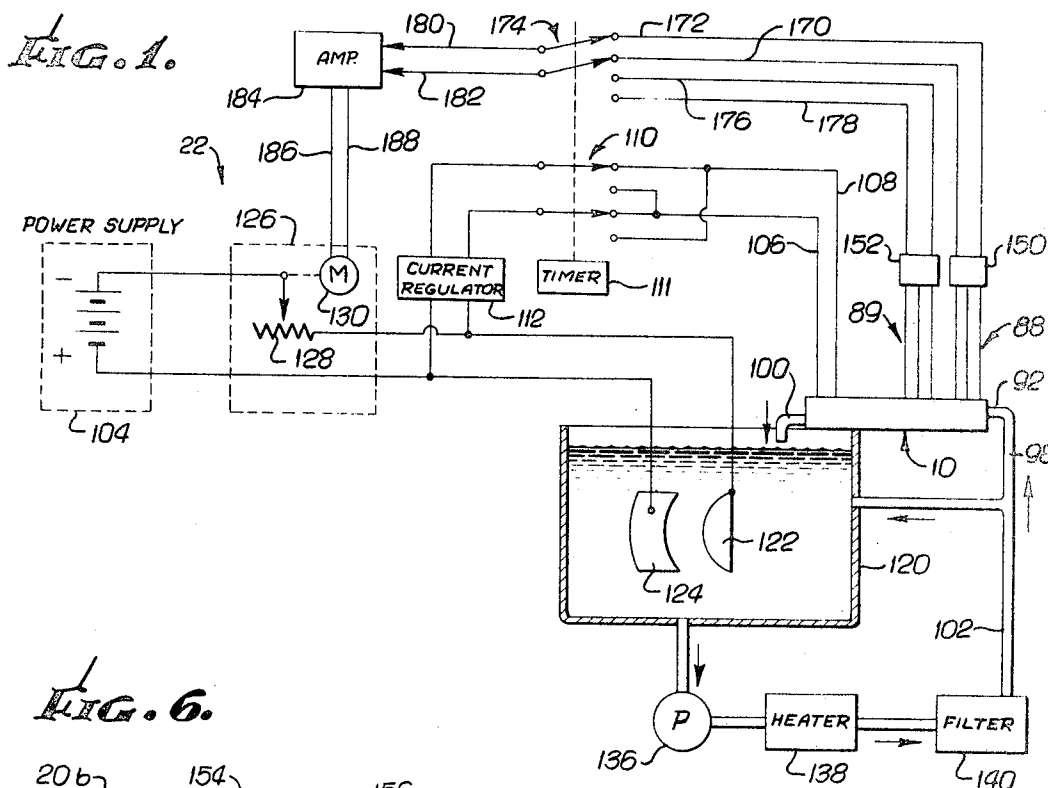
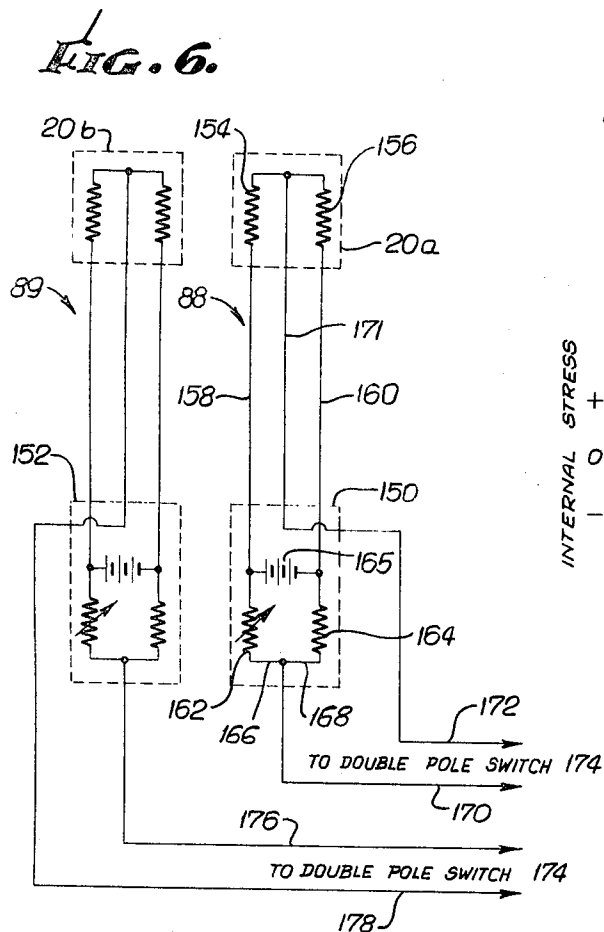
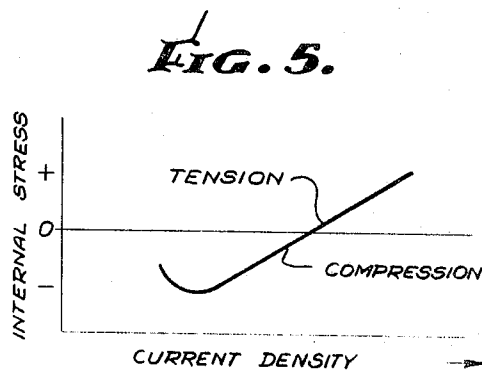


