

METAL AIR BATTERY ROLLING CONTACT CONNECTOR GALVANIC CELL DISC DRIVE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to, and is a non-provisional of, U.S. Patent Application 63/602,479 (filed November 24, 2023), the entirety of which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Metal air batteries provide a power source that shows promising applications for mobile and stationary distributed power sources. They have the potential to replace the internal combustion engines found in hybrid cars, locomotives, ships and aircraft since the energy density and efficiency of conversion approach those of hydrocarbon fuels.

[0003] Metal air batteries suffer from a number of problems that have, to date, excluded them from use in the aforementioned areas. The power output of metal air batteries is limited by their relatively large space. It would be desirable to produce metal air batteries with a compact profile such that they can be tightly packed, thereby allowing for high power density. It would also be desirable to provide a way to physically support large anodes. Unfortunately, the weight of large anodes often complicates battery design.

[0004] A number of attempts have been made to resolve the aforementioned problems. There has been much research into the chemistry of electrolyte additives that can inhibit the production of hydrogen gas during operation and when in open circuit without much success. Some removable electrode designs have been tested that incorporate protection of the edges of the anode from corrosion and gas production with limited success. Other designs have attempted to mount the anode on a moving apparatus to reduce the increase in resistance due to larger gaps between the electrode and cathode. These have been shown to be mechanically complicated, relatively large and limit the ability to load the battery with fresh metal anodes quickly. None of these solutions have

been applied in combination with success leaving the metal air battery as a once use item and difficult to use for intermittent power applications.

[0005] The discussion above is merely provided for general background information and is not intended to be used as an aid in determining the scope of the claimed subject matter.

SUMMARY

[0006] This disclosure provides a metal air battery with an anode. As the anode changes shape (e.g. diameter and/or thickness) during use, rotating wheels or spring-mounted brushes move to compensate. Such a configuration permits anodes that are exceptionally thin to be efficiently utilized.

[0007] In a first embodiment, a metal air battery is provided. The metal air battery comprising: an outer stator; an anode disposed within the outer stator, the anode having a first lateral surface and a second lateral surface; a cathode with a third lateral surface that is parallel to, and proximate to, the first lateral surface; and a means for adjusting for changes in anode shape comprising at least one of (1) a means for compressing the anode that compensates for changes in a diameter of the anode as the anode changes diameter during operation of the metal air battery, the means for compressing maintaining an electrical connection between the anode and the outer stator throughout the operation; or (2) a means for pinching the anode that that compensates for changes in a thickness of the anode as the anode changes thickness during operation of the metal air battery, the means for pinching maintain an electrical connection between the anode and the outer stator throughout the operation.

[0008] In a second embodiment, a metal air battery is provided. The metal air battery comprising: an outer stator; an inner raceway ring disposed within the outer stator, the inner raceway ring being rotatable; a plurality of rolling contact wheels mounted to the inner raceway ring, the rolling contact wheels being electrically conductive; an anode

disposed within the outer stator, the anode having a first lateral surface and a second lateral surface; a cathode with a third lateral surface that is parallel to, and proximate to, the first lateral surface; a means for rotating the anode; wherein the rolling contact wheels are contiguous with both the anode and the outer stator such that an electrical connection is formed; a means for pinching that maintains physical contact between each wheel in the plurality of wheels and both (1) the outer stator and (2) the anode while the anode changes thickness during operation of the metal air battery; a means for compressing the anode that compensates for changes in a diameter of the anode as the anode changes diameter during operation of the metal air battery.

[0009] In a third embodiment, a metal air battery is provided. The metal air battery comprising: an outer stator; an inner raceway ring disposed within the outer stator, the inner raceway ring being rotatable; a plurality of rolling contact wheels mounted to the inner raceway ring, the rolling contact wheels being electrically conductive; an anode with a first surface and a second surface; wherein the rolling contact wheels are contiguous with both the anode and the outer stator such that an electrical connection is formed; wherein each rolling contact wheel in the plurality of rolling contact wheels comprises a first splined and grooved wheel and a second splined and grooved wheel that mate with one another; a means for pinching that maintains physical contact between each wheel in the plurality of wheels and both (1) the outer stator and (2) the anode while the anode changes shape during operation of the metal air battery; and a cathode with a third surface that is parallel to, and proximate to, the first surface.

