



(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
07.10.2026 Bulletin 2026/41

(51) International Patent Classification (IPC):
F01P 7/14^(2006.01)

(21) Application number: **26158391.8**

(52) Cooperative Patent Classification (CPC):
**F01P 7/00; F01P 7/14; F01P 7/164; F04D 15/0005;
F04D 15/0038**

(22) Date of filing: **13.02.2026**

(84) Designated Contracting States:
**AL AT BE BG CH CY CZ DE DK EE ES FI FR GB
GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL
NO PL PT RO RS SE SI SK SM TR**
Designated Extension States:
BA
Designated Validation States:
GE KH LA MA MD TN

(72) Inventors:
• **AIMAR, Bruno**
10156 Torino (IT)
• **RUSSO, Maria**
10156 Torino (IT)
• **IANNACCONI, Giuseppe**
10156 Torino (IT)
• **PIROLLO, Gabriele**
10156 Torino (IT)

(30) Priority: **19.02.2025 IT 202500003225**

(71) Applicant: **FPT Industrial S.p.A.**
10156 Torino (IT)

(74) Representative: **Fiume, Orazio et al**
Praxi Intellectual Property S.p.A.
Corso Vittorio Emanuele II, 3
10125 Torino (IT)

(54) **COOLING SYSTEM FOR AN INTERNAL COMBUSTION**

(57) A method of controlling a variable-displacement pump (P) of an internal combustion engine refrigeration system, wherein the flow rate is adjustable by means of a sliding sleeve (SS) capable of being maintained in a predetermined position in relation to a target flow rate by means of an electro-hydraulic actuation comprising a

solenoid valve (SV), the method comprising a step of acquiring a target position and controlling said solenoid valve to actuate the sliding sleeve to said target position only when a change (E) in position exceeds a predetermined percentage threshold (Th).

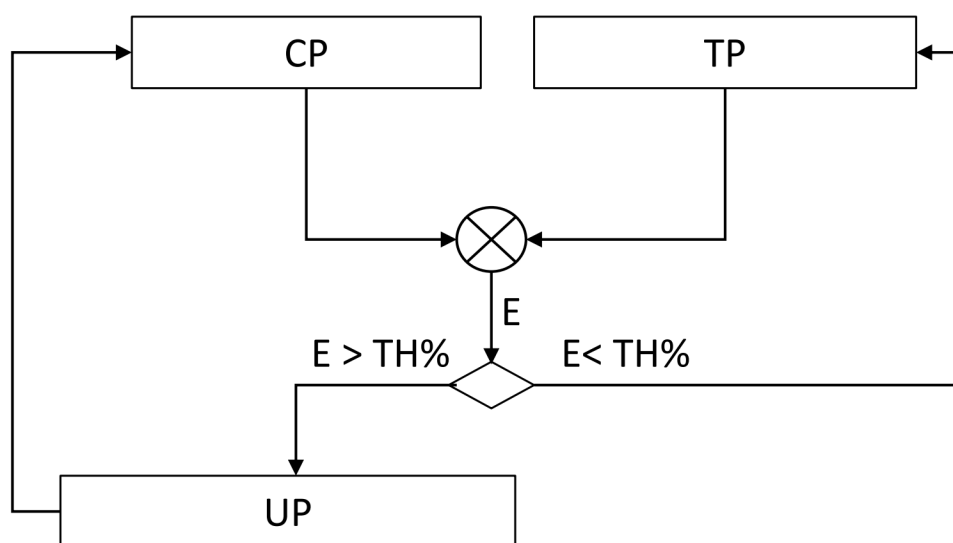


Fig. 2

Description

Field of the invention

[0001] The present invention relates to the field of refrigeration systems for internal combustion engines, particularly Otto cycle engines. More specifically, the system includes a variable displacement pump.

[0002] The system is intended for implementation in a heavy-duty vehicle.

State of the art

[0003] Coolant circulation pumps are widely used to remove excess heat from propulsion systems.

[0004] In heavy-duty vehicles, additional devices that represent a significant thermal load, such as an intercooler (or a retarder), may be present.

[0005] When sized, the pump and radiator of the vehicle cooling circuit must be able to handle the maximum possible thermal load under the worst environmental conditions. For this reason, the pump must be able to provide a predetermined maximum flow rate.

