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(56) Documents Cited:
GB 0799951 A
FR 001003239 A
US 5863973 A
US 5273673 A
US 20150315444 A1
US 20120160963 A1

(58) Field of Search:
INT CL **B64C, B64D, B64F, C09D**
Other: **WPI; EPODOC; Patent Fulltext**

(54) Title of the Invention: **Protecting aircraft inpingement surfaces from adhesion of surface contaminants**
Abstract Title: **Protecting an aircraft from surface contaminants using a temporary coating material having Bingham plastic properties**

(57) An aircraft impingement surface 12 is coated with a material 20 having Bingham plastic properties, including a yield stress, to protect it from surface contaminants 52, such as insects or airborne debris or dirt. The yield stress may be greater than the shear stress experienced by the coating during pre-take-off manoeuvres of the aircraft. The material acts as a solid and may be adhesive or have low surface tension to capture and bind the insects or dirt. The yield stress of the material may be less than the shear stress experienced by the coating during take-off or climb of the aircraft. This results in the material flowing as a viscous liquid, carrying the insects or dirt away from a leading edge 12 or leading edge slat (fig.4B,14), for example. The benefit is reduction of turbulent flow, and therefore aerodynamic drag, arising from surface imperfections caused by the contaminants, improving fuel efficiency of the aircraft.

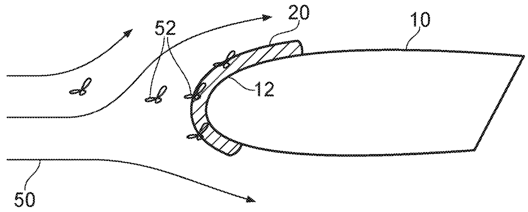

FIG. 3A

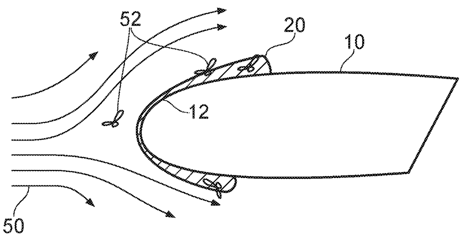

FIG. 3B

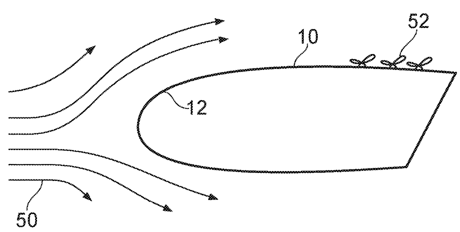

FIG. 3C

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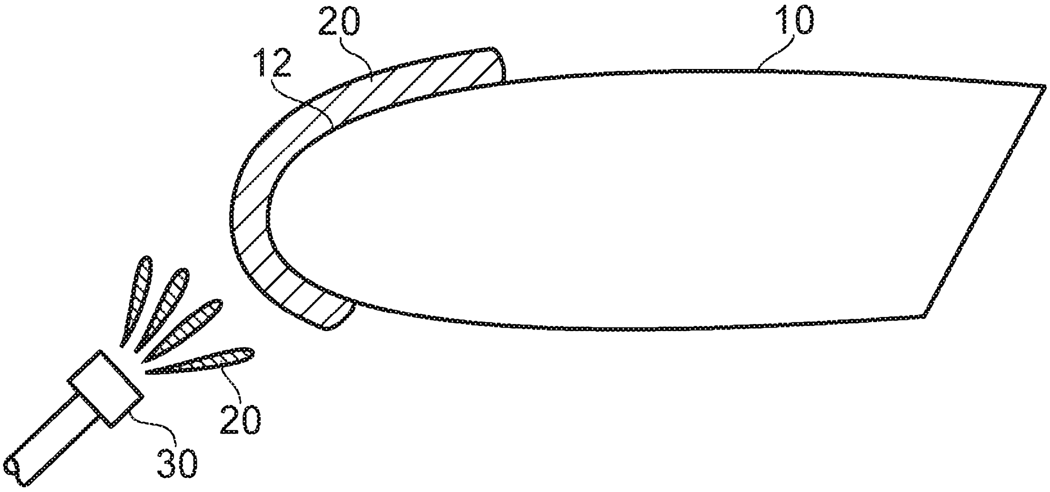

