A method and apparatus for interlocking at least one first tube (10) having a first diametric spacing between opposite points of the tube wall with a second tube (4) having a second diametric spacing between opposite points of the tube wall which is larger than the first diametric spacing. The first tube is loaded over a mandrel (50) having a punching end (54), and disposed into a holding block (30) having a holding cavity (32) conforming closely to the outer surface of the first tube. The second tube is disposed over a receiving block (40), which has a receiving cavity conforming closely to the outer surface of the first tube. The punching end of the mandrel is driven through the second tube and into the cavity in the receiving block, followed by the first tube. When the first tube reaches a lower limit of the receiving cavity, the first tube is compressed axially. The mandrel supports the interior of the first tube, the holding cavity prevents the trailing portion of the first tube from swelling outwardly, and the receiving cavity prevents the leading portion of the first tube from swelling outwardly. Thus, the portion of the first tube disposed inside the second tubular member swells under the axial compressive force, permanently interlocking the first tube with the second tube. The punching steps can be separated from the remaining steps of the method of the invention, or the second tube can be pre-punched. In further embodiments the method and apparatus of the invention can create a clinched interlock and/or a 'T'-shaped interlocked assembly.
METHOD AND APPARATUS FOR INTERLOCKING TUBULAR MEMBERS

FIELD OF THE INVENTION

This invention relates to the construction of tubular frames. In particular, this invention relates to a method and apparatus for interlocking tubular members without welding.

BACKGROUND OF THE INVENTION

Tubular frames are used in many applications. A tubular frame can be used to form a support for myriad types of materials, for example springs, cushions, straps, fabric etc. Although the tubular frame is often concealed within these other materials, it forms the support infrastructure and provides the necessary strength for the finished article.

Many components of an automobile are constructed from one or more tubular frames. In one common example, an automobile seat is constructed by layering springs, cushioning and fabric over a tubular seat frame. The main seat frame is typically bent from a single length of tubing, for example, cylindrical steel tubing. However, a typical seat frame consists of many tubular subassemblies and components, each of which must be affixed to the main seat frame.

The conventional method of affixing a tubular component to another tubular component, such as a tubular frame, is by welding. Using the example of an automobile seat frame, in order to affix a headrest support to the main seat frame a tubular support post is welded to the top member of the seat frame.

However, welding is a slow, labour-intensive, inconsistent and dirty process. Further, the welding of parts creates quality control concerns, even when welding is effected by a skilled welder. The effectiveness of a weld is typically assessed visually, and problems such as burn-through, metal fatigue in the material surrounding the weld, incomplete adhesion due to contaminants on the tubular components and so on, are not always avoidable. In applications such as automobile parts, these types of problems can cause serious safety concerns.

U.S. Pat. No. 6,035,516 entitled “Securement of Head Rest Support into Automobile Seat Frame”, issued Mar. 14, 2000 to Petersen, which is incorporated herein by reference, describes a method of securing a headrest support to a tubular seat frame which presses the tubular seat frame flat at the position of the joint, and utilizes lock-beads swaged into the headrest support post on either side of the main frame member to secure the post. Although this process does not involve welding, it is a multi-step process which requires many expensive machinery stages for automated production. Also, because the frame is flattened, the tangent points at which the support post contacts the frame are brought very close together, so the resistance against torsional stresses is reduced.

It would accordingly be advantageous to provide a method for affixing tubular components to other tubular components without the need for welding and in a single-step process, while increasing the strength and consistency of the joints, by removing the element of judgment and other variables inherent in the welding process.

SUMMARY OF THE INVENTION

The present invention overcomes these disadvantages by providing a method and apparatus for interlocking tubular members, which is especially suitable for metal tubes. According to the method of the invention, a first tubular member (for example a headrest support post) having a first diametric spacing between opposite points of its wall is interlocked with a second tubular member (for example the main frame of an automobile seat) having a second diametric spacing between opposite points of its wall which is larger than the first diametric spacing. In the preferred embodiment this is accomplished in a single operation, thus saving considerable time and cost relative to conventional welding operations, and relative to the swaging process described in U.S. Pat. No. 6,035,516, while providing a much stronger connection between the interlocked components.