[0010] This brief description of the invention is intended only to provide a brief overview of subject matter disclosed herein according to one or more illustrative embodiments, and does not serve as a guide to interpreting the claims or to define or limit the scope of the invention, which is defined only by the appended claims. This brief description is provided to introduce an illustrative selection of concepts in a simplified form that are further described below in the detailed description. This brief description is not intended to identify key features or essential features of the claimed subject matter,

nor is it intended to be used as an aid in determining the scope of the claimed subject matter. The claimed subject matter is not limited to implementations that solve any or all disadvantages noted in the background.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] So that the manner in which the features of the invention can be understood, a detailed description of the invention may be had by reference to certain embodiments, some of which are illustrated in the accompanying drawings. It is to be noted, however, that the drawings illustrate only certain embodiments of this invention and are therefore not to be considered limiting of its scope, for the scope of the invention encompasses other equally effective embodiments. The drawings are not necessarily to scale, emphasis generally being placed upon illustrating the features of certain embodiments of the invention. In the drawings, like numerals are used to indicate like parts throughout the various views. Thus, for further understanding of the invention, reference can be made to the following detailed description, read in connection with the drawings in which:

[0012] FIG. 1A and FIG. 1B are two views of a metal air battery.

[0013] FIG. 2 is an exploded view of the metal air battery.

[0014] FIG. 3A, FIG. 3B, FIG. 3C and FIG. 3D depict two splined and grooved wheels that collectively form a rolling contact wheel.

[0015] FIG. 4A and FIG. 4B depict a means for pinching that is applied by the rolling contact wheel.

[0016] FIG. 4C depicts another means for pinching that is applied by the rolling contact wheel.

- [0017] FIG. 5A and FIG. 5B illustrate the rolling contact wheel connecting to an anode and an outer stator.
- [0018] FIG. 6 depicts the rolling contact wheel engaging an edge of the anode.
- [0019] FIG. 7 is an exploded view of a raceway for holding the rolling contact wheel.
- [0020] FIG. 8 is another view of the raceway for holding the rolling contact wheel.
- [0021] FIG. 9A and FIG. 9B depict another embodiment of a metal air battery that uses gear teeth to rotate the anode.
- [0022] FIG. 10 depicts another embodiment of a metal air battery that uses a magnet to rotate the anode.
- [0023] FIG. 11 is a bisected view of a metal air battery depicting a fluid path for liquid electrolyte.
- [0024] FIG. 12A is a perspective view of an array of multiple metal air batteries.
- [0025] FIG. 12B and FIG. 12C depict an anode with a keyed hole and a driveshaft for rotating the same.
- [0026] FIG. 13A and FIG. 13B depict a cleaning wheel disposed in the raceway.
- [0027] FIG. 14A, FIG. 14B and FIG. 14C depict a cleaning brush disposed in the raceway.
- [0028] FIG. 15 illustrates a cross-anode scraper 1500 for cleaning the anode.
- [0029] FIG. 16A and FIG. 16B show an anode connected to an outer stator by a coiled spring.
- [0030] FIG. 17A and FIG. 17B show an anode connected to an outer stator by a leaf spring.

[0031] FIG. 17C shows various anodes and stators for use with the disclosed metal air battery.

[0032] FIG. 18 is a depiction of another embodiment of the raceway.

[0033] FIG. 19 depicts an anode with a keyed hole and a driveshaft for rotating the same using the raceway of FIG. 18.

DETAILED DESCRIPTION OF THE INVENTION

[0034] Referring to FIG. 1A, this disclosure provides a metal air battery 100 that comprises an outer stator 102 that provides an electrically conductive track. The metal air battery 100 also has a raceway 104 that carries a plurality of rolling contact wheels 106. The raceway 104 is a ring that is configured to rotate about an anode 108, thereby providing a means for rotating the anode 108. The raceway 104 is rotated by a rotary drive such as a turbine, a gear drive, an integral electric motor, a hydraulic turbine, a direct electric drive with magnets embedded in the raceway 104 and other suitable means for rotating. After benefitting from reading this specification, other rotary drives would be apparent to those skilled in the art and such drives are contemplated for use with this invention. Electrical power is withdrawn from the anode 108 through the radial edges of the anode 108.