[0006] In traditional pumps, the pump flow rate depends exclusively on the rotation speed of its impeller. It is driven by the crankshaft of the internal combustion engine. Initial attempts to make the coolant flow rate generated by the pump independent involved the mechanical connection of the impeller to the crankshaft of the internal combustion engine, allowing the transmission ratio to be varied.

[0007] This solution has been largely abandoned due to the risks associated with potential failure of the mechanical connection.

[0008] With reference to Figure 1 of the prior art, a variable-displacement pump P is known, comprising an axially sliding sleeve SS, capable of varying the flow rate generated by the pump impeller IM. Specifically, advancing the sleeve reduces the flow rate generated by the impeller; while retracting it increases the flow rate generated by the impeller.

[0009] This pump is particularly advantageous because the resistive load applied to the internal combustion engine is directly proportional to the flow rate generated by the pump. Therefore, at low thermal loads, the pump absorbs relatively low torque, contributing to a reduction in the efficiency of the entire propulsion system.

[0010] The sleeve position control mechanism is electro-hydraulic. The impeller generates a primary flow, intended for cooling the propulsion system, which passes through the main conduit MCHO. The impeller also generates a secondary flow that passes through a first secondary conduit CH1 and is diverted into a second conduit CH2 or a third secondary conduit CH3.

[0011] Both the primary and secondary flow rates are a function of the pump rotational speed. However, the sleeve position is controlled in a closed loop using a controller, such as a PID (proportional, integral, deriva-

tive). This means that the rotational speed of the prime mover, to which the impeller is connected, is generally not relevant, as it is compensated by the feedback control scheme.

[0012] The third secondary line, CH3, is a secondary flow release line.

[0013] The second secondary line, CH2, is operationally connected to a reduction chamber RC arranged to advance the sleeve SS.

[0014] An ON/OFF solenoid valve (SV) is arranged to selectively direct the secondary flow into the second or third line to control the expansion of the reduction chamber RC.

[0015] The sliding sleeve SS has a portion communicating with the main conduit MCHO, therefore it interacts with the main conduit, being affected by the pressure generated by the impeller in the main conduit. This means that in the event of a blocked or broken solenoid valve, the sleeve automatically moves to the maximum retraction position, thus generating maximum flow.

[0016] Variable flow pumps based on different principles, more specifically variable geometry pumps with feedback control, are known.

[0017] Among these, some are intrinsically safe, meaning that in the event of a failure of the relevant control system, they automatically return to maximum flow conditions.

[0018] Evidently, since it is an ON/OFF valve, a predetermined sleeve position can be obtained by supplying the solenoid valve with a modulated signal. This means that when the sleeve is in a desired intermediate position between the maximum retraction and maximum advanced positions, it oscillates, at least virtually, around the desired intermediate position.

[0019] The electro-hydraulic drive implemented has relatively slow dynamics; therefore, under stationary conditions, the sleeve can remain essentially stationary at the desired intermediate position, although the solenoid valve switches at a predetermined frequency to maintain the sleeve at the same desired intermediate position.

[0020] Generally, the pump is equipped with a sensor that detects the current position of the sliding sleeve, from which the flow rate generated by the pump can be calculated.

[0021] The pump lifespan depends on the number of forward and backward actuations of the sliding sleeve.

[0022] The variable displacement pump described above is known to the applicant, but this does not mean it is known to those skilled in the art.

[0023] Unless specifically excluded in the detailed description that follows, the descriptions in this chapter are to be considered an integral part of the detailed description.

Summary of the invention

[0024] The purpose of this invention is to extend the

service life of a variable-displacement pump equipped with a sliding sleeve.

[0025] The basic idea of this invention is to acquire a current flow rate, calculate a target flow rate, and vary the position of the sliding sleeve only if the flow rate variation exceeds a predetermined threshold value, such as 10%.

[0026] Preferably, the present invention does not impact the type of position control scheme implemented, which, as described above, may be feedback.

[0027] Obviously, the control is performed by a controller comprising suitable electronic circuitry.