The invention accomplishes this by loading the first tubular member over a mandrel having a punching end, and disposing one end of the first tubular member into a holding block having a holding cavity conforming closely to the outer surface of the first tubular member. The second tubular member is disposed in the required orientation (typically substantially perpendicular to the first tubular member) over a receiving cavity in a receiving block, the receiving cavity also conforming closely to the outer surface of the first tubular member. The punching end of the mandrel and the first tubular member are driven through the second tubular member. The mandrel punches through opposed points in the wall of the second tubular member and penetrates into the receiving cavity in the receiving block, followed by the first tubular member.

When the first tubular member reaches the lower limit of the receiving cavity, an axial compressive force is applied to the first tubular member. The mandrel supports the interior of the first tubular member along substantially its entire length, and thus prevents the first tubular member from buckling inwardly under the axial compressive force. The holding cavity in the holding block prevents the trailing portion of the first tubular member (disposed within the holding cavity) from swelling outwardly under the axial compressive force. Similarly, the receiving cavity in the receiving block prevents the leading portion of the first tubular member (which has penetrated into the receiving cavity) from swelling outwardly under the axial compressive force. Therefore, the only portion of the first tubular member which can deform under the axial compression is an interlocking portion, i.e. the portion of the first tubular member disposed inside the second tubular member. The interlocking portion of the first tubular member swells under the axial compressive force, positively engaging the wall of the first tubular member against the shoulders created in the wall of the second tubular member by the punching end of the mandrel. The first tubular member is thus permanently interlocked with the second tubular member. The interlocked assembly can then be removed from the holding and receiving blocks and the mandrel withdrawn from the first tubular member for further processing.

In the preferred embodiment the lower limit of the receiving cavity is defined by a tube seat disposed in the receiving cavity, having a hollow end for receiving the punching end of the mandrel. Also, in the preferred embodi-
The holding and receiving blocks in the apparatus of the invention may be provided with a single holding cavity and receiving cavity, respectively, for interlocking a single tubular member with another tubular member. In an alternate embodiment the holding and receiving blocks can be respectively provided with multiple holding cavities and receiving cavities, allowing for the simultaneous interlocking of a plurality of first tubular members with the second tubular member. In either embodiment, the apparatus of the invention is easily automated because it is a single-stroke process.

Thus, in one stroke the apparatus of the invention provides a complete and fully secure interlocking engagement between the first and second tubular members. In effect, the first tubular member is embedded in the second tubular member. The protruding shoulder formed by punching through the wall of the second tubular member provides additional support for the joint against torsional forces, and the entrance to the receiving cavity may be bevelled or chamfered to control the depth and angle of the protruding shoulder.

It will be appreciated that the method and apparatus of the invention can be used with any malleable tubing, including without limitation metal, plastic and other composites. The invention is particularly well suited for use with metal tubing, of any desired diameter and having any desired cross sectional configuration or geometry including, without limitation, round, oval, square, hexagonal etc. The invention can also be used to join tubing of different compositions and/or geometries, the only limitations being that the tubing must be hollow, the wall of the first tubular member must be malleable, and the diametric spacing between opposite points of the wall of the second tubular member must be larger than or equal to the diametric spacing between opposite points of the wall of the first tubular member. Thus, for example, the second tubular member can be nominally smaller than the first tubular member, but the invention can be applied as long as the second tubular member is flattened so that it has, in one direction, a diametric spacing between opposite points of its wall which is larger than or equal to a diametric spacing between opposite points of the wall of the first tubular member.

The holding and receiving cavities and the mandrel body are configured according to the configuration of the tubing, to ensure that the axial compressive force applied during the interlocking process causes only the interlocking portion of the first tubular member to swell. The interlocking method according to the invention is much faster and less expensive than both welding and swaging techniques, and provides a cleaner, more consistent result having a greater joint strength.

It will also be appreciated that the steps of punching the second tubular member and driving the first tubular member through the holes in the second tubular member can be separated. For example, opposed holes can be pre-punched or pre-cut through the wall of the second tubular member, and the method and apparatus of the invention can be applied to affix the first tubular member to the second tubular member without the punching step being involved in the actual securing process.

In further embodiments of the invention the second tubular member may be generally flattened when the first tubular member is punched through, and beads may be formed in the first tubular member above and/or below the wall of the second tubular member. The apparatus for producing this embodiment is modified to provide spaces into which the wall of the first tubular member can expand to form the beads. Also, a 'T'-shaped interlocking tube assembly may be formed in accordance with a further embodiment of the invention by omitting the receiving cavity so that the first tubular member bottoms out on the bottom wall of the second tubular member.

