(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 March 2020 (19.03.2020)

WIPO | PCT

(10) International Publication Number
WO 2020/053844 A1

(51) International Patent Classification:
G06F 30/15 (2020.01) *G06F 111/10* (2020.01)

(21) International Application Number:
PCT/IB2019/057778

(22) International Filing Date:
16 September 2019 (16.09.2019)

(25) Filing Language: Italian

(26) Publication Language: English

(30) Priority Data:
102018000008620 14 September 2018 (14.09.2018) IT

(71) Applicant: **FERRARI S.P.A.** [IT/IT]; Via Emilia Est, 1163, 41100 Modena (IT).

(72) Inventors: **ZANETTI, Luca**; c/o Ferrari S.p.A., Via Emilia Est, 1163, 41100 Modena (IT). **CATTABRIGA, Adalberto**; c/o Ferrari S.p.A., Via Emilia Est, 1163, 41100 Modena (IT). **BIANCALANA, Matteo**; c/o Ferrari S.p.A., Via Emilia Est, 1163, 41100 Modena (IT).

(74) Agent: **D'ANGELO, Fabio** et al.; c/o Studio Torta S.p.A., Via Viotti, 9, 10121 Torino (IT).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH,

(54) Title: COMPUTER-ASSISTED PROCESS FOR MAKING A STYLISTIC PATTERN ON AN EXTERNAL SURFACE OF A VEHICULAR PRODUCT OR A MODEL CORRELATED TO SAID VEHICULAR PRODUCT

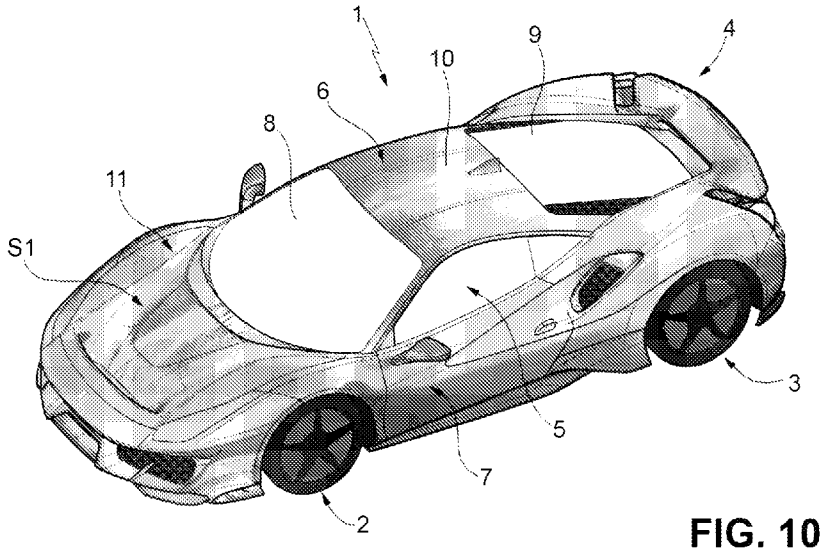


FIG. 10

(57) Abstract: A computer-assisted process for making a stylistic pattern (S1-S9) on an external surface (11) of a vehicular product (1) comprising the steps of: carrying out, in a virtual environment and by means of a computer, a simulation of aerodynamic flow in pre-set operating conditions based on a first three-dimensional mathematical model (M1) of the vehicular product (1) in order to calculate a second three-dimensional mathematical model (G1, G2) representing the development of the aforesaid aerodynamic flow and/or of the values assumed by at least one pre-set operating quantity on at least part of the external surface of the first three-dimensional mathematical model (M1); generating, in a virtual environment and by means of a computer, a third three- dimensional mathematical model representing the stylistic pattern (S1-S9) to be made; and making the stylistic pattern (S1-S9) on the vehicular product (1); the third three-dimensional mathematical model representing the aforesaid stylistic pattern (S1-S9) is based on the second three-dimensional mathematical model (G1, G2).

WO 2020/053844 A1

[Continued on next page]

GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*
— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

"COMPUTER-ASSISTED PROCESS FOR MAKING A STYLISTIC PATTERN ON AN EXTERNAL SURFACE OF A VEHICULAR PRODUCT OR A MODEL CORRELATED TO SAID VEHICULAR PRODUCT"

CROSS-REFERENCE TO RELATED APPLICATIONS

This patent application claims priority from Italian patent application no. 102018000008620 filed on 14/09/2018, the entire disclosure of which is incorporated herein by reference.

TECHNICAL SECTOR

The present invention relates to a computer-assisted process for providing a stylistic pattern or livery on an external surface of a vehicular product or a model correlated to said vehicular product.

The present invention moreover relates to a vehicular product or to a model correlated to said vehicular product, obtained via the aforesaid process.

It is pointed out that, in the present description and in the claims, the term "vehicular product" is used to designate not only motorcars, motor vehicles, and vehicles in general, but also components thereof or accessories used when driving said vehicles, such as helmets, that due to their nature are designed to move in fluid fields.

The phrase "model correlated to a vehicular product" is, instead, used to designate a full-scale model, an

enlarged-scale model, or a reduced-scale model of the aforesaid vehicular products or part of the latter.

The present description will refer to high-performance cars and to models correlated to these cars, without this implying any loss of generality.

PRIOR ART

As is known, the first stage when building a new high-performance motor vehicle comprises definition of the external shape on the basis of one or more new aerodynamic concepts in order to achieve performance targets by exploiting the forces developed by the interaction of the shapes of the motor vehicle with the fluid in which the latter is moving. Said aerodynamic concepts, expressed through specifications on the shapes of the motor vehicle, are then reinterpreted by operators working on the style of the motor vehicle to create variants thereof, which are tested to check that they are actually effective and meet the aforesaid aerodynamic concepts.

To do this, both in the stage of definition of the aerodynamic specifications and in the stage of testing of the stylistic variants, virtual simulations are developed through finite-volume fluid-dynamic calculation software of a known type, where it is assumed that the motor vehicle is travelling at a pre-set constant speed, generally higher than 100 km/h, and is subjected to a flow of air having a

pre-set direction, for example aligned with the longitudinal axis of the motor vehicle itself.

The aerodynamic flows and operating quantities associated to said flows are then analysed, and possibly modifications are made to the external surfaces and to the shapes of the motor vehicle. Then, the simulations are again made to check that the desired performance has been achieved.

In parallel to the virtual simulations described above, also wind-tunnel tests are frequently carried out on scale models, for example full-scale models or reduced-scale models, usually at scales from 40% to 60%, equipped with strain-gauge load cells in order to measure the aerodynamic forces. In particular, during wind-tunnel testing, in some significant areas of the scale model sensors and/or probes and/or detection devices are arranged adapted to measure particular physical quantities, for example pressure, velocity, etc. The results obtained are then compared with those coming from the virtual simulations to enable precise verification that the modellings used in the virtual simulations match the actual phenomena.

The final shape of the motor vehicle is hence the result of the interaction between stylistic concepts and modelling of the shapes and details, guided by the

achievement of aerodynamic performance.

Of particular importance is then the type of paint that is applied on the motor vehicles thus designed. It is in fact evident that the use of a certain colour and/or of given aesthetic effects can bring out some peculiarities of shape and/or some stylistic and/or aerodynamic elements present on the motor vehicle.

It is, for example, known to use metallic paint, pearlescent paint and/or paint with other aesthetic effects. It is also known to use coloured stripes with shades that are in contrast with the colour of the rest of the bodywork, for example, that run longitudinally all along the side of the motor vehicle in order to bring out a particular feature of a sports-car nature.

Finally, it is known to use "maskings" applied on the bodywork of motor the vehicles for advertising purposes, embellishment, etc.

DESCRIPTION OF THE INVENTION

The aim of the present invention is to provide a computer-assisted process for making, on an external surface of a vehicular product or a model correlated to said vehicular product, a stylistic pattern capable of bringing out given technical peculiarities of the vehicular product itself and/or providing a passive performance indicator of the latter.

According to the present invention, a computer-assisted process for making a stylistic pattern or a livery on an external surface of a vehicular product or a model correlated to said vehicular product is provided, as specified in Claim 1.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described with reference to the attached drawings, which illustrate some non-limiting examples of embodiment thereof and in which:

- Figure 1 is a lateral-frontal perspective view of an example of vehicular product, in particular a motor vehicle, to which the process according to the present invention is applied;

- Figure 2 is a lateral-rear perspective view of the vehicular product of Figure 1;

- Figures 3 to 9 are representations in different views of the pattern of a pre-set operating quantity measured on a three-dimensional mathematical model of the vehicular product of Figures 1 and 2 during a first type of simulation of aerodynamic flow in a virtual environment by means of a computer;

- Figures 10 and 11 illustrate, at a reduced scale and in lateral-frontal and lateral-rear perspective view, respectively, the vehicular product of Figures 1 and 2 following upon application of the process according to the

present invention based upon the first type of simulation of aerodynamic flow;

- Figure 12 is a virtual graphic representation in side view of the development of trajectories of fluid particles on a three-dimensional mathematical model of the vehicular product of Figures 1 and 2 during a second type of simulation of aerodynamic flow in a virtual environment by means of a computer;

- Figures 13 and 14 illustrate, at a reduced scale and in lateral-frontal and lateral-rear perspective view, respectively, the vehicular product of Figures 1 and 2 following upon application of the process according to the present invention based upon the second type of simulation of aerodynamic flow;

- Figures 15 and 16 illustrate, at a reduced scale and in lateral-frontal and lateral-rear perspective view, respectively, the vehicular product of Figures 1 and 2 following upon application of the process according to the present invention based upon a third type of simulation of aerodynamic flow in a virtual environment by means of a computer;

- Figures 17 and 18 illustrate, at a reduced scale and in lateral-frontal and lateral-rear perspective view, respectively, the vehicular product of Figures 1 and 2 following upon application of the process according to the

present invention based upon a fourth type of simulation of aerodynamic flow in a virtual environment by means of a computer;

- Figures 19 and 20 illustrate, at a reduced scale and in lateral-frontal and lateral-rear perspective view, respectively, the vehicular product of Figures 1 and 2 following upon application of the process according to the present invention based upon a fifth type of simulation of aerodynamic flow in a virtual environment by means of a computer;

- Figures 21 and 22 illustrate, at a reduced scale and in lateral-frontal and lateral-rear perspective view, respectively, the vehicular product of Figures 1 and 2 following upon application of the process according to the present invention based upon a sixth type of simulation of aerodynamic flow in a virtual environment by means of a computer;

- Figures 23 and 24 illustrate, in lateral-frontal and lateral-rear perspective view, respectively, an example of a scale model of the vehicular product of Figures 1 and 2, in which the development of pre-set trajectories of fluid particles, detected in a virtual environment during a seventh type of simulation of aerodynamic flow, is applied in three dimensions on the model itself;

- Figure 25 illustrates in lateral-frontal perspective

view a scale model of the vehicular product of Figures 1 and 2, which is used for wind-tunnel testing and on which the representation of Figures 3 to 9 is applied, according to the process of the present invention; and

- Figure 26 is a perspective view of a picture incorporating a portion of a model of the vehicular product of Figures 10 and 11 obtained by means of the process according to the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

Figures 1 and 2 illustrate a first example of a vehicular product forming the subject of the process according to the present invention. In particular, said vehicular product is represented by a motor vehicle 1, in the case in point a high-performance motor vehicle.

As has already been mentioned at the start of the present description and as will be explained in greater detail in what follows, the process according to the present invention may be applied not only to cars, but also to other types of vehicular product, such as motor vehicles, vehicles in general, components of vehicles, and accessories used when driving vehicles, such as helmets, that for their nature are designed to move in fluid fields.

The process according to the present invention may moreover be applied to full-scale, enlarged-scale, or reduced-scale models of the vehicular products defined

above or part of the latter.

The motor vehicle 1 has two front wheels 2 and two rear wheels 3 and comprises a body 4 and a passenger compartment 5, provided within the body 4 between the front and rear wheels 2, 3 themselves.

The body 4 includes a bodywork 6 and two side doors 7, provided with windows, for enabling access to the passenger compartment 5.

In the light of the foregoing, the passenger compartment 5 is hence delimited by the doors 7, by a windscreen 8, a rear window 9, and a roof 10.

The bodywork 6, the doors 7, the windscreen 8, and the rear window 9 define as a whole an external surface 11 of the motor vehicle 1.

During the stage of design of the motor vehicle 1, a three-dimensional mathematical model M1 thereof undergoes, in a virtual environment by means of a computer, a series of simulations of aerodynamic flows to check that no critical aspects are present. These simulations are conducted through finite-volume fluid-dynamic calculation software of a known type (for example, known by the trade names ANSA® and META of BETA™ CAE System, Fluent® of Ansys) and may also include wind-tunnel tests.

