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**Curtis et al.**

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[54] **METHOD OF PRODUCING A STRANDED WIRE ASSEMBLY BY FRICTION WELDING**

[75] Inventors: **Ronald E. Curtis**, Chillicothe, Ill.; **Gary L. English**, Scotia, N.Y.; **James R. Hense**, Peoria, Ill.

[73] Assignee: **Production Technology Inc.**, Peoria, Ill.

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[52] **U.S. Cl.** ......................**29/470.3,** 228/2, 339/275

[51] **Int. Cl.** ..............................................**B23k 27/00**

[58] **Field of Search** .........................29/470.3; 228/2; 156/73; 339/275, 276

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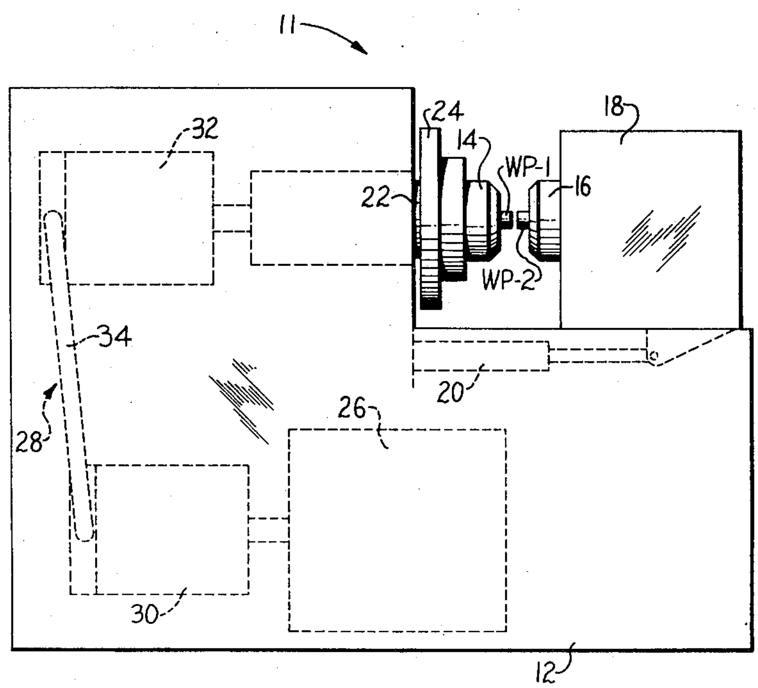
*Primary Examiner*—J. Spencer Overholser
*Assistant Examiner*—Robert J. Craig
*Attorney*—Fryer, Tjensvold, Feix, Phillips & Lempio

[57] **ABSTRACT**

A method for producing a stranded wire assembly whereby a connector member is metallurgically bonded to the end of a stranded wire cable. The wire cable is inserted into one end of a hollow sleeve member until the end of the cable is flush with the opposite end of the sleeve. The sleeve is then mechanically fastened to the cable and the coplanar surface of cable and sleeve is friction welded to the connector.