The present invention thus provides a method of interlocking a first tubular member having a first diameter with a second tubular member having a second diameter larger than or equal to the first diameter and opposed holes having diameters substantially equal to the diameter of the first tubular member, comprising the steps of: a) disposing through the first tubular member a mandrel having a body with an exterior surface substantially conforming to an interior surface of the first tubular member, to support the interior surface of the first tubular member; b) disposing a trailing end of the first tubular member within a holding cavity in a holding block, the holding cavity supporting an outer surface of the trailing end; c) driving the a leading end of the first tubular member through the wall of the second tubular member and into a receiving cavity in a receiving block, the receiving cavity supporting an outer surface of the leading end, until the leading end reaches a lower limit; and d) applying an axial compressive force to the first tubular member; whereby an unsupported portion of the first tubular member contained within the second tubular member swells under the axial compressive force, interlocking the first tubular member to the second tubular member.

The present invention further provides a method of interlocking a first tubular member having a first diameter with a second tubular member having a second diameter larger than or equal to the first diameter, comprising the steps of: a) punching through a wall of the second tubular member to create opposed holes having diameters substantially equal to the diameter of the first tubular member, b) disposing through the first tubular member a mandrel having a body with an exterior surface substantially conforming to an interior surface of the first tubular member, to support the interior surface of the first tubular member; c) disposing a trailing end of the first tubular member within a holding cavity in a holding block, the holding cavity supporting an outer surface of the trailing end; d) driving a leading end of the first tubular member through the wall of the second tubular member and into a receiving cavity in a receiving block, the receiving cavity supporting an outer surface of the leading end, until the leading end reaches a lower limit; and e) applying an axial compressive force to the first tubular member; whereby an unsupported portion of the first tubular member contained within the second tubular member swells under the axial compressive force, interlocking the first tubular member to the second tubular member.
under the axial compressive force, interlocking the first tubular member to the second tubular member.

[0020] In further aspects of the method of the invention: the mandrel is provided with a punching end and the steps of punching through the wall of the second tubular member and driving the a leading end of the first tubular member through the wall of the second tubular member are performed in a single stroke; an entrance to the receiving cavity is bevelled; the second tubular member is disposed within a channel having a configuration conforming to an outer surface of the second tubular member and extending over an entrance to the receiving cavity; the channel is formed in the receiving block; the holding block is provided with a channel conforming to an outer surface of the second tubular member and extending over an entrance to the holding cavity; the method includes, before step a., the step of clamping the holding block against the receiving block; the first tubular member is driven through the second tubular member by a punch plate to which the mandrel is anchored; and/or the method is used for interlocking a plurality of first tubular members with the second tubular member; the lower limit of the receiving cavity is defined by a tube seat.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] In drawings which illustrate by way of example only a preferred embodiment of the invention,

[0024] FIGS. 1A to 1C are schematic perspective views of the first and second tubular members before, during and after the interlocking method of the invention, respectively;

[0025] FIGS. 2A to 2G are schematic perspective views of the apparatus of the invention during the stages of the interlocking method of the invention,

[0026] FIG. 2H is a cross-sectional perspective view of an interlocked tube assembly constructed according to a first embodiment of the invention;

[0027] FIG. 3 is a perspective view of the punch plate;

[0028] FIG. 4 is a perspective view of the mandrel;

[0029] FIG. 5 is a perspective view of the holding block;

[0030] FIG. 6 is a perspective view of the receiving block;

[0031] FIG. 7 is a perspective view of the die button;

[0032] FIG. 8 is a perspective view of the tube seat;

[0033] FIG. 9 is a cross-sectional perspective view of an interlocked tube assembly constructed according to a further embodiment of the invention;

[0034] FIG. 10 is a cross-sectional perspective view of the apparatus of the invention for constructing the interlocked tube assembly of FIG. 9;

[0035] FIG. 11 is a cross-sectional perspective view of a "T"-shaped interlocked tube assembly constructed according to a further embodiment of the invention; and

[0036] FIG. 12 is a cross-sectional perspective view of the apparatus of the invention for constructing the interlocked tube assembly of FIG. 11.

DETAILED DESCRIPTION OF THE INVENTION

[0037] The principles and operation of the method and apparatus of the invention will be described in the context of affixing a headrest support post 10 (a first tubular member) to a frame member 4 (a second tubular member) of the main seat frame 2 of an automobile seat (not shown). It will be appreciated that the method and apparatus of the invention can be equally implemented in numerous other environments, industries and applications, and the following description in the environment of an automobile seat frame is merely an illustrative example.

