Oct. 9, 1962 J. W. PITTS 3,057,381

METHOD AND APPARATUS FOR STRETCH-FORMING WIRE-GRID STRAIN GAGES

Filed April 30, 1959 2 Sheets-Sheet 1

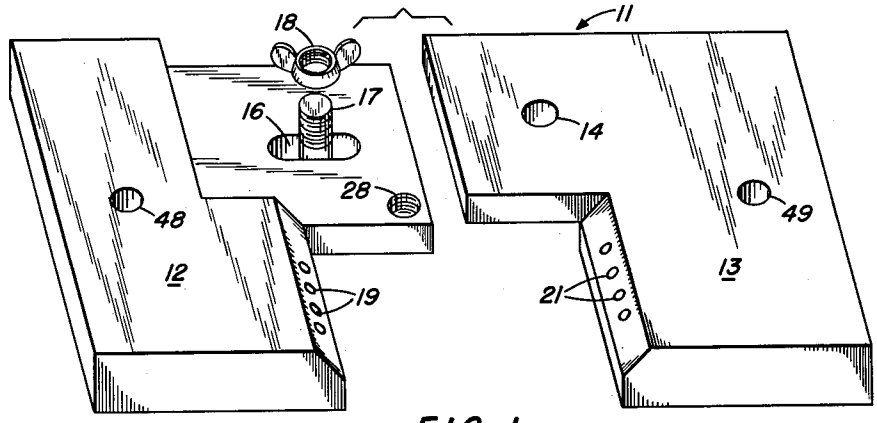


FIG. 1

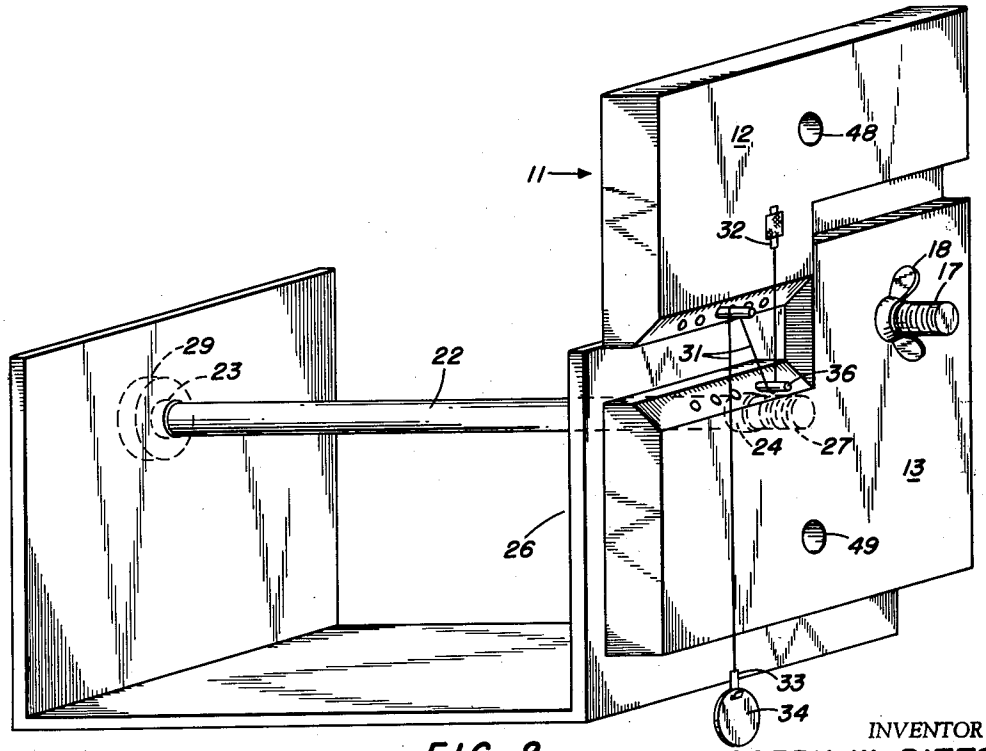


FIG. 2

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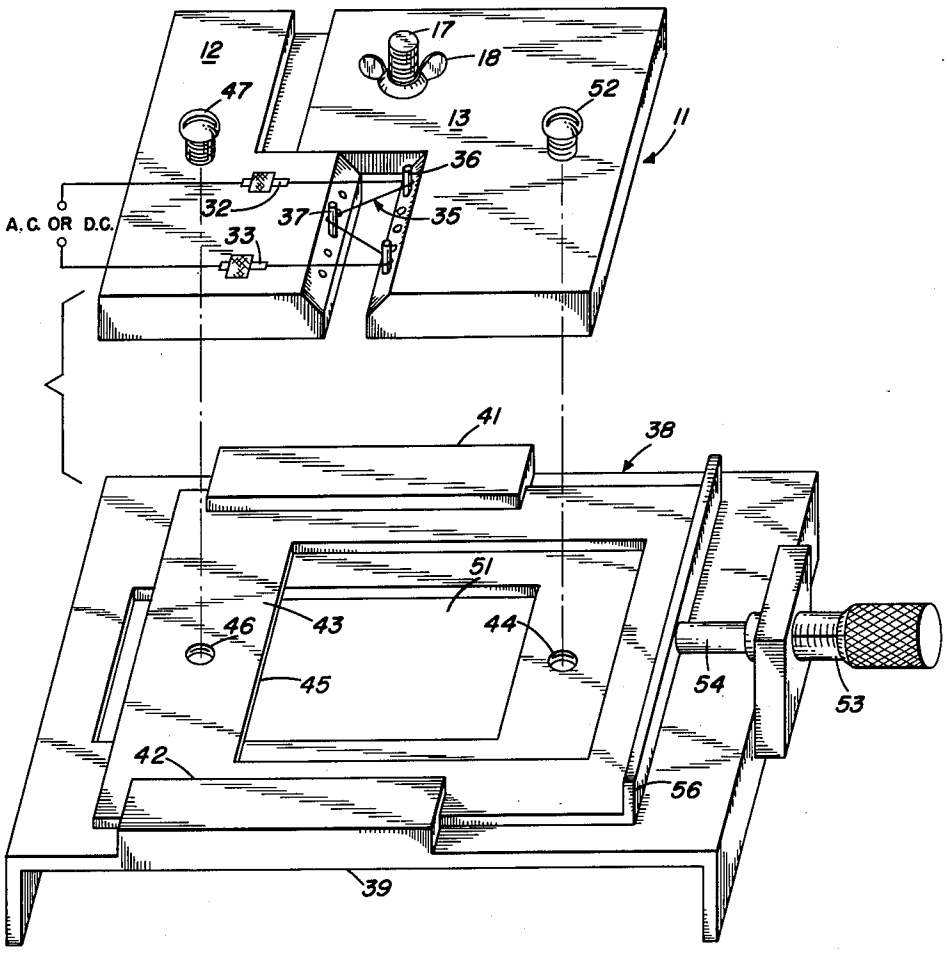


FIG. 3

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3,057,381
Patented Oct. 9, 1962

3,057,381

METHOD AND APPARATUS FOR STRETCH-FORMING WIRE-GRID STRAIN GAGES

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Filed Apr. 30, 1959, Ser. No. 810,189
2 Claims. (Cl. 140—71)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates generally to strain gages used in the field of stress analysis and more particularly to a method and apparatus for "fixing" or "setting" wire-grid strain gages by the employment of stretch-forming.

The type of wire-grid strain gage made in accordance with the present invention has the configuration of a series of connected loops lying substantially in a common plane. Such gages are formed by winding a very thin wire (of the magnitude of 0.001 of an inch in diameter) of known electrical strain characteristics about and between successive pins arranged in two parallel rows in a jig. The length of filament which is wound into the gage is determinative of the amount of electrical resistance thereof.

In the prior art various means have been employed to maintain the shape of the wound filament so that upon removal from the jig the filament could be transferred "as wound" and bonded to the surface to be strained or simply retained in the prepared configuration until needed.

One form of gage provides for bonding the effective length of the filament to a thin membrane of paper or other suitable insulating material by means of an adhesive. Generally the prepared membrane is placed over the filament in the jig after winding. Then after the formed filament and membrane have dried and hardened they are removed as a unit thereby permanently maintaining their configurations "as wound."

Another prior art expedient is to form the desired filament configuration and then to apply a bonding cement to cover a major portion of the wound filament (usually leaving the loop ends uncovered). When the cement has hardened, embedding the filament, the filament and cement and any backing used are lifted from the jig as a unit.

