

AIRCRAFT BRAKING SYSTEMS

This invention relates to aircraft braking systems, and particularly to braking systems for aircraft having a plurality of friction brakes.

An aircraft brake may comprise a stack of discs slidably mounted on a non-rotating torque tube surrounding a wheel axle and mounted within a landing wheel rim. Alternate (rotor) discs are drivable by the wheel rim and the remaining (stator) discs are keyed to the torque tube. Axially directed thrust is applied to an hydraulic system to squeeze the rotor and stator discs together to apply the brake.

In advanced brake systems of this kind the discs may be of carbon, normally a carbon-carbon composite in which carbon fibres are embedded in a dense carbon matrix. Manufacture of such discs is very expensive, and it is therefore highly desirable to minimise the rate of wear of the discs in service so as to reduce the frequency of disc replacement and the average cost per landing.

According to the present invention, an aircraft braking system comprising a plurality of brakes comprises means for selectively disabling at least one of said brakes for taxiing only, said means being arranged to ensure that the disabling of said at least one of said brakes does not affect the directional stability of the aircraft when the braking system is operated.

In accordance with another aspect of the present invention there is provided an aircraft braking system comprising a plurality of brakes operable to apply a braking effect during landing, and control means responsive to at least one parameter indicative of whether the aircraft is in a landing mode or a taxiing mode and operable to selectively control said brakes whereby at least one of said brakes is disabled during a taxiing manoeuvre and only one or some of said brakes are operable to apply a braking effect during the

taxiing manoeuvre, said control means being arranged to ensure that the disabling of said at least one of said brakes and operation of only said one or some of said brakes during a taxiing manoeuvre does not affect the directional stability of the aircraft.

Preferably in an aircraft braking system in accordance with the invention and comprising at least two brakes associated with wheels on each side of an aircraft, means is provided for disabling at least one of said brakes on each side of the aircraft during taxiing.

The invention also provides a method of minimising the rate of wear of carbon discs in an aircraft braking system comprising a plurality of aircraft brakes each having a stack of carbon discs, comprising the steps of associating each aircraft brake with a corresponding wheel of the aircraft, applying an operative braking condition to all the brakes during landing of the aircraft, and applying an operative braking signal to less than all the brakes during taxiing of the aircraft, the application of said operative braking signal to less than all the brakes during taxiing being arranged to ensure that the directional stability of the aircraft is not affected.

In a braking system comprising braked wheels on the centre line of the aircraft it would be possible to disable the brakes of one or more of such wheels without affecting the directional stability of the aircraft during braking.

The invention is based on the discovery that the rate of wear of a carbon brake is dependent to a major extent on the number of braking operations effected, even though a considerable number of such operations during taxiing may dissipate relatively little energy compared with that dissipated during a landing run. Thus, for example, by providing means for disabling certain brakes of an

undercarriage during taxiing it is possible greatly to extend the wear life of the brakes on the aircraft.

By the above means those brakes disabled during taxiing will have a much extended life as determined by the amount of wearable material provided in the brake design and indicated by the brake wear pin detector compared with those brakes not disabled during taxiing. Means may be provided to disable different brakes selectively during a series of braking applications during taxiing so as to provide reasonably even wear on all of the brakes and thereby to make it possible to extend the disc replacement intervals for the whole of the braking system. Alternatively to extending the life of a brake by disabling it during taxiing the design may make use of this reduction in wear by reducing the amount of wearable material provided and hence reduce the weight of that brake.

In either kind of application as described in the preceding paragraph, braking during the taxiing operation is preferably under the control of an automatically-controlled system which does not require intervention by the pilot of the aircraft. Control of such a system may, for instance, be determined primarily by the wheel speed, the system being operative to disable certain brakes when the wheel speed is below a certain threshold level and above a certain minimum (to retain full braking when the aircraft is at rest). However, to avoid additional brake operation as the aircraft is about to come to rest the disabling of brakes may, preferably, be arranged to continue at speeds down to and including standstill. In this latter case manual or automatic override may be provided to enable the aircraft to be held at rest against full engine thrust. Means may be provided to respond to brake temperatures and the algorithms for determining which brakes should be disabled for taxiing may take into account the temperatures of each brake to ensure that, within limits set by other considerations,

- i) the temperatures of brakes are reasonably uniform across the aircraft, or

- ii) certain brakes are deliberately allowed to achieve an increased temperature (in order to take advantage of an enhanced temperature - dependent friction characteristic of the brake material), or
- iii) at least one disabled brake is brought into operation if the temperature of one or more of the remaining brakes exceeds a predetermined level.

Alternatively the system may take into account the variation in wear between all brakes across the aircraft in order to optimise the safety and maintenance procedures for these brakes.

Preferably an override capability is provided, so that if a predetermined input level at the pilot's brake pedal is exceeded all the brakes are applied as in a normal brake operating system.

