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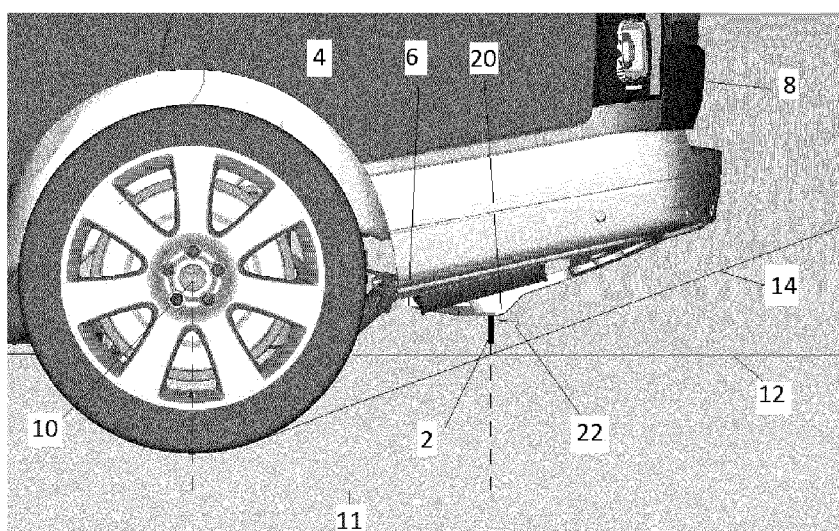


Fig. 1

(57) Abstract: Embodiments of the present invention provide an airflow displacement apparatus, a vehicle and a method for reducing soiling of a vehicle. Embodiments of the invention comprise an airflow displacement apparatus configured to be deployed on a vehicle underbody, the airflow displacement apparatus protrudes downward from the underbody so that when the vehicle is in motion, the airflow exiting from the vehicle underbody is altered by the airflow displacement apparatus, to reduce soiling on the rear of the vehicle by dirt entrained in the airflow, compared to soiling for a vehicle without an airflow displacement apparatus.



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APPARATUS AND METHOD FOR REDUCING SOILING OF A VEHICLE

TECHNICAL FIELD

5 The present disclosure relates to apparatus and a method for reducing soiling of a vehicle, particularly, but not exclusively, to an airflow displacement apparatus, to a vehicle, to a use of an airflow displacement apparatus and to a method for reducing soiling on the rear of a vehicle. Aspects of the invention relate to an airflow displacement apparatus, to a vehicle, to a use of an airflow displacement apparatus and to a method for reducing soiling on the rear of a vehicle.

BACKGROUND

10 Vehicles driving in wet or dirty conditions are often subject to soiling, particularly on the rear portion of the vehicle. This is because dirt or water is sprayed from vehicle tyres or picked up in the airflow moving around the vehicle. Some dirt particles, particularly smaller dirt particles, or water spray can become entrained into the airflow behind the vehicle as it moves forwards. The dirt or spray is then circulated in a wake behind the vehicle where it can be deposited onto the rear of the vehicle. It will also be appreciated that dirt or spray may be deposited on other surfaces of the vehicle.

20 One way to mitigate against soiling is to provide mud flaps which cover a portion of the wheel to reduce the water or dirt that is thrown directly from the tyres, or thrown up from the ground when the tyres pass through standing water. This however, has little or no effect on the spray or dirt particles that become entrained into the wake.

25 Another way to mitigate against soiling is to shape the body of the vehicle to minimise the size of wake left behind the vehicle. This approach however is often not possible or ineffective owing to other design constraints on body shape, in particular, for sports utility vehicles (SUVs) or other square-backed vehicle body types, which inherently have the highest incidence of soiling. Furthermore, owing to design constraints, the reduction of the wake size achievable by this approach is often small.

30 Another way to mitigate against soiling is to provide an aerofoil structure under the body of the vehicle. Such devices use increased pressure on the top surface and rear portions of the aerofoil to direct airflow downwards. Airflow over the top of the aerofoil and airflow over the aerofoil are smoothly combined rearward of the aerofoil, to minimise separation of airflow from the vehicle underbody. However, the efficacy of these devices may be limited, especially

when applied to square-backed vehicle body types. It also requires the apparatus to be relatively large, rigid and to extend substantially along the whole width of the vehicle, in order for it to have a noticeable effect on soiling.

- 5 It is an object of embodiments of the invention to address one or more of the problems of the prior art.

SUMMARY OF THE INVENTION

- 10 Aspects and embodiments of the invention provide an airflow displacement apparatus, a vehicle, a use of an airflow displacement apparatus and a method for reducing soiling on the rear of a vehicle as claimed in the appended claims.

- 15 According to an aspect of the invention there is provided an airflow displacement apparatus for the underbody of a vehicle, the airflow displacement apparatus comprising a body and an attachment portion to attach the airflow displacement apparatus to the underbody of a vehicle to be deployed in an operative configuration. The airflow displacement apparatus in the operative condition being adapted to protrude downward from the underbody, so that when the vehicle is in motion, the airflow transmitted along the centre of the vehicle underbody is altered by the airflow displacement apparatus, so that the airflow that exits from the rear of the vehicle underbody is suppressed from forming a vortex proximal to the rear surface of the vehicle, to reduce soiling on the rear of the vehicle by dirt suspended in the airflow, compared to soiling for the vehicle without the airflow displacement apparatus.

- 25 Spoilers are known apparatus, typically used on the top of vehicles to 'spoil' airflows over the vehicle body. They are predominantly used to increase downforce on a vehicle or to increase a vehicle's grip on the road surface. They are also used on some body types to reduce drag. The airflow displacement apparatus of the present invention, however, alters the airflow exiting from the underbody of the vehicle, and in particular, may alter the airflow moving approximately parallel to the centreline of the vehicle. By providing an airflow displacement apparatus that can be deployed in an operative configuration that protrudes downward from the vehicle underbody, the formation of vortices proximal to or against the rear surfaces of the vehicle body may be suppressed. In particular, suppressing vortices which form close to the road surface which tend to recirculate dirty air. Suppression may include, for example, displacing the vortices downward or rearward from the rear surfaces of the vehicle, preventing vortices from forming or reducing the diameter, magnitude or the amount of air in the vortex. By suppressing the airflow exiting from the vehicle underbody from forming vortices proximal to

the vehicle body, the soiling on the rear surface of the vehicle may be reduced. This may occur partly because circulation of the airflow containing dirt from the road surface against the rear surface of the vehicle is reduced. By suppressing vortices proximal to the rear surfaces formed from air exciting the vehicle underbody, an increased amount of air flow from over the top of the vehicle may circulate against the rear surfaces instead. Airflow from over the top of the vehicle may contain less dirt and so reduce the soiling on the rear surface of the vehicle.

The inventors have found that by using an airflow displacement apparatus on the underbody of a vehicle, a significant reduction of soiling on the rear of the vehicle may be achieved. The distribution of the soiling pattern is largely affected by the airflow behind the rear of the vehicle. Using an airflow displacement apparatus on the underbody may also rotate the rear wake streamlines to a downward direction into the rear body, i.e. directing more air from the top of the vehicle into the wake proximal to the rear of the vehicle.

In an embodiment, the airflow displacement apparatus may be configured so that when the airflow displacement apparatus is in an operative configuration, the airflow displacement apparatus alters or influences the airflow under the underbody of the vehicle. The airflow displacement apparatus may alter or influence the airflow by creating a local region of higher pressure in front of the airflow displacement apparatus. The airflow displacement apparatus may alter or influence the airflow by creating a region of low airflow velocity immediately rearward of the apparatus. The airflow displacement apparatus may alter or influence the airflow by creating a region of high static pressure immediately behind the apparatus.

In embodiments, the airflow displacement apparatus may direct airflow from in front of the airflow displacement apparatus to beneath the lowermost part of the airflow displacement apparatus. For example, where the airflow displacement apparatus is a rectangular planar member, the majority of the airflow travelling along the centre line of the vehicle may be directed downwards, to flow over the lowermost edge of the airflow displacement apparatus. This aggressive displacement of airflow may cause the airflow to separate from the vehicle body behind the airflow displacement apparatus. The separation of airflow may suppress the formation of vortices behind the vehicle and may encourage more clean air to flow from over the top of the vehicle towards the region behind the airflow displacement apparatus. In embodiments, the airflow is not split so that it flows above and below the airflow displacement apparatus as it may with an aerofoil.