FIG. 1

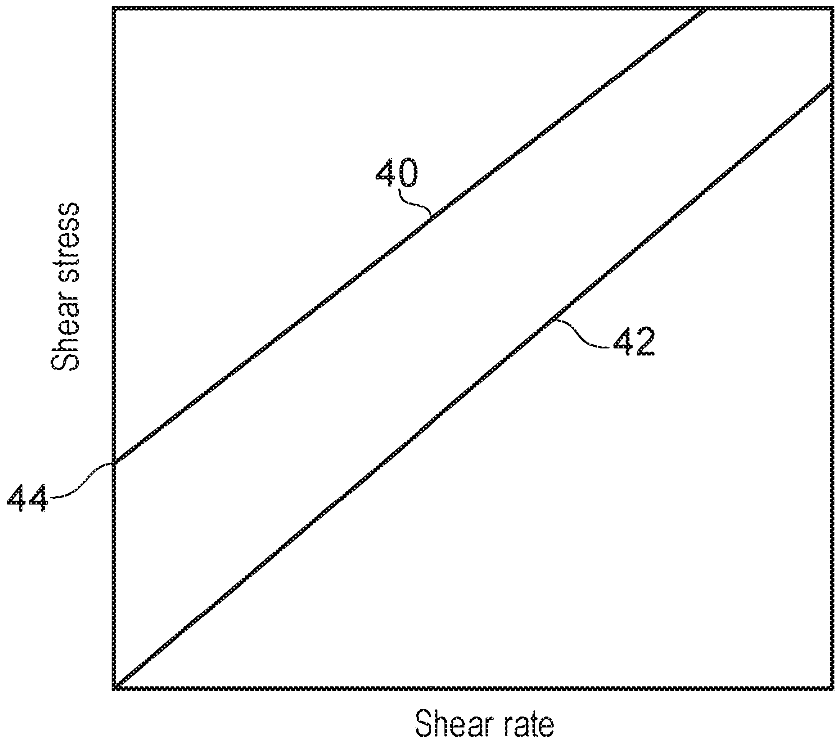

FIG. 2

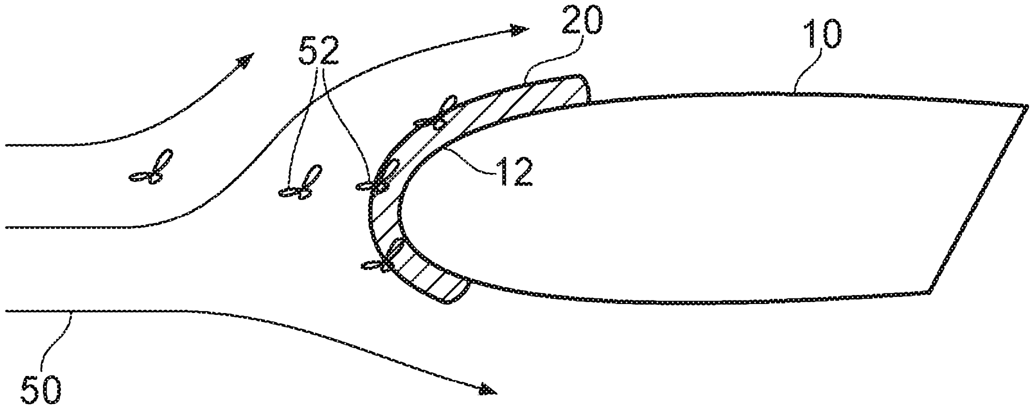

FIG. 3A

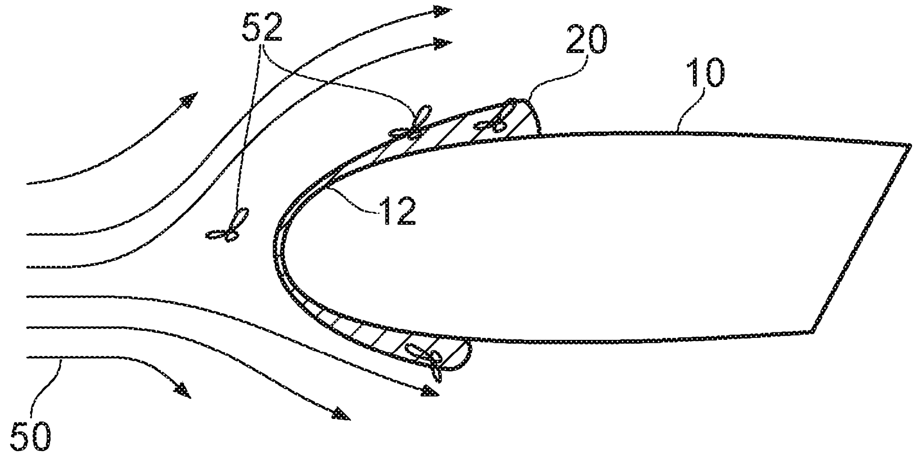

FIG. 3B

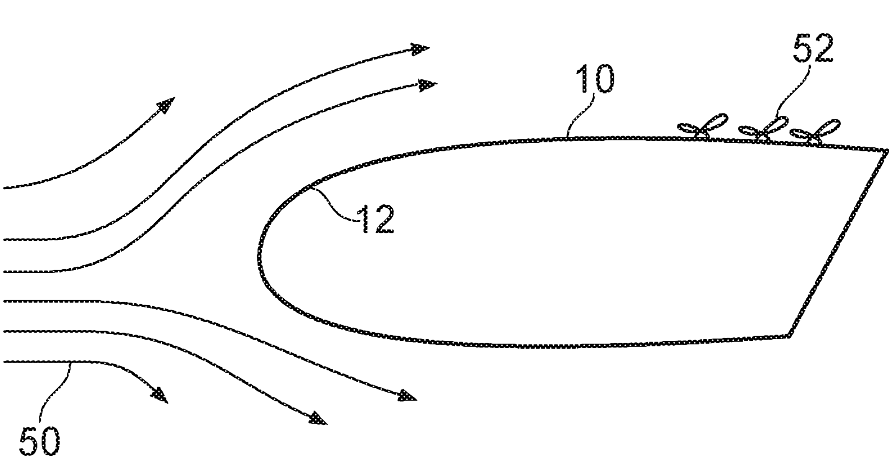

FIG. 3C

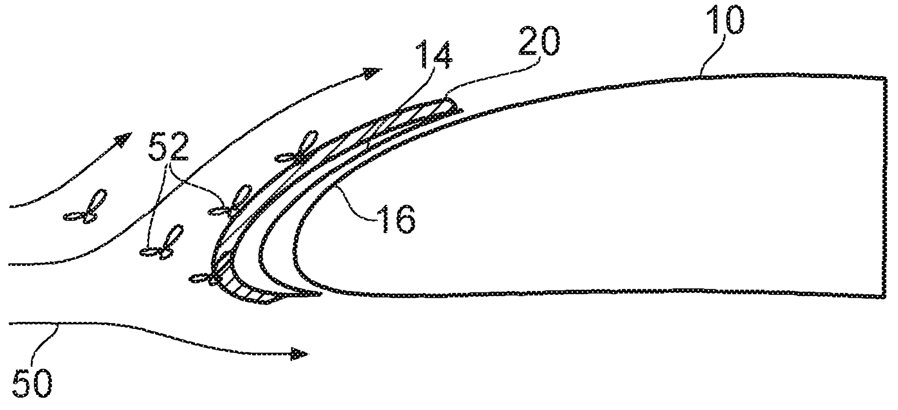

FIG. 4A

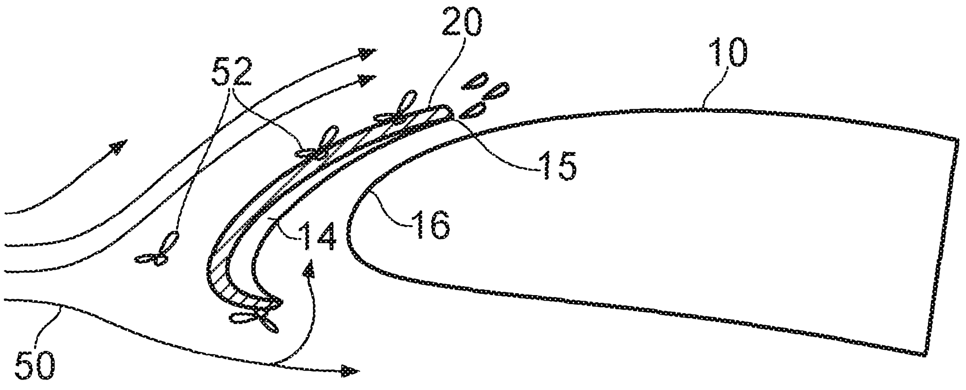

FIG. 4B

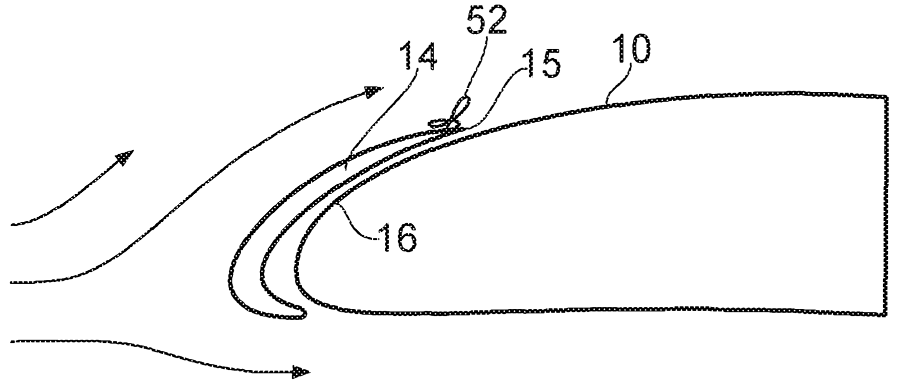

FIG. 4C

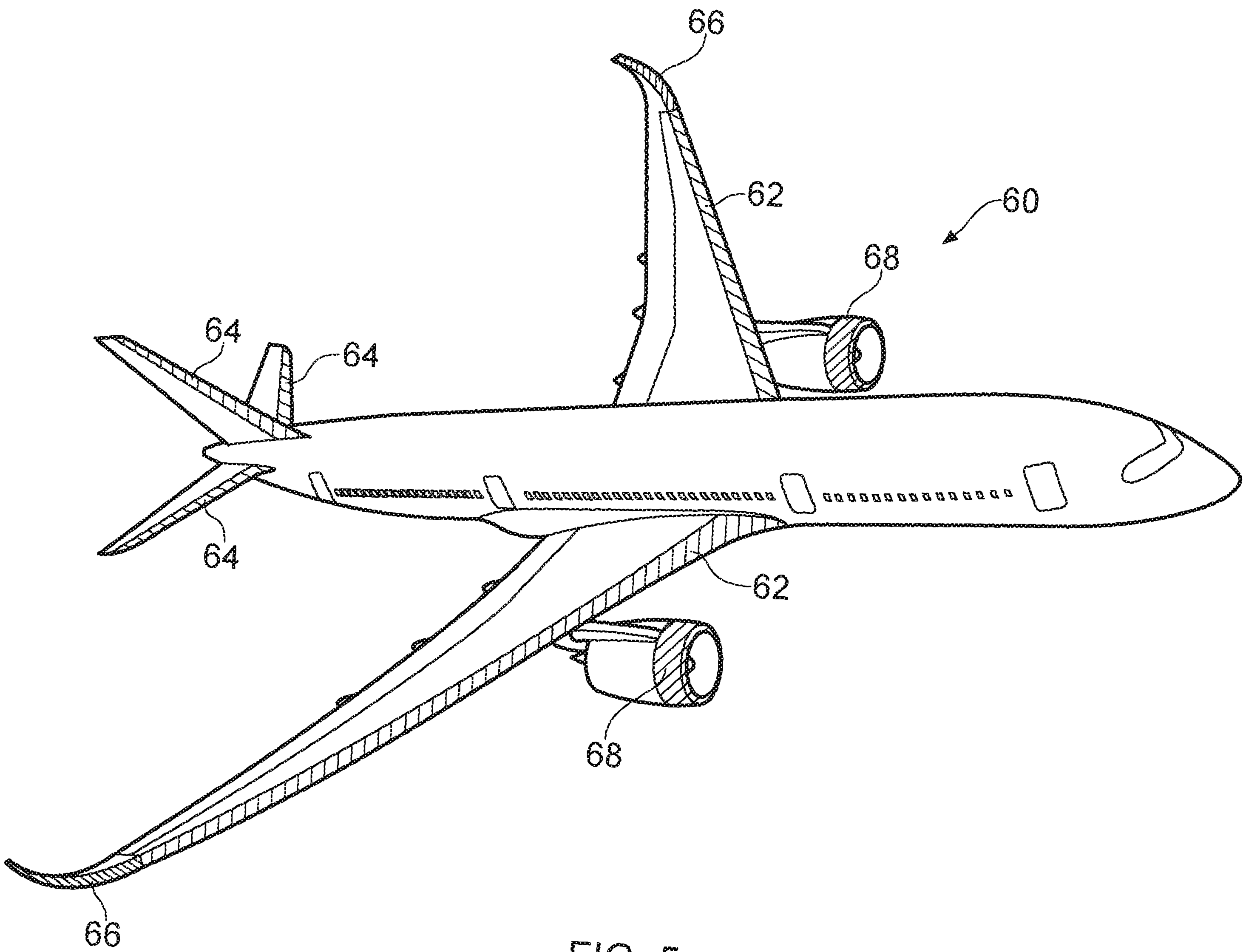

FIG. 5

PROTECTING AIRCRAFT IMPINGEMENT SURFACES FROM ADHESION OF SURFACE CONTAMINANTS

FIELD OF THE INVENTION

[0001] The present invention relates to a method of protecting an aircraft impingement surface such as a wing or empennage leading edge from build-up of surface contaminants such as insect and other airborne debris.

BACKGROUND OF THE INVENTION

[0002] The flow over an aircraft wing or empennage surface is typically turbulent, the transition from laminar flow having been induced through surface imperfections. Aircraft manufacturers strive to reduce such turbulent flow in order to reduce aerodynamic drag, and thereby reduce fuel usage. A wing, or wing leading edge, which can achieve laminar flow in flight is a key goal for aircraft designers.