[0028] According to a preferred aspect of the invention, the target value, which represents the input to the position control scheme, is the maximum value between:

- A first flow rate value to dissipate a thermal load generated by the internal combustion engine,
- A second flow rate value to dissipate a thermal load generated by a subsystem of the propulsion system,
- A third flow rate value to dissipate a thermal load generated by a request from a vehicle subsystem including the propulsion system.

[0029] According to a further preferred aspect of the invention, the regulation is performed within a predetermined coolant temperature range, while outside of said range, the solenoid valve is kept deactivated so as to bring the sliding sleeve to the maximum retracted position and therefore to bring the pump to its nominal flow rate. According to a further preferred aspect of the invention, an actuation delay of the sliding sleeve varies depending on the type of thermal load and the sign of the variation in the thermal load.

[0030] Therefore, the present invention relates to a method of controlling a variable-displacement pump equipped with a sliding sleeve and a control system for the pump, which is an integral part of the cooling system of an internal combustion engine.

[0031] The present invention is applicable to any variable-displacement pump with variable geometry.

[0032] The pump is controlled by "feedback control," meaning that the pump itself or the hydraulic circuit to which it is connected is equipped with a sensor, either measuring the position of the geometry or the generated flow rate, based on which the position is adjusted.

[0033] It is worth noting that a variable geometry implies two opposite extreme positions; therefore, the geometry can vary between these extreme positions, defining a stroke, regardless of the characteristics of the pump geometry.

[0034] In a sliding sleeve pump, as described in the previous chapter, the geometry stroke coincides with the stroke of the sliding sleeve. However, the nature of the variable geometry pump is not essential to the present invention. Since sliding sleeve pumps are the most delicate from a robustness standpoint, it is clear that the present invention demonstrates the greatest benefits when combined with a sliding sleeve pump. However,

an oscillating blade pump can also benefit from the present invention. Indeed, if the pump stator were equipped with oscillating blades, the geometry stroke would coincide with the oscillation stroke of the oscillating blades, and the present invention would help limit wear on the oscillating blade supports. The dependent claims describe preferred variants of the invention and form an integral part of this specification.

Brief description of the figures

[0035] Further purposes and advantages of the present invention will become clear from the following detailed description of an embodiment thereof (and variations thereof) and the accompanying drawings, provided purely for explanatory and non-limiting purposes, in which:

Fig. 1 shows an example of a variable-displacement pump according to the prior art that is the subject of the present invention;

Fig. 2 shows an exemplary flow diagram of a first variation of the present invention;

Fig. 3 shows a diagram representing a flow variation as a function of a sliding sleeve position.

[0036] The same reference numbers and letters in the figures identify the same elements or components or functions.

[0037] It should also be noted that the terms "first," "second," "third," "upper," "lower," and the like may be used here to distinguish various elements. These terms do not imply a spatial, sequential, or hierarchical order for the modified elements unless specifically indicated or inferred from the text.

[0038] The elements and features illustrated in the various preferred embodiments, including the drawings, may be combined with each other without departing from the scope of protection of this application as described below.

Detailed description of preferred embodiments

[0039] According to the present invention, to limit the number of actuations of the sliding sleeve, a step is performed to acquire a target position TP and control said solenoid valve SV to actuate UP the sliding sleeve to said target position only when a position variation E, between the current position CP and the target position TP, exceeds a predetermined percentage threshold Th.

[0040] The term "control" used here means varying the target position, but not tracking the target position, as tracking is achieved by the position control scheme, which can be any.

[0041] Obviously, the position variation is calculated with respect to the current position CP of the sliding sleeve SS.

[0042] The method is executed cyclically. When the

position of the sliding sleeve is actually changed, this causes a change in the value relative to the current position, therefore the flow chart in Figure 2 shows a connection between the sleeve actuation block UP and the block CP representing the current position acquisition step.

[0043] The current position can be acquired using a position sensor, not shown in Figure 1, such as a Hall effect sensor, applied to the pump body and/or the sliding sleeve. Position control can be open-loop or closed-loop.

[0044] This threshold can be set in a range between 5 and 15%, with an optimal value of 10%.

[0045] An excessively high threshold value can lead to overheating in the refrigeration system; conversely, too low a threshold can reduce the effectiveness of this method. According to a preferred aspect of the invention, a CPU is configured to control the actuation of the sliding sleeve based on knowledge of the activation of a device that introduces a thermal load.