In embodiments, the airflow displacement apparatus may direct a portion airflow around the lateral sides of the airflow displacement apparatus. For example, where the airflow

displacement apparatus is a rectangular planar member, some of the airflow travelling along the centre line of the vehicle may be directed around the two vertical, lateral sides of the airflow displacement apparatus. This aggressive diversion of airflow may also cause the airflow to separate from the vehicle body behind the airflow displacement apparatus. This lateral
5 diversion of air may also further direct the wakes from the rear wheels of the vehicle outwards, away from the centre line of the vehicle. This may further reduce the airflow (and also spray) entering the wake behind the vehicle.

10 The airflow exiting from along the centre of the vehicle underbody may include any airflow passing under the vehicle underbody between the vehicle wheels. The airflow exiting from along the centre of the vehicle underbody may include any airflow passing under the vehicle underbody between the vehicle wheels that is not part of the wakes around the wheels. The
15 airflow exiting from along the centre of the vehicle underbody may include any airflow attached to the underbody of the vehicle. The airflow exiting from along the centre of the vehicle underbody may include any detached turbulent airflow present along the underbody of the vehicle.

In an embodiment, the airflow displacement apparatus may be configured to be deployed in
20 an operative condition on a vehicle underbody, so that it is positioned over the centreline of the vehicle. In an embodiment, the airflow displacement apparatus may be configured to be deployed on a vehicle underbody, so that it is centred over the centreline of the vehicle

In an embodiment, the body of the airflow displacement apparatus is a planar member. This
25 shape may provide a airflow displacement apparatus with simplified ease of construction, and is a shape that may provide good displacement of airflow for reduction of soiling. In embodiments, the planar member may be rectangular.

In an embodiment, the airflow displacement apparatus is configured so that when it is
30 deployed in an operative condition on a vehicle underbody, a planar surface of the airflow displacement apparatus is orientated perpendicular or substantially perpendicular to the direction of travel of the vehicle. By orientating the airflow displacement apparatus perpendicular to the air flow or close to perpendicular, a further reduction of soiling may be
35 achieved.

In embodiments, the airflow displacement apparatus may comprise a planar surface, with sharp edges at the perimeter of the planar surface to induce flow separation. In embodiments,

the sharp edges may be edges with a thickness between 1mm and 15mm. In embodiments where the body of the airflow displacement apparatus is a planar member, the thickness of the edges may be the thickness of the planar member.

- 5 In an embodiment, the body of the airflow displacement apparatus may be formed from a flexible material with sufficient stiffness to provide from the underbody at high speeds and be deformable to ground contact. This may provide a spoiler with improved resistance to striking from ground objects, for example, if the vehicle is used off-road. This may also further improve resistance to striking if the airflow displacement apparatus protrudes to, or beyond the ground
10 line and/or departure line of the vehicle.

In an embodiment, the airflow displacement apparatus may be configured to be releasably or movably attached to the underbody of the vehicle. This may provide a spoiler that can be easily removed or deployed depending on the user's need for reduction of soiling.

- 15 In an embodiment, a spoiler of an aspect of the invention may be used for reducing the soiling of the rear of a vehicle.

In an aspect of the invention, a vehicle may comprise a spoiler of an aspect of the invention.

- 20 In an embodiment, a spoiler of the invention may deployed in an operative condition on a vehicle underbody. Wherein, the airflow displacement apparatus may protrude from the underbody between 5 and 80mm, or between 10 and 60 mm, or between 20 and 40mm, or a range with any combination of the aforesaid values. A protrusion of this amount may provide
25 the improved reduction of soiling.

- In an embodiment, the airflow displacement apparatus may be positioned to be deployed over the centreline to extend laterally into to the wakes produced by the rear wheels and/or the front wheels. The airflow displacement apparatus may be configured so as to re-direct the
30 wakes of the rear wheels towards the lateral sides of the vehicle. This position may cause an increase of airflow velocity in between the airflow displacement apparatus and wheels and an increase of static pressure behind the airflow displacement apparatus which may push the wheel wakes further outboard.

- 35 In an embodiment, the airflow displacement apparatus may be deployed on a vehicle underbody to protrude beyond the ground line, wherein the ground line is a line or plane parallel to the road surface and coincident with the lowest rigid component of the underbody.

In an embodiment, the airflow displacement apparatus may be deployed on a vehicle underbody, to protrude beyond the departure line, wherein the departure line is a line or plane from the points where the rear tyres contact the road to the rearmost portion of the vehicle.

- 5 The angle the departure line forms with a horizontal line is known as the departure angle. The departure angle is the maximum angle a vehicle can achieve when moving from horizontal ground, over an obstacle or up an incline, without the rear of the vehicle contacting the ground.

- 10 In an embodiment, the airflow displacement apparatus may be positioned over the centreline of the vehicle. In an embodiment, the airflow displacement apparatus may be centred over the centreline of the vehicle. This position may further reduce soiling.

- 15 In an embodiment, the airflow displacement apparatus may be deployed between the rear wheels, of a vehicle or rearward thereof. In an embodiment the airflow displacement apparatus may be positioned or deployed between 0 cm and the rear most point of the vehicle underbody, or between 0 cm and 100 cm rearward of the rear axle, or between 20 cm and 80 cm rearward of the rear axle, or between 40 cm and 60 cm rearward of the rear axle, or between any combinations of the aforesaid end points. Any of these positions may direct airflow to pass between the wheels and the airflow displacement apparatus, which may also
20 cause an increase the airflow parallel to and rearward of the wheels and may also direct the wheel wakes outward, which may further lower spray from the wheels.

- 25 In an embodiment, a vehicle may comprise an airflow displacement apparatus wherein, the airflow displacement apparatus is incorporated into or formed by the shape of another a component of the underbody of the vehicle. This may provide a lower cost way of providing a vehicle with an underbody spoiler or an easier method of manufacturing a vehicle with an underbody spoiler.

- 30 In an embodiment, a vehicle may comprise an airflow displacement apparatus wherein, the airflow displacement apparatus is deployed on a battery box of the underbody of a vehicle. For some vehicles, the battery box may provide a straightforward location for attaching the airflow displacement apparatus to the underbody, and may also be a location which may which provide further improved reduction of soiling.

- 35 In an embodiment, a vehicle may comprise an airflow displacement apparatus wherein, the vehicle also comprises a spoiler mounted on the top line of the vehicle, wherein the spoiler mounted on the top line is configured to promote airflow over the rear window of the vehicle.

This combination of spoilers increase airflow locally over the rear window of the vehicle from the top of the vehicle; and may provide additional reduction of soiling by further lowering the position of the wake behind the vehicle.

- 5 In an embodiment, a vehicle may comprise an airflow displacement wherein, the vehicle comprises a rear window with a rake angle between 40° and 90° , or between 45° and 80° , or between 50° and 65° , or a range of any combination of the aforesaid angles. Use of an airflow displacement apparatus of the invention with a vehicle having an aforementioned rake angle may provide further improved reduction of soiling. The rake angle for a window may be
10 considered to be the angle a rear window makes with the horizontal. In general terms it may be considered to be the angle between the rear-most point of the body at the roof to the rear most point at the base of the car below the rear window, when measured to the horizontal.

- In an embodiment, the vehicle may have an SUV or estate body type. Use of an airflow
15 displacement apparatus of the invention with a vehicle with this body type may provide significantly improved reduction of soiling.

- According to an aspect of the invention, there is provided a method of reducing soiling on the rear of a vehicle comprising altering the airflow transmitted along the centre of the vehicle
20 underbody, to cause a reduction of soiling on the rear of the vehicle by dirt entrained in the airflow.

- In an embodiment, the method may comprise deploying an airflow displacement apparatus to a vehicle underbody (6) to protrude downward from the vehicle underbody; and wherein the
25 airflow displacement apparatus alters the airflow transmitted along the centre of the vehicle underbody.

