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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
06 March 2025 (06.03.2025)

WIPO | PCT

(10) International Publication Number
WO 2025/048736 A1

(51) International Patent Classification:
F02K 9/84 (2006.01)

(21) International Application Number:
PCT/TR2023/051657

(22) International Filing Date:
22 December 2023 (22.12.2023)

(25) Filing Language: Turkish

(26) Publication Language: English

(30) Priority Data:
2023/010648 29 August 2023 (29.08.2023) TR

(71) Applicant: OSTİM TEKNİK ÜNİVERSİTESİ [TR/TR]; 100. Yıl Blv 55/F 06374 Ostim OSB, 06374 Yenimahalle/Ankara (TR).

(72) Inventor: YAMAN, Kemal; 100. Yıl Blv 55/F 06374 Ostim OSB, 06374 Yenimahalle/Ankara (TR).

(74) Agent: DESTEK PATENT, INC.; Odunluk Mah. Akademi, Cad. Zeno İş Merkezi D Blok K:4, 16110 Nilüfer/Bursa (TR).

(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, CV, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IQ, IR, IS, IT, JM, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, MG, MK, MN, MU, 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, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, 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, ME, 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).

(54) Title: BALL THRUST VECTOR NOZZLE SYSTEM

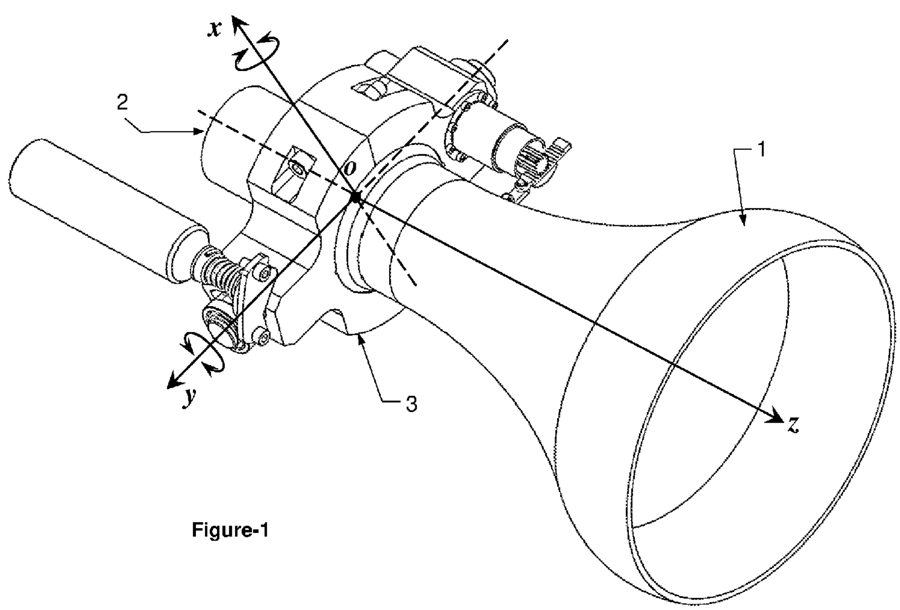


Figure-1

(57) Abstract: The invention relates to a ball thrust vector nozzle (BTN) system, which is a kind of tail rudder system, especially in liquid-fuelled rockets, for steering a missile, rocket or any thrusted aircraft by directing the exhaust gas output.

WO 2025/048736 A1

[Continued on next page]

Published:

— *with international search report (Art. 21(3))*

— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

BALL THRUST VECTOR NOZZLE SYSTEM

Technical Field

The invention relates to a ball thrust vector nozzle (BTN) system, which is a kind of tail rudder system, especially in liquid-fuelled rockets, for steering a missile, rocket or any thrusted aircraft by directing the exhaust gas output.

State of the Art

Nowadays, many guidance solutions are used to steer rocket-powered (thrusted) or thrustless (free-floating) missiles and/or other types of aircraft to the target. In aeroplanes, smart bombs with gliding wings and some missiles, guidance can be provided by the up and down movements of the blades on the wings, while this guidance process can be provided by the rotational movements of the protrusions (blades) called ailerons on the fuselage around the connection axis. In these two types of guidance solutions, the steering of the aircraft is provided by the effect of the air flow coming to the ailerons or blades defined as the control surface. In thrust-vector controlled systems, the steering of the aircraft, rocket or aircraft is based on the ability to manipulate the direction of the thrust coming from the engine. For this reason, thrust vectoring systems can respond much faster, engage the target in a short time and have much higher manoeuvrability compared to guidance systems from control surfaces. Nowadays, thrust vectoring systems have become very important especially in terms of providing vertical landing and take-off capability to fighter aircraft. Furthermore, while other systems cannot steer in non-atmospheric airless environments such as space, thrust-vector control (TVC) systems can easily steer in airless environments. Therefore, they are widely used in spacecraft and ballistic intercontinental missiles.