**2 Claims, 4 Drawing Figures**



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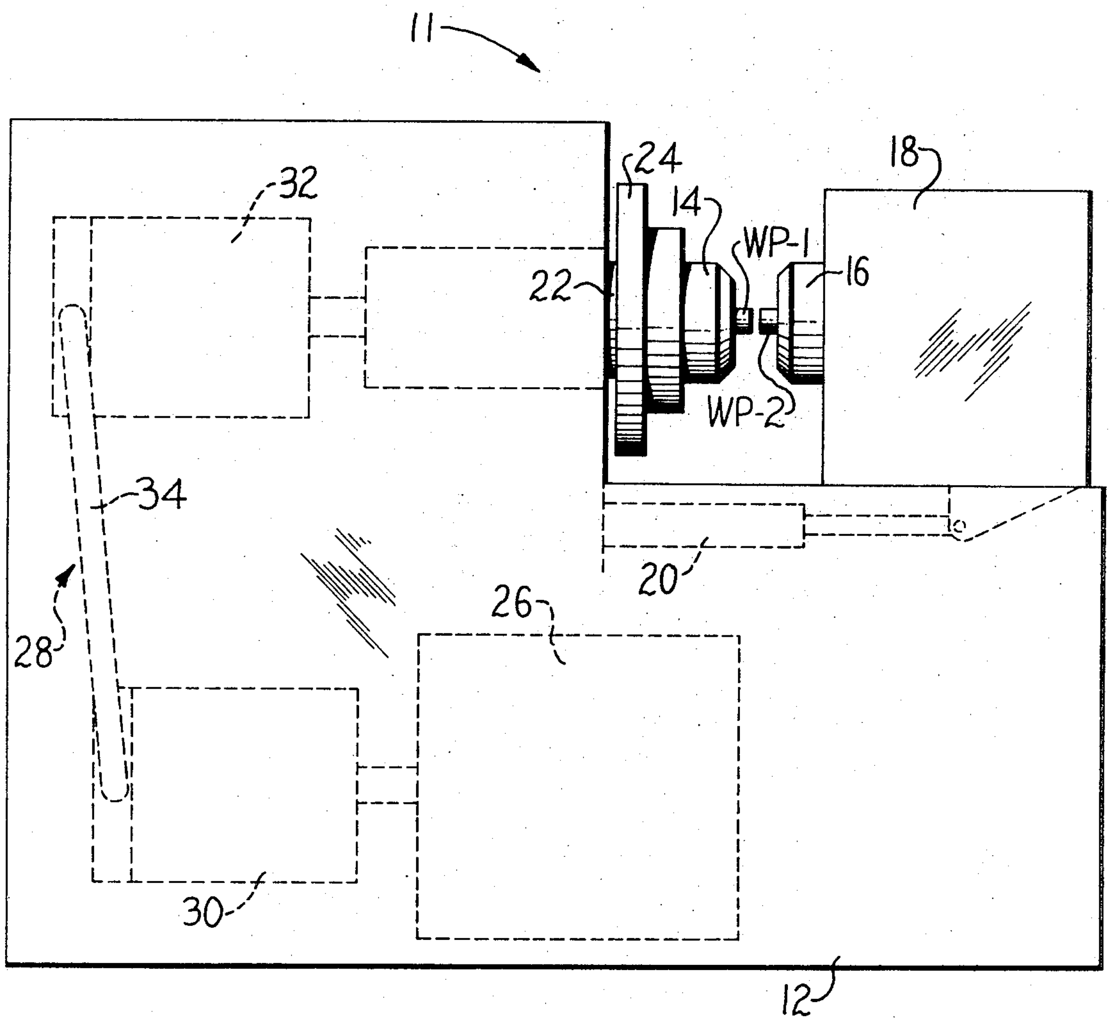