[0003] If an aerofoil surface is sufficiently geometrically smooth then laminar flow can be achieved, but during normal operation at certain climatic conditions it can be expected that the aircraft leading edges will be contaminated by insect and dirt impingements during take-off. The presence of such insect and/or dirt surface contaminants is sufficient to cause transition from laminar to turbulent flow during cruise, and there is therefore a desire to provide a means of preventing build-up of such surface contaminants.

[0004] Previous solutions to this problem include the Kruger high lift device, which is deployed during take-off - at which time it collects insect and dirt debris - and is retracted during climb and cruise. Some aircraft incorporate Kruger high lift devices, but such devices are not suitable for all aircraft and in particular are difficult to retrofit to a wing incorporating a slat. They also add significant weight to the aircraft, which may negate any drag reduction benefit they provide.

[0005] An alternative solution is to allow insects and dirt to adhere to the leading edge surface and then deploy a 'bug-wiper' device to scrape the debris from the surface during flight. Such an approach is used by glider pilots, who can manually deploy such devices, but would be difficult to incorporate into a commercial aircraft and again will add weight.

SUMMARY OF THE INVENTION

[0006] At its most general the present invention provides a method of protecting an aircraft impingement surface from surface contaminants, comprising coating the impingement surface with a coating material capable of binding airborne debris, and having properties causing it to flow under shear stresses exerted by an airflow during take-off or climb. The coating material preferably has Bingham plastic properties including a yield stress.

[0007] A first aspect of the invention provides a method of protecting an aircraft impingement surface from surface contaminants, comprising coating the impingement surface with a coating material having Bingham plastic properties including a yield stress.

[0008] In this way, surface contaminants such as airborne insect and dirt debris can adhere to the coating material, and the coating material can subsequently flow from the impingement surface, taking the debris with it, when its yield stress is reached or exceeded. A Bingham plastic material is one which does not flow when subjected to shear stresses below its yield stress, but flows like a viscous fluid when subjected to shear stresses equal to or exceeding the yield stress.

[0009] As the skilled reader will appreciate, insect and dirt debris is generally only present in the atmosphere at low altitudes experienced during the pre-take-off, take-off and initial climb phases. Thus, the coating material provides a temporary coating over the impingement surface which is applied when the aircraft is on the ground, remains in place while the aircraft taxis and accelerates for take-off, and starts to flow over the impingement surface as the speed increases during the take-off or climb phase and the yield stress of the Bingham plastic material is reached. Once the aircraft enters the cruise phase the coating material has flowed away from the impingement surface, taking the surface contaminant debris with it. Thus, the impingement surface is free from surface contaminant debris during cruise, such that laminar flow may be achieved over that surface.

[0010] A particular advantage of the claimed method is that it requires no modification to the aircraft itself, and may be applied only when local conditions dictate that it is necessary. That is, the method of the invention may be used at certain airports where insects are particularly problematic, or when particular weather conditions are prevalent.

[0011] Moreover, the weight of the surface coating is minimal, and is reduced or even completely removed during the cruise flight phase as the coating material is eroded away.