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APPARATUS AND METHOD FOR DETERMINING AND CONTROLLING
STRESS IN AN ELECTROFORMED PART

Filed July 18, 1966

Sheet / of 2



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FIG. 2.

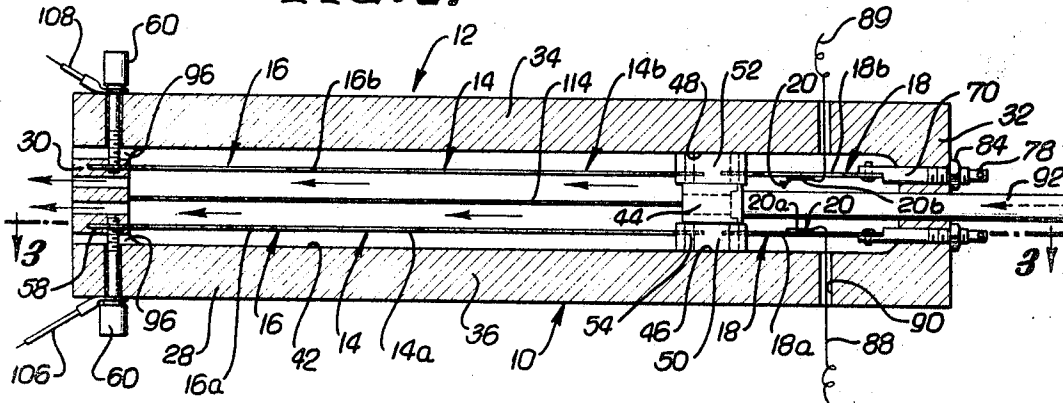


FIG. 3.

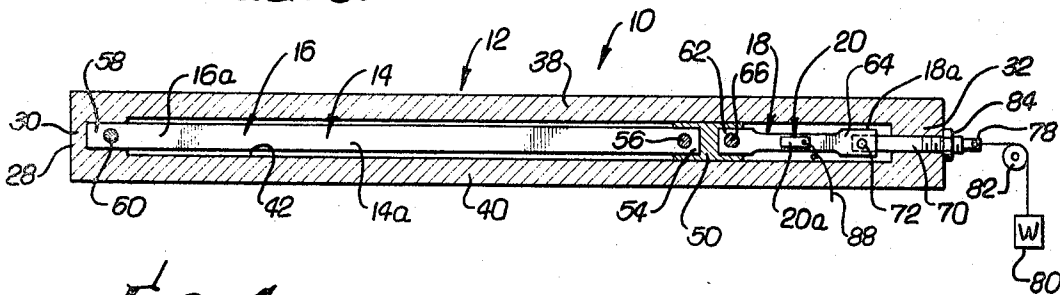
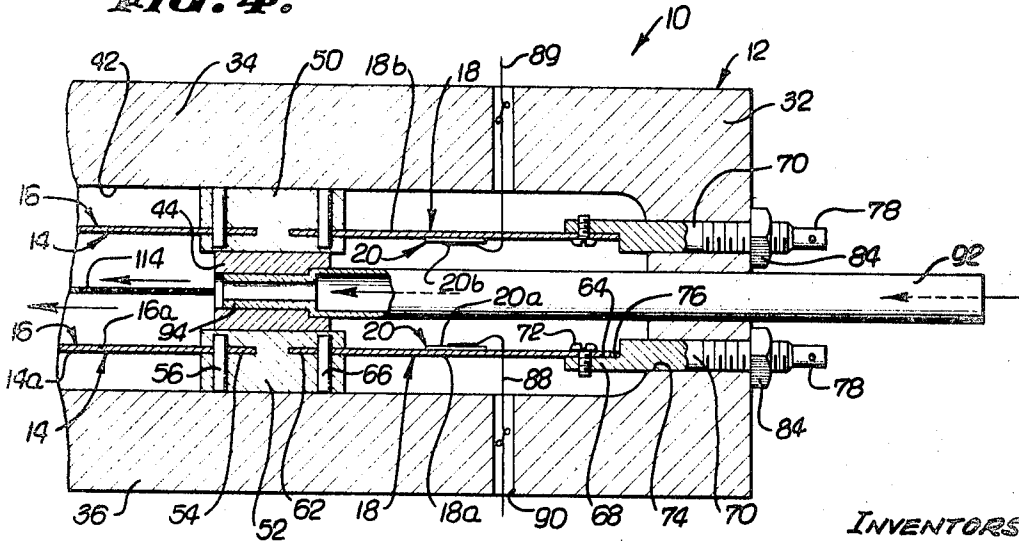


FIG. 4.



