DYNAMIC SYMMETRY TURBINES

Technical Field

The present invention refers to the design and construction of rotors for turbomachinery in general that must operate at the same time as a pump and an engine without being conditioned for the use of a given working fluid or specific application as, for example, gas turbine engines.

State of the Art

Making engines more efficient, lighter, more compact and simpler are goals constantly pursued by engineers. One of the most limiting factors for the design of gas turbines is the high temperature combustion necessary for good performance, but which negatively affects the resistance of the materials. Of the various techniques that have been proposed to optimize gas turbine engines, which are important to understand this invention due to their parallelism, are those which exploit the idea of employing hollow blades of a conventional axial turbine also as a radial compressor circulating fresh air through its interior prior to entering the combustor in order to redirect the hot gases originating from the combustor against the blades of the axial turbine using a loop. This cools the turbine blades which are simultaneously a radial pump and an axial engine.

This idea of a radial-axial rotor is not new and the following patents are examples in which it is used with varying particularities: US1603966A (1926), US1640784A (1927), US1702264A (1929) granted to C. Lorenzen; US2611241A (1952) granted to T. R. Schulz; US3283509A (1966) granted to H. Nitsch; US6430917B1 (2002) granted to D. A. Platts; US2003192303A1 (2003) granted to M. A. Paul. An obvious variation of this radial-axial rotor configuration would consist in reversing the direction of the flow of gases, resulting, in this case, with a configuration of an axial compressor and a centripetal radial turbine. Another variation is that proposed by D.A. Platts in its patent US6430917B1 (2002), developed later in patent US7044718B1 (2006), to transform its radial-axial rotor into a radial-radial single rotor. This idea is basically to eliminate the axial character of the turbine blades, diverting its flow and making it more perpendicular to the shaft resulting in a configuration as a radial compressor that interleaves its channels with those of an equally radial turbine. There are also applications, as explained in WO2006060003A2 (2006), in which a hollow axial blade is also used as a radial pump, but here it only facilitates compression since afterwards the flow originating from the combustor is not redirected against said axial blade.

Traditionally the design of gas turbine engines has included three clearly separate primary functional blocks: compressor, combustor and hot gas turbine. Approximately

50% of the power obtained from the turbine must be employed to power the compressor. Typically, it is a solid shaft which transmits the power from the turbine to the compressor. The patents previously mentioned as examples employ another technique to transmit this power, since the gases themselves originating from the combustor are those which push directly upon the compressor, utilizing the possibility offered by hollow blades to convey two currents of different fluids whose paths cross. This type of design offers several advantages: it decreases the length and weight of the engine eliminating the need for a shaft that transmits power from the turbine to the compressor, it cools the turbine blades allowing for higher temperatures and a lower proportion of excess air; the cooling action itself implies a heat recovery effect that improves thermal efficiency, the blades are subjected to less mechanical stress due to partial compensation of the fluid pressure on both sides of its active surfaces.

To design a hollow blade, which acts as piping through which air may also circulate radially is a useful and intuitive idea but could pose certain possible unsuitable restrictions since it definitively conditions the configuration of the machinery as it is equipped with a compressed air outlet to the periphery and at the same time conditioning the radial flow transitions from and toward the rotor due to the tubular shape of the blades.

The objective of this invention is to provide an alternative design and manufacturing strategy to that previously mentioned of the hollow blades, which, while less intuitive, once understood is more functionally natural and versatile with considerably simplified architectures and smooth inlet and outlet profiles without the need for any additional foreign elements to eliminate flow discontinuity. It is likewise the objective of this invention to facilitate innovative constructive solutions with respect to that of hollow blades, eliminating the constraints of radial compression, as well as for existing conventional state of the art blade shapes.

Using the criterion of dynamic symmetry, the classic 2D methodology is abandoned while taking advantage of the potential of current engineering tools in order to concentrate technological effort in the design of non-conventional 3D shapes for two types of twisted plates and the subsequent manufacture thereof. Its use achieves intrinsically cooled, dynamically compensated rotors whose structures are constructed simply by the proper joining of only these two types of plates. At the same time it minimises the need for solid elements to transmit mechanical stress while providing flexibility in the design of the turbomachinery to which they are incorporated. Its constitution provides great resistance to the pressures exerted by compressing and expanding fluids, allowing the load of each stage to increase by using shapes with sharp curves and higher flow rates. The obligation of crossing the compressing and expanding fluids within the same rotor does not necessarily imply having to provision markedly larger sections than those of a conventional rotor, rather what dynamic symmetry achieves, is taking advantage of the unused space on the interior of conventional rotor blades, especially if high-pressure geometries are to be used. As opposed to what occurs with hollow blade rotors, dynamic symmetry plate rotors facilitate the conception of turbomachinery with several compression-expansion stages without having to increase the diameter of the turbomachinery as the use of this design philosophy is not compromised by the need for radial compression or expansion. The reduced inertia of the rotors allows, as a start-up procedure, compressed air to be directly injected into the combustion chambers, thus allowing for the replacement of other heavier slower conventional systems.

Industrial Applicability

Although the intended advantages are desirable for any gas turbine engine application, this invention may be particularly useful for the manufacture of low-power turbines and microturbine units, portable power generator units, distributed electric power generation, unmanned vehicle drives, non-reusable engines such as those for cruise missiles, auxiliary engines for vertical lift in VTOL aircraft, hybrid propulsion primary generators, quick start turbine engines, turbochargers, etc.

Disclosure of Invention

A theoretical dynamic symmetry surface is that which has a twisted shape, such that a current of fluid can be conveyed along one of the faces thereof, following a pre-determined path and exerting thereon pre-determined stresses, while at the same time another current of fluid can be conveyed along the other face thereof, following another path symmetrical to the first and exerting thereon other stresses symmetrical to the first.

This invention relates to the design of turbine rotors which are manufactured by joining two types of plates, a pressure plate (active surface) and a suction plate (passive surface), the non-conventional shapes of which are based on the criterion of dynamic symmetry. This technique allows the rotor to operate both as a pump and as an engine, substantially reducing the need for structural materials for the construction thereof. Any surface of the rotor is in contact with the expanding fluid along one of its faces and it is also in contact with the compressing fluid along the other face. One of the plate types carries out the function of an active surface for compression along one of its faces and for expansion along the other. The other plate type carries out the function of a passive surface for compression along one of its faces and for expansion along the other. Due to the special geometric characteristics of dynamic symmetry plate rotors it is not possible to speak on the classic concept of blades as construction elements. The rotor is simply constructed by the proper joining of an alternating sequence of active and passive plates so that they form two equally alternative channels, one to circulate compressed fluid and the other adjacent channel to circulate expanded fluid. Both plate types are very similar in shape and may be obtained using analogue manufacturing processes. The plates must be joined together along their edges by welding, adhesive bonding, assembly slots for detachable rotors or any suitable method. The possibility of employing a manufacturing method, which permits obtaining a single-piece rotor directly without first manufacturing the plates and the subsequent joining thereof, shall be considered.

Based on the objective fact that both compressors and hot gas turbines are very similar turbomachinery that respond to the same physical phenomena, the concept of dynamic symmetry intends for the dynamic behaviour of the compressing fluid along one face of the active surface to be similar to that of the expanding fluid along the other face of the same active surface. In order for power to be transferred between the rotor and the fluid, movement (rotation) and force (pressure) are required. Pressure between the surface and the fluid is generated due to the acceleration thereof, i.e., changes in flow rate for both module as well as direction. The change in flow rate may be due to the curvature of the surface as with axial flow or to the change of speed of the surface itself at different distances from the rotational axis as with radial flow. It may also be due a combination of both. The fact that the flow type is predominately radial or axial is merely circumstantial and does not alter the application of the criterion of dynamic symmetry. For axial flow, dynamic symmetry surfaces have a double curvature whose shape resembles a horse saddle. For radial flow, dynamic symmetry surfaces may by flat as changes in flow rate are not dependent on the existence of curvature rather, on shorter or longer distances from the rotational axis. Mixed flow dynamic symmetry surfaces are similar to axial flow in that geometrically, curvature is most important. From a geometric standpoint, radial flow dynamic symmetry surfaces may be considered borderline for axial flow in which curvature is zero. In practical applications these surfaces are rarely geometrically symmetrical given the disparity among the thermodynamic conditions of expanding and compressing fluids. Real surfaces of the plates that shall be used for the construction of the rotors are derived from the criterion of dynamic symmetry taking into account resistance requirements, mechanical fluid optimisation, heat transfer and suitability in accordance with the specific application being designed. The plates need not have a uniform width; this will depend on the design requirements in each case.

Regardless of rotor layout, axial flow is understood as that in which the curvature of the surface is the primary cause for accelerations in flow facilitating the transfer of energy between the rotor and fluid; radial flow is understood as that in which the variation of the distance to the rotational axis is the primary cause for accelerations in flow facilitating the transfer of energy between the rotor and fluid; mixed flow is understood as that in which the curvature of the surface as well as the variation of the distance to the rotational axis are the causes for accelerations in flow facilitating the transfer of energy between the rotor and fluid.

Given that the rotors interact with not only the fluid but rather are incorporated into machinery, adaptation will be necessary, in general, in order to perform additional functions: optionally the plates may be equipped with extensions on specific parts along the edges as mounting flanges, which act as bearings, as airtight seals, as balancers, as anchor points for detachable rotors or to house additional accessories. Optionally mounting rings may be added to the rotor structure on specific parts, which act as continuous reinforcement elements, as bearings, as airtight seals, as balancers, as an anchor chassis for detachable rotor plates or to store additional accessories. Optionally, plate surfaces may be extended beyond the joint edges between them forming a fin, which performs fluid dynamic functions.

In order to better understand the previous explanation, drawings and examples are provided, which should not to be construed as limited or exclusive with respect to the applicability of this invention. Given their non-conventional shapes, dynamic symmetry plate surfaces are displayed using polygon mesh in order to better see the three-dimensional shapes thereof. Different perspectives of the same parts are displayed. In order to simplify the illustrations some parts that would normally be hollow or lightened are presented as solid. Attachment components, bearings, seals, fuelling services, diffusers, inductors, combustion chambers and in general details, devices and systems whose descriptions are beyond the scope of this invention and, which provide no relevant information for a person skilled in the art to consider beyond that which is obvious, have all been intentionally omitted. Other advantages and innovative characteristics will be later established or will become apparent for an expert on the subject or may be learned by the practical implementation of the invention.

<u>Brief Description of the Drawings</u>

Fig. 1 and 2: Perspectives of an axial or mixed flow dynamic symmetry active surface.

Fig. 3 and 4: Perspectives of an axial or mixed flow dynamic symmetry passive surface.

Fig. 5, 6, 7 and 8: Perspectives of the channels formed between the axial or mixed flow dynamic symmetry active and passive surfaces.

Fig. 9: Options for joining dynamic symmetry active and passive surfaces.

Fig. 10, 11, 12, 13 and 14: Perspectives of an axial or mixed flow dynamic symmetry plate rotor.

Fig. 15: Perspective of a basic engine incorporating a dynamic symmetry plate rotor.

Fig. 16: Schematic diagram of the engine in Figure 15.

Fig. 17: Cross sectional view of the volute flow line.

Fig. 18 and 19: Perspectives of an axial or mixed flow dynamic symmetry passive surface with mounting flanges.

Fig. 20: Perspective of an axial or mixed flow dynamic symmetry passive surface with mounting flanges and rings.

Fig. 21: Detail of the area in which a dynamic symmetry rotor contacts the structure of the turbomachinery to which it is incorporated.

Fig. 22: Possible attachment sections for mounting flanges and rings.

Fig. 23 and 24: Possible assembly techniques for dynamic symmetry surfaces on a detachable rotor.

Fig. 25: Schematic diagram of an electric generator powered by an axial flow dynamic symmetry plate rotor.

Fig. 26: Schematic diagram of a turboprop engine that combines an axial flow dynamic symmetry plate rotor with stages of conventional blades.

Fig. 27: Schematic diagram of a turbofan engine that combines two axial flow dynamic symmetry plate rotors.

Fig. 28 and 29: Perspectives of an active surface of one of the rotors in Figure 27.

Fig. 30 and 31: Perspectives of the joint of one passive and two active surfaces of one of the rotors in Figure 27.

Fig. 32 and 33: Perspectives of one of the rotors in Figure 27.

Fig. 34: Schematic diagram of an engine powered by a mixed flow dynamic symmetry plate rotor.

Fig. 35: Schematic diagram of a turbofan engine powered by a mixed flow dynamic symmetry plate rotor.

Fig. 36 and 37: Perspectives of the rotor in Figure 34.

Fig. 38 and 39: Perspectives of the rotor in Figure 35.

Fig. 40 and 41: Perspectives of the joint of one passive and two active surfaces of the rotor in Figure 35.

Fig. 42: Schematic diagram of a turboprop engine that combines two axial flow dynamic symmetry plate rotors and one mixed flow dynamic symmetry plate rotor.

Fig. 43 and 44: Perspectives of one of the axial flow rotors in Figure 42.

Fig. 45: Schematic diagram of turbomachinery incorporating a basic radial flow dynamic symmetry plate rotor.

Fig. 46 and 47: Perspectives of an active surface of the rotor in Figure 45.

Fig. 48 and 49: Perspectives of the rotor in Figure 45.

Fig. 50: Schematic diagram of turbomachinery incorporating a radial flow dynamic symmetry plate rotor adapted to axial flow near the shaft.

Fig. 51 and 52: Perspectives of an active surface of the rotor in Figure 50.

Fig. 53 and 54: Perspectives of the rotor in Figure 50.

Fig. 55, 56, 57 and 58: Perspectives of radial flow dynamic symmetry active and passive surfaces with fins for adaptation to axial flow near the shaft.

Fig. 59 and 60: Perspectives of a radial flow dynamic symmetry plate rotor with fins for adaptation to axial flow near the shaft.

Detailed Description of the Drawings

The illustrations provided will facilitate a better understanding of the concept of dynamic symmetry by visualising the shapes corresponding to the plates with which the rotors are constructed from different perspectives, whether separated or joined, being axial, radial or mixed flow. The edges of the joint between the active and passive surfaces are displayed as sharp in order to facilitate distinction, but in practice may also be rounded. Additionally, various options of carrying out the invention are outlined, which constitute a sufficient sample of the wide range of construction possibilities offered by this design strategy.

Figures 1 and 2 display perspectives of a dynamic symmetry active surface 1 in which rows of arrows indicating the direction of expanding flow 2 as well as that of compressing flow 3 can also be seen. Note how these curved paths imply the occurrence of pressure between the surface and the fluid. In this case it would be an axial or mixed flow dynamic symmetry surface, i.e. the shape must force the fluid to convey a curved path. Note in this theoretical example how the shape and paths are symmetrical with respect to an imaginary straight line passing through two opposite vertices of the surface.

Figures 3 and 4 display perspectives of a dynamic symmetry passive surface 4 in which rows of arrows indicating the direction of expanding flow can also be seen 2 as well as that of compressing flow 3. Note how these curved paths imply the occurrence of suction between the surface and the fluid. As happens with classic axial flow blades, dynamic symmetry passive surfaces have more pronounced curvature than active surfaces.

Figures 5 and 6 display perspectives of the joint of one dynamic symmetry passive surface 4 and two dynamic symmetry active surfaces 1. These views help illustrate how the channels are formed through which expanding 2 and compressing 3 fluids must flow. Note how the passive surface 4 is joined along two of its edges with one of the active surfaces 1 and along the other two with the other active surface 1. Reciprocally the opposite occurs to the active with respect to passive surfaces. As can be seen in this example, dynamic symmetry active surfaces will have all the edges thereof joined to a passive surface, however this does not occur with dynamic symmetry passive surfaces which will have some free edges. This is due to mere geometric suitability, but it would be perfectly conceivable for either both surfaces or only the active surface to have free edges, although this would generate slightly forced shapes. The fact that a channel is for compression or expansion depends not on the shape of the surfaces but rather on how the entire machinery as well as the rotational direction of the rotor are designed. A single rotor may be considered as axial flow for a specific configuration of the machinery and mixed flow for a different configuration if the radial flow component for expansion or compression flow is utilised therein. For a better idea of how a channel is configured, Figures 7 and 8 display perspectives of a set of sections 5 of one of the channels at the same time displaying the path 6 of the fluid circulating through the interior of the channel.

Dynamic symmetry surfaces are displayed using polygon mesh in order to better see the three-dimensional shapes thereof. This polygon mesh is comprised of two families of curvature, which are simply generatrices used to create the shape and should not be confused with the actual paths in which the fluid is conveyed along each of the faces thereof, although they may seem similar. As can be inferred from the shape of the channels, when the fluid circulates therein it will tend to concentrate more in the areas along the edges of the joint between the active and passive surfaces, which must therefore be properly joined. Figure 9 illustrates a cross section of a channel. This drawing details several options for joining the passive 7 and active 8 surfaces. Option 9 displays a welded or adhesive joint, while options 10 through 13 display possible types of joints to be used for detachable rotors. Similar joints may also be fashioned in the case of rounded edges as opposed to sharp edges.

Figures 10 and 11 display perspectives of an axial or mixed flow rotor in which only active surfaces 1 are installed. Figures 12 and 13 display perspectives of the same rotor but with passive surfaces 4 installed. Note how the passive surfaces 4 practically hide the active surfaces 1. Figure 14 illustrates how active 1 and passive 4 surfaces would be sequentially and alternately joined in order to manufacture a rotor.

Figure 15 displays the perspective of a cutaway diagram of a basic gas turbine engine in order to see the layout of the axial flow dynamic symmetry plate rotor 15, its rotational direction 21 and the arrows indicating the flow of gases on the interior thereof. Figure 16 displays the schematic diagram of the same engine. Fresh air 14 enters the engine and contacts the rotor 15 passing through the compression channels thereof. It then exits the rotor at point 16 partially compressed with a great amount of kinetic energy. Through a spiral volute the air is conveyed toward the combustor intake 17 where it is fully compressed with little kinetic energy upon contact. The air exits the combustor at point 18 after providing thermal energy and then through another spiral volute is conveyed toward point 19 where part of the pressure thereof is lost while obtaining a great amount of kinetic energy. It then enters the expansion channels of the rotor 15 where part of the energy thereof is given off to the rotor to then finally exit the engine at point 20. Figures 15 and 16 do not display the volutes that connect the rotor with the combustor, but its cross section would be spiral, such as that, for example, indicated in Figure 17. Note that the rotor is classified as axial flow given that in this configuration, in no way is the radial flow component utilised since the compressing flow runs toward the rotational axis and expanding flow runs away. The points indicated as number 22 are the points of the rotor, which make contact with the engine structure. On these points there must be some type of sealing system, which impedes the unintentional circulation of gases outside the rotor channels as well as some type of support mechanism, which facilitates the transmission of stress between the rotor and the engine structure. These requirements give rise to the use of mounting flanges on the structure of the dynamic symmetry plates whose functions are explained in the following figures.

Figures 18 and 19 display perspectives of a dynamic symmetry passive surface to which extensions 22 denominated as mounting flanges have been installed along its free edges. These mounting flanges are simply extensions of the surface structure that may be employed in a variety of ways in accordance with the suitability of the application. These are displayed on the passive surface as having free edges; however they may be installed on active surfaces with free edges as well. Normally these will act as bearings in order to transmit stress to the turbomachinery structure to which the rotor is incorporated; they also serve as a surface against which airtight sealing may be applied; as a support for accessories that must be driven directly by the rotor and as an anchor point for other elements. When turbomachinery is incorporated with several rotors it is likely that the sealing as well as the transmission of stress must be applied between the rotors themselves in addition to between the rotors and the turbomachinery. Additionally, the mounting flanges will support counterweights employed for the operation of rotor balancing.

Figure 20 displays a perspective of a dynamic symmetry passive surface 4 in which two of its mounting flanges 22 are used for the joining thereof to several rings 23. Although from an operational standpoint, these rings are not essential, they are suitable due to being structurally continuous elements that can be adapted to more elaborate designs, while requiring no more than simple turning. Obviously rings may be joined to the plates without requiring the use of mounting flanges. They may be employed to carry out the same functions as mounting flanges and in particular, as an anchor chassis for detachable rotor dynamic symmetry surfaces. A reasonable technique for the construction of axial or mixed flow detachable rotors is to utilise as a constructive element the resulting assembly of the welding of an active surface with no mounting flanges to a passive surface with mounting flanges along its free edges.

Whether mounting flanges or rings are employed, these elements are normally housed on the interior of a compartment constructed for such purposes within the structure of the turbomachinery to which the rotor is incorporated. Figure 21 displays a drawing of this area in a cutaway diagram of the turbomachinery. The dynamic symmetry plate rotor 15 has mounting flanges 22 joined to a ring 23. This assembly is housed on the interior of a compartment within the structure 27 of the turbomachinery. This compartment is constructed using a number of machining operations to create an airtight labyrinth seal 24, which impedes fresh air 14 entering the compression channels of the rotor 15 from making contact with exhaust gases 20 emanating from the expansion channel of the same rotor. Both the ring 23 as well as the turbomachinery structure 27 are formed in such a way as to create surfaces 25 intended to act as a friction bearing in order to support possible stresses such as thrust or centrifugal force. Additionally, the ring 23 and the turbomachinery structure 27 are equipped with the electromagnetic accessories 26 required for the turbomachinery to operate as an electrical power generator.

Figure 22 displays sections of possible mounting flange configurations; simple configurations on the left or combinations with rings on the right. Note that mounting flanges may be designed to carry out a variety of functions without requiring the use of rings.

Figure 23 displays a partial frontal view of a dynamic symmetry plate rotor 15 with mounting flanges 22 and ring 23. In this example, the mounting flanges 22 and the ring 23, as opposed to being welded or riveted, are simply assembled using pivots 28, which fit into the respective bore holes in the mounting flanges 22, thus obtaining a detachable rotor. While an unlikely option, Figure 24 displays a partial frontal view of a dynamic symmetry plate rotor 15 with mounting flanges 22 manufactured using a special machining operation 29 in order to facilitate direct assembly without the need for welding or use of a ring.

Having described the shape of the axial or mixed flow dynamic symmetry surfaces and having described how the combination thereof is used to construct rotors, the following presents a number of possible turbomachinery layouts that incorporate this type of rotor. For simplification, details of the mounting flanges and possible rings have been intentionally omitted from the rotor displays.

Figure 25 displays an axial schematic diagram section of an electric generator powered by an axial flow dynamic symmetry plate rotor 15 whose combustion chamber 31 is centred. Through conduit 33 fuel and electrical ignition are supplied to the combustion chamber 31. The rotor 15 is joined to a ring 23 to which electrical power generation accessories 34 have been coupled. It is possible to start the generator electrically using the same elements 34 as those used for power generation. Alternatively, the generator may be started by blowing compressed air from a bottle into the combustion chamber through the conduit 33. Once started, this same conduit 33 is employed for the intake of air from the entrance of the combustion chamber while filling the bottle of compressed air by using suitably arranged valves. Fresh air 14 enters the generator and contacts the rotor 15 passing through the compression channels thereof. The air then exits the rotor and enters the compression spiral volute 30, which then conveys it to the combustion chamber 31. After supplying thermal energy, the air exits the combustion chamber and enters the expansion spiral volute 32, which then conveys it to the rotor 15. The gas passes through the expansion channels of the rotor 15 where its energy is given off, to then finally exit the generator at point 20.

