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(54) **ESTIMATION OF THE PARTICULATE COMBUSTION RATE IN THE PARTICULATE FILTER FOR INTERNAL COMBUSTION ENGINES OF VEHICLES WITH THERMAL OR HYBRID PROPULSION DURING THE INJECTION OF THE ENGINES THEMSELVES**

(57) Vehicular control system (S) for estimating the soot combustion or oxidation rate in a particulate filter (GPF) in a vehicle (V), the vehicle (V) includes a vehicular powertrain (GM) comprising a propulsion unit (P) and a transmission system (T) interposed between the propulsion unit (P) and drive wheels (W) of the vehicle (V); the propulsion unit (P) includes at least one internal combustion (MT) engine configured to be fuel powered. The vehicle (V) also includes exhaust components (CS) connected to the internal combustion engine and including a catalytic converter (TWC) to convert the major pollutants in the exhaust gas into less polluting gases and a particulate filter (GPF) connected to the catalytic converter (TWC) and designed to filter the soot emitted by the internal combustion engine (MT). The vehicular control system (S) is designed to: acquire a model (**GPF_Soot_Load_Rate_Mdld**) of soot combustion rate in the particulate filter (GPF) and a model (**GPF_SL_Regen_Burn_Rate_Mdld**) of soot load regeneration combustion rate in the particulate filter (GPF); acquire quantities

indicative of exhaust oxygen concentration mass flow (**Exh_O2_Mass_Flow**), soot load (**GPF_Soot_Load**) in the particulate filter (GPF) and temperature (**GPF_Temp**) of the particulate filter (GPF); determine a soot combustion rate (**GPF_Soot_Burn_Rate_Firing_Lean**) in the particulate filter (GPF) in the case of excess oxygen for conducting the soot combustion reaction based on the exhaust oxygen concentration mass flow (**Exh_O2_Mass_Flow**), soot load (**GPF_Soot_Load**) in the particulate filter (GPF) and temperature (**GPF_Temp**) of the particulate filter (GPF); and determine the actual soot combustion rate in the particulate filter (GPF) based on the model (**GPF_Soot_Load_Rate_Mdld**) of soot combustion rate in the particulate filter (GPF), the model (**GPF_SL_Regen_Burn_Rate_Mdld**) of soot load regeneration combustion rate in the particulate filter (GPF) and the soot combustion rate (**GPF_Soot_Burn_Rate_Firing_Lean**) in the particulate filter (GPF) in the case of excess oxygen for conducting the soot combustion reaction.

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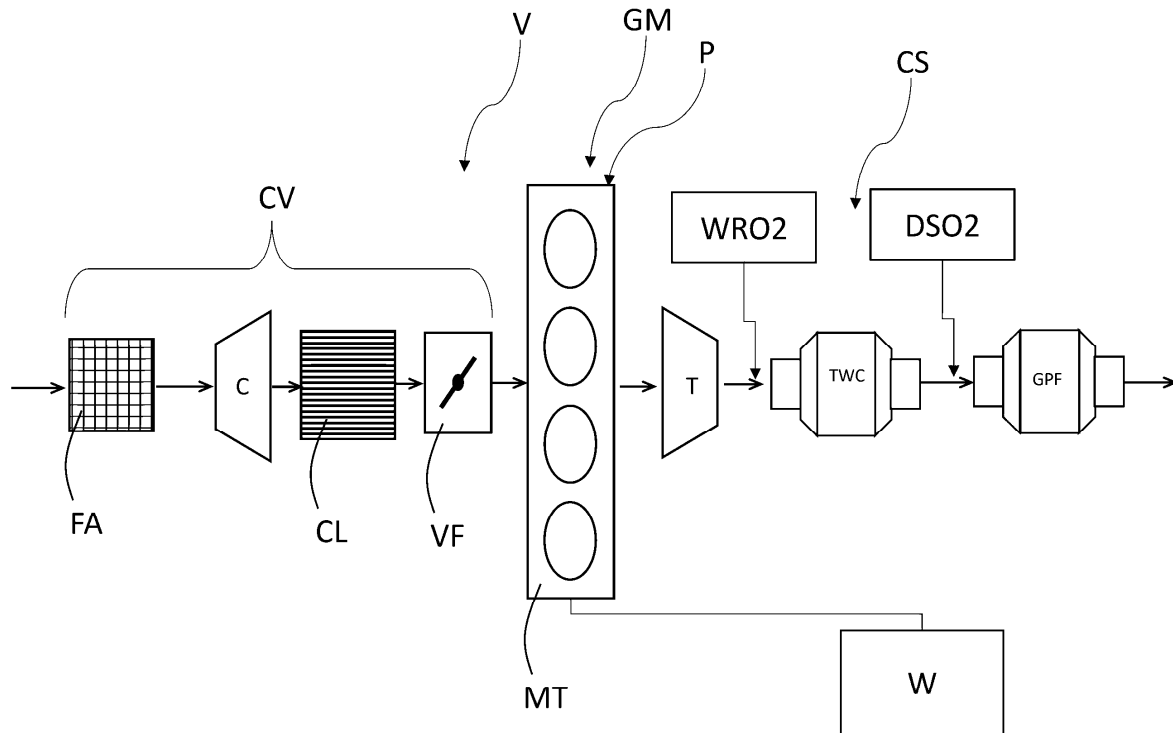


FIG. 1

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Description

CROSS-REFERENCE To RELATED APPLICATIONS

[0001] This patent application claims priority from Italian patent application no. 102025000007065 filed on April 2, 2025, the entire disclosure of which is incorporated herein by reference.

TECHNICAL FIELD OF THE INVENTION.

[0002] The present invention relates in general to the field of internal combustion or thermal engine management, in particular the estimation of the rate of combustion or oxidation of particulate matter in the particulate filter for internal combustion engines of vehicles with thermal or hybrid propulsion, in particular during fuel injection (fueling).

[0003] The present invention relates to a vehicular control system and a computer program product or software for estimating the rate of combustion or oxidation of particulate matter in a particulate filter of a vehicle, in particular a vehicle with thermal or hybrid propulsion.

[0004] The present invention has application in any type of road vehicle, whether it is used to transport people, such as a passenger car, bus, motor home, etc., or to transport goods, such as an industrial vehicle (truck, tractor-trailer, etc.) or light or medium-heavy commercial vehicle (van, van-van, cruiser, etc.).

STATE OF THE ART.

[0005] As is well known, in internal combustion engines equipped with a Gasoline Particulate Filter (GPF), e.g., in vehicles with thermal or hybrid propulsion, it is important to know the concentration of oxygen in the exhaust gas entering the particulate filter as well as the flow rate at which this oxygen enters the said particulate filter.