[0038] The components of the apparatus 20 of the invention are illustrated in FIGS. 3 to 8. In the preferred embodiment the apparatus 20 comprises a holding block 30 comprising at least one holding cavity 32; a receiving block 40 comprising at least one receiving cavity 42, disposed in opposition to the holding cavity 32; for each set of holding/ receiving cavities 32, 42, a mandrel 50 having an anchored end 52 and a punching end 54 with a punch 56; a punch plate 60 to which the mandrels 50 are anchored; and for each mandrel 50 a tube seat 70 anchored to a seat plate 80.
The holding block 30 is preferably provided with a channel 34 extending over the holding cavities 32, configured to substantially conform to the outer wall of the frame member 4. Similarly, the receiving block 40 is preferably provided with a channel 44 extending over the receiving cavities 42, also configured to substantially conform to the outer wall of the frame member 4. In the embodiment shown the channels 34, 44 are each semi-circular in cross-section, to thus closely conform to the cylindrical outer surface of the frame member 4 when the holding and receiving blocks 30 and 40 are clamped together. This holds the frame member 4 securely in place during the interlocking process, and resists flattening of the frame member 4 under the compressive force imparted by the punching end 54 of the mandrel 50. The holding block 30 and receiving block 40 are mounted in opposition, preferably so that they can be moved toward and away from each other for loading the support posts 10 onto the mandrels 50, and for clamping the frame member 4 into position for interlocking.

Each mandrel 50 has a body 58 configured with a close tolerance to the inner wall of the support post 10, which in the embodiment shown is cylindrical, and extends substantially the entire length of the support post 10. The anchoring ends 52 of the mandrels 50 are anchored to the punch plate 60, for example bolted, in anchoring recesses 62. The mandrels 50 are positioned on the punch plate 60 such that the mandrels 50 slidably extend through openings (not shown) into the holding cavities 32. The punching ends 54 of the mandrels 50 thus can be moved to protrude out of the holding cavities 32 and penetrate through the frame member 4 and into the receiving cavities 42 during the interlocking operation.

Preferably a tube seat 70, for example a die button having a hollow end for receiving the punching end 54 of the mandrel 50, is disposed within each receiving cavity 42, anchored to a seat plate 80. The tube seats 70 are each provided with an opening 72 facing the punching end 54 of the corresponding mandrel 50, forming a punch seat 74 into which the punching end 54 can nest without damaging the punch 56. The rim 76 of the tube seat 70 forms a lower limit of the path of travel of the support post 10, as described below.

It will be appreciated that the tube seats 70 and seat plate 80 can be formed as an integral unit if desired. Also, the use of a separate tube seat 70 facilitates changing the lower limit of the receiving cavity 42, for example to accommodate a different length of support post 10, by merely switching to a tube seat 70 of a different length. However, the lower limit can instead be formed within the receiving cavity 42 itself, for example as a ledge milled into the cavity wall, although this is less convenient as it would require changing the entire receiving block 40 in order to accommodate a different length of support post 10.

All of the components of the apparatus are composed of a strong, rigid material, for example hardened steel, in order to withstand the stresses of the interlocking operation without substantial deformation or deterioration. The apparatus 20 may be actuated by any suitable reciprocating device (not shown), for example a motor, solenoid, hydraulic or pneumatic piston, etc. Electrical actuators are preferred, as they ordinarily provide faster cycle intervals.

The apparatus 20 of the invention has been described and illustrated using an embodiment arranged to simultaneously interlock two support posts 10 to the frame member 4. It will be appreciated that the apparatus 20 can be designed to interlock a single support post 10 to the frame member 4, or to interlock more than two support posts 10 to the frame member 4, depending solely upon the number of holding and receiving cavities 32, 42 respectively provided in the holding and receiving blocks 30, 40, each with an associated punching mandrel 50, and with the appropriate compressive force applied to deform multiple support posts 10.

Further, the apparatus of the invention has been described using tubular members 4 and 10 which each have generally circular cross-sections, in which case the frame member 4 must have a diameter which is larger than or equal to the diameter of the support posts 10, so that the second tubular member has a diametric spacing between opposite points of its wall (in this case, any diameter) which is larger than or equal to a diametric spacing between opposite points of the wall of the first tubular member. However, as noted above, the invention can be implemented if the support posts 10 were nominally larger than the frame member 4, as long as the frame member 4 is flattened so that it has, in one direction, a diametric spacing between opposite points of its wall which is larger than a diametric spacing between opposite points of the wall of the support posts 10.