Figure 26 displays an axial schematic diagram section of a turboprop engine with an axial flow dynamic symmetry plate rotor 15 whose combustion chamber is centred. 31. The engine body is composed of an outer casing 38 and a central body 40 connected by a stator 39. The propellers comprise part of the outer rotor 37, which has a stage of conventional blades 35 on the interior thereof facilitating compression and another stage of conventional turbine blades 36, which power the entire outer rotor using exhaust gases. In this case the dynamic symmetry plate rotor 15 is used only to facilitate compression while the useful power is obtained by the blades 36 of the outer rotor 37. The outer rotor 37 and the dynamic symmetry plate rotor 15 rotate in opposite directions. Through conduit 33 fuel and electrical ignition are supplied to the combustion chamber 31. The engine may be started by blowing compressed air from a bottle into the combustion chamber through the conduit 33. Once started, this same conduit 33 is employed for the intake of air from the entrance of the combustion chamber while filling the bottle of compressed air. The fresh air 14 is partially accelerated and compressed by the blades 35 of the outer rotor 37 and then contacts the rotor 15 after passing through the compression channels thereof. The air then exits the rotor 15 and enters the compression spiral volute 30 which then conveys it to the combustion chamber 31. After supplying thermal energy, the air exits the combustion chamber and enters the expansion spiral volute 32, which then conveys it to the rotor 15. The gas passes through the expansion channels of the rotor 15 where part of the energy thereof is given off. After exiting the rotor 15 the gas impinges on the turbine blades 36 supplying useful power to the outer rotor 37 to then finally exit the engine at point 20.

Figure 27 displays an axial schematic diagram section of a turbofan engine with a centred combustion chamber 31 and, which combines two axial flow dynamic symmetry plate rotors; one for compression 15 and the other for propulsion 43; both rotate in opposite directions. Through conduit 33 fuel and electrical ignition are supplied to the combustion chamber 31. The engine may be started by blowing compressed air from a bottle into the combustion chamber through the conduit 33. Once started, this same conduit 33 is employed for the intake of air from the entrance of the combustion chamber while filling the bottle of compressed air. The fresh air that enters through point 14 passes through the compression channels of the rotor 43. The majority of the air is expelled through point 44 in order to obtain thrust. The other part of the pumped air is conveyed through point 41 toward the compression channels of the rotor 15. The air then exits the rotor 15 and enters the compression spiral volute 30, which then conveys it to the combustion chamber 31. After supplying thermal energy, the air exits the combustion chamber and enters the expansion volute 32, which then conveys it to the rotor 15. The gas passes through the expansion channels of the rotor 15 where part of the energy thereof is given off. The gas then exits at point 42 toward the expansion channels of the rotor 43 where the energy necessary for the activation thereof is given off, to then finally outlet as exhaust at point 20. In order to separate the conduit 41 and 42 a ring 45 is employed, which is able to rotate freely with respect to the rotors. Note that there is no element separating the flows 44 and 20 that exit the rotor 43 as the shape is designed specifically so that the flow rates thereof are very similar at point 46. The following figures offer better displays of the shape of the dynamic symmetry plate rotor 43, which is designed to pump a large amount of air flow while creating a lower flow rate.

Figures 28 and 29 display perspectives of a dynamic symmetry active surface 1 of the rotor 43 displayed in Figure 27. Rows of arrows indicating the direction of expanding flow 2 as well as that of compressing flow 3 can also be seen. Note how the compression path has only slight curvature in order to prevent excessive flow rate. In this case, this is an axial flow dynamic symmetry surface, i.e. the shape must force the fluid to convey a curved path and the radial flow component is used neither for compression nor expansion.

Figures 30 and 31 display perspectives of the joint of one dynamic symmetry passive surface 4 and two dynamic symmetry active surfaces 1 of the rotor 43 displayed in Figure 27. Note the amplitude of the compression channel compared against that of the expansion channel. Figure 31 displays the indicated points 46, which are also displayed in Figure 27. Figures 32 and 33 display perspectives of the rotor 43 displayed in Figure 27. The rotational direction is indicated as 21. The point of view of Figure 32 provides a better display of the intake areas for both compression as well as expansion channels while the point of view of Figure 33 provides a better display of the outlet areas.

Figure 34 displays an axial schematic diagram section of a gas turbine engine powered by a mixed flow dynamic symmetry plate rotor 15 with an annular combustion chamber 31 located at the periphery of the rotor in which diffusion and induction areas are also incorporated. The useful power is distributed through the shaft 47, which is also used to start the engine. Fresh air 14 enters the engine and contacts the rotor 15 passing through the compression channels thereof. The air then exits the rotor and enters the annular combustion chamber 31. After supplying thermal energy, the gas exits the combustion chamber and passes through the expansion channels of the rotor 15 where the energy thereof is given off, to then finally exit the engine at point 20. As previously indicated, the mixed flow rotor is conceptually identical to that of an axial flow rotor; the only modification is the configuration of the machinery, which does utilise the radial flow component for both compression and expansion. In later figures, the rotors employed in this machinery shall be displayed.

Figure 35 displays an axial schematic diagram section of a turbofan engine powered by a mixed flow dynamic symmetry plate rotor 15 whose periphery makes contact with an external combustion chamber via the volutes 30 and 32. The engine may be started by blowing compressed air from a bottle into the combustion chamber. The fresh air that enters through point 14 passes through the compression channels of the rotor 15. The majority of the air is expelled through point 48 in order to obtain thrust. The other part of the pumped air is conveyed toward the compression volute 30 and from there to the combustion chamber. After supplying thermal energy, the air exits the combustion chamber and enters the expansion volute 32, which then conveys it to the rotor 15. The gas passes through the expansion channels of the rotor 15 where the energy thereof is given off, to then finally outlet as exhaust at point 20. The thrust air 48 is conveyed through the stator 49 prior to exiting the engine. The following figures offer better views of the shape of the dynamic symmetry plate rotor 15, which is designed to pump a large amount of air flow through the central part while providing it with a lower speed.

Figures 36 and 37 display perspectives of the rotor 15 displayed in Figure 34. The rotational direction is indicated as 21. Note that this is essentially no different than those observed for axial flow.

Figures 38 and 39 display perspectives of the rotor 15 displayed in Figure 35. The rotational direction is indicated as 21. The point of view of Figure 38 provides a better display of the intake areas for both compression as well as expansion channels while the point of view of Figure 39 provides a better display of the outlet areas. Figures 40 and 41 display perspectives of the joint of one dynamic symmetry passive surface 4 and two dynamic symmetry active surfaces 1 of the rotor 15 displayed in Figure 35. Note the amplitude of the compression channel compared against that of the expansion channel.

Figure 42 displays an axial schematic diagram section of a turboprop engine whose combustion chamber 31 is centred, and, which combines the use of a mixed flow dynamic symmetry plate rotor 15 with two axial flow dynamic symmetry plate rotors 49 and 52. The engine body is composed of an outer casing 38 and a central body 40 connected by a stator 39. The propellers comprise part of the outer rotor 37, which is solidly joined to the rotors 49 and 52. In this case, the three dynamic symmetry plate rotors are used to facilitate compression, but only the rotors 49 and 52 supply useful power to the outer rotor 37. The mixed flow dynamic symmetry plate rotor 15 rotates in the opposite direction to that of the outer rotor 37 and therefore, also opposite to that of the axial flow dynamic symmetry plate rotors 49 and 52. Through conduit 33 fuel and electrical ignition are supplied to the combustion chamber 31. The engine may be started by blowing compressed air from a bottle into the combustion chamber through the conduit 33. Once started, this same conduit 33 is employed for the intake of air from the entrance of the combustion chamber while filling the bottle of compressed air. The fresh air 14 is partially compressed in the compression channels of the rotor 49 exiting through the conduit 50. The air is then compressed further passing through the compression channels of the rotor 15 exiting through the conduit 51. Next, the air is then compressed even further passing through the compression channels of the rotor 52. The air then exits the rotor 52 and enters the compression spiral volute 30, which then conveys it to the combustion chamber 31. After supplying thermal energy, the air exits the combustion chamber and enters the expansion spiral volute 32, which then conveys it to the rotor 49. The gas passes through the expansion channels of the rotor 49 where part of the energy thereof is given off to the outer rotor 37, exiting through the conduit 53. From there it passes through the expansion channels of the rotor 15 where part of the energy thereof is given off, exiting through the conduit 54. Finally, the gas passes through the expansion channels of the rotor 52 supplying the remaining useful power to the outer rotor 37, to then finally exit the engine at point 20. The following figures display the shape of the axial flow dynamic symmetry plate rotor 49 whose peculiarity is that the compression flow thereof occurs on a plane almost parallel to the shaft, while expansion flow occurs on a plane almost perpendicular thereto and in the opposite direction to that considered desirable for utilisation of the radial component of its movement.

Figures 43 and 44 display perspectives of the rotor 49 displayed in Figure 42. The rotational direction is indicated as 21.

Having illustrated many examples of axial or mixed flow dynamic symmetry plate rotor layouts and for turbomachinery where they may be incorporated, the following shall illustrate examples for radial flow dynamic symmetry plate rotors. Radial flow may be considered as borderline for mixed flow in which net curvature is zero and therefore, a radial flow rotor designed with the same techniques as a mixed flow rotor would be perfectly feasible Nevertheless, the design flexibility afforded by the criterion of dynamic symmetry allows for other more advantageous constructive solutions for radial flow. As can be determined from the following figures, it is possible to manufacture a dynamic symmetry plate rotor in which compressing flow need not forcibly cross the expanding flow and in which it is not necessary that the channels are completely formed by the active and passive surfaces.

Figure 45 displays an axial schematic diagram section of turbomachinery, which uses a radial flow dynamic symmetry plate rotor 15 in order to interchange energy between two currents of fluid. The rotor is equipped with mounting flanges 22 in order to seal it against the casing. Figures 46 and 47 display perspectives of a dynamic symmetry active surface 1 of the rotor 15 displayed in Figure 45. Rows of arrows indicating the direction of expanding flow 2 as well as that of compressing flow 3 can also be seen. Note how in the central area both the expanding as well as compressing flows run approximately parallel without their paths crossing. Figures 48 and 49 display perspectives of the rotor 15 displayed in Figure 45 indicating several active 1 and passive 4 surfaces. One of the key differentiating characteristics of this radial flow dynamic symmetry plate rotor as opposed to an axial or mixed flow rotor is that the compression and expansion channels are not enclosed between the active 1 and passive 4 surfaces but rather a part thereof must be enclosed by the machinery casing, as can be seen in point 55 of Figure 45. This is also a common characteristic for conventional radial turbomachinery. The area of the channels enclosed by the casing coincides with the area in which the expanding 2 and compressing 3 flows run approximately parallel. In reference to Figure 45, the compressed fluid enters the turbomachinery through point 14, near the rotational axis and passes through the compression channels of the rotor 15 whereby receiving energy as it circulates radially toward the volute 56 at the periphery. The expanding fluid reaches the volute 57 in the periphery, and then passes through the expansion channels of the rotor 15 whereby giving off energy as it circulates radially toward the rotational axis to then exit the turbomachinery at point 20. In this example the shape of the surfaces is very simple: a flat active surface and a passive surface, which closely resembles a ruled surface. While this design is perfectly feasible, it may be optimised by suitable twisting of the surfaces for better adapting to the axial flow that is prevalent in the areas close to the rotational axis as displayed in the following figures.

Figure 50 displays an axial schematic diagram section of turbomachinery, which uses a radial flow dynamic symmetry plate rotor 15 in order to interchange energy between two currents of fluid. Except for the shape of the rotor, the turbomachinery is identical to that displayed in Figure 45. Figures 51 and 52 display perspectives of a dynamic symmetry active surface 1 of the rotor 15 displayed in Figure 50. Rows of arrows indicating the direction of expanding flow 2 as well as that of compressing flow 3 can also be seen. Note how in this example the compressing flow intake surface area 3 is convexed like a spoon, as is the expanding flow outlet surface area. Figures 53 and 54 display perspectives of the rotor 15 displayed in Figure 50 indicating several active 1 and passive 4 surfaces. Note how in this example the active 1 as well as the passive 4 surfaces have free edges. This same adaptation to the axial flow that is prevalent in the areas close to the rotational axis may be achieved using fins to a similar effect but with fewer forced shapes, as displayed in the following figures.

Figures 55 and 56 display perspectives of a dynamic symmetry active surface 1 for a rotor similar to that of the turbomachinery displayed in Figure 50. A row of arrows indicating the direction of compressing flow 3 can be seen. The surface is equipped with an extension 58 in the form of a fin specifically suited to be adapted to axial flow intake. Figures 57 and 58 display perspectives of the joint of one dynamic symmetry passive surface 4 and one dynamic symmetry active surface 1. Rows of arrows indicating the direction of expanding flow 2 as well as that of compressing flow 3 can also be seen. The passive surface 4 also incorporates its own fin 59 in order to be adapted to axial flow outlet, although both fins may indeed be installed only on either the active or the passive surface. Figures 59 and 60 display perspectives of a dynamic symmetry plate rotor comprised of the previously described surfaces. These fins, as opposed to dynamic symmetry surfaces are washed by the same fluid on both faces, i.e. they are extensions as they themselves do not comply with the criterion of dynamic symmetry, while the rest of the surface does. They may be utilised equally for axial or mixed flow dynamic symmetry plate rotors but they are especially suitable for those of radial flow given that there is usually an area where flow is notably axial.

Claims

Turbine rotors which operate both as a pump and an engine, whether axial, radial or mixed flow, said rotors are characterised by the joining of two types of plates, a pressure plate and a suction plate, which, joined in an alternating sequence along the edges thereof, form two equally alternative channels, one to circulate compressing fluid and the other adjacent channel to circulate expanding fluid due to the design using a special shape based on the criterion of dynamic symmetry, whereby a theoretical dynamic symmetry surface has a twisted shape, such that a current of fluid can be conveyed along one of the faces thereof, following a pre-determined path and exerting thereon pre-determined stresses, while at the same time another current of fluid can be conveyed along the other face thereof, following another path symmetrical to the first and exerting thereon other stresses symmetrical to the first. Optionally the plates may be equipped with extensions on specific parts along the edges as mounting flanges, which act as bearings, as an airtight seal, as balancers, as anchor points for detachable rotors or to house additional accessories. Optionally mounting rings may be added to the rotor structure on specific parts, which act as continuous reinforcement elements, as bearings, as an airtight seal, as balancers, as an anchor chassis for detachable rotor plates or to house additional accessories. Optionally, plate surfaces may be extended beyond the joint edges between them forming a fin, which performs fluid dynamic functions.

Summary

The invention relates to the design of turbine rotors which operate both as a pump and a motor and which are essentially made by joining two types of plates, namely a pressure plate and a suction plate, the shapes of which are based on the criterion of dynamic symmetry, whereby a theoretical dynamic symmetry surface (1) has a twisted shape, such that a current of fluid (2) can be conveyed along one of the faces thereof, following a pre-determined path and exerting thereon pre-determined stresses, while at the same time another current of fluid (3) can be conveyed along the other face thereof, following another path symmetrical to the first and exerting thereon other stresses symmetrical to the first. The invention provides different structural solutions that demonstrate the application of the criterion of dynamic symmetry to the design of radial, axial and mixed flow turbines.