During the aforesaid simulations, the values assumed $V_0 - V_n$ by pre-set operating quantities on the external

surface of the three-dimensional mathematical model M1 of the motor vehicle 1 or in the proximity thereof are measured.

Alternatively, the trajectories of fluid particles in the proximity of the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1 or of particles adhering to the external surface itself are detected.

An example of the results that can be obtained with a first type of simulation, in a virtual environment by means of a computer, on the three-dimensional mathematical model M1 of the motor vehicle 1 is illustrated in Figures 3 to 9. In this case, the operating quantity measured is the modulus of the velocity vector at any point of the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1. Alternatively, the modulus of the velocity vector could be measured only at selected points of the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1.

In particular, said simulation is carried out in a virtual environment in pre-set operating conditions, specifically by setting a constant speed of the three-dimensional mathematical model M1 of the motor vehicle 1 of 120 km/h and a direction of the flow of air that impinges upon the three-dimensional mathematical model M1 aligned

with the longitudinal axis of the latter.

The velocity vector is defined on a point-by-point basis in the proximity of the solid surfaces of the three-dimensional mathematical model of the motor vehicle 1, i.e., in the proximity of the external surface thereof. As is known, in the proximity of solid walls of the motor vehicle 1, the condition of zero flow rate implies that the fluid, i.e., the air, and the body have the same velocity.

There is hence generated, in a virtual environment by means of a computer, a three-dimensional mathematical model G1 (Figures 3 to 9) of the values V_0 – V_n measured of the modulus of the velocity vector with pre-set colours or shades on the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1. Alongside each of Figures 3 to 9 the colorimetric scale or shade used is indicated, in which it may be noted how corresponding to different bands of colour or shades are different values V_0 – V_n of local velocity of the flow. The three-dimensional mathematical model G1 of the distribution of the values V_0 – V_n of the modulus of the velocity vector on the external surface of the three-dimensional mathematical model of the motor vehicle 1 is thus obtained.

At this point, a further three-dimensional mathematical model is generated in a virtual environment by means of a computer, said further three-dimensional

mathematical model representing a stylistic pattern S1 to be made on the motor vehicle 1.

The three-dimensional mathematical model representing the stylistic pattern S1 is advantageously based on the three-dimensional mathematical model G1.

The motor vehicle 1 is finally subjected to a step of application, on the external surface 11, of the stylistic pattern S1 thus obtained.

Preferably, the stylistic pattern S1 is applied on the external surface 11 of the motor vehicle 1 by painting.

More preferably, the stylistic pattern S1 is applied on the external surface 11 of the motor vehicle 1 by means of a robot controlled by the computer.

In particular, in the specific case, the three-dimensional mathematical model representing the stylistic pattern S1 reproduces closely the three-dimensional mathematical model G1 except for the areas of the windscreen 8, the rear window 9, the door windows 7, the front wheels 2, the rear wheels 3, and the various grills present.

In general, the three-dimensional mathematical model representing the stylistic pattern S1 can reproduce the three-dimensional mathematical model G1 either totally or only in part.

In parallel to the simulation in a virtual

environment, wind-tunnel tests can also be carried out using scale models of the motor vehicle 1 and employing probes, sensors and detection devices (defining, as a whole, a sensor system, which is known and, therefore, not shown herein) arranged in particular points of the model itself, in order to detect parameters correlated to the modulus of the velocity vector. The measurements made are then compared with the corresponding values extracted from the virtual environment simulation to verify that the modellings used in the simulation match the actual phenomena.

In this case, the process according to the invention can comprise the further step of calculating a further three-dimensional mathematical model (not shown) based on outputs of the sensor system defined above; the three-dimensional mathematical model representing the stylistic pattern S1 would then be also based on the three-dimensional mathematical model calculated taking into account the outputs of the sensor system.

Figure 12 illustrates another example of the results that can be obtained with a second type of simulation on the three-dimensional mathematical model of the motor vehicle 1. In this case, the trajectories of fluid particles entering some of the air intakes of the motor vehicle 1 and exiting therefrom are detected in a virtual

environment by means of a computer.

Also in this case, the above simulation is carried out in a virtual environment by means of a computer in the same operating conditions provided previously, i.e., by setting a constant speed of the three-dimensional mathematical model M1 of the motor vehicle 1 of 120 km/h and a direction of the flow of air that impinges upon the three-dimensional mathematical model M1 itself aligned with the longitudinal axis of the latter.

On the basis of the simulation in a virtual environment by means of a computer, a three-dimensional mathematical model G2 is generated that makes it possible to depict the trajectories of the fluid particles entering the air intakes selected of the three-dimensional mathematical model M1 motor vehicle 1 and exiting therefrom, assigning specific colours or shades T1 – T4 to each set of trajectories. This enables display with different colours or shades of the trajectories of the fluid particles associated with the respective air intakes.

As may be appreciated from Figure 12, the trajectories displayed of the fluid particles are in this case external to the three-dimensional mathematical model M1 of the motor vehicle 1 and proceed beyond the front, rear, and side limits thereof.

At this point, a further three-dimensional

mathematical model is generated in a virtual environment by means of a computer, said further three-dimensional mathematical model representing a stylistic pattern S2 to be made on the motor vehicle 1.

The three-dimensional mathematical model representing the stylistic pattern S2 is based on the three-dimensional mathematical model G1 and is obtained by projecting the trajectories of the fluid particles that proceed beyond the limits of the three-dimensional mathematical model M1 of the motor vehicle 1 onto the external surface thereof. As to the areas at the front and at the back of the three-dimensional mathematical model M1 of the motor vehicle 1, the projection of the trajectories of the fluid particles is made at a pre-set distance from the three-dimensional mathematical model M1 itself, for example 30 cm from the front and rear limits of the latter. In a way similar to what has been seen previously as regards the simulation of Figures 3 to 9, the motor vehicle 1 is also here subjected to a step of application, on the external surface 11, of the stylistic pattern S2.

Preferably, application of the stylistic pattern S2 on the external surface 11 of the motor vehicle 1 is provided by painting.

More preferably, the stylistic pattern S2 is applied on the external surface 11 of the motor vehicle 1 by means

of a robot controlled by the computer.

The final result is visible in Figures 13 and 14, where, once again, the areas of the windscreen 8, the rear window 9, the door windows 7, the front wheels 2, the rear wheels 3, and the various grills present are left out from application of the stylistic pattern S2.

Similarly to what disclosed for the first type of simulation, wind tunnel tests based on a suitable sensor system can be carried out in parallel to the detections in a virtual environment by means of the aforesaid software.

In this case, the process according to the invention can comprise the further step of calculating a further three-dimensional mathematical model (not shown) based on outputs of the aforesaid sensor system; the three-dimensional mathematical model representing the stylistic pattern S2 would then be also based on the three-dimensional mathematical model calculated taking into account the outputs of the sensor system.

Figures 15 to 22 illustrate other examples of stylistic patterns S3, S4, S5, S6 that can be applied, preferably by painting, on the external surface 11 of the motor vehicle 1 and based on corresponding three-dimensional mathematical models (not illustrated) obtained from further types of simulations of aerodynamic flows in a virtual environment by means of a computer.

In particular, in the case of the stylistic pattern S3 (Figures 15 and 16), during the corresponding virtual environment simulation, the trajectories of particles adhering to the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1 carried by the moving fluid are detected.

As already mentioned above, said virtual environment simulation is carried out applying a finite-volume fluid-dynamic calculation by setting a constant speed of the three-dimensional mathematical model M1 of the motor vehicle 1 of 120 Km/h and a direction of the flow of air that impinges upon the three-dimensional mathematical model M1 itself aligned with the longitudinal axis of the latter.

In a way similar to what has been seen as regards the three-dimensional mathematical model G2, also in this case, at the end of the simulation in a virtual environment by means of a computer, a three-dimensional mathematical model of the aerodynamic flow taken into account (not illustrated) is generated. Unlike the three-dimensional mathematical model G2, the three-dimensional mathematical model obtained here is in a single pre-set colour or shade and is reproduced by the stylistic pattern S3 except for the areas of the windscreen 8, the rear window 9, the door windows 7, the front wheels 2, the rear wheels 3, and the various grills present.

In this case, again, in parallel to the simulation in a virtual environment by means of a computer, wind-tunnel tests can be carried out, coating the surfaces of interest with a particular paint (typically made up of fluorescent pigments or pigments with an oily matrix, usually paraffin). With the paint still fresh, the flow of air is brought to the desired testing speed and, as a result of the actions of friction on the paint, the trajectories of the particles in the proximity of the surfaces examined remain visible.

In the case of the stylistic pattern S4 (Figures 17 and 18), during the corresponding simulation in a virtual environment by means of a computer, the value of the pressure coefficient at each point of the external surface 11 of the three-dimensional mathematical model M1 of the motor vehicle 1 is measured. In practice, the pressure coefficient is the operating quantity measured in the course of this simulation.

As an alternative, the pressure coefficient could be measured only at some selected points of the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1.

As is known, the pressure coefficient is a non-dimensional quantity defined, for each point of the external surface 11 of the motor vehicle 1, as the ratio

between:

- the difference between the absolute pressure in that point and the environmental reference pressure; and

- the dynamic pressure.

The dynamic pressure is in turn defined in a known way as 0.5 times the density of the air by the speed of the motor vehicle (or of the air that impinges upon the motor vehicle in the wind tunnel) squared.

As in the previous cases, said virtual environment simulation is carried out applying a finite-volume fluid-dynamic calculation by setting a constant speed of the three-dimensional mathematical model M1 of the motor vehicle 1 of 120 Km/h and a direction of the flow of air that impinges upon the three-dimensional mathematical model M1 itself aligned with the longitudinal axis of the latter.

In a way similar to what has been seen as regards the three-dimensional mathematical model G1, also in this case, at the end of the simulation in a virtual environment by means of a computer, a three-dimensional mathematical model (not illustrated) is generated, with pre-set colours or shades, of the distribution of the values measured of the pressure coefficient on the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1. Said three-dimensional mathematical model is then reproduced by the stylistic pattern S4 except for the areas

of the windscreen 8, the rear window 9, the door windows 7, the front wheels 2, the rear wheels 3, and the various grills present.

As in the other cases, in parallel to the simulation in a virtual environment by means of a computer, wind-tunnel tests can also be carried out. In particular, by definition, the sum point-by-point of the pressure coefficient multiplied by the area on which it acts and by the dynamic pressure (which depends only upon the speed) yields as result the overall force acting on the motor vehicle 1 (or rather on the scale model used for the wind-tunnel tests) generated by the interactions between the field of motion of the air and the portions of the external surface 11 of the motor vehicle 1 itself lapped by the air. Therefore, in the wind tunnel, the force that develops on the motor vehicle 1 as a result of the actions of pressure of the air on its external surface 11 is measured using calibrated strain-gauge scales. Moreover, during the wind-tunnel tests on scale models, probes are arranged in some significant areas of the motor vehicle 1 for measuring the point-by-point value of the pressure. Known algorithms then enable calculation of the value of the pressure coefficient. Said point-by-point measurements are then compared with the corresponding values drawn from the simulation in a virtual environment by means of a computer

to verify that the modellings used in the simulations themselves match the actual phenomena also in a point-by-point way.

In the case of the stylistic pattern S5 (Figures 19 and 20), during the corresponding simulation in a virtual environment by means of a computer the trajectories followed by the fluid particles in the proximity of some portions of interest of the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1 are detected.

Also here, said virtual environment simulation is carried out by means of a finite-volume fluid-dynamic calculation and in the same operating conditions referred to previously, i.e., by setting a constant speed of the three-dimensional mathematical model M1 of the motor vehicle 1 of 120 km/h and a direction of the flow of air that impinges upon the three-dimensional mathematical model M1 itself aligned with the longitudinal axis of the latter.

On the basis of the virtual environment simulation, also in this case, in a way similar to what has been described as regards the three-dimensional mathematical model G2, a three-dimensional mathematical model of the aerodynamic flow taken into account (not illustrated) is generated that makes it possible to represent the trajectories of the fluid particles in the proximity of the

portions of interest of the external surface of the three-dimensional mathematical model M1. However, a colorimetric scale or a scale of shades is here used on the basis of the modulus of the local velocity vector of the particles themselves.

In this type of simulation, the trajectories of the fluid particles depicted are external to the three-dimensional mathematical model of the motor vehicle 1 and proceed beyond the front, rear, and side limits thereof.

In a way corresponding to what has been previously described with reference to the simulation of Figure 12, the three-dimensional mathematical model representing the stylistic pattern S5 is obtained by projecting the trajectories of the fluid particles onto the external surface of the three-dimensional mathematical model M1 of the motor vehicle 1. As regards, in particular, the areas at the front and at the back of the three-dimensional mathematical model M1 of the motor vehicle 1, the projection of the trajectories of the fluid particles is carried out at a pre-set distance from the three-dimensional mathematical model M1 of the motor vehicle 1 itself, for example, at 30 cm from the front and rear limits of the latter.

