



(11)

EP 4 303 493 A1

(12)

EUROPEAN PATENT APPLICATION
published in accordance with Art. 153(4) EPC

(43) Date of publication:

10.01.2024 Bulletin 2024/02

(21) Application number: **22762724.7**

(22) Date of filing: **21.03.2022**

(51) International Patent Classification (IPC):

F23N 1/00 (2006.01) **F23D 14/00** (2006.01)
F23N 5/00 (2006.01) **F23N 5/20** (2006.01)

(52) Cooperative Patent Classification (CPC):

F23D 14/00; F23N 1/00; F23N 5/00; F23N 5/20

(86) International application number:

PCT/IB2022/052542

(87) International publication number:

WO 2022/185294 (09.09.2022 Gazette 2022/36)

(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 MK MT NL NO
PL PT RO RS SE SI SK SM TR**

Designated Extension States:

BA ME

Designated Validation States:

KH MA MD TN

(30) Priority: **02.03.2021 PCT/BR2021/039375**

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Remarks:

No restoration request during international phase.

(54) **RAPID FLAME CONTROLLER WITH CONTINUOUSLY VARIABLE RESPONSE**

(57) Fast flame controller with continuously variable response is a fast flame controller with continuously variable response designed for use in heating, drying and roasting systems for food products, enabling greater accuracy, repeatability and refinement in the process control. The processors and circuits for power supply, process sensing and power amplification (1) form, together with electromagnetic or piezoelectric fuel injectors/valves (3), an electromechanical system for controlling the flow of gaseous fuel. This control is achieved by adjusting the injection timings, drive frequency and phase shift (Pulse Width Modulation - PWM) of the fuel injectors/valves (3), resulting in instantaneous and repetitive control of flame intensity with a wide linear working range, and allowing compensation for fuel characteristics and operating conditions, utilizing injection phases, when multiple injectors are used, to reduce flame pulsation and enhance stability. The innovation is directed towards the field of regulation and control of gaseous fuel.

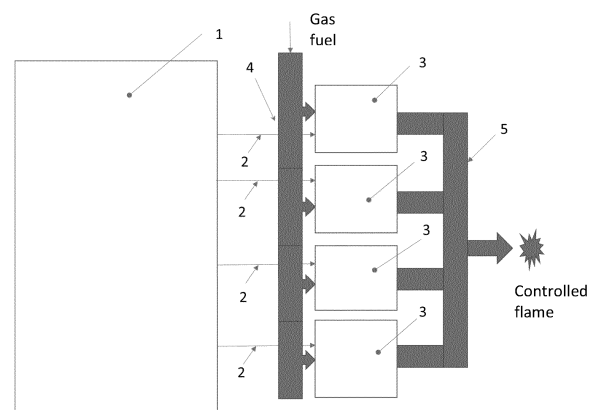


Figure 1

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Description

FIELD OF APPLICATION

[0001] The present invention relates to a fast flame controller with continuously variable response to be used in heating, drying and roasting systems for food products, capable of providing greater accuracy, repeatability and precision in process control.

[0002] The innovation is directed towards the field of regulation and control of gaseous fuel.

PRIOR ART

[0003] Equipment with direct or indirect heating are used in current processes of heating, drying and roasting food products, said processes using electrical devices or apparatuses for burning gaseous fuels as heat sources.

[0004] For systems using gaseous fuels, mechanical valves are employed to control gas flow, serving as a means to adjust flame intensity, capable of controlling the energy input into the process and of indirectly adjusting temperature.

[0005] In prior art, mechanical valves of ball, needle, gate, or cylinder types are employed, with rotary and linear mechanical or electromechanical actuators, to restrict the flow of gas and to control the flow rate. These devices have limited actuation speed and, at times, exhibit significant hysteresis and reduced repeatability and stability.