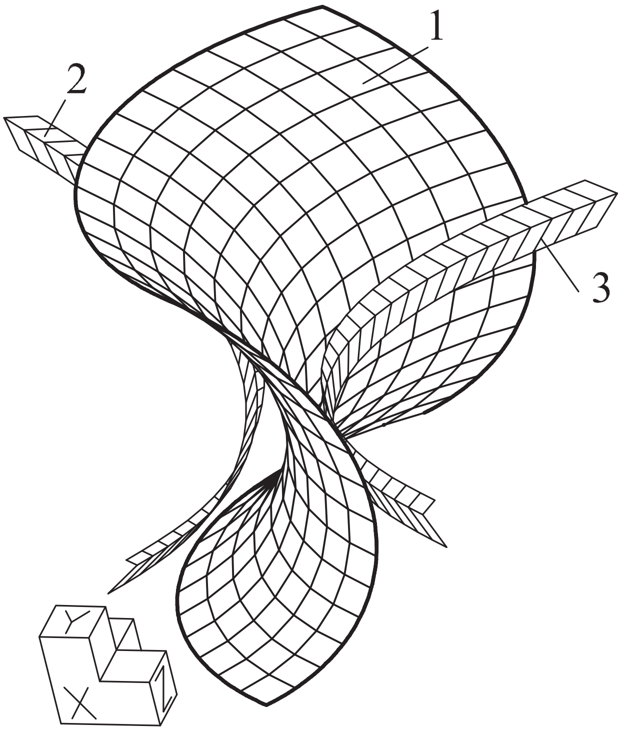


FIG. 1

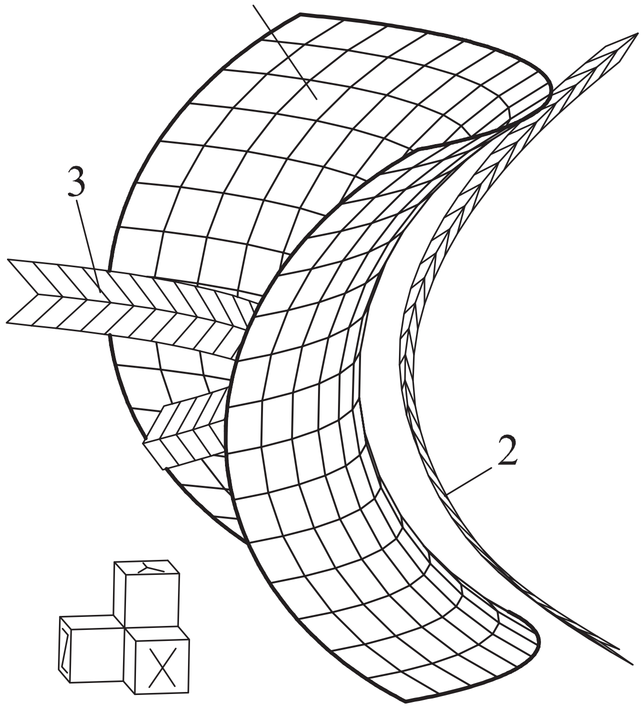


FIG. 2

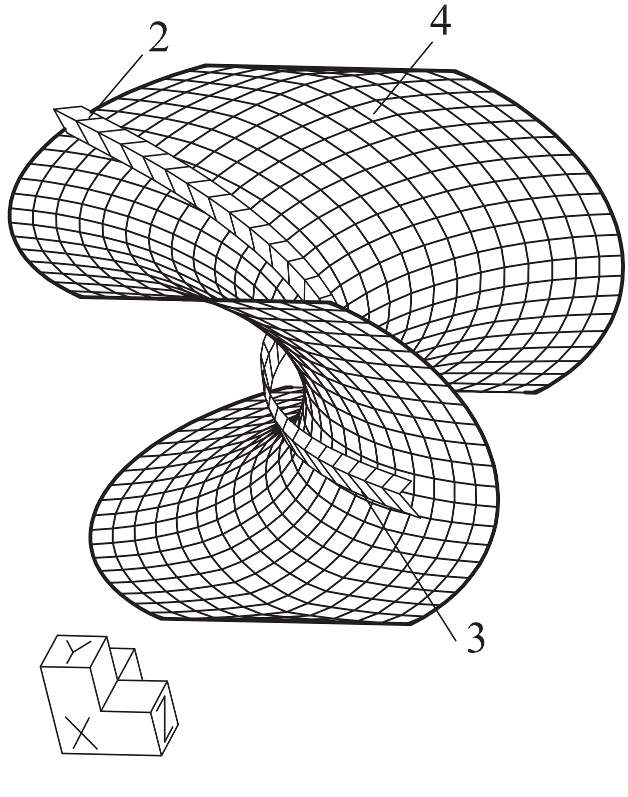


FIG. 3

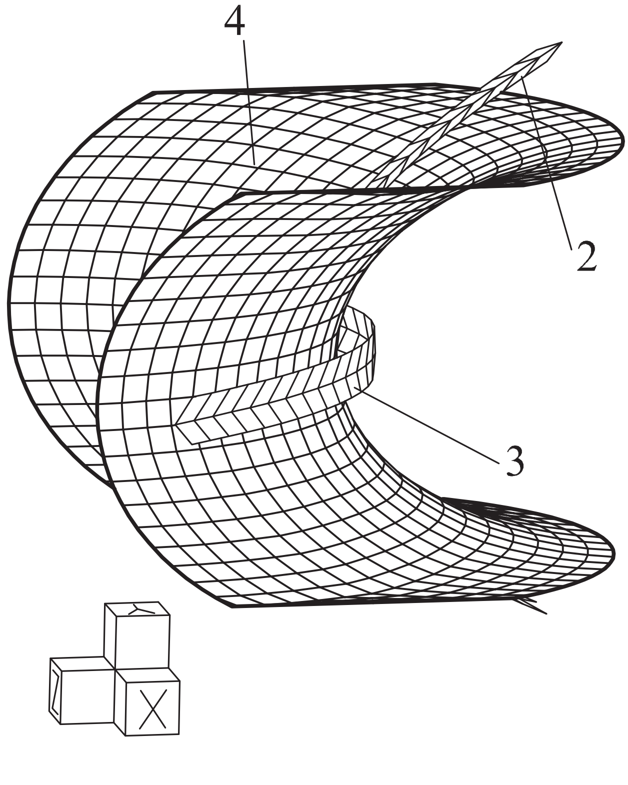


FIG. 4

FIG. 5

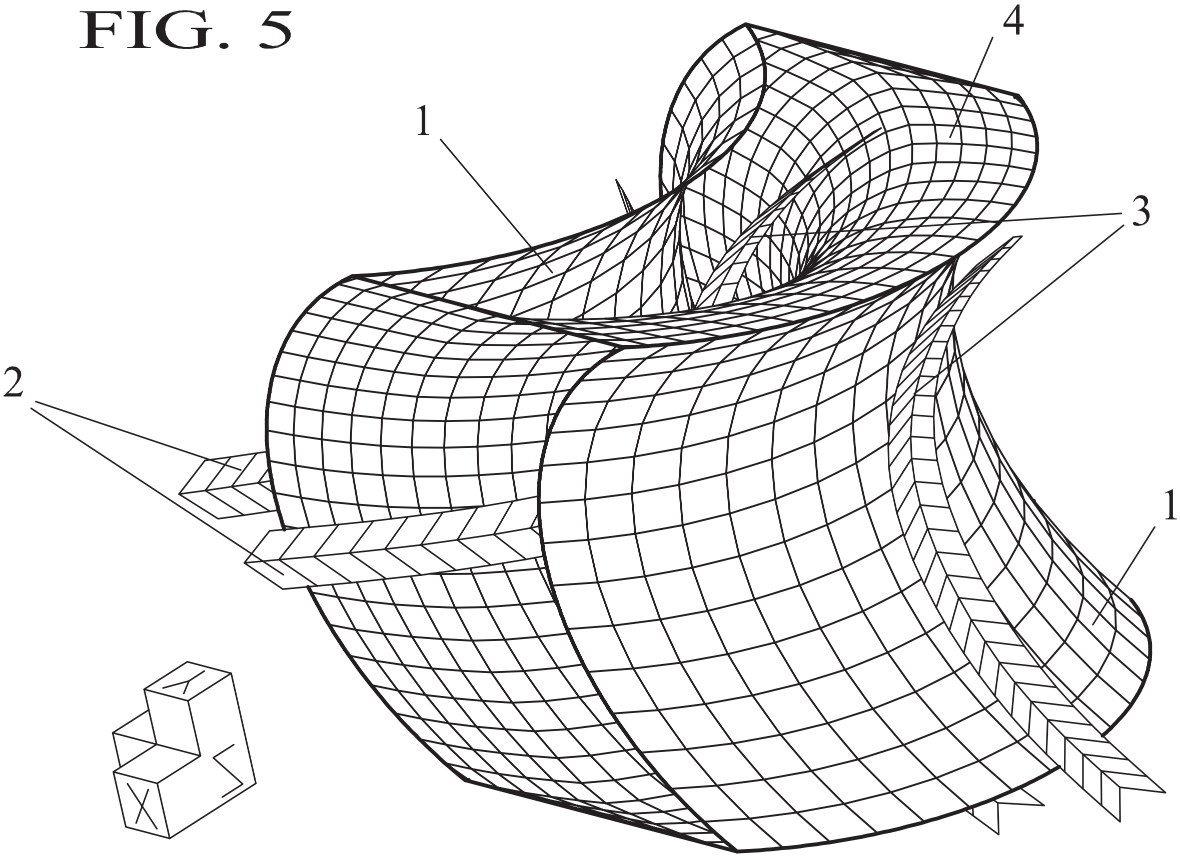


FIG. 6

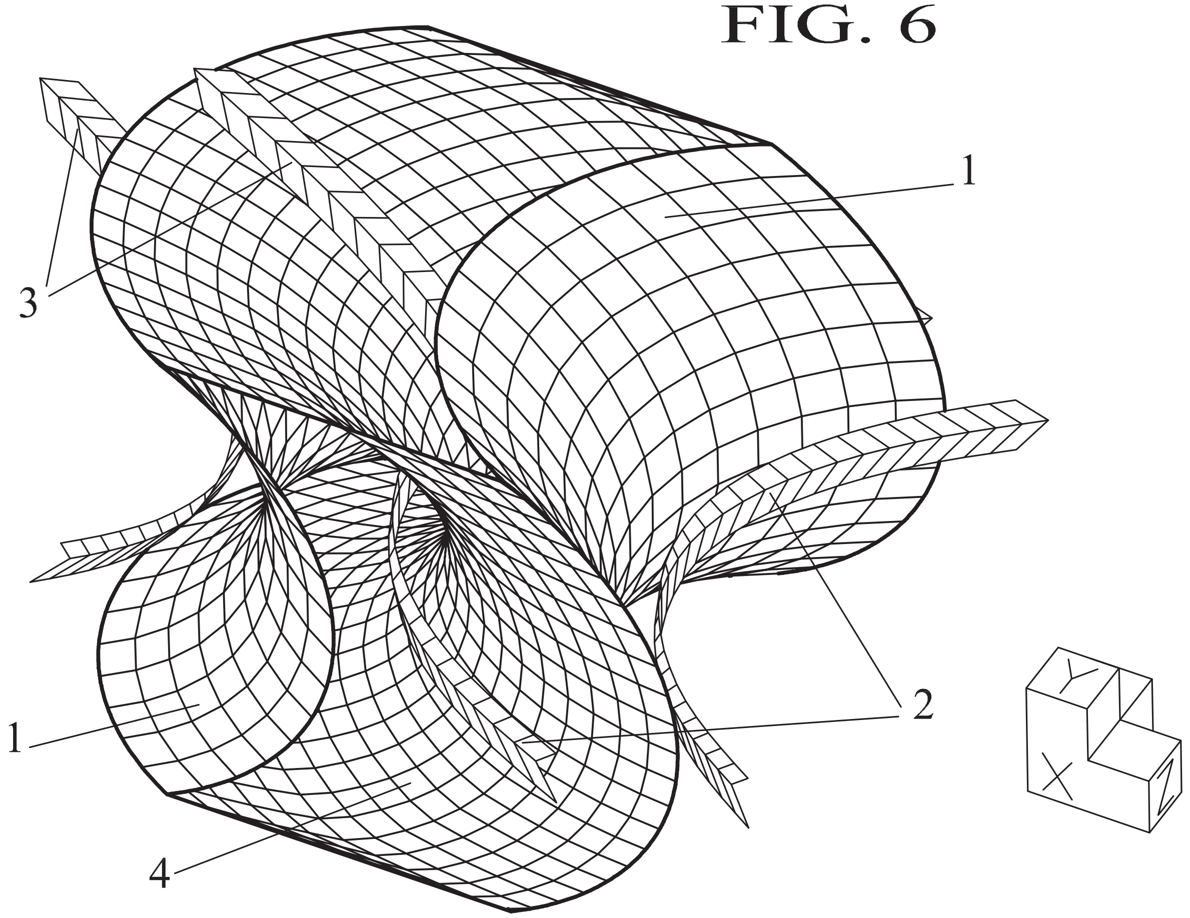


FIG. 8

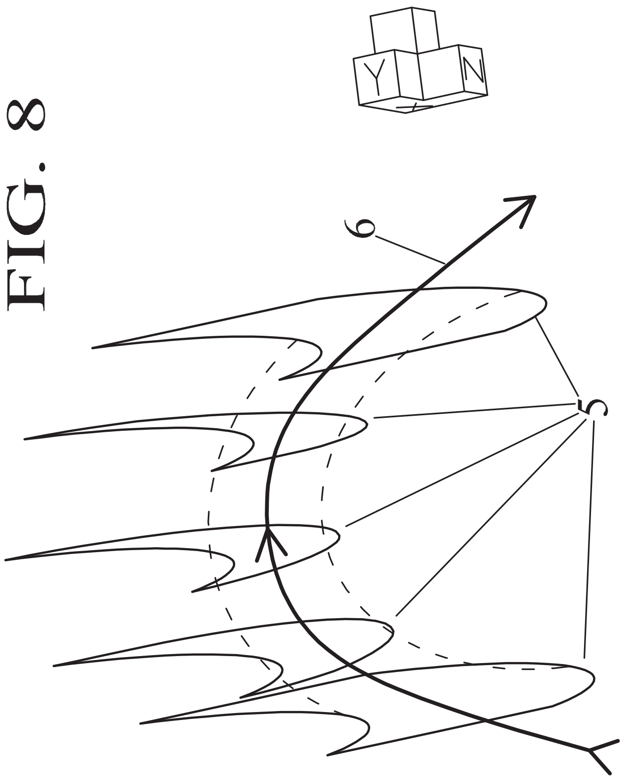


FIG. 7

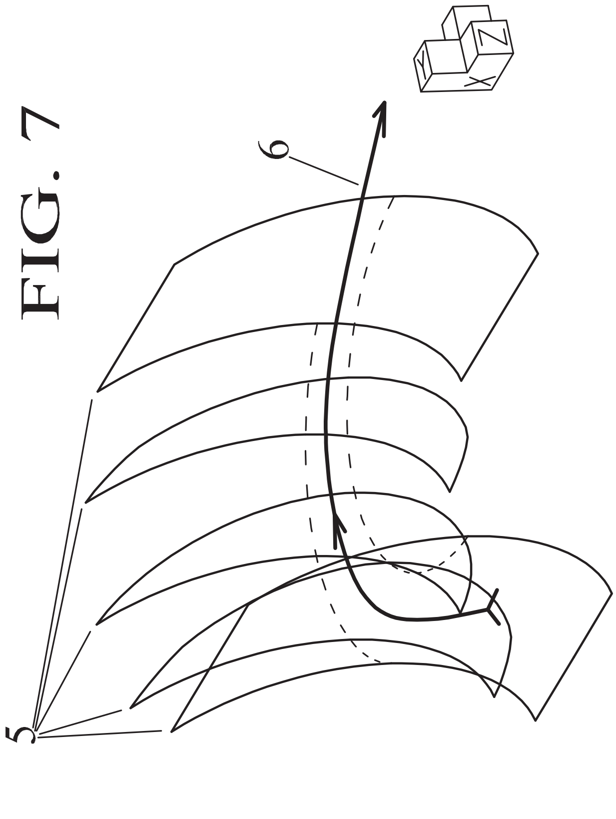
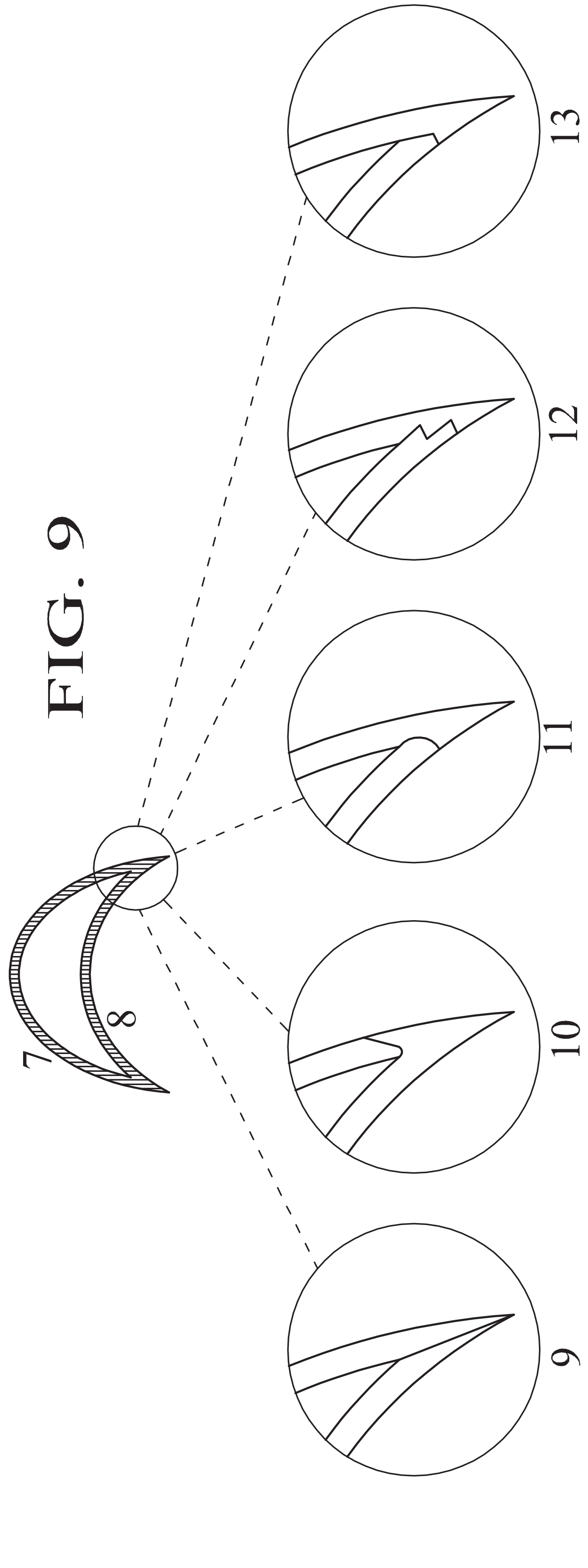