[0006] Figure 1 schematically shows a vehicle **V**, for example with thermal or hybrid propulsion, comprising a vehicular powertrain **GM** comprising a propulsion unit **P**, for example thermal or hybrid type, and a transmission system **T** interposed between the propulsion unit **P** and the drive wheels **W** of the vehicle **V**. In particular, the propulsion unit **P** comprises at least one internal combustion engine, also referred to as a thermal engine, **MT**.

[0007] The vehicle **V** also comprises vehicular components **CV**, the latter comprising at least one valve **VF** in particular a throttle valve designed to allow upstream regulation of the internal combustion engine **MT** of the amount of air trapped in the cylinders. In addition, as shown in Figure 1, the vehicular components **CV** comprise:

- an air filter **FA** designed to filter air entering the vehicle **V**;
- a compressor **C** connected to the air filter **FA** and

- designed to receive the filtered air to compress it; and
- a cooling system or cooler **CL** connected to compressor **C** and the valve **VF** and designed to perform cooling of the compressed air coming from compressor **C**.

[0008] The vehicle **V** also comprises exhaust components **CS**, which are connected to the internal combustion engine **MT** and here comprise a supercharger turbine **T**, designed to employ the exhaust gas produced by the internal combustion engine **MT** to propel the compressor **C** of the vehicle **V** to increase its rotational speed and to acquire air from the outside and supply compressed air to the internal combustion engine **MT** to allow more fuel to be burned; and a catalytic converter **TWC**, the latter being connected to the supercharger turbine **T**, designed to convert the major pollutants in the exhaust gas (in particular, hydrocarbons, carbon monoxide and nitrogen oxides) into less polluting gases. According to one aspect of the present invention, the exhaust components **CS** also comprise the particulate filter **GPF**, which is connected to the catalytic converter **TWC** and designed to filter particulate matter emitted by the internal combustion engine **MT**.

[0009] It is known that, in order to perform combustion or oxidize a mass of particulate matter or soot in the particulate filter **GPF**, the amount of oxygen to be supplied for soot combustion is typically provided during a phase of operation of the internal combustion engine **MT** called Deceleration Fuel *Shut Off* (DFSO), in which the required torque is essentially zero (in particular, the accelerator pedal of vehicle **V** is completely released) and fuel is not injected into the combustion chamber of the same vehicle **V** so that a non-negligible amount of air passes through the combustion chamber, exhaust, catalytic converter **TWC** and the particulate filter **GPF**, thus achieving the above-mentioned oxidation.

[0010] Methods and systems are known to control the rate of combustion or oxidation of particulate matter in the particulate filter **GPF**.

OBJECT AND ABSTRACT OF THE INVENTION

[0011] The Applicant has seen that the known solutions are amenable to improvement.

[0012] In particular, current models for estimating soot combustion rate trends in the particulate filter **GPF** predict that the particulate combustion rate is positive (i.e., the particulate is burning) only as long as the internal combustion engine **MT** is in the DFSO phase or in the shutdown phase, and is zero during the remaining operating phases of the internal combustion engine **MT**. Therefore, the current models do not consider operating points of the internal combustion engine **MT** wherein the phenomena of feeding and simultaneous combustion of particulate matter occur, without there being a DFSO phase. In this regard, the Applicant noted that particulate matter can also be burned in the particulate filter **GPF** due

to the oxygen created within the catalytic converter **TWC**, i.e., at high temperatures, e.g., greater than 800°C, and with high exhaust gas flows, during fuel injection; in addition, additional oxygen is generated as a reaction product from the dissociation reaction of carbon dioxide into carbon monoxide and oxygen, thus resulting in a greater presence of oxygen, which leads, therefore, to greater oxidation/combustion of particulate matter.

[0013] In addition, particulate matter, which comprises carbon in its composition, can be further combusted through a Boudouard reaction, where carbon dioxide and carbon are the reactants and carbon monoxide is the reaction product; such a reaction can take place in the presence of a high amount of carbon (i.e., with a high level of particulate matter) and generally for thermal combustion engines **MT** with stoichiometric lambda equal to one and lower carbon monoxide emissions. In more detail, the aforementioned Boudouard reaction is favoured under high load and high engine speed operating conditions due to the high carbon dioxide flux and high temperature of the exhaust gas produced.

[0014] In addition, it is known to perform particulate combustion during the shutdown of the internal combustion engine **MT**, such as during Start&Stop events, which, however, do not allow the implementation of effective soot combustion reaction control strategies.

[0015] In addition, as anticipated above, the production of high amounts of oxygen can cause the particulate combustion reaction if the catalytic converter **TWC** has a low *Oxygen Storage Capacity* (OSC) and not allow the conversion of the total pollutants produced. In fact, the free oxygen produced can pass from the catalytic converter **TWC** to the particulate filter **GPF** in the case of high space velocity (defined in particular as the ratio of the total volumetric exhaust gas flow to the volume of the catalytic converter **TWC**); this results in a reduction of the time required for the conversion of the pollutants produced in the catalytic converter **TWC**, and, therefore, the free oxygen will be used for the combustion of particulate matter.

[0016] Therefore, the currently known methods and systems do not allow accurate control of the rate of combustion or oxidation of particulate matter, because, as explained above, there are several factors that contribute to substantial changes in the trend prediction produced by the known methods and systems.

[0017] Accordingly, it is the purpose of the present invention to make available a vehicular control system and related software for estimating the rate of combustion or oxidation of particulate matter in a particulate filter of a vehicle, in particular a vehicle with thermal or hybrid propulsion, even more in particular during fueling or fuel injection which will enable at least partial solutions to the problems that plague the solutions of the known art.

[0018] According to the present invention, a vehicular control system and related software are provided for estimating the rate of combustion or oxidation of particulate matter in a particulate filter of a vehicle, in parti-

cular a thermal-propelled vehicle or a hybrid vehicle, even more in particular during fuel supply or fuel injection, as claimed in the appended claims.

5 BRIEF DESCRIPTION OF THE DRAWINGS

[0019]

Figure 1 schematically shows a vehicle comprising an internal combustion engine including exhaust components.

Figure 2 schematically shows a diagram of a method for estimating the rate of combustion or oxidation of particulate matter in a particulate filter of a vehicle according to the present invention.

Figure 3 schematically shows a diagram of a method for estimating a quantity related to the combustion rate of particulate matter in a particulate filter of a vehicle when fuel is injected according to the present invention.