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APPARATUS AND METHOD FOR DETERMINING AND CONTROLLING STRESS IN AN ELECTROFORMED PART

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14 Claims

The present invention relates generally to electroforming, and more particularly to apparatus and method for determining and controlling the stress in an electroformed part.

Electroforming involves forming a part by electrolytically depositing metal on a mandrel or base to produce a relatively thin-walled part which is a reverse duplicate of the shape of the mandrel, and then separating the part from the mandrel. This method is particularly adapted for high accuracy replication of parts having critical dimensions. Thus, this method is used to manufacture optical components such as precision, metal, solar mirrors that reflect sunlight for providing supplementary power in space vehicles. Nickel is often the metal used because of its strength, high modulus of elasticity and low coefficient of thermal expansion; however, nickel tends to develop high internal stresses (both tensile and compressive) incident to its electroformation. Stress of 2,000 to 5,000 p.s.i. are common in commercially electroformed nickel parts, and stress of 10,000 to 20,000 p.s.i. and even 50,000 p.s.i. may be encountered if the process is not carefully controlled. While such stress is generally not critical in heavy sections, electroformed parts normally have wall thickness in the range of about 0.001 of an inch up to about 0.2 of an inch, so that such stress becomes very significant. Such high internal stress can cause warpage and dimensional changes (or even cracking) in the electroformed part. Further, internal stress reduces stress that can be applied externally to the part during service. While there are several competing theories as to the cause of such internal stress, it is known that the internal stress is a function of a number of variables such as the character of the bath solution (e.g., major constituents, wetting agents, addition agents, metallic and organic impurities), solution temperature, current density, and agitation. By regulating these variables, the internal stress can be controlled. For example, as illustrated in the graph of FIG. 5, varying the current density while holding the other variables generally constant will change the internal stress being produced in the electroformed nickel part from compression to tension. It will be noted that there is a theoretical transition or neutral stress point where the stress being produced is zero. By regulating current density so as to operate at or near this point, the internal stress may be maintained at a very low value. However, in actual operation, the many variables which affect stress being produced by the process do not remain constant with time, so that it is necessary to maintain observation of the stress being produced so that the current density may be changed as necessary to maintain the internal stress at a low value.

Heretofore, the stress being produced by the process was periodically checked or tested by introducing a small sample test strip into the bath solution and electroforming a coating or plating of metal on the strip. The deformation of the test strip was then measured with a micrometer or through the change in volume of a closed vessel and the amount of deformation was translated into a stress value. This stress value was used to direct manual adjustment of the bath conditions to reduce the internal

stress being produced by the process in the metal being electroformed. Several such tests were usually made before the electroforming of a part was started, involving an initial delay of usually several hours. During the electroforming of the part, the tests were made periodically, and there was a time lag between the plating of each test strip and the determination of the internal stress being produced at the time of the plating. Thus, the test data was subject to question as to accuracy and timeliness since the bath conditions changed over such periods of time. This method was also subject to experimental error because the plating deposited on the sample strips had to be manually stripped after the testing, thereby subjecting the strips to mechanical deformation. Also, since the test strips deformed by bending or curving, the mathematical analysis of the stresses involved were quite complicated.

Broadly, the present invention contemplates apparatus and method for continuously determining and controlling the internal stress in a part being electroformed. This involves electroforming on test elements in parallel with the regular electroforming operation, determining the internal stress being produced in the test elements, and using that information to continuously regulate the variables, such as current density, of the operation to minimize the internal stress produced in the part being electroformed. In the preferred form of apparatus and method illustrated in the drawings, a pair of test strips, which are effectively in parallel with the regular operation, are placed in linear tension and connected with opposite polarities so that one test strip is plated while the other is deplated. Changes in linear tension of the test strip being plated, which are directly related to the internal stress being produced in the part being electroformed, produce a control signal which controls the current density of the operation to minimize internal stress in the part. By reversing the test strip polarities periodically, the test apparatus may be used continuously. This continuous and generally contemporaneous determination of internal stress permits continuous control over the electroforming operation, making it possible, if desired, to automate that operation. Further, since the test strips are always in linear tension, they remain flat and do not deform due to bending or curvature; this acts to maintain the integrity of the test strips for long periods of time and greatly simplifies the conversion analysis necessary to establish the true internal stress. In addition, mechanical stripping of the test strip is eliminated since the test strips are alternately and automatically deplated.