FIG. 9



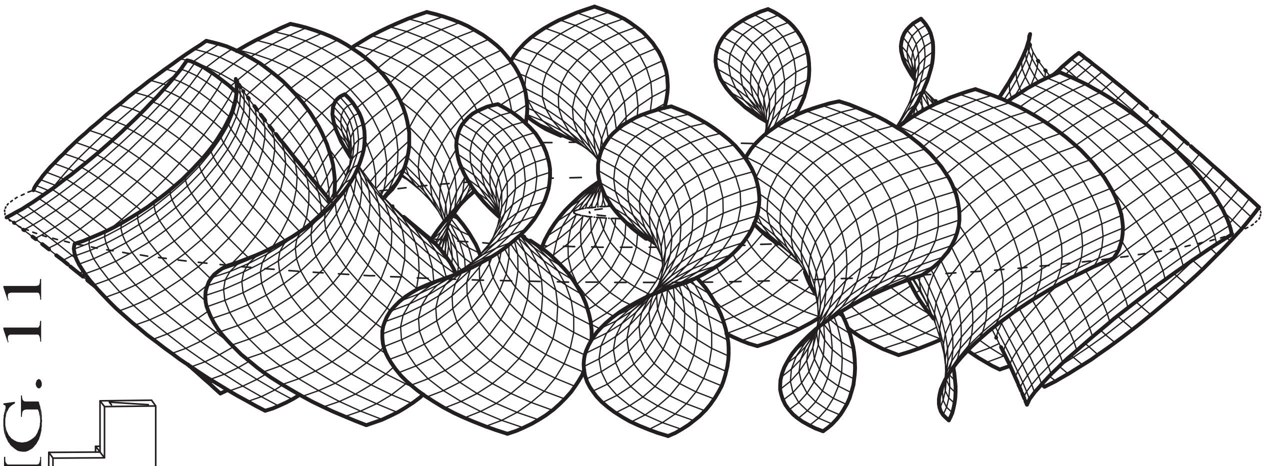


FIG. 11

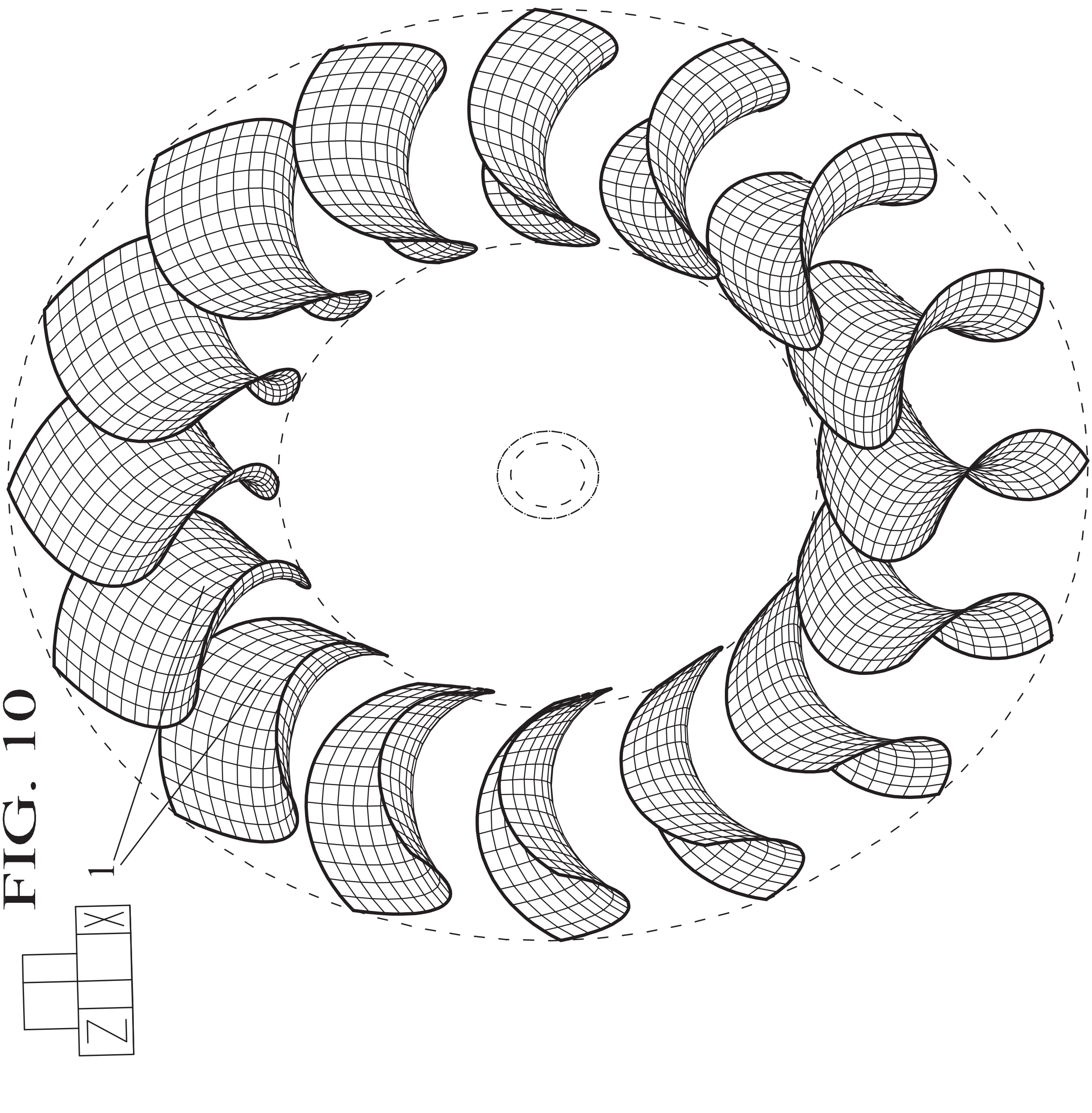


FIG. 10

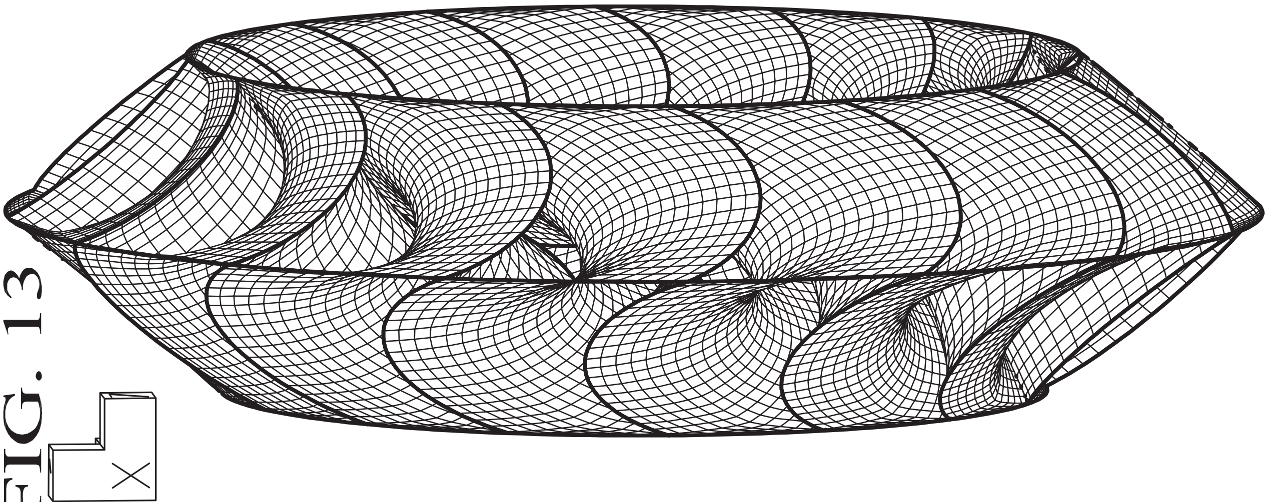


FIG. 13

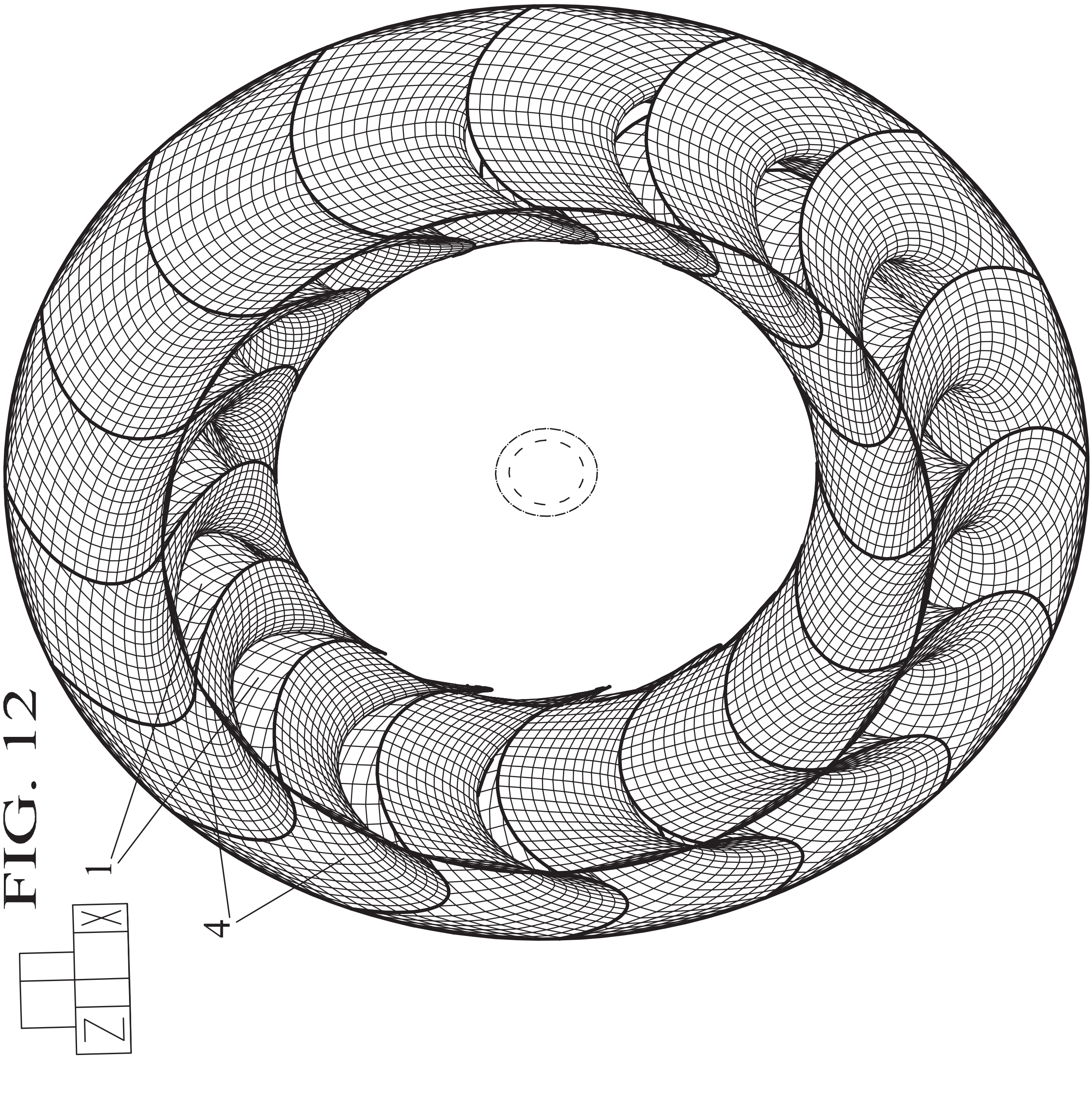


FIG. 12

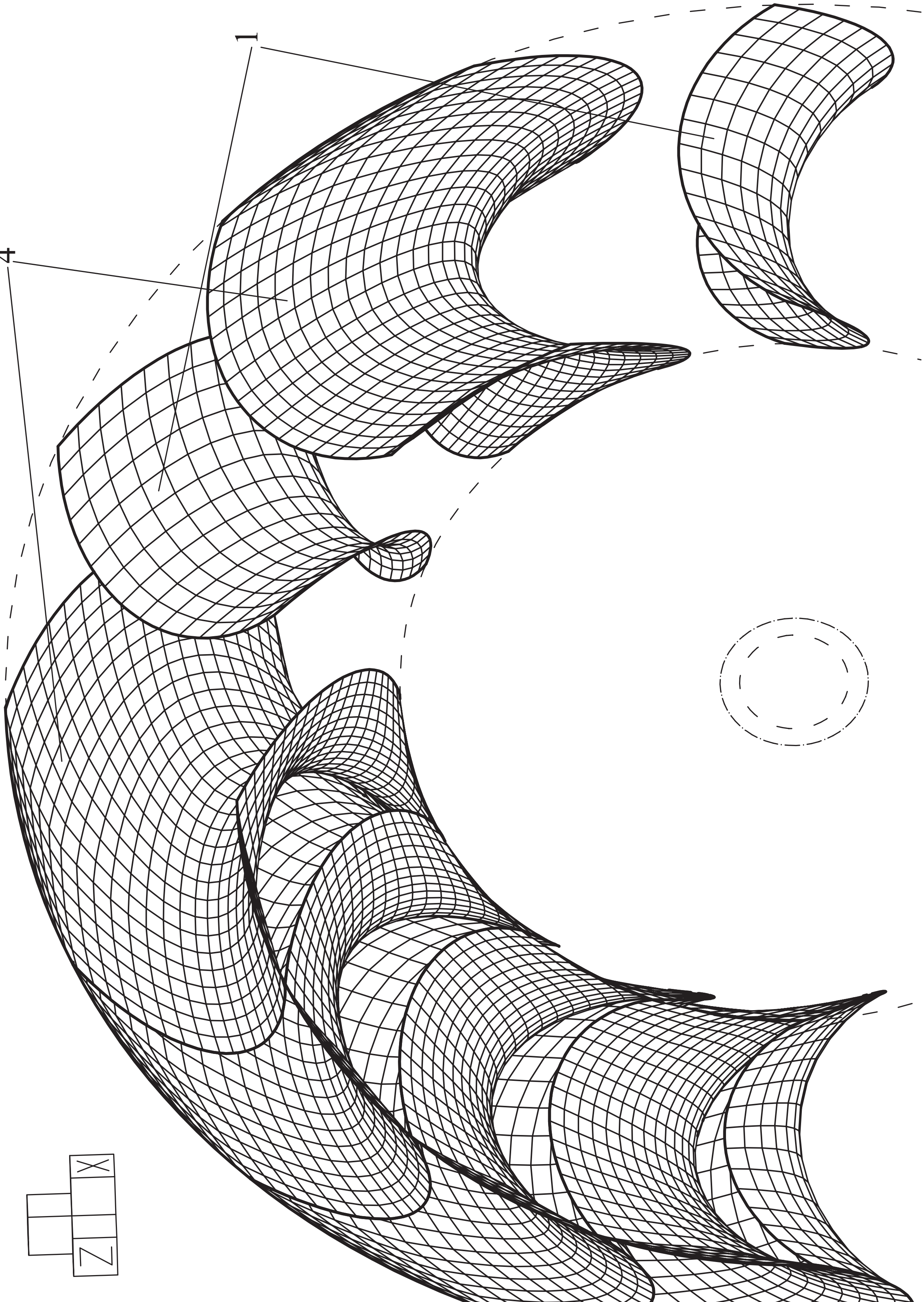


FIG. 14

FIG. 15

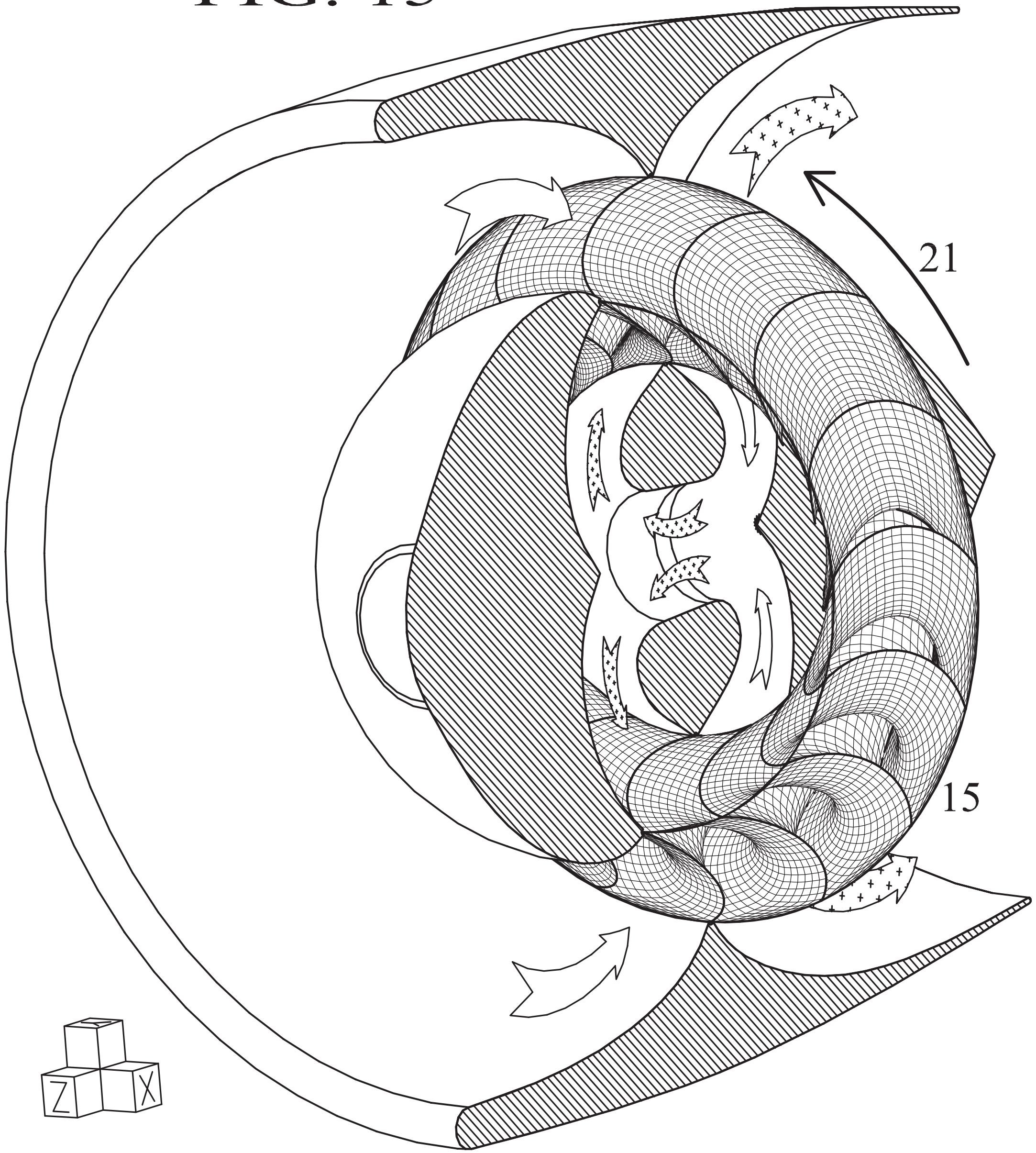
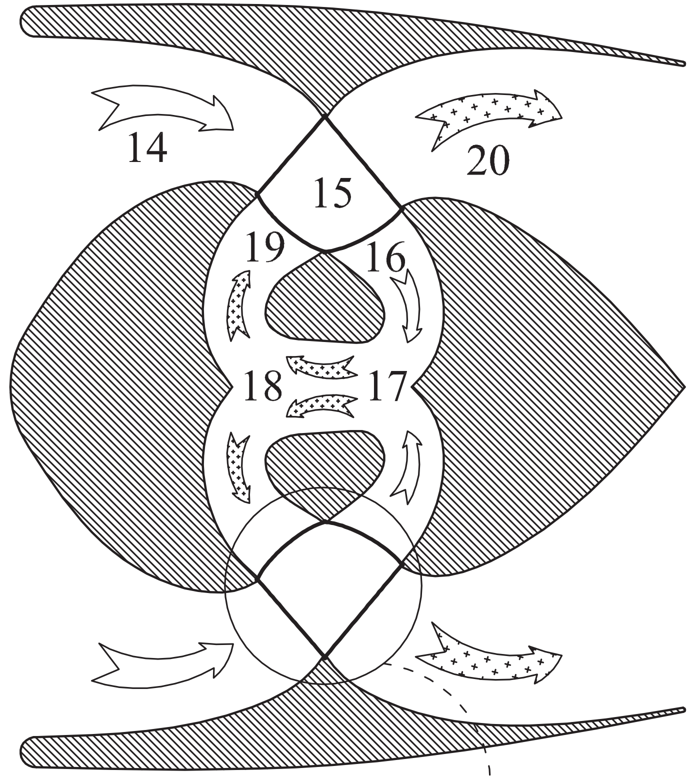


FIG. 16



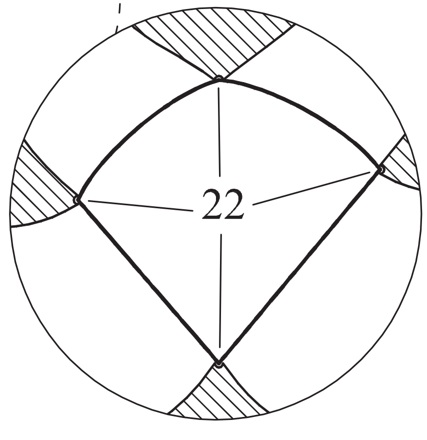


FIG. 17

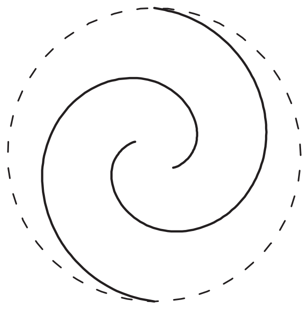
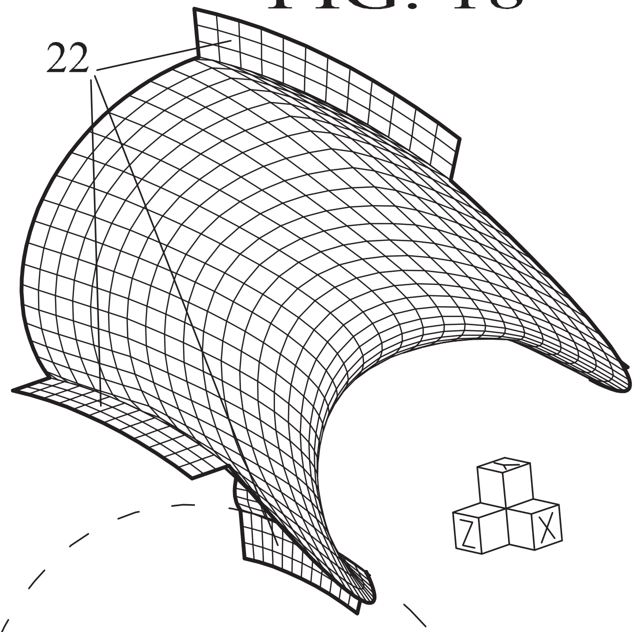


FIG. 18



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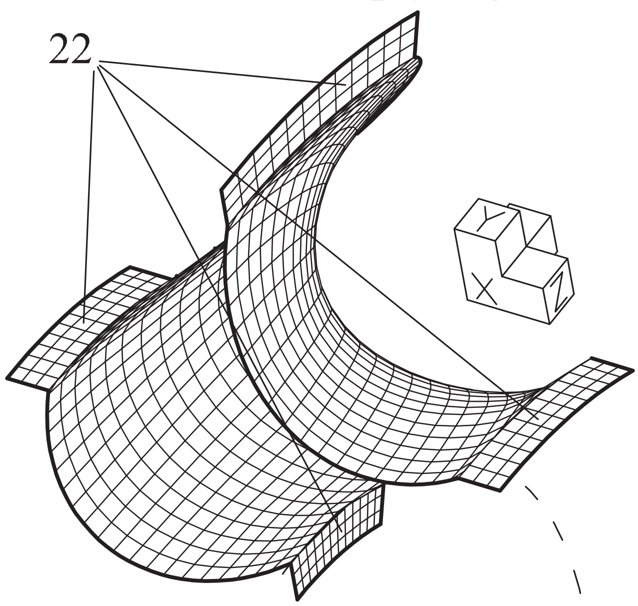