Figure 4 schematically shows a diagram of a method for estimating a quantity relative to the combustion rate of particulate matter in a particulate filter of a vehicle at elevated temperatures according to the present invention.

DESCRIPTION OF PREFERRED FORMS OF EMBODIMENT OF THE INVENTION

[0020] The present invention will now be described in detail with reference to the attached figures to enable a skilled person to realize and use it. Various modifications to the described embodiments will be immediately apparent to skilled persons, and the generic principles described can be applied to other embodiments and applications without departing from the protective scope of the present invention as defined in the appended claims. Therefore, the present invention should not be considered limited to the embodiments described and illustrated, but should be accorded the broadest scope of protection consistent with the features described and claimed.

[0021] Where not otherwise defined, all technical and scientific terms used herein have the same meaning commonly used by persons of ordinary experience in the field pertaining to the present invention. In case of conflict, this description, comprising the definitions provided, will be binding. Furthermore, the examples are provided for illustrative purposes only and as such should not be considered limiting.

[0022] In particular, the block diagrams included in the attached figures and described below are not intended as representations of structural features, i.e., constructional limitations, but are to be interpreted as representations of functional features, i.e., properties that are intrinsic to the devices and defined by the effects obtained, i.e., functional limitations and that can be implemented in different ways, thus in a way that protects the functionality of the

same (ability to function).

[0023] In order to facilitate the understanding of the embodiments disclosed here, some specific embodiments will be referred to and a specific language will be used to disclose them. The terminology used herein is intended to disclose only particular embodiments, and is not intended to limit the scope of the present invention.

[0024] To summarize, the present invention relates to a vehicular control system and a related computer program product or software designed to estimate the particulate load in a vehicle's particulate filter by updating the calculated value using preset models even when the vehicle's internal combustion engine is fuelled, thus without waiting for a DFSO phase.

[0025] In the following, reference is made to a thermal- or hybrid-powered vehicle similar to the one shown in Figure 1; therefore, in the following and without any loss of generality, reference will be made to the thermal- or hybrid-powered **V** vehicle shown in Figure 1 and its references.

[0026] Figure 2 schematically shows a vehicular control system **S** for estimating the rate of combustion or oxidation of particulate matter in the particulate filter **GPF** in the vehicle **V**; in particular, with particular reference to Figure 3, the vehicular control system **S** is designed to:

- acquire a model of soot combustion rate in the particulate filter **GPF**, referred to as **GPF_Soot_Load_Rate_Mdlld** in the following, and a model of soot load regeneration combustion rate in the particulate filter **GPF**, referred to as **GPF_SL_Regen_Burn_Rate_Mdlld** in the following;
- acquire quantities indicative of exhaust oxygen concentration mass flow **Exh_O2_Mass_Flow**, soot load in the particulate filter **GPF**, denoted hereafter as **GPF_Soot_Load**, and a temperature of the particulate filter **GPF**, referred to as **GPF_Temp** in the following;
- determine a soot combustion rate in the particulate filter **GPF** wherein there is excess oxygen to conduct the soot combustion reaction, denoted below as **GPF_Soot_Burn_Rate_Firing_Lean** and indicative of conditions wherein, for example, there is a dissociation reaction leading to an increase in the amount of oxygen available, based on the mass flow of exhaust oxygen concentration **Exh_O2_Mass_Flow**, the soot load in the particulate filter **GPF** **GPF_Soot_Load**, and the temperature of the particulate filter **GPF** **GPF_Temp**; e
- determine the actual soot combustion rate in the particulate filter **GPF** based on the soot combustion rate model in the particulate filter **GPF** **GPF_Soot_Load_Rate_Mdlld**, of the soot load regeneration combustion rate model in the particulate filter **GPF** **GPF_SL_Regen_Burn_Rate_Mdlld** and the soot combustion rate model in the particulate filter **GPF** in case of excess oxygen for conducting the particulate combustion reaction **GPF_Soot_Burn_Ra-**

te_Firing_Lean, in particular by means of an addition module **ADD**.

[0027] It is noted that the value of the temperature of the particulate filter **GPF** can be either the temperature at the inlet of the particulate filter **GPF** or the internal temperature of the particulate filter **GPF**, depending on the type of layout of the particulate filter **GPF**, the vehicle **V**, and the characteristics of the internal combustion engine **MT**.

[0028] Furthermore, according to one aspect of the present invention, the soot combustion rate pattern in the particulate filter **GPF** **GPF_Soot_Load_Rate_Mdlld**, and the soot load regeneration combustion rate pattern in the particulate filter **GPF** **GPF_SL_Regen_Burn_Rate_Mdlld** are predetermined by the system **S**, for example, based on outputs provided by sensors and/or control logic integrated in the gas exhaust system and engine control unit of the vehicle **V**.

[0029] In particular, with reference to Figure 3, in order to determine the soot combustion rate in the particulate filter **GPF** in case of excess oxygen for conducting the particulate combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean**, the system **S** is designed to:

- verify (block **S1**) that vehicle **V** is in a phase wherein it is fuelled, *i.e.*, vehicle **V** is not in DFSO mode;
- verify (block **S2**) that the oxygen concentration at the inlet to the particulate filter **GPF** is greater than or equal to a predetermined threshold value, referred to below as **WRO2_US_Firing_Thr**, *i.e.*, that the mixture of air and soot is poor or lean (*i.e.*, there is a greater amount of oxygen than the amount of soot present).

[0030] In more detail, the system **S** is designed to verify that the vehicle **V** is in a different condition than the DFSO condition, *i.e.*, when the **V** vehicle is not fuelled, wherein, for example, there is both fuelling and particulate combustion. In particular, with reference to block **S1** in Figure 3, system **S** is designed to verify that a DFSO activation command is different from one, *i.e.*, does not occur.

[0031] In addition, the phases shown with reference to block **S2** are indicative of whether the mixture of air and fuel at the particulate filter **GPF**, shown in the following as an oxygen quantity value **WRO2_11_Lambda**, is greater than or equal to the predetermined threshold value **WRO2_US_Firing_Thr**, received by the system **S** (block **S4**). In this regard, with reference to Figure 1, the vehicle **V** is equipped with a sensory system **WRO2**, **DSO2** designed to generate outputs indicative of quantities related to the amount of oxygen entering the particulate filter **GPF** of vehicle **V**; in particular, the sensory system **WRO2**, **DSO2** comprises a first and a second oxygen sensor **WRO2**, **DSO2** arranged upstream and downstream of the catalytic converter **TWC**, respectively, and thus designed to monitor the flow of oxygen entering the catalytic converter **TWC** and the particulate filter **GPF**.

and, thus, determine the value of the amount of oxygen **WRO2_11_Lambda** (block **S3**).