During the landing run, it will be desirable for the disabling system to be inoperative, i.e. for full braking to be provided throughout the run including any period when the wheel speed falls below the threshold level mentioned above. That is, the disabling system is inoperative in a situation in which a speed below said threshold level exists as a result of a progressive reduction of speed from above said threshold level. This may be achieved by, for example a time delay actuated by a 'weight switch' which responds to the aircraft weight being imposed on the landing gear when the aircraft touches down.

One embodiment of the invention will now be described, by way of example, with reference to the accompanying drawing, which is a block schematic illustration of an aircraft braking system in accordance with the invention.

For simplicity, a system employing only two main landing gears 10,11, each with two wheels 15,16,19,20 respectively is shown. The landing gear 10 is mounted

on the left-hand side of an aircraft and the landing gear 11 on the right-hand side. The brakes, which have carbon discs, are actuated by conventional hydraulic means 25,26,27,28 via electrohydraulic valves 30,31,32,33 which are supplied with hydraulic power from a supply unit 40 through a supply line 41, a return line 42 being provided in conventional manner. The supply and return lines 40,41, and connecting lines between the valves and the brakes are shown broken to indicate the provision of various conventional system components such as hydraulic fuses which are provided but which do not require description in the present context.

Individual control of each of the electrohydraulic valves 30-33 is provided by an electronic control unit 50. This receives input from the pilot's brake pedal transducers 52, wheel speed transducers 54 and brake temperature sensors 56.

The electronic control unit 50 is arranged so that if the wheel speed is between a predetermined low level (to enable all the brakes to operate when the aircraft is stationary) and a predetermined higher level, the brakes of either the two outboard wheels 15 and 20 or the two inboard wheels 16 and 19 are disabled.

Algorithms governing the operation of the unit 50 also include requirements for the brake temperature, aircraft weight switch and other input signals from conventional sensors which may be provided. Essentially, however, the system is designed to disable the selected brakes during taxiing.

A further function of the electronic control unit 50 is to apply the disabling condition to a different pair of brakes following each brake operation during a given taxiing period. Thus the inboard brakes 16 and 19 may be disabled and the outboard brakes 15 and 20 operative during the first brake application. The system will then change to disabling the brakes

15 and 20 and rendering operative the brakes 16 and 19 on the next brake application, and so on.

By the means described above, the number of brake applications for each individual brake during taxiing will be halved. For installations having greater numbers of brakes different ratios of use:non-use of individual brakes may be chosen.

The invention is equally applicable to braking systems in which the brakes are actuated electrically rather than hydraulically.

Whilst in the embodiment described above the control of the braking system is primarily dependent on wheel speed, use may be made of other parameters to identify to the control unit the phase of flight the aircraft is entering or has already entered (ie taxiing out, take-off, in flight, landing, taxiing-in or stationary on the ground).

In aircraft braking systems there are usually more than the one system described in the embodiment above. These multiple systems may operate as individual systems where not all the systems are operating at any moment of time or they may act in unison, each contributing to the overall deceleration of the aircraft. In order to achieve the objectives of this invention the systems may be designed such that rather than disabling brakes during taxi a reduced number of brakes are actuated during taxi as a result of suitable selection of operating systems.

The facility to change from one pair or group of brakes to another pair or group of brakes for taxi purposes could be achieved by changing from one braking system to another braking system if each system were designed to operate all brakes for landing and take-off but only a restricted group of brakes for taxi, the restricted group of brakes being different for the two systems.

Whilst in the embodiment described above the system is arranged to apply the disabling condition

to a different pair of brakes following each brake operation during a given taxiing period in order to provide reasonably even wear on all of the brakes a braking system in accordance with the invention may alternatively be arranged always to disable the same brakes during typical taxiing. This will provide a very greatly extended wear life, but only for those brakes which are disabled during taxiing. In terms of cost, however, such a system has a distinct advantage in that the control unit can be simplified.

One method of control for the variant described in the preceding paragraph may be to provide means for responding to the brake pressure selected by the pilot, so that if a pressure under, say, half the maximum pressure is selected (as is usual during taxiing) some brakes are disabled, but if a pressure above that threshold is selected all the brakes are operated. This control system can be provided with less complexity and cost.

In a further alternative system in accordance with the invention, advantage may be taken of the substantially lower rate of wear of a carbon brake at higher temperatures than at lower temperatures. Thus for a given number of brake applications (of similar energy input) a brake will wear at a substantially lower rate during taxiing after landing, when the brakes are hot, than during taxiing before take-off, when the brakes in most cases are relatively cold. There is therefore an option to arrange the system to disable certain brakes during a taxi-out whilst retaining those brakes in operation during a taxi-in.