The operation of the invention will be described in relation to a preferred embodiment of the method of the invention, illustrated in FIGS. 2A to 2C. The mandrel 50 is inserted through the holding block 30, and the headrest support posts 10 are loaded onto the mandrels 50 with their trailing ends 10v inserted into the holding cavities 32, as shown in FIG. 2A. The frame member 4 is loaded into the channel 44 in the receiving block 40, as shown in FIG. 2B. FIG. 2C illustrates a cross-section of the apparatus with the support posts 10 and frame member 4 loaded for interlocking. The holding block 30 and receiving block 40 are then clamped together, securing the frame member 4 in position, as shown in FIG. 2D.

The punch plate 60 is driven toward the holding block 30 by an actuator (not shown), which in turn drives the mandrels 50 through opposed sides of the wall of the frame member 4 and forces the leading ends 10b of the support posts 10 through the openings punched through the wall of the frame member 4, until the leading ends 10b of the support posts 10 strike the rims 76 of the tube seats 70. At this stage the support posts 10 are in the correct within the frame member 4 for interlocking, and there remains a small clearance or gap between the punch plate 60 and the holding block 30, as shown in FIG. 2E. In the preferred embodiment there is also a small clearance or gap between the seat plate 80 and the receiving block 40, as shown in FIG. 2E.

With the support posts 10 abutting the lower limit of the receiving cavities 42, defined by the rims 76 of the tube seats 70, as the punch plate 60 is driven into contact with the holding block 30 (as shown in FIG. 2F) the seat plate 80 is brought into contact with the receiving block 40 and the support posts 10 are thus axially compressed, because the tube seats 70 block the leading ends 10b of the support posts 10 from moving further into the receiving cavities 40. It will be appreciated that the punch seat 74 must extend sufficiently deep within the hollow end of the tube seat 70 that the punching end 54 of the mandrel 50 does not
contact the punch seat 74 before the punch plate 60 contacts the holding block 30, to ensure that the mandrel 50 does not resist the axial compressive force applied to deform the support post 10.

[0049] The body 58 of the mandrel 50 supports the interior surface of the support post 10 and prevents the support post 10 from buckling inwardly under the axial compressive force. The holding and receiving cavities 32, 42 respectively support the outer surface of the support post 10. Thus, the holding cavity 32 prevents the trailing end 10a of the support post 10 from swelling outwardly under the axial compressive force, and the receiving cavity 42 prevents the leading end 10b of the support post 10 from swelling outwardly under the axial compressive force. Therefore, the only unsupported portion of the wall of the support post 10 is the outer wall of the interlocking portion 12, which is the portion of the support post 10 disposed inside the frame member 4. The interlocking portion 12 thus swells under the axial compressive force, positively engaging the wall of the support post 10 against the shoulders 4a, 4b created in the tube wall by the punching end 54 of the mandrel 50 (best seen in FIG. 21H). The entrance to the receiving cavity 42 may be bevelled or chamfered, as at 42a, to control the depth and angle of the protruding shoulder 4b.

[0050] Following the application of axial compressive force the support post 10 cannot be moved axially relative to the tubular member 4, because the swollen interlocking portion 12 is larger than the openings in the wall of the frame member 4. The swollen interlocking portion 12 of the support post 10 positively engages against the shoulders 4a, 4b formed in wall of the frame member 4, providing resistance to rotational and torsional forces. The support posts 10 are thus permanently interlocked with the frame member 4. The holding and receiving blocks 30, 40 are then drawn apart, withdrawing the mandrels 50 from the support posts 10 as shown in FIG. 2G, and the interlocked assembly (shown in FIG. 2H) can be removed from the receiving block 40 for further processing.

[0051] Thus, in a single stroke the apparatus 20 of the invention can provide a complete and fully secure interlocking engagement between the support posts 10 and frame member 4, without welding and without the need to swage or affix extraneous components to secure the joint.

[0052] To effect the steps of punching through the wall of the frame member 4 and driving the a leading end of the support post 10 through the wall of the frame member 4 in a single stroke, the mandrel 50 is provided with a punching end 54. However, it will be appreciated that in an alternative embodiment the steps of punching through the wall of the frame member 4 and driving the a leading end of the support post 10 through the wall of the frame member 4 can be effected in two separate operations, in which case the mandrel 50 need only be configured to support the interior wall of the support post 10. Although the wall of the frame member 4 must be punched before the support post 10 is driven through the frame member 4, the support post 10 can be loaded on the mandrel 50 and into the holding block 30 either before or after the punching step. This two-stroke method is somewhat less efficient, but the principles of the invention apply equally and the resulting joint would be comparable to the single-stroke method described above.