[0012] The invention is particularly applicable to leading edge slats. Thus, the aircraft impingement surface may comprise a leading edge slat of a wing. The leading edge slat is preferably deployable relative to a fixed leading edge of the wing so that it is deployed during take-off and retracted during cruise. Once flow is induced in the coating material (i.e. by accelerating the aircraft until the shear stress exerted by the airflow exceeds the yield stress of the coating material), the coating material and any surface contaminant debris bound by it is transported to a trailing edge of the slat, from where it may be borne away from the wing by the air flow. That is, the coating material and bound debris may be completely removed from the slat, and preferably from the whole wing. In this way, laminar flow may be achieved over the leading edge slat during cruise.

[0013] The coating material is arranged to collect, or bind, insect or other airborne debris that comes into contact with it. Thus, the coating material may have adhesive properties such that it is capable of binding airborne debris. Also, the coating material may have sufficiently low surface tension properties to be capable of binding airborne debris.

[0014] The method preferably includes the step of accelerating the aircraft until an airflow over the impingement surface causes the coating material to be subjected to a shear stress that is equal to or greater than the yield stress. The step of accelerating the aircraft may include take-off or climb of the aircraft. Thus, the coating material - along with any debris bound thereto - may be arranged to enter its viscous/plastic flow phase only once the aircraft is sufficiently high in the atmosphere that there is little or no airborne debris.

[0015] The yield stress is preferably less than a shear stress experienced by the coating material during take-off or climb of the aircraft. In this way, the contaminated coating material may be arranged to flow only once the aircraft is sufficiently high in the atmosphere that there is little or no airborne debris.

[0016] The yield stress of the coating material is preferably greater than a shear stress experienced by the coating material during pre-take-off manoeuvres of the aircraft. Thus, the coating material does not flow prior to take-off, and therefore provides a uniform coating over the impingement surface for adhering insects and other debris carried in the air flow during the pre-take-off flight phase.

[0017] The impingement surface may comprise a leading edge of a wing or empennage of the aircraft. In some embodiments the impingement surface comprises a leading edge slat. By preventing surface contamination of a wing leading edge and/or leading edge slat it may be possible to achieve laminar flow over those critical regions.

[0018] A second aspect of the invention provides an aircraft having an impingement surface, the impingement surface being coated with a coating material having Bingham plastic properties including a yield stress.

[0019] The second aspect also provides the advantages discussed above in relation to the first aspect. All features, both essential and optional, discussed in relation to the first aspect may also be applied to the second aspect.

[0020] All optional and/or desirable features described above or below in relation to aspects or embodiments of the invention may be applied to any claimed aspect of the invention either singly, or in any combination.

BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Embodiments of the invention will now be described with reference to the accompanying drawings, in which:

[0022] Figure 1 shows a schematic cross-sectional view of a wing leading edge being coated with a coating material according to an embodiment of the invention;

[0023] Figure 2 is a graph illustrating the relationship between shear stress and shear rate for both a Bingham plastic liquid and a Newtonian liquid;

[0024] Figures 3A, 3B and 3C show schematic cross-sectional views of a wing leading edge coated with a coating material according to an embodiment of the invention during the pre-take-off phase (Figure 3A), take-off and initial climb (Figure 3B), and cruise (Figure 3C);

[0025] Figures 4A, 4B and 4C show schematic cross-sectional views of a wing leading edge having a deployable leading edge slat coated with a coating material according to an embodiment of the invention during the pre-take-off phase (Figure 4A), take-off and initial climb (Figure 4B), and cruise (Figure 4C); and

[0026] Figure 5 shows a schematic perspective view of an aircraft suitable for use in an embodiment of the present invention, with possible debris impingement zones identified.

DETAILED DESCRIPTION OF EMBODIMENT(S)

[0027] As illustrated in Figure 1, an embodiment of the invention comprises coating the leading edge 12 of a wing 10 (or empennage, or other aircraft debris impingement surface) with a coating material 20. The coating material 20 is sprayed on to the leading edge 12 via a hose 30, but in other embodiments may be applied by any appropriate method. The skilled reader will understand that the figures are not to scale such that the thickness of the coating material 20 layer is exaggerated in Figures 1, 3 and 4 for clarity, and that the actual thickness of the coating material 20 layer may be very small. For example, the thickness of the coating material 20 may range between approximately 1mm and approximately 1cm.