When the systems in the present art are examined, it is seen that in the TVC systems, the nozzle moves by sliding on the surfaces of the interlocking structures for the nozzle rotation process. During this sliding, a high-power requirement arises in order to turn the nozzle in unfavourable situations such as the particles trapped between the sliding surfaces preventing the sliding over time, deformations and dimensional distortions due to production, and the occurrence of jams due to thermal shrinkage in colder environments. This requirement makes the currently used systems cumbersome and requires the use of very large and powerful actuator systems to drive these systems and as a result, it makes the construction (structure) of the TVC larger than expected. This size causes unnecessary weight and reduces the payload value of the aircraft. In this case, a system in which point contact is provided, friction is eliminated and the nozzle is guided with much less power is required.

As a result of the research on the subject in the literature, application US4157788A was found. The application relates to a movable nozzle providing low friction. In the present art, a rocket nozzle with a circular, thin, narrow, narrow, slippery, bearing pad between the bearing surfaces of the moving and fixed elements, which functions as a gas-tight gasket, is mentioned. However, there is no information about a ball and bearing with a point contact to prevent friction specifically.

Another application encountered as a result of the research is the application EP1529163A1. The application relates to a rocket engine with a rotary nozzle. In the present art, a nozzle comprising a movable divergent section and a fixed part rigidly connected to the rear end of the combustion chamber of the engine is mentioned. However, there is no information about a ball and bearing with point contact to prevent friction specifically.

As a result, due to the above-mentioned disadvantages and the inadequacy of the existing solutions, a development in the relevant technical field has become necessary.

Aim of Invention

The invention is inspired by the present situations and aims to solve the above-mentioned problems.

The main aim of the invention is to provide a ball thrust vector nozzle (BTN) system, which is a kind of tail rudder system, which directs the exhaust gas output in liquid-fuelled rockets and provides steering of the missile, rocket or any thrusted aircraft.

The other aim of the invention is to provide a cost-effective guidance system that enables missiles and rockets to be easily guided from the nozzle handle under much lower forces and without allowing abrasion, and that can perform much more precise and agile three-dimensional movement than its counterparts.

The other aim of the invention is to eliminate the friction by providing point contact by means of the balls placed inside each other. In this way, it is to realise the guidance of the nozzle by applying much less power.

Another aim of the invention is to enable the use of smaller diameter motors by means of steering using less power. In this way, the total TVC construction becomes more compact, simpler and lighter.

In order to fulfil the aforementioned objects, a ball thrust vector nozzle system providing a means for guiding a missile, rocket or any propelled aircraft by directing the exhaust gas outlet in liquid-fuelled rockets, and comprising the following

- A nucleus (2) where the fuel burned in the combustion chamber is transmitted at high pressure,
- A nozzle that receives the high-pressure gas coming from the nozzle, throws it out and creates a thrust in the opposite direction according to the launch angle and
- The nozzle chamber assembly, which holds the nozzle and nucleus together, comprises two main parts as the left nozzle chamber and the right nozzle chamber, and is fixed by passing into the slots corresponding to the two protrusions located on the spherical surface of the nozzle and positioned at an angle of 180 degrees between them.

characterized by comprising; the following;

- A nucleus ball chamber held stationary on the nucleus and placed on the spherical surface evenly spaced at 90-degree intervals,
- A nucleus ball, which is placed in the nucleus ball chamber and allows the nozzle to rotate freely without friction, and
- A nozzle ball placed 180 degrees apart on the nozzle spherical surface and allowing the nozzle to rotate independently in both directions on the horizontal axis.

The structural and characteristic features and all advantages of the invention will be more clearly understood by means of the figures given below and the detailed description written by making references to these figures, and therefore, the evaluation should be made by taking these figures and detailed description into consideration.

Figures to Help Understanding the Invention

Figure 1 is a perspective view of the basic components of the inventive ball thrust vector nozzle (BTN) system.

Figure 2 is a disassembled view of the basic components of the inventive ball thrust vector nozzle (BTN) system.

Figure 3 is a side, cross-sectional and detail view of the inventive ball thrust vector nozzle (BTN) system.

Figure 4 is a cross-sectional view of the basic components of the inventive ball thrust vector nozzle (BTN) system.

Figure 5 is a view of the nucleus and interface parts.

Figure 6 is a view of the inventive ball thrust vector nozzle (BTN) system according to the rotation angles in different axes.