Accordingly, it is an object of the present invention to provide a novel and improved apparatus and method for determining information as to internal stress being produced in a part being electroformed.

It is another object of the present invention to provide such apparatus and method for generally continuously and contemporaneously determining the stress being produced in a part being electroformed.

It is another object of the present invention to provide such apparatus and method which uses the information as to stress to control the electroforming operation to minimize the internal stress in the part.

It is a further object of the present invention to provide such apparatus and method that automatically controls the electroforming of the part in response to generally continuously determined information as to the internal stress being produced in the part to minimize that stress.

It is a more specific object of the present invention to provide such apparatus and method for continuously measuring changes in linear stress in a test element being electroplated in parallel with a part being electroformed,

and for using that information to generally continuously and contemporaneously control the conditions of the electroforming operation to minimize the internal stress in the part being electroformed.

It is a further object of the present invention to provide such apparatus and method that causes a test member to be subject to and measures only linear changes in stress to eliminate bending or curvature of the test member incident to the testing.

It is another object of the present invention to provide such apparatus and method which utilize a pair of test members connected to opposite polarities so that one is being deplated while the second is being plated, and for periodically reversing the polarities of the test members so that the second is being deplated while the first is being plated, for continuous operation.

Other objects and advantages of the present invention will become more apparent from the following description and the drawings, wherein:

FIG. 1 is a diagrammatic and schematic showing of an electroforming operation and of one form of apparatus which embodies the present invention for testing and controlling the operation and which illustrates the method of the invention;

FIG. 2 is a top plan sectional view of a test device for the apparatus shown in FIG. 1;

FIG. 3 is a side section taken generally along the line 3—3 on FIG. 2;

FIG. 4 is an enlarged top plan sectional view of a portion of the test device shown in FIGS. 2 and 3;

FIG. 5 is a chart showing the relationship of the current density of the electroforming operation to the internal stress in the part being electroformed by the operation; and

FIG. 6 is a schematic showing of the strain gauges and bridge balancing means of the illustrated test device.

Briefly, the illustrated apparatus includes a test device 10 which includes a frame or support 12 that supports a pair of elongated test lines 14 in linear end-to-end prestressed tension. Each of the test lines 14 comprises an elongated flat test strip or foil 16 and an elongated flat gauge strip or foil 18 on which a strain gauge 20 is mounted. The test strip 16 and the gauge strip 18 in each test line are aligned end-to-end and are electrically insulated from one another. The bath solution of the electroforming operation continuously flows past and around the test strips and the test strips 16 are reversibly connected with opposite polarities of the electrical power supply 104 of the electroforming operation so that one strip is being plated in parallel with the operation while the other is being deplated. Changes in the tension of the test strip 16 being plated are also present in the aligned gauge strip 18, and produce dimensional changes in the gauge strip which are measured by the associated strain gauge 20. This information is used by control means 22 to control the internal stress in the electroformed part by automatically regulating the current density of the electroforming operation in response to the information. By reversing the polarity of the test strips periodically, the test strips are alternately plated and deplated so that the test device can be used continuously. Thus, generally continuous and contemporaneous determination and control of the internal stress being produced in the part by the electroforming operation are provided.

Now considering the illustrated apparatus in further detail, the support, frame or holder 12 of the test device 10 is a generally elongated, rectangular box-shaped structure made of a suitable strong and rigid material. Desirably, the material used for the support has a coefficient of thermal expansion close to that of the material used for the test line 14. This is to minimize any difference in thermal expansion or contraction between the support and the test lines resulting from temperature variations, because such differences could change the tension on the test lines to distort the test data. The support 12 is com-

prised of a base section 28 having a forward end wall 30, a rearward end wall 32, and a pair of elongated side walls 34, 36. The support 12 also includes a rectangular top plate or section 38 and a rectangular bottom plate or section 40 that are both releasably secured to the base section 28 by suitable fastener means (not shown) to define a generally elongated, rectangular internal cavity or compartment 42.

A vertical spacer section 44 is provided in the compartment 42 centered intermediate the side walls 34, 36 and extending from the bottom plate 40 to the top plate 38. The spacer section 44 is positioned intermediate the ends of the compartment 42, but substantially closer to the rearward end. The spacer section 44 defines a pair of spaced openings 46, 48, respectively, adjacent the side walls 34, 36. Each of the openings 46, 48 is occupied by a generally rectangular connector block 50, 52 which is loosely received in the opening for sliding movement longitudinally of the compartment 42. Each of the connector blocks 50, 52 is constructed of a suitable electrical insulating material, such as various plastics. It is desirable that the coefficient of thermal expansion of the blocks be compatible with that of the test and gauge strips. The spacer section 44 and the two connector blocks 50, 52 thus generally form a divider across the interior of the compartment 42, dividing it into a short rearward part and a longer forward part. As will be explained more fully, the test strips 16 are disposed in the forward part of the compartment and the gauge strips 18 are disposed in the rearward part of the compartment.