[0053] As noted above, the steps of punching the frame member 4 and driving the support post 10 through the frame member 4 can be separated. For example, opposed holes can be pre-punched or pre-cut through the wall of the frame member 4, and the method and apparatus of the invention can be used to affix the support post 10 to the frame member 4 in the manner described above.

[0054] It is also possible to punch through the frame member 4 so that a protruding shoulder 4a is created exterior to both of the opposed holes. This is accomplished by piercing through the frame member 4 to create small holes at the desired position; positioning a ball bearing or other like element of the required diameter (i.e. the diameter of the support post 10) inside the frame member 4 at the position of the holes; driving the ball bearing through one of the holes from inside the frame member 4; repositioning the ball bearing or other like element inside the frame member 4 at the position of the holes; and driving the ball bearing through the other of the holes from inside the frame member 4. This provides the advantage of greater distance between the tangent points, which in turn provides greater support for the joint.

[0055] In the embodiment described above, the tube seat 70 is lodged in a stationary position within the receiving cavity 42. Optionally a compressive cushion, for example a nitrogen spring (not shown), is disposed in the receiving cavity 42 beneath the tube seat 70, so that the tube seat 70 is initially raised in the receiving cavity 42, and as the mandrel punches through the tubular member 4 and enters into the receiving cavity 42, the tube seat 70 is pushed through the receiving cavity 42 as the holding block 30 is clamped to the receiving block 40. This may facilitate a more controlled compression of the support post 10.

[0056] As shown in FIG. 2F, the holding and receiving cavities 32, 42 may optionally be provided with annular cavities 32a, 42a immediately above and below the position of the frame member 4 (allowing clearance for the shoulder 4a). In this embodiment, when axially compressed the support post 10 expands into the annular cavities 32a, 42a to create swage rings 10a, 10b, for additional support.

[0057] In the preferred embodiment described above, the frame member 4 is clamped within the tubular channel formed by the channel 34 in the holding block 30 and the channel 44 formed in the receiving block 40. This retains the frame member 4 in position and helps to ensure that only the punched portion of the frame member 4 deforms under the punching force of the mandrel 50. However, it will be appreciated that other means can be used for retaining and supporting the frame member 4 during the interlocking process.

[0058] Although the preferred embodiment of the invention so described and illustrated is adapted for interlocking two support posts 10 with the frame member 4, the holding and receiving blocks 30, 40 may be provided with a single holding cavity 32 and receiving cavity 42, respectively, for interlocking a single support post 10 with the frame member 4, or the holding and receiving blocks 30, 40 can be respectively provided with any desired additional number of holding cavities 32 and receiving cavities 42, allowing for the simultaneous interlocking of any number of support posts 10 with the frame member 4.

[0059] FIG. 9 illustrates a further embodiment of the invention that provides particularly strong resistance to
rotation of the first tubular member 110 (e.g., a support post) in the second tubular member 104 (e.g., a frame member). The second tubular member 104 is generally flattened when the first tubular member 110 is punched through, and beads 110a, 110b are formed in the first tubular member 110 against both the interior and the exterior the wall of the second tubular member 104.

[0060] The apparatus for producing this embodiment is shown in FIG. 10, in which the holding block 130 comprises at least one holding cavity 132 having a recess 131 which provides a space into which the wall of the first tubular member 110 expands to form the bead 110a; the recess 131 being formed about a mouth 133 which flattens the second tubular member 104 during compression. Likewise, the receiving block 140 comprises at least one receiving cavity 142, disposed in opposition to the holding cavity 132, having a recess 141 which provides a space into which the wall of the first tubular member 110 expands to form the bead 110b; and the recess 141 is formed about a mouth 143 which flattens the second tubular member 104 during compression.

[0061] As long as equal force is applied to each end of the first tubular member 110 during the compression stage, the beads 110a, 110b will form substantially equally and will clinch the wall of the second tubular member 104 tightly to resist both axial dislodgement of the first tubular member 110 from the second tubular member 104 and rotation of the first tubular member 110 within the second tubular member 104. In this embodiment, the extent of expansion of the wall of the first tubular member 110 inside the second tubular member 104 is limited because the second tubular member 104 is flattened during the compression process. The size of the beads 110a, 110b can be controlled by a combination of the size of the recess 131, 134 and the length of the compression stroke. This embodiment of the invention otherwise operates as described above.