FIG. 20

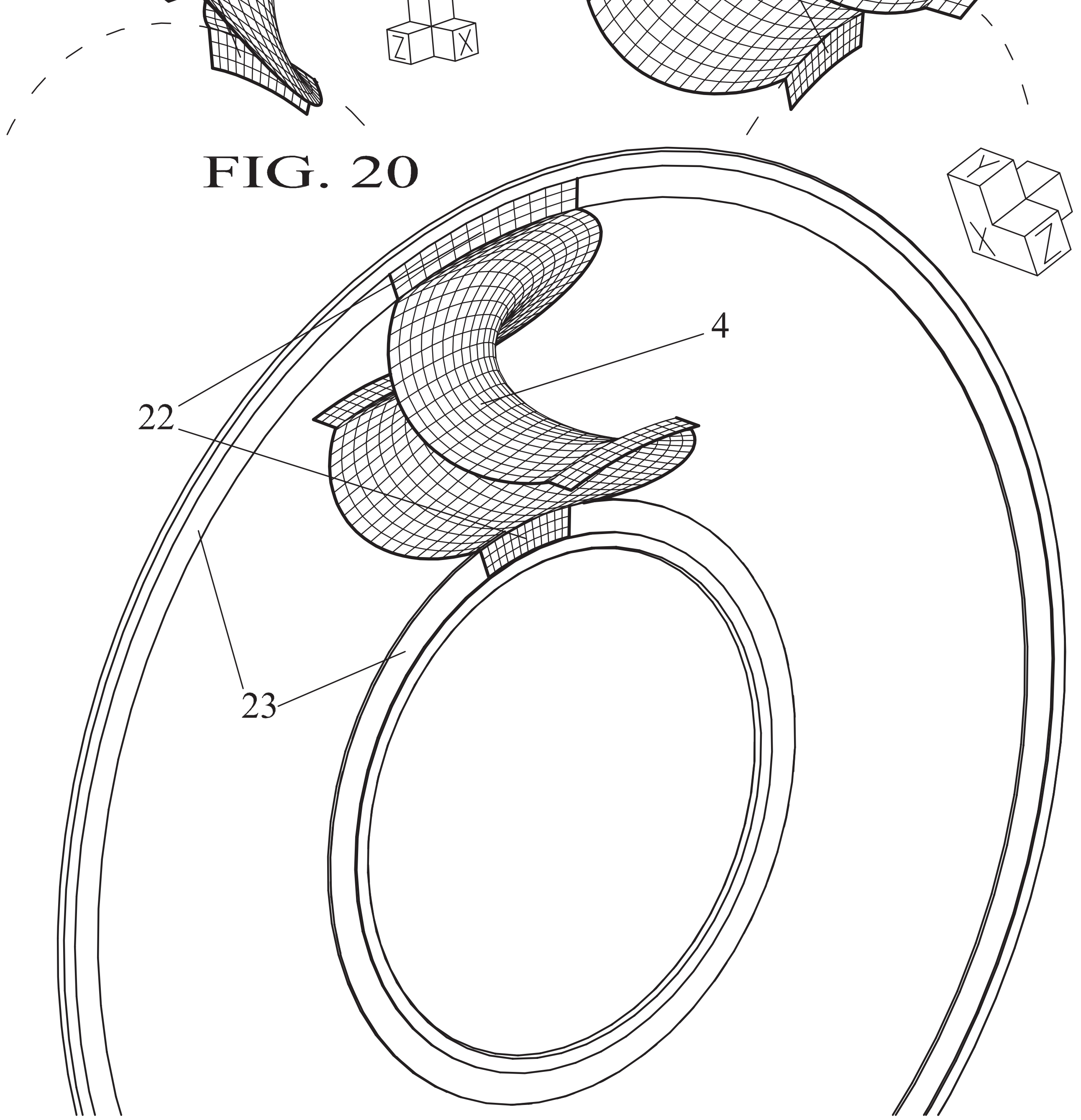


FIG. 21

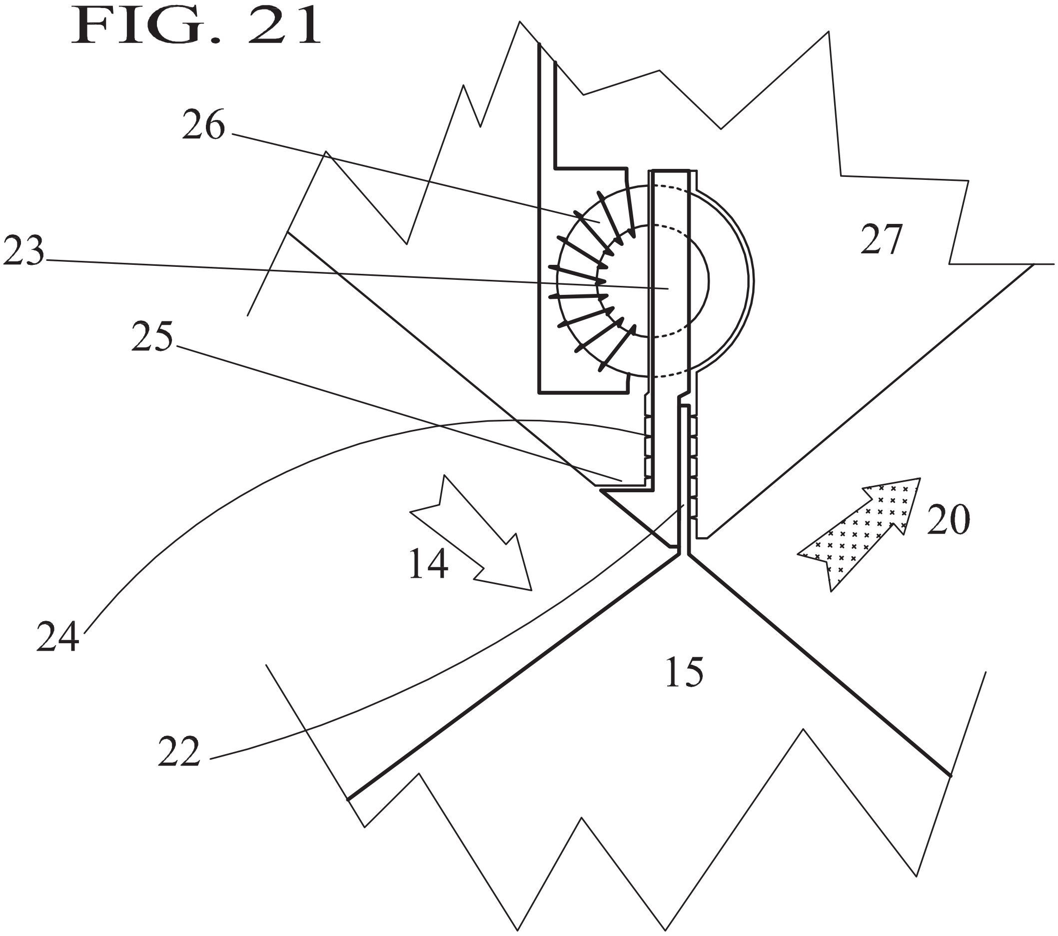


FIG. 22

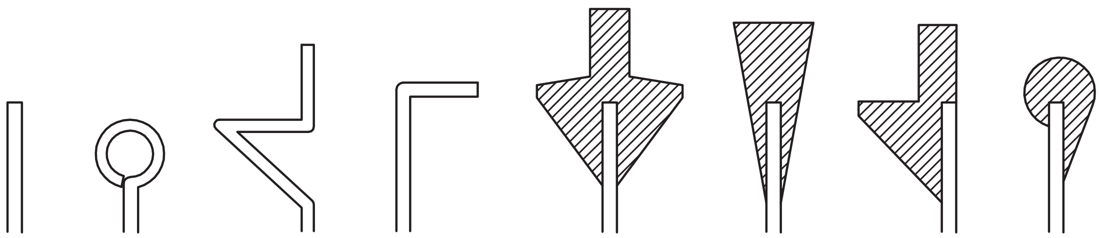


FIG. 23

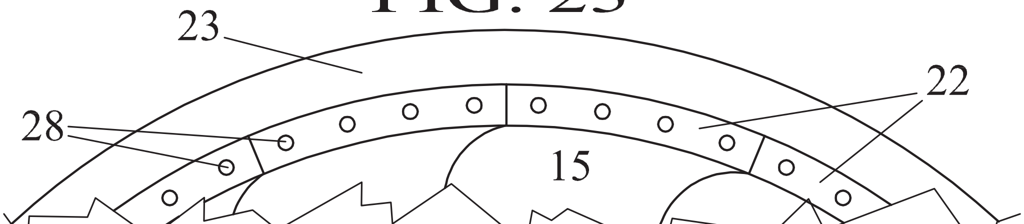


FIG. 24

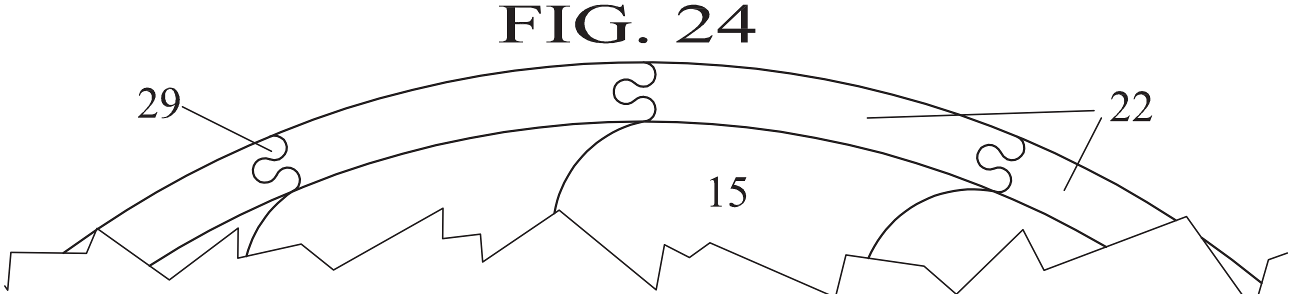


FIG. 25

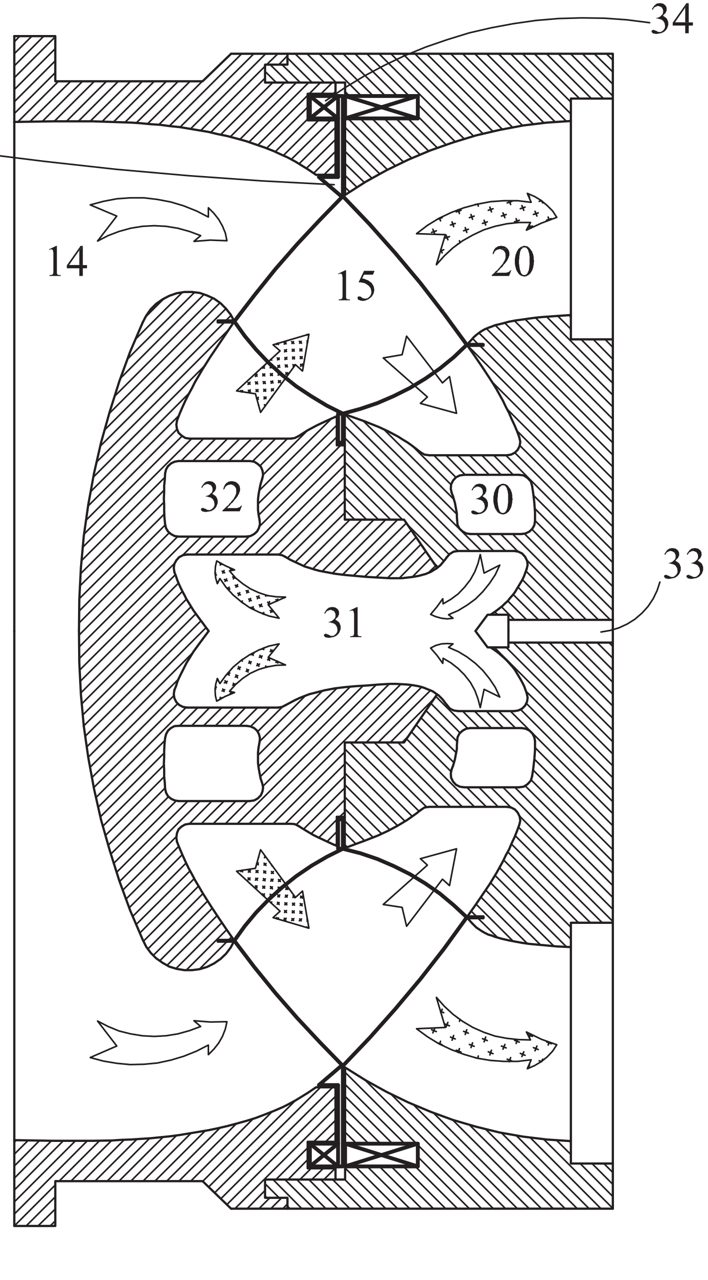


FIG. 26

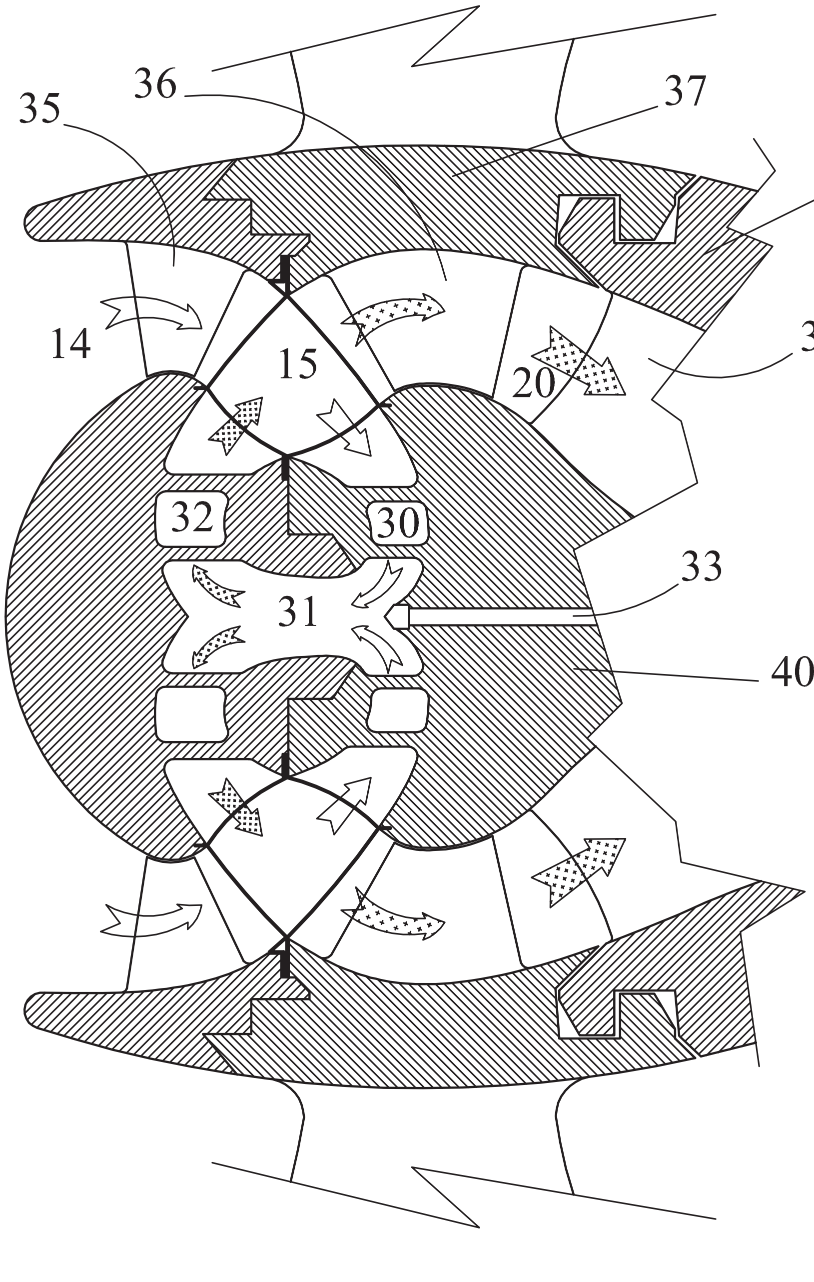
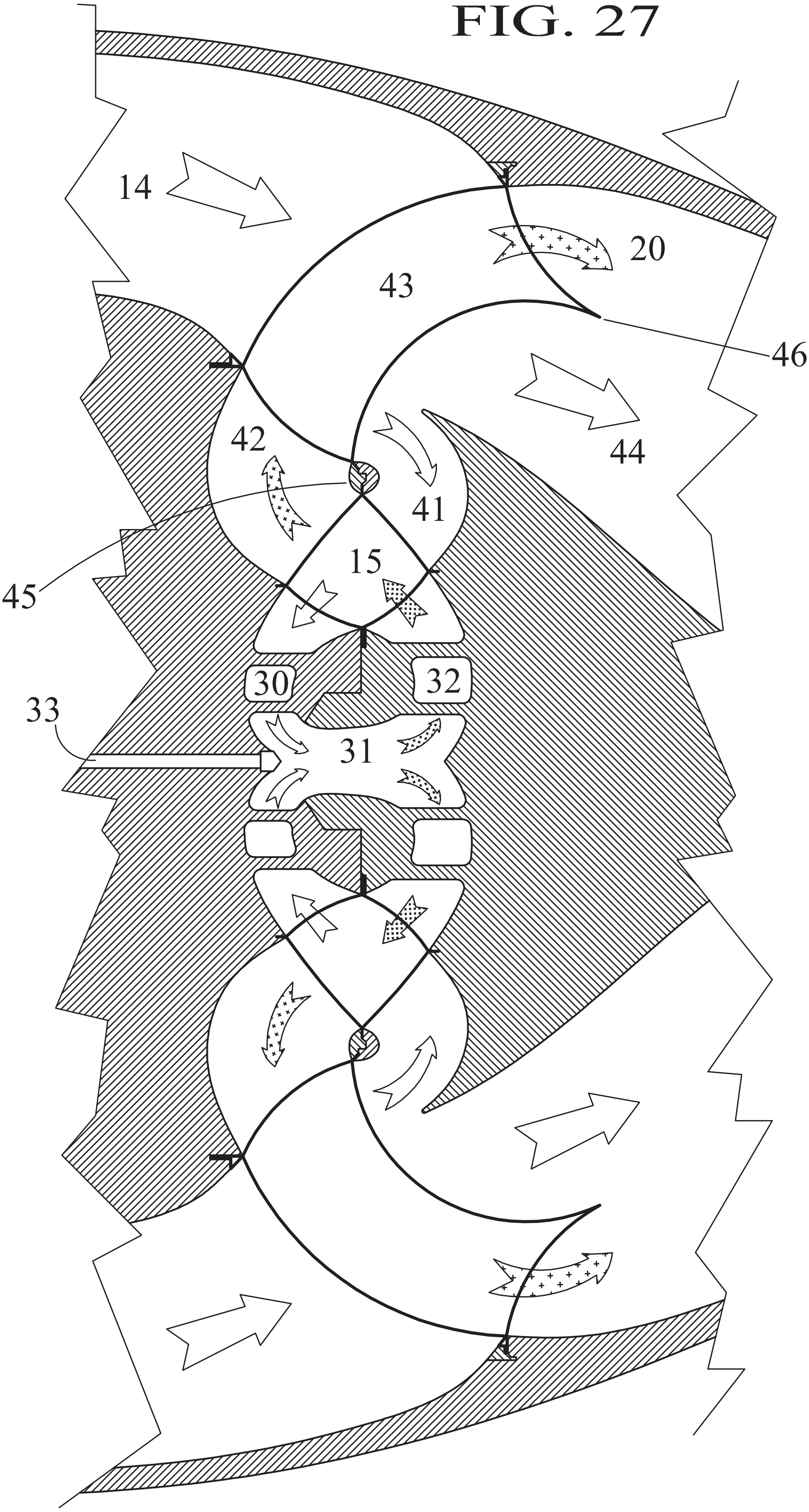


FIG. 27



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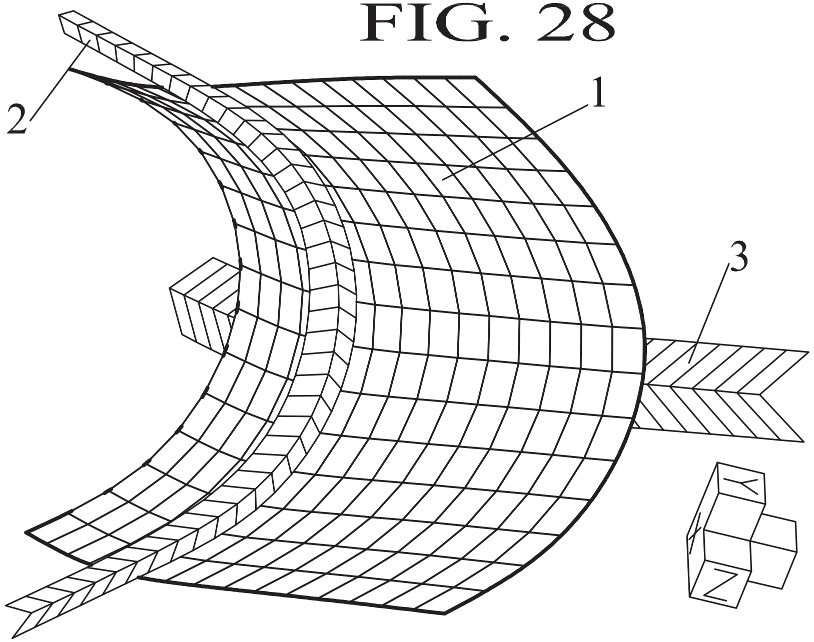


FIG. 29

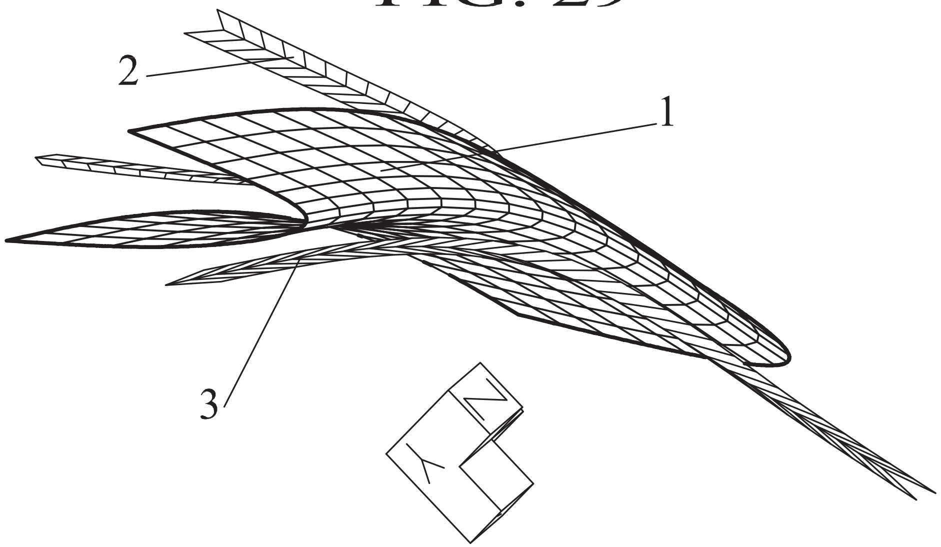


FIG. 30

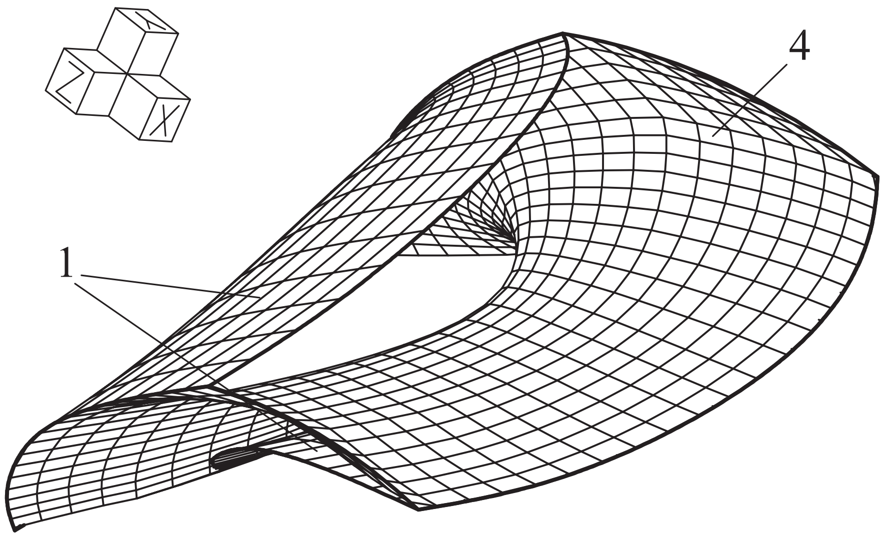


FIG. 31

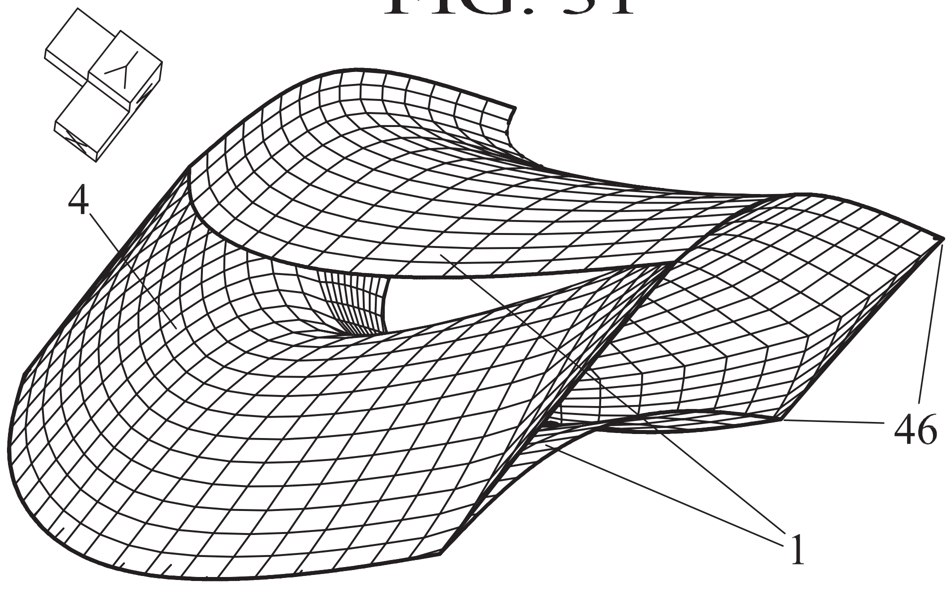


FIG. 32

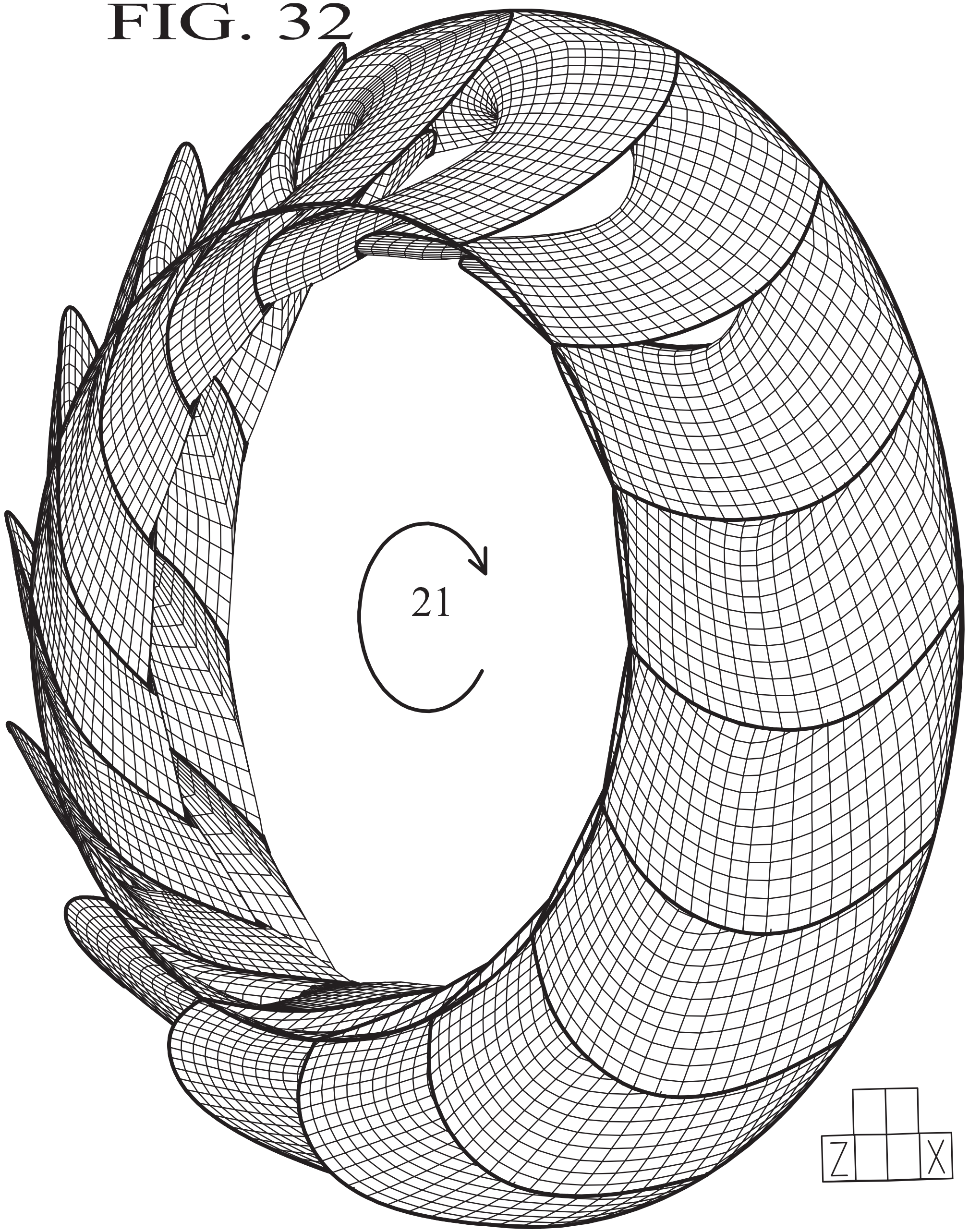
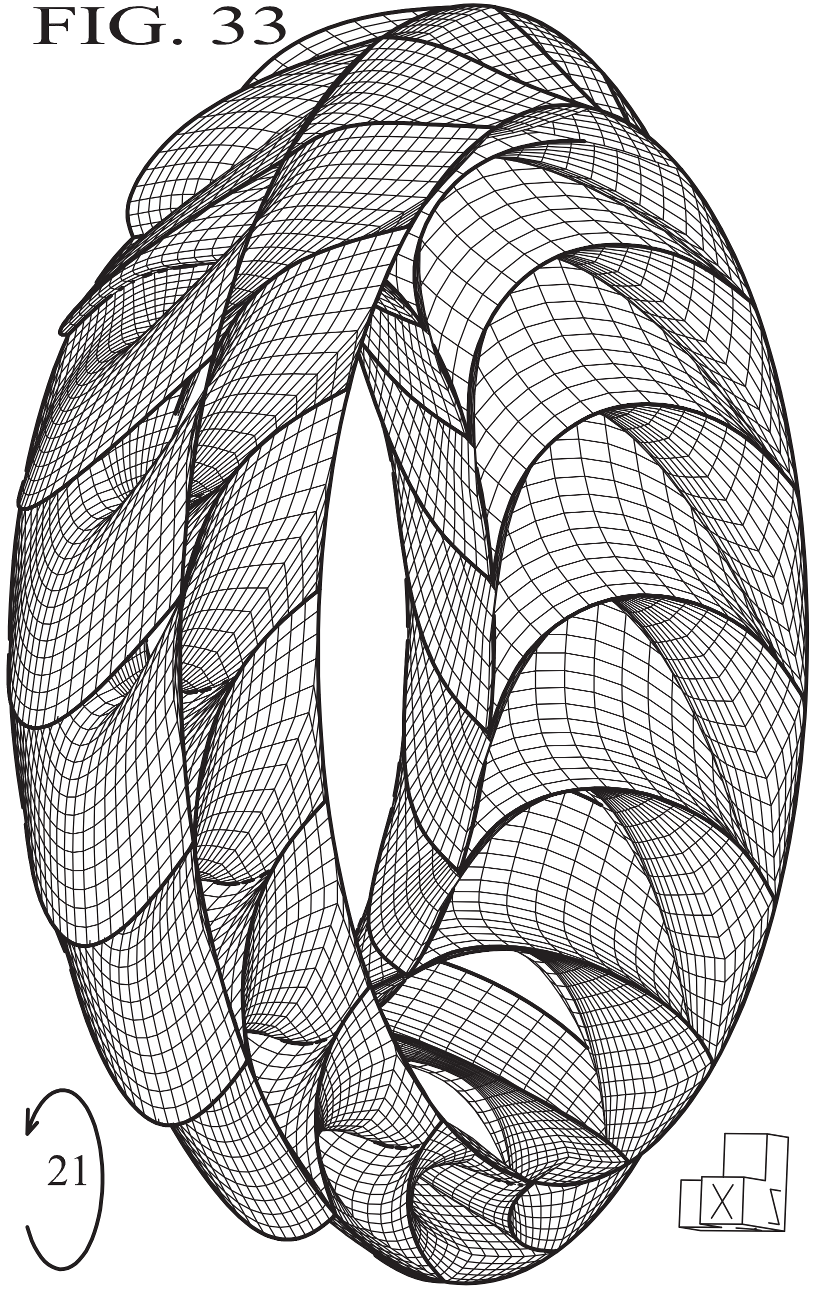