Fig_1

INVENTORS
RONALD E. CURTIS
GARY L. ENGLISH
JAMES R. HENSE

BY
Fryer, Tjensvold, Feix, Phillips & Lempio
ATTORNEYS

Fig. 2

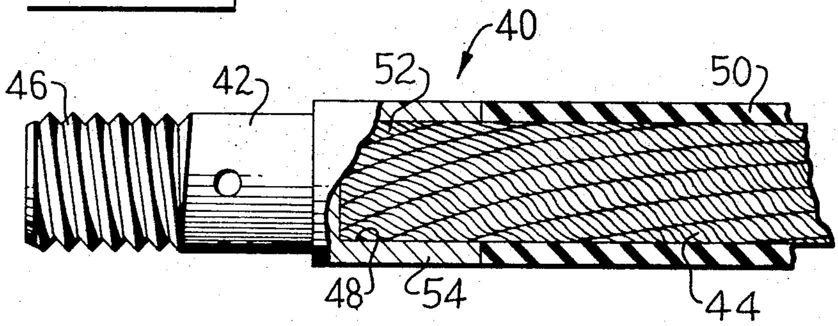



Fig. 3

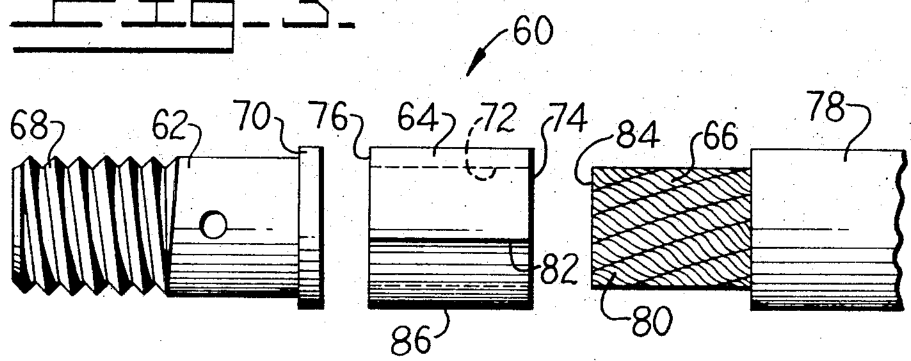
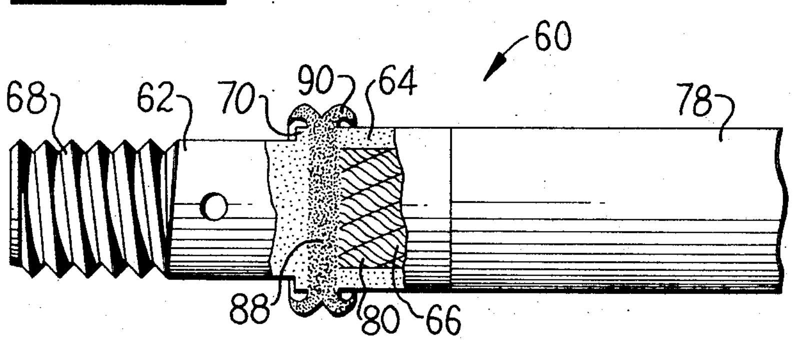



Fig. 4




INVENTORS
RONALD E. CURTIS
GARY L. ENGLISH
JAMES R. HENSE

BY

Fryer, Tjensvold, Feix, Phillips & Lempio
ATTORNEYS

# METHOD OF PRODUCING A STRANDED WIRE ASSEMBLY BY FRICTION WELDING

## BACKGROUND OF THE INVENTION

Various types of attaching methods are currently used to fasten stranded wire cables to connectors. All of the known methods employ some sort of mechanical locking means between the end of the cable and the connector. Typical of these methods are bolted together split clamps, tapered wedges and sleeves, split sleeves which are collapsed onto the cable, and various combinations of these methods.

Although presently known and used methods for fastening stranded cable to connectors are not always satisfactory, results must sometimes be comprised if it is necessary or desirable to use stranded cable. The elaborate and time-consuming methods of joining stranded cable to connectors results in rather expensive assemblies.

In the case of an electrical connection, wherein a current carrying stranded cable is fastened to a connector, a copper cable is mechanically fastened to the connector. In most such cases it is necessary to use a relatively large copper cable rather than less expensive aluminum cable, or smaller copper cable, due to the poor electrical conduction across the mechanical connection between cable and connector.

Although a metallurgical bond between the cable and connector, provided by welding, would be most desirable, it would be extremely difficult, if not impossible to weld the stranded cable to a connector using present welding methods and processes. For this reason, the various mechanical fastening methods previously mentioned are employed.

## SUMMARY AND OBJECTS OF THE INVENTION

The present invention relates to a method of producing a stranded wire cable assembly wherein the stranded cable is permanently bonded to a connector and the cable and connector are a honogeneous structure. The end of the cable is sufficiently restrained to allow friction welding of the cable to the connector. This produces a true metallurgical bond between cable and connector. Friction welding of the conventional or inertia type may be used.

It is, therefore, an object of this invention to overcome the above-described problems by providing a method of metallurgically bonding a stranded wire cable to a connector member.

It is also an object to restrain the end of the cable so that the cable strands can be friction welded to the connector.

It is a further object to friction weld a connector across a common coplanar surface of the cable and a restraining sleeve.

It is another object to produce a stranded cable assembly having mechanical and electrical conduction properties superior to presently known assemblies.

## BRIEF DESCRIPTION OF THE DRAWINGS

Other objects of this invention will become apparent from the following description and accompanying drawings wherein:

FIG. 1 is a side elevation view illustrating one embodiment of a friction welding machine which may be used to practice the method of the present invention;



FIG. 2 is a side view, partially in section, of a stranded wire assembly produced by one of the Prior Art methods;

FIG. 3 is a side view, partially in section of the individual components used in producing an assembly by the instant invention;

FIG. 4 is a side view, partially in section, of a completed assembly produced by the method of the present invention.

## DESCRIPTION OF THE PREFERRED EMBODIMENTS

A friction welding machine constructed in accordance with one exemplary embodiment of the present invention is indicated generally by the reference numeral **11** in FIG. **1**. As shown, the machine comprises a frame or housing structure generally denoted at **12** for housing the various elements of the machine. The two parts to be welded, workpieces **WP-1** and **WP-2** are mounted within chucks **14** and **16**.