[0046] For example, the motor itself can be operated at a motor point that causes an increase or decrease in the thermal load.

[0047] Similarly, the activation or deactivation of an intarder can cause a change in the thermal load faced by the refrigeration system.

[0048] Different heat sources can be identified:

- The internal combustion engine and its subsystems, such as the intercooler, the EGR (Exhaust Gas Recirculation) exchanger,
- A propulsion system subsystem, such as the intarder, or the transmission,
- A vehicle subsystem, such as the electric heater and/or the vehicle cabin air conditioning compressor.

[0049] According to a preferred aspect of the invention, the CPU is configured to acquire an operating condition of each on-board device capable of providing a thermal load and to calculate the current or future maximum thermal load and a corresponding position of the sliding sleeve.

[0050] Furthermore, in relation to the device that causes an increase in the thermal load, the processing unit is configured to assign a predetermined delay to the actuation of the sliding sleeve.

[0051] Furthermore, the processing unit can determine an actuation delay of the sliding sleeve based on the sign of a thermal load change.

[0052] According to a preferred variant of the invention, the actuation delay for the advancement of the sliding sleeve is approximately 10 times greater than the actuation delay for the retraction of the sliding sleeve.

[0053] For example, if a 1-s delay is applied to increase the coolant flow rate, a 10-s delay is applied to decrease the coolant flow rate.

[0054] In other words, according to a preferred variant of the invention, a sort of symmetric hysteresis is created in terms of the position change of the sliding sleeve and an asymmetric delay before the position change is im-

plemented. Figure 3 helps understanding of the characteristics of the variable displacement pump P shown in Figure 1.

[0055] The x-axis indicates the percentage position of the sliding sleeve, meaning that at 0% it is in the fully retracted position, while at 100% it is in the fully advanced position.

[0056] The y-axis indicates a percentage value of the flow generated by pump P. Specifically, at 100% the flow is nominal, while at 0% the flow is zero.

[0057] Looking at the graph in Figure 3, it is clear that the minimum flow is different from zero, for safety reasons.

[0058] It is also noted that the trend is highly nonlinear. In particular, near the complete retraction of the sleeve, the flow is not very sensitive to changes in the sleeve position. Conversely, near the complete advancement of the sleeve, the flow varies rapidly from approximately 85% to 30% with a change in the sleeve position of just 20%, i.e., between 80% and 100%.

[0059] By exploiting the nonlinear characteristics of flow regulation, according to the present invention, when the refrigerant temperature exceeds a predetermined threshold, the sleeve is brought to complete retraction, thus limiting the adjustment operations of the sleeve position.

[0060] The invention also relates to the CPU processing unit which comprises:

- a first input arranged to be connected to a position sensor of a variable displacement pump P of a refrigeration system of an internal combustion engine, wherein the pump comprises a sliding sleeve SS arranged to be maintained in a predetermined position in relation to a target flow rate by an electrohydraulic drive comprising a solenoid valve SV,
- a second input arranged to be connected to a temperature sensor associated with the refrigeration system to measure the temperature of a corresponding coolant,
- a first output to power said solenoid valve of the variable displacement pump P.

[0061] The processing unit comprises an interface to a vehicle data network, wherein the unit is configured to monitor messages published on the vehicle data network and detect an operating condition of a user, including

- said internal combustion engine and/or
- a subsystem of a propulsion system other than said internal combustion engine and/or
- a subsystem of a vehicle other than said internal combustion engine. Propulsion system,

wherein the processing unit is configured to select the maximum thermal load caused by said user and calculate a corresponding pump flow rate P and a corresponding sliding sleeve position, and to actuate the sliding sleeve

via the first output.

[0062] Furthermore, the processing unit is preferably configured to implement a variable delay in the actuation of the sliding sleeve based on the type of user generating the thermal load as described above.

[0063] The present invention can advantageously be implemented using a computer program that includes coding means for implementing one or more steps of the method when this program is executed on a computer. Therefore, it is intended that the scope of protection extends to said computer program and also to computer-readable media comprising a recorded message, said computer-readable media comprising program coding means for implementing one or more steps of the method when said program is executed on a computer.

