additional uncoupling means, the screws are fuse screws forming the fuse connecting element of the additional uncoupling means.

[0030] The invention will be better understood, and other objects, details, features and advantages thereof will become more clearly apparent during the detailed explanatory description which follows, of an embodiment of the invention given as a purely illustrative and non-limiting example, with reference to the appended schematic drawings wherein:

[0031] FIG. **1** is an overall view of a turbomachine according to a prior state of the art;

[0032] FIG. **2**A is a sectional view of the front portion of a turbomachine according to the invention equipped with a first embodiment of an uncoupling means;

[0033] FIG. **2**B is a detailed view of FIG. **2**A;

[0034] FIG. **3**A is a sectional view of the front portion of a turbomachine according to the invention equipped with a second embodiment of an uncoupling means;

[0035] FIG. **3**B is a detailed view of FIG. **3**A,

[0036] FIG. **4** is a diagram illustrating the resistant torque exerted by the speed reduction device on the turbine shaft versus time during the loss of a blade of the fan.

[0037] FIG. **5** is a schematic sectional view of the front portion of a turbomachine according to the invention equipped with a second embodiment of an additional uncoupling means;

[0038] FIG. **6** is a detail view of a first embodiment of the additional uncoupling means;

[0039] FIG. **7** is a detail view of a second embodiment of the additional uncoupling means;

[0040] FIG. **8**A is a perspective view of a third embodiment of the uncoupling means or the additional uncoupling means;

[0041] FIG. **8**B is a detailed sectional perspective view of a third embodiment of the uncoupling means or the additional uncoupling means prior to uncoupling;

[0042] FIG. **8**C is a detailed sectional view of the third embodiment of the uncoupling means or the additional uncoupling means during uncoupling.

[0043] In the description which follows, identical reference numbers designate identical parts or having similar functions.

[0044] In FIG. **1** is illustrated a turbomachine such as a turbine engine **10** made according to a prior state of the art. In a known way, the turbine engine **10** includes, from the upstream side to the downstream side along the gas flow flux "F", a fan **12**, a low pressure compressor **14**, a high pressure compressor, a combustion chamber, a high pressure turbine and a low pressure turbine (not shown). The fan **12** includes blades **13**. The high pressure compressor and the high pressure turbine are connected through a high pressure shaft and form with it a high pressure body. The low pressure compressor **14** and the low pressure turbine are connected through a low pressure shaft **16** and form with it a low pressure body. The fan **12** as for it is borne by a fan shaft **18** which, in the illustrated example, is bound in rotation to the LP shaft **16**, through a device **20** for reducing the speed of rotation between both shafts **16**, **18**.

[0045] Indeed, it is interesting to have the fan **12** rotated at a speed of rotation of less than that of the LP shaft **16**, notably when the latter is of a very large size, with the purpose of better adapting it aerodynamically.

[0046] The HP and LP shafts **16** extend along an axis "A" of rotation of the turbine engine **10**.

[0047] The turbine engine **10** also comprises, conventionally, a fan case (not shown) which allows channeling of the gases sucked up by the fan **12** towards a vein **22** of a primary flow, which crosses the LP and HP bodies, and a secondary flow vein (not shown) which surrounds a case of the LP and HP bodies and joins up with the primary flow vein in a nozzle (not shown) of the turbine engine.

[0048] As illustrated by FIG. **1**, the reduction device **20** is positioned between the fan shaft **18** and the LP shaft **16**. This reduction device, for example of the epicycloidal type is illustrated in the schematic form of rectangles only showing its congestion. It is, non-limitingly with respect to the invention, driven by a planetary pinion **24** (shown by the outline of its teeth) borne by an input shaft **26** which is connected in rotation to the LP shaft **16**, the shaft **16** being, only as an example, received without any play by being fitted into the shaft **26**. It also includes a planet carrier **49** (shown by the axis of its planet gears) secured to a case **46** of the turbomachine, and a crown **48** that drives the shaft **18** of the fan **12**.

[0049] In this configuration, it may occur that the fan **12** looses a blade **13**, for example in the case of ingestion of a foreign body such as a bird or subsequently to a fatigue break resulting from unsuitable maintenance. This phenomenon, also known as "Fan Blade Out" (FBO) causes off-centering of the fan **12** relatively to the axis "A", which has the consequence of causing a contact of the ends of its blades **13** with the case (not shown) of the fan **12**. This contact may suddenly slow down the fan **12** even while the reduction device **20** and the LP turbine shaft **16** are still driven by the LP turbine, which may create a high torsional torque in the LP turbine shaft **16** and in the reduction device **20**.