In still another prior art construction the gage is interlaid and cemented between cover sheets which are cemented together with the lead-conductors projecting therefrom.

Still another method and the only prior art method known to the inventor which provides a permanent set for the filament in the configuration "as wound" without resorting to some form of backing is that of pressing or flattening the filament. In this method the filament is wound in a jig and means are provided for submitting the filament to pressure so as to deform the filament an amount sufficient to cause the filament to retain its shape "as wound" upon removal from the forming jig.

Aside from the added expense of providing the backing or embedding material the first three methods described above have certain disadvantages. Any membrane backing or cover sheets may have to be removed at the time of gage installation. Also in the case of gages embedded in material, such material because of its nature may have to be removed at the time of gage installation. The process of removal of backing or cover involves the danger of damaging the gage while the removal of backing membrane, cover or embedding material all are

tedious and time consuming. Also, if an embedding material is used which is intended to form an integral part of the gage it has the disadvantages first, of interposing an extra layer between the gage and the surface to be tested and second, of requiring that the cement used to bond the gage to the testing surface must also be one which bonds to the embedding material.

As for the last-mentioned prior art method, wire-flattening, though this method does produce an unsupported permanently-set grid, unfavorable changes are likely to be produced in the metallurgical properties of the filament as a result of the severe deformation caused in order to produce the "set" required. Also, since the pressing operation must be executed prior to attaching the lead-conductors, handling of the pressed filament is difficult.

Therefore, an object of the present invention is to provide a method and apparatus for producing an unsupported, permanently-set but essentially metallurgically unchanged grid-filament for a strain gage.

Another object of the present invention is to provide a method of stretch-forming for producing an unsupported, shaped filament having a permanent set.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same become better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

FIG. 1 is an isometric view of the winding jig composed of two interlocking and partially overlapping parts;

FIG. 2 is an isometric view of the vertical support equipment with the winding jig attached thereto in the filament winding position; and

FIG. 3 is an exploded isometric view of the holder indicating how the winding jig is secured therein for straining the filament.

Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, there is shown in FIG. 1 which indicates a preferred embodiment a winding jig **11** consisting of two pieces **12** and **13** of wood (or other non-conducting material) made to interlock and partially overlap each other when placed in juxtaposition. As shown in FIG. 1 parts **12** and **13** are separated. The parts are assembled by placing hole **14** over slot **16**, inserting bolt **17** therethrough, and screwing wingnut **18** thereon thereby fastening the parts **12** and **13** together upon tightening wingnut **18**. A pre-determined gage length having been chosen the spacing between parallel rows of holes **19** and **21** is set to produce the desired gage length before tightening wingnut **18**. The assembled winding jig **11** is then attached to rotatable rod **22** set in bearings **23** and **24** of vertical support equipment **26**. One end of rod **22** has formed thereon threads **27** which are arranged to enable rod **22** to be screwed into threaded hole **28** in jig **11**. The opposite end of rod **22** has formed thereon a knurled knob **29** by which rod **22** can be grasped and rotated by the operator during the winding procedure.

Gage filament **31** is prepared by spot welding, crimping or otherwise joining the desired length of fine wire to the heavier material forming leads **32, 33**.

With the long axis of jig **11** in a vertical position as shown in FIG. 2 lead **32** is taped to the upper half of jig **11** (in this case part **12**) allowing filament **31** and lead **33** to hang freely. Small weight **34** is attached to lead **33** to apply constant tension to filament **31** during the winding operation. Weight **34** is made of sheet metal in order that its flat, thin contour will prevent oscillatory rotation of filament **31**. The size of weight **34** is so selected that the strain applied to filament **31** thereby is well below its elastic limit. Winding pin **36** preferably made of glass fiber is next inserted in one of the holes