[0064] Implementation variants of the non-limiting example described are possible, without departing from the scope of protection of the present invention, which includes all embodiments equivalent to the claims for a person skilled in the art.

[0065] From the above description, a person skilled in the art is able to implement the object of the invention without introducing further construction details.

Claims

1. A method for controlling a variable displacement pump (P) of a refrigeration system for an internal combustion engine, wherein the flow rate is adjustable by varying the pump geometry using an electro-hydraulic drive comprising a solenoid valve (SV) to assume a predetermined position corresponding to a target flow rate, the method comprising a step of acquiring a current position of the pump geometry and a target position and controlling said solenoid valve to actuate said target position only when a change (E) in position between the target position and the current position exceeds a predetermined percentage threshold (Th).
2. A method according to claim 1, wherein said geometry comprises a sliding sleeve (SS) and said variability of the geometry is achieved by varying the position of the sliding sleeve.
3. A method according to claim 1 or 2, wherein said percentage threshold is between 5% and 15%, preferably 10%.
4. A method according to any preceding claim, wherein said threshold is calculated in terms of geometry stroke or in terms of variation in the current pump flow rate.
5. A method according to any of claims 1 - 4, wherein said target position is calculated as a function of a maximum value between
 - A first flow rate value to dissipate a first heat load generated by the internal combustion engine,
 - A second flow rate value to dissipate a second heat load generated by a subsystem of the propulsion system other than the internal combustion engine,
 - A third flow rate value to dissipate a third heat load generated by a request from a vehicle subsystem other than the propulsion system.
6. A method according to any preceding claim, wherein said target position is calculated only when a coolant temperature value is within a predetermined temperature range, while outside said range, the target position is forced to the fully retracted position corresponding to a nominal flow rate value.
7. A method according to any of the preceding claims 5 or 6, wherein an actuation delay of the sliding sleeve varies as a function of a user generating said first and/or second and/or third thermal load.
8. A method according to any of the preceding claims, wherein the actuation delay of the sliding sleeve varies as a function of the sign of a thermal load change.
9. A method according to claim 8, wherein said delay is relatively greater when said sign of the thermal load is negative and relatively smaller when said sign is positive.
10. A method according to any preceding claim, wherein said pump comprises a position sensor associated with said sliding sleeve and wherein the method comprises a preliminary step of acquiring a current position of the sliding sleeve to calculate said position variation (E) between said current position and said target position.
11. A processing unit (CPU) comprising
 - a first input operably connected to a position sensor of a variable displacement pump (P) of a refrigeration system for an internal combustion engine, wherein the pump comprises a variable geometry (SS) controllable by an electro-hydraulic drive comprising a solenoid valve (SV) to assume a predetermined position corresponding to a target flow rate,
 - a second input operably connected to a temperature sensor associated with the refrigeration system to measure the temperature of a related coolant,
 - a first output to power said solenoid valve of the variable displacement pump (P), wherein the processing unit is configured to per-

form all the steps of claim 1.

12. A processing unit according to claim 11, further comprising an interface to a vehicular data network, wherein the unit is configured to monitor messages published on the vehicular data network and detect an operating condition of a user, including
 - said internal combustion engine and/or
 - a subsystem of a propulsion system other than said internal combustion engine and/or
 - a subsystem of a vehicle other than the propulsion system,
 wherein the processing unit is configured to select a maximum thermal load value caused by said load and calculate a corresponding pump flow rate value (P) and a corresponding target pump geometry position, and to actuate the geometry via said first output.
13. Processing unit according to claim 12, further configured to implement a variable geometry actuation delay based on the type of load generating the thermal load.
14. A vehicle comprising a propulsion system equipped with an internal combustion engine and comprising a refrigeration system for the propulsion system and/or a vehicle subsystem, wherein the refrigeration system comprises a variable displacement pump (P) with a variable geometry (SS) and a processing unit (CPU) according to one of claims 10-13, operatively associated with the pump (P) to feedback control a flow rate generated by the variable displacement pump via a solenoid valve (SV).
15. A vehicle according to claim 14, wherein the variable displacement pump (P) is intrinsically safe.
16. A vehicle according to claim 14 or 15, wherein the variable displacement pump is intrinsically safe.
17. Vehicle according to claim 16, wherein the variable geometry of the variable displacement pump is defined by an axially sliding sleeve (SS), wherein an impeller is operatively connected with a main conduit (MCHO) and a secondary conduit (CH2, CH3), wherein said secondary conduit, by means of said solenoid valve (SV), is connected with a reduction chamber (RC) arranged to bring the sliding sleeve (SS) forward towards a flow reduction and wherein the sliding sleeve (SS) is arranged to interact with the main conduit (MCHO) so that in the event of blockage or breakage of the solenoid valve, the sliding sleeve automatically moves to a maximum retraction condition.