- In an embodiment, the method may comprise deploying an airflow displacement apparatus where the airflow displacement apparatus alters the airflow transmitted along the centre of the
30 vehicle underbody so that airflow that exiting from the rear of the vehicle underbody is suppressed from forming a vortex proximal to the rear surface of the vehicle, to reduce soiling on the rear of the vehicle by dirt suspended in the airflow, compared to soiling for the vehicle without the airflow displacement apparatus.

- 35 By altering the airflow moving along the centre of the vehicle underbody and below the underbody, soiling on the rear surfaces of the vehicle may be reduced.

This may be achieved, for example, by deploying an airflow displacement apparatus to protrude downward from the underbody of the vehicle to alter the airflow or by inducing flow detachment near the rear of the vehicle. The airflow may be altered so that the airflow exiting from the vehicle underbody is suppressed from forming vortices proximal to or against the rear surfaces of the vehicle body. Suppression may include, for example, displacing the vortices rearward away from the rear surfaces of the vehicle or preventing the airflow from forming of vortices or reducing the amount of air in the vortex. By suppressing the airflow exiting from the vehicle underbody from forming vortices proximal to the vehicle body, the soiling on the rear surface of the vehicle may be reduced. By using an airflow displacement apparatus that protrudes downward from the vehicle underbody or that induces flow separation towards the rear of the vehicle, the formation of vortices proximal to or against the rear surfaces of the vehicle body may be suppressed.

Within the scope of this application it is expressly intended that the various aspects, embodiments, examples and alternatives set out in the preceding paragraphs, in the claims and/or in the following description and drawings, and in particular the individual features thereof, may be taken independently or in any combination. That is, all embodiments and/or features of any embodiment can be combined in any way and/or combination, unless such features are incompatible. The applicant reserves the right to change any originally filed claim or file any new claim accordingly, including the right to amend any originally filed claim to depend from and/or incorporate any feature of any other claim although not originally claimed in that manner.

BRIEF DESCRIPTION OF THE DRAWINGS

One or more embodiments of the invention will now be described by way of example only, with reference to the accompanying figures, in which:

Figure 1 shows a representation of an embodiment of the invention;

Figure 2 shows a representation of a vehicle without and a vehicle with an airflow displacement apparatus of the invention;

Figure 3 shows a representation of an embodiment of the invention.

Figure 4 shows a representation of a vehicle without and a vehicle with an airflow displacement apparatus of the invention;

Figure 5 shows a representation of a vehicle without and a vehicle with an airflow displacement apparatus of the invention; and

- 5 Figure 6 shows a representation of a vehicle without and a vehicle with an airflow displacement apparatus of the invention.

DETAILED DESCRIPTION

- 10 As used herein, the term “rearward” refers to the direction opposite to the normal forward direction of travel of the vehicle, i.e. away from the rear surface of the vehicle. As used herein, “rear” refers to the tail end of the vehicle, which is the end facing the rearward direction. As used herein, the term “rear surfaces” refers to the surfaces of the body of the vehicle at the rear of the vehicle which are facing the rearward direction.

15

As used herein, the term “spoiler” includes any apparatus on an external surface of a vehicle to alter or ‘spoil’ the airflow near to the spoiler. The airflow displacement apparatus may alter airflow by providing an obstacle that causes the airflow to change path, and thus may be considered a spoiler.

20

As used herein, the term “airflow displacement apparatus” may include any apparatus on an external surface of a vehicle that displaces or diverts airflow so that it is prevented from re-joining its original path. Thus for example, baffles or airflow dams mounted to a vehicle to obstruct airflow may be considered airflow displacement apparatus. However, aerofoil type
25 spoilers, which split airflow then restore it to its original path do not permanently displace airflow away from its original path and thus are not considered airflow displacement apparatus. In embodiments, the airflow displacement apparatus may be characterised by inducing flow separation immediately after the apparatus. In embodiments, the airflow displacement apparatus may be characterised by low or zero airflow velocity immediately behind the
30 apparatus.

As used herein, the term “underbody” refers to the surface beneath the vehicle facing the road.

- 35 As used herein, the term “protrudes” refers to the distance from the immediate surroundings of the underbody that the airflow displacement apparatus extends into the airflow beneath the underbody.

As used herein, the term “deployed” in reference to an airflow displacement apparatus includes positioning the airflow displacement apparatus in the airflow under the vehicle underbody. Deployed may include deploying by attaching an airflow displacement apparatus and/or by moving the airflow displacement apparatus in to a position or operative configuration to alter the airflow, from a position where it does not alter the airflow.

As used herein, the term “retracted” in reference to an airflow displacement apparatus includes but is not limited to moving an airflow displacement apparatus out of the airflow under the vehicle underbody, and/or at least partially reducing the amount a spoiler protrudes into the airflow.

As used herein, the term “motion” refers to the forward direction of the vehicle. Motion may also specifically refer to the condition where the forward direction is greater than 20 km/h or 30 km/h or 40 km/h or 50 km/h or 60 km/h or 70 km/h or 80 km/h or 90 km/h or 100 km/h or 110 km/h or 120 km/h.

As used herein, the term “centre of vehicle underbody” includes but is not limited to the region on the vehicle underbody excluding the wheels. “Centre of vehicle underbody” may be considered to be the region between the suspension arms on the underbody of the vehicle. “Centre of vehicle underbody” may be considered to be the region of the vehicle underbody within 5 cm, 10 cm, 15 cm, 30 cm, 40 cm, 50 cm, 70 cm or 80 cm either side of the centreline.

As used herein “airflow transmitted along the centre of the vehicle underbody” includes airflow that passes underneath at least a portion of the centre of the vehicle underbody. This may include only airflow that flows within 15 cm, 10 cm, 5 cm or 2 cm beneath the centre of the vehicle underbody. This may include only airflow that is not part of the wakes from the wheels.

As used herein, the term “airflow that exits from the rear of vehicle underbody” includes but is not limited to airflow that has travelled under at least part of the centre of the vehicle underbody and has passed rearward out from under the centre of vehicle underbody.

As used herein, the term “supress” includes but is not limited to reducing the magnitude or diameter of a vortex, lowering the height of a vortex, moving a vortex rearward, and/or preventing the formation of a vortex.

As used herein, the term “vortex” refers to a region of airflow that rotates about a central axis.

As used herein, the term “centre of vehicle underbody” includes but is not limited to the region on the vehicle underbody excluding the wheels. “Centre of vehicle underbody” may be considered to be the region between the suspension arms on the underbody of the vehicle. “Centre of vehicle underbody” may be considered to be the region of the vehicle underbody within 5 cm, 10 cm, 15 cm, 30 cm, 40 cm, 50 cm, 70 cm or 80 cm either side of the centreline.

As used herein “airflow transmitted along the centre of the vehicle underbody” includes airflow that passes underneath at least a portion of the centre of the vehicle underbody. This may include only airflow that flows within 15 cm, 10 cm, 5 cm or 2 cm beneath the centre of the vehicle underbody. This may include only airflow that is not part of the wakes from the wheels.

As used herein, the term “airflow that exits from the rear of vehicle underbody” includes but is not limited to airflow that has travelled under at least part of the centre of the vehicle underbody and has passed rearward out from under the centre of vehicle underbody.

As used herein, the term “supress” includes but is not limited to reducing the magnitude or diameter of a vortex, lowering the height of a vortex, moving a vortex rearward, and/or preventing the formation of a vortex.

As used herein, the term “proximal” in reference to vortices at the rear surface refers to vortices with airflow rotating against or near the rear surface of the vehicle. This may include vortices with a central axis of rotation within 2 m, 1.75 m, 1.5 m, 1.25 m, 1 m, 0.75 m, 0.5 m or 0.25 m from the rear surface of the vehicle in the rearward direction. This may include vortices with a central axis of rotation within 2 m, 1.75 m, 1.5 m, 1.25 m, 1 m, 0.75 m, or 0.5 m from the ground.

As used herein, the term “soiling” includes any deposition of a dirt on the vehicle. As used herein, the term “dirt” includes any unwanted substance that may be deposited on the vehicle. This may include but is not limited to water, mud or fine particulates. The dirt may be carried in air, in water carried in the air, in droplet or aerosol form, for example.