[0062] FIG. 11 illustrates a "T"-shaped interlocking tube assembly, formed in accordance with a further embodiment of the invention. In this embodiment, shown in FIG. 12, the receiving block 240 does not have a receiving cavity. The leading end of the first tubular member 210 bottoms on the bottom wall of the second tubular member 204, which serves as a tube seat (supported by the channel 244, to prevent deformation of the wall of the second tubular member 204), and the application of a compressive force by the punch plate 260 swells the first tubular member 210 in the manner described above. This embodiment of the invention otherwise operates as described above, with or without a bead 210a.

[0063] Various embodiments of the present invention having been thus described in detail by way of example, it will be apparent to those skilled in the art that variations and modifications may be made without departing from the invention. The invention includes all such variations and modifications as fall within the scope of the appended claims.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A method of interlocking a first tubular member having a first diametric spacing between opposite points of a wall of the first tubular member with a second tubular member having a second diametric spacing diametric spacing between opposite points of a wall of the first tubular member which is larger than or equal to the first diametric spacing, comprising the steps of:

   a. punching through a wall of the second tubular member to create opposed holes each having a diametric spacing between opposite points of an edge of the hole substantially equal to the diametric spacing of the first tubular member,

   b. disposing through the first tubular member a mandrel having a body with an exterior surface substantially conforming to an interior surface of the first tubular member, to support the interior surface of the first tubular member;

   c. disposing a trailing end of the first tubular member within a holding cavity in a holding block, the holding cavity supporting an outer surface of the trailing end;

   d. driving a leading end of the first tubular member through the wall of the second tubular member and into a receiving cavity in a receiving block, the receiving cavity supporting an outer surface of the leading end, until the leading end reaches a lower limit; and

   e. applying an axial compressive force to the first tubular member,

   whereby an unsupported portion of the first tubular member contained within the second tubular member swells under the axial compressive force, interlocking the first tubular member to the second tubular member.

2. The method of claim 1 wherein the mandrel is provided with a punching end and the steps of punching through the wall of the second tubular member and driving the leading end of the first tubular member through the wall of the second tubular member are performed in a single stroke.

3. The method of claim 1 wherein an entrance to the receiving cavity is bevelled.

4. The method of claim 1 wherein the second tubular member is disposed within a channel having a configuration conforming to an outer surface of the second tubular member and extending over an entrance to the receiving cavity.

5. The method of claim 4 wherein the channel is formed in the receiving block.

6. The method of claim 5 wherein the holding block is provided with a channel conforming to an outer surface of the second tubular member and extending over an entrance to the holding cavity.

7. The method of claim 6 including, before step a, the step of clamping the holding block against the receiving block.

8. The method of claim 7 wherein the first tubular member is driven through the second tubular member by a punch plate to which the mandrel is anchored.

9. The method of claim 1 for interlocking a plurality of first tubular members with the second tubular member.

10. The method of claim 1 wherein the lower limit of the receiving cavity is defined by a tube seat.

11. A method of interlocking a first tubular member having a first diametric spacing between opposite points of a wall of the first tubular member with a second tubular member having a second diametric spacing between opposite points of a wall of the second tubular member which is larger than or equal to the first diametric spacing, and opposed holes each having a diametric spacing diametric spacing between opposite points of a wall of the first tubular member which is larger than or equal to the first diametric spacing, comprising the steps of:
spacing between opposite points of an edge of the hole substantially equal to the diametric spacing of the first tubular member, comprising the steps of:

a. disposing through the first tubular member a mandrel having a body with an exterior surface substantially conforming to an interior surface of the first tubular member, to support the interior surface of the first tubular member;

b. disposing a trailing end of the first tubular member within a holding cavity in a holding block, the holding cavity supporting an outer surface of the trailing end;

c. driving the a leading end of the first tubular member through the wall of the second tubular member and into a receiving cavity in a receiving block, the receiving cavity supporting an outer surface of the leading end, until the leading end reaches a lower limit; and

d. applying an axial compressive force to the first tubular member;

whereby an unsupported portion of the first tubular member contained within the second tubular member swells under the axial compressive force, interlocking the first tubular member to the second tubular member.

12. The method of claim 1 comprising, before the step of driving a leading end of the first tubular member through the wall of the second tubular member, the step of punching through a wall of the second tubular member.