The final result is visible in Figures 19 and 20, where once again the areas of the windscreen 8, the rear

window 9, the door windows 7, the front wheels 2, the rear wheels 3, and the various grills present are left out from application of the stylistic pattern S5.

Similarly to what disclosed above for the previous types of simulation, wind tunnel tests can be carried out in parallel to the simulation in a virtual environment by means of a computer.

The stylistic pattern S6 (Figures 21 and 22) is correlated to the same phenomenon used for generation of the stylistic pattern S5, with the sole difference that detection of the trajectories of the fluid particles is extended to the entire external surface of the three-dimensional mathematical model M1 of the motor vehicle 1.

Designated as a whole by 1' in Figures 23 and 24 is a scale model of the motor vehicle 1, in the specific case illustrated a 15% scale model.

According to an important aspect of the present invention, the model 1' has been subjected to a step of application of a stylistic pattern S7, generated on the basis of some of the trajectories detected in the course of the type of simulation that has produced the stylistic pattern S6.

Advantageously, the stylistic pattern S7 has been obtained by three-dimensional printing and then applied on selected portions of the external surface of the model 1'.

In Figure 25, designated as a whole by 1'' is a scale model of the motor vehicle 1, in the specific case illustrated a 40% scale model.

The model 1'' is of the type used for wind-tunnel tests.

According to an important aspect of the present invention, the model 1'' has been subjected to a painting step, in which, on its own external surface, a stylistic pattern S8 has been applied based on the three-dimensional mathematical model G1 and substantially reproducing totally the latter.

In Figure 26, a picture is designated as a whole by 20 incorporating a portion 1''' of a scale model of the motor vehicle 1 of Figures 1 and 2, on which a stylistic pattern S9 based on the three-dimensional mathematical model G1 has been applied. In particular, the portion 1''' is constituted by a bottom portion or underside of the motor vehicle 1 encased in the picture 20.

From an examination of the characteristics of the process provided according to the present invention and of the vehicular product or the model obtained by means of the aforesaid process the advantages that the invention affords are evident.

In particular, application on a vehicular product or on a model correlated thereto of a stylistic pattern or a

livery based on a three-dimensional mathematical model of the results of the simulation of aerodynamic flows calculated in a virtual environment by means of a computer makes it possible to bring out the technical peculiarities of the latter. In other words, said type of stylistic pattern or livery becomes a sort of passive indicator of performance of the vehicular product with which it has been associated, visible to all users.

Finally, it is clear that modifications and variations may be made to the process described and illustrated herein, without thereby departing from the sphere of protection defined by the claims.

CLAIMS

1.- A computer-assisted process for making a stylistic pattern (S1, S2, S3, S4, S5, S6, S7, S8, S9) on an external surface (11) of a vehicular product (1) or a model (1', 1'', 1''') correlated to said vehicular product (1), said process comprising the steps of:

a) carrying out, in a virtual environment and by means of said computer, a simulation of aerodynamic flow in pre-set operating conditions based on a first three-dimensional mathematical model (M1) of the entire vehicular product (1) or of part thereof in order to calculate a second three-dimensional mathematical model (G1, G2) representing the development of said aerodynamic flow and/or of the values assumed by at least one pre-set operating quantity on at least part of the external surface of said first three-dimensional mathematical model (M1) of said vehicular product (1); said second three-dimensional mathematical model (G1, G2) being represented using pre-set colours and/or shades associated with trajectories of predefined particles of said aerodynamic flow and/or with values assumed by said operating quantity in the different selected points of the external surface of said first three-dimensional mathematical model (M1);

b) generating, in a virtual environment and by means of said computer, a third three-dimensional mathematical

model representing the stylistic pattern (S1, S2, S3, S4, S5, S6, S7, S8, S9) to be made on said vehicular product (1) or on said model (1', 1'', 1''') correlated to said vehicular product (1); and

c) making said stylistic pattern (S1, S2, S3, S4, S5, S6, S7, S8, S9) on said external surface (11) of said vehicular product (1) or on an external surface of said model (1', 1'', 1''') correlated to said vehicular product (1);

wherein said third three-dimensional mathematical model representing said stylistic pattern (S1, S2, S3, S4, S5, S6, S7, S8, S9) is based on said second three-dimensional mathematical model (G1, G2).

2.- The process according to Claim 1, wherein said step c) is carried out by a robot controlled by said computer.

3.- The process according to Claim 1 or 2, wherein said step c) comprises the step of painting the external surface (11) of said vehicular product (1) or the external surface of said model (1', 1'', 1''') correlated to said vehicular product (1).

4.- The process according to any one of the preceding Claims, wherein said virtual environment simulation is conducted by means of fluid-dynamic calculation software.

5.- The process according to any one of the preceding

Claims, comprising the further step of:

d) calculating a fourth three-dimensional mathematical model based on outputs of a sensor system cooperating with said vehicular product or with a model (1', 1'', 1''') correlated to said vehicular product (1) subjected to wind tunnel tests; said third three-dimensional mathematical model representing the stylistic pattern (S1, S2, S3, S4, S5, S6, S7, S8, S9) being further based on said fourth three-dimensional mathematical model.

6.- The process according to any one of the preceding Claims, wherein in said step a) the trajectories of fluid particles in the proximity of the external surface of said first three-dimensional mathematical model (M1) of said vehicular product (1) or of particles adhering to the external surface itself are calculated.

7.- The process according to Claim 6, wherein said trajectories of fluid particles calculated in said step a) extend beyond the limits of said first three-dimensional mathematical model (M1) of the vehicular product (1), and wherein, in said step b), the third three-dimensional mathematical model is calculated by projecting the trajectories of the fluid particles that proceed beyond the limits of said first three-dimensional mathematical model (M1) onto the external surface thereof.

8.- The process according to any one of the preceding

Claims, wherein, in said step a), the operating quantity measured is chosen from among at least the following operating quantities:

- the pressure coefficient in some or all of the points of the external surface of said first three-dimensional mathematical model (M1) of said vehicular product (1); and

- the modulus of the velocity vector in some or all of the points of the external surface of said first three-dimensional mathematical model (M1) of said vehicular product (1).