As used herein, the term “releasably” includes any non-permanent attachment. This may include but is not limited to means that allow attachment by hand or with tools, for example using screws, clips or other known non-permanent fastening means.

As used herein, the term “movably” includes an attachment that permits motion of the body of the airflow displacement apparatus. This may include but is not limited to rotation or sliding of the body.

5 As used herein, the term “rear stagnation point” may be considered as the point behind the vehicle where the airflow reaches zero velocity when averaged over time. The rear stagnation point is in the centre of the region of high pressure created when the recirculating air in the wake behind the vehicle is directed to the rear surface of the vehicle.

10 An airflow displacement apparatus and vehicle in accordance with embodiments of the present invention will now be described with reference to the accompanying Figures.

With reference to Figure 1, a vehicle 4 may comprise a body having a rear 8, and an underbody 6. The rear of the vehicle body is a region of the vehicle susceptible to spoiling by dirt entrained
15 in the wake behind the vehicle 4 when it moves. The rear of the vehicle 4 may comprise a rear window and body panelling. A vehicle underbody 6 may comprise an irregular surface formed from exposed components of the vehicle, or may comprise a panel, covering the underbody components of the vehicle.

20 A vehicle typically comprises a reference line or plane called the ground line. The ground line is a line, or plane, parallel to the road surface and coincident with the lowest permissible rigid part of the underbody. The height of the ground line may also define the ground clearance height of the vehicle.

25 A vehicle typically comprises a reference line or plane called the departure line. The departure line is a line, or plane, from the points in which the rear tyres contact the road to the rearmost portion of the vehicle. The angle between departure line and ground, known as the departure angle is the maximum angle the vehicle can achieve when driving over obstacles or transitioning to steep ground.

30

The term vehicle refers to any land vehicle. A vehicle 4 may include amongst others, any automobile, for example, cars, vans, lorries or other goods vehicles. The airflow displacement apparatus 2 may be deployed on a vehicle with any known body type. In particular, the airflow displacement apparatus may provide a significant reduction of soiling when fitted to a vehicle
35 with a square back, hatchback or SUV body type. A square back body type is one with a vertical rear end. A square back body type may include for example, estates and vans amongst others. Sports utility vehicle (SUV) and hatchback body types may have a near-

vertical rear window. In particular, the spoiler of the invention may provide a further reduction of soiling when deployed on a vehicle with a rear window rake angle between 40° and 90° to the horizontal, or between 45° and 80°, or between 50° and 65°, or between any combination of the aforesaid angles.

5

When a vehicle moves forwards, air is displaced and flows around the vehicle. The airflow passing under the vehicle underbody may be generally described as attached airflow, except close to within the wake of the wheels, where separated airflow may be present. The attached airflow passing under the vehicle underbody may comprise a turbulent boundary layer from the front valance panel rearward. The generally described attached under the vehicle underbody airflow may include local separations and reattachment points along the underbody, depending upon the underbody surface shape. For example, on most vehicles, typically the suspension arms or rear axle are the lowest points on the underbody and are usually uncovered, the turbulent boundary layer may separate from the body behind the suspension arms especially if the rear underbody rises from the rear axle.

10

15

A wake is a region of recirculating airflow. Wakes occur amongst others behind the wheels and behind the vehicle (the rear wake) when it is motion.

20

25

As used herein, attached airflow is airflow that has not separated from the object it is travelling over. Attached airflow may be laminar or turbulent airflow. As used herein, separated airflow is where high velocity air moving along the vehicle underbody is replaced with lower velocity recirculating air. Flow separation occurs when the flow encounters an adverse pressure gradient along a surface and the flow slows down at the surface or reverses in direction separating the higher velocity flow away from the surface. The separation contains recirculating air, airflow at lower velocities and typically lower pressures.

30

The airflow transmitted along the centre of the vehicle underbody may be considered to be any airflow passing under the vehicle underbody between the vehicle wheels. Alternatively, the airflow passing along the centre of the vehicle underbody may include an airflow passing under the vehicle underbody between either the front pair or rear pair of wheels that is not part of the wakes around the wheels. Alternatively the airflow passing along the centre of the vehicle underbody may include airflow moving approximately parallel to the centreline of the vehicle.

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With reference to Figure 1, an airflow displacement apparatus 2 is shown attached to the underbody 6, of a vehicle 4. The airflow displacement apparatus comprises a body and an

attachment means (not shown). The attachment means is for attaching the airflow displacement apparatus to on the vehicle. The airflow displacement apparatus is shown deployed behind the rear axis 10 and is centred over the centreline of the vehicle. The airflow displacement apparatus 2 is shown positioned rearward of the rear axis 10 by approximately 500 mm. The rearward distance of the airflow displacement apparatus may be calculated by measuring the horizontal separation (i.e. distance parallel to the ground or ground line) between the centre of the rear axis and the spoiler, as illustrated in figure 1, numeral 11. The airflow displacement apparatus shown in figure 1, comprises a body formed as a planar member, positioned so that it extends close to the ground line 12 and the departure line 14 of the vehicle. The airflow displacement apparatus 2 is positioned so a planar face of the spoiler is orthogonal to the air direction when the vehicle is moving forward, i.e. perpendicular to the forward direction of the vehicle 4. In this particular embodiment, the airflow displacement apparatus is shown mounted to the underbody by attaching the airflow displacement apparatus 2 to the lowermost surface of the battery box 20 of the vehicle underbody.

'Deployed' in the context of the invention includes the airflow displacement apparatus being attached integrated or mounted to the underbody. 'Deployed' also includes the airflow displacement apparatus being moved from a position where it does not spoil the airflow (for example, with the airflow displacement apparatus body parallel to the air flow) to one where it can spoil airflow (for example, with the airflow displacement apparatus body perpendicular to the airflow).

Figure 2 shows a vehicle 3 without an airflow displacement apparatus fitted, in side view A and rear view B, and a vehicle 4 with an airflow displacement apparatus 2 fitted, in side view C and rear view D. In D, the airflow displacement apparatus 2 is shown as the white rectangular region for which the longest dimension is the width and the shortest is the protrusion of the airflow displacement apparatus. Stream lines are drawn on side views A and C to illustrate the air flow that passes above and underneath the vehicle 3, 4 when it is moving forwards. As can be seen by a comparison of the stream lines between A and C, the effect of the airflow displacement apparatus 2 is to alter airflow in rear wake. The airflow displacement apparatus may achieve this by, creating a higher static air pressure in the airflow moving along the underbody of the vehicle, directly behind the airflow displacement apparatus and increasing acceleration of air to the sides and below the airflow displacement apparatus. This may suppress the airflow exiting from along the centre of the vehicle underbody from forming a vortex proximal to or against the rear surface of the vehicle. This may move the vortex rearwards from the vehicle, lower its axis of rotation, velocity of rotation or amount of airflow circulating, or prevent vortex formation. Suppression of a vortex may reduce entrained dirt in

the airflow from reaching the rear of the vehicle, or may lower the height at which entrained dirt is deposited. The airflow displacement apparatus may also separate the wakes formed behind the wheels from the rear wake. The airflow displacement apparatus may also cause increased airflow from the top of the vehicle proximal to the rear surface of the vehicle.

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The change in wake behind the vehicle may reduce entrainment of road spray in the wake and increases the amount of airflow from over the top or around the car that is circulated in the wake. This may further reduce the airflow from underneath the vehicle rising into the rear wake, thereby further reducing the amount of road spray entrained into the rear wake.

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An airflow displacement apparatus of the invention may protrude down into the higher velocity air flowing beneath the largely separated and low velocity airflow regions, which result from turbulent interactions with the underbody of the vehicle.

15 The airflow displacement apparatus 2 may be flexible, as illustrated in figure 1. The hatched lines 22, illustrate deflection of the airflow displacement apparatus, which may deflect if, for example, the vehicle drives over a high object. Because air flow speed increases the faster a vehicle is driven, a flexible airflow displacement apparatus may need to have sufficient rigidity to resist higher air speeds to maintain its position, but still be sufficiently flexible to deform
20 when in contact with an object.