[0028] The coating material 20 comprises a Bingham plastic fluid, such fluids resisting flow in response to a shear stress until that shear stress reaches or exceeds a yield stress of the fluid. That is, a Bingham plastic behaves like a solid at low shear stresses but flows as a viscous fluid at shear stresses which equal or exceed the yield stress of the material.

[0029] This concept is illustrated in the graph shown in Figure 2 in which the line 40 represents the relationship between shear stress (vertical axis) and shear rate (horizontal axis) of a Bingham plastic, and the line 42 represents the corresponding relationship for a Newtonian liquid such as water. As the skilled reader will understand, shear stress in this context is a measure of the stress applied to a fluid to tend to make it flow, and shear rate is a measure of how the velocity of that flow changes with distance. The point at which the line 40 intersects the vertical axis (shear stress) represents the yield stress 44 of the Bingham plastic, and the gradient, or slope, of this line represents the plastic viscosity.

[0030] The coating material 20 is also able to capture, or bind, flying insects or other airborne debris that makes contact with the coating material layer. The material may have adhesive properties, or be tacky or sticky, to achieve this. Alternatively, the coating material 20 may have sufficiently low surface tension properties to enable such airborne debris to be entrapped, or restrained, by the material.

[0031] Figures 3A-3C show the wing 10 of Figure 1 during pre-take-off manoeuvres (Figure 3A), take-off (Figure 3B), and climb/cruise (Figure 3C). During pre-take-off manoeuvres the coating material 20 that coats the leading edge 12 remains unaffected by the airflow 50 over the wing, since the air flow is not sufficiently fast to induce a shear stress within the coating material 20 that is higher than the yield stress of that material. Thus, the coating material 20 does not flow over the wing surface. Flying insects and other debris 52 carried in the airflow 50 adhere to the coating material 20 so that they are bound by the coating material layer and thus transported with the wing 10.

[0032] As the aircraft accelerates for take-off (Figure 3B) the velocity of the air flow 50 is increased to the point that it induces a shear stress within the coating material 20 that is higher than the yield stress. Thus, the coating material 20 begins to flow towards the trailing edge of the wing (to the right in Figure 3B), and the adhered insects 52 and other debris are transported aftwards with the material flow. The point at which the yield stress is exceeded may occur soon after take-off or during the initial climb phase, but in any event will occur before the cruise phase is reached.

[0033] Eventually all of the coating material 20 flows away from the leading edge 12 so that the flies and other debris 52 accumulate at a position that is approximately 10-25% along the wing chord, as illustrated in Figure 3C. This stage is typically achieved prior to, or during, the climb flight phase such that during cruise the leading edge 12 is uncontaminated by either the coating material 20 or the flying insects and other airborne debris 52. Thus, it may be possible to achieve laminar flow over the forwardmost 10-25% chordwise extent of the wing 10.

[0034] It is possible that the coating material 20 and debris bound therein will be entirely, or mostly, eroded from the full chordwise extent of the wing 10 - or at least a chordwise extent greater than 25% - during the aircraft's flight. For example, rain droplets or ice crystals may erode any accumulated coating material deposits.

[0035] In some embodiments the coating material 20 is formulated to, or includes an element that is formulated to, dissolve insects or other debris bound by (or adhered to) the coating material 20. For example, the coating material 20 may have an enzyme property. In this way the coating material 20 may be applied to aircraft surfaces which are already contaminated with insect debris so that the coating acts to dissolve that debris.

[0036] Figures 4A-C illustrate an embodiment which is in most respects identical to the embodiment shown in Figures 1 and 3A-C, and uses the same reference numerals for ease of comparison, but with the notable difference that the impingement surface of the wing 10 is a leading edge slat 14 that is deployable relative to a fixed leading edge 16. The slat 14 is retracted during pre-take-off manoeuvres (Figure 4A) and during cruise (Figure 4C), but is deployed forwardly and downwardly during take-off and the initial climb phase (Figure 4B) to increase lift.

[0037] The slat 14 is coated with a layer of the coating material 20 described above in relation to the embodiment shown in Figures 1 and 3A-C. Thus, the coating material 20 has Bingham plastic properties including a yield stress that is higher than shear stresses exerted by the air flow during pre-take-off manoeuvres (Figure 4A) such that the material 20 does not flow during this flight phase. As the aircraft accelerates for take-off and the initial climb phase (Figure 4B) the air flow speed increases and the shear stresses exerted on the coating material 20 accordingly increase also. The material properties are selected such that the shear stresses exerted during this flight phase (or at least prior to the cruise flight phase) exceed the yield stress and the layer of coating material 20 begins to flow aftwards. Thus, flying insects and other airborne debris 52 that have adhered to the coating material 20 during the pre-take-off manoeuvre, take-off and initial climb phases are carried with the flowing material 20 towards the trailing edge 15 of the slat 14.