[0032] Therefore, if the above conditions are both valid (block **S5**), the system **S** is designed to determine the particulate combustion rate in the particulate filter **GPF** in case of excess oxygen for conducting the particulate combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean** as disclosed in more detail below. Note that the system **S** is designed to provide (block **S8**) a multiplication index (block **S5**) to be provided to determine the particulate combustion rate in the particulate filter **GPF** in case of excess oxygen for conducting the particulate combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean**; in particular, the multiplication index can take binary value, specifically equal to 0 if at least one of the above conditions is determined to be invalid and equal to 1 if both of the above conditions are determined to be valid. In other words, the aforementioned soot combustion rate in the particulate filter **GPF** in the case of excess oxygen for conducting the soot combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean** is determined only if both of the above conditions are determined to be valid.

[0033] In order to determine the soot combustion rate in the particulate filter **GPF** in the case of excess oxygen for conducting the soot combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean**, the system **S** is designed to:

- determine (block **S6**) a value related to a degree of soot combustion based on the value of exhaust oxygen concentration mass flow **Exh_O2_Mass_Flow** and soot load in the particulate filter **GPF GPF_Soot_Load**;
- determine (block **S7**) a soot temperature multiplication value based on the temperature of the particulate filter **GPF GPF_Temp**; and
- if it is verified that the vehicle **V** is fueled and the concentration of oxygen at the inlet of the particulate filter **GPF** is greater than the predetermined threshold value **WRO2_US_Firing_Thr**, determine (block **S8**) the soot combustion rate in the particulate filter **GPF** in case of excess oxygen for conducting the soot combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean** also on the basis of the value related to a soot combustion degree and the soot temperature multiplication value.

[0034] In greater detail, according to one aspect of the present invention, in order to determine (block **S6**) the value relating to a degree of soot combustion, the system **S** is designed to extract the value relating to a degree of soot combustion from a value map, referred to in the following as **Surf_Lean_Mix**, dependent on the values of the exhaust oxygen concentration mass flow **Exh_O2_Mass_Flow** and the soot load in the particulate filter **GPF GPF_Soot_Load**. In addition, in order to determine (block **S7**) the soot temperature multiplication

value, system **S** is designed to extract the temperature multiplication value from a temperature multiplication vector, denoted in the following as **GPF_Temp_Multiplier_Lean**, based on the value of the temperature of the particulate filter **GPF GPF_Temp**.

[0035] Therefore, the soot combustion rate in the particulate filter **GPF** in case of excess oxygen for conducting the soot combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean** is the soot combustion rate derived from the value map **Surf_Lean_Mix**, the latter being a calibratable surface, dependent on the amount of exhaust oxygen **Exh_O2_Mass_Flow**, the latter being dependent on the amount of oxygen entering the particulate filter **GPF** and of the soot load in the particulate filter **GPF GPF_Soot_Load**. Note that the value map **Surf_Lean_Mix** is populated by running a dyno analysis of the internal combustion engine **MT** of the vehicle **V** at different levels of exhaust oxygen amount **Exh_O2_Mass_Flow** and at different temperatures of the particulate filter **GPF** and repeating it for various soot load values.

[0036] The value thus obtained from the value map **Surf_Lean_Mix** is then multiplied by the aforementioned multiplication index and soot temperature multiplication value, the latter being an index to dampen the value relative to a degree of soot combustion obtained, i.e., apply a weighting to it. Note that, if the multiplication index is equal to 1, i.e., the above conditions at block **S5** are valid, the temperature considered for soot combustion is the maximum acceptable temperature for particulate combustion in the particulate filter **GPF**; otherwise, if the multiplication index is 0, then the temperature considered for particulate combustion is the minimum acceptable temperature for soot combustion in the particulate filter **GPF**, i.e., we have a particulate combustion rate in the particulate filter **GPF** in the case of excess oxygen for conducting the soot combustion reaction **GPF_Soot_Burn_Rate_Firing_Lean** that is essentially zero.

[0037] As also highlighted in Figure 1, the model of soot combustion rate in the particulate filter **GPF GPF_Soot_Load_Rate_Mdl** is also fitted as a function of a soot combustion rate in the particulate filter **GPF** in the case of high temperature, denoted in the following as **GPF_Soot_Burn_Rate_Firing_High_Temp**; in particulate matter, this model relates to the particulate combustion rate at high temperature of the particulate filter **GPF**, derived, for example, from a Boudouard reaction, where high particulate loads and high internal combustion engine **MT** speeds occur due to high carbon dioxide fluxes and high exhaust gas temperature.

[0038] In particular, with reference to Figure 1, after acquiring the soot combustion rate model in the particulate filter **GPF GPF_Soot_Load_Rate_Mdl**, the soot load regeneration combustion rate model in the particulate filter **GPF GPF_SL_Regen_Burn_Rate_Mdl**, the quantities indicative of exhaust oxygen concentration mass flow **Exh_O2_Mass_Flow**, of the soot load in

the particulate filter **GPF** **GPF_Soot_Load** and the temperature of the particulate filter **GPF** **GPF_Temp**, and in addition to performing the previously described phases to determine the soot combustion rate in the particulate filter **GPF** in the case of excess oxygen for conducting the soot combustion reaction **GPF_Soot_Burn_Rate_Firing_Le****an**, the system **S** is also designed to:

- determine the soot combustion rate in the particulate filter **GPF** in case of high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp** based on the mass flow of exhaust gas flow dependent **Exh_Mass_Flow**, the soot load in the particulate filter **GPF** **GPF_Soot_Load**, and the temperature of the particulate filter **GPF** **GPF_Temp**; and
- determine the actual soot combustion rate in the particulate filter **GPF** also based on the soot combustion rate in the particulate filter **GPF** at high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp**.

[0039] Similar to what is disclosed with reference to Figure 2, in order to determine the soot combustion rate in the particulate filter **GPF** in the case of high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp**, the system **S** is designed to

- verify (blocks **S10**) that vehicle **V** is in a phase where in it is fuelled, i.e., the vehicle **V** is not in **DFSO** mode;
- verify (blocks **S12**) that the temperature of the particulate filter **GPF** **GPF_Temp** (acquired by the **S** system at block **S13**) is greater than or equal to a predetermined threshold value, shown below as **Temp_Burn_Firing_Thr** (acquired by the **S** system at block **S14**).