Each of the connector blocks 50, 52 forms a part of one of the test lines 14. Since the two test lines 14 are of generally the same construction, only one, which is designated 14a, will be described in detail. The connector block 50 of the line 14a is connected to the rearward end 54 of the test strip 16a, which is a thin, flat, elongated, rectangular strip or band made of a relatively inert material, such as platinum or titanium, which will provide substantially no ions into solution. The illustrated test strip may, for example, be about 12 inches in length, 1/2 inch in width and 5 or 10 mils in thickness. The rearward end 54 of the test strip 16a is received in a vertical slot in the connector block 50 and it is held in place by any suitable means, such as a horizontal pin or screw 56, which extends through the connector block and a suitable aperture in the end of the test strip. The forward end 58 of the test strip 16a is received in a vertical slot in the forward end wall 30 and held in place by a screw 60 which is threaded in a suitable tapped hole in the support and which extends through a suitable aperture in the forward end 58 of the test strip.

The gauge strip 18a of the test line 14a is a thin, flat, elongated, generally rectangular strip or band which may be of the same or a similar material as used for the test strip. The gauge strip 18a has generally the same thickness and width at its ends 62, 64 as does the test strip 16a; however, the width of the gauge strip 18a is reduced or necked at its center to provide a cross-section generally one-half the cross-section of the test strip 16a. The gauge strip 18a is secured at its forward end 62 in a vertical slot in the rear of the connector block 50 by suitable means, such as a horizontal pin or screw 66, and at its rearward end 64 to the forward end 68 of a tensioning rod 70, as by means of a pin or screw 72. The tensioning rod 70 is a generally cylindrical, elongated element slidably disposed in an aperture 74 in the rearward end wall 32 of the support for longitudinal movement. The forward end 68 of the tensioning rod 70 is bisected to provide a flat surface 76 against which the rearward end 64 of the gauge strip 18a is secured by the screw 72. As illustrated schematically in FIG. 3, the rearward end 78 of the tension rod 70, which extends outwardly of the support 12, is adapted to be connected to a weight 80 disposed over a pulley 82 to tension the rod 70 rearwardly and thereby

tension the test line 14a. In this connection, the test line 14a is fixed at its forward end by the screw 60 holding the forward end 58 of the test strip 16a, and the connector block 50 is slidable longitudinally so that the test strip 16a and the gauge strip 18a may be tensioned by rearward pull on the tension rod 70 to achieve the desired prestressing. It will be noted that the test strip 16a and the gauge strip 18a are arranged in series so that a change in the stress or strain exerted on one is transmitted to the other. The test line 14a may be preloaded with a tension of, for example, from about 5,000 to 10,000 p.s.i. The rearward end 78 of the tension rod is threaded and provided with a lock nut 84 which is tightened against the support rear end wall 32 to maintain the tension established by the weight 80.

As noted above, the gauge strip 18a is narrowed at its center portion, and, as shown best in FIG. 3, the strain gauge 20a, which is a small flat, rectangular element, is secured to the center portion of the gauge strip 18a by suitable known procedures so that substantially all portions of the strain gauge are connected to adjacent portions of the gauge strip. The strain gauge thereby senses and measures any change in linear or longitudinal dimension of the gauge strip which is directly proportional to any change in the longitudinal dimension of the test strip, which, in turn, is directly related to a change in stress in the test strip. Because the center portion of the gauge strip has a cross-section approximately one-half that of the test strip as noted above, the change in length sensed and measured by the gauge is twice what it would be if the gauge were directly on the test strip so that the sensitivity of the device is doubled. The strain gauge 20a is connected, by a suitable electrical line 88 that enters through a port 90 in the side wall 36 of the support, to the control means 22.

The other test line 14b, which includes test strip 16b, gauge strip 18b and strain gauge 20b, is connected by line 89 to the control means 22.