[0035] The anode 108 may be, for example, an aluminum anode. In some embodiments, the anode 108 is an anode disc. In other embodiments, the anode 108 is a non-disc shape, such as a square, a rectangle, or other shapes. In one embodiment, both lateral surfaces of the anode 108 are exposed such that both lateral surfaces are consumed to provide electrical power. On each lateral surface of the anode 108 is an air breathing cathode 200 (see FIG. 2) to provide oxygen for the electrochemical reaction that produces the electric power. FIG. 1B provides a perspective view of the metal air battery 100. This configuration results in a very thin cell design that allows for stacking multiple

metal air batteries in high density to approach the power to volume ratio of internal combustion engines.

[0036] FIG. 2 is an exploded view of the metal air battery 100. The outer stator 102 is supported by a housing 202, 204 that, in the embodiment of the figure, is segmented into two pieces for easy re-loading of the anode 108. The two segments of the housing 202, 204 may be removably fastened to one another by a fastener 206, such as an elongated screw. The air breathing cathode 200 is positioned such that its lateral surface is parallel and proximate to the lateral surface of the anode 108. In FIG. 2, a single air breathing cathode 200 is shown. In another embodiment, a second air breathing cathode is disposed on a front side of the anode 108. As the electrochemical reaction progresses, the anode 108 is consumed and gradually begins to thin. As discussed in detail elsewhere in this specification, the rolling contact wheels 106 are configured to accommodate this thinning while maintaining a physical and electrical connection between the anode 108 and the outer stator 102. The outer stator 102 may be formed of a metal, such as brass, steel or copper. A cover 208 forms a plenum 1204 (see FIG. 12) that permits ambient air to reach the cathode 200.

[0037] Each of the rolling contact wheels 106 is fixed to the raceway 104 so that rotating the raceway 104 will cause the anode 108 to rotate in a similar manner to a planetary gear with the anode 108 turning up to a 3 to 1 ratio, determined by the diameter of the rolling contact wheels 106. The rolling contact wheels 106 rotate in a first rotary direction and the anode 108 and the raceway 104 rotate in a second rotary direction that is opposite the first rotary direction. For example, the first rotary direction may be clockwise and the second rotary direction may be anticlockwise. The raceway 104 and the outer stator 102 can separate to allow a new anode 108 to be loaded into the metal air battery 100.

[0038] The rolling contact wheels 106 have a forced contact with a radial surface of the anode 108 and the outer stator 102. The anode 108 changes shape (e.g. thickness and diameter) during operation and each of the rolling contact wheels 106 is designed to

accommodate for this change. Each rolling contact wheel 106 can be made in a variety of shapes according to the radial edge shape of the anode 108. Each rolling contact wheel 106 may be formed of a metal, such as brass or steel. The rolling contact wheels 106 may be gold plated to reduce corrosion and increase electrical conductivity.

[0039] Referring to FIGS. 3A-3D, in one embodiment, the rolling contact wheels 106 comprise a first splined and grooved wheel 300 with a male ring 302 (see FIG. 3B). The rolling contact wheels 106 also comprise a second splined and grooved wheel 304 with a female receptacle 306. A free-floating shaft 308 is also provided which has a first shaft piece 308a and a second shaft piece 308b that fixedly engage one another. Referring to FIG. 3C, the spines of one wheel fit into grooves of the other wheel. In some embodiments, the grooves extend through the thickness of the wheel such that the splines of the other wheel can pass through the thickness of the wheel. See, for example, FIG. 3D wherein the splines of the first splined and grooved wheel 300 extends through the grooves of the second splined and grooved wheel 304.

[0040] The shaft 308 includes flanges on each of pieces 308a, 308b. One of the two pieces (e.g. second piece 308b) has an upper male projection that mates with a corresponding female receptacle on the other piece (e.g. first piece 308a). Each of the two pieces also has a raised protection that fits into an elongated slot (see elongated slot 800 of FIG. 8).

[0041] Referring to FIG. 4A, the anode 108 is placed between the first splined and grooved wheel 300 and the second splined and grooved wheel 304. A means for adjusting for changes in anode shape is provided. In the embodiment of FIG. 4A, the means for adjusting comprises a means for pinching 400 that is applied between the first splined and grooved wheel 300 and the second splined and grooved wheel 304 which provides a physical and electrical connection to the anode 108. The means for pinching 400 compensates for changes in the thickness of the anode 108 such that electrical connection between the anode 108 and the outer stator 102 is maintained. The means for pinching 400 applies a forced directed perpendicular to a lateral surface of the anode 108.