Description of Part References

1. Nozzle

2. Nucleus

3. Nozzle chamber assembly

- **3.1.** Left nozzle chamber
- **3.2.** Right nozzle chamber

4. Large motor

5. Small motor

6. Worm screw pinion gear

7. Worm screw

8. Worm screw connection plate

9. Small motor gear chamber

10. Rack and pinion gear

11. Nucleus ball chamber

12. Small motor pinion gear

13. Nozzle hanger arm

14. First bearing element

15. Large motor fitting

16. Nozzle hanger arm pin

17. Nozzle ball

18. Second bearing element

19. First ring

20. First fastener

21. Connection nut

22. Nucleus ball

23. Nucleus ball holder

24. Third bearing element

25. Second ring

26. Third ring

27. Second fastener

28. Third fastener

29. Fourth fastener

30. Fourth ring

31. Combustion chamber

32. Body

Detailed Description of the Invention

In this detailed description, the preferred embodiments of the inventive ball thrust vector nozzle (BTN) system are described only for a better understanding of the subject matter.

The ball thrust vector nozzle (BTN) system of the invention basically comprises three parts as shown in Figure 1. These are a nozzle (1), a nucleus (2), a nozzle chamber assembly (3). The rocket motor whole (RMW) is obtained by integrating the combustion chamber (31) and body components shown in Figure 4 into the system. The fuel burnt in the RMW combustion chamber (31) component is transferred to the nucleus (2) with high pressure. The high-pressure exhaust gas in the nucleus (2) is transferred to the nozzle (1) and the high-pressure exhaust gas expelled from the nozzle (1) creates a thrust in the direction opposite to the launch angle. By means of this thrust, the aircraft moves in the direction of this angular vector.

The nozzle (1) in the ball thrust vector nozzle (BTN) system of the invention can rotate freely by means of the 13 nucleus balls (22) placed in the nucleus ball chamber (11), which is kept fixed and placed on the spherical surface at equal intervals of 90 degrees each. The nozzle (1), comprises three parts, is placed on the nucleus (2) by means of an apparatus and welded in situ with electron beam welding. In order to roll the nucleus ball (22) without slipping, the nucleus ball holder (23) is used. The nozzle (1) can rotate independently in both directions only around the horizontal axis, i.e. x-axis, by means of a total of 10 nozzle balls (17) placed 180 degrees apart on its spherical surface. The horizontal axis, i.e. the x-axis, and the vertical axes, i.e. the y-axis and the z-axis, shown in Figure 1, are considered as a perpendicular (Cartesian) coordinate system placed at the volume centre (point o) of the nucleus (2). The nozzle (1) rotates simultaneously around this orthogonal coordinate system and scans the vector position according to polar coordinates. The nozzle (1) can only rotate in both directions around the x-axis thanks to the channels opened on the left nozzle chamber (3.1) and right nozzle chamber (3.2) parts and the circular protrusion opened on the nozzle (1), while rotation around the y-axis is provided by these mutual channel and protrusion geometries that can pass into each other within a certain tolerance. The nozzle chamber assembly (3), which comprises two parts, is connected to each other with two first fasteners (20) and two connection nuts (21) by tightening at a certain torque value. The nozzle chamber assembly (3), which becomes a whole with this connection, is fixed by passing into the slots corresponding to the two protrusions located on the spherical surface of the nozzle (1) and angularly positioned 180 degrees between them (Figure 2). The nozzle chamber assembly (3) is supported at both ends by the body (32), which is integrated into the combustion chamber (31), so that it can rotate freely in the y-axis with the first bearing element (14) and the second bearing element (18) parts. The rotation process according to the position orders from the aircraft autopilot is carried out by the drive from a direct current stepper motor called large motor (4), which is fixed on the body (32) with two large motor fittings (15) and eight third fasteners (28). The large motor (4) transfers the rotational movement it produces to the worm screw (7) to which it is connected. The rotational movement is then transferred via the worm screw (7) to the worm screw pinion gear (6). The rotating worm screw pinion gear (6) rotates the nozzle chamber assembly (3) connected to it. The worm screw (7) specially designed here is hyperbolic. The reason for this is to minimise the backlash between the gears that occurs during the movement in conventional systems with this design. As the backlash are smaller, the flight control is so precise.

As shown in Figure 2 and Figure 4, the large motor (4) and worm screw (7) are mounted to the body (32) by means of the worm screw connection plate (8). The third bearing element (24) and the third segment (26) are used in the bearing process. While the nozzle chamber assembly (3) rotates around the y-axis, the nozzle (1) can rotate around the x-axis with the drive of the small motor (5). Due to the rotating effect of these two synchronised motors, the nozzle (1) scans the x-y-z polar coordinate by acting like a spherical joint from the handle (spherical region), which is in point contact with the balls of the nucleus (2). In this way, the nozzle (1) moves in real time (simultaneously, synchronously) in three axes according to the position signals received by the autopilot to which it is connected, and positions the platform (Missile or Rocket) to which it is connected in real time.