FIG. 33



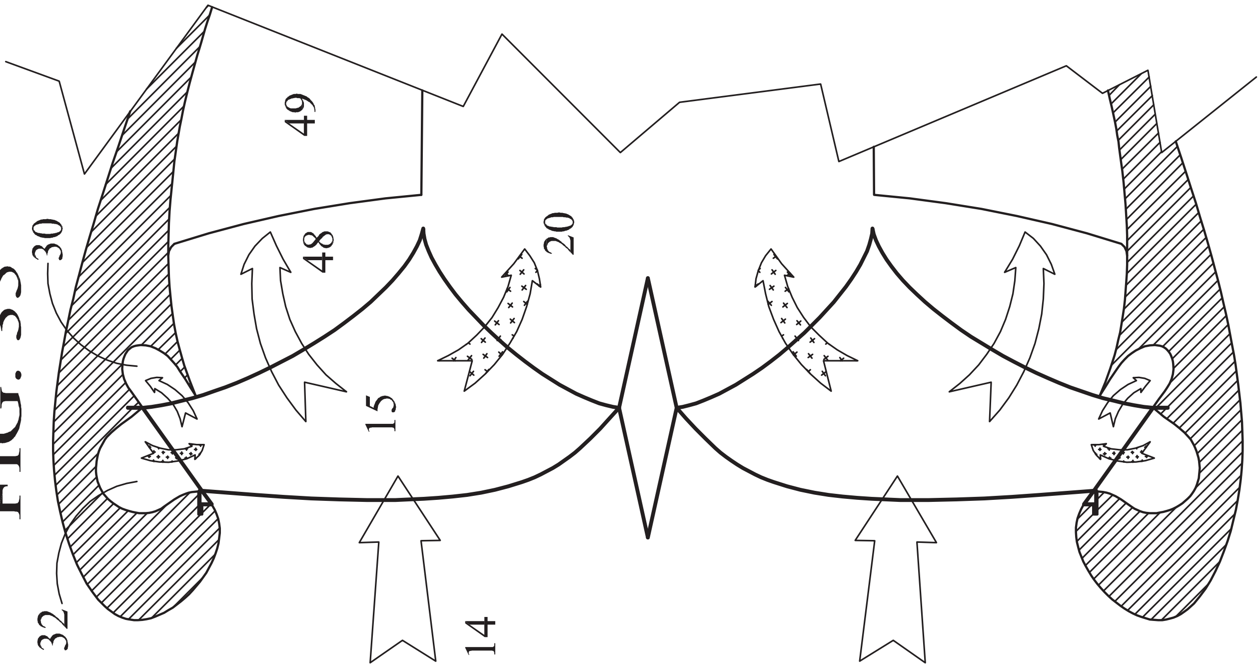


FIG. 35

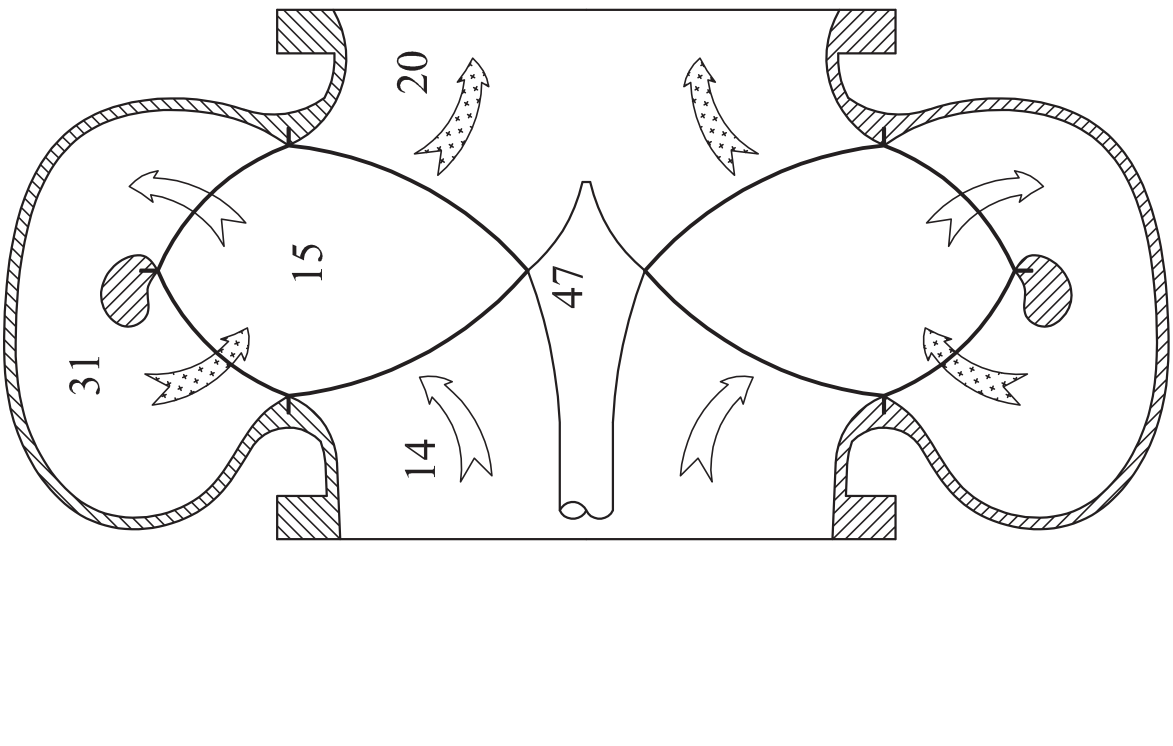


FIG. 34

FIG. 36

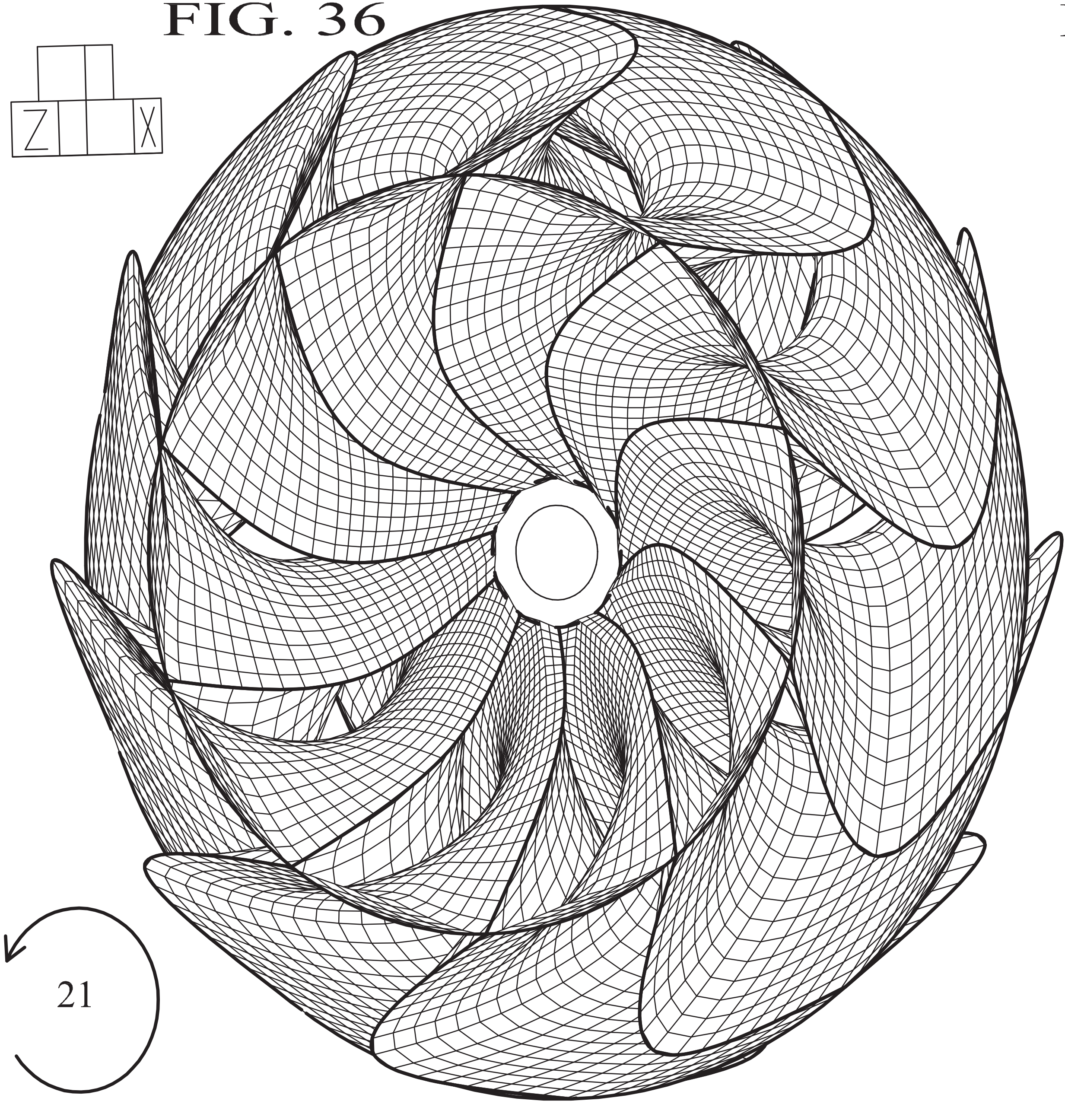
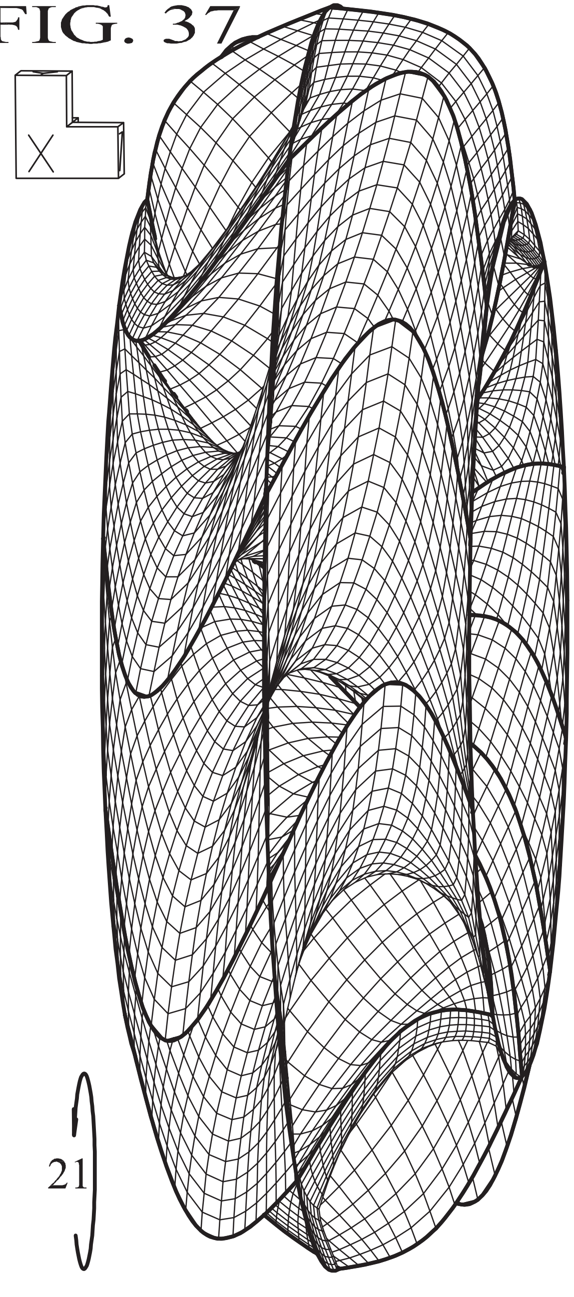