The first splined and grooved wheel 300 and the second splined and grooved wheel 304 are both electrically conductive. The means for pinching 400 may be applied by a magnetic force. The shaft 308 is free-floating such that each wheel can freely move over the shaft's length. The magnetic force may be applied by forming each of the first splined and grooved wheel 300 and the second splined and grooved wheel 304 of a magnetic material such that the wheels magnetically adhere to one another. The magnetic material may be, for example, a ferromagnetic material. The magnetic material may be plated with a corrosion-resistant material, such as gold, to reduce corrosion.

[0042] Referring to FIG. 4B, as the anode 108 is consumed, the means for pinching 400 pulls the first splined and grooved wheel 300 and the second splined and grooved wheel 304 toward one another, thereby maintaining contact with the anode 108. In the embodiment of FIGS. 4A and 4B, the radial edge of the anode 108 is pointed and the splines of the wheels are angled to form a bevel such that they mate with one another.

[0043] In the embodiment of FIG. 4A and FIG. 4B, the means for adjusting for changes in anode shape also comprises a means for compressing 401 that is applied by the angled splines of the wheels 300, 304. The means for compressing 401 applies a force directed toward a center of the anode 108 that is parallel with its lateral surface. The means for compressing 401 compensates for changes in the diameter of the anode 108 such that electrical connection between the anode 108 and the outer stator 102 is maintained. The means for compressing 401 maintains electrical contact with both the outer stator 102 and the anode 108 while the anode changes diameter during operation of the metal air battery.

[0044] As shown in FIG. 4C, the means for pinching may be applied by a spring 402 that provides an expanding force between a flange 404 on the shaft 308 and the rolling contact wheel 106. In such an embodiment, the shaft 308 is not free-floating but, instead, maintains a constant distance between the respective flanges 404.

[0045] In one embodiment, at least three rolling contact wheels 106 are present. In another embodiment, from three to six rolling contact wheels 106 are present.

[0046] Referring to FIG. 5A and FIG. 5B, the means for pinching 400 also maintains contact between the rolling contact wheels 106 and the outer stator 102. The interior, radial edge of the outer stator 102 is also pointed such that the angled splines likewise engage that radial edge.

[0047] Referring to FIG. 6, the splines of the wheels 300, 304 have an angle θ relative to a plane 500 that is parallel to the lateral surface of the anode 108. The angle θ may be, for example, from 10°-55°, from 30°-50° or from 40°-50°.

[0048] FIG. 7 is a bisected, exploded view of the raceway 104. The raceway 104 comprises a first support ring 700 and a second support ring 702 which sandwich a support 704. The support 704 functions to space the first support ring 700 and a second support ring 702 by a distance that permits free rotation of the rolling contact wheels 106 (not shown). In the embodiment of FIG. 7, the support 704 has a plurality of segments with the rolling contact wheels 106 (not shown) being rotatably mounted between the segments. The support 704 includes holes 706 which permit liquid electrolyte and oxygen to access interior components of the metal air battery 100.

[0049] As the anode 108 is consumed, its shape changes. The first support ring 700 and the second support ring 702 has an elongated slot 800 (see FIG. 8) that permits the rolling contact wheels 106 to adjust for this change. Terminal portions of the shaft 308 extend through the elongated slot 800, thus permitting the shaft 308 to float within the elongated slot 800 as the anode 108 changes shape. The means for pinching 400, combined with the angled splines, moves the rolling contact wheels 106 in the direction of arrow 802, thus accommodating anode 108 when its diameter shrinks. Arrow 802 extends along a longitudinal axis of the elongated slot 800.

[0050] In one embodiment, the rotary drive that rotates the raceway 104 comprises turbine blades 804 in its circumference such that they do not interfere with the rolling contact wheels 106. In such an embodiment, the stator 102 has jet outlets (not shown) in its interior, radial edge to allow high pressure jets of electrolyte to contact the turbine blades 804 and, through impulse design, rotate the raceway 104. Alternatively, compressed air is used instead of electrolyte for high-speed spin drying of the anode 108. In this manner, the metal air battery 100 provides for complete, rapid shutdown of power without parasitic corrosion and production of dangerous hydrogen gas.

[0051] Referring to FIG. 9A and FIG. 9B, another rotary drive uses gear teeth 900 that mesh with a drive gear 902 that projects through the center of the stator 102 and meshes with the gear teeth to rotate the raceway 104. In this manner, a means for rotating the anode 108 is provided.