A flexible airflow displacement apparatus may be achieved for example, by using an inherently flexible material, such as a rubber or other flexible polymer. Flexibility can be varied by using different thickness or by cutting grooves or other points of weakness into the material. The
25 airflow displacement apparatus may also comprise a rigid material such as a metal or polymer. The airflow displacement apparatus may be hinged to the underbody or comprise multiple hinges along its length, each hinge may act against a biasing means such as a spring to retain it in a deployed position.

30 The airflow displacement apparatus may protrude from the underbody, this may include but is not limited to protruding between 5 and 80 mm, or between 10 and 60 mm or between 20 and 40 mm, or any combination of the aforesaid values. The airflow displacement apparatus may also protrude to the ground line, or protrude beyond the ground line. The airflow displacement apparatus may also protrude to the departure line, or protrude beyond the departure line.

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The width of the airflow displacement apparatus may be between 100 mm and the width of the vehicle, or between 200 mm and 1000 mm, or between 500 mm and 300 mm, or a range

of any combination of the aforesaid values. As used herein, "width" in reference to an airflow displacement apparatus includes the total span of the body of the airflow displacement apparatus in a direction perpendicular to the direction of travel of the vehicle and parallel to the ground. Specifically, this may refer to the largest overall dimension of the airflow displacement apparatus body in some embodiments.

The body of the airflow displacement apparatus may comprise any shape capable of displacing the airflow. This may include planar members, boxes, channels or hollow members, or any combination of these. The body of the airflow displacement apparatus may additionally comprise ridges, grooves or channels to direct airflow. A planar member provides a shape that can be retracted easily to lie flat against the underbody, it can also easily be made to be flexible. The body of the airflow displacement apparatus refers to the main portion of the airflow displacement apparatus that is exposed to airflow, i.e. excluding a portion for attaching the airflow displacement apparatus to a vehicle.

Portions of the airflow displacement apparatus may be orientated, shaped or arranged differently to the rest of the body of the airflow displacement apparatus to direct airflow, for example, the airflow displacement apparatus may be configured so that a portion of the airflow is directed around the sides of the airflow displacement apparatus or towards the lateral edges of the vehicle.

The airflow displacement apparatus may be positioned anywhere on the underbody of the vehicle. The airflow displacement apparatus may be positioned between the front wheels or rear wheels, or rearward thereof. This position may permit air to pass between the wheels and the airflow displacement apparatus which may cause an increase of airflow parallel to and rearward of the wheels to direct the wheel wakes outward which may further reduce soiling. The airflow displacement apparatus may be positioned so as not to interact with turbulent airflow coming from the wheels, in particular, the rear wheels. The airflow displacement apparatus may be centred over the centreline of the vehicle or positioned laterally. The airflow displacement apparatus may be positioned between the rear axle and the rear edge of the vehicle. The vehicle may comprise one airflow displacement apparatus or more than one.

The airflow displacement apparatus attachment portion may be attached to the vehicle using any known fastening method that provides a sufficiently secure connection. The airflow displacement apparatus attachment portion may comprise fasteners or mounting points to facilitate attachment to the vehicle. Fasteners may include screws, clips, quick release systems and other known fastening systems. The vehicle may comprise a mounting point on

the underbody. Mounting points may include pins, holes (for example, for screws) or any shape that may be aligned with a corresponding shape on the airflow displacement apparatus. The airflow displacement apparatus may be attached to the vehicle permanently, or releasably so that the airflow displacement apparatus can be detached from the vehicle. The airflow displacement apparatus may also be movably attached to the vehicle underbody. Alternatively, the airflow displacement apparatus may be incorporated into a component on the underbody, for example, a battery box may be shaped so that it includes a planar member that extends below the vehicle underbody.

The airflow displacement apparatus may be configured so that it can be deployed in a position where it spoils airflow to reduce soiling, and to a position where it does not spoil airflow. The airflow displacement apparatus, may comprise an attachment portion to attach the airflow displacement apparatus to an attachment point on the vehicle. The attachment portion may enable attachment of the airflow displacement apparatus in any of the aforementioned positions. For example, the airflow displacement apparatus may be connected to the vehicle underbody with a hinge. The hinge may permit the airflow displacement apparatus to move between a position where it extends into airflow under the vehicle underbody and one where it is retracted to lie flat against the vehicle underbody. The airflow displacement apparatus or vehicle may comprise clips or any other locking mechanisms which secure the airflow displacement apparatus in either of these positions. This may improve usability allowing the airflow displacement apparatus to be deployed when reduction of soiling is required (e.g. wet road conditions), and retracted when not required, (e.g. dry conditions, or when maximum ground clearance is needed). In a similar manner, the airflow displacement apparatus may be configured to be positioned in multiple positions between one of maximum protrusion into the airflow beneath the vehicle underbody, and one of minimum protrusion thereto. This may improve usability allowing the user to match protrusion and therefore extent the airflow displacement apparatus interferes with the airflow, to the driving conditions, such as vehicle speed, or wind speed, or off-road use.

The vehicle may comprise an additional spoiler mounted on the top line of the vehicle. The additional spoiler may be shaped to promote airflow over the rear window of the vehicle. This in combination with an airflow displacement apparatus herein described may provide a significant reduction of soiling by further lowering the height of the wake behind the rear of the vehicle and thereby further lowering the amount of dirt deposited on the rear of the vehicle. Figure 3 shows an additional spoiler 302 mounted to the rearmost-top portion of a vehicle 300. The airflow displacement apparatus is shaped and positioned so that channels 301 are formed between the vehicle body and the forward facing edge of the airflow displacement apparatus.

These channels direct airflow from over the top of the vehicle downward over the rear window of the vehicle. When used in combination with an airflow displacement apparatus on the underbody of the vehicle it may provide an increase of recirculation of clean air around the upper rear surfaces of the vehicle, and a further suppression of the lower vortex.

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All of the features disclosed in this specification (including any accompanying claims, abstract and drawings), and/or all of the steps of any method or process so disclosed, may be combined in any combination, except combinations where at least some of such features and/or steps are mutually exclusive.

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Each feature disclosed in this specification (including any accompanying claims, abstract and drawings), may be replaced by alternative features serving the same, equivalent or similar purpose, unless expressly stated otherwise. Thus, unless expressly stated otherwise, each feature disclosed is one example only of a generic series of equivalent or similar features.

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The invention is not restricted to the details of any foregoing embodiments. The invention extends to any novel one, or any novel combination, of the features disclosed in this specification (including any accompanying claims, abstract and drawings), or to any novel one, or any novel combination, of the steps of any method or process so disclosed. The claims should not be construed to cover merely the foregoing embodiments, but also any embodiments which fall within the scope of the claims.

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EXAMPLES

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A SUV was subjected to rear soiling testing in a climatic wind tunnel, whereby water containing a UV tracer is sprayed onto the rear wheels or just in front of the rear wheels on a dynamometer. The test was conducted to simulate a vehicle speed of 80 km/h. In the test, water gets picked up by the wheels and generates a spray of water thrown from the tyre face that becomes entrained in the airflow passing under the vehicle. The test was run for a predetermined time after which the extent of soiling can be measured quantitatively by taking images of the rear of the vehicle under a UV source and measuring the intensity of fluorescence of the UV tracer. The intensity of the UV corresponds to an increase in depth of the water film or size of droplets. The intensity and percentage area of contamination is calculated using image processing software for specific regions of interest on the rear of the car. The higher intensity of UV, corresponds to a lighter shade on Figure 4.

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The test was repeated under identical conditions with the addition of an airflow displacement apparatus formed from a 400 mm by 40 mm aluminium plate attached to the battery box on the underbody of the vehicle. The plate was orientated so a flat face of the plate was perpendicular to the underbody airflow.

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Figure 4 demonstrates the difference in soiling between a vehicle without an airflow displacement apparatus of the invention fitted to the underbody in image A and a vehicle with an airflow displacement apparatus of the invention fitted in image B. Image B clearly shows a significant reduction of soiling compared to image A demonstrated by the lighter regions present in A. Image C and D are the images of A and B but with regions 35 and 36 to illustrate the distribution of soiling for the vehicle without the airflow displacement apparatus and the vehicle with respectively. Comparison of these regions shows that with an airflow displacement apparatus fitted, the distribution of soiling is smaller in size and lower down the rear of the vehicle, below the rear window. Furthermore, within region 36 the intensity of soiling is less compared to region 35.