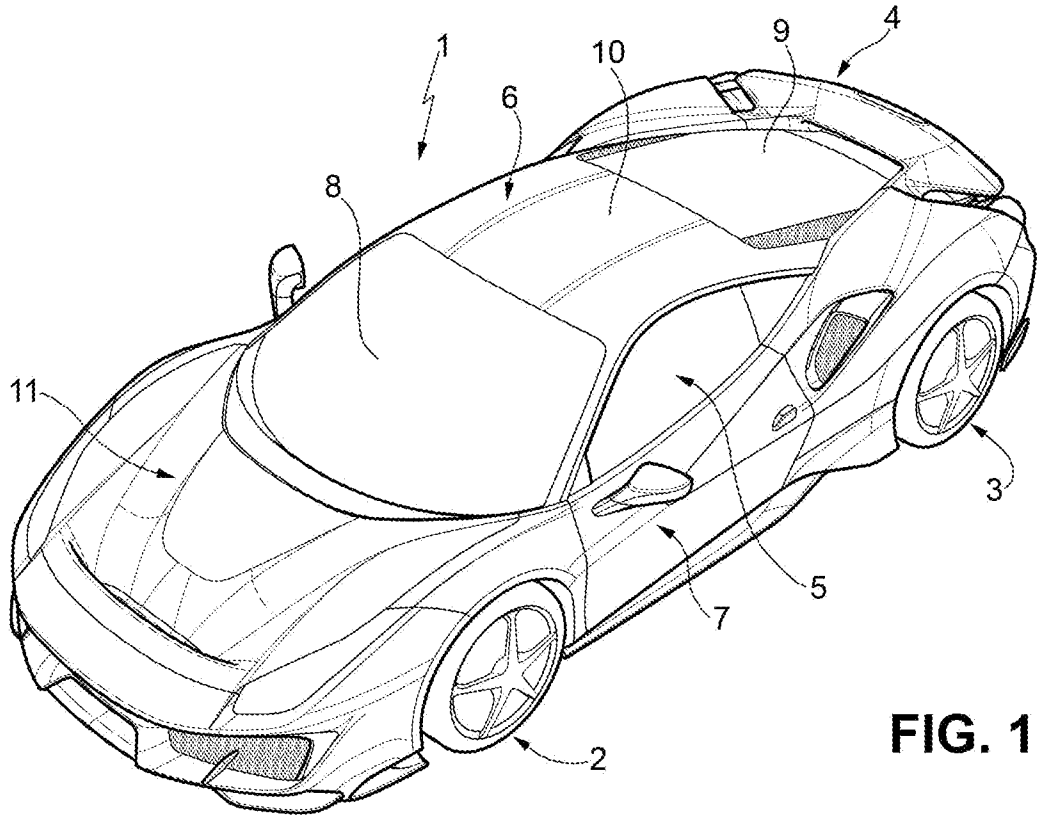


FIG. 1

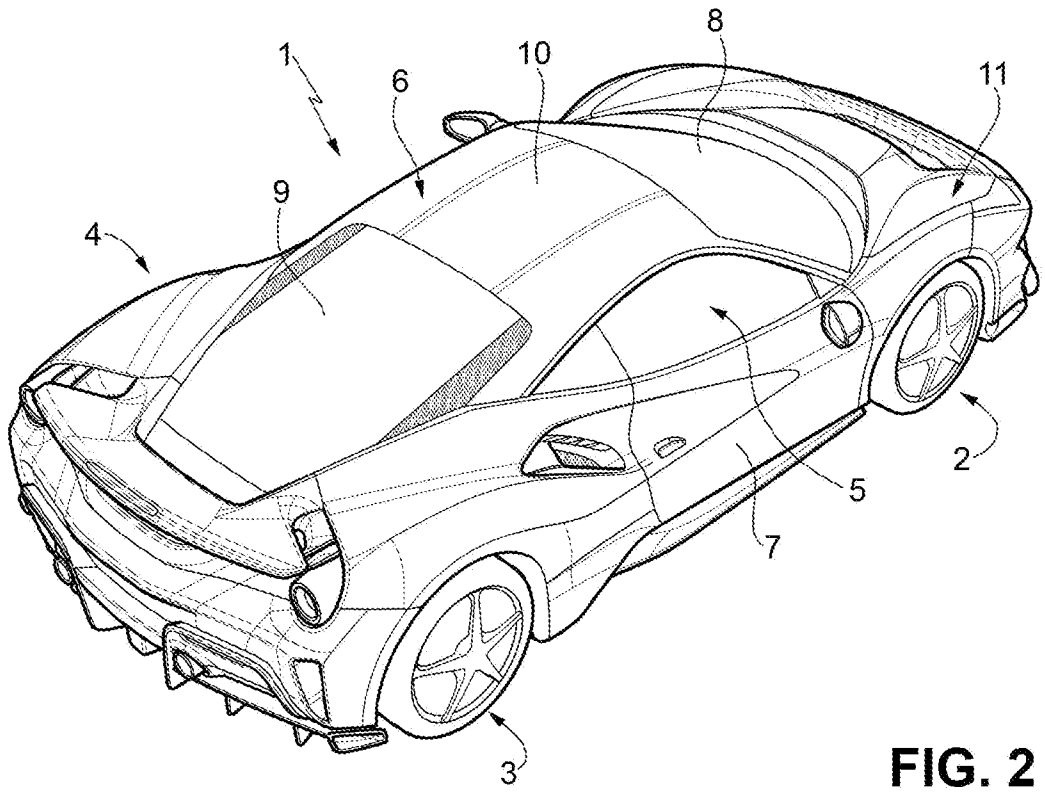


FIG. 2

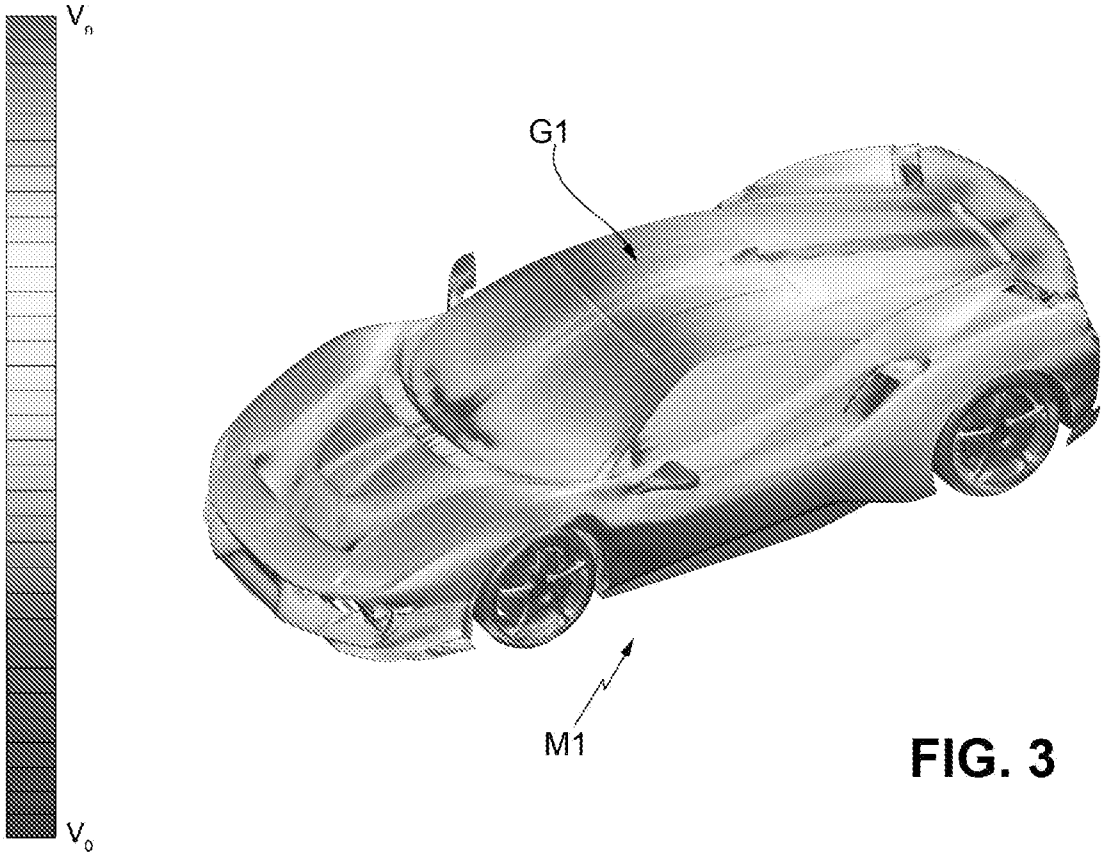


FIG. 3

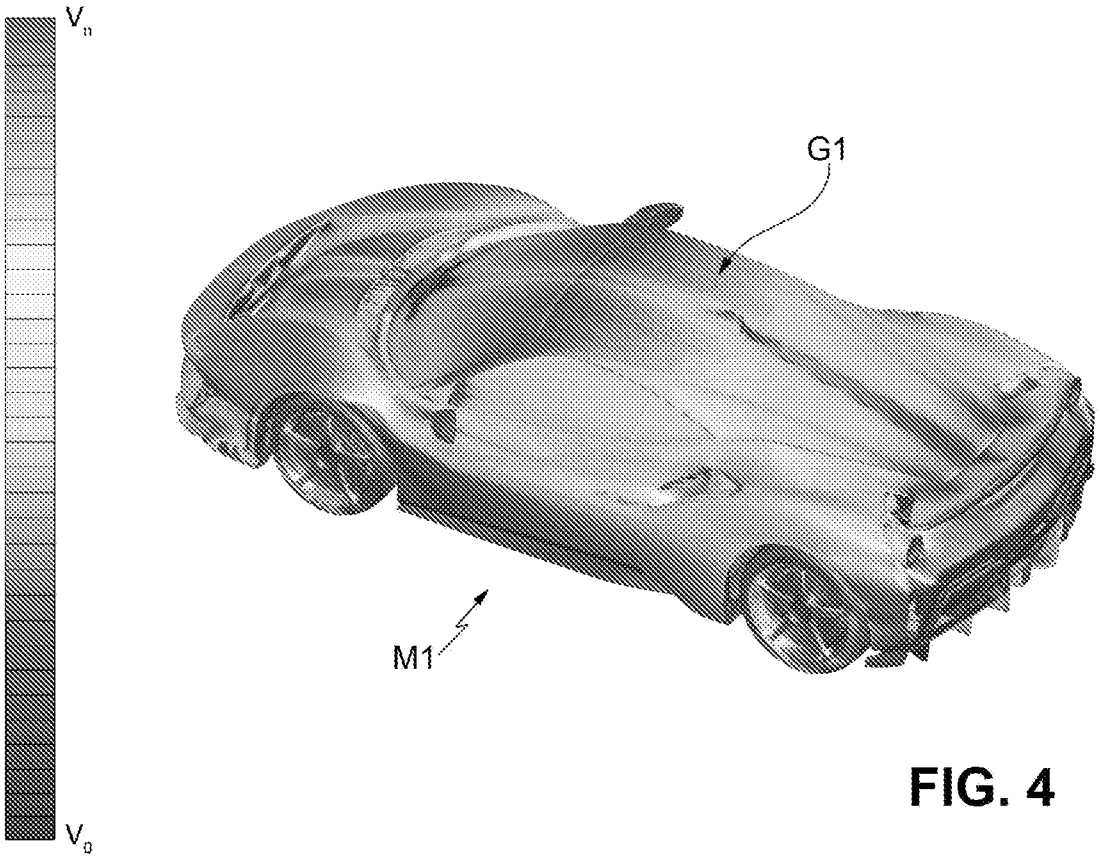


FIG. 4

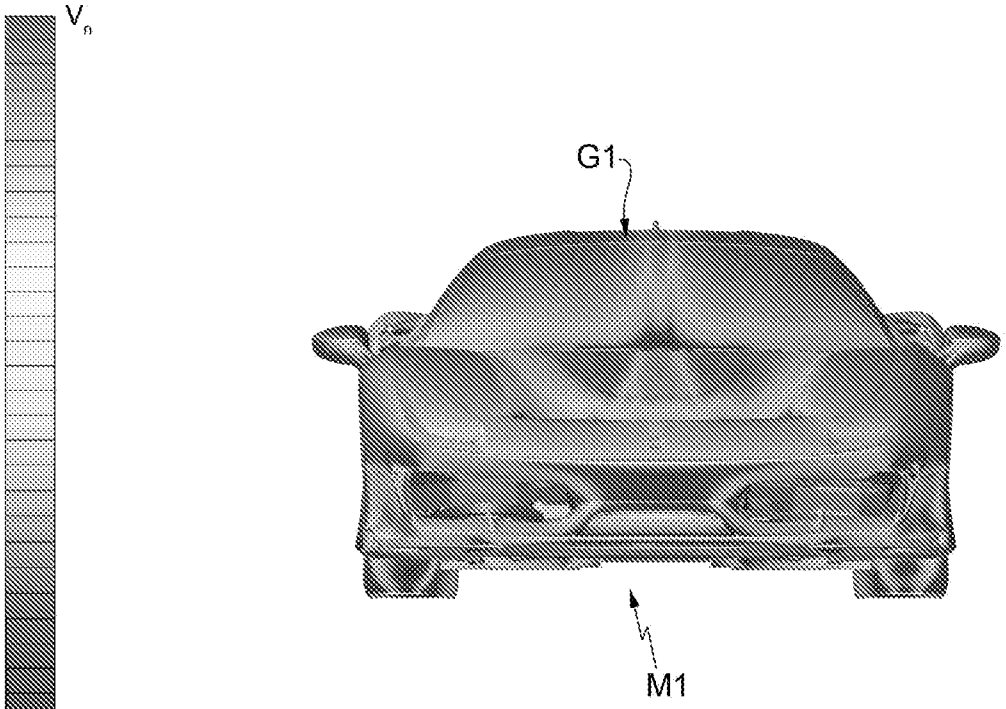


FIG. 5

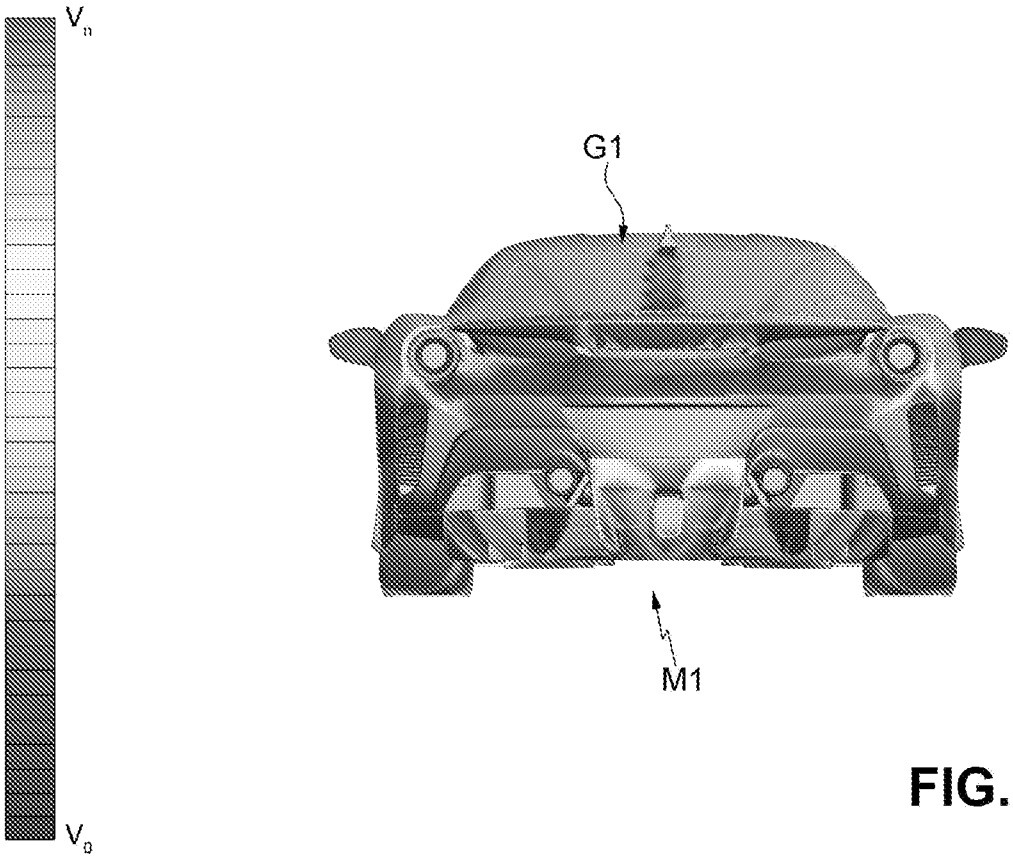


FIG. 6

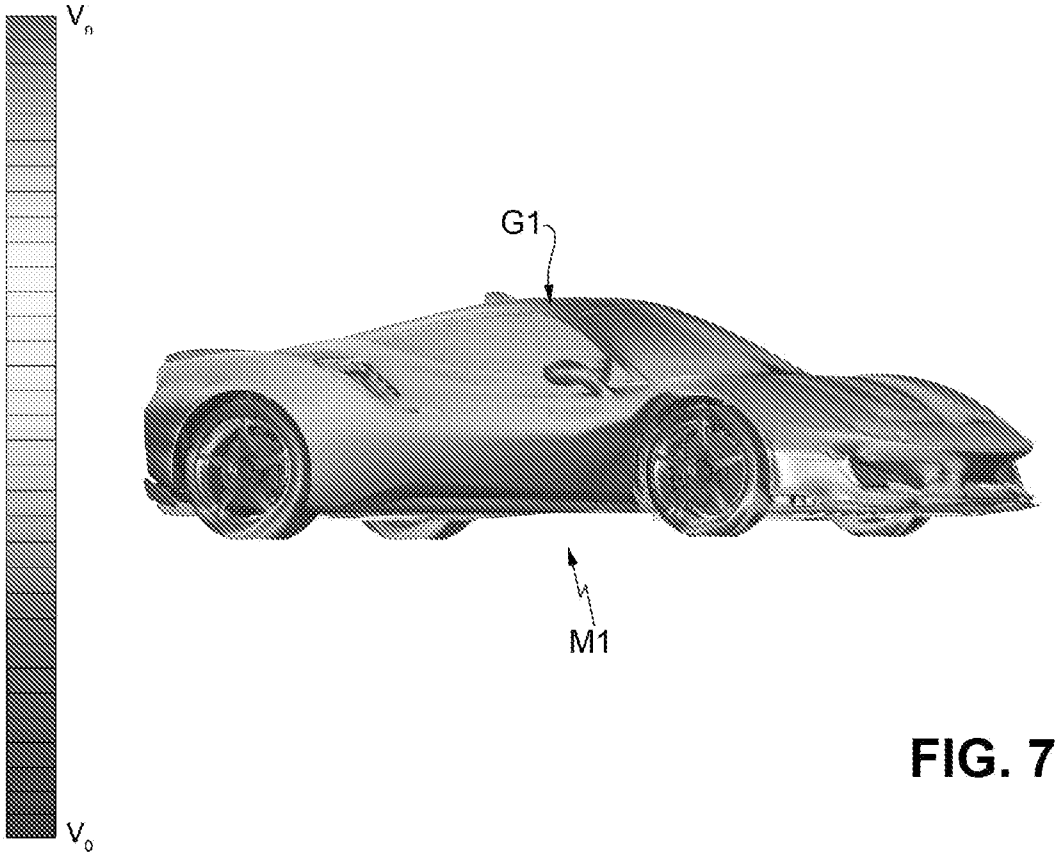


FIG. 7

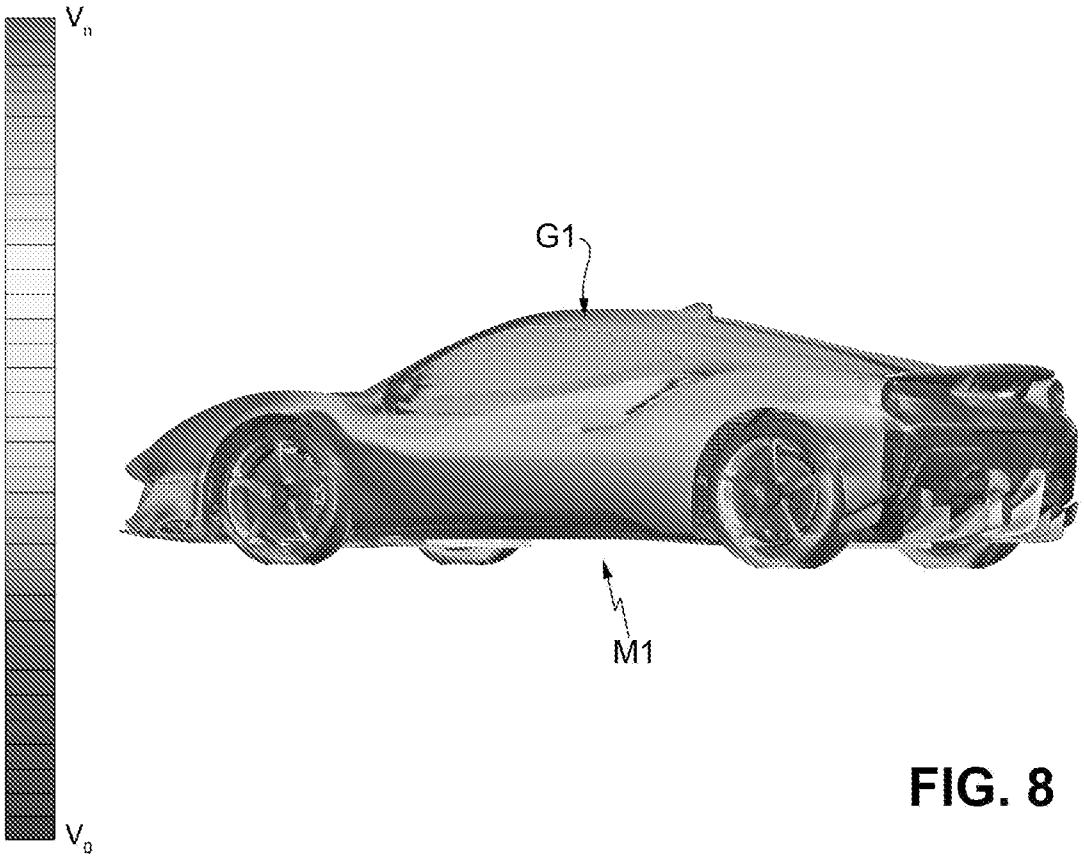


FIG. 8

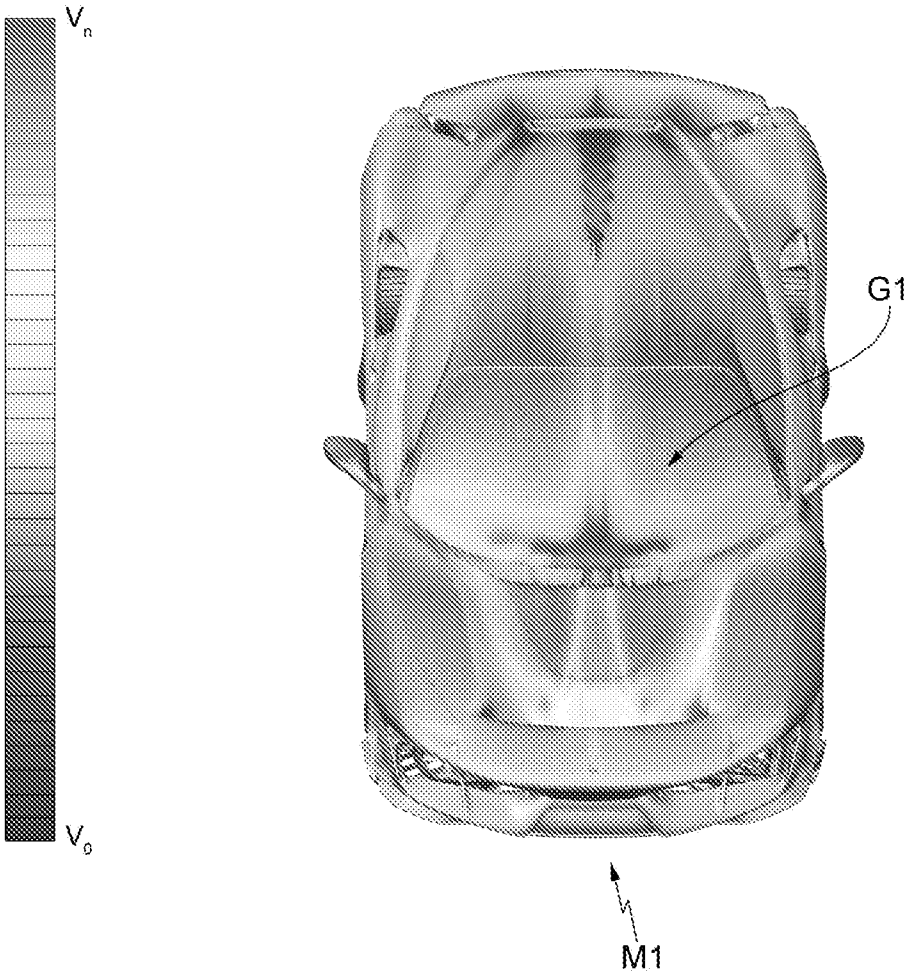


FIG. 9

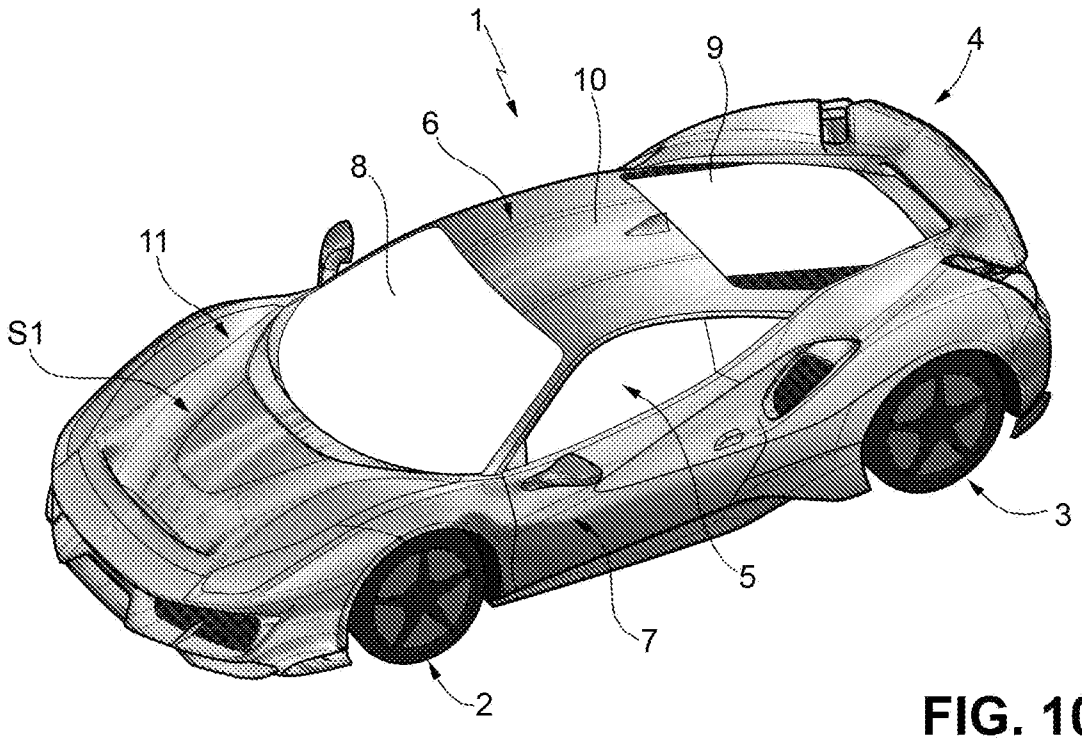


FIG. 10

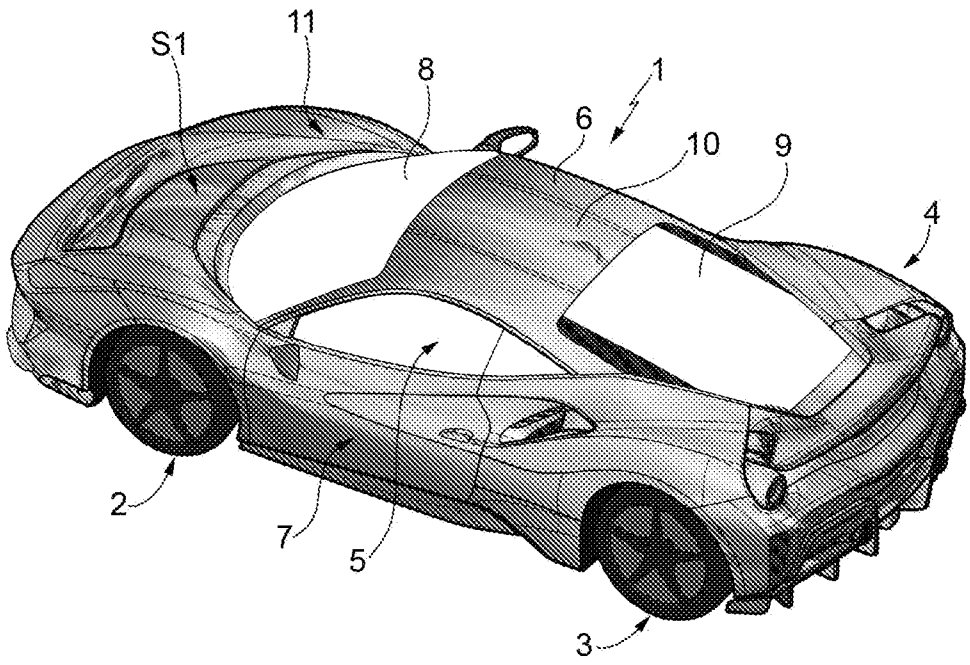


FIG. 11

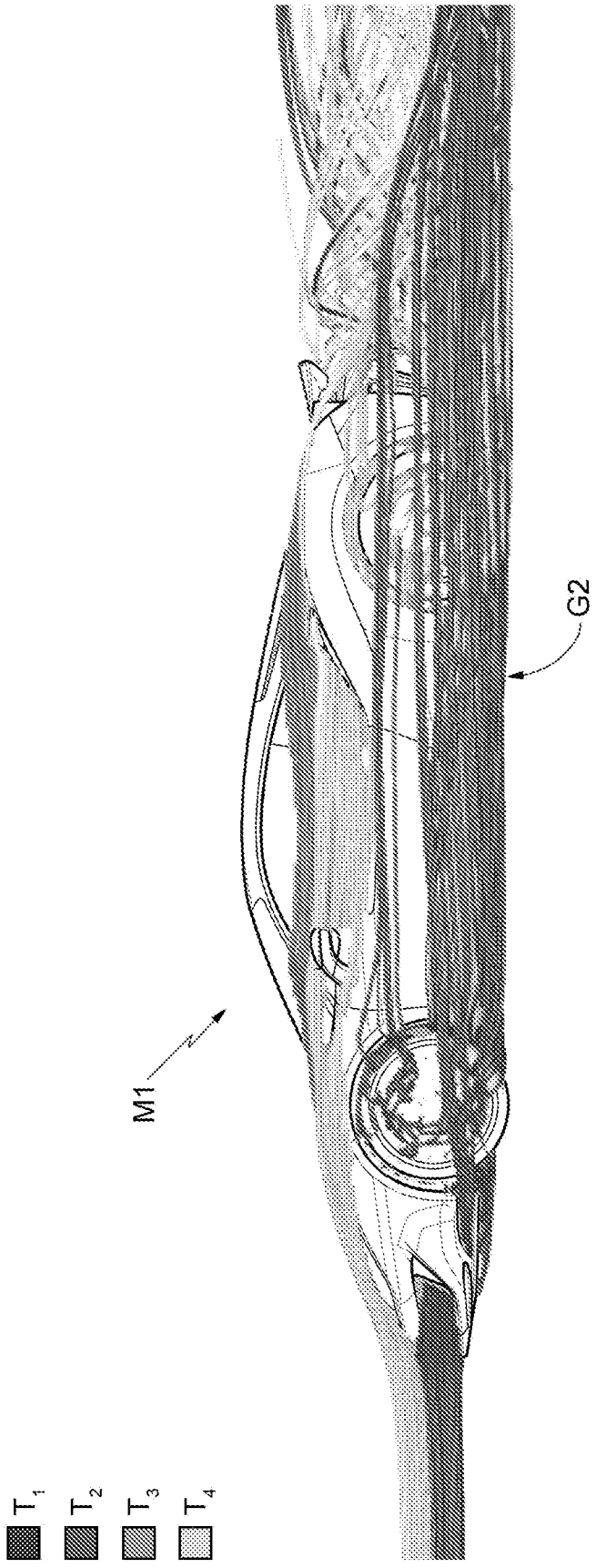


FIG. 12

