ABSTRACT: This invention relates to devices for coupling metallic tubes and in particular to a two piece magnetic swaging device having a split single turn winding in the form of a rectangular assembly with upper and lower symmetrical parts with semicylindrical recesses therein selectively joined to form the swaging device. The upper and lower pieces each consists of a solid half-turn coil with an extension which overlaps the extension of the other piece to provide parallel current paths and reduced circuit inductance.
TWO PIECE MAGNETIC SWAGING DEVICE

BACKGROUND OF THE INVENTION

The swaging of metallic tubes by magnetic forming is accomplished by applying magnetic pressure to the end portions of the tubes to be joined. A high amperage current is applied to a forming coil surrounding the tubes to generate a high intensity magnetic field which interacts with current in the skin of the tubes to generate the magnetic pressure. The large amount of pressure available from magnetic swaging produces a rigid and tight joint which is vastly superior to the more common methods of coupling tubes.

In a copending application entitled "Magnetic Swaging Device," in the name of Ralph W. Waniek, there is described a magnetic swaging device in which the swaging coil consists of two structural pieces which can be closed over metallic tubes to be joined and opened to be removed after the swaging operation. The massive single turn coil of two separable parts is especially adaptable in applications wherein tubs to be joined are either long, have their ends structurally obstructed, or vary appreciably in cross section.

The device of the present invention represents a substantial improvement over the above described magnetic swaging configuration and is aimed particularly at improving the efficiency of current conduction. In the above described copending application a single turn winding in the form of a rectangular assembly has upper and lower symmetrical parts with semicylindrical recesses therein joined to form the swaging device. The transition point between the parts has a high current overlap tab at right angles to the axis of the winding to reduce arcing during current passage. Nevertheless current problems such as arcing and increased inductance occur due to mechanical imperfections in the structure. The magnetic swaging device of the present invention reduces arcing and inductance by providing two parallel plates utilized as transmission lines for directly coupling current from a source to the swaging coils.

OBJECTS OF THE INVENTION

Accordingly it is an object of this invention to provide a two piece magnetic swaging device of improved efficiency. It is another object of this invention to provide a two piece magnetic swaging device having a low inductance in the current supply coils. It is a further object of this invention to provide a magnetic swaging device in which the current coils are two-piece coils of low inductance. It is still another object of this invention to provide a magnetic swaging device in which current is directly coupled from the energy source to the swaging coils.

SUMMARY OF THE INVENTION

The magnetic swaging device of this invention swages two tubes to be joined by magnetic forming. Two massive metallic structures are shaped to be joined and to form one massive single turn current coil having a recess for receiving the metallic tubes to be coupled by swaging. Each of the pieces of the coil consists of a solid semicircular shape having an extension which overlaps the extension of the other piece to provide a parallel current path. Each of the coils is structurally joined to and forms a part of a massive plate transmission line. The plates are completely overlapped to provide a low inductance current path.

According to one embodiment of the invention the two-piece coil is formed to provide a circular recess for insertion of tubes to be swaged. According to another embodiment of the invention a pair of coils are shaped to provide an opening whose connection is adjustable by moving the coil pieces vertically. In this manner the size of the cross section may be varied according to the desired size and shape of the tubes to be swaged. According to still another embodiment of the invention the two-piece coil is formed of two coil pieces each having flexible leads at their ends which are spring loaded to provide a compact magnetic swaging device. In still another embodiment of the invention the coil pieces are structured to be perpendicular to the flow of current through the circular recesses.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a magnetic swaging device of the invention illustrating an embodiment in which a pair of tubes are in place for swaging by magnetic forming. FIG. 2 is a view of the device of FIG. 1 showing the twopiece coil before being put in place for forming. FIG. 3 is a cross-sectional view of a magnetic swaging device of the invention illustrating another embodiment in which the two piece coil is in the form of a pair of pear-shaped coils. FIG. 4 is a cross-sectional view showing the coils of the device of FIG. 5, and FIG. 5 is a cross-sectional view of another embodiment of the invention in which the leads of the two-piece coils are flexibly attached during operation. FIG. 6 is an end view of the embodiment of the invention illustrated in FIG. 5. FIGS. 7a and 7b are views of another embodiment of the invention in which the swaging assembly is arranged to swage tubes of extreme length. FIGS. 8a and 8b illustrate an embodiment of the invention in which the swaging assembly is normal to the coils.

DETAILED DESCRIPTION OF A PARTICULAR EMBODIMENT

Referring to the drawings and in particular to FIG. 1 there is illustrated a magnetic swaging device according to the invention in which a pair of metallic tubes 11 and 12 are to be swaged. The tubes 11 and 12 may be obstructed such as being rigidly joined making it impractical to fit a multturn coil around the tubes at the point to be swaged. A pair of massive single turn coils 13 and 14 are fitted together to provide a split single turn structure having a cylindrical recess to encompass the metallic tubes 11 and 12. Each of the coils 13 and 14 is structurally joined to and forms a portion of a massive plate transmission line, 26 for coil 13, and 27 for coil 14 which is connected optionally through a coupling transformer 18 to a source of energy (as shown in FIG. 5) such as a capacitor bank through a switch. Thus the coils are directly coupled to the transformer 18 through the usual conductor leads. Each of the coils 13 and 14 is constructed identically as shown in the view of FIG. 2 with a suitable insulated separating the coils. The current path through the coils 13 and 14 is illustrated by arrows 26 for coil 13 and 27 for coil 14. The current from a transformer (shown in FIG. 5) is fed separately to each of the coils 13 and 14 or with the coils in series.