A continuous flow of bath solution is provided through the device 10 and particularly past the test strips 16 in the forward part of the support compartment 42. An inlet tube or conduit 92 extends through the center of the rear end wall 32, through the center of the rear part of the compartment intermediate the gauge strips 18, and through the spacer section 44 to communicate with the forward part of the compartment. The forward end 94 of the inlet tube 92 is reduced in size and is connected, as by a press fit, in a suitable aperture extending longitudinally through the spacer section 44. Outlet ports 96 are provided in the forward end wall 30. The flow, which may be like that of slow-running tap water, is primarily through the inlet conduit 92, into the forward part of the compartment 42 past the inward faces of the test strips 16, and out through the outlet ports 96. However, the connector blocks 50, 52 are somewhat smaller than their respective openings 46, 48 so that solution will also enter the rear part of the compartment. The gauge strips 18 and the gauges 20 will not be plated because they are electrically insulated from the test strips 16.

Each of the test strips 16 is connected to one pole of the electrical power supply 104 (FIG. 1) of the electroforming operation. More particularly, each of the screws 60, which engages and secures the forward end of one of the test strips 16 in place, is connected through a suitable electrical connector 106, 108 to the power supply 104. A suitable double pole reversing switch 110 is placed between the power supply 104 and the test strips 16 and periodically operated by an automatic timer 111 to reverse the polarity of the two test strips. Suitable adjustable means 112 for regulating current are also placed between the power supply 104 and the test strips 16 to reduce the current density to the test device 10 in the same general proportion as the surface area of the test strip being plated compares to the surface area over which metal is being electroformed by the regular opera-

tion. This subjects the test strip to the same effective current density as the part being electroformed.

Thus, one of the test strips 16, which is connected to the negative pole of the power supply 104, acts as a cathode to draw nickel ions from the solution and to thereby be plated in parallel with the electroforming of the regular operation. The plating takes place on the inward side of the strip, with the outward side of the strip being treated, as with a plastic coating, to prevent plating on that side. The other test strip, which is connected to the positive pole of the power supply, acts as an anode, giving nickel ions from its plating or coating up to the solution to thereby be depleted. When the switch 110 is reversed, the test strips are connected to opposite poles so that the strip which was being plated will be depleted and the strip which was depleted will be plated.

It will be noted that the walls of the compartment 42 are brought into close proximity to the edges of the test strips 16 (FIG. 3) to minimize edge effect, which is the tendency for heavier metal deposit at the edges of parts due to higher current densities at the edges.

A vertical screen 114 of a porous fabric, such as cheese cloth, is disposed in the compartment 42 intermediate the test strips 16 to prevent flakes or particles of plating from the test strip which is deplating (since deplating takes place in a nonuniform manner) from reaching the test strip which is plating to distort test data.

FIGURE 1 illustrates diagrammatically and schematically the regular electroforming operation which is tested and controlled by the test device 10 described above and the control means 22. An electroforming tank 120 holds a volume of a bath solution which is appropriate for the metal being electrodeposited. Nickel is often used as the electroformed metal because of its desirable properties as noted above, and it is referred to by way of example, although it is noted that a number of other metals may also be electroformed. A mandrel 122, which is generally a reverse duplicate of the part to be electroformed, is disposed within the solution in the tank 120 and is connected to the negative pole of the power supply 104 to serve as the cathode of the electrolytic process. An anode 124, which may be conforming or partially conforming to the shape of the mandrel-cathode 122, is also disposed within the solution in the tank 120 adjacent to the mandrel and is connected to the positive pole of the power supply 104. The anode 124 is comprised of an electroforming metal so as to replace in the solution metal ions as they are deposited on the mandrel 122 to electroform the part.

In the electroforming operation, the solution is continuously circulated through a recirculation line 102 leading from the lower portion of the tank 120 back to the upper portion of the tank. A suitable pump 136 is provided in the line 102 as are a heater 138 and a filter 140. The inlet conduit 92 of the test device 10 is connected through a line 98 to the recirculation line 102 so that the pump 136 also provides the flow or circulation through the test device and back to the tank through outlets 96 and a return line 100.

Suitable current density control means 126 are provided in this electroforming circuit to vary the current density, which, as noted above, is one of the variables controlling the internal stress in the electroformed part. The current density control means 126 may comprise, for example, a variable resistance 128 operated by a suitable reversible servo drive comprising a D.C. motor 130. At any given time, the motor 130 is operated, as will be explained in detail, by the electrical output from the strain gauge 20 associated with the test strip 16 being plated to control the current density in the electroforming circuit to minimize the internal stress in the part being electroformed. In this connection, FIG. 5 shows a graph, which as noted above, plots negative stress (compression) and positive stress (tension) against current density. It will be noted that the curve crosses the zero stress line, indicating that

setting the current density at that value will produce no internal stress in the electroform part. This optimum current density for achieving zero stress is not an absolute value, however, and depends on the other variables of the electroforming operation. The optimum current density will vary with time since the other variables of the operation will so vary. By continuously determining the internal stress being produced by the electroforming operation, however, the current density may be increased or decreased, depending on whether stress tension or compression is being produced, to reduce that stress in the part.