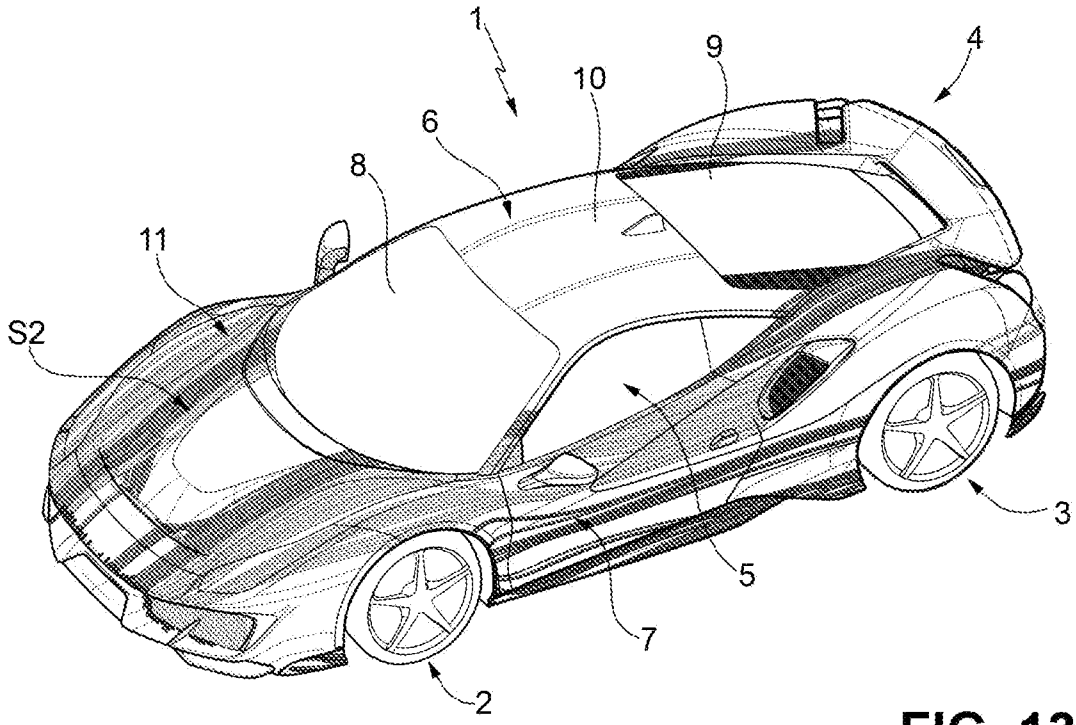


FIG. 13

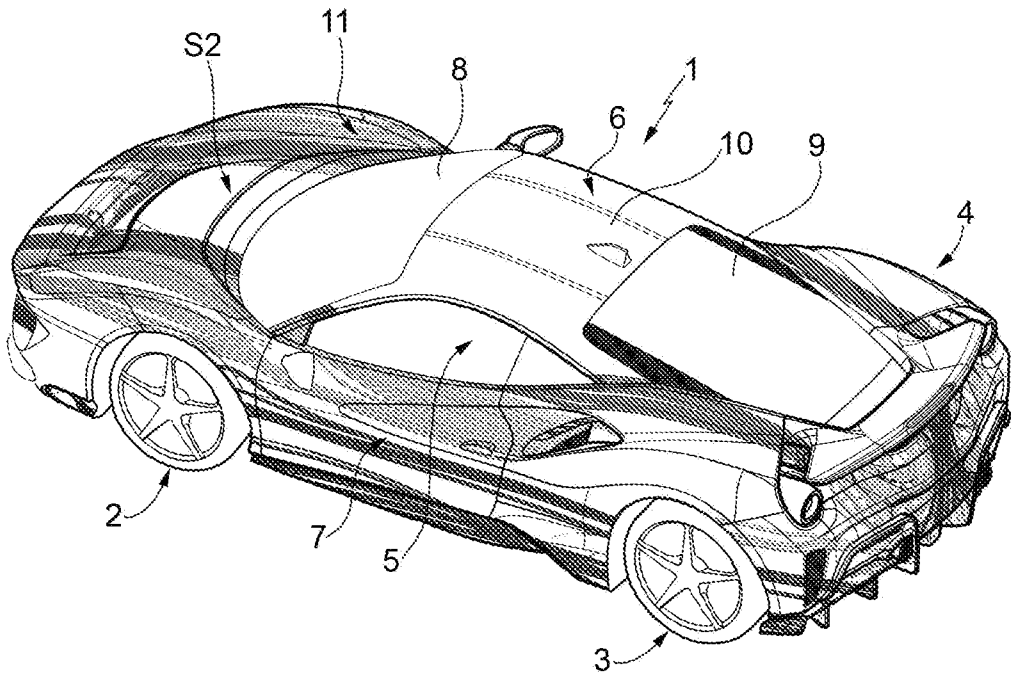


FIG. 14

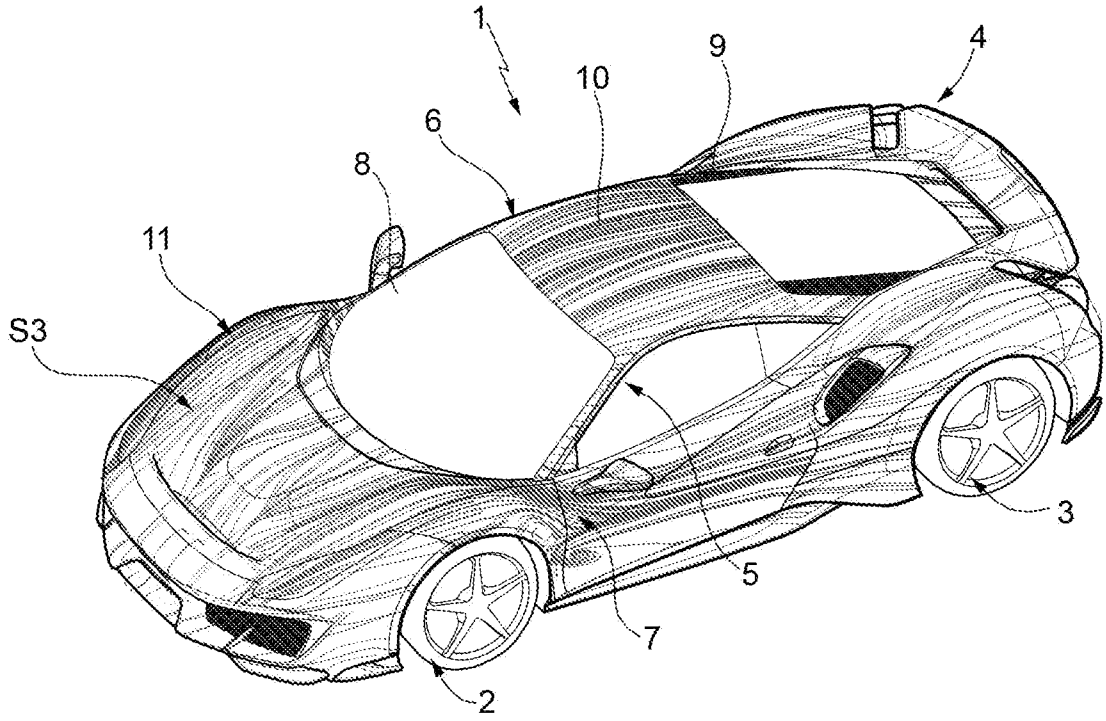


FIG. 15

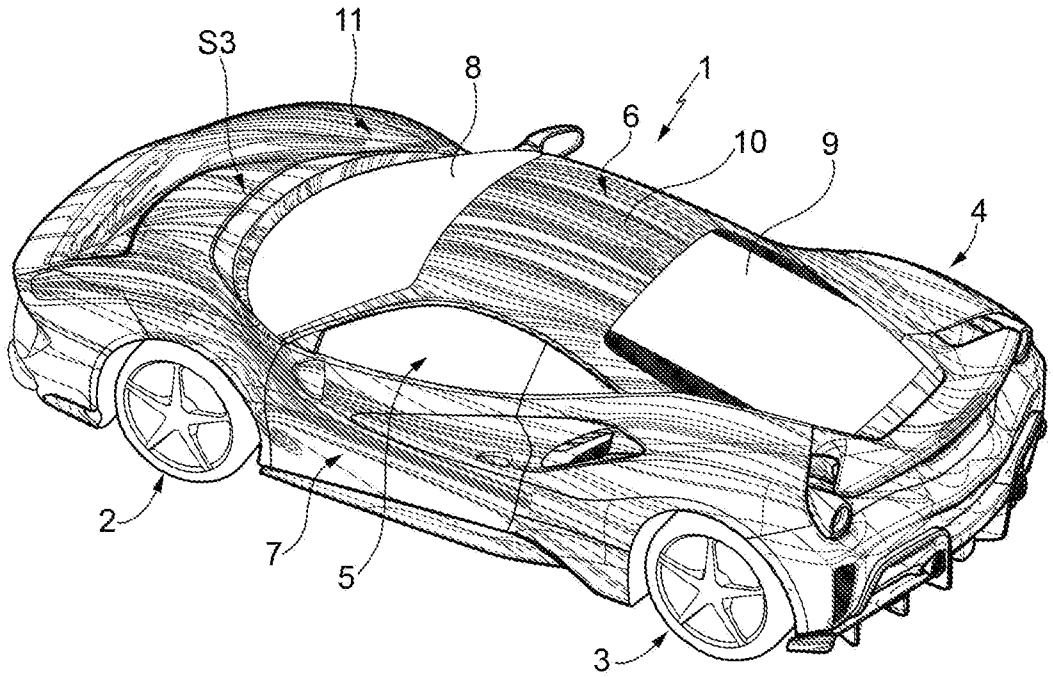


FIG. 16

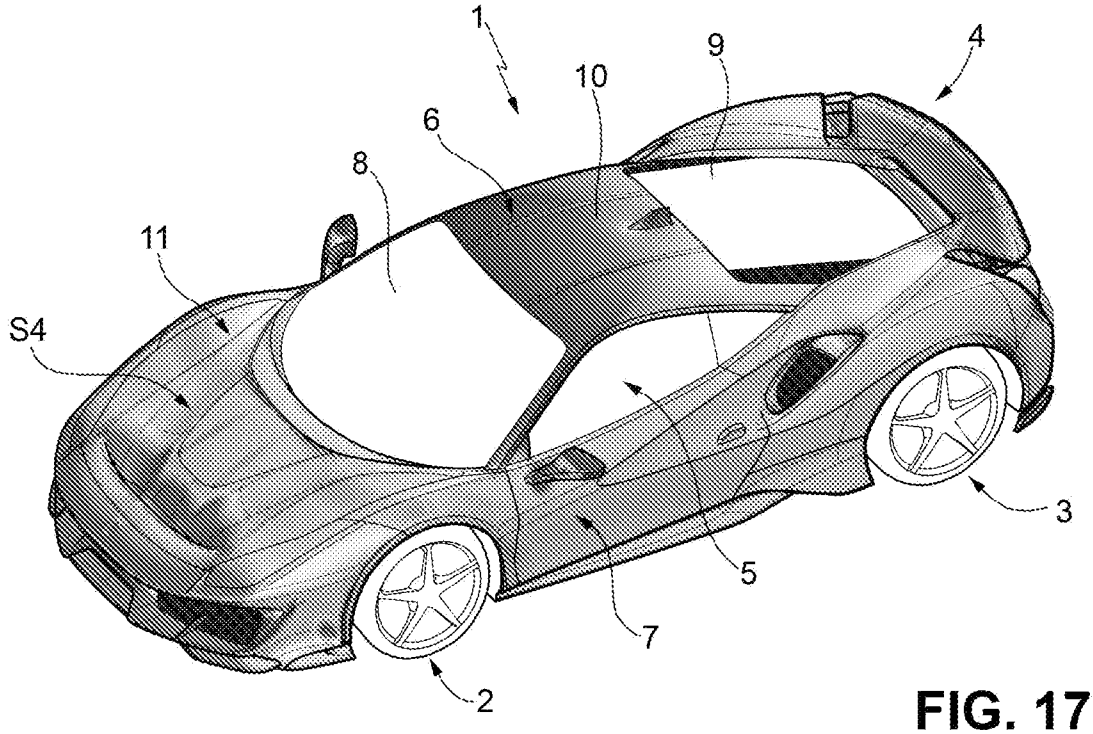


FIG. 17

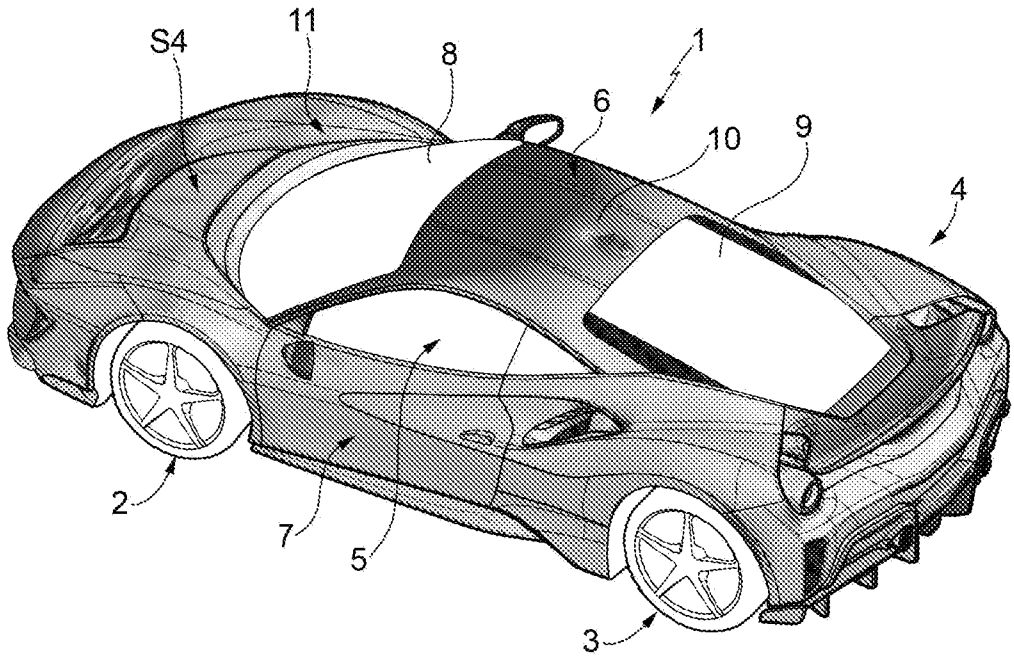


FIG. 18

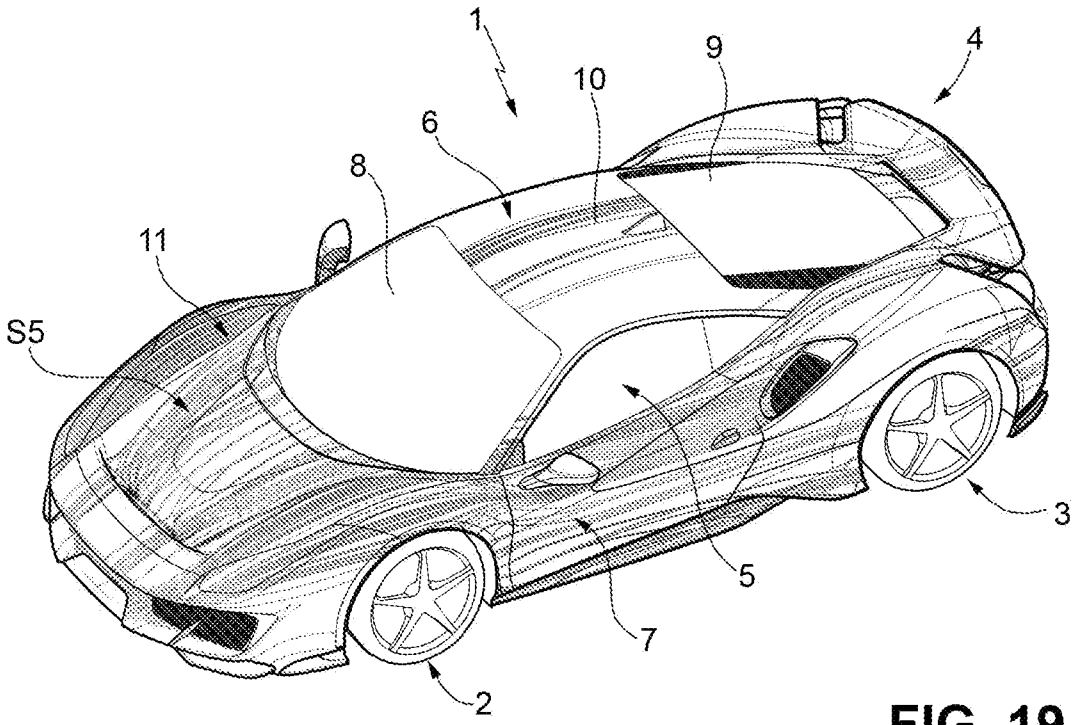


FIG. 19

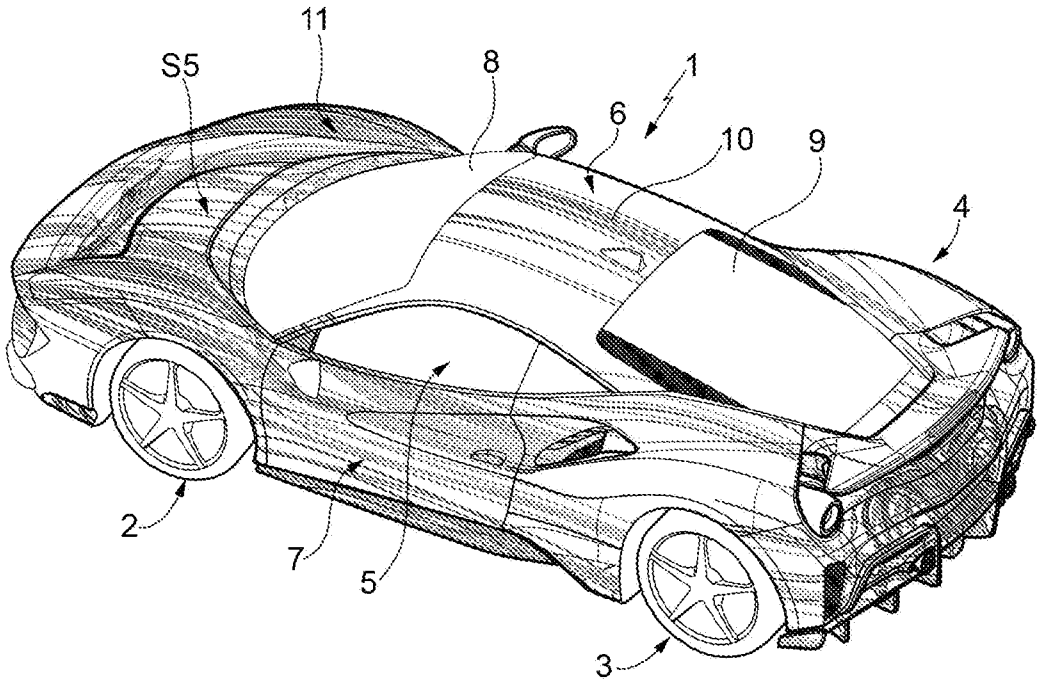


FIG. 20

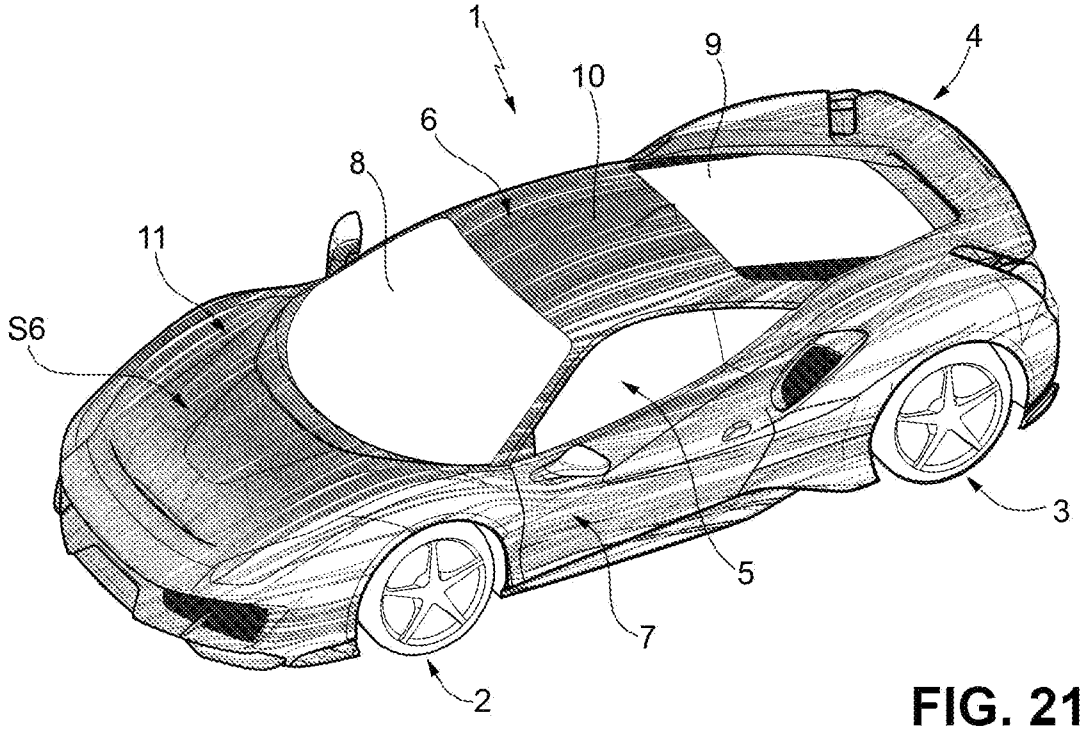


FIG. 21

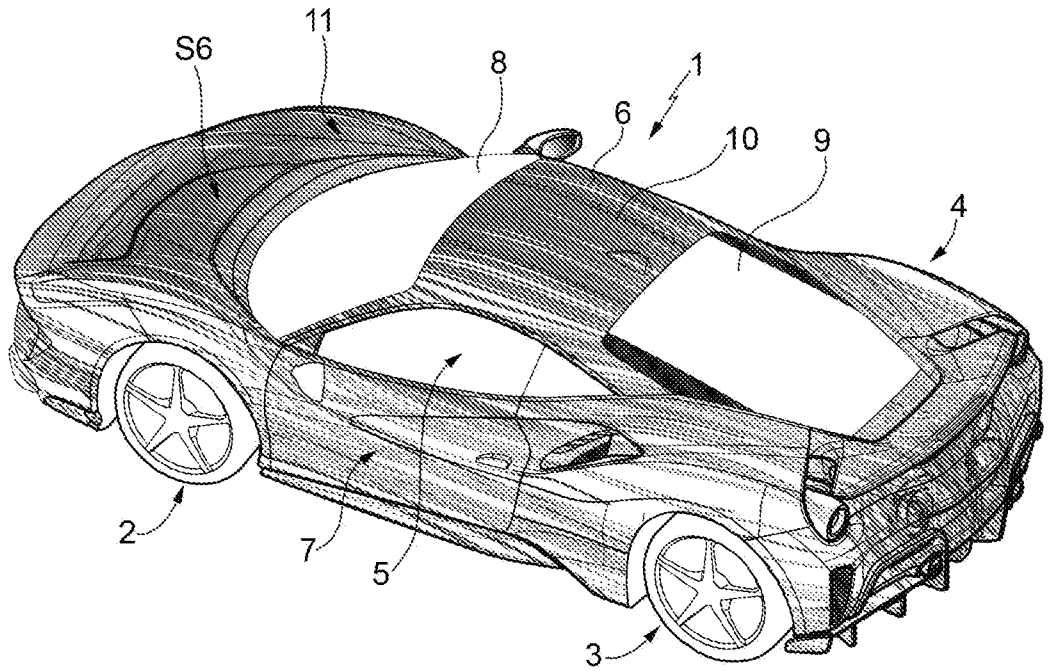


FIG. 22

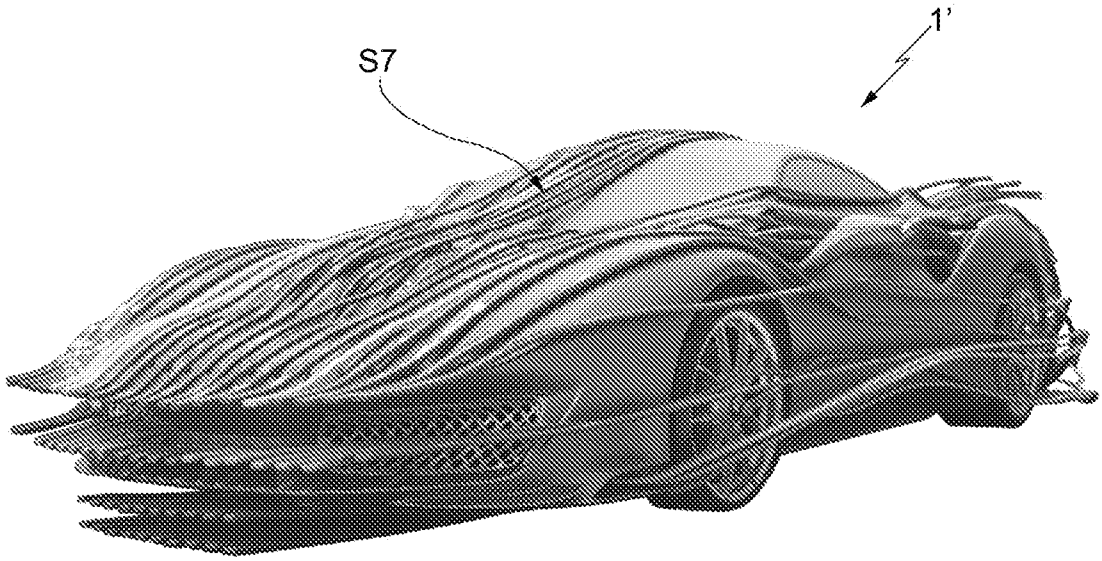


FIG. 23

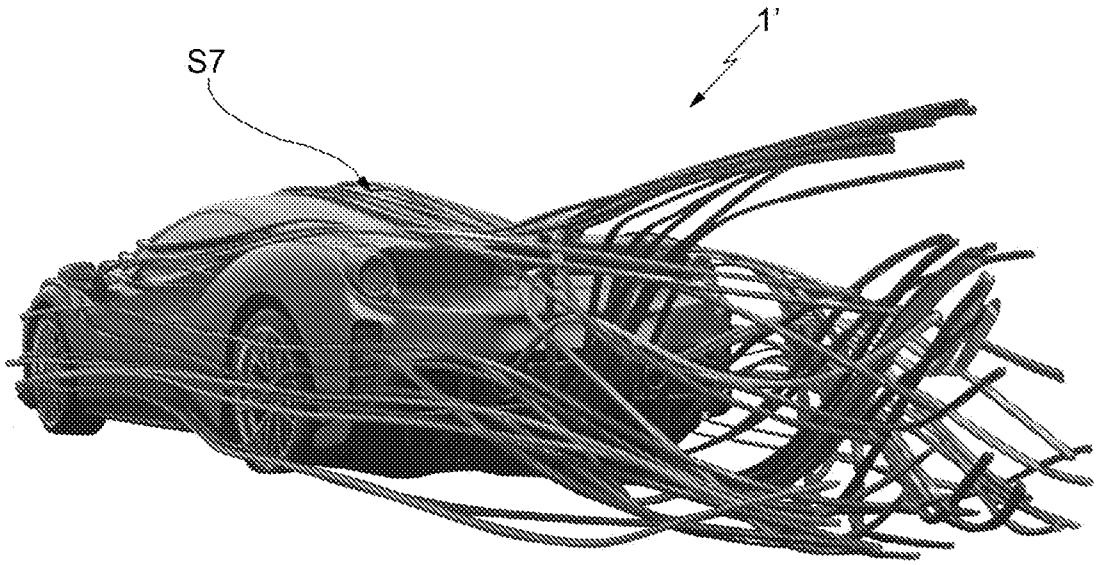


FIG. 24

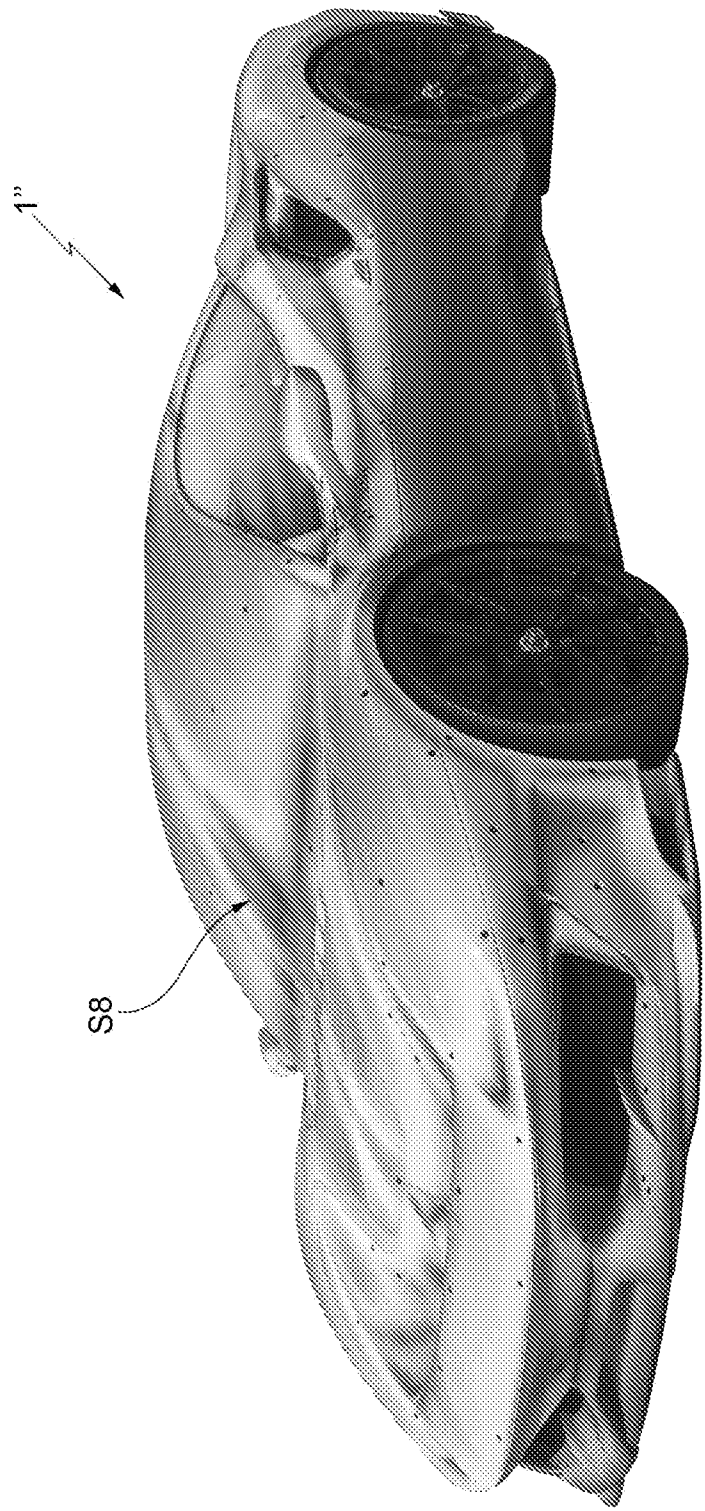