[0050] Such a torsional torque in the case of loss of a blade **13** risks seriously damaging the reduction device **20**, which then may be blocked and make the rotation of the fan **12** impossible. This would have the consequence of suddenly increasing the aerodynamic drag of the engine, making the airplane impossible to pilot.

[0051] In order to find a remedy to this drawback, a solution consists of limiting the torsional torque which may pass through the reduction device **20** and the LP turbine shaft **16**, in order to avoid blocking of the fan **12**.

[0052] The limitation of the torsional torque has another advantage, which is to give the possibility of avoiding over-dimensioning of the members of the reduction device **20** and of the LP turbine shaft **16** able to ensure their resistance to such a torsional torque during exceeding of a determined resistant torque exerted by the speed reduction device **20** on the turbine shaft **16**.

[0053] Moreover, the limitation of this torque gives the possibility of avoiding any over-dimensioning of the members of the reduction device **20** and of the low pressure turbine shaft **16**, and therefore alleviating the design of the reduction device **20** and of the LP turbine shaft **16**.

[0054] With this purpose, the invention proposes a turbomachine of the type described earlier, characterized in that it includes an uncoupling means **28** interposed between the reduction device **20** and the turbine shaft **16**, which is able to uncouple the reduction device **20** from the turbine shaft in response to the exceeding of a determined resistant torque, called uncoupling torque, exerted by the speed reduction device **20** on the turbine shaft **16**.

[0055] More particularly, as illustrated by FIGS. **2**A, **3**A and **8**A, the uncoupling means **28** includes at least one fuse connecting element **30**, **30'**, **30"** which is interposed between the reduction device **20** and the turbine shaft **16** and which is able to be broken when it is subject to the resistant torque a so called uncoupling torque exerted by the speed reduction device on the turbine shaft, and which notably corresponds to a determined resistant torque exerted by the fan **12** on the speed reduction device **20**, and then transmitted through said speed reduction device.

[0056] Benefitting from the positioning of at least one fuse connecting element **30**, **30'**, **30"** between the reduction device **20** and the turbine shaft **16** has several advantages.

[0057] Firstly, this positioning of the fuse connecting element **30**, **30'**, **30"** between the reduction device **20** and the turbine shaft **16** is easy to achieve at the reduction device **20** since the shaft **18** of the fan **12** is supported by two bearings **32**, **34**, and since the shaft **16** of the LP turbine is itself also supported by two bearings, a single bearing **36** of which has been illustrated in FIGS. **2**A, **3**A. The breaking of the fuse element **30**, **30'** therefore has no incidence on the maintaining in rotation of the shaft **16** of the LP turbine or the shaft **18** of the fan **12**.

[0058] Secondly, the uncoupling of the reduction device **20** and of the turbine shaft **16** involves a free speed of rotation of the fan **12** after stopping the turbine engine that is greater than that which the same fan **12** would have in a conventional turbine engine wherein the turbine engine would be stopped without uncoupling the fan **12**. Thus, the fan **12** is subject to a free speed of rotation or "wind-milling" which allows the turbine engine to only produce a reduced drag.

[0059] Thirdly, the positioning of the fuse connecting element **30**, **30'**, **30"** between the reduction device **20** and the turbine shaft **16** allows, as this will be seen later on in the continuation of the present description, protection of the reduction device **20** in the case of excess speed of the shaft **16** of the turbine.

[0060] According to a first embodiment of the decoupling device **28** which was illustrated in FIG. **2**A and in particular in FIG. **2**B, the fuse element consists of a segment **30** of the input shaft **26** of the reduction device bound to the shaft **16** of the turbine. This segment **30** is able to be broken when it is subject to a maximum torsional torque corresponding to the determined uncoupling resistant torque exerted by the reduction device **20** on the shaft **16**.

[0061] Any known solution of the state of the art may be suitable for properly producing a segment **30** with reduced torsional rigidity. In particular, the segment may be a tubular segment with reduced thickness "e", as illustrated in FIG. **2**A. This may also be an open-worked segment **30** and/or including areas for initiating the break (not shown).

[0062] According to a second embodiment of the uncoupling device **28** which has been illustrated in FIG. **3**A and in particular in FIG. **3**B, the input shaft **26** of the reduction device includes a tubular end segment **38** which is uncoupled with a complementary tubular end segment **40** of the turbine shaft **16** via at least one radial element **30**, forming the fuse connecting element. This radial element **30'** is able to be broken when it is subject to a shear stress corresponding to the resistant uncoupling torque.