[0006] In order to mitigate these issues, the market employs high-cost valves with refined designs. Such valves are sometimes equipped with mechanical flow linearization through the profile of the seat and actuator assembly, as well as actuation systems using stepper motors or servo motors.

[0007] In view of this, attempts were made to create a system for effective control of gaseous fuel flow, that is, with a rapid and precise response, that assures process safety, that is suitable to electric-electronic controls to simultaneously ensure the mechanical and electrical resistance required for the machine's operation. Moreover, it should not exhibit disadvantages like hysteresis and a complex design.

[0008] Patent EP2923057_B1, titled "Fuel injector calibration and trimming," employs a control of the gas volume, correcting the amount according to a prior calibration, which indicates losses and differences between nominal and actual injected quantities. Patent US6244525_B1, titled "Fuel injector for an internal combustion engine," adds rotation to the injection and modifies the injector profile to enhance nozzle response speed and eliminate dead time.

[0009] In order to avoid the need of changing tools or calibration services, the present invention adopts the concept of patent US10158347-B2, titled "Device and method for providing a signal having an adjustable pulse duty factor," to control the flow of gaseous fuel in heating,

drying and roasting systems for food products, using one or a set of gaseous fuel injectors (valves) controlled by processors to adjust injection timings, drive frequency and phase shift (Pulse Width Modulation - PWM) of the fuel injectors/valves (3), resulting in instantaneous and repetitive control of flame intensity with a wide linear working range, compensating for fuel characteristics and operating conditions, and making use of injection phases, when multiple injectors are used, to reduce flame pulsation and to enhance stability.

OBJECTIVES

[0010] To provide a fast flame controller with continuously variable response to be used in heating, drying and roasting systems for food products, enabling a more accurate, repetitive and refined process control.

SUMMARY OF THE INVENTION

[0011] This invention aims to provide a fast flame controller with continuously variable response for use in heating, drying and roasting systems for food products, enabling more accurate, repetitive and refined process control.

[0012] This controller consists of one or a set of electromagnetic or piezoelectric fuel injectors/valves (3) that match the fuel demand of the systems, allowing, through electro electronic actuation, a precise control of the flow of fuel to be burned and an indirect control of the main energy source introduced into the process where the injectors/valves are employed. These fuel injectors/valves (3) comprise: an injection valve provided with a movable needle; a support body; and an electromagnetic or piezoelectric actuator.

[0013] The apparatus employs one or more processors and circuits for power supply, process sensing and power amplification (1), forming an electronic system to control the flow of fuel through adjustment of injection timings, drive frequency and phase shift (Pulse Width Modulation - PWM) of the fuel injectors/valves (3), which results in instantaneous and repetitive control of flame intensity with a wide linear working range, allowing for a compensation of fuel characteristics and operating conditions, making use of injection phases, when multiple injectors are used, aiming at reducing flame pulsation and enhancing stability.

DETAILED DESCRIPTION OF THE INVENTION

[0014] The present invention aims at providing a fast flame controller with continuously variable response to be used in heating, drying and roasting systems for food products, capable of providing a more accurate, repetitive and precise control of the processes.

[0015] The product to be protected consists of one or more processors and circuits for power supply, process sensing and power amplification (1), which, by means of

command lines (2), control the gas quantity (4) through one or a set of gaseous fuel injectors/valves (3), providing an appropriate gas output (5) to meet the fuel demand of the heating, drying and roasting systems for food products (Figure 1).

[0016] Each of these fuel injectors/valves (3) is characterized by comprising: an injection valve provided with a movable needle to regulate the flow of fuel through an injection nozzle; a support body with a feed channel ending at the injection valve; and an electromagnetic or piezoelectric actuator comprising a spring, which tends to keep the needle in a closed position, an electromagnet or piezoelectric crystal and a retainer, arranged inside the support body, against the direction of the spring, mechanically coupled to the needle. By means of electro electronic actuation, said fuel injectors/valves (3) provide a refined control of the flow of fuel to be burned, and a consequent indirect control of the main energy source introduced into the process where the injectors/valves are employed.