FIG. 25

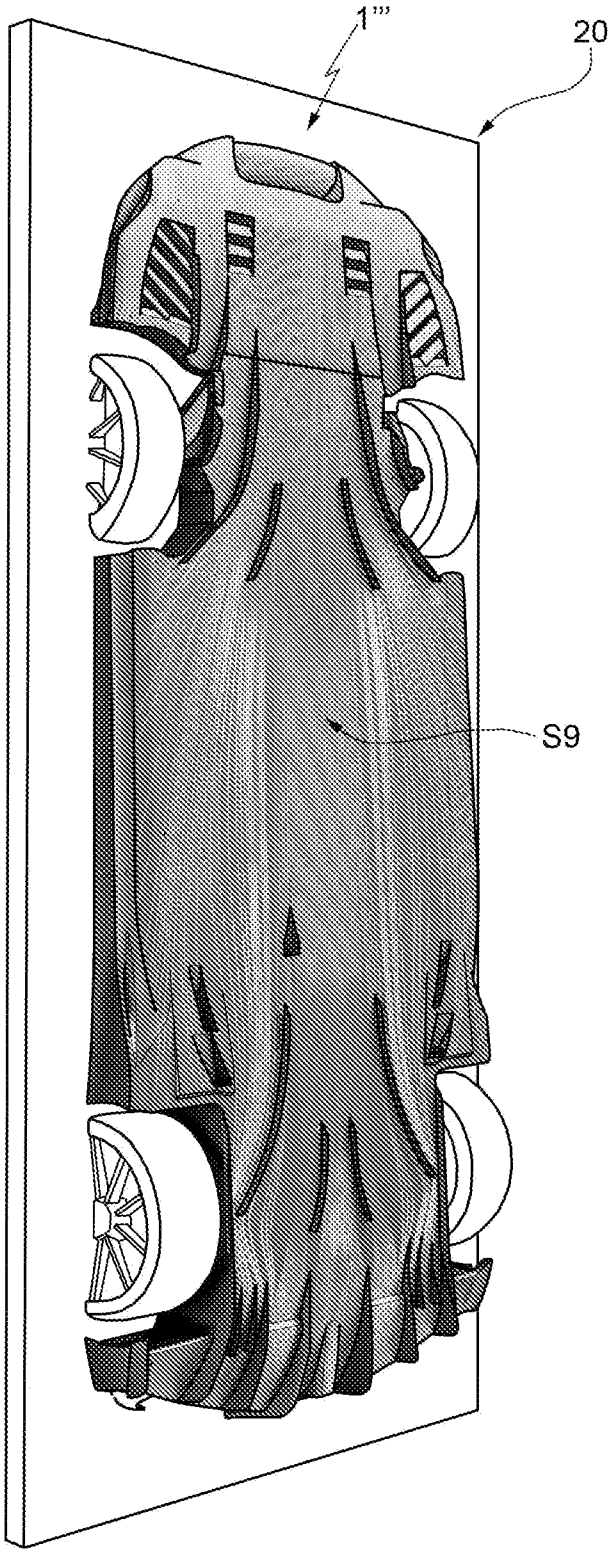


FIG. 26

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/057778

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F30/15
ADD. G06F111/10

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)
G06F

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Autodesk: "Autodesk Flow Design - A Virtual Wind Tunnel On Your Desktop", , 29 January 2014 (2014-01-29), page 1, XP054979371, Retrieved from the Internet: URL:https://www.youtube.com/watch?v=2RBOtd-Z8O8 [retrieved on 2019-05-09] 0:20-1:27 the whole document	1-8

-/--