The small motor (5) in the inventive system has a lower power motor structure since it only moves the nozzle (1) load. The small motor (5) is fixed to the left nozzle chamber

(3.1) by means of the small motor gear chamber (9) using the fourth fastener (29) bolts. The movement of the nozzle (1) in the x-axis pulls or pushes the nozzle (1) towards itself by means of the nozzle hanger arm (13) as a result of the rotation of the small motor pinion gear (12) on the rack and pinion gear (10). These pulling and pushing movements force the nucleus (2) part of the nozzle (1) to rotate around the centre of the sphere and according to the x-axis (Figure 4). The operation of this synchronised rotational movement is shown in Figure 6 for a maximum rotation angle of 15°in the x-axis and a rotation angle of 10°in the y-axis.

The inventive ball thrust vector nozzle (BTN) system is an electro-mechanical system, which reduces friction significantly by contacting friction point by point thanks to the nested balls used in its structure, and thus can be easily driven and driven by very small stepper motors without requiring much power. In this way, the thrust system takes up much less space and is much lighter than friction systems, resulting in an increase in range in rockets and an increase in both range and payload in missiles. Furthermore, since hydraulic and pneumatic systems are more cumbersome than mechanical systems, their manoeuvrability in very narrow spaces is very low. In the BTN system, on the other hand, manoeuvrability is much higher since it is very light and its reaction times are much lower (faster) than other systems. High manoeuvrability allows the air platform (vehicle) to quickly engage the target and also provides superior capabilities such as the ability to quickly get rid of enemy elements.

Furthermore, since mechanical systems can be driven much more precisely than hydraulic and pneumatic systems, they are inevitably preferred in systems that require precise hitting capability. By means of the backlash-free mechanism used in the BTN system, the backlash errors between the controller and the actuator are minimised and much more precise positioning and thus hitting capability is provided. Furthermore, the cost of the BTN system is lower and more reliable than other systems in terms of lighter weight, less volume and less components (compactness) compared to other systems.

CLAIMS

1. A ball thrust vector nozzle system for guiding a missile, rocket or any thrusted aircraft by directing the exhaust gas outlet in liquid-fuelled rockets, and comprising the following

    - A nucleus (2) where the fuel burned in the combustion chamber is transmitted at high pressure,
    - A nozzle (1), which receives the high-pressure gas coming from the nucleus (2), throws it out and creates a thrust in the opposite direction according to the launch angle, and
    - A nozzle chamber assembly (3), which holds the nozzle (1) and the nucleus (2) together, comprises two main parts, a left nozzle chamber (3.1) and a right nozzle chamber (3.2), and is fixed by passing into slots corresponding to two protrusions located on the spherical surface of the nozzle (1) and angularly positioned 180 degrees apart.

    characterized by comprising; the following;

    - A nucleus ball chamber (11) held stationary on the nucleus (2) and evenly spaced at 90-degree intervals on its spherical surface,
    - A nucleus ball (22) placed in the nucleus ball chamber (11) and allowing the nozzle (1) to rotate freely without friction, and
    - A nozzle ball (17) placed 180 degrees apart on the spherical surface of the nozzle (1) and allowing the nozzle (1) to rotate independently in both directions on the horizontal axis.

2. A ball thrust vector nozzle system according to claim 1, **characterized by comprising;** a first fastener (20) and a connection nut (21) which are tightly connected to each other so that the nozzle chamber assembly is integrated with the left nozzle chamber (3.1) and the right nozzle chamber (3.2).

3. A ball thrust vector nozzle system according to claim 1, **characterized by comprising;** a first bearing element (14) and a second bearing element (18)

which enable the nozzle chamber assembly (3) to rotate freely on a vertical axis by means of a body part (32) integral with the combustion chamber (31).

4. A ball thrust vector nozzle system according to claim 1, **characterized by comprising;** a large motor (4) which provides the necessary drive for rotation in accordance with the position orders from the aircraft autopilot.

5. A ball thrust vector nozzle system according to claim 4, **characterized by comprising;** a worm screw (7) which receives the rotational movement from the large motor (4) and a worm screw pinion gear (6) which rotates the nozzle chamber assembly (3) by means of the drive received from said worm screw (7).

6. A ball thrust vector nozzle system according to claim 1, **characterized by comprising;** a small motor (5) which enables the nozzle chamber assembly (3) to rotate about the vertical axis while also rotating about the horizontal axis.

7. A ball thrust vector nozzle system according to claim 6, **characterized by comprising;** a small motor gear chamber (9) and a fourth fastener (29) for fixing the small motor (5) to the nozzle chamber assembly (3).

8. A ball thrust vector nozzle system according to claim 1, **characterized by comprising;** a rack and pinion gear (10) for pulling or pushing the nozzle hanger arm (13) connected to the upper part of the nozzle (1) and for rotating the nozzle on a horizontal axis by this pushing or pulling movement.