[0063] It will be understood that the radial element **30'** forming the fuse element may be conformed according to many embodiments. However, in a preferential way of the

invention, the radial element **30'** consists of a pin, notably a cylindrical pin which is received in a radial orifice **42** of the end segment of the input shaft **26** and into an orifice **44** facing the end segment of the shaft **16** of the turbine.

[0064] In each of these two embodiments, it will be understood that the positioning of the fuse connecting element **30**, **30'** on the input shaft gives the possibility of ensuring support of the planetary gear **24** of the reduction device after uncoupling.

[0065] Indeed, the planetary gear **24** is supported via the satellite-bearer with the output shaft (not shown) of the reduction device **20**.

[0066] According to a third embodiment of the uncoupling device **28** which has been illustrated in FIG. **8**A, the reduction device **20** is coupled to the turbine shaft **16** via a coupling **17** with trapezoidal teeth of the "curvic" type. Such a coupling, known from the state of the art, is conventionally used in turbomachines to couple trunnions, the juxtaposition of which forms the high-pressure shaft.

[0067] In the context of the third embodiment of the uncoupling device **28** of the invention, this coupling **17** is used differently here, since it is inserted between the input shaft **26** of the reduction gear **20** and the turbine shaft **16**. It includes two toothed coupling plates **19**A, **19**B including trapezoidal teeth **21**A, **21**B, whereof the direction of the height of the corresponding trapezoids is oriented parallel to the axial direction, and which mesh with one another. The teeth **21**A, **21**B have inclined planes **27**A, **27**B arranged in contact with one another. The plates **19**A, **19**B are joined to one another by axial screws. As illustrated in FIGS. **8**A and **8**B, a functional clearance J is arranged between the ends of the teeth **21**A and the bottoms of the teeth **21**B to guarantee good contact between the inclined planes **27**A, **27**B.

[0068] According to the invention, the screws are axial fuse screws **30"** that traverse piercings **23**A, **23**B arranged substantially along an intermediate radius R of the teeth **21**A, **21**B, substantially at the middle of said teeth. The axial fuse screws **30"** each form the fuse connecting element **30"** of the uncoupling means **28**. To that end, the screws **30"** are tightened with a determined tightening torque that does not risk causing them to break.

[0069] More particularly, as illustrated in FIG. **8**B, the axial fuse screws **30"**, with primary diameter "D", each include a segment **25** with a reduced diameter "d" forming a break primer. As illustrated in FIG. **8**C, when such a coupling undergoes a torsional torque between its two plates **19**A, **19**B, the trapezoidal teeth **21**A, **21**B, via their inclined faces **27**A, **27**B, convert the forces resulting from the torsional torque into a resultant axial force F between the plates **19**A, **19**B that is exerted in the form of a traction force on the screws **30"**. This traction force results in causing the screws **30"** to break at their segments **25** with a smaller diameter. The number of screws **30"** and their diameter depend on the value of the uncoupling torque C_D.

[0070] In the case of a reduction gear of the planetary or epicycloidal type, the input shaft **26** is mounted in a sun gear of this reduction gear via a set of complementary splines similar to the set of splines **54** that was shown as an illustration in FIGS. **2**A and **3**A. This set of splines more particularly includes splines (not shown) inside the sun gear **24** that receive outer splines (not shown) of the input shaft **26**. The inner splines allow the input shaft **26** to slide in the sun gear **24**. The forces resulting from the torsional torque exerted between the plates **19**A, **19**B cause a resultant axial force between these plates **19**A, **19**B that results in causing their separation. This separation continues after the fuse screws **30"** break during the separation of the plates **19**A, **19**B. The possibility of sliding offered by the complementary splines of the sun gear **24** and the input shaft **26** of the reduction gear allow the axial separation of the input shaft **26** and the low-pressure turbine shaft **16**.

[0071] In each of these three embodiments, the fuse element **30**, **30'**, **30"** is calibrated so as to break when respectively the segment **30**, the pin **30'**, or each screw **30"** is subject to an uncoupling torque corresponding to a resistant torque exerted by the fan on the speed reduction device **20** in the case of loss of at least one blade **13** of the fan driven by said fan shaft **18**, and transmitted by the reduction device **20**.

[0072] Thus the break is provided as a minimum and this, as soon as the loss of a single blade **13**.

[0073] It is also possible to choose another break criterion of the fuse connecting element **30**, **30'**, **30"**, for example seizing of the reduction gear **20**. In this case, the torque C_D is situated in a range from 200% to 300% of the maximum torque to which the turbine shaft **12** is subjected.

[0074] Conversely, it is provided that the break only occurs in the case of break or loss of a blade **13**, and not in the case of a simple slowing down of the fan **12**.