[0040] In particular, the phases shown with reference to blocks **S12** are indicative that the temperature of the particulate filter **GPF** is suitable for soot combustion in the particulate filter **GPF** itself.

[0041] Therefore, if the above conditions are both valid (block **S15**), the system **S** is designed to determine the soot combustion rate in the particulate filter **GPF** at high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp** as disclosed in more detail below. Note that, similar to what is disclosed with reference to Figure 2, the system **S** is designed to provide (block **S15**) a relative multiplication index to be provided to determine the soot combustion rate in the particulate filter **GPF** in the case of high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp**; in particular, the multiplication index can take binary value, specifically equal to 0 if at least one of the above conditions is determined to be invalid and equal to 1 if both of the above conditions are determined to be valid. In other words, the abovementioned soot combustion rate in the particulate filter **GPF** under high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp** is determined only if both of the above

conditions are determined to be valid.

[0042] In order to determine the soot combustion rate in the particulate filter **GPF** in the case of high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp**, the **S** system is designed to:

- determine (block **S16**) a value related to a degree of soot combustion based on the value of exhaust gas mass flow **Exh_Mass_Flow** and soot load in the particulate filter **GPF** **GPF_Soot_Load**;
- determine (block **S17**) a soot temperature multiplication value based on the temperature of the particulate filter **GPF** **GPF_Temp**; and
- if it is verified that the vehicle **V** is fuelled and that the temperature of the particulate filter **GPF** **GPF_Temp** is greater than or equal to the predetermined threshold value **Temp_Burn_Firing_Thr**, determine (block **S18**) the soot combustion rate in the particulate filter **GPF** in case of high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp** also on the basis of the value related to a soot combustion degree and soot temperature multiplication value.

[0043] In more detail, according to one aspect of the present invention, in order to determine (block **S16**) the value relative to a degree of soot combustion, the system **S** is designed to extract the value relative to a degree of soot combustion from a value map, denoted in the following as **Surf_High_Temp**, dependent on the values of exhaust gas mass flow **Exh_Mass_Flow** and soot load in the particulate filter **GPF** **GPF_Soot_Load**. In addition, in order to determine (block **S17**) the soot temperature multiplication value, system **S** is designed to extract the temperature multiplication value from a temperature multiplication vector, denoted below as **GPF_Temp_Multiplier_High_Temp**, based on the value of the temperature of the particulate filter **GPF** **GPF_Temp**.

[0044] Therefore, the particulate combustion rate in the **GPF** particulate filter at high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp** is the particulate combustion rate derived from the **Surf_High_Temp** value map, the latter being a calibratable surface, dependent on the exhaust gas mass flow **Exh_Mass_Flow**, the latter being dependent on the amount of oxygen input to the particulate filter **GPF** and the soot load in the **GPF** particulate filter **GPF_Soot_Load**. Note that the value map **Surf_High_Temp** is populated by running a dyno analysis of the internal combustion engine **MT** of the vehicle **V** at different levels of exhaust gas mass quantity resulting from the exhaust gas mass flow **Exh_Mass_Flow** and at different temperatures of the particulate filter **GPF** and repeating it for various particulate load values.

[0045] The value thus obtained from the value map **Surf_High_Temp** is then multiplied by the above multiplication index and the soot temperature multiplication value, the latter being an index for damping the value

relative to a degree of soot combustion obtained by applying a weighting to it. Note that, if the multiplication index is equal to 1, i.e., the above conditions at block **S18** are valid, the temperature considered for soot combustion is the maximum acceptable temperature for particulate combustion in the particulate filter **GPF**; otherwise, if the multiplication index is 0, the temperature considered for particulate combustion is the minimum acceptable temperature for soot combustion in the particulate filter **GPF**, i.e., we have a soot combustion rate in the particulate filter **GPF** at high temperature **GPF_Soot_Burn_Rate_Firing_High_Temp** that is essentially zero.

[0046] Based on the above disclosure, the advantages that the present invention achieves are obvious.

[0047] In particular, the present invention makes it possible to improve the accuracy of the model related to the particulate matter accumulated in the particulate filter **GPF** of the **V** vehicle, so as to facilitate the fulfilment of the requirements of the emission limits, KPIs or key *performance* indicators for drivability and durability of the particulate filter **GPF** itself.

[0048] In addition, the present invention also achieves, through increased accuracy, increased robustness in the emission control of the internal combustion engine **MT**, increased durability and improved driveability.

Claims

1. Vehicular control system (**S**) for estimating the soot combustion or oxidation rate in a particulate filter (**GPF**) in a vehicle (**V**), the vehicle (**V**) includes a vehicular powertrain (**GM**) comprising a propulsion unit (**P**) and a transmission system (**T**) interposed between the propulsion unit (**P**) and drive wheels (**W**) of the vehicle (**V**);

the propulsion unit (**P**) includes at least one internal combustion (**MT**) engine configured to be fuel powered,

the vehicle (**V**) also includes exhaust components (**CS**) connected to the internal combustion engine and including a catalytic converter (**TWC**) to convert the major pollutants in the exhaust gas into less polluting gases and a particulate filter (**GPF**) connected to the catalytic converter (**TWC**) and designed to filter the soot emitted by the internal combustion engine (**MT**), the vehicular control system (**S**) is designed to:

- acquire a model (**GPF_Soot_Load_Rate_Mdlld**) of soot combustion rate in the particulate filter (**GPF**) and a model (**GPF_SL_Regen_Burn_Rate_Mdlld**) of soot load regeneration combustion rate in the particulate filter (**GPF**);
- acquire quantities indicative of exhaust oxygen concentration mass flow (**Ex-**

h_O2_Mass_Flow), soot load (**GPF_Soot_Load**) in the particulate filter (**GPF**) and temperature (**GPF_Temp**) of the particulate filter (**GPF**);

- determine a soot combustion rate (**GPF_Soot_Burn_Rate_Firing_Lean**) in the particulate filter (**GPF**) in the case of excess oxygen for conducting the soot combustion reaction based on the exhaust oxygen concentration mass flow (**Ex-h_O2_Mass_Flow**), soot load (**GPF_Soot_Load**) in the particulate filter (**GPF**) and temperature (**GPF_Temp**) of the particulate filter (**GPF**); and

- determine the actual soot combustion rate in the particulate filter (**GPF**) based on the model (**GPF_Soot_Load_Rate_Mdlld**) of soot combustion rate in the particulate filter (**GPF**), the model (**GPF_SL_Regen_Burn_Rate_Mdlld**) of soot load regeneration combustion rate in the particulate filter (**GPF**) and the soot combustion rate (**GPF_Soot_Burn_Rate_Firing_Lean**) in the particulate filter (**GPF**) in the case of excess oxygen for conducting the soot combustion reaction.