9. A ball thrust vector nozzle system according to claim 6, **characterized in that;** said horizontal axis is the x-axis and said vertical axis is the y-axis.

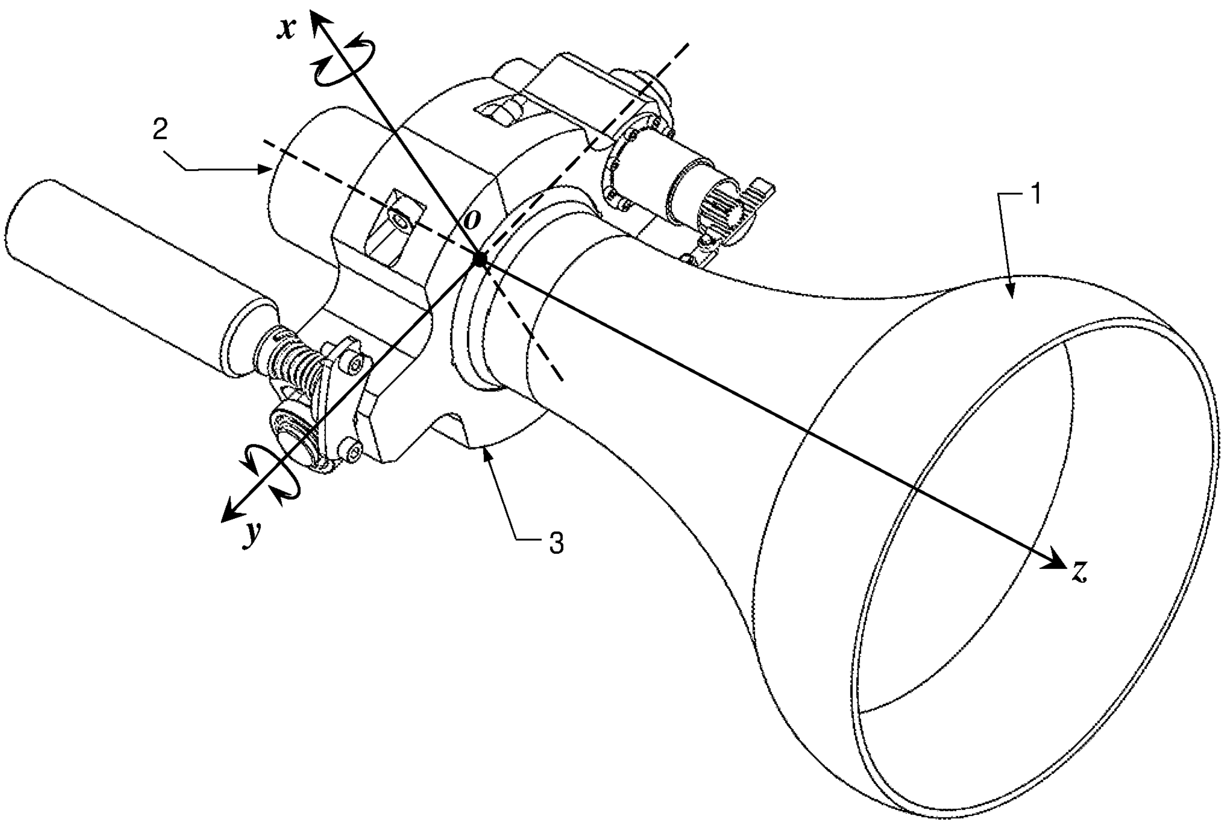