[0017] The processors and circuits for power supply, process sensing, and power amplification (1) form an electronic system to control the flow of fuel through adjustment of injection timings, drive frequency and phase shift (Pulse Width Modulation - PWM) of the fuel injectors/valves (3). This results in an instantaneous and repetitive control of flame intensity with a wide linear working range, compensating for fuel characteristics and operating conditions, and making use of injection phases, when multiple injectors are used, to reduce flame pulsation and to enhance stability.

[0018] The number of fuel injectors/valves (3) will depend on their functional characteristics, flow rate, linearity curve, and on the system's demand where they will be employed. There must be a number of fuel injectors/valves (3) to ensure a suitable compromise between minimum and maximum flame in the burner system employed. It should also be avoided injectors/valves (3) from operating in a nonlinear region by adjusting the injection opening time (T). The combination of the number of fuel injectors/valves (3) and the adjustment of their opening times guarantees flame control. To ensure flame stability, a phase shift strategy between the fuel injections of each injector is employed, such as for example: in the case of 2 injectors, a 180° valve opening phase shift (Figure 2); in the case of 3 injectors, a 120° phase shift (Figure 3); in the case of 4 injectors, a 90° phase shift (Figure 4), and so on, wherein the phase shift is inversely proportional to the number of injectors.

[0019] Thus, it is evident that this system efficiently controls flow of gaseous fuel, guaranteeing a rapid and precise flame intensity control (energy source modulation) with reduced pulsation. All of this comes at a low cost and is suitable for operation, safety and durability conditions.

LIST OF FIGURES

[0020]

5 Figure 1 - Block diagram of the fast flame controller with continuously variable response.

Figure 2 - Valve opening phase shift for 2 injectors/valves.