[0052] Referring to FIG. 10, yet another rotary drive uses one or more magnets 1000 embedded in the raceway 104 distributed in a similar manner to a pancake electric motor. The raceway 104 is rotated by electric coils 1002 mounted in the stator 102 in the same manner as a brushless motor drives its shaft. In this manner, a means for rotating the anode 108 is provided. However, in this case, the raceway is the functional equivalent of the shaft.

[0053] Because debris and fouling coatings can be formed inside electrochemical cells, the stator 102 and edges of the anode 108 could become insulated by contaminations. This can be mitigated, in some embodiments of the disclosed design, by having a surface etched roughness (e.g. grooves with a depth of $1\text{ mm} \pm 0.1\text{ mm}$) into the rolling contact wheels 106 to scrub the surface of the stator 102 and anode 108. This helps maintain clean electrical conducting surface on all parts. In one embodiment, one of the two rolling contact wheels 106 is a dielectric grooved wheel that enhances the cleaning action while the system rotates.

[0054] Referring to FIG. 11, fresh electrolyte is introduced at a bottom 1100 of the metal air battery 100 and exits out a top 1102 above an upper diameter of the anode 108. The electrolyte then falls down a path that contains a gas knockout 1004 to remove hydrogen bubbles and moves the electrolyte down into a sump (not shown) under the cells.

[0055] FIG. 12A depicts an array of multiple metal air batteries 100. Each of the metal air batteries may be connected in series or in parallel. Ambient air is directed along arrow 1200 within the cover 208. The presence of a divider 1202 helps circulate the ambient air along a circulator trajectory. One such cover 208 is present between each metal air battery in the array.

[0056] In the embodiment of FIG. 12B, each anode 108 comprises a keyed hole 1206. The cathode has been omitted for clarity of illustration. The keyed hole 1206 is non-circular such that rotation of a corresponding drive shafted engages the anode 108 and causes it to rotate. A variety of non-circular keyed holes may be used such as a cross-shaped hole 1206a or a notched half-circle 1206b. Referring to FIG. 12C, in those embodiments that have an array of multiple anode 108, each anode 108 is mounted free-floating (lengthwise) along a common driveshaft 1208. A rolling contact connector (not shown) connects to the driveshaft 1208 to complete an electrical circuit and permit electrical power to be withdrawn from the metal air battery. In FIG. 12C, the driveshaft 1208 has a single drive gear 1210 at the end of the driveshaft 1208 that is connected to a motor 1212 through a sealed shaft 1214. Geared teeth on the sealed draft 1214 and the drive gear 1210 permit geared rotation. The outer stator 102 may be fixedly connected to the housing to prevent rotation. A variety of other means for driving the driveshaft 1208 would be apparent to those skilled in the art after benefitting from reading this specification and such means are contemplated for use with the disclosed configuration. The anode 108 is rotated by the driveshaft 1208 that causes the rolling contact wheels 106 to rotate around the anode 108 and contact both the anode edge and the stator 102. In this manner, a means for rotating the anode 108 is provided.

[0057] Referring to FIG. 13A and FIG. 13B, additionally or alternatively, a rotating cleaning wheel 1300 is mounted to the raceway 104 such that it cleans both the anode 108 and the stator 102. The rotating cleaning wheel 1300 has a surface etched roughness (e.g. grooves with a depth of $1\text{mm} \pm 0.1\text{mm}$) that rubs against each surface providing cleaning to maintain good electrical conductivity.

[0058] FIG. 14A, FIG. 14B and FIG. 14C depict a stationary (e.g. non-rotating) cleaning brush 1400 that cleans the stator 102 and the anode 108. The stationary cleaning brush 1400 comprises two segments with a spring 1402 that presses each of the segments against the stator 102 and the anode 108, respectively.

[0059] Referring to FIG. 15, in one embodiment, a cross-anode scraper 1500 is presented that is mounted to the raceway 104. The cross-anode scraper 1500 extends inwardly toward the center of the anode 108 such that, during rotation of the anode 108, the cross-anode scraper 1500 contacts the lateral surface of the anode 108 to clean it.