As shown in FIGS. 1 and 6, one strain gauge 20a is connected through three leads of the line 88 to a bridge balancing means 150, while the other strain gauge 20b is connected through three leads of the line 89 to a bridge balancing means 152. Each of the strain gauges and its associated bridge balancing means forms a balancing Wheatstone bridge arrangement. More particularly, as shown schematically in FIG. 6, strain gauge 20a comprises a pair of strain resistances 154, 156, each connected through a lead 158, 160 of the line 88 to a balancing resistance 162, 164 of the bridge balancing means 150. One of the balancing resistances 162 is manually variable for a purpose that will be explained below. A source of uniform voltage, such as a D.C. battery 165, is connected between the leads 158, 160. The balancing resistances 162, 164 are connected through leads 166, 168 to a common first output lead 170. The strain gauge 20a also includes a plain lead 171 of the line 88 which is connected to a second output lead 172. The output leads 170, 172 of the strain gauge 20a lead to a double pole switch 174 (FIG. 1) that is also operated by the timer 111. The other strain gauge 20b and the bridge balancing means 152 are the same as the gauge 20a and the bridge balancing means 150, having a pair of output leads 176, 178 that also lead to the switch 174. The switch 174 is operated by the timer 111 to connect either one set of output leads 170, 172 or the other set of output leads 176, 178 to lines 180, 182. The lines 180, 182 are connected to an amplifier 184, which is connected by lines 186, 188 to the D.C. motor 130 of the current density control means 126. The reversing switches 110, 174 are periodically both operated whereby each time the polarity of the test strips is reversed, the output from the strain gauge 20 associated with the test strip 16 which is then being plated is connected to the current density control means 126, while the output from the strain gauge associated with the test strip which is being deplated is disconnected from the current density control means.

OPERATION

The overall operation of the test apparatus may now be more readily understood. With the electroforming operation in progress, solution is continuously circulated through the test device 10 with the test strips 16 being provided with opposite electrical polarity. One of the test strips 16 is plated in parallel with the electroforming of the part, i.e., under approximately the same conditions as the regular electroforming operation. Any stress or strain caused by the plating of that test strip 16 is also present in the aligned gauge strip 18, and the longitudinal dimension change caused by such stress is sensed by the associated strain gauge 20.

Using strain gauge 20a as an example, it will be recalled that an initial tension is placed on each test line 14. This would cause an unbalancing of the Wheatstone bridge comprised by the strain gauge 20a and the bridge balancing means 150, with a resultant voltage differential or output. However, the resistor 162 is manually adjusted to balance the Wheatstone bridge so that there is a zero or null output from the strain gauge 20a, although the associated gauge strip 18a is under the prestressed tension.

Now any added tension or compression of the test strip 16a sensed by the strain gauge 20a produces a positive or negative voltage across the output leads 170, 172. For example, if tensile stress was being produced in the electroforming part, such tension would also be created in the plating being formed on the test strip 16a. This would vary the resistances 154, 156 in the strain gauge 20a, to unbalance the Wheatstone bridge and create a positive voltage across output leads 170, 172. This is transmitted through the switch 174 and the amplifier 184 to the D.C. motor 130, which operates the motor to change the variable resistor 128 to decrease the current density in the electroforming circuit. Thus, the electroplating current density would be reduced so long as there was tensile stress above the prestressed value. The decrease in the electroforming current density would tend to change the condition of the electroforming metal along the curve shown in FIG. 5 toward the left to first reduce the tensile stress and then begin to produce compressive stress in the electroforming metal. When the net effect of stress on the test strip 16a becomes compression, the strain gauge 20a senses that compression, and operates to unbalance the Wheatstone bridge to provide negative potential across the output leads 170, 172. This negative potential operates the D.C. motor 130 in the opposite direction to increase the current density of the electroforming circuit to thereby reduce the compressive stress and move to the right along the curve of FIG. 5. Thus, a low level cycling or oscillation around the mid or zero stress line is achieved to minimize stress within the electroformed part.

To permit continuous operation, the polarity of the test strips 16 is periodically reversed, with test strip 16b now being electroplated, while the metal coating on test plate 16a is being deplated. This is accomplished by the timer 111 operating the reversing switch 110. At the same time, the timer 111 also operates the switch 174 to disconnect the strain gauge 20a and its output leads 170, 172 from the lines 180, 182 that are connected to the D.C. motor 130, and instead connect strain gauge 20b through its output leads 176, 178 to lines 180, 182 to the motor 130. Thus, the strain gauge 20b associated with the test strip 16b being plated is connected to the current density control means 126 and serves to control the electroforming operation. The timer 111 operates at regular intervals, such as every one or two hours, to provide a nominal thickness of plating on a test strip such as 5 mils.