2. The system (**S**) according to claim 1, wherein, in order to determine the soot combustion rate (**GPF_Soot_Burn_Rate_Firing_Lean**) in the particulate filter (**GPF**), the system (**S**) is designed to:

- verify (**S1**) that the vehicle (**V**) is in a phase where it is fuelled by fuel;
- verify (**S2-S4**) that the inlet oxygen concentration (**WRO2_11_Lambda**) to the particulate filter (**GPF**) is greater than or equal to a predetermined threshold value (**WRO2_US_Firing_Thr**).

3. The system (**S**) according to claim 2, wherein, in order to determine the soot combustion rate (**GPF_Soot_Burn_Rate_Firing_Lean**) in the particulate filter (**GPF**), the system (**S**) is designed to:

- determine (**S6**) a value related to a degree of soot combustion based on the value of exhaust oxygen concentration mass flow (**Ex-h_O2_Mass_Flow**) and the value of soot load (**GPF_Soot_Load**) in the particulate filter (**GPF**);
- determine (**S7**) a soot temperature multiplication value based on the temperature (**GPF_Temp**) of the particle filter (**GPF**); and
- if it is verified that the vehicle (**V**) is fuelled by fuel and the inlet oxygen concentration (**WRO2_11_Lambda**) in the particulate filter (**GPF**) is higher than the predetermined thresh-

old value **(S5)**, determine **(S8)** the soot combustion rate **(GPF_Soot_Burn_Rate_Firing_Lean)** in the particulate filter **(GPF)** in case of excess oxygen for conducting the soot combustion reaction also based on the value related to a value related to a degree of soot combustion and the soot temperature multiplication value.

in any one of claims 1-5 when executed.

4. The system **(S)** according to claim 3, wherein, in order to determine **(S6)** a value related to a degree of soot combustion based on the value of exhaust oxygen concentration mass flow **(Exh_O2_Mass_Flow)** and the value of soot load **(GPF_Soot_Load)** in the particulate filter **(GPF)**, the system **(S)** is designed to extract the value related to a degree of soot combustion from a value map **(Surf_Lean_Mix)** dependent on the values of exhaust oxygen concentration mass flow **(Exh_O2_Mass_Flow)** and soot load **(GPF_Soot_Load)** in the particulate filter **(GPF)**.
5. The system **(S)** according to any one of claims 3-4, wherein, in order to determine **(S7)** the soot temperature multiplication value based on the temperature **(GPF_Temp)** of the particle filter **(GPF)**, the system **(S)** is designed to extract the temperature multiplication value from a temperature multiplication vector based on the value of the temperature **(GPF_Temp)** of the particulate filter **(GPF)**.
6. Vehicle **(V)** comprising a vehicular powertrain **(GM)** comprising a propulsion unit **(P)** and a transmission system **(T)** interposed between the propulsion unit **(P)** and drive wheels **(W)** of the vehicle **(V)**;
the propulsion unit **(P)** includes at least one internal combustion **(MT)** engine configured to be fuel powered,
the vehicle **(V)** also includes exhaust components **(CS)** connected to the internal combustion engine and including a catalytic converter **(TWC)** to convert the major pollutants in the exhaust gas into less polluting gases and a particulate filter **(GPF)** connected to the catalytic converter **(TWC)** and designed to filter the soot emitted by the internal combustion engine **(MT)**,
the vehicle **(V)** is designed to be in communication with a vehicular control system **(S)** for estimating the soot combustion or oxidation rate in the particulate filter **(GPF)** in the vehicle **(V)** according to any of the preceding claims.
7. A computer program product loadable into and executable by a vehicular system **(S)** for estimating the soot combustion or oxidation rate in a particulate filter **(GPF)** in a vehicle **(V)** according to any one of claims 1-5 and designed to cause the vehicular control system **(S)** to operate in the manner claimed