Figure-1

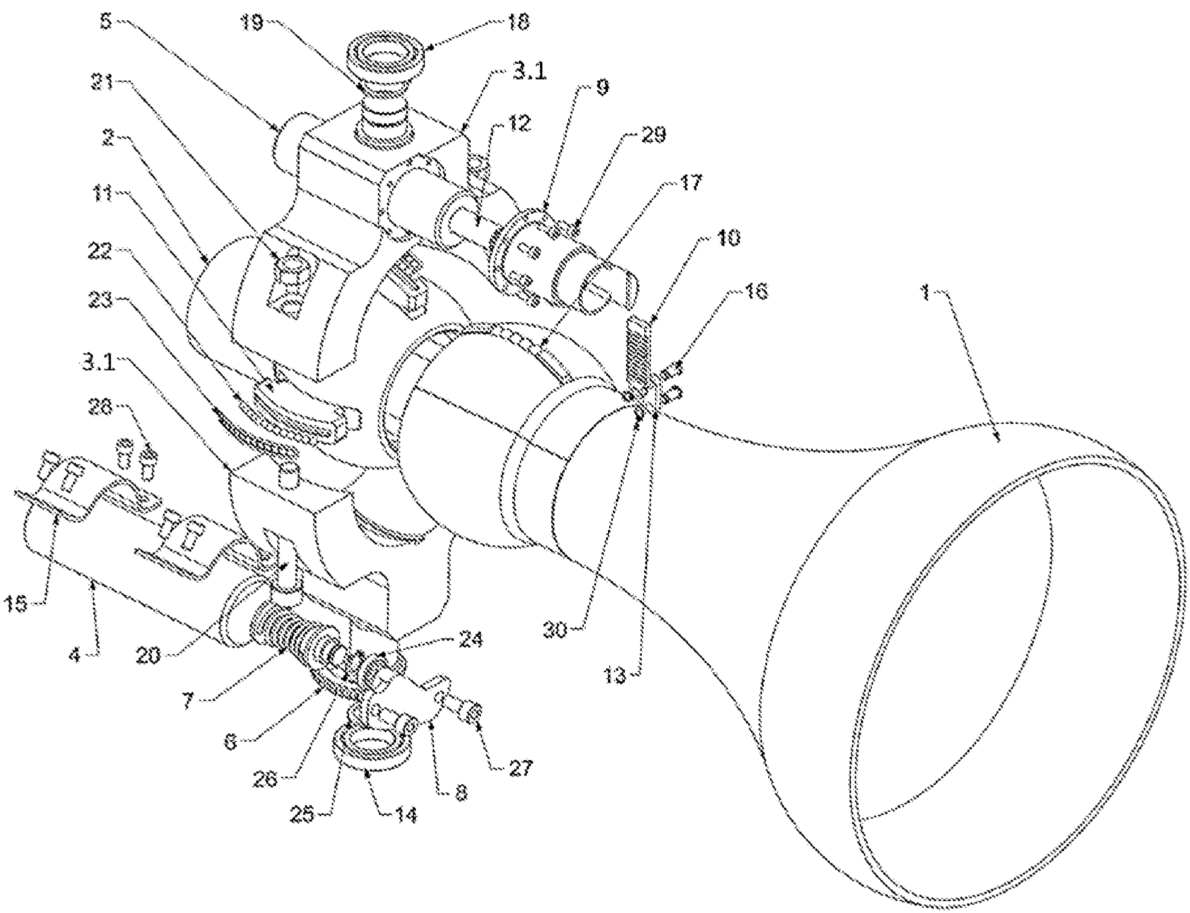
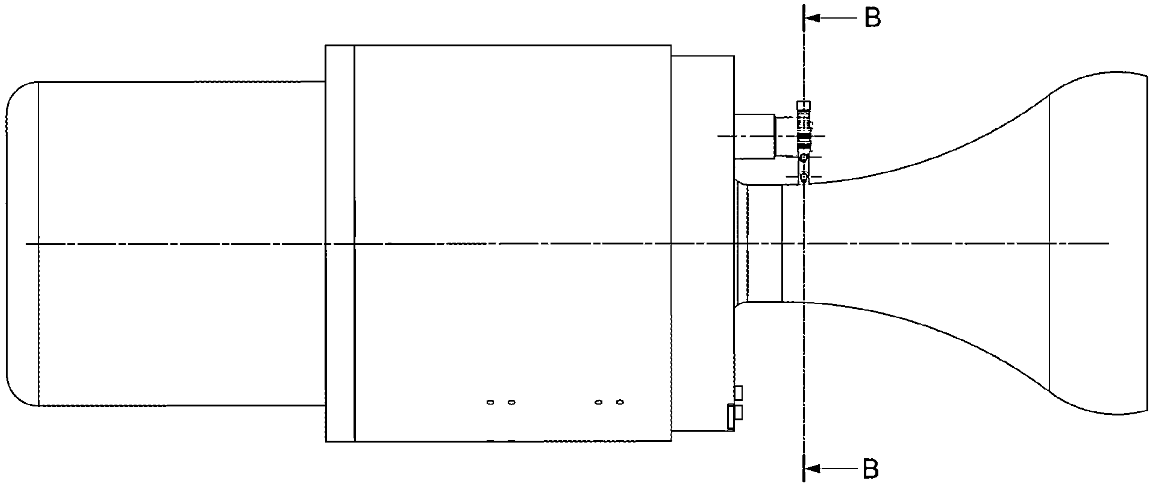
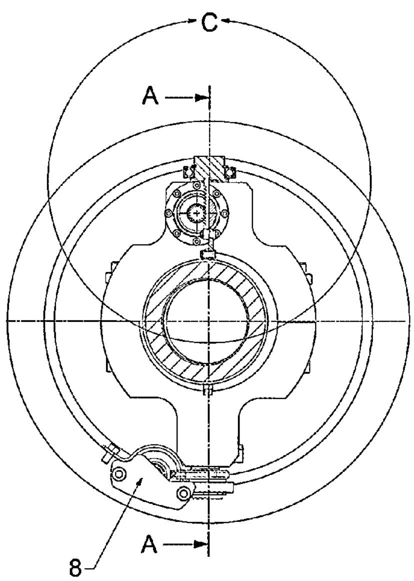
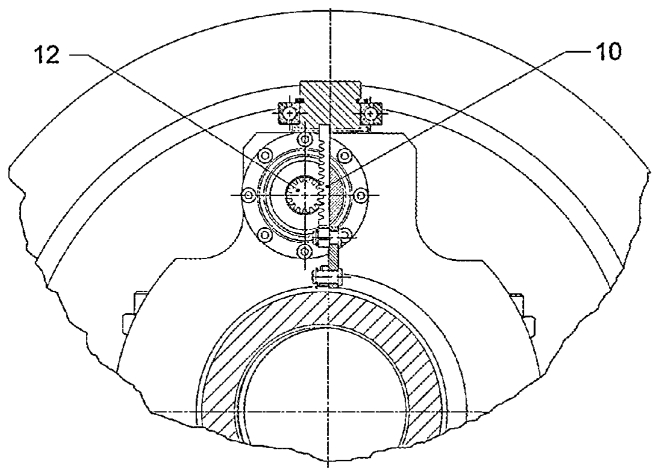