10 Figure 3 - Valve opening phase shift for 3 injectors/valves.

15 Figure 4 - Valve opening phase shift for 4 injectors/valves.

Claims

- 20 1. A fast flame controller with continuously variable response consisting of one or a set of electromagnetic or piezoelectric fuel injectors/valves (3) which allows, by means of electro electronic actuation, a precise control of the flow of fuel to be burned used in heating, drying and roasting systems for food products, **characterized by** using the combination of number of fuel injectors/valves (3), adjustment of injection timings, drive frequency and primarily the phase shift strategy between the injections of fuel of each injector, the phase shift being inversely proportional to the number of injectors, in order to ensure flame control and stability.
- 25 2. The fast flame controller with continuously variable response of claim 1, **characterized by** following a predefined and tabulated calibration of phase shift dependent on the number of injectors used during roasting.
- 30 3. The fast flame controller with continuously variable response of claim 2, **characterized by** using a phase shift inversely proportional to the number of injectors, using a formula for the calculation of a phase shift angle, wherein the obtained angle is equal to the division of 360 degrees and the number of injectors used (Phase Shift 360/N, wherein N is the number of injectors).
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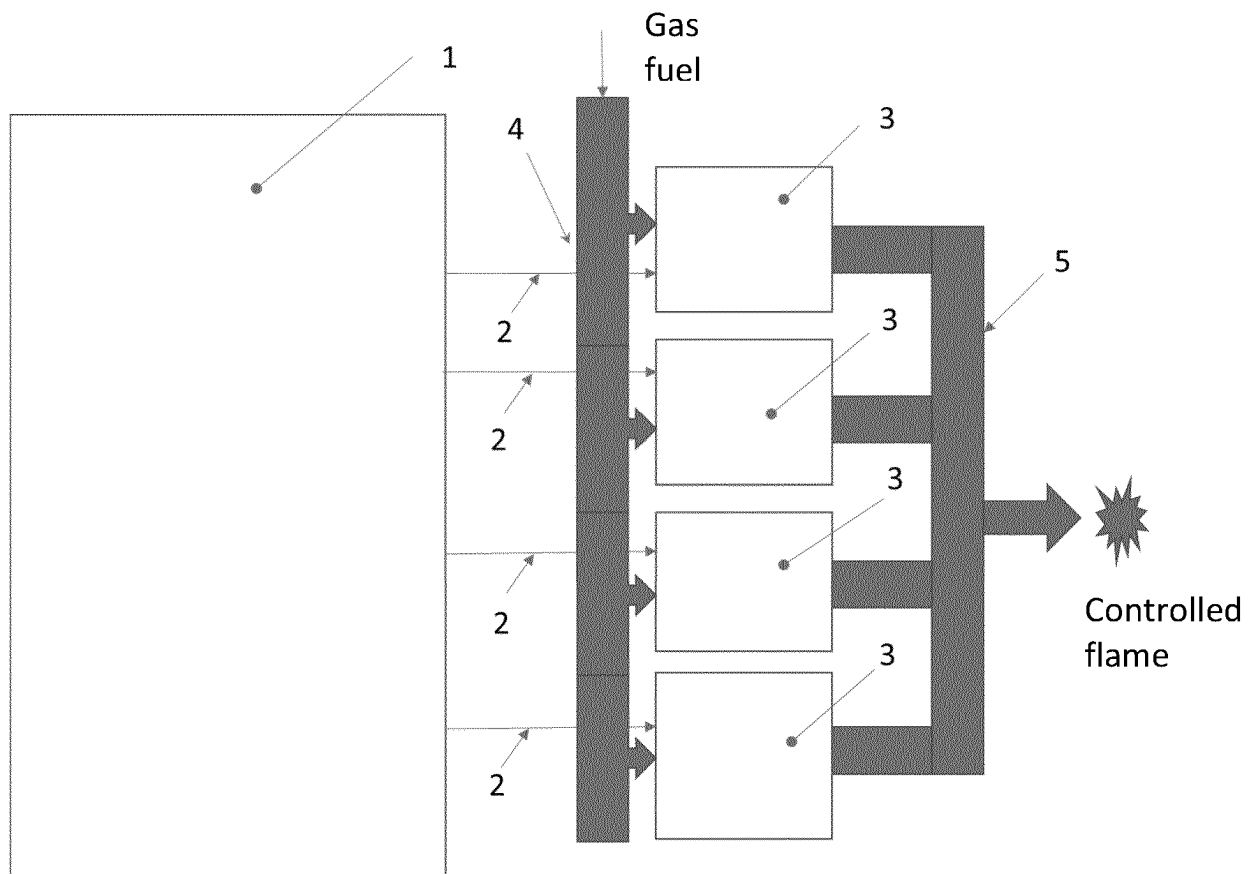