[X] 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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"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	Date of mailing of the international search report
13 January 2020	22/01/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Joris, Pierre

1

Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2019/057778

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	Altair Engineering Inc.: "HyperWorks Virtual Wind Tunnel", , 23 June 2014 (2014-06-23), page 1, XP054979375, Retrieved from the Internet: URL:https://www.youtube.com/watch?v=toqtl4x35qM [retrieved on 2019-05-09] 0:00-1:10 the whole document	1-8
X	S. CHANDRA: "CFD Analysis of PACE Formula-1 Car", COMPUTER-AIDED DESIGN AND APPLICATIONS, vol. 8, no. PACE, 1 December 2011 (2011-12-01), pages 1-14, XP055586870, US ISSN: 1686-4360, DOI: 10.3722/cadaps.2011.PACE.1-14 abstract sections 6, 8, 9 figures 13-16 the whole document	1-8
X	R. B SHARMA ET AL: "CFD Simulation for Flow over Passenger Car Using Tail Plates for Aerodynamic Drag Reduction", IOSR JOURNAL OF MECHANICAL AND CIVIL ENGINEERING, vol. 7, no. 5, 1 January 2013 (2013-01-01) , pages 28-35, XP055586861, ISSN: 2320-334X, DOI: 10.9790/1684-0752835 abstract sections II, V, VI figures 8-10, 17-19 the whole document	1-8

1