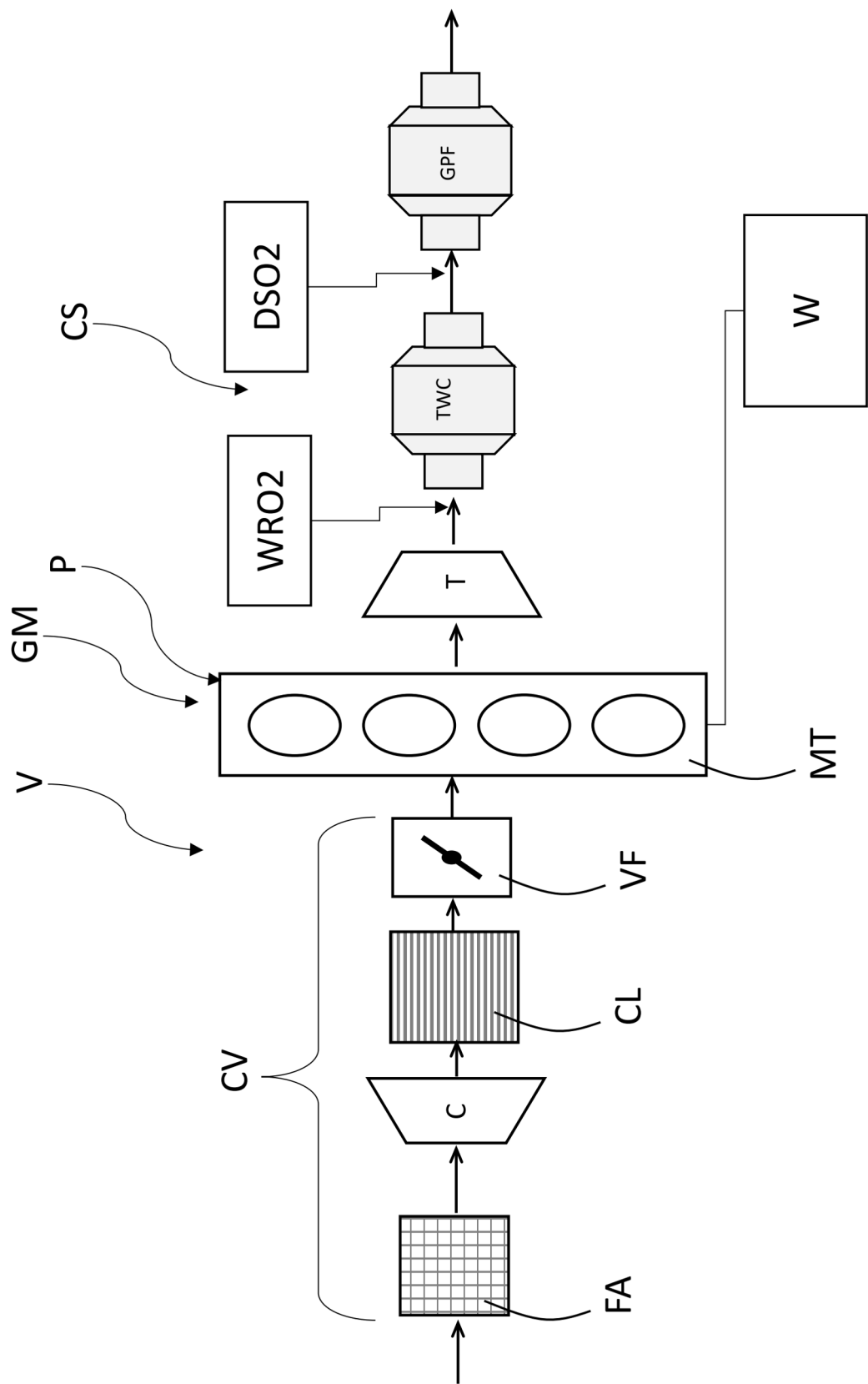


FIG. 1

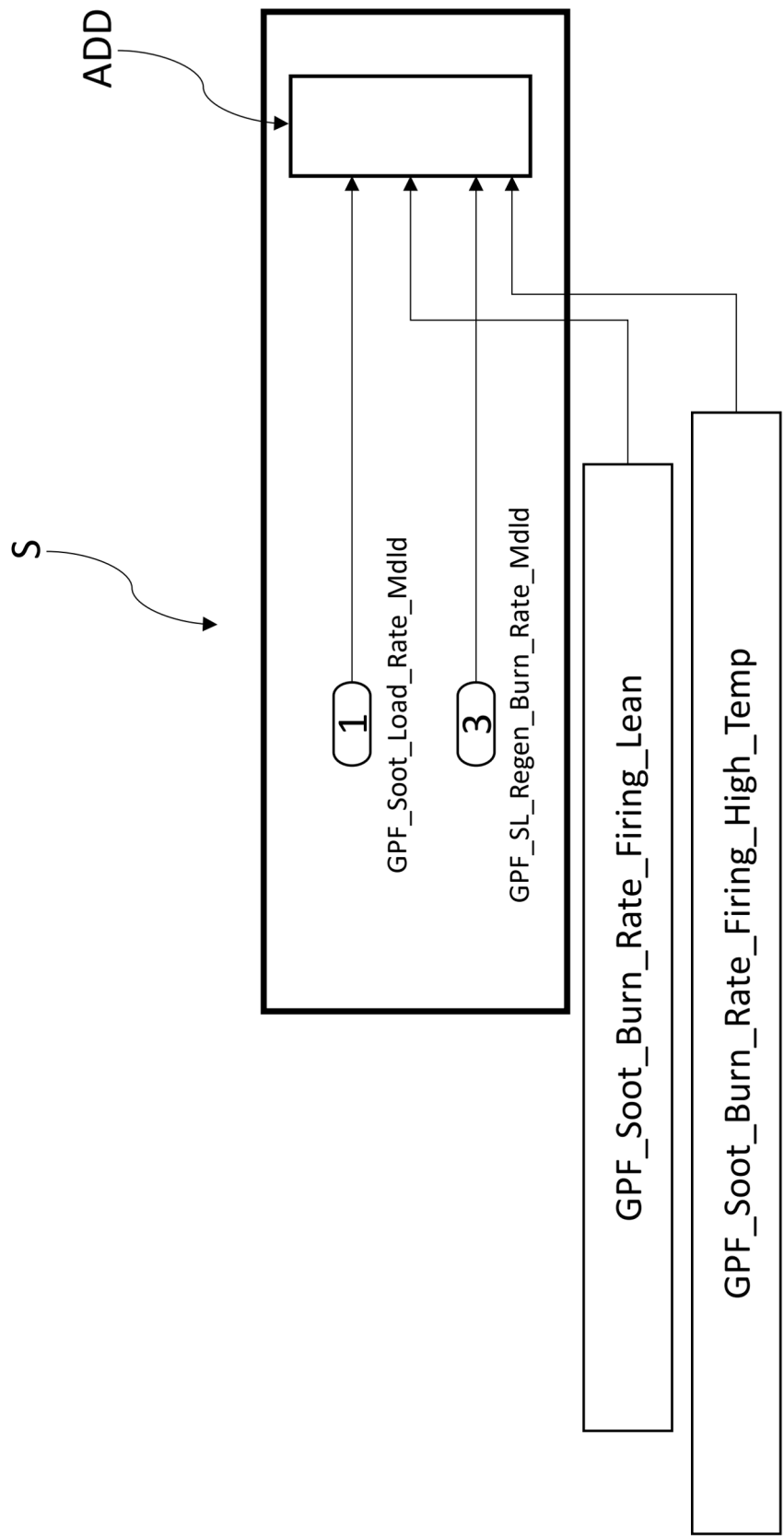


FIG. 2

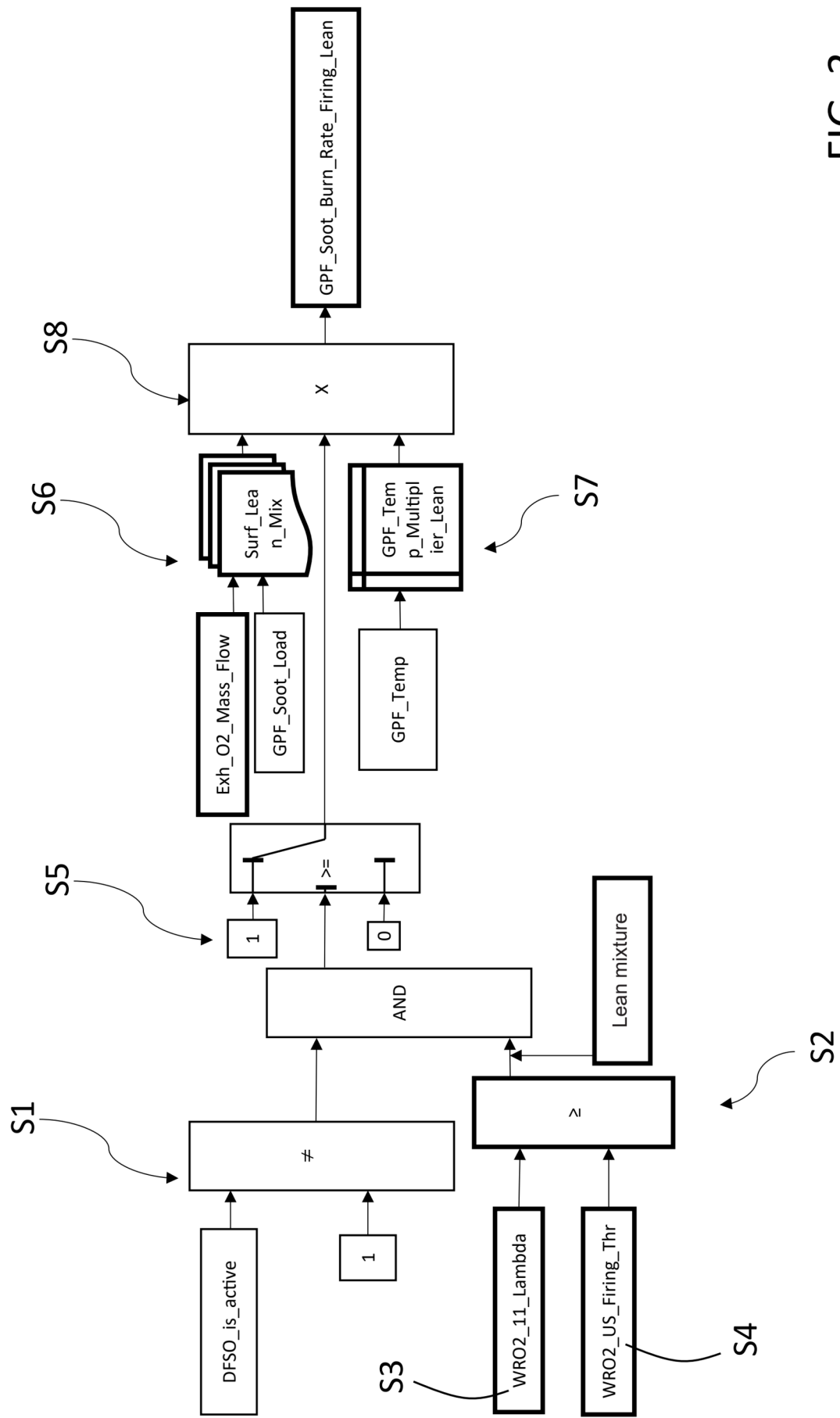


FIG. 3