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Figure 5 shows a computational fluid dynamic analysis of a vehicle with a SUV body type. Image A is of a vehicle with no spoiler 3, and image B is the same vehicle 4 with a 400 mm by 60 mm spoiler 2 and with otherwise identical conditions to image A. A CFD analysis simulated the airflow around the vehicle when it is in motion. The CFD analysis simulated a vehicle motion of 100 km/h. Image A shows underbody air flow velocity (41 is an example of a high velocity region and 42 is an example of a low velocity region). In image A, the rear wheel wakes (shown as region 43 on simplified image C) are being drawn in towards the centreline behind the vehicle, promoting interaction with the rear wake (shown as region 45 on simplified image C). By comparing image A to image B, a region of lower velocity, and higher static pressure air behind the airflow displacement apparatus can be seen on image B (shown as region 46 on simplified image D). This region also has the effect of pushing the wheel wakes 44 outwards behind the vehicle.

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Figure 6 shows CFD images from the same CFD model taken from the centreline of the vehicles. Again, image A shows a vehicle without an airflow displacement apparatus fitted 3 and image B shows a vehicle 4 with the airflow displacement apparatus fitted 2. The lines represent velocity distributions and flow paths along the centreline of the vehicle. 53 is an example of a high velocity region and 54 is an example of a low velocity region. 51 shows a vortex in the rear wake behind the vehicle. 52 shows the edge of a vortex in the rear wake behind the vehicle with an airflow displacement apparatus fitted. As can be seen by a comparison of images A and B, the position of the vortex has been displaced rearward and

reducing its diameter. Furthermore, there is an increase of airflow from the top of the vehicle 33 into the vehicle's wake 31.

CLAIMS

1. An airflow displacement apparatus for an underbody of a vehicle, the airflow displacement apparatus comprising an airflow displacement apparatus body and an attachment means to attach the airflow displacement apparatus to be deployed in an operative configuration on the underbody of a vehicle,
the airflow displacement apparatus in the operative condition being adapted to protrude downward from the underbody, to alter the airflow transmitted along the centre of the vehicle underbody when the vehicle is in motion, to suppress the airflow that exits from the rear of the vehicle underbody from forming a vortex proximal to the rear surface of the vehicle, to reduce soiling on the rear of the vehicle by dirt suspended in the airflow, compared to soiling for the vehicle without the airflow displacement apparatus.
2. An airflow displacement apparatus of claim 1 wherein, when the airflow displacement apparatus is adapted so that when it is deployed on a vehicle underbody, the airflow displacement apparatus body protrudes from the underbody of the vehicle between 10 and 60 mm.
3. An airflow displacement apparatus of any preceding claim wherein, the body of the airflow displacement apparatus comprises a planar member.
4. An airflow displacement apparatus of any preceding claim wherein, the airflow displacement apparatus is adapted so that when it is deployed on a vehicle underbody, a planar surface of the airflow displacement apparatus is orientated perpendicular to the direction of travel of the vehicle.
5. An airflow displacement apparatus of any preceding claim wherein, the body of the airflow displacement apparatus is formed from a flexible material with sufficient stiffness to resist airflow and be deformable to ground contact.
6. An airflow displacement apparatus of any preceding claim wherein, the attachment means is adapted to releasably or movably attach the airflow displacement apparatus to the underbody of the vehicle.
7. The use of an airflow displacement apparatus according to any preceding claim for reducing the soiling of the rear of a vehicle.

8. A vehicle comprising an airflow displacement apparatus according to any of claims 1 to 7.
- 5 9. A vehicle of claim 8 wherein, the airflow displacement apparatus is attached to an attachment point on the underbody of the vehicle so that the airflow displacement apparatus can be deployed rearward of the rear axle of the vehicle.
- 10 10. A vehicle of any of claims 8 or 9 wherein, the airflow displacement apparatus is attached to an attachment point on the underbody of the vehicle so that the airflow displacement apparatus can be deployed to protrude beyond the ground line of the vehicle, wherein the ground line is a line or plane parallel to the road surface and coincident with the lowest rigid component of the underbody.
- 15 11. A vehicle of any of claims 8 to 10 wherein, the airflow displacement apparatus is attached to an attachment point on the underbody of the vehicle so that the airflow displacement apparatus can be deployed to protrude beyond the departure line of the vehicle, wherein the departure line is a line or plane from the points in which the rear tyres contact the road to the rearmost portion of the vehicle.
- 20 12. A vehicle according to any of claims 8 to 11, wherein the attachment point is on a battery box of the underbody of a vehicle.
- 25 13. A vehicle according to any of claims 8 to 12 which further comprises an airflow displacement apparatus mounted on the top line of the vehicle, wherein the airflow displacement apparatus mounted on the top line is adapted to promote airflow over the rear window of the vehicle.
- 30 14. A vehicle according to any of claims 8 to 13 wherein the vehicle comprises a rear window with a rake angle between 55 and 85° to the horizontal.
- 35 15. A method of reducing soiling on the rear of a vehicle comprising:
altering the airflow transmitted along the centre of the vehicle underbody, to cause a reduction of soiling on the rear of the vehicle by dirt carried in the airflow.
16. A method according to claim 15 comprising:

deploying an airflow displacement apparatus to a vehicle underbody to protrude downward from the vehicle underbody; and wherein the airflow displacement apparatus alters the airflow transmitted along the centre of the vehicle underbody.

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17. A method according to claim 16 wherein:

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the airflow displacement apparatus alters the airflow transmitted along the centre of the vehicle underbody so that airflow that exiting from the rear of the vehicle underbody is suppressed from forming a vortex proximal to the rear surface of the vehicle, to reduce soiling on the rear of the vehicle by dirt suspended in the airflow, compared to soiling for the vehicle without the airflow displacement apparatus.

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18. A method according to any of claims 16 or 17 wherein, the airflow displacement apparatus is adapted to be deployed to protrude from the underbody between 10 and 60 mm.

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19. A method according to any of claims 16 to 18 wherein, the airflow displacement apparatus is attached to the vehicle behind the rear axle of the vehicle.

20. A method according to any of claims 16 to 19 wherein, the body of the airflow displacement apparatus is a planar member.

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21. A method according to any of claims 16 to 20 wherein, spoiler is formed from a flexible material with sufficient stiffness to resist airflow and deformable to ground contact.

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22. A method according to any of claims 16 to 21 wherein, the airflow displacement apparatus is adapted to be deployed to protrude from the underbody of the vehicle or be retracted from the underbody of the vehicle, depending on a condition of the vehicle during driving.

23. A method according to claim 22 wherein, the airflow displacement apparatus can be deployed to protrude to a varying extent depending on the condition.

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24. A method according to any of claims 22 or 23 wherein, the condition is any of: detecting water on the road, detecting precipitation, operating the windscreen wipers, toggling a

switch, driving above and/or below a speed threshold, and/or selection of a driving mode.

25. A method according to any of claims 16 to 24 wherein, the vehicle comprises a rear window with an angle between 55 and 85° from horizontal.

26. A method according to any of claims 16 to 25 wherein, the vehicle further comprises an airflow displacement apparatus mounted on the top line of the vehicle, wherein the airflow displacement apparatus mounted on the top line is adapted to promote airflow over the rear window of the vehicle.

27. An airflow displacement apparatus for the underbody of a vehicle, a vehicle, the use of an airflow displacement apparatus, or a method of reducing soiling on the rear of a vehicle, substantially as described herein and optionally with respect to the accompanying drawings.