[0075] Thus, it is provided that the determined resistant torque be strictly greater than any torque corresponding to a resistant torque exerted by the fan **12** on the speed reduction device **20** and transmitted through the device **20**, in the case of ingestion of a bird without any loss of a blade by said fan **12**, such an event may produce a tangential force slowing down the fan **12**, but which does not risk damaging the reduction device **20** or blocking the relevant kinematical chain.

[0076] FIG. **4** comparatively illustrates the transmitted resistant torque "C", in ordinates, versus the time "t" in abscissas, in the case of break of a blade **13** of the fan.

[0077] As this may be seen on the curve in solid lines, in a conventional turbomachine, from an optimal operating torque C_0, a break of a blade **13** may occur at an instant T_R. This break leads to an increase in the resistant torque up to a limiting value C_{max} corresponding to the blocking of the reduce device **20** and of the fan **12**, or more exactly to a risk of blocking according to the specifications of the reduction device, making the latter unable to be used.

[0078] In the turbomachine according to the invention, the maximum torque is tared with a couple C_D or uncoupling torque. Consequently, during operation, a break of a blade **13** may also occur at an instant T_R which leads to an increase in the resistant torque up to the value C_D or uncoupling torque value. The torque decreases then, according to the curve in dotted lines, down to a value C_{min} corresponding to a state of free rotation of the fan **12**.

[0079] As an example, and in a non-limiting way of the invention, an order of magnitude of the determined transmitted uncoupling torque C_D, when the fan includes metal blades, is of 120 to 140% of a normal torque in the maximum speed conditions of the turbomachine.

[0080] When the fan includes blades in a composite material, an order of magnitude of the determined transmitted uncoupling torque is from 130 to 170% of a normal torque under maximum speed conditions of the turbomachine.

[0081] As just one non-limiting example of the invention, we will preferably consider the case of a turbomachine

having a maximum thrust between 100 kN and 300 kN, with a fan **12** having a diameter between 2 and 3 m, and a reduction gear having a reduction ratio between 2.5 and 5. In this case, the maximum input torque of the input shaft **26** of the reduction gear **20** is comprised between 15,000 and 50,000 N·m. The maximum output torque of the reduction gear **20** is comprised between 50,000 and 170,000 N·m.

[0082] In this configuration, non-limitingly with respect to the invention, the value of the determined uncoupling torque in all three embodiments of the uncoupling means **28** therefore varies substantially between 50,000 N·m and 400,000 N·m.

[0083] In this configuration, non-limitingly with respect to the invention, the value of the determined uncoupling torque C_D in all three embodiments of the additional uncoupling means **28'** therefore varies substantially between 60,000 N·m and 500,000 N·m.

[0084] Of course it will be understood that these values are only indicative and depend both on the type of blade used, on the architecture and the dimensioning of the engine.

[0085] It will be understood that from the moment when the fan **12** is uncoupled from the turbine shaft **16**, the turbine **16** is no longer subject to a resistant torque from said fan. There is therefore a risk of run-off of the turbine and the reduction gear **20** if the reduction gear **20** is not uncoupled. This run-off of the reduction gear **20** risks stressing it at speeds for which it is not provided to operate.

[0086] It will be noted that another essential advantage of the positioning of the fuse connecting element **30**, **30'** **30"** between the reduction device **20** and the turbine shaft **16** is therefore to allow protection of the reduction device **20** in the case of run-off of the turbine, the latter no longer risking being subject to high speeds of rotation for which it would not be intended.

[0087] However, according to the invention, the turbomachine or turbine engine **10** includes means for detecting uncoupling of the reduction device **20** and of the turbine shaft **16** able to control at least a reduction of speed of the turbine, or even a complete stopping of the turbine engine.

[0088] Thus, it is known how to measure the speed of the turbine shaft **16** with a speed sensor. Detection of the runaway of the measured speed may thus be interpreted as an uncoupling and trigger the activation of regulation members of the engine. Consequently it is possible to limit the fuel flow rate in order to cause drop of the speed of the turbine, or, if one has a turbine comprising an axial brake between a rotor portion and a stator portion, to active this brake in order to slow down and/or stop the turbine.

[0089] As illustrated in FIG. **5**, this design may advantageously be further improved by adding an additional uncoupling means **28'** interposed between the reduction device **20** and the fan **12** shaft **18**, which is able to uncouple the reduction device **20** and the fan shaft **18** in response to exceeding a determined resistant torque C_D', called uncoupling torque, exerted by the fan shaft **18** on the reduction device **20**. This configuration advantageously makes it possible to ensure total uncoupling of the reduction gear **20**, on the side of the turbine shaft **16** as previously seen, but also on the side of the fan **12** shaft **18**, which makes it possible to prevent any of the internal members of the reduction gear **20** from being subjected to an excessive speed and consequently makes it possible to avoid any risk of blow out of the reduction gear **20**.