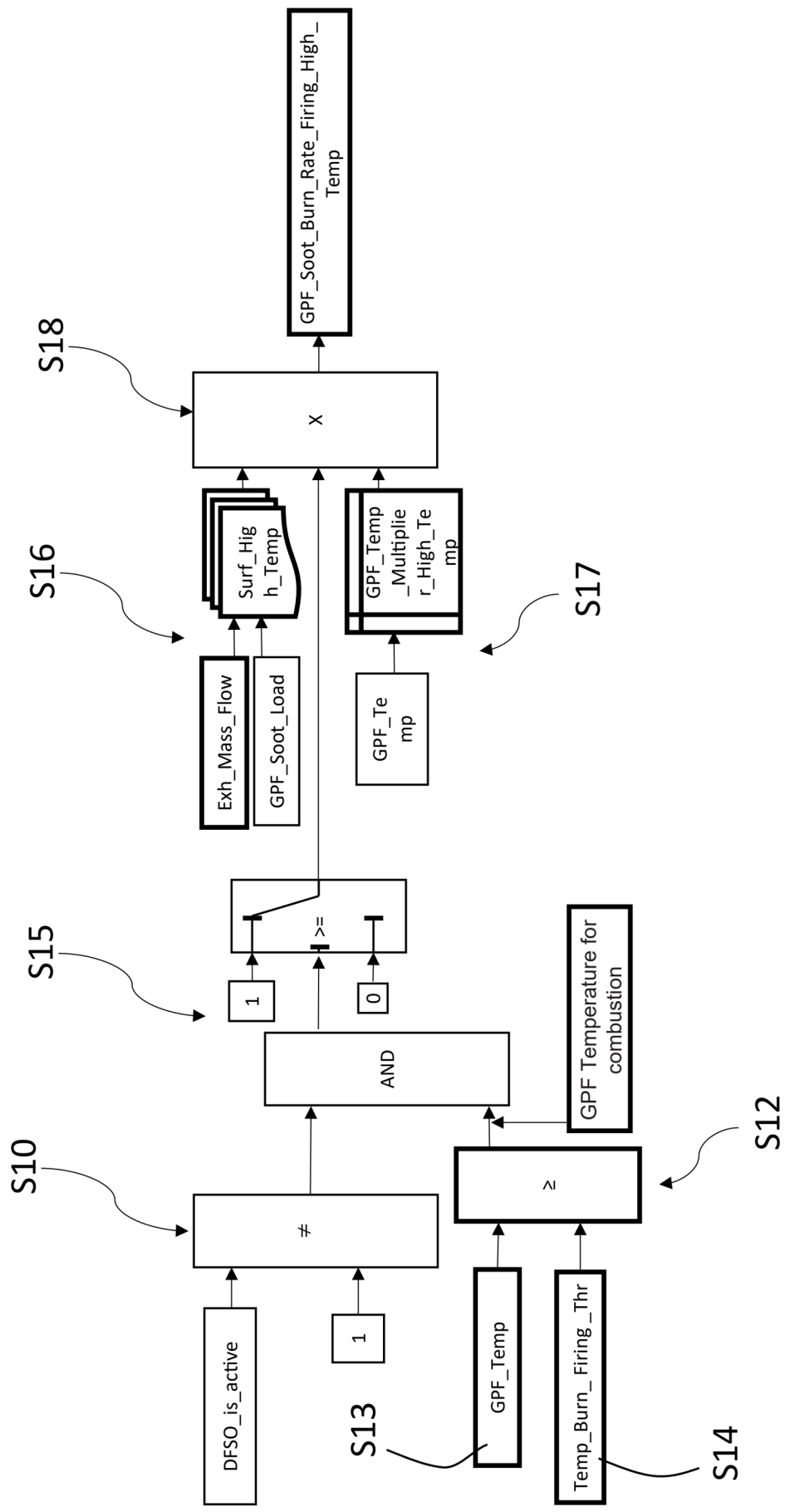


FIG. 4



EUROPEAN SEARCH REPORT

Application Number

EP 26 16 9513

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