[0060] Referring to the embodiment of FIG. 16A and FIG. 16B, the rolling contact wheels 106 and the raceway 104 are omitted and brushes 1600 (e.g. a conducting slipper) are provided, which are in physical and electrical contact with the anode 108 but permit the anode 108 to rotate between gripping edges of the brushes 1600. Each brush 1600 is fixedly connected to the outer stator 102 by a coiled spring 1602. The spring 1602 is electrically conductive to complete an electrical circuit and permit electrical power to be withdrawn from the metal air battery. In such an embodiment, the anode 108 may be rotated by the common driveshaft 1208 shown in FIG. 12C. In the embodiment of FIG. 16A and FIG. 16B, the means for adjusting for changes in anode shape comprises a means for compressing that includes the brushes 1600 and the coiled springs 1602.

[0061] FIG. 17A and FIG. 17B depicts an embodiment similar to that of FIG. 16A and FIG. 16B except in that a leaf spring 1604 is used instead of the coiled spring 1602.

[0062] FIG. 17C depicts an embodiment wherein the anode 108 is a stationary anode that does not rotate during operation. In some embodiments, an oscillating device 1700 is present that vibrates the anode 108 to promote mass transfer around the anode 108. The oscillating device 1700 may be, for example, a vibratory motor. The oscillating device 1700 vibrates the stator 102, the springs 1602, 1604, and/or the anode 108 during operation of the metal air battery. Such a configuration may also be used with disc-shaped anodes (top figures) or non-disc anodes (bottom figures) such as square anodes, rectangular anodes, etc. This also provides for the use of ring-shaped stators (top figures) and non-ring-shaped stators (bottom figures) such as square stators, rectangular stators, etc. The shape of the stator 102 and the anode 108 may be the same (e.g. both ring shaped, both square, etc.) or different (e.g. a square stator 102 and a ring-shaped anode 102).

[0063] FIG. 18 depicts another embodiment of a raceway 1810 that is disposed on only one side of the anode 108. Rolling contact wheels 1802 are depicted that comprise a first magnet 1800a and a second magnet 1800b that are separated by a gap 1800c. A free-floating shaft 308 is present that is fixedly connected to the raceway 1810 but permits the first magnet 1800a to float along a length of the shaft 308 while keeping the second magnetic 1800b fixedly connected to the race 1810. The first magnet 1800a is connected to a first brim 1802a and the second magnet 1800b is connected to a second brim 1802b. The first magnet 1800a is connected to the shaft 308 through a hole with a beveled edge 1800d. The anode 108 is sandwiched between the first brim 1802a and the second brim 1802b. As the anode 108 is consumed the thickness changes. The magnetic attraction between the first magnet 1800a and the second magnet 1800b provide a means for pinching that decreases gap 1800c and thus maintains the first brim 1802a and the second brim 1802b in physical contact with the anode 108 as the thickness of the anode 108 changes. The beveled edge 1800d permits the first brim 1802a to adopt an angle relative to the second brim 1802b and, in this manner, pinch the anode 108 as it changes thickness. A cathode 1808 is also present in the embodiment of FIG. 18.

[0064] FIG. 19 depicts one embodiment of a metal air battery that utilizes the raceway 1810 with multiple anode 108. Each anode 108 has a keyed hole 1206. A common driveshaft 1208 extends through the keyed hole. Like the embodiment of FIG. 12C, the driveshaft 1208 has a single drive gear 1210 that is connected to a motor 1212 through a sealed shaft 1214.

[0065] As would be apparent to those skilled in the art after benefitting from reading this specification, a variety of edge treatments and shapes on both the stator 102 and the raceway 104 can provide for different designs for mechanical convenience as per anode diameter to thickness. Thicker anode discs might utilize multiple rolling contact wheels 106 that are mounted side-by-side in multiple, stacked raceways.

[0066] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

What is claimed is:

1. A metal air battery comprising:
 - an outer stator;
 - an anode disposed within the outer stator, the anode having a first lateral surface and a second lateral surface;
 - a cathode with a third lateral surface that is parallel to, and proximate to, the first lateral surface; and
 - a means for adjusting for changes in anode shape comprising at least one of
 - (1) a means for compressing the anode that compensates for changes in a diameter of the anode as the anode changes diameter during operation of the metal air battery, the means for compressing maintaining an electrical connection between the anode and the outer stator throughout the operation;
 - or
 - (2) a means for pinching the anode that that compensates for changes in a thickness of the anode as the anode changes thickness during operation of the metal air battery, the means for pinching maintain an electrical connection between the anode and the outer stator throughout the operation.
2. The metal air battery as recited in claim 1, wherein the means for compressing is a spring that connects a radial edge of the anode to the outer stator.
3. The metal air battery as recited in claim 2, wherein the spring is a coiled spring.
4. The metal air battery as recited in claim 2, wherein the spring is a leaf spring.
5. The metal air battery as recited in claim 2, further comprising a means for rotating the anode, wherein the anode comprises a keyed hole and the means for rotating the anode comprises a keyed driveshaft operatively connected to a motor.