[0090] As illustrated in FIG. **5**, the reduction gear **20** is also connected to a case **46** of the turbomachine by at least one of its members. For example, non-limitingly with respect to the invention, as illustrated in FIG. **5**, a crown **48** of the reduction gear **20** is connected to the case **46** via a flexible link made up of an axially deformable crown support **52**, while a planet carrier of the reduction gear **20** is coupled to this fan shaft **18** and a sun gear is coupled to the turbine shaft **16** via a set of complementary splines **54**. It will be understood that this arrangement is not limiting with respect to the invention and that the elements of the reduction gear could be linked differently to the case **46**, the fan shaft **18**, and the turbine shaft **16**.

[0091] For example, in the same manner as the arrangement known from the state of the art that was described in reference to FIG. **1**, a crown **48** of the reduction tour **20** could be coupled to the fan shaft **18**, while a planet carrier of the reduction gear **20** would be connected to the case **46** via an axially deformable support, and a sun gear **24** would be coupled to the turbine shaft **16** via a set of splines.

[0092] This configuration makes it possible to guarantee that, once the reduction gear **20** has been uncoupled from the turbine shaft **16** and the fan shaft **18**, it nevertheless continues to be maintained in the case **46** of the turbomachine.

[0093] FIG. **5** shows the uncoupling means **28'** in the form of a coupling with trapezoidal teeth of the "curvic" type, but it will also be understood that this arrangement is not limiting with respect to the invention, and that, as will be seen in the continuation of the present description, the uncoupling means **28'** can assume other forms.

[0094] Like the uncoupling means **28**, the additional uncoupling means **28'** includes at least one fuse connecting element **31**, **31'**, **31"** which is interposed between the reduction device **20** and the fan shaft **18** and which is able to be broken when it is subject to the uncoupling resistant torque C_D exerted by the fan shaft **18** on the reduction device **20**.

[0095] According to a first embodiment of the decoupling device **28** which was illustrated in FIG. **6**, the fuse element for example consists of a segment **31** of the fan shaft **18** that is bound to an output shaft **50** of the reduction device **20**. This segment **31** is able to be broken when it is subject to a maximum torsional torque corresponding to the determined uncoupling resistant torque exerted by the reduction device **20** on the shaft **18**.

[0096] The output shaft **50** of the reduction device **20** and the fan shaft **18** can be fixed to one another using any means known from the state of the art. However, preferably, in this first embodiment, the output shaft **50** of the reduction device **20** and the fan shaft **18** are combined and form a single and same part.

[0097] Any known solution of the state of the art may be suitable for properly producing a segment **31** with reduced torsional rigidity. In particular, the segment may be a tubular segment with reduced thickness "e", as illustrated in FIG. **6**. This may also be an open-worked segment **31** and/or including areas for initiating the break (not shown).

[0098] According to a second embodiment of the uncoupling device **28** which has been illustrated in FIG. **7**, the output shaft **50** of the reduction device includes a tubular end segment **38** which is uncoupled with a complementary tubular end segment **40** of the fan shaft **18** via at least one radial element **31'**, forming the fuse connecting element.

This radial element **31'** is able to be broken when it is subject to a shear stress corresponding to the resistant uncoupling torque C_D.

[0099] It will be understood that the radial element **31'** forming the fuse element may be conformed according to many embodiments. However, in a preferential way of the invention, the radial element **31'** consists of a pin, notably a cylindrical pin which is received in a radial orifice **42** of the end segment **38'** of the output shaft **50** and into an orifice **44'** facing the end segment of the fan shaft **18**.

[0100] According to a third embodiment of the uncoupling device **28** which has been illustrated in detail in FIG. **8**A, the reduction device **20** is coupled to the fan shaft **18** via a coupling **17** with trapezoidal teeth of the "curvic" type. More particularly, this coupling **17** is inserted between the output shaft **50** of the reduction gear **20**, configured in the form of a flange, and the fan shaft **18**. It includes two toothed coupling plates **19**A, **19**B including trapezoidal teeth **21**A, **21**B, whereof the direction of the height of the corresponding trapezoids is oriented parallel to the axial direction, and which mesh with one another. The teeth **21**A, **21**B have inclined planes **27**A, **27**B arranged in contact with one another. The plates **19**A, **19**B and the shaft **50** are configured in a flange joined to one another by axial screws. It will be understood that alternatively, the plate **19**B could be formed in a single piece with the output shaft **50** configured in a flange.