The chuck **16** does not rotate and is mounted on a tailstock fixture **18**. The fixture **18** is mounted for axial movement on the machine frame **12** under the control of a load cylinder **20**. A pressure control circuit, not shown, regulates the pressure in the load cylinder, and thus determines the force with which the parts **WP-1** and **WP-2** are engaged.

The chuck **14** is mounted on a spindle **22**, and the chuck and spindle are mounted for rotation within the frame **12**. The rotary spindle **22** is adapted to receive flywheels **24** which may be of various size and mass depending upon the particular application of the machine.

An electric motor **26** rotates the spindle through a hydrostatic transmission generally indicated by the reference numeral **28**. The hydrostatic transmission includes a hydraulic pump **30**, a hydraulic motor **32**, and a manifold **34** between the pump and motor.

The drive ratio between the motor and the spindle **22** can be varied by changing the cam angles in either the pump **30** or the motor **32**, and the motor and pump can be used to effectively disconnect the motor **26** from the spindle **22** by moving the cam of the pump **30** to a position in which the pump **30** does not displace any hydraulic fluid to the motor **32**.

It is to be understood that the flywheel weights **24** are mounted on the spindle **22** so that the welding machine **11** can be operated as an inertia welding machine as described in U.S. Pat. No. 3,273,233 and as described in further detail below. A welding operation to join a first workpiece, such as an electrical connector designated as **WP-1** to a second workpiece such as an electrical cable designated as **WP-2**, for example, can be performed by operating the machine in the following general manner. The first workpiece **WP-1** is firmly clamped in the rotatable chuck **14** located on the spindle **22**. The second workpiece **WP-2** is firmly clamped in the non-rotatable chuck **16** which is located on the tailstock portion **18** of the machine. Upon actuation of the motor **26**, the flywheels and workpiece **WP-1** are accelerated to a predetermined velocity.

Once the predetermined velocity has been obtained, the motor **26** is disconnected or shut down and the ram mechanism **20** is actuated to move tailstock portion **18** forward and cause workpiece **WP-2** to contact the rapidly rotating workpiece **WP-1**. As the two workpieces are brought into contract under the upsetting pressure applied through the ram **20**, heat is generated at the contacting surfaces or interface of the weld pieces. This heating increases until the workpieces reach the welding temperature, at which time the upsetting pressure, applied by the ram **20** at either a constant or varying pressure, causes flashing or upsetting to occur. During this heating and flashing, the rotational velocity of the spindle member **22** has continued to decrease. At the time the rotation of the spindle ceases, upsetting has taken place and the weld is completed. The clamping force of chucks **14** and **16** is then released, ram **20** is then deactivated, and the completed weld assembly can be removed from the machine.

A stranded wire connector assembly produced by one of the presently known methods is illustrated in FIG. **2**. This assembly **40** is an electrical cable connector assembly and comprises a connector member **42** and a length of cable **44**. The connector member **42** contains a solid threaded portion **46** on the one end and a hollow bored portion **48** on the other end. The threaded portion **46** is for connecting the assembly **40** to a terminal (not shown), and the hollow bored portion **48** is for receiving an end of the cable **44**. A protective insulative coating **50** surrounds the cable **44** except for the end portion **52** which is inserted into the bored portion **48** of connector **42**.

Using presently known methods, the connector **42** and cable **44** are joined into the assembly **40** by inserting the bare end portion **52** of the cable into the bore **48** of connector **42**, and applying a circumferential pressure to the outside surface of the hollow bored portion **48** which causes the portion **48** to collapse on to the cable **44** and become mechanically attached to the cable. The walls **54** of bored portion **48** can contain one or more longitudinal slots to facilitate collapsing of the connector on to the cable.

In an electrical connector assembly such as **40**, electrical current is conducted from the cable **44** to the connector **42** by means of the external cable strands only. This is due to the nature of the mechanical joint between the connector **42** and the cable **44** wherein only the external strands of cable **44** are in intimate contact with the connector **42**. Since current is transmitted from the cable **44** to the connector **42** mainly by the external strands of the cable **44**, a larger cable is required to transmit a given amount of current from the cable to the connector. In such an electrical connector assembly, the more expensive copper cable must be used, as opposed to the less expensive aluminum cable, in view of the poor electrical conduction across the mechanical joint.