5
19
18
3.1
21
9
12
29
2
11
17
22
10
16
1
23
3.1
28
15
4
20
24
30
13
7
6
27
26
8
25
14

Figure-2





SECTION B-B



DETAIL C(1:1)

Figure-3

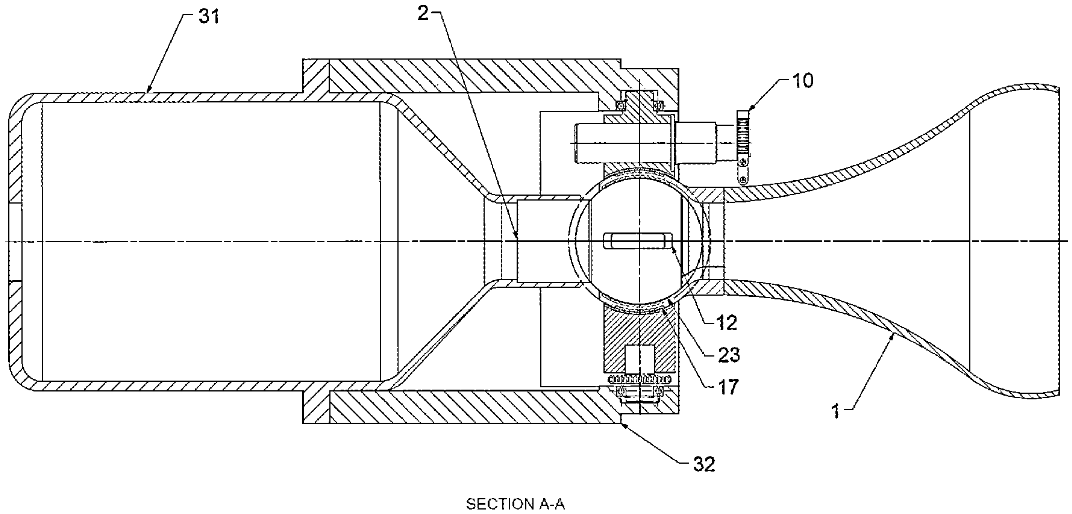


Figure-4

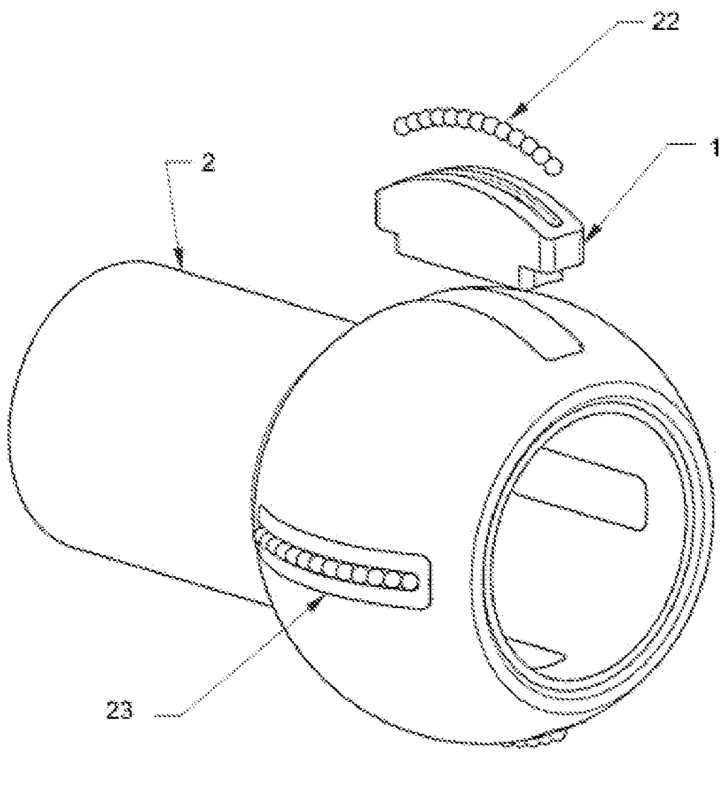


Figure-5

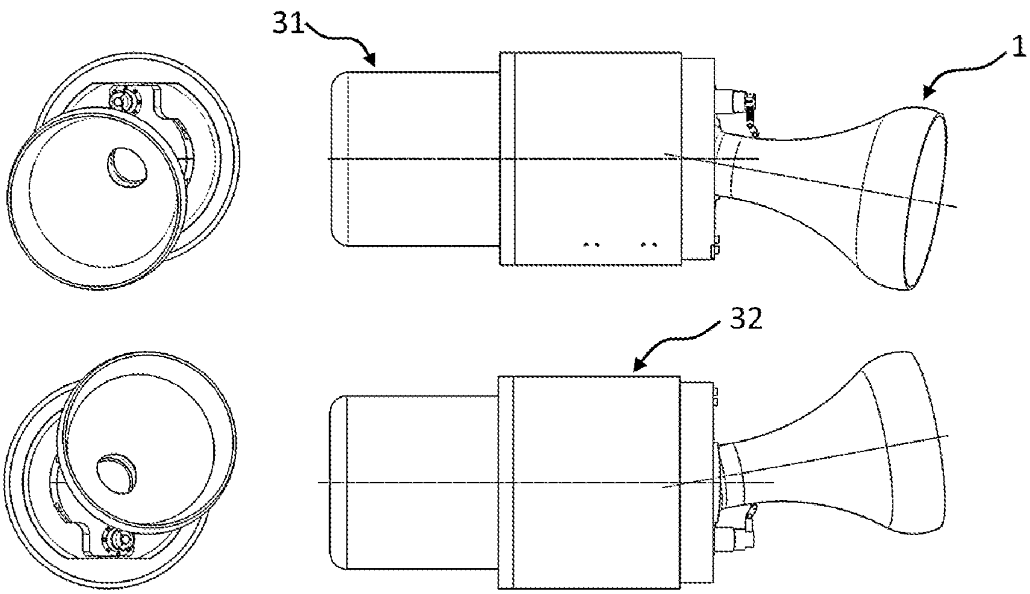


Figure-6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/TR2023/051657

A. CLASSIFICATION OF SUBJECT MATTER

F02K 9/84 (2006.01)i

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)

F02K 9/84

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

Published patent and utility model applications of Turkey, 2005-2024

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

EPO Abstract & Fulltext Databases, WPI & Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
D,A	US 4157788 A (THIOKOL CORP [US]) 12 June 1979 (1979-06-12) Whole document	1-9
A	GB 1248573 A (ROLLS ROYCE) 06 October 1971 (1971-10-06) Whole document	1-9
D,A	US 2005016158 A1 (BERDOYES MICHEL,) 27 January 2005 (2005-01-27) Whole document	1-9

☐ 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
- "D" document cited by the applicant in the international application
- "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

22 March 2024