FIG. 37



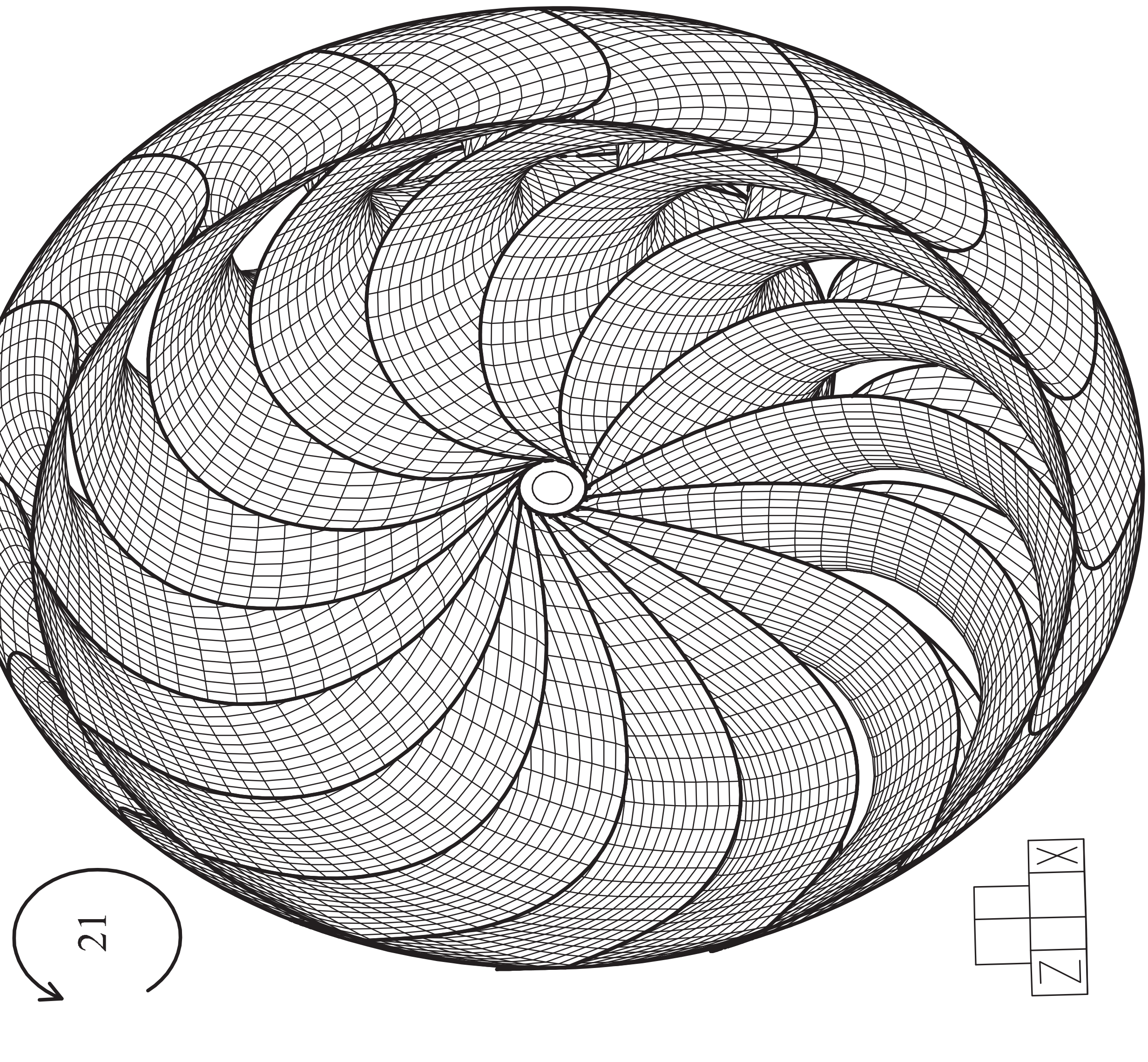


FIG. 38

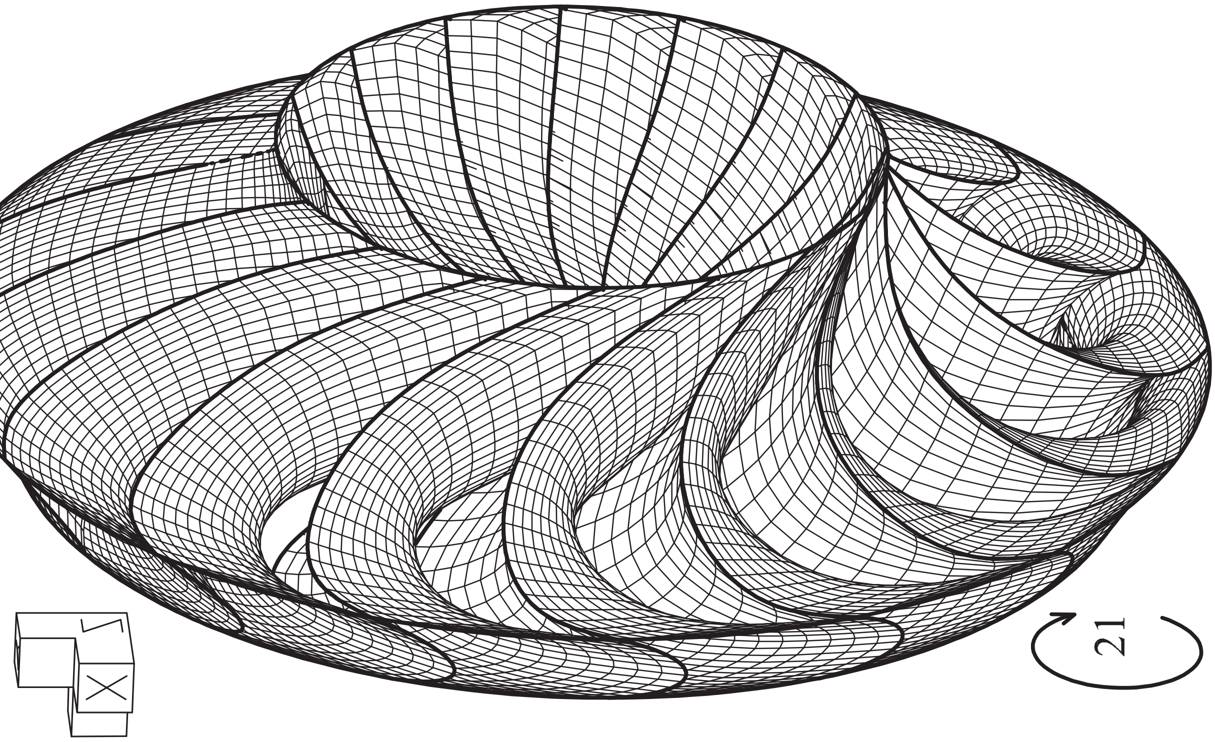


FIG. 39

FIG. 40

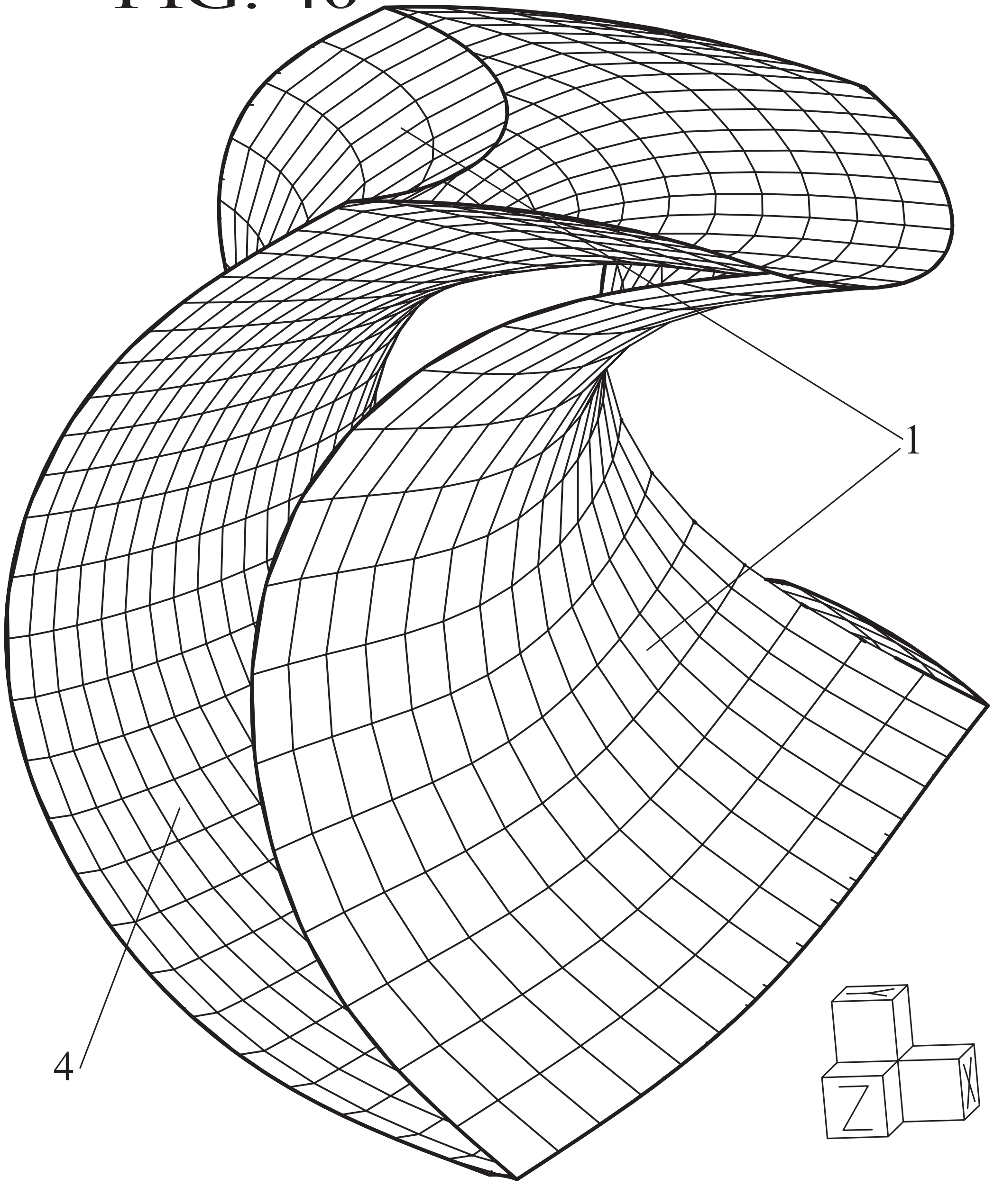


FIG. 41

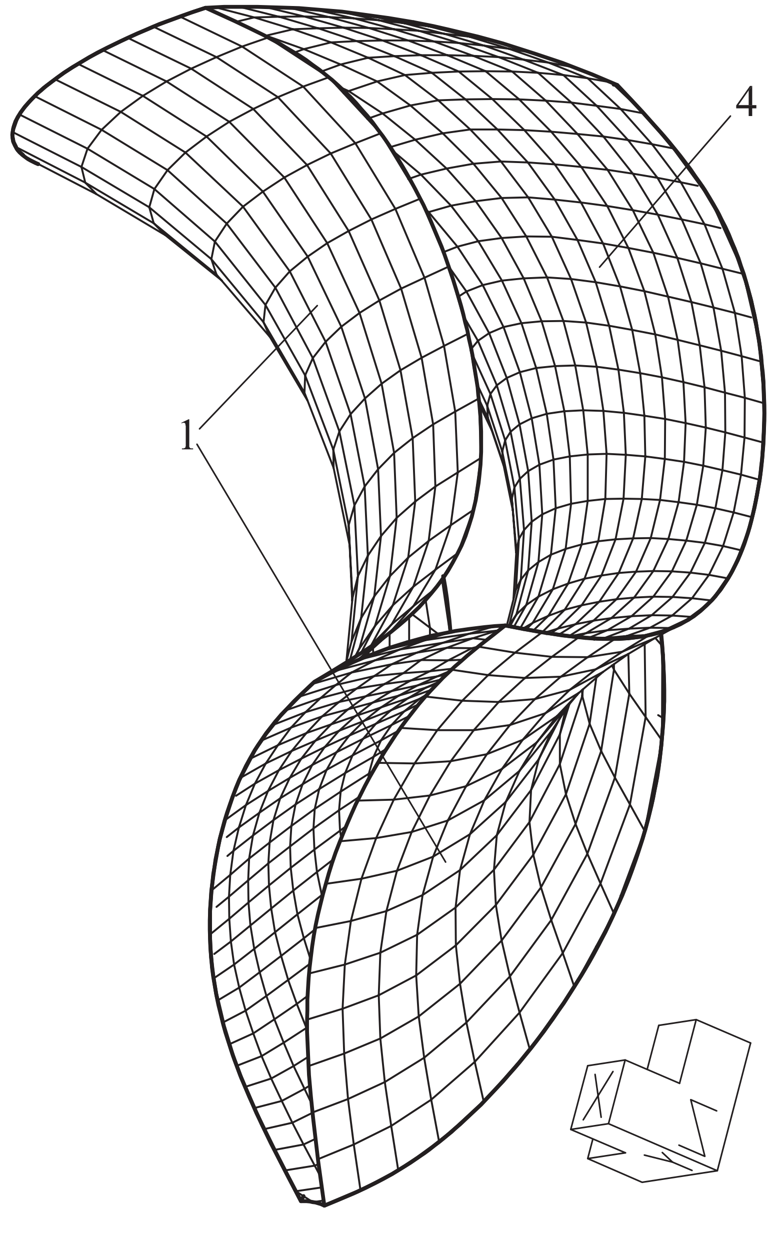
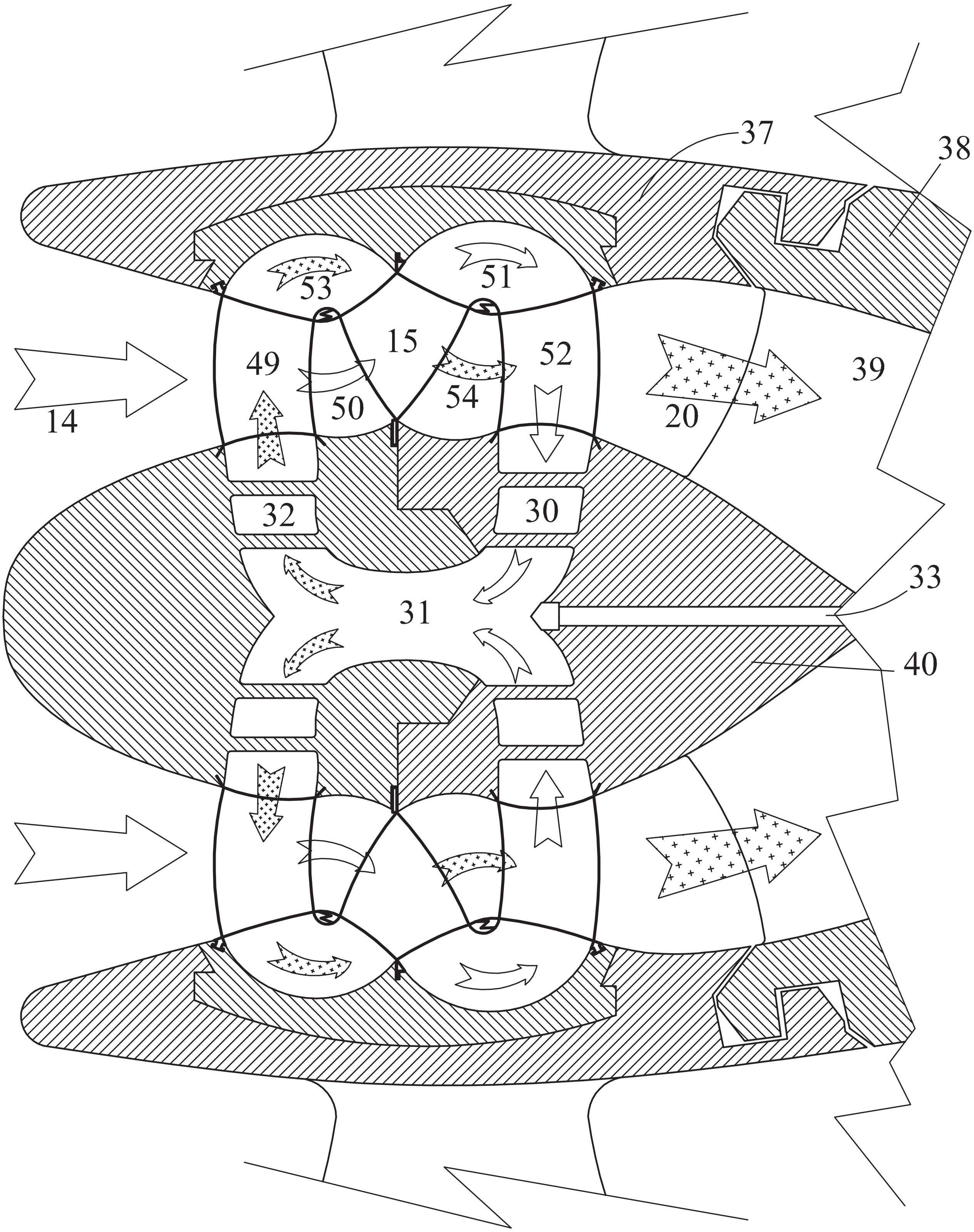