Figure 1

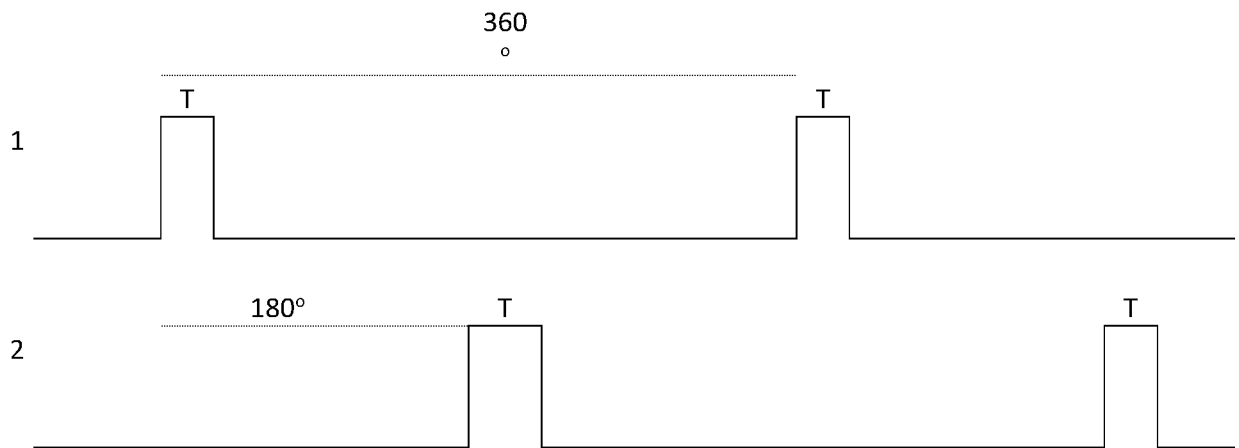


Figure 2

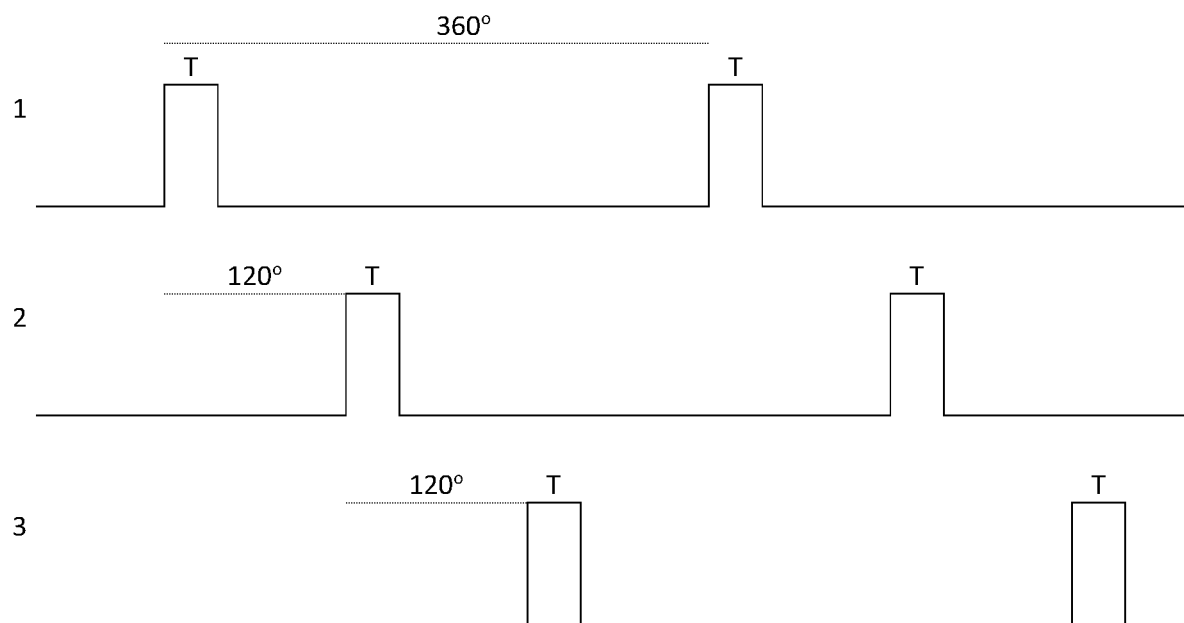


Figure 3

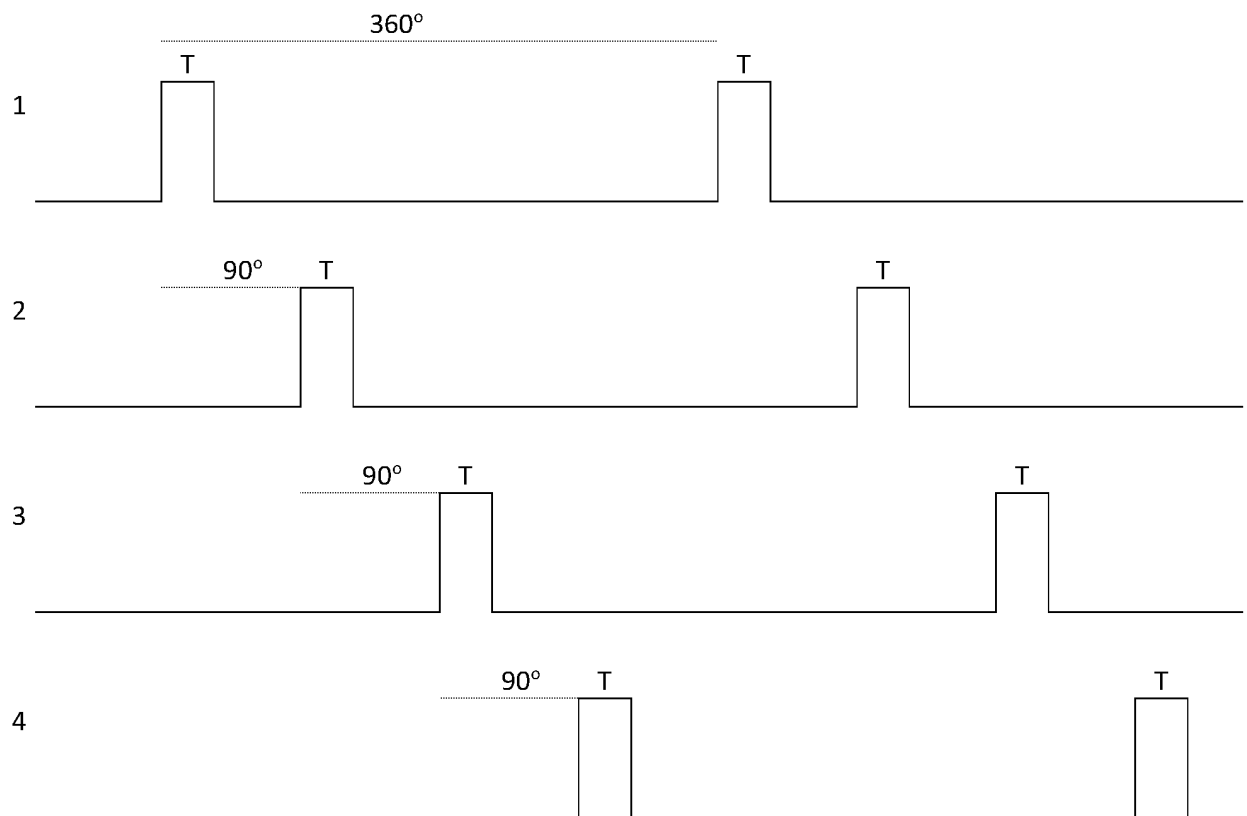


Figure 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2022/052542

A. CLASSIFICATION OF SUBJECT MATTER

IPC: F23N1/00 (2006.01), F23D14/00 (2006.01), F23N5/00 (2006.01), F23N5/20 (2006.01).

CPC: F23N1/002, F23N5/203, F23D2208/00, F23D2203/00.

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)

F23N, F23D.

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

Banco de patentes brasileiro - INPI/BR.

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

DERWENT INNOVATION.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	CN 110657458 A (MITSUMI ELECTRIC CO) 07January2020 (2020-01-07) The whole document	1 – 6
Y	US 6918757 B2 (NORITZ CORP [JP]) 19 July 2005 (2005-07-19) The whole document	1 – 6
Y	WO 2013017346 A1 (ABATE MAURIZIO ACHILLE [IT]) 07 February 2013 (2013-02-07) The whole document	1 – 6

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Date of the actual completion of the international search

14/07/2022

Date of mailing of the international search report

19/07/2022

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2022/052542

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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Y	EP 1222429 B1 (ZHOU FENG [CA]) 03 September 2008 (2008-09-03) The whole document	1 – 6
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Information on patent family members

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REFERENCES CITED IN THE DESCRIPTION

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