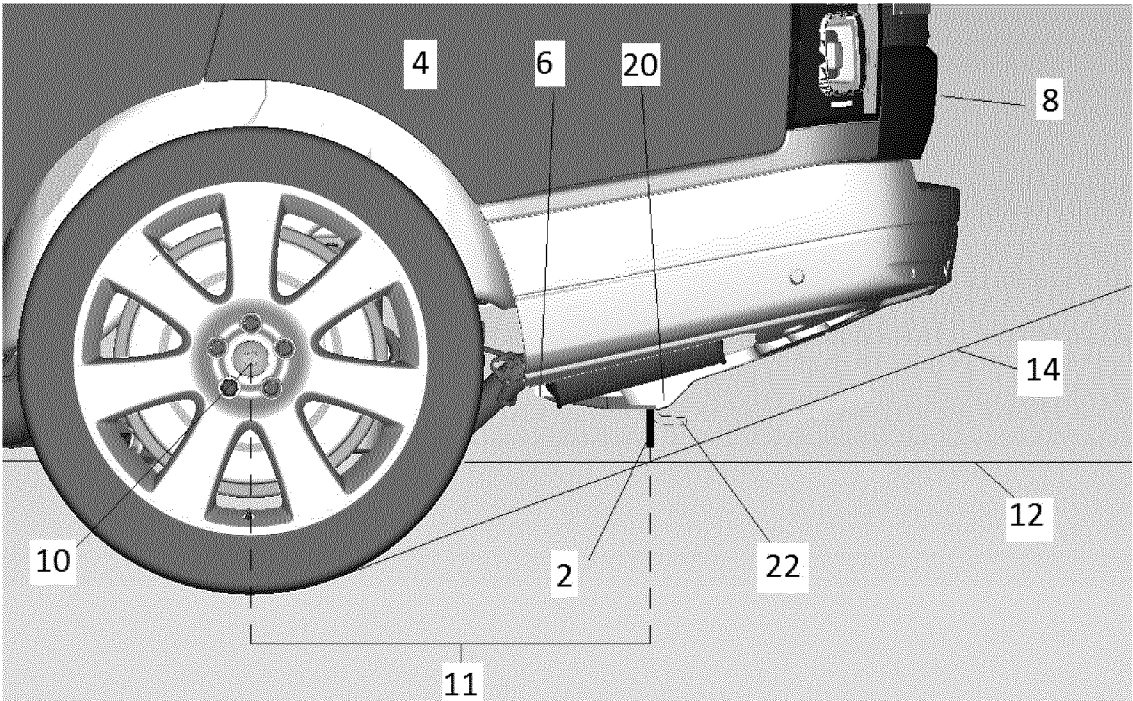


Fig. 1

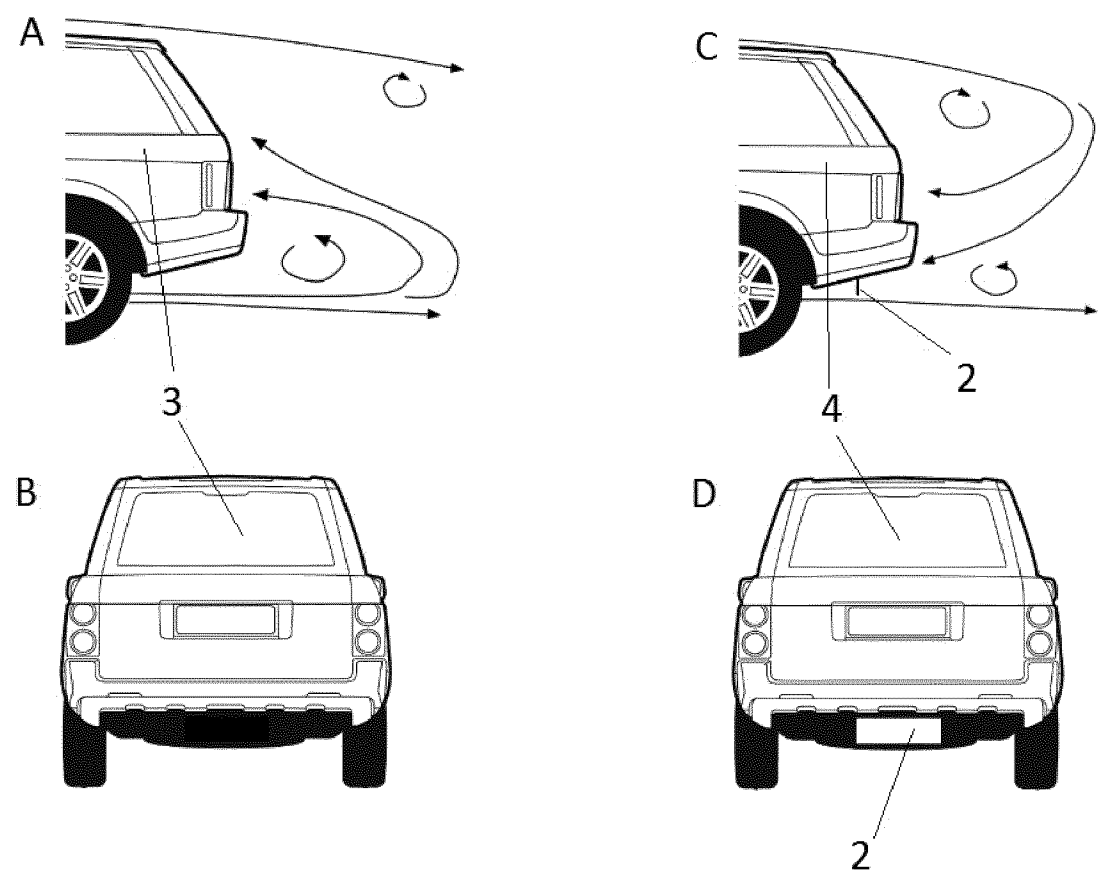


Fig. 2

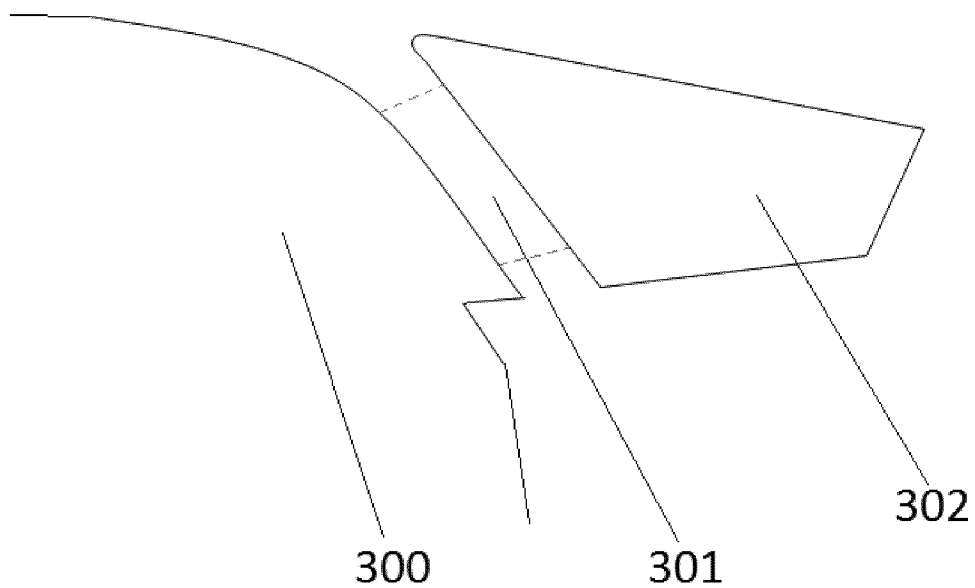


Fig. 3

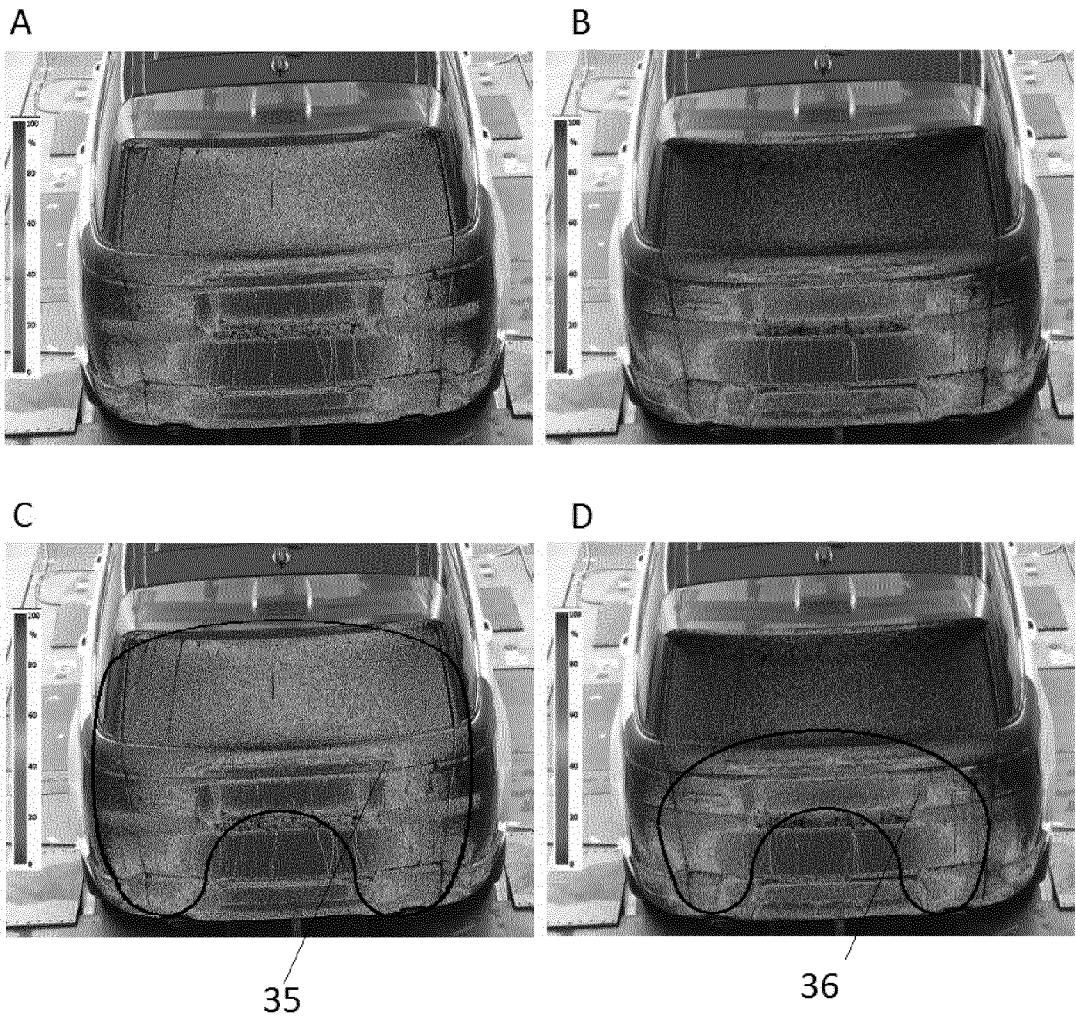


Fig. 4

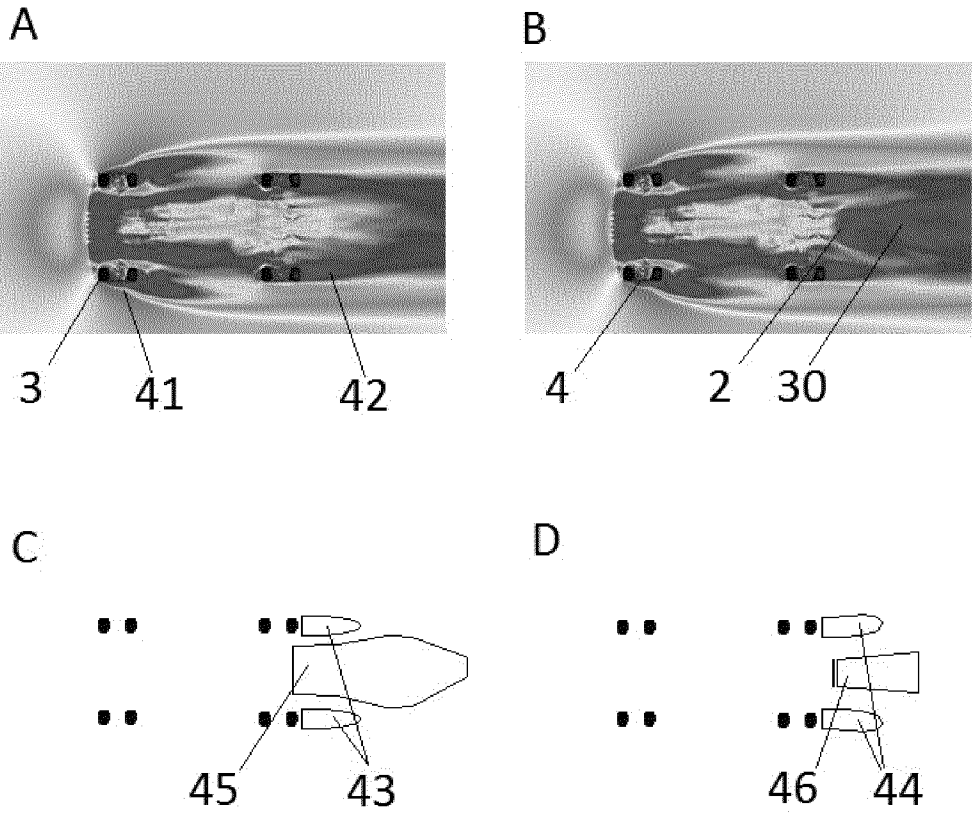


Fig. 5

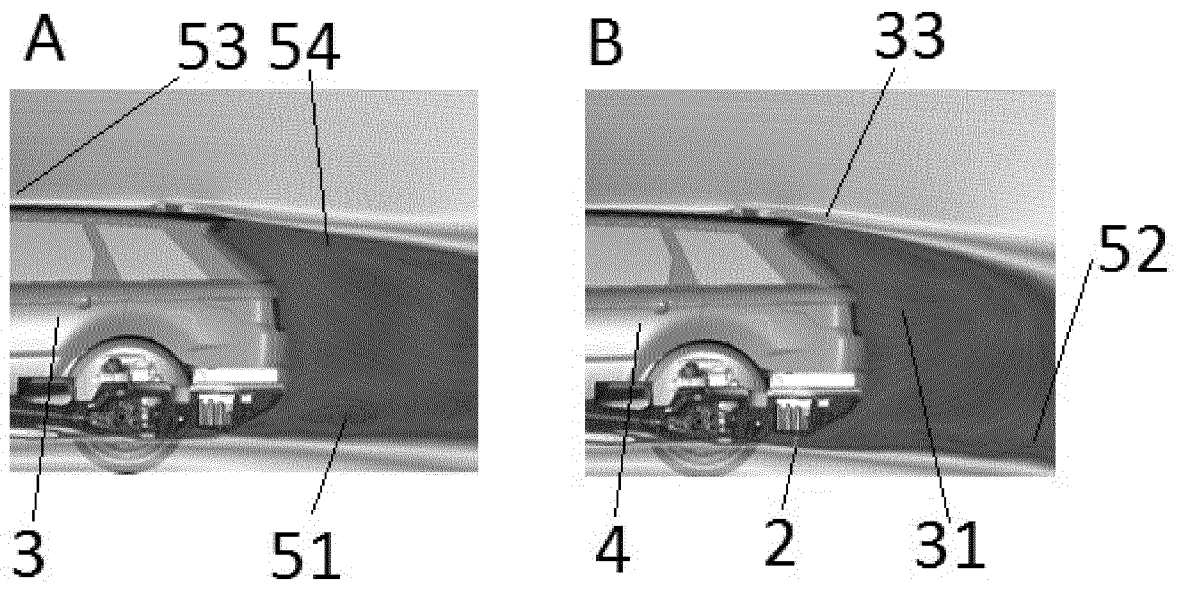


Fig. 6

INTERNATIONAL SEARCH REPORT

International application No

PCT/EP2017/071753

A. CLASSIFICATION OF SUBJECT MATTER

INV. B62D35/00 B62D37/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B62D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	JP 2011 057147 A (TOYOTA MOTOR CORP) 24 March 2011 (2011-03-24) abstract; figures 1-6 ----- -/-	1-4,6,8, 9,12, 15-20,27



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

8 December 2017

Date of mailing of the international search report

21/12/2017

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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