It will be understood that the illustrated test apparatus is the presently preferred form of apparatus embodying the invention, but that various modifications and changes may be made in the illustrated structure without departing from the spirit and scope of the present invention. For example, and without limitation, instead of defining a closed cavity or compartment for the submersion of the test strips, the support may be an open structure and the test device may be submerged in the bath solution so as to submerge the test strips so long as adequate flow is provided. Similarly, the support may take various shapes and configurations. It will also be noted that the information as to stress may be used to manually control the electroforming operation and that the test apparatus may be operated intermittently, rather than generally continuously, in particular circumstances if so desired.

The illustrated test apparatus affords rapid continuous measurement, monitoring and control over stresses being produced in a part being electroformed. The illustrated apparatus operates automatically without repeated individual tests, without measuring or manually stripping of test members, and without the attendant delays of such test methods. The apparatus further eliminates curvature or bending of the test members to simplify calculations and afford more accurate and dependable results. The illustrated apparatus is relatively simple and economical to manufacture, operate, and maintain and is durable and dependable. It appears that internal stress in the electro-

formed parts may be controlled to within the range of about 10 to about 50 p.s.i.

Various features of the present invention are set forth in the following claims.

What is claimed is:

1. Apparatus for determining the internal stress produced in a part being electroformed, said apparatus comprising: a test member having a plating-receiving area; support means for holding said test member under force in one linear direction; means for operatively connecting said test member to the means that electrolytically form the part to form an electrodeposited plating on said area of said test member; and sensing means for sensing changes in the force on said test member in said linear direction.
2. Apparatus as defined in claim 1, further including control means actuated by said sensing means to control the electrolytic forming means to control internal stress in the electroformed part.
3. Apparatus as defined in claim 2, wherein said control means controls the current density of the electrolytic forming means for relatively rapid response.
4. Apparatus as defined in claim 1, wherein said test member is an elongated strip and said support means holds said test member in substantial linear tension.
5. Apparatus as defined in claim 1, further comprising a second test member having a plating receiving area, and a second sensing means for sensing changes in the force on said second test member in said linear direction, said support means holding said second test member under force in one linear direction, and said connection means being operable to alternately and periodically cause said electrolytic forming means to first form a plating on one test member while removing the plating from the other test member, and then to remove the plating from the one test member while forming a plating on the other test member.
6. Apparatus as defined in claim 5, further including control means operatively connected to one of said sensing means to be actuated thereby to control the electrolytic forming means to control the internal stress in the electroformed part, and automatic switching means for periodically reversing the polarity of the first and second test members while shifting the connection of said control means at the same periodic times to the one of said sensing means associated with the test member then to be plated.
7. Apparatus as defined in claim 1, wherein said sensing means senses changes in the force on the test member generally contemporaneously with the formation of the plating on the test member.
8. Apparatus as defined in claim 1, wherein said apparatus comprises a pair of elongated test lines, said support means holding each of said test lines under tension longitudinally of said lines, each of said lines comprising one of said test members in the form of an elongated test strip and an elongated gauge strip arranged in series with said test strip, said connection means including conductor means defining a path past said test strips for electrolytic solution used to electroform the part and means for re-

versibly connecting the test strips to opposite electrical poles so that first one test strip is plated while the other test strip is deplated, and then the other test strip is plated while said one test strip is deplated, said apparatus further comprising a strain gauge mounted on each of said gauge strips for determining changes in longitudinal stress on the associated gauge strip, and control means operated by said strain gauges to control the electroform of the part to minimize the internal stress in the part.

9. Apparatus as defined in claim 8, wherein said test and gauge strips are generally flat and the plating receiving area comprises substantially one face of each test strip, said support means extending in close proximity to the edges of said test strip faces.

10. A method for determining the internal stress in an electroformed part, said method comprising the steps of placing a test member under force in one linear direction; subjecting the test member to electrolytic conditions directly comparable to those under which the part is being electroformed to electrodeposit a coating of metal on the test member; sensing changes in force in said linear direction on the test member.

11. A method as defined in claim 10, wherein said electrodepositing is done generally contemporaneously with the electroforming of the part and said sensing is done generally contemporaneously with said electrodepositing.

12. A method as defined in claim 10, including the further step of changing the conditions under which the part is electroformed to control the internal stress in the part in response to the sensed changes in force.

13. A method as defined in claim 10, including the further steps of placing a second test member under force in a linear direction; subjecting the second test member to electrolytic conditions to remove a coating of metal from the second test member; and periodically reversing the action on the two test members for generally continuous operation.

14. A method as defined in claim 10, wherein the force under which the test member is placed is linear tension.

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