6. The metal air battery as recited in claim 1, wherein the means for compressing the anode applies a compression force directed toward a center of the anode that is parallel with a lateral surface of the anode.
7. The metal air battery as recited in claim 1, wherein the metal air battery further comprises a means for rotating the anode that comprises a raceway that is rotated by a rotary drive, the anode being in direct contact with a plurality of rolling contact wheels that are rotatably mounted to the raceway such that rotation of the raceway rotates the rolling contact wheels and the anode.
8. The metal air battery as recited in claim 7, wherein the raceway comprises at least one of a turbine blade, a magnet or a gear.
9. The metal air battery as recited in claim 7, wherein each rolling contact wheel in the plurality of rolling contact wheels comprises a first splined and grooved wheel and a second splined and grooved wheel.
10. A metal air battery comprising:
 - an outer stator;
 - an inner raceway ring disposed within the outer stator, the inner raceway ring being rotatable;
 - a plurality of rolling contact wheels mounted to the inner raceway ring, the rolling contact wheels being electrically conductive;
 - an anode disposed within the outer stator, the anode having a first lateral surface and a second lateral surface;
 - a cathode with a third lateral surface that is parallel to, and proximate to, the first lateral surface;
 - a means for rotating the anode;
 - wherein the rolling contact wheels are contiguous with both the anode and the outer stator such that an electrical connection is formed;

a means for pinching that maintains physical contact between each wheel in the plurality of wheels and both (1) the outer stator and (2) the anode while the anode changes thickness during operation of the metal air battery;

a means for compressing the anode that compensates for changes in a diameter of the anode as the anode changes diameter during operation of the metal air battery.

11. The metal air battery as recited in claim 10, further comprising a second cathode with a fourth lateral surface that is parallel to, and proximate to, the second lateral surface.
12. The metal air battery as recited in claim 10, wherein each rolling contact wheel in the plurality of rolling contact wheels comprises a first splined and grooved wheel and a second splined and grooved wheel that mate with one another.
13. The metal air battery as recited in claim 12, wherein the first splined and grooved wheel and the second splined and grooved wheel each comprise angled splines that have an angle (θ) relative to a plane that is parallel to the first lateral surface of the anode, wherein θ is from 10° to 55° .
14. The metal air battery as recited in claim 12, wherein the first splined and grooved wheel and the second splined and grooved wheel each comprise angled splines that have an angle (θ) relative to a plane that is parallel to the first lateral surface of the anode, wherein θ is from 30° to 50° .
15. The metal air battery as recited in claim 12, wherein the rolling contact wheels comprise a magnet.
16. The metal air battery as recited in claim 12, wherein the rolling contact wheels comprise a spring.

17. The metal air battery as recited in claim 10, wherein the means for compressing the anode applies a compression force directed toward a center of the anode that is parallel with the first lateral surface of the anode.
18. The metal air battery as recited in claim 10, wherein the means for pinching applies a forced directed perpendicular to the first lateral surface of the anode.
19. The metal air battery as recited in claim 10, wherein the means for compressing the anode applies a compression force directed toward a center of the anode that is parallel with the first lateral surface of the anode and the means for pinching applies a forced directed perpendicular to the first lateral surface of the anode.
20. A metal air battery comprising:
 - an outer stator;
 - an inner raceway ring disposed within the outer stator, the inner raceway ring being rotatable;
 - a plurality of rolling contact wheels mounted to the inner raceway ring, the rolling contact wheels being electrically conductive;
 - an anode with a first surface and a second surface;
 - wherein the rolling contact wheels are contiguous with both the anode and the outer stator such that an electrical connection is formed;
 - wherein each rolling contact wheel in the plurality of rolling contact wheels comprises a first splined and grooved wheel and a second splined and grooved wheel that mate with one another;
 - a means for pinching that maintains physical contact between each wheel in the plurality of wheels and both (1) the outer stator and (2) the anode while the anode changes shape during operation of the metal air battery; and
 - a cathode with a third surface that is parallel to, and proximate to, the first surface.