Date of mailing of the international search report

22 March 2024

Name and mailing address of the ISA/TR

Turkish Patent and Trademark Office (Turkpatent)
Hipodrom Caddesi No. 13
06560 Yenimahalle
Ankara
Türkiye

Telephone No. **+903123031000**
Facsimile No. **+903123031220**

Authorized officer

Mustafa AKSOY

Telephone No. **+903123031644**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/TR2023/051657

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
US	4157788	A	12 June 1979	NONE			
GB	1248573	A	06 October 1971	DE	1803937	A1	02 October 1969
				FR	1587011	A	06 March 1970
US	2005016158	A1	27 January 2005	US	6948307	B2	27 September 2005
				AU	2003260651	A1	23 January 2004
				CA	2484262	A1	15 January 2004
				CA	2484262	C	22 May 2012
				DE	60336062	D1	31 March 2011
				EP	1529163	A1	11 May 2005
				EP	1529163	B1	16 February 2011
				FR	2841939	A1	09 January 2004
				FR	2841939	B1	22 September 2006
				IL	162928	A	08 July 2008
				JP	2005531724	A	20 October 2005
				JP	4361483	B2	11 November 2009
				NO	20043945	L	21 September 2004
				NO	338429	B1	15 August 2016
				RU	2004122626	A	27 May 2005
				RU	2309281	C2	27 October 2007
				UA	79965	C2	10 August 2007
				WO	2004005690	A1	15 January 2004