The importance of the saving in brake wear achieved by the invention may be appreciated if one takes into account the fact that an aircraft makes many brake applications during taxiing, before take-off and after landing, and that the consequential brake wear of a carbon brake is very significant.

The system in accordance with the invention has a further advantage in that the disabling of some brakes during taxiing provides the system with improved 'feel' for the pilot, who is enabled to apply a more gentle retardation than is the case with conventional systems in which all the brakes operate during taxiing.

CLAIMS:

1. An aircraft braking system comprising a plurality of brakes and means for selectively disabling at least one of said brakes for taxiing only, said means being arranged to ensure that the disabling of said at least one of said brakes does not affect the directional stability of the aircraft when the braking system is operated.
2. An aircraft braking system comprising a plurality of brakes operable to apply a braking effect during landing, wherein it comprises control means responsive to at least one parameter indicative of whether the aircraft is in a landing mode or a taxiing mode and operable to selectively control said brakes whereby at least one of said brakes is disabled during a taxiing manoeuvre and only one or some of said brakes are operable to apply a braking effect during the taxiing manoeuvre, said control means being arranged to ensure that the disabling of said at least one of said brakes and operation of only said one or some of said brakes during a taxiing manoeuvre does not affect the directional stability of the aircraft.
3. An aircraft braking system according to claim 2 wherein the control means is arranged to ensure that during a landing run the system for disabling of at least one brake is inoperative whereby full braking may be provided throughout the landing run.
4. An aircraft braking system according to any one of the preceding claims and comprising at least two brakes for association with wheels on each side of an aircraft, means being provided for disabling at least one of said brakes on each side of the aircraft during taxiing.
5. An aircraft braking system according to any one of the preceding claims wherein the brakes are carbon brakes.
6. An aircraft braking system according to any one of the preceding claims wherein the system is arranged



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to disable different brakes selectively during a series of braking applications during taxiing so as to tend to provide even wear on all of the brakes.

7. An aircraft braking system according to any of claims 1 to 5 wherein the system is arranged to disable the same brakes during a series of braking applications during taxiing.

8. An aircraft braking system according to any of the preceding claims wherein control of the system is determined primarily by wheel speed, the system being operative to disable certain brakes when the wheel speed is below a threshold level and above a minimum level.

9. An aircraft braking system according to any one of the preceding claims wherein the means for selectively disabling at least one of the brakes during taxiing is arranged to ensure that full braking may be provided when the aircraft is at rest.

10. An aircraft braking system according to any of the preceding claims wherein means is provided to respond to brake temperatures and to effect control of the disabling action of the system in accordance therewith.

11. An aircraft braking system according to claim 10 wherein the system is arranged to tend to provide uniform brake temperatures in all of the brakes.

12. An aircraft braking system according to claim 10 wherein the system is arranged so that certain brakes are allowed to achieve an increased temperature relative to other brakes.

13. An aircraft braking system according to claim 10 wherein the system is operable to bring at least one disabled brake into operation if the temperature of at least one of the remaining brakes exceeds a predetermined level.

14. An aircraft braking system according to any of the preceding claims and comprising means which provide an over-ride capability so that if a predetermined



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input level at the pilot's brake pedal is exceeded all the brakes are applied.

15. An aircraft braking system according to any of the preceding claims and comprising a weight switch which is actuated on touchdown and a time delay means which is actuated by the weight switch to render the brake disabling system inoperative during the landing run.

16. An aircraft braking system according to claim 6 wherein two brake application systems are provided, each brake application system being arranged to be capable of operating all brakes for landing and take-off but only a restricted group of brakes for taxiing, the brakes operated for taxiing being different in the two brake application systems, and means being provided for changing from one brake application system to the other selectively during a series of braking operations during taxiing so as to tend to provide even wear on all of the brakes.

17. An aircraft braking system according to any of the preceding claims wherein certain brakes are arranged to be operative during taxi-in and disabled during taxi-out.

18. An aircraft braking system constructed and arranged substantially as herein described with reference to the accompanying drawing.

19. A method of minimising the rate of wear of carbon discs in an aircraft braking system comprising a plurality of aircraft brakes each having a stack of carbon discs, comprising associating each aircraft brake with a corresponding wheel of the aircraft, applying an operative braking condition to all the brakes during landing of the aircraft and applying an operative braking signal to less than all the brakes during taxiing of the aircraft, the application of said operative braking signal to less than all the brakes during taxiing being arranged to ensure that the directional stability of the aircraft is not affected.



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20. A method according to claim 19 wherein there are at least two wheels on each side of the aircraft and each wheel having a brake associated therewith and at least one of said brakes on each side of the aircraft is disabled during taxiing.

21. A method according to claim 19 or claim 20 wherein at least some brakes which are operated during taxi-in are not operated during taxi-out.

22. A method according to claim 19 and substantially as hereinbefore described.

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