The friction welded stranded wire cable assembly **60** of the present invention, as best shown in FIGS. **3** and **4**, comprises a connector member **62**, a hollow circular sleeve member **64**, and a length of stranded wire cable **66**. As depicted in FIGS. **3** and **4**, assembly **60** is an electrical conductor assembly, similar to assembly **40** of FIG. 2.

Connector **62** is a solid member containing a threaded portion **68** on one end and a shoulder portion **70** on the other end. The sleeve **64** contains a through bore **72**, a first end **74** for receiving the stranded wire cable **66**, and a second end portion **76** for mating with the shoulder portion **70** of connector **62**. Sleeve **64** contains a longitudinal slot **82** cut through the wall of the sleeve and running the entire length of the sleeve. Although the slot **82** is shown as running parallel to the axis of the sleeve, it could also be cut at an angle to the longitudinal axis of the sleeve or in a spiral pattern around the sleeve. A protective coating **78** surrounds the stranded cable **66** except for the end portion **80** which is inserted into the bore **72** of sleeve **64**.

The individual components are permanently joined into an assembly in the following manner. The end portion **80** of cable **66** is inserted into the bore **72** of sleeve **64** until the end surface **84** of the cable is flush with the end surface **76** of the sleeve **64**. A radially inward compressive force is then applied to the circumferential surface **86** of sleeve **64** which causes the sleeve to collapse on to the cable **66** and thereby mechanically lock the sleeve **64** to the cable **66**. End surface **84** of cable **66** and end surface **76** of sleeve **64** now form a common coplanar surface.

The locked together sleeve and cable assembly is then clamped or fastened in a non-rotatable chuck or holding fixture on the tailstock portion of a friction welding machine. The connector member **62** is then clamped in a rotatable chuck or holding fixture on the spindle of the same machine. A friction welding operation, as previously described, is then performed and the common coplanar surface of the sleeve and cable is welded to the shoulder portion **70** of the connector member **62**.

The finished friction welded assembly **60** then consists of the sleeve and cable unit friction welded to the connector member at interface **88**. A true metallurgical bond now exists between the cable **66** and the connector **62**. The material of the cable **66** and of the connector **62** are then a homogeneous structure and there is absolutely no hinderance of electrical current flow between the two. Due to the metallurgical bond between the cable and the connector, and the fact that the materials are a homogeneous structure, in the embodiment of an electrical connector assembly, the less expensive aluminum cable can be used to replace the more expensive copper cable, since full electrical current flow is now available between cable and connector.

After the friction weld operation is completed, the flash **90** produced during the weld operation can be machined away to produce a smooth exterior surface. Once the flash **90** has been removed, there is no external evidence that a weld joint exists between the cable, sleeve and connector.

Although the above description indicates that the sleeve **64** is mechanically clamped on to the cable **66** while the pieces are outside the confines of the friction welding machine, it would be entirely possible, and even desirable, to allow the clamping force of the holding fixture to produce the force necessary to lock the sleeve on to the cable. This eliminates a separate operation for attaching the sleeve to the cable.

Although the present invention has been described herein with particular reference to its use as an electrical connector assembly, it is to be understood that the disclosed method and article is adaptable for use with other types of materials and applications, such as steel cable attached to an eye or hook connector. Also, it is to be understood that changes and modification may be made in the above-described methods without departing from the spirit and scope of the present invention as described in the appended claims.

We claim:

1. A method of joining a stranded wire cable to a connector comprising the steps of:

providing a hollow circular sleeve member containing a first and second end and forming in the sleeve a slot traversing the axial length of the sleeve,

inserting the wire into the first end of the sleeve until the end surface of the wire is flush with the second end of the sleeve to form a coplanar surface,

restraining radial outward movement of the ends of the strands by applying a radially inward compressive force to the circumferential surface of the sleeve to reduce the circumferential dimension of the sleeve and thereby mechanically fasten the wire within the sleeve, said compressive force being applied to a holding device forming a portion of a friction welding machine, and

relatively rotating and engaging the connector and the reduced end of the sleeve together, applying an axial load while in rotating rubbing contact to heat the engaged connector, sleeve, and wire to a plastic state to friction weld the coplanar surface of the sleeve and the wire to the connector.

2. A method as set forth in claim 1 wherein said friction welding is of the inertia type in which the energy required for welding is stored in rotating flywheels.

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