[0038] In time, the material 20 and the debris 52 it retains are either jettisoned into the air flow from the slat trailing edge 15 (as illustrated in Figure 4B), or accumulate at the trailing edge 15 (as illustrated in Figure 4C). Thus, the slat 14 is either fully or substantially clear of material 20 and the debris 52 it retains during cruise (Figure 4C), so that laminar flow over the slat may be achieved in this flight phase.

[0039] Figure 5 illustrates possible impingement surfaces of an aircraft 60 to which the present invention may be applied. The identified impingement surfaces include the wing leading edges 62, empennage leading edges 64, wing tips 66 and engine cowlings 68.

[0040] Where the word 'or' appears this is to be construed to mean 'and/or' such that items referred to are not necessarily mutually exclusive and may be used in any appropriate combination.

[0041] Although the invention has been described above with reference to one or more preferred embodiments, it will be appreciated that various changes or modifications may be made without departing from the scope of the invention as defined in the appended claims.

Claims

1. A method of protecting an aircraft impingement surface from surface contaminants, comprising coating the impingement surface with a coating material having Bingham plastic properties including a yield stress.

2. A method according to claim 1, including the step of accelerating the aircraft until an airflow over the impingement surface causes the coating material to be subjected to a shear stress that is equal to or greater than the yield stress.

3. A method according to claim 2, wherein the step of accelerating the aircraft includes take-off or climb of the aircraft.

4. A method according to any of claims 1 to 3, wherein the yield stress is less than a shear stress experienced by the coating material during take-off or climb of the aircraft.

5. A method according to any of claims 1 to 4, wherein the yield stress of the coating material is greater than a shear stress experienced by the coating material during pre-take-off manoeuvres of the aircraft.

6. A method according to any of claims 1 to 5, wherein the impingement surface comprises a leading edge of a wing or empennage of the aircraft.

7. A method according to any of claims 1 to 6, wherein the impingement surface comprises a leading edge slat.

8. An aircraft having an impingement surface, the impingement surface being coated with a coating material having Bingham plastic properties including a yield stress.

9. An aircraft according to claim 8, wherein the yield stress of the coating material is less than a shear stress experienced by the coating material during take-off or climb of the aircraft.

10. An aircraft according to claim 8 or claim 9, wherein the yield stress of the coating material is greater than a shear stress experienced by the coating material during pre-take-off manoeuvres of the aircraft.

11. An aircraft according to any of claims 8 to 10, wherein the impingement surface

comprises a leading edge of a wing or empennage of the aircraft.

12. An aircraft according to any of claims 8 to 11, wherein the impingement surface comprises a leading edge slat.

Intellectual Property Office

Application No:	GB1708382.5	**Examiner:**	Mr Keir Howe
Claims searched:	1-12	**Date of search:**	8 November 2017

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-12	US2015/315444 A1 (CHAUHAN et al.) See whole document, noting non-Newtonian fluid layer applied to aircraft
X	1-12	US5273673 A (ASHRAWI & COFFEY) See whole document noting aircraft coating composition exhibiting a highly pseudoplastic rheology.
X	1-12	US5863973 A (CARDER et al.) See whole document, noting coating applied to aircraft which permits windshear-induced removal during take-off.
A	-	GB799951 A (GOODRICH CO) See whole documents, noting a variety of compositions having Bingham plastic properties.
A	-	US2012/160963 A1 (STENZEL et al.) See abstract and paragraph 51 in particular, noting coating for protection of aircraft against insects or ice, intended to detach during flight.
A	-	FR1003239 A (SNCASO) See whole document noting coating for aircraft to protect it from insects, which melts during flight.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC[X] :

Worldwide search of patent documents classified in the following areas of the IPC

B64C; B64D; B64F; C09D

The following online and other databases have been used in the preparation of this search report

WPI; EPODOC; Patent Fulltext

International Classification:

Subclass	Subgroup	Valid From
B64F	0005/30	01/01/2017
B64F	0005/40	01/01/2017