Each of the coils 13 and 14 has an extended portion of transmission line 24, for coil 13, and 25 for coil 14, as seen in FIG. 2, which overlaps the other extended portion of the other respective coil. The extended portions 26 and 27 are suitably insulated by insulator 29 to provide overlapping parallel plates. Metallic tubes 11 and 12 are suitably placed in the fitting hole formed by semicircular openings of the coils 13 and 14. When the coils 13 and 14 are fitted together under suitable pressure (not shown) a circular hole is formed to fit adjacent to the periphery of the tubes 11 and 12. The coils 13 and 14 are held together by suitable means for maintaining them structurally joined even at a large pressure. In the cylindrical recess formed by the coils 13 and 12 the tubes 11 and 12 are insulated from the coils 13 and 14 by insulator 26. The coils 13 and 14 are insulated from each other at the junction points by insulator 27.

Magnetic swaging of the tubes 11 and 12 is accomplished by the generation of magnetic pressure by the interaction of the magnetic field generated by the coils 13 and 14 on the skin of
the tubes 11 and 12 and the current flowing in the tubes. Magnetic pressure is simultaneously applied to the upper and lower halves of the tubes 11 and 12 by the simultaneous application of high current pulses to the coils 13 and 14.

As current flows from the transformer into the coil pieces 13 and 14 current paths are created through the extension pieces 24 and 25 which are in parallel and thus provide a low inductance path to minimize current losses. As seen by arrows 28 and 29 in FIG. 2, current in the coils 13 and 14 flows in parallel at the extensions 26 and 27.

In another embodiment of the invention as shown in FIGS. 3 and 4 the massive single turn coil is achieved by two pole pieces 31 and 32 which have noncircular openings and adapted to fit over each other to form an aperture which is varied in cross section by the movement of the coils 31 and 32 with respect to each other. The coil 31 is a massive single turn coil and is connected to receive a high amp current pulse from the high current pulse transformer connected to a suitable energy source through a switch. The coil piece 32 is similarly shaped and connected to receive a current pulse from a transformer in turn connected to a capacitor through a switch (as seen in FIG. 5). The pieces 31 and 32 are complimentarily shaped so that when fitted over each other as shown in FIG. 4 they form a cylindrical recess which can be varied in size and shape to fit the tubes to be swaged. Movement of the coils 31 and 32 up and down allows the increase of the opening to fit tubes with protrusions.

In the embodiment of FIGS. 3 and 4 current passes through the pieces 31 and 32 along current paths which are in parallel as illustrated by the arrows 41 and 42 in FIG. 4.

FIGS. 5 and 6 illustrate an embodiment of the invention in which a pair of coil pieces 51 and 52 each has flexible leads which are under suitable pressure (not shown) when the pieces 51 and 52 are in position for swaging.

Referring now to FIGS. 7a and 7b there is illustrated an embodiment of the invention in which the swaging coil lies in a surface which is at an angle with the transmission lines. In FIGS. 7a and 7b the coils 61 and 61 are fed current from a source (not shown) through parallel transmission line plates 64 and 65. Tubes 66 and 67, to be swaged, may have protrusions (not shown) which will not interfere with the transmission line plates 64 and 65.

In FIGS. 8a and 8b the swaging coils 71 and 72 lie in a surface which is normal to the surface of the transmission line plates 73 and 74. The device of FIGS. 8a and 8b has the same advantage of the device of FIGS. 7a and 7b, in addition to being more adaptable to fit the necessary hardware for applying pressure to the coil during the swaging operation.

The illustrated magnetic swaging devices swage a pair of metallic tubes. It is to be realized that it is within the scope of the invention for a device patterned after those illustrated in the drawings to swage any shape metallic objects other than the cylindrical shapes illustrated.

While the invention has been disclosed herein with respect to the embodiments illustrated in the drawings, it will be readily apparent that numerous variations and modifications may be made within the spirit and scope of the invention. It is claimed:

1. In a magnetic swaging device, a pair of semicircular coils arranged to fit side by side to form a single current carrying swaging coil, each said coil having an extended portion overlapping the extended portion of the other said coil, each said coil forming one-half of an assembly having upper and lower symmetrical parts consisting of said coils with semicircular recesses therein, said coils overlapping each other except in the region of said circular recesses, a pair of transmission lines structurally joined to respective coils, a source of high current energy for each said transmission line, said coils responsive to said sources of energy connected through said transmission lines for generating magnetic fields, each said coil having a magnetic field penetrating said semicircular recesses, the current flowing through each said coil overlapping the current flowing in the other said coil so as to provide a low impedance, said circular recess adapted to receive a pair of metallic tubes to be swaged.

2. The magnetic swaging device recited in claim 1 wherein said coils are noncircularly shaped to provide a circular aperture of variable cross section as said coils are moved with respect to each other.

3. The magnetic swaging device recited in claim 1 wherein said transmission lines are in the form of parallel plates.

4. The magnetic swaging device recited in claim 1 wherein said transmission lines are in the form of parallel plates which are arranged to completely overlap each other to provide extremely low impedance to the flow of current.

5. The magnetic swaging device recited in claim 1 wherein said transmission lines are in a surface normal to the surface of said coils.

6. The magnetic swaging device recited in claim 1 wherein said transmission lines are in the form of parallel plates which lie in a surface parallel to the surface of said coils.

7. The magnetic swaging device recited in claim 1 wherein said transmission lines are in the form of parallel plates which lie in a surface at a predetermined angle to the surface of said coils to allow noninterference with said metallic tubes.