13. The method of claim 11 wherein the mandrel is provided with a punching end and comprising, simultaneously with the step of driving a leading end of the first tubular member through the wall of the second tubular member, the step of punching through a wall of the second tubular member.

14. An apparatus for interlocking at least one first tubular member having a first diametric spacing between opposite points of a wall of the first tubular member with a second tubular member having a second diametric spacing between opposite points of a wall of the second tubular member which is larger than the first diametric spacing, comprising

a. holding block having at least one holding cavity for supporting an outer surface of a trailing end of the first tubular member,

b. a receiving block having at least one receiving cavity disposed in opposition to the holding cavity, for supporting an outer surface of a leading end of the first tubular member, the receiving cavity having a lower limit,

at least one mandrel having a body with an exterior surface substantially conforming to an interior surface of the first tubular member, to support the interior surface of the first tubular member, extending through the holding cavity, and

a punch,

whereby the punch creates opposed holes in a wall of the second tubular member, and the mandrel and a leading end of the first tubular member are driven through the wall of the second tubular member and into the receiving cavity, and when the leading end of the first tubular member reaches the lower limit an axial compressive force applied to the first tubular member causes an unsupported portion of the first tubular member contained within the second tubular member to swell under the axial compressive force, interlocking the first tubular member to the second tubular member.

15. The apparatus of claim 14 wherein the punch is provided by a punching end of the mandrel.

16. The apparatus of claim 14 wherein an entrance to the receiving cavity is bevelled.

17. The apparatus of claim 14 wherein the second tubular member is disposed within a channel having a configuration conforming to an outer surface of the second tubular member and extending over an entrance to the receiving cavity.

18. The apparatus of claim 17 wherein the channel is formed in the receiving block.

19. The apparatus of claim 18 wherein the holding block is provided with a channel conforming to an outer surface of the second tubular member and extending over an entrance to the holding cavity.

20. The apparatus of claim 19 wherein at least one of the holding block and the receiving block are movable and can be moved toward the other of the holding block and the receiving block.

21. The apparatus of claim 14 wherein the mandrel and first tubular member are driven through the second tubular member by the punch plate.

22. The apparatus of claim 14 comprising a plurality of mandrels, holding cavities and receiving cavities for interlocking a plurality of first tubular members with at least one second tubular member.

23. The apparatus of claim 14 wherein the lower limit of the receiving cavity is defined by a tube seat.

24. A method of interlocking a first tubular member having a first diametric spacing between opposite points of a wall of the first tubular member with a second tubular member having a second diametric spacing diametric spacing between opposite points of a wall of the first tubular member which is larger than or equal to the first diametric spacing, comprising the steps of:

a. punching through a wall of the second tubular member to create a hole having a diametric spacing between opposite points of an edge of the hole substantially equal to the diametric spacing of the first tubular member,

b. disposing through the first tubular member a mandrel having a body with an exterior surface substantially conforming to an interior surface of the first tubular member, to support the interior surface of the first tubular member;

c. disposing a trailing end of the first tubular member within a holding cavity in a holding block, the holding cavity supporting an outer surface of the trailing end;

d. driving a leading end of the first tubular member through the wall of the second tubular member and against a diametrically opposed point of the wall of the second tubular member,

e. supporting the diametrically opposed point of the wall of the second tubular member to thus create a lower limit for the leading end of the first tubular member; and
f. applying an axial compressive force to the first tubular member;

whereby an unsupported portion of the first tubular member contained within the second tubular member swells under the axial compressive force, interlocking the first tubular member to the second tubular member.

25. The method of claim 24 wherein the mandrel is provided with a punching end and the step of punching through the wall of the second tubular member and driving the leading end of the first tubular member through the wall of the second tubular member are performed in a single stroke.

26. The method of claim 24 wherein the second tubular member is disposed within a channel having a configuration conforming to an outer surface of the second tubular member to support the diametrically opposed point of the wall of the second tubular member.

27. The method of claim 26 wherein the channel is formed in the receiving block.

28. The method of claim 27 wherein the holding block is provided with a channel conforming to an outer surface of the second tubular member and extending over an entrance to the holding cavity.

29. The method of claim 28 including, before step a, the step of clamping the holding block against the receiving block.

30. The method of claim 29 wherein the first tubular member is driven through the second tubular member by a punch plate to which the mandrel is anchored.

31. The method of claim 24 for interlocking a plurality of first tubular members with the second tubular member.

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