in the bottom row of holes (in this case row 21) and rod 22 is rotated thereby rotating jig 11 through 180°. In the process of rotation filament 31 is looped over pin 36 while under constant strain from weight 34. A second pin, pin 37 is inserted in row 19 (which has now become the bottom row) and jig 11 is then counter-rotated 180° to its original vertical position with the upper half of jig 11 being part 12. At this point filament 31 has been looped twice, once over pin 36 and once over pin 37. This produce is repeated until the requisite number of loops have been made completing the grid 35. After making the last loop the free lead, lead 33, is taped to the part 12 of jig 11 alongside and parallel to lead 32. Weight 34 is removed and then jig 11 is removed from the vertical support equipment 26 and placed on holder 38 as shown in FIG. 3. Holder 38 is composed of a base 39 having affixed thereto ways 41 and 42 adapted to permit slide 43 to move longitudinally but preventing the lateral movement thereof. Base 39 has a tapped hole 44 therein; slide 43 has a tapped hole 46 therein as shown. Screw 47 is inserted through hole 48 in part 12 and into tapped hole 46 in slide 43. Slide 43 is moved to achieve the coincidence of tapped hole 44 with hole 49 in part 13 (slide 43 having opening 45 therethrough and base 39 having opening 51 therethrough); screw 52 is then inserted through hole 49 and into tapped hole 44. Micrometer screw 53 which is mounted on base 39 is then manipulated to advance shaft 54 until it is in contact with upturned abutment portion 56 of slide 43. In this manner the relative position of parts 12 and 13 may be maintained after the removal of wingnut 18 and screw 17 from hole 14 which is the next step in the process.

A supply of electric current is connected across leads 32, 33 and sufficient current is then applied to heat grid 35 to 1200° to 1400° F. While the filament is elongated due to thermal expansion micrometer screw 53 is turned advancing slide 43 (and thereby part 12 affixed thereto) to take up the slack between the expanded filament and the winding pins (such as pins 36 and 37). The current is then cut off and grid 35 is allowed to cool. During the period of cooling filament 31 is submitted to the uniform axial strain resulting from the opposition offered by the winding pins as filament 31 seeks to contract to its position prior to the heating-expansion step. This sequence of heating, expansion, taking up of slack and cooling is termed "stretch-forming" since stretching of the grid takes place during the cooling of the grid as a result of the restrained thermal contraction of filament 31. Such an operation can be very easily standardized by experimentally determining the exact amount of elongation required to "set" a given type and size of wire.

Removal of the completed gage from jig 11 is facilitated by retracting the shaft 54 to allow relative movement between parts 12 and 13 and then removing the winding pins. The completed gage with its leads 32 and 33 held in place by adhesive tape or similar substance can then be removed without danger of altering the pattern of grid 35.

Although steel winding pins have been used successfully, it has been found that glass pins result in better control because of the reduced heat loss at the loop ends during heating.

As has been stated before, the unique properties of strain gages produced by the method described above is that as a result thereof the series of connected loops comprising the grid maintain their configuration "as wound" although entirely unsupported by backing or embedding material of any kind and without the detrimental effects of the prior art flattening process.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. The method of stretch-forming a strain gage filament which comprises the steps of rotatably mounting an adjustable winding jig in a substantially vertical plane, affixing one end of said filament to the upper portion of the surface of said jig, attaching means to the opposite end of said filament to strain said filament substantially below its elastic limit, inserting a first winding pin in the first of two parallel horizontally-disposed rows of holes in said jig, said first row being vertically disposed below the second row of holes at the time of pin insertion, rotating said jig 180° whereby said filament is looped over said first pin, inserting a second winding pin in the second row of holes, rotating said jig 180° counter to the immediately preceding rotation whereby said filament is looped over said second pin, inserting a third winding pin in said first row of holes, rotating said jig 180° counter to the immediately preceding rotation whereby said filament is looped over said third pin, affixing the opposite end of said filament adjacent and parallel to said one end of said filament, removing said straining means, controllably heating said filament to promote the expansion thereof, readjusting said winding jig to a gage length substantially coinciding with that of the expanded filament, allowing said filament to cool and contract, continuing to restrain said grid whereby said filament is submitted to uniform axial strain by said restraining of the filament during thermal contraction thereof and removing the completed grid from said winding pins, said grid having been formed with a permanent set therein.

2. The method of stretch-forming a strain gage filament which comprises the steps of setting winding pins to a predetermined gage length, winding said filament thereon to form a grid comprising at least one loop, passing electric current through said filament thereby generating heat to promote expansion of said filament whereby said grid is slightly increased in gage length, placing said filament under tension by re-setting said winding pins to a new restrained position coinciding substantially with the increased gage length of said grid while continuing to apply heat, cutting off said current, allowing said filament to cool and contract, restraining said grid during thermal contraction whereby said filament is submitted to uniform axial strain and removing said grid from said winding pins, said grid having been formed with a permanent set therein.

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