[0101] Like for the uncoupling means **28**, the screws are axial fuse screws **31"** that traverse piercings **23**A, **23**B arranged substantially along an intermediate radius R of the teeth **21**A, **21**B, substantially at the middle of said teeth. The axial fuse screws **31"** each form the fuse connecting element of the uncoupling means **28"**. As illustrated in FIGS. **8**A and **8**B, a functional clearance J is arranged between the ends of the teeth **21**A and the bottoms of the teeth **21**B to guarantee good contact between the inclined planes **27**A, **27**B.

[0102] More particularly, as illustrated in FIG. **8**B, the axial fuse screws **31"**, with primary diameter "D", each include a segment **25** with a reduced diameter "d" forming a break primer. As illustrated in FIG. **8**C, when such a coupling undergoes a torsional torque between its two plates **19**A, **19**B, the trapezoidal teeth **21**A, **21**B, via their inclined faces **27**A, **27**B, convert the forces resulting from the torsional torque into a resultant axial force F between the plates **19**A, **19**B that is exerted in the form of a traction force on the screws **31"**. This traction force results in causing the screws **31"** to break at their segments **25** having a smaller diameter. It will be understood that, like for the uncoupling means **28**, the number and diameter of the fuse screws **31"** depends on the value of the uncoupling torque C_D.

[0103] In general, in the case of a reduction gear **20** of the planetary or epicycloidal type, the input shaft **26** is mounted in an input member of this reduction gear **20** via a set **54** of complementary splines inserted between the input shaft **26** of the reduction gear and the input member of the reduction gear. The reduction gear **20** also includes another member fixed to the case **46** with axial mobility, and lastly an axially fixed output member.

[0104] For example, and non-limitingly with respect to the invention, the reduction gear **20** shown in FIG. **5** includes a sun gear **24** (shown by the outline of its teeth), which receives, via the set of complementary splines **54**, the input shaft **26** of the reduction gear. The reduction gear **20** includes a planet carrier **49** (shown by the outline of the axes of its planet gears) that meshes with the sun gear and with a crown **48**, fixed to the case **46** of the turbomachine via an axially deformable support **52**.

[0105] The forces resulting from the torsional torque exerted between the plates **19**A, **19**B cause a resultant axial force between these plates **19**A, **19**B that results in causing their separation. This separation continues after the fuse screws **30"** break during the separation of the plates **19**A, **19**B. The possibility of sliding offered by the set **54** of complementary splines of the sun gear **24** and the input shaft **26**, and by the support **52** of the crown **48**, which is axially deformable, allows the separation of output input shaft **50**, which accompanies the reduction gear **20**, from the shaft **18** of the fan **12**.

[0106] Like for the uncoupling means **28**, the break of the fuse connecting element **31**, **31'**, **31"** of the uncoupling means **28"** can be provided a minima, once a single blade **13** is lost. This configuration is not limiting with respect to the invention, and the loss of a larger number of blades could be tolerated.

[0107] Conversely, if it is provided that the break of the fuse connecting element **31**, **31'**, **31"** only occurs in the case of break or loss of a blade **13**, it is provided that this break does not occur in the case of a simple slowing down of the fan **12**.

[0108] Thus, it is provided that the determined resistant torque be strictly greater than any torque corresponding to a resistant torque exerted by the fan **12** on the speed reduction device **20**, in the case of ingestion of a bird without any loss of a blade by said fan **12**, such an event may produce a tangential force slowing down the fan **12**, but which does not risk damaging the reduction device **20** or blocking the relevant kinematical chain. In this case, such an event does not cause the break of the fuse connecting element **31**, **31'**, **31"**.

[0109] The break is, however, anticipated for an event corresponding to a determined percentage of the maximum torque to which the shaft **18** of the fan **12** is subjected. For example, it is possible to tare the break torque C_D to respond to the loss of a blade, as previously seen. In the aforementioned configuration of the turbomachine, this torque $C_{D'}$ is then situated in a range from 120% to 200% of the maximum torque to which the shaft **18** of the fan **12** is subjected.

[0110] It is also possible to choose another break criterion of the fuse connecting element **31**, **31'**, **31"**, for example seizing of the reduction gear **20**. In this case, the torque C_D is situated in a range from 200% to 300% of the maximum torque to which the shaft **18** of the fan **12** is subjected.

[0111] Of course it will be understood that these values are only indicative and depend on the dimensioning of the turbomachine.

[0112] Like for the uncoupling means **28**, means for detecting uncoupling of the reduction device **20** and the fan shaft **18** by the uncoupling means **28'** can be provided to control at least a reduction of speed of the turbine, or even a complete stopping of the turbine engine.