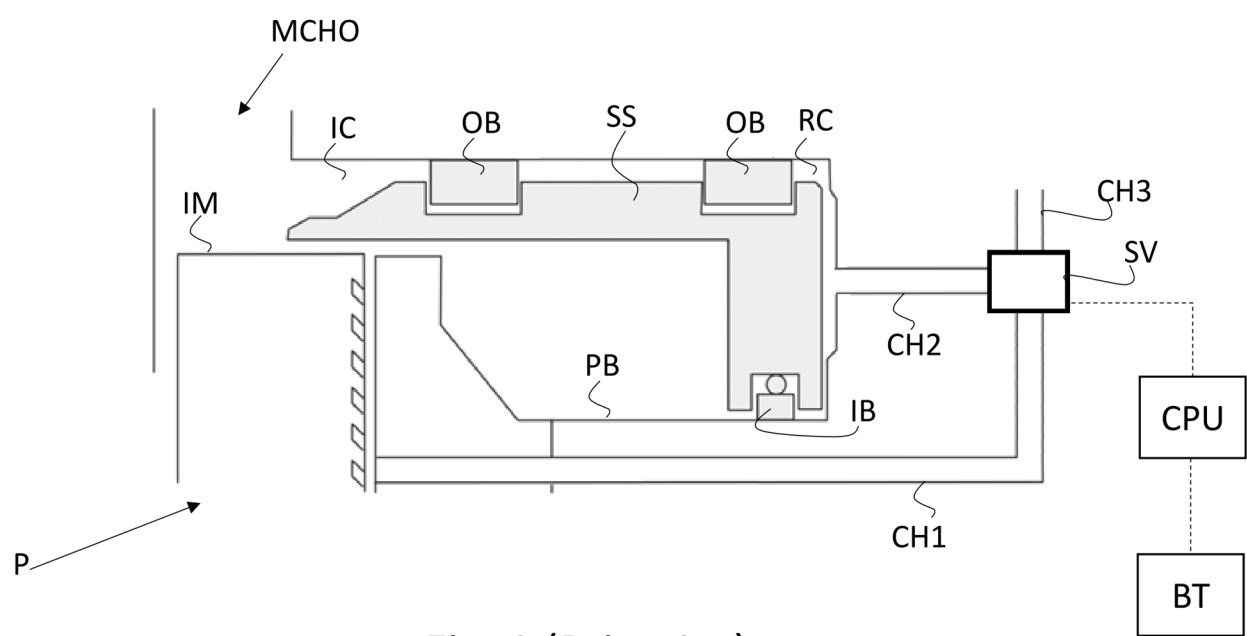


Fig. 1 (Prior Art)