FIG. 42



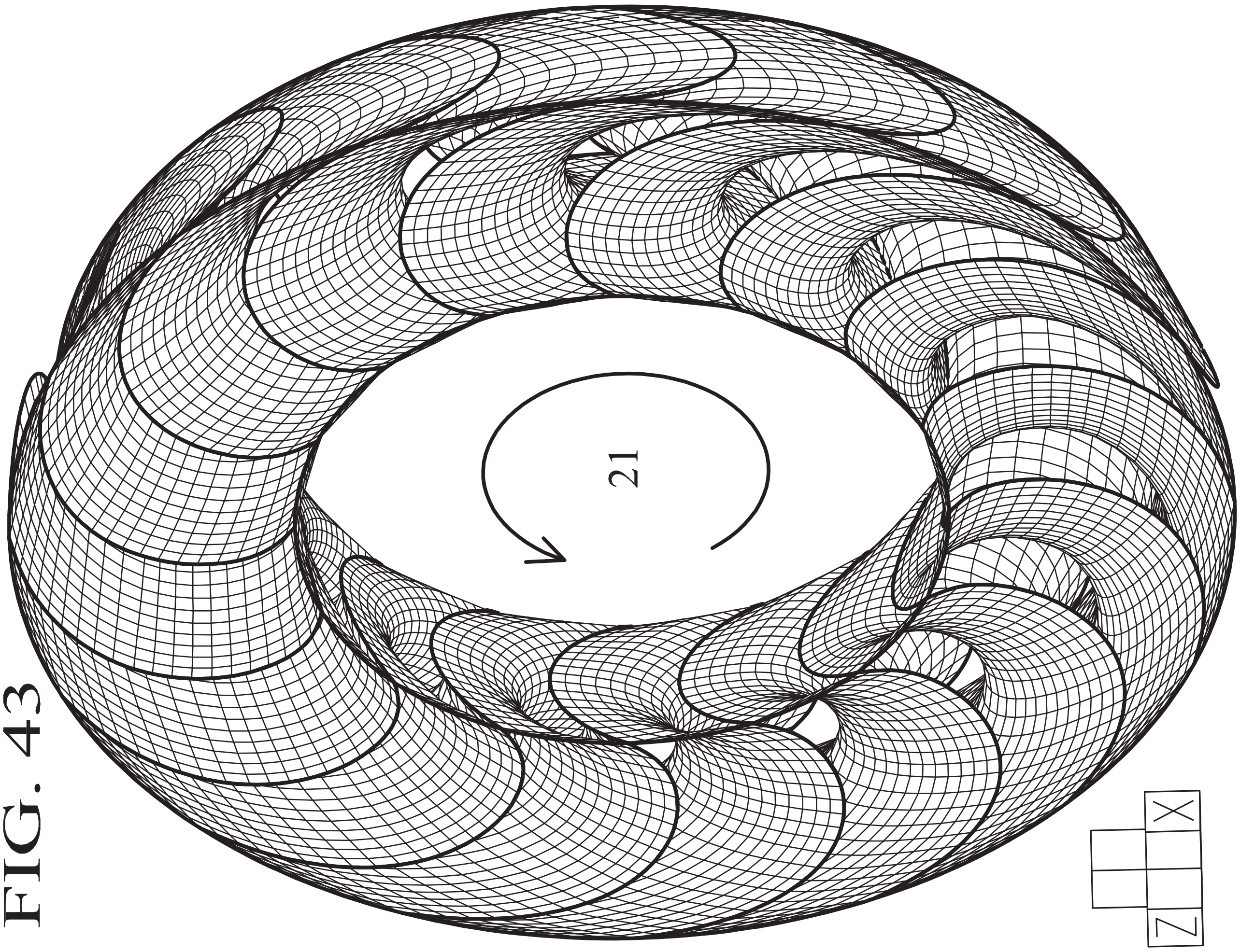


FIG. 43

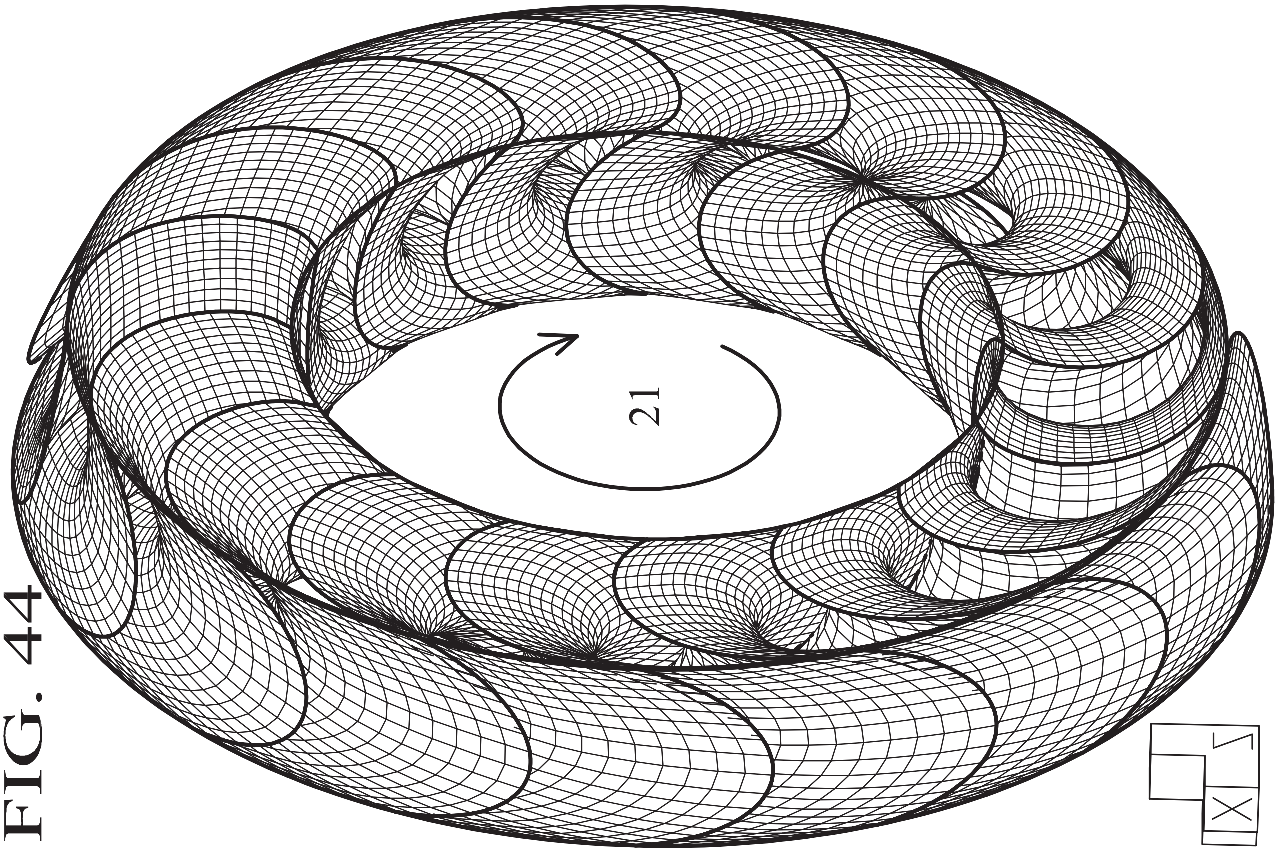


FIG. 44

FIG. 45

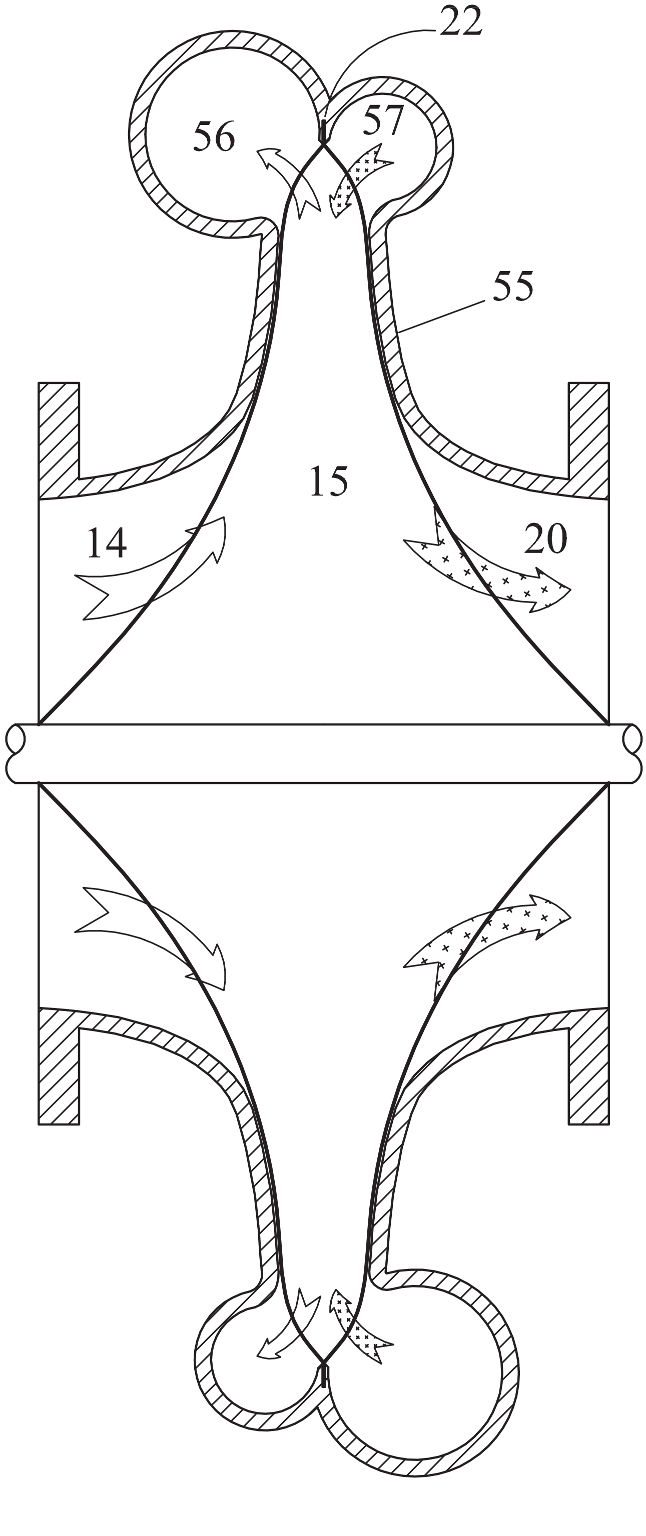


FIG. 46

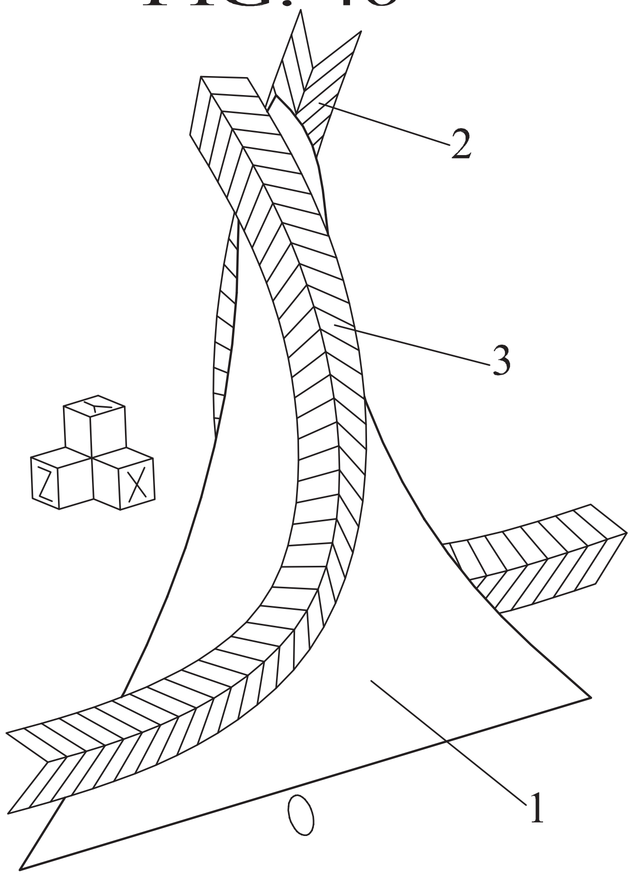


FIG. 47

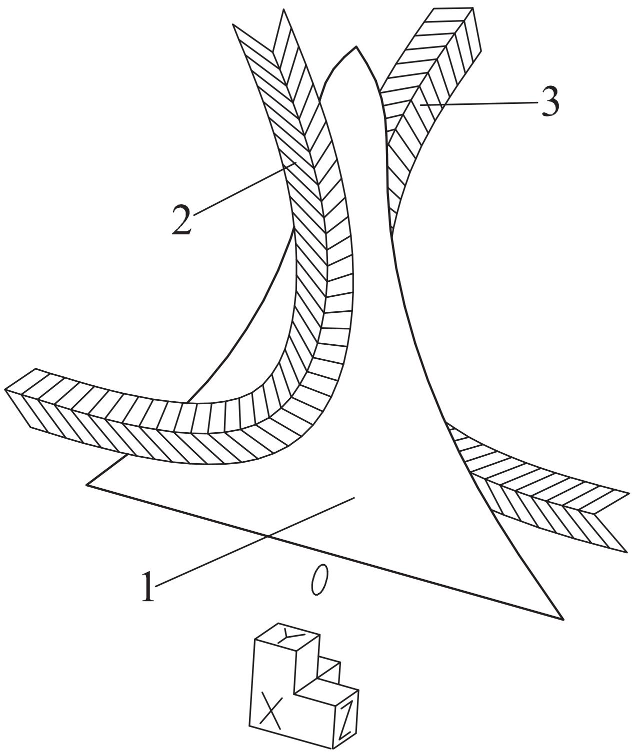


FIG. 49

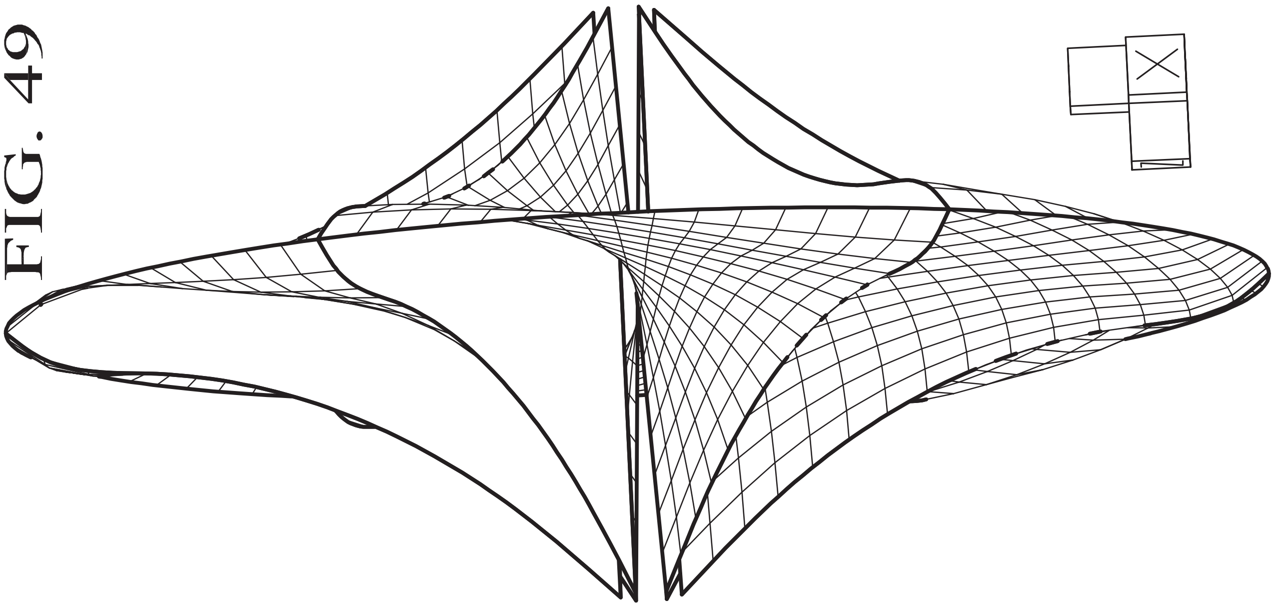


FIG. 48

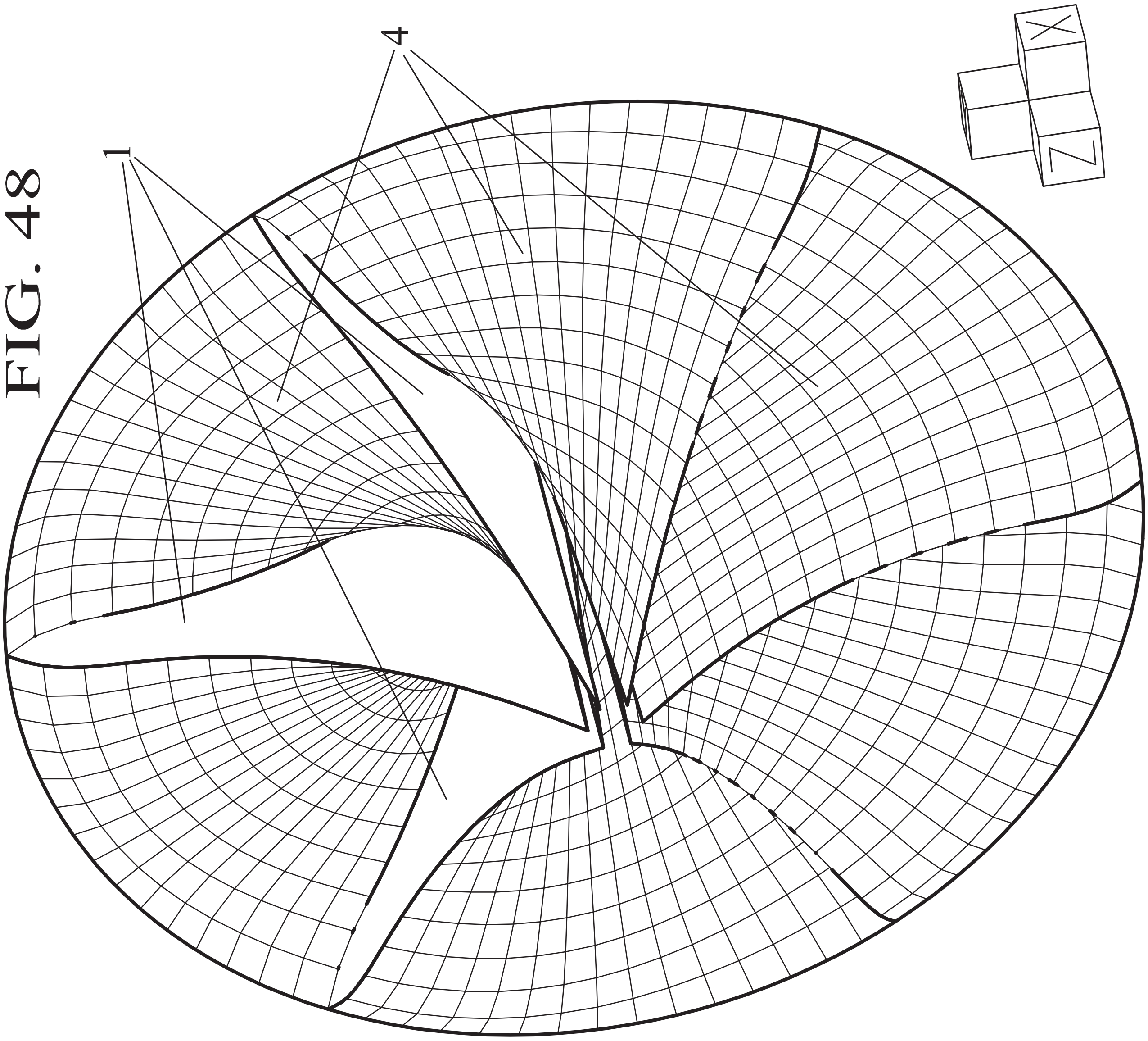


FIG. 50

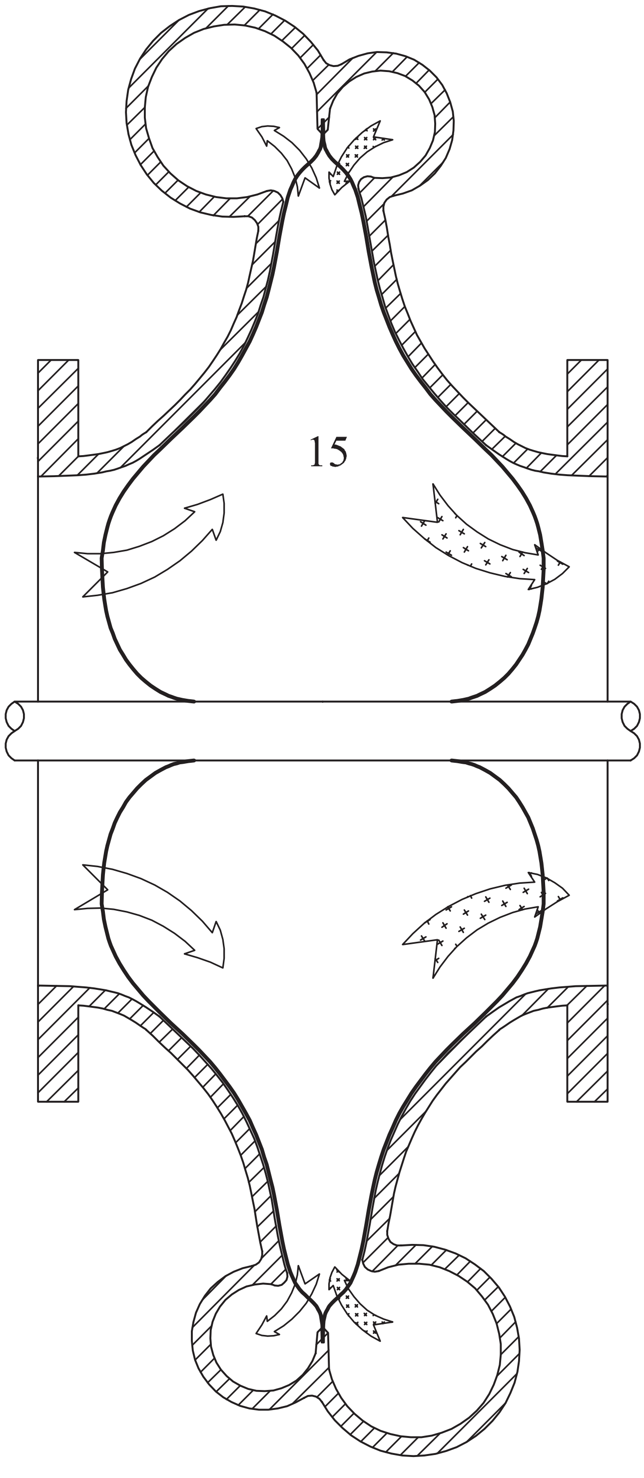


FIG. 51

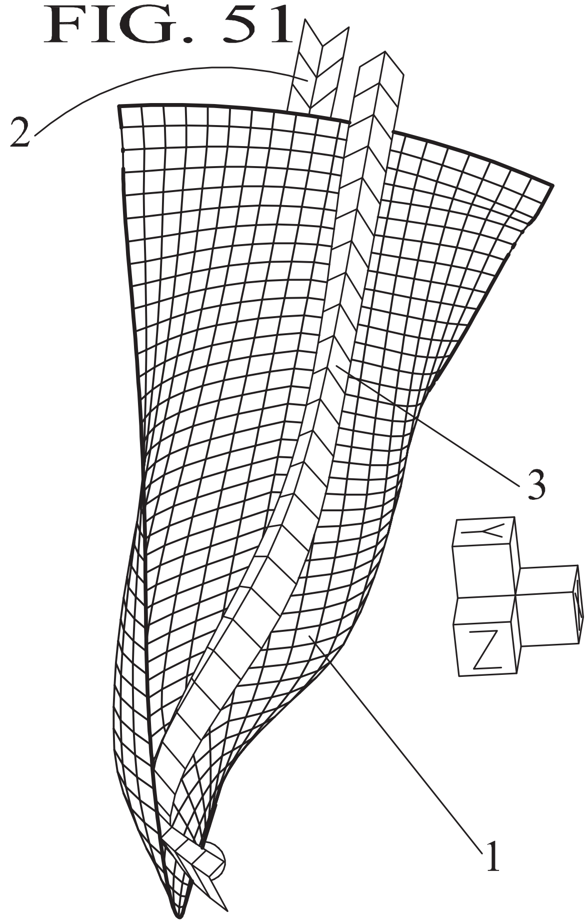


FIG. 52

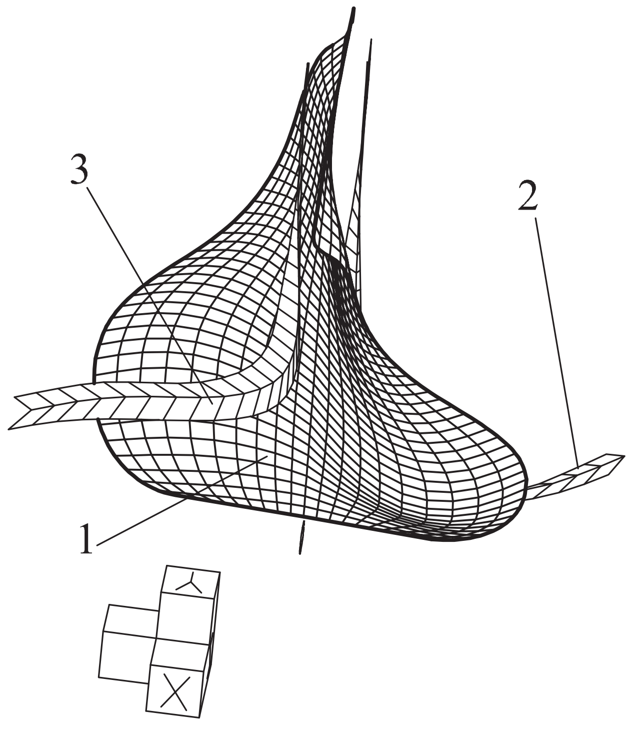


FIG. 54

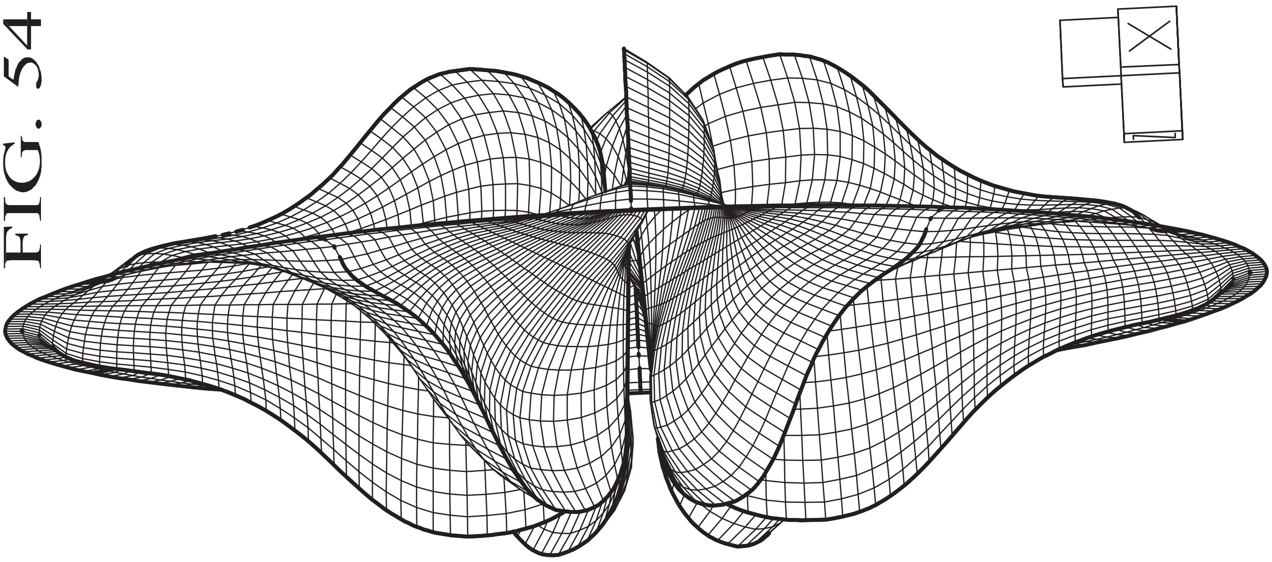


FIG. 53

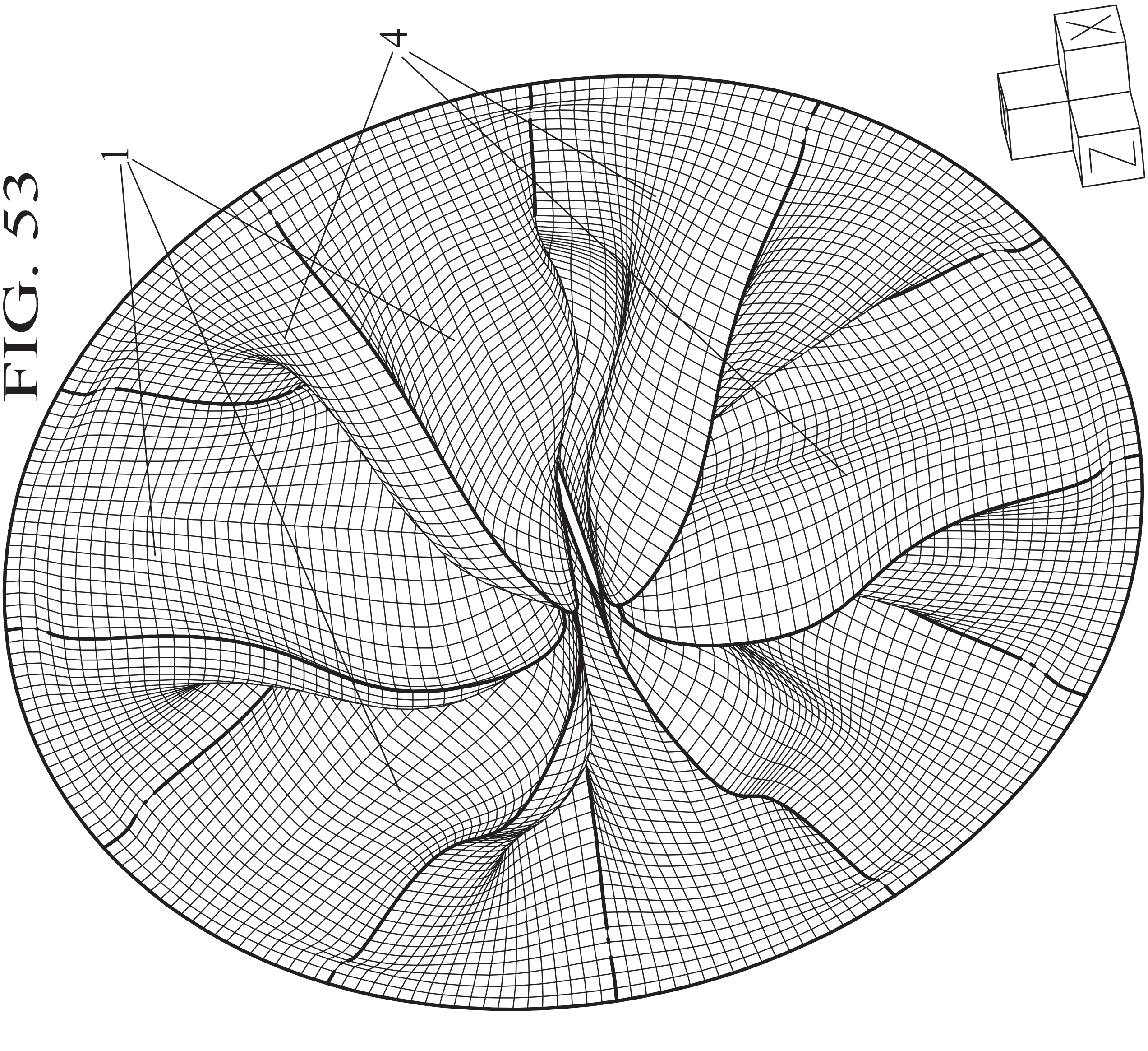


FIG. 55

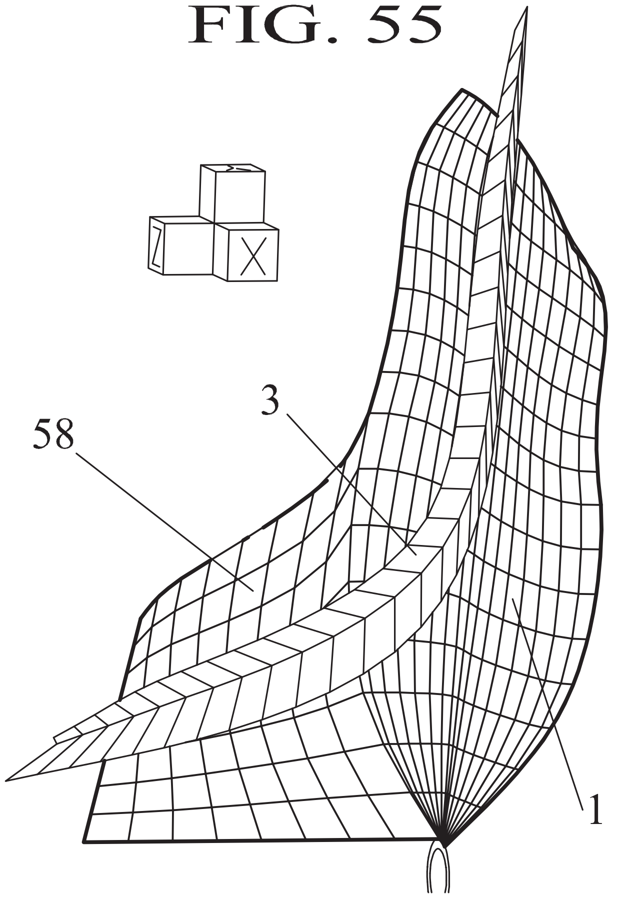


FIG. 56

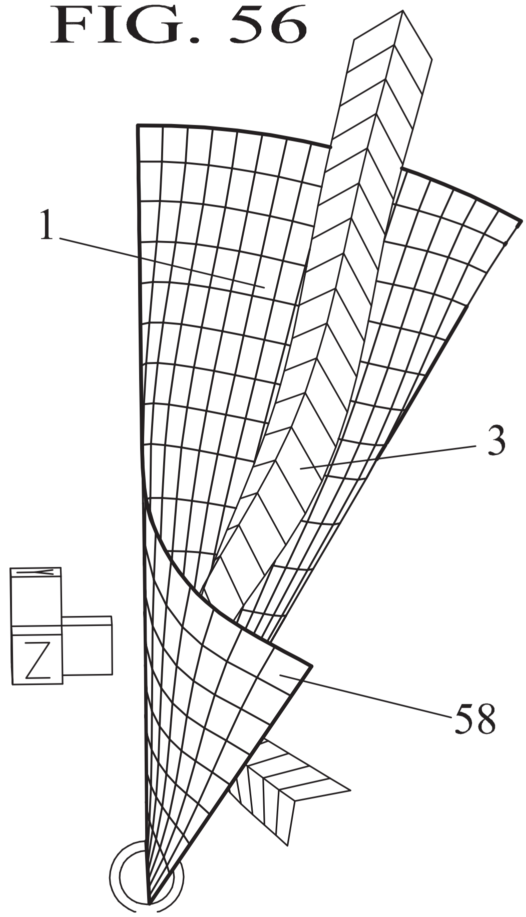


FIG. 57

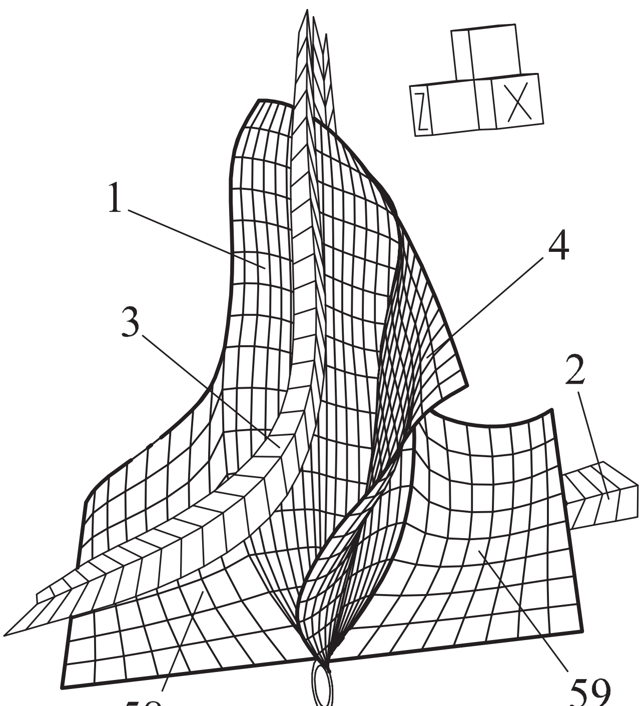


FIG. 58

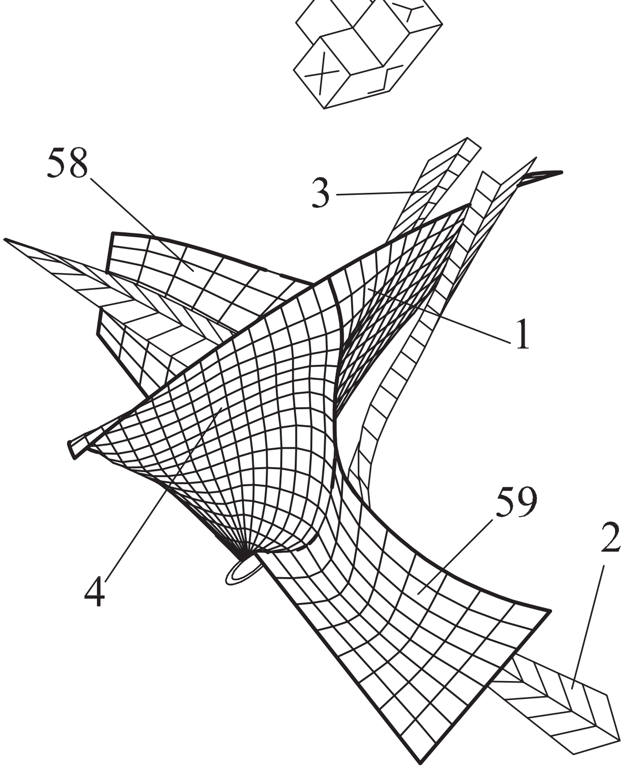


FIG. 60

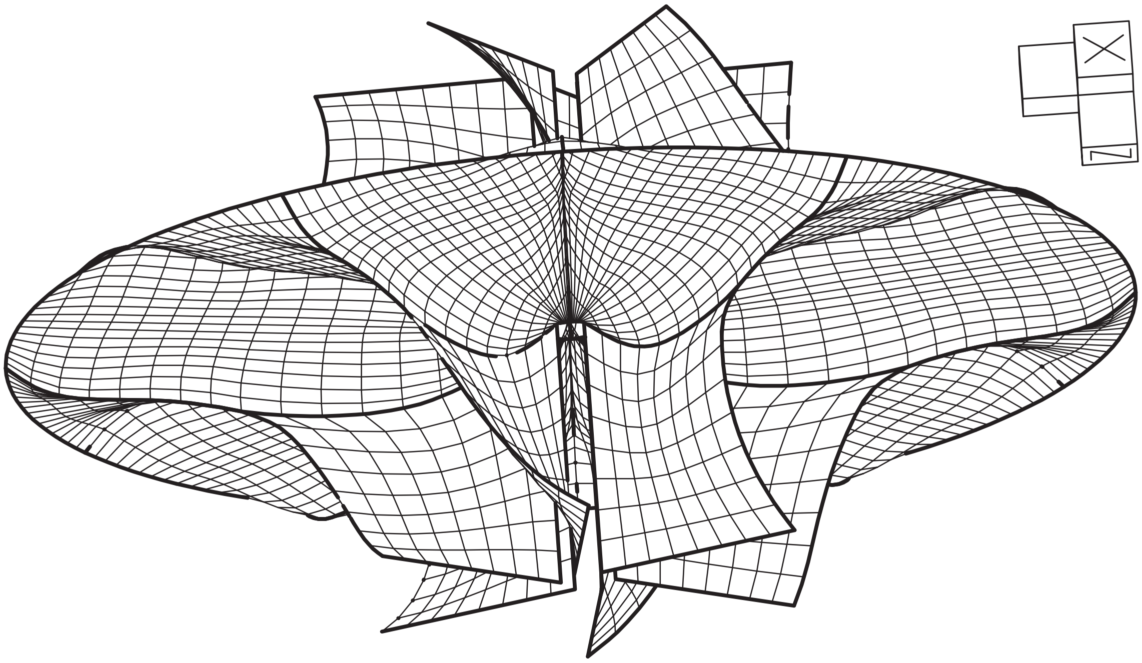


FIG. 59