[0113] Thus, it is possible to measure the speed of the output shaft **50** of the reduction gear **20**. Detection of the runaway of this speed relative to that of the fan **12** may thus be interpreted as an uncoupling and trigger the activation of regulation members of the engine. Consequently, it is possible to limit the fuel flow rate in order to cause drop of the speed of the turbine, and if one has a turbine comprising an

axial brake between a rotor portion and a stator portion, to active this brake in order to slow down and/or stop the turbine.

[0114] The triggering of the break of the fuse connecting element **31**, **31'**, **31"** of the uncoupling means **28'** may or may not be simultaneous with that of the fuse element **30**, **30'**, **30"** of the uncoupling means **28**. Preferably, elements **30**, **30'**, **30"** and **31**, **31'**, **31"** will be chosen whose strength is tuned so as to offer simultaneous uncoupling of the input shaft **26** and the output shaft **50** of the reduction gear **20**, so as to completely uncouple the reduction gear from the kinematic chain in order to reduce the speed of its internal members as quickly as possible and thus avoid any risk of blow out. However, it will be understood that this arrangement is not limiting with respect to the invention and that the fuse elements **30**, **30'**, **30"**, **31"**, **31**, **31'**, **31"** can break when they are subjected to different respective torques C_D, $C_{D'}$.

[0115] Thus, depending on the available space in the case **46** of the turbomachine to respectively house the uncoupling means **28**, **28'** therein and based on the respective uncoupling torques C_D, $C_{D'}$ of these uncoupling means, it is possible to combine the fuse elements **30**, **30'**, **30"**, **31"**, **31**, **31'**, **31"**.

[0116] According to a first combination, the input shaft segment **30** of the reduction device **20** is combined with the segment **31** of the output shaft **50** of the reduction device **20**.

[0117] According to a second combination, the input shaft segment **30** of the reduction device **20** is combined with the radial element **31'** inserted between the end segment **40'** of the fan shaft **18** and the output shaft **50** of the reduction device **20**.

[0118] According to a third combination, the input shaft segment **30** of the reduction device **20** is combined with the axial fuse screws **31"** of the curvic-type coupling inserted between the output shaft **50** of the reduction gear **20** and the fan shaft **18**.

[0119] According to a fourth combination, the radial element **30'** inserted between the input shaft **26** of the reduction device **20** and the tubular end segment **40** of the turbine shaft **16** is combined with the segment **31** of the output shaft **50** of the reduction device **20**.

[0120] According to a fifth combination, the radial element **30'** inserted between the input shaft **26** of the reduction device **20** and the tubular end segment **40** of the turbine shaft **16** is combined with the radial element **31'** inserted between the end segment **40'** of the fan shaft **18** and the shaft **50** of the reduction device **20**.

[0121] According to a sixth combination, the radial element **30'** inserted between the input shaft **26** of the reduction device **20** and the tubular end segment **40** of the turbine shaft **16** is combined with the axial fuse screws **31"** of the curvic-type coupling inserted between the output shaft **50** of the reduction device **20** and the fan shaft **18**.

[0122] According to a seventh combination, the axial fuse screws **30"** of the curvic-type coupling inserted between the input shaft **26** of the reduction gear **20** and the turbine shaft **16** are combined with the segment **31** of the output shaft **50** of the reduction device **20**.

[0123] According to an eighth combination, the axial fuse screws **30"** of the curvic-type coupling inserted between the input shaft **26** of the reduction device **20** and the turbine shaft **16** are combined with the radial element **31'** inserted between the end segment **40'** of the fan shaft **18** and the shaft **50** of the reduction device **20**.

[0124] According to a ninth combination, the axial fuse screws **30"** of the curvic-type coupling inserted between the input shaft **26** of the reduction device **20** and the turbine shaft **16** are combined with the axial fuse screws **31"** of the curvic-type coupling inserted between the output shaft **50** of the reduction device **20** and the fan shaft **18**.

[0125] The invention therefore provides a safe solution to the risks of excess speed of the kinematic line between a fan and a turbine shaft of a turbomachine, in particular in case of fan blade break of the turbomachine.

[0126] Finally, the invention also gives the possibility, by limiting the torque transmitted to the reduction device **20**, of avoiding any over-dimensioning of the members of the reduction device **20**, the fan shaft **18**, and the low pressure turbine shaft **16** in order to overcome the known risks of increase of said torque in the case of a blade loss. As these members no longer need to be over-dimensioned for meeting the high torsional constraints, they may have their dimensioning reduced, which has the consequence of globally alleviating the design of the reduction device **20**, the fan shaft **18** and the LP turbine shaft **16**.