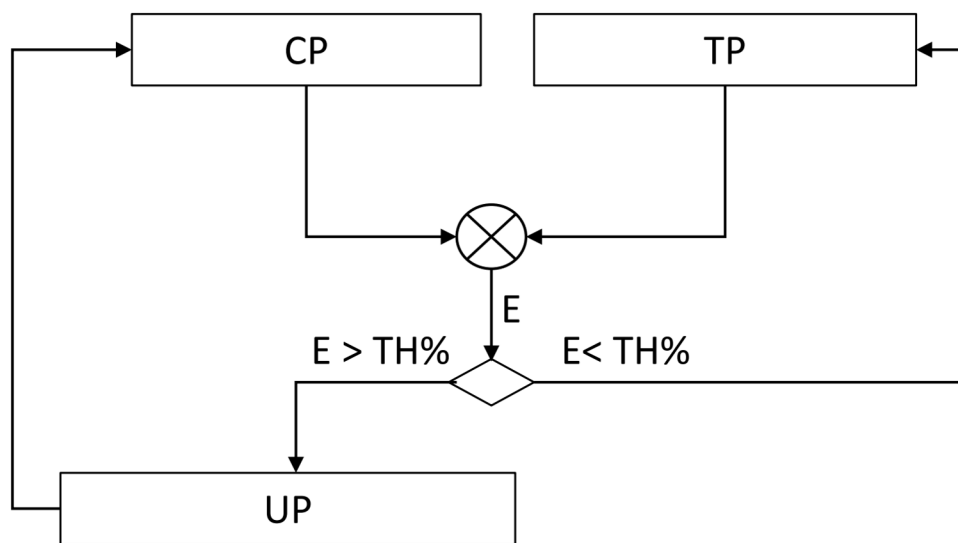


Fig. 2

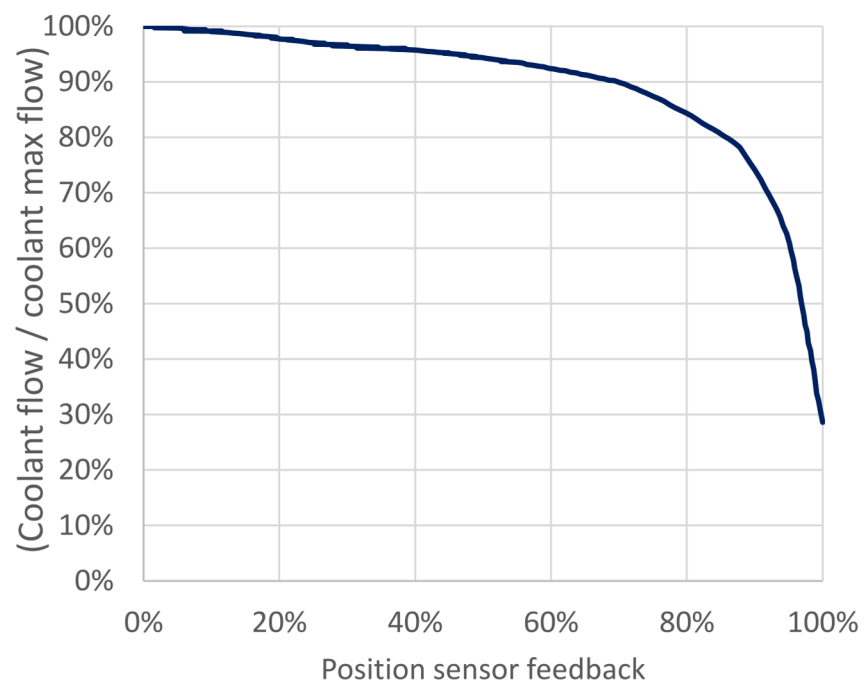


Fig. 3



EUROPEAN SEARCH REPORT

Application Number

EP 26 15 8391

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	CN 113 339 319 B (ZHOU GUANGDA) 1 December 2023 (2023-12-01) * claim 1; figure 1 *	1-17	INV. F01P7/14
X	CN 105 745 450 A (BROSE FAHRZEUGTEILE) 6 July 2016 (2016-07-06) * claim 1; figure 1 *	1-17	
X	US 2018/320694 A1 (ZIELBERG STEPHAN [DE] ET AL) 8 November 2018 (2018-11-08) * claim 1; figure 1 *	1-17	
			TECHNICAL FIELDS SEARCHED (IPC)
			F01P F04D
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		1 September 2026	Seifert, Marco
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.82 (P24C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 26 15 8391

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

01-09-2026

10

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 113339319 B	01-12-2023	NONE	

CN 105745450 A	06-07-2016	CN 105745450 A	06-07-2016
		US 2016258340 A1	08-09-2016
		WO 2015070955 A1	21-05-2015

US 2018320694 A1	08-11-2018	CN 108350890 A	31-07-2018
		DE 102015119098 A1	11-05-2017
		EP 3371463 A1	12-09-2018
		JP 6647540 B2	14-02-2020
		JP 2019500532 A	10-01-2019
		US 2018320694 A1	08-11-2018
		WO 2017076644 A1	11-05-2017

15

20

25

30

35

40

45

50

55

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82