1. A turbomachine comprises a fan shaft driven by a turbine shaft via a device for reducing the speed of rotation, wherein the turbomachine includes an uncoupling device interposed between the reduction device and the turbine shaft the uncoupling device being configured to uncouple the reduction device and the turbine shaft in response to the exceeding of a determined resistant torque called uncoupling torque exerted by the reduction device on the turbine shaft.

2. The turbomachine according to claim **1**, wherein the uncoupling device includes at least one fuse connecting element which is interposed between the reduction device and the turbine shaft and which is configured to be broken when subjected to the resistant uncoupling torque exerted by the speed reduction device on the turbine shaft.

3. The turbomachine according to claim **2**, wherein the fuse element comprises a segment of an input shaft of the reduction device bound to the shaft of the turbine, said segment being configured to be broken when subjected to a maximum torsional torque corresponding to the resistant uncoupling torque.

4. The turbomachine according to claim **2**, wherein an input shaft of the reduction device includes a tubular end segment which is coupled with a complementary tubular end segment of the turbine shaft via at least one radial fuse connecting element configured to be broken when subjected to a shear stress corresponding to the resistant uncoupling torque.

5. The turbomachine according to claim **4**, wherein the radial fuse connecting element includes a pin which is received in a radial orifice of the end segment of the input shaft and into an orifice facing the end segment of the turbine shaft.

6. The turbomachine according to claim **2**, wherein the reduction device is coupled to the turbine shaft via a coupling with trapezoidal teeth of the curvic type, including two toothed coupling plates meshing with one another and fastened to one another via axial fuse screws forming fuse connecting elements of the uncoupling device.

7. The turbomachine according to claim **1**, wherein the fuse connecting element is configured to be broken as soon as it is subject to a resistant uncoupling torque corresponding to a resistant torque exerted by the fan on the speed

reduction device in the case of loss of at least one blade of a fan driven by said fan shaft.

8. The turbomachine according to claim **1**, wherein the fuse connecting element is configured to be broken as soon as it is subject to a resistant torque which is strictly greater than any torque corresponding to a resistant torque exerted by the fan on the speed reduction device in the case of ingestion of a bird without any blade loss by said fan.

9. The turbomachine according to claim **7**, wherein the fuse connecting element is associated with a fan including metal blades and is configured to be broken as soon as it is subject to a resistant uncoupling torque comprised between 120% and 140% of a normal torque under maximum speed conditions of the turbomachine.

10. The turbomachine according to claim **7**, wherein the fuse connecting element is associated with a fan including composite blades and is configured to be broken as soon as it is subject to a resistant uncoupling torque comprised between 130% and 170% of a normal torque under maximum speed conditions of the turbomachine.

11. The turbomachine according to claim **1**, wherein the turbomachine includes means for detecting uncoupling of the reduction device and of the turbine shaft able to control a reduction of speed of the turbine and/or a stopping of the turbomachine.

12. The turbomachine according to claim **1**, wherein the resistant uncoupling torque is greater than 50,000 N·m, and preferably comprised between 50,000 N·m and 400,000 N·m.

13. The turbomachine according to claim **1**, wherein the turbomachine includes an additional uncoupling device interposed between the reduction device and the shaft of the fan, which is configured to uncouple the reduction device and the fan shaft in response to exceeding a determined resistant torque, called uncoupling torque, exerted by the fan shaft on the reduction device.

14. The turbomachine according to claim **13**, wherein the uncoupling device includes at least one fuse connecting element which is interposed between the reduction device and the fan shaft and which is configured to be broken when it is subject to the resistant uncoupling torque exerted by fan shaft on the speed reduction device.

15. The turbomachine according to claim **14**, wherein the fuse element comprises a segment of an input shaft of the reduction device bound to the shaft of the fan, said segment being configured to be broken when it is subject to a maximum torsional torque corresponding to the resistant uncoupling torque.

16. The turbomachine according to claim **14**, wherein an output shaft of the reduction device includes a tubular end segment which is coupled with a complementary tubular end segment of the fan shaft via at least one fuse connecting radial element configured to be broken when subject to a shear stress corresponding to the resistant uncoupling torque.

17. The turbomachine according to claim **16**, wherein the radial fuse connecting element includes a pin which is received in a radial orifice of the end segment of the output shaft and in an orifice facing the end segment of the fan shaft.

18. The turbomachine according to claim **14**, wherein the reduction device is coupled to the fan shaft via a coupling with trapezoidal teeth of the curvic type, including two toothed coupling plates with trapezoidal axiafusel teeth meshing with one another and fastened to one another via axial fuse screws forming meltable connecting